ON THE HEAVENS

by Aristotle

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Book I

1

THE science which has to do with nature clearly concerns itself for the most part with bodies and magnitudes and their properties and movements, but also with the principles of this sort of substance, as many as they may be. For of things constituted by nature some are bodies and magnitudes, some possess body and magnitude, and some are principles of things which possess these. Now a continuum is that which is divisible into parts always capable of subdivision, and a body is that which is every way divisible. A magnitude if divisible one way is a line, if two ways a surface, and if three a body. Beyond these there is no other magnitude, because the three dimensions are all that there are, and that which is divisible in three directions is divisible in all. For, as the Pythagoreans say, the world and all that is in it is determined by the number three, since beginning and middle and end give the number of an 'all', and the number they give is the triad. And so, having taken these three from nature as (so to speak) laws of it, we make further use of the number three in the worship of the Gods. Further, we use the terms in practice in this way. Of two things, or men, we say 'both', but not 'all': three is the first number to which the term 'all' has been appropriated. And in this, as we have said, we do but follow the lead which nature gives. Therefore, since 'every' and 'all' and 'complete' do not differ from one another in respect of form, but only, if at all, in their matter and in that to which they are applied, body alone among magnitudes can be complete. For it alone is determined by the three dimensions, that is, is an 'all'. But if it is divisible in three dimensions it is every way divisible, while the other magnitudes are divisible in one dimension or in two alone: for the divisibility and continuity of magnitudes depend upon the number of the dimensions, one sort being continuous in one direction, another in two, another in all. All magnitudes, then, which are divisible are also continuous. Whether we can also say that whatever is continuous is divisible does not yet, on our present grounds, appear. One thing, however, is clear. We cannot pass beyond body to a further kind, as we passed from length to surface, and from surface to body. For if we could, it would cease to be true that body is complete magnitude. We could pass beyond it only in virtue of a defect in it; and that which is complete cannot be defective, since it has being in every respect. Now bodies which are classed as parts of the whole are each complete according to our formula, since each possesses every dimension. But each is determined relatively to that part which is next to it by contact, for which reason each of them is in a sense many bodies. But the whole of which they are parts must necessarily be complete, and thus, in accordance with the meaning of the word, have being, not in some respect only, but in every respect.

2

The question as to the nature of the whole, whether it is infinite in size or limited in its total mass, is a matter for

subsequent inquiry. We will now speak of those parts of the whole which are specifically distinct. Let us take this as our starting−point. 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 of this 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. This seems to be in exact accord with what we said above: as body found its completion in three dimensions, so its movement completes itself in three forms.

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 in the latter case the motion will be that of the simple body which prevails in the composition. Supposing, then, that there is such a thing as simple movement, and that circular movement is an instance of it, and that both movement of a simple body is simple and simple movement is of a simple body (for if it is movement of a compound it will be in virtue of a prevailing simple element), then there must necessarily be some simple body which revolves naturally and in virtue of its own nature with a circular movement. By constraint, of course, it may be brought to move with the motion of something else different from itself, but it cannot so move naturally, since there is one sort of movement natural to each of the simple bodies. Again, if the unnatural movement is the contrary of the natural and a thing can have no more than one contrary, it will follow that circular movement, being a simple motion, must be unnatural, if it is not natural, to the body moved. If then (1) the body, whose movement is circular, is fire or some other element, its natural motion must be the contrary of the circular motion. But a single thing has a single contrary; and upward and downward motion are the contraries of one another. If, on the other hand, (2) the body moving with this circular motion which is unnatural to it is something different from the elements, there will be some other motion which is natural to it. But this cannot be. For if the natural motion is upward, it will be fire or air, and if downward, water or earth. Further, this circular motion is necessarily primary. For the perfect is naturally prior to the imperfect, and the circle is a perfect thing. This cannot be said of any straight line:−not of an infinite line; for, if it were perfect, 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 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 preponderates in the composition. These premises clearly give the conclusion that there is in nature some bodily substance other than the formations we know, prior to them all and more divine than they. But it may also be proved as follows. We may take it that all movement is either natural or unnatural, and that the movement which is unnatural to one body is natural to another−as, for instance, is the case with the upward and downward movements, which are natural and unnatural to fire and earth respectively. It necessarily follows that circular movement, being unnatural to these bodies, is the natural movement of some other. Further, if, on the one hand, circular movement is natural to something, it must surely be some simple and primary body which is ordained to move with a natural circular motion, as fire is ordained to fly 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, being nevertheless contrary to nature. At any rate the evidence of all other cases goes to show that it is the unnatural which quickest passes away. And so, if, as some say, the body so moved is fire, this movement is just as unnatural to it as downward movement; for any one can see that fire moves in a straight line away from the centre. 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.

3

In consequence of what has been said, in part by way of assumption and in part by way of proof, it is clear that not every body either possesses lightness or heaviness. As a preliminary we must explain in what sense we are using the words 'heavy' and 'light', sufficiently, at least, for our present purpose: we can examine the terms more closely later, when we come to consider their essential nature. 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. The body, then, which moves in a circle cannot possibly possess either 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. Suppose, then, that the movement is unnatural. In that case, if it is the downward movement which is unnatural, the upward movement will be natural; and if it is the upward which is unnatural, the downward will be natural. For we decided that of contrary movements, if the one is unnatural to anything, the other will be natural to it. But since the natural movement of the whole and of its part of earth, for instance, as a whole and of a small clod−have one and the same direction, it results, in the first place, that this body can possess no lightness or heaviness at all (for that would mean that it could move by its own nature either from or towards the centre, which, as we know, is impossible); and, secondly, that it cannot possibly move in the way of locomotion by being forced violently aside in an upward or downward direction. For neither naturally nor unnaturally can it move with any other motion but its own, either itself or any part of it, since the reasoning which applies to the whole applies also to the part.

It is equally reasonable to assume that this body will be ungenerated and indestructible and exempt from increase and alteration, since everything that comes to be comes into being from its contrary and in some substrate, and passes away likewise in a substrate by the action of the contrary into the contrary, as we explained in our opening discussions. 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 in contraries that generation and decay subsist. 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 diminution, 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 without exception 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 experience and to be confirmed by it. 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 inconceivable. 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 common name, too, which has been handed down from our distant ancestors even to our own day,

seems to show that they 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 a name of its own, aither, derived from the fact that it 'runs always' for an eternity of time. Anaxagoras, however, scandalously misuses this name, taking aither as equivalent to fire.

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.

4

That there is no other form of motion opposed as contrary to the circular may be proved in various ways. In the first place, there is an obvious tendency to oppose the straight line to the circular. For concave and convex are a not only regarded as opposed to one another, but they are also coupled together and treated as a unity in opposition to the straight. And so, if there is a contrary to circular motion, motion in a straight line must be recognized as having the best claim to that name. But the two forms of rectilinear motion are opposed to one another by reason of their places; for up and down is a difference and a contrary opposition in place. Secondly, it may be thought that the same reasoning which holds good of the rectilinear path applies also the circular, movement from A to B being opposed as contrary to movement from B to A. But what is meant is still rectilinear motion. For that is limited to a single path, while the circular paths which pass through the same two points are infinite in number. Even if we are confined to the single semicircle and the opposition is between movement from C to D and from D to C along that semicircle, the case is no better. For the motion is the same as that along the diameter, since we invariably regard the distance between two points as the length of the straight line which joins them. It is no more satisfactory to construct a circle and treat motion 'along one semicircle as contrary to motion along the other. For example, taking a complete circle, motion from E to F on the semicircle G may be opposed to motion from F to E on the semicircle H. But even supposing these are contraries, it in no way follows that the reverse motions on the complete circumference contraries. Nor again can motion along the circle from A to B be regarded as the contrary of motion from A to C: for the motion goes from the same point towards the same point, and contrary motion was distinguished as motion from a contrary to its contrary. And even if the motion round a circle is the contrary of the reverse motion, one of the two would be ineffective: for both move to the same point, because that which moves in a circle, at whatever point it begins, must necessarily pass through all the contrary places alike. (By contrarieties of place I mean up and down, back and front, and right and left; and the contrary oppositions of movements are determined by those of places.) One of the motions, then, would be ineffective, for if the two motions were of equal strength, there would be no movement either way, and if one of the two were preponderant, the other would be inoperative. So that if both bodies were there, one of them, inasmuch as it would not be moving with its own movement, would be useless, in the sense in which a shoe is useless when it is not worn. But God and nature create nothing that has not its use.

5

This being clear, we must go on to consider the questions which remain. First, is there an infinite body, as the majority of the ancient philosophers thought, or is this an impossibility? The decision of this question, either way, is not unimportant, but rather all−important, to our search for the truth. It is this problem which has practically always been the source of the differences of those who have written about nature as a whole. So it has been and so it must be; since the least initial deviation from the truth is multiplied later a thousandfold. Admit, for instance, the existence of a minimum magnitude, and you will find that the minimum which you have introduced, small as it is, causes the greatest truths of mathematics to totter. The reason is that a principle is great rather in power than in extent; hence that which was small at the start turns out a giant at the end. Now the conception of the infinite possesses this power of principles, and indeed in the sphere of quantity possesses it in a higher degree than any

other conception; so that it is in no way absurd or unreasonable that the assumption that an infinite body exists should be of peculiar moment to our inquiry. The infinite, then, we must now discuss, opening the whole matter from the beginning.

Every body is necessarily to be classed either as simple or as composite; the infinite body, therefore, will be either simple or composite.

But it is clear, further, that if the simple bodies are finite, the composite must also be finite, since that which is composed of bodies finite both in number and in magnitude is itself finite in respect of number and magnitude: its quantity is in fact the same as that of the bodies which compose it. What remains for us to consider, then, is whether any of the simple bodies can be infinite in magnitude, or whether this is impossible. Let us try the primary body first, and then go on to consider the others.

The body which moves in a circle must necessarily be finite in every respect, for the following reasons. (1) If the body so moving is infinite, the radii drawn from the centre will be infinite. But the space between infinite radii is infinite: and by the space between the radii I mean the area outside which no magnitude which is in contact with the two lines can be conceived as falling. This, I say, will be infinite: first, because in the case of finite radii it is always finite; and secondly, because in it one can always go on to a width greater than any given width; thus the reasoning which forces us to believe in infinite number, because there is no maximum, applies also to the space between the radii. Now the infinite cannot be traversed, and if the body is infinite the interval between the radii is necessarily infinite: circular motion therefore is an impossibility. Yet our eyes tell us that the heavens revolve in a circle, and by argument also we have determined that there is something to which circular movement belongs.

(2) Again, if from a finite time a finite time be subtracted, what remains must be finite and have a beginning. And if the time of a journey has a beginning, there must be a beginning also of the movement, and consequently also of the distance traversed. This applies universally. Take a line, ACE, infinite in one direction, E, and another line, BB, infinite in both directions. Let ACE describe a circle, revolving upon C as centre. In its movement it will cut BB continuously for a certain time. This will be a finite time, since the total time is finite in which the heavens complete their circular orbit, and consequently the time subtracted from it, during which the one line in its motion cuts the other, is also finite. Therefore there will be a point at which ACE began for the first time to cut BB. This, however, is impossible. The infinite, then, cannot revolve in a circle; nor could the world, if it were infinite.

(3) That the infinite cannot move may also be shown as follows. Let A be a finite line moving past the finite line, B. Of necessity A will pass clear of B and B of A at the same moment; for each overlaps the other to precisely the same extent. Now if the two were both moving, and moving in contrary directions, they would pass clear of one another more rapidly; if one were still and the other moving past it, less rapidly; provided that the speed of the latter were the same in both cases. This, however, is clear: that it is impossible to traverse an infinite line in a finite time. Infinite time, then, would be required. (This we demonstrated above in the discussion of movement.) And it makes no difference whether a finite is passing by an infinite or an infinite by a finite. For when A is passing B, then B overlaps A and it makes no difference whether B is moved or unmoved, except that, if both move, they pass clear of one another more quickly. It is, however, quite possible that a moving line should in certain cases pass one which is stationary quicker than it passes one moving in an opposite direction. One has only to imagine the movement to be slow where both move and much faster where one is stationary. To suppose one line stationary, then, makes no difficulty for our argument, since it is quite possible for A to pass B at a slower rate when both are moving than when only one is. If, therefore, the time which the finite moving line takes to pass the other is infinite, then necessarily the time occupied by the motion of the infinite past the finite is also infinite. For the infinite to move at all is thus absolutely impossible; since the very smallest movement conceivable must take an infinity of time. Moreover the heavens certainly revolve, and they complete their circular orbit in a finite time; so that they pass round the whole extent of any line within their orbit, such as the finite line AB. The revolving body, therefore, cannot be infinite.

(4) Again, as a line which has a limit cannot be infinite, or, if it is infinite, is so only in length, so a surface cannot be infinite in that respect in which it has a limit; or, indeed, if it is completely determinate, in any respect whatever. Whether it be a square or a circle or a sphere, it cannot be infinite, any more than a foot−rule can. There is then no such thing as an infinite sphere or square or circle, and where there is no circle there can be no circular movement, and similarly where there is no infinite at all there can be no infinite movement; and from this it follows that, an infinite circle being itself an impossibility, there can be no circular motion of an infinite body.

(5) Again, take a centre C, an infinite line, AB, another infinite line at right angles to it, E, and a moving radius, CD. CD will never cease contact with E, but the position will always be something like CE, CD cutting E at F. The infinite line, therefore, refuses to complete the circle.

(6) Again, if the heaven is infinite and moves in a circle, we shall have to admit that in a finite time it has traversed the infinite. For suppose the fixed heaven infinite, and that which moves within it equal to it. It results that when the infinite body has completed its revolution, it has traversed an infinite equal to itself in a finite time. But that we know to be impossible.

(7) It can also be shown, conversely, that if the time of revolution is finite, the area traversed must also be finite; but the area traversed was equal to itself; therefore, it is itself finite.

We have now shown that the body which moves in a circle is not endless or infinite, but has its limit.

6

Further, neither that which moves towards nor that which moves away from the centre can be infinite. For the upward and downward motions are contraries and are therefore motions towards contrary places. But if one of a pair of contraries is determinate, the other must be determinate also. Now the centre is determined; for, from whatever point the body which sinks to the bottom starts its downward motion, it cannot go farther than the centre. The centre, therefore, being determinate, the upper place must also be determinate. But if these two places are determined and finite, the corresponding bodies must also be finite. Further, if up and down are determinate, the intermediate place is also necessarily determinate. For, if it is indeterminate, the movement within it will be infinite; and that we have already shown to be an impossibility. The middle region then is determinate, and consequently any body which either is in it, or might be in it, is determinate. But the bodies which move up and down may be in it, since the one moves naturally away from the centre and the other towards it.

From this alone it is clear that an infinite body is an impossibility; but there is a further point. If there is no such thing as infinite weight, then it follows that none of these bodies can be infinite. For the supposed infinite body would have to be infinite in weight. (The same argument applies to lightness: for as the one supposition involves infinite weight, so the infinity of the body which rises to the surface involves infinite lightness.) This is proved as follows. Assume the weight to be finite, and take an infinite body, AB, of the weight C. Subtract from the infinite body a finite mass, BD, the weight of which shall be E. E then is less than C, since it is the weight of a lesser mass. Suppose then that the smaller goes into the greater a certain number of times, and take BF bearing the same proportion to BD which the greater weight bears to the smaller. For you may subtract as much as you please from an infinite. If now the masses are proportionate to the weights, and the lesser weight is that of the lesser mass, the greater must be that of the greater. The weights, therefore, of the finite and of the infinite body are equal. Again, if the weight of a greater body is greater than that of a less, the weight of GB will be greater than that of FB; and thus the weight of the finite body is greater than that of the infinite. And, further, the weight of unequal masses will be the same, since the infinite and the finite cannot be equal. It does not matter whether the weights are commensurable or not. If (a) they are incommensurable the same reasoning holds. For instance, suppose E multiplied by three is rather more than C: the weight of three masses of the full size of BD will be greater than C. We thus arrive at the same impossibility as before. Again (b) we may assume weights which are commensurate;

for it makes no difference whether we begin with the weight or with the mass. For example, assume the weight E to be commensurate with C, and take from the infinite mass a part BD of weight E. Then let a mass BF be taken having the same proportion to BD which the two weights have to one another. (For the mass being infinite you may subtract from it as much as you please.) These assumed bodies will be commensurate in mass and in weight alike. Nor again does it make any difference to our demonstration whether the total mass has its weight equally or unequally distributed. For it must always be Possible to take from the infinite mass a body of equal weight to BD by diminishing or increasing the size of the section to the necessary extent.

From what we have said, then, it is clear that the weight of the infinite body cannot be finite. It must then be infinite. We have therefore only to show this to be impossible in order to prove an infinite body impossible. But the impossibility of infinite weight can be shown in the following way. A given weight moves a given distance in a given time; a weight which is as great and more moves the same distance in a less time, the times being in inverse proportion to the weights. For instance, if one weight is twice another, it will take half as long over a given movement. Further, a finite weight traverses any finite distance in a finite time. It necessarily follows from this that infinite weight, if there is such a thing, being, on the one hand, as great and more than as great as the finite, will move accordingly, but being, on the other hand, compelled to move in a time inversely proportionate to its greatness, cannot move at all. The time should be less in proportion as the weight is greater. But there is no proportion between the infinite and the finite: proportion can only hold between a less and a greater finite time. And though you may say that the time of the movement can be continually diminished, yet there is no minimum. Nor, if there were, would it help us. For some finite body could have been found greater than the given finite in the same proportion which is supposed to hold between the infinite and the given finite; so that an infinite and a finite weight must have traversed an equal distance in equal time. But that is impossible. Again, whatever the time, so long as it is finite, in which the infinite performs the motion, a finite weight must necessarily move a certain finite distance in that same time. Infinite weight is therefore impossible, and the same reasoning applies also to infinite lightness. Bodies then of infinite weight and of infinite lightness are equally impossible.

That there is no infinite body may be shown, as we have shown it, by a detailed consideration of the various cases. But it may also be shown universally, not only by such reasoning as we advanced in our discussion of principles (though in that passage we have already determined universally the sense in which the existence of an infinite is to be asserted or denied), but also suitably to our present purpose in the following way. That will lead us to a further question. Even if the total mass is not infinite, it may yet be great enough to admit a plurality of universes. The question might possibly be raised whether there is any obstacle to our believing that there are other universes composed on the pattern of our own, more than one, though stopping short of infinity. First, however, let us treat of the infinite universally.

7

Every body must necessarily be either finite or infinite, and if infinite, either of similar or of dissimilar parts. If its parts are dissimilar, they must represent either a finite or an infinite number of kinds. That the kinds cannot be infinite is evident, if our original presuppositions remain unchallenged. For the primary movements being finite in number, the kinds of simple body are necessarily also finite, since the movement of a simple body is simple, and the simple movements are finite, and every natural body must always have its proper motion. Now if the infinite body is to be composed of a finite number of kinds, then each of its parts must necessarily be infinite in quantity, that is to say, the water, fire, which compose it. But this is impossible, because, as we have already shown, infinite weight and lightness do not exist. Moreover it would be necessary also that their places should be infinite in extent, so that the movements too of all these bodies would be infinite. But this is not possible, if we are to hold to the truth of our original presuppositions and to the view that neither that which moves downward, nor, by the same reasoning, that which moves upward, can prolong its movement to infinity. For it is true in regard to quality, quantity, and place alike that any process of change is impossible which can have no end. I mean that if it is impossible for a thing to have come to be white, or a cubit long, or in Egypt, it is also impossible for it to be in

process of coming to be any of these. It is thus impossible for a thing to be moving to a place at which in its motion it can never by any possibility arrive. Again, suppose the body to exist in dispersion, it may be maintained none the less that the total of all these scattered particles, say, of fire, is infinite. But body we saw to be that which has extension every way. How can there be several dissimilar elements, each infinite? Each would have to be infinitely extended every way.

It is no more conceivable, again, that the infinite should exist as a whole of similar parts. For, in the first place, there is no other (straight) movement beyond those mentioned: we must therefore give it one of them. And if so, we shall have to admit either infinite weight or infinite lightness. Nor, secondly, could the body whose movement is circular be infinite, since it is impossible for the infinite to move in a circle. This, indeed, would be as good as saying that the heavens are infinite, which we have shown to be impossible.

Moreover, in general, it is impossible that the infinite should move at all. If it did, it would move either naturally or by constraint: and if by constraint, it possesses also a natural motion, that is to say, there is another place, infinite like itself, to which it will move. But that is impossible.

That in general it is impossible for the infinite to be acted upon by the finite or to act upon it may be shown as follows.

(1. The infinite cannot be acted upon by the finite.) Let A be an infinite, B a finite, C the time of a given movement produced by one in the other. Suppose, then, that A was heated, or impelled, or modified in any way, or caused to undergo any sort of movement whatever, by in the time C. Let D be less than B; and, assuming that a lesser agent moves a lesser patient in an equal time, call the quantity thus modified by D, E. Then, as D is to B, so is E to some finite quantum. We assume that the alteration of equal by equal takes equal time, and the alteration of less by less or of greater by greater takes the same time, if the quantity of the patient is such as to keep the proportion which obtains between the agents, greater and less. If so, no movement can be caused in the infinite by any finite agent in any time whatever. For a less agent will produce that movement in a less patient in an equal time, and the proportionate equivalent of that patient will be a finite quantity, since no proportion holds between finite and infinite.

(2. The infinite cannot act upon the finite.) Nor, again, can the infinite produce a movement in the finite in any time whatever. Let A be an infinite, B a finite, C the time of action. In the time C, D will produce that motion in a patient less than B, say F. Then take E, bearing the same proportion to D as the whole BF bears to F. E will produce the motion in BF in the time C. Thus the finite and infinite effect the same alteration in equal times. But this is impossible; for the assumption is that the greater effects it in a shorter time. It will be the same with any time that can be taken, so that there will no time in which the infinite can effect this movement. And, as to infinite time, in that nothing can move another or be moved by it. For such time has no limit, while the action and reaction have.

(3. There is no interaction between infinites.) Nor can infinite be acted upon in any way by infinite. Let A and B be infinites, CD being the time of the action A of upon B. Now the whole B was modified in a certain time, and the part of this infinite, E, cannot be so modified in the same time, since we assume that a less quantity makes the movement in a less time. Let E then, when acted upon by A, complete the movement in the time D. Then, as D is to CD, so is E to some finite part of B. This part will necessarily be moved by A in the time CD. For we suppose that the same agent produces a given effect on a greater and a smaller mass in longer and shorter times, the times and masses varying proportionately. There is thus no finite time in which infinites can move one another. Is their time then infinite? No, for infinite time has no end, but the movement communicated has.

If therefore every perceptible body possesses the power of acting or of being acted upon, or both of these, it is impossible that an infinite body should be perceptible. All bodies, however, that occupy place are perceptible. There is therefore no infinite body beyond the heaven. Nor again is there anything of limited extent beyond it.

And so beyond the heaven there is no body at all. For if you suppose it an object of intelligence, it will be in a place−since place is what 'within' and 'beyond' denote−and therefore an object of perception. But nothing that is not in a place is perceptible.

The question may also be examined in the light of more general considerations as follows. The infinite, considered as a whole of similar parts, cannot, on the one hand, move in a circle. For there is no centre of the infinite, and that which moves in a circle moves about the centre. Nor again can the infinite move in a straight line. For there would have to be another place infinite like itself to be the goal of its natural movement and another, equally great, for the goal of its unnatural movement. Moreover, whether its rectilinear movement is natural or constrained, in either case the force which causes its motion will have to be infinite. For infinite force is force of an infinite body, and of an infinite body the force is infinite. So the motive body also will be infinite. (The proof of this is given in our discussion of movement, where it is shown that no finite thing possesses infinite power, and no infinite thing finite power.) If then that which moves naturally can also move unnaturally, there will be two infinites, one which causes, and another which exhibits the latter motion. Again, what is it that moves the infinite? If it moves itself, it must be animate. But how can it possibly be conceived as an infinite animal? And if there is something else that moves it, there will be two infinites, that which moves and that which is moved, differing in their form and power.

If the whole is not continuous, but exists, as Democritus and Leucippus think, in the form of parts separated by void, there must necessarily be one movement of all the multitude. They are distinguished, we are told, from one another by their figures; but their nature is one, like many pieces of gold separated from one another. But each piece must, as we assert, have the same motion. For a single clod moves to the same place as the whole mass of earth, and a spark to the same place as the whole mass of fire. So that if it be weight that all possess, no body is, strictly speaking, light: and if lightness be universal, none is heavy. Moreover, whatever 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, as experience shows. Necessarily, therefore, not everything possesses weight or lightness, but some things do and some do not. From these arguments then it is clear that the body of the universe is not infinite.

8

We must now proceed to explain why there cannot be more than one heaven−the further question mentioned above. For it may be thought that we have not proved universal of bodies that none whatever can exist outside our universe, and that our argument applied only to those of indeterminate extent.

Now all things rest and move naturally and by constraint. A thing moves naturally to a place in which it rests without constraint, and rests naturally in a place to which it moves without constraint. On the other hand, a thing moves by constraint to a place in which it rests by constraint, and rests by constraint in a place to which it moves by constraint. Further, if a given movement is due to constraint, its contrary is natural. If, then, it is by constraint that earth moves from a certain place to the centre here, its movement from here to there will be natural, and if earth from there rests here without constraint, its movement hither will be natural. And the natural movement in each case is one. Further, these worlds, being similar in nature to ours, must all be composed of the same bodies as it. Moreover each of the bodies, fire, I mean, and earth and their intermediates, must have the same power as in our world. For if these names are used equivocally, if the identity of name does not rest upon an identity of form in these elements and ours, then the whole to which they belong can only be called a world by equivocation. Clearly, then, one of the bodies will move naturally away from the centre and another towards the centre, since fire must be identical with fire, earth with earth, and so on, as the fragments of each are identical in this world.

That this must be the case is evident from the principles laid down in our discussion of the movements, for these are limited in number, and the distinction of the elements depends upon the distinction of the movements. Therefore, since the movements are the same, the 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.

To postulate a difference of nature in the simple bodies according as they are more or less distant from their proper places is unreasonable. For what difference can it make whether we say that a thing is this distance away or that? One would have to suppose a difference proportionate to the distance and increasing with it, but the form is in fact the same. Moreover, the bodies must have some movement, since the fact that they move is quite evident. Are we to say then that all their movements, even those which are mutually contrary, are due to constraint? No, for a body which has no natural movement at all cannot be moved by constraint. If then the bodies have a natural movement, the movement of the particular instances of each form must necessarily have for goal a place numerically one, i.e. a particular centre or a particular extremity. If it be suggested that the goal in each case is one in form but numerically more than one, on the analogy of particulars which are many though each undifferentiated in form, we reply that the variety of goal cannot be limited to this portion or that but must extend to all alike. For all are equally undifferentiated in form, but any one is different numerically from any other. What I mean is this: if the portions in this world behave similarly both to one another and to those in another world, then the portion which is taken hence will not behave differently either from the portions in another world or from those in the same world, but similarly to them, since in form no portion differs from another. The result is that we must either abandon our present assumption or assert that the centre and the extremity are each numerically one. But this being so, the heaven, by the same evidence and the same necessary inferences, must be one only and no more.

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. (Even in circular movement there is a sort of opposition between the ends of the diameter, though the movement as a whole has no contrary: so that here too the movement has in a sense an opposed and finite goal.) 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. For as superior speed in downward movement implies superior weight, so infinite increase of weight necessitates infinite increase of speed.

Further, it is not the action of another body that makes one of these bodies move up and the other down; nor is it constraint, like the 'extrusion' of some writers. For in that case the larger the mass of fire or earth the slower would be the upward or downward movement; but the fact is the reverse: the greater the mass of fire or earth the quicker always is its movement towards its own place. Again, the speed of the movement would not increase towards the end if it were due to constraint or extrusion; for a constrained movement always diminishes in speed as the source of constraint becomes more distant, and a body moves without constraint to the place whence it was

moved by constraint.

A consideration of these points, then, gives adequate assurance of the truth of our contentions. The same could also be shown with the aid of the discussions which fall under First Philosophy, as well as from the nature of the circular movement, which must be eternal both here and in the other worlds. It is plain, too, from the following considerations that the universe must be one.

The bodily elements are three, and therefore the places of the elements will be three also; the place, first, of the body which sinks to the bottom, namely the region about the centre; the place, secondly, of the revolving body, namely the outermost place, and thirdly, the intermediate place, belonging to the intermediate body. Here in this third place will be the body which rises to the surface; since, if not here, it will be elsewhere, and it cannot be elsewhere: for we have two bodies, one weightless, one endowed with weight, and below is place of the body endowed with weight, since the region about the centre has been given to the heavy body. And its position cannot be unnatural to it, for it would have to be natural to something else, and there is nothing else. It must then occupy the intermediate place. What distinctions there are within the intermediate itself we will explain later on.

We have now said enough to make plain the character and number of the bodily elements, the place of each, and further, in general, how many in number the various places are.

9

We must show not only that the heaven is one, but also that more than one heaven is and, further, that, as exempt from decay and generation, the heaven is eternal. We may begin by raising a difficulty. From one point of view it might seem impossible that the heaven should be one and unique, since in all formations and products whether of nature or of art we can distinguish the shape in itself and the shape in combination with matter. For instance the form of the sphere is one thing and the gold or bronze sphere another; the shape of the circle again is one thing, the bronze or wooden circle another. For when we state the essential nature of the sphere or circle we do not include in the formula gold or bronze, because they do not belong to the essence, but if we are speaking of the copper or gold sphere we do include them. We still make the distinction even if we cannot conceive or apprehend any other example beside the particular thing. This may, of course, sometimes be the case: it might be, for instance, that only one circle could be found; yet none the less the difference will remain between the being of circle and of this particular circle, the one being form, the other form in matter, i.e. a particular thing. Now since the universe is perceptible it must be regarded as a particular; for everything that is perceptible subsists, as we know, in matter. But if it is a particular, there will be a distinction between the being of 'this universe' and of 'universe' unqualified. There is a difference, then, between 'this universe' and simple 'universe'; the second is form and shape, the first form in combination with matter; and any shape or form has, or may have, more than one particular instance.

On the supposition of Forms such as some assert, this must be the case, and equally on the view that no such entity has a separate existence. For in every case in which the essence is in matter it is a fact of observation that the particulars of like form are several or infinite in number. Hence there either are, or may be, more heavens than one. On these grounds, then, it might be inferred either that there are or that there might be several heavens. We must, however, return and ask how much of this argument is correct and how much not.

Now it is quite right to say that the formula of the shape apart from the matter must be different from that of the shape in the matter, and we may allow this to be true. We are not, however, therefore compelled to assert a plurality of worlds. Such a plurality is in fact impossible if this world contains the entirety of matter, as in fact it does. But perhaps our contention can be made clearer in this way. Suppose 'aquilinity' to be curvature in the nose or flesh, and flesh to be the matter of aquilinity. Suppose further, that all flesh came together into a single whole of flesh endowed with this aquiline quality. Then neither would there be, nor could there arise, any other thing

that was aquiline. Similarly, suppose flesh and bones to be the matter of man, and suppose a man to be created of all flesh and all bones in indissoluble union. The possibility of another man would be removed. Whatever case you took it would be the same. The general rule is this: a thing whose essence resides in a substratum of matter can never come into being in the absence of all matter. Now the universe is certainly a particular and a material thing: if however, it is composed not of a part but of the whole of matter, then though the being of 'universe' and of 'this universe' are still distinct, yet there is no other universe, and no possibility of others being made, because all the matter is already included in this. It remains, then, only to prove that it is composed of all natural perceptible body.

First, however, we must explain what we mean by 'heaven' and in how many senses we use the word, in order to make clearer the object of our inquiry. (a) In one sense, then, we call 'heaven' the substance of the extreme circumference of the whole, or that natural body whose place is at the extreme circumference. We recognize habitually a special right to the name 'heaven' in the extremity or upper region, which we take to be the seat of all that is divine. (b) In another sense, we use this name for the body continuous with the extreme circumference which contains the moon, the sun, and some of the stars; these we say are 'in the heaven'. (c) In yet another sense we give the name to all body included within extreme circumference, since we habitually call the whole or totality 'the heaven'. The word, then, is used in three senses.

Now the whole included within the extreme circumference must be composed of all physical and sensible body, because there neither is, nor can come into being, any body outside the heaven. For if there is a natural body outside the extreme circumference it must be either a simple or a composite body, and its position must be either natural or unnatural. But it cannot be any of the simple bodies. For, first, it has been shown that that which moves in a circle cannot change its place. And, secondly, it cannot be that which moves from the centre or that which lies lowest. Naturally they could not be there, since their proper places are elsewhere; and if these are there unnaturally, the exterior place will be natural to some other body, since a place which is unnatural to one body must be natural to another: but we saw that there is no other body besides these. Then it is not possible that any simple body should be outside the heaven. But, if no simple body, neither can any mixed body be there: for the presence of the simple body is involved in the presence of the mixture. Further neither can any body come into that place: for it will do so either naturally or unnaturally, and will be either simple or composite; so that the same argument will apply, since it makes no difference whether the question is 'does A exist?' or 'could A come to exist?' From our arguments then it is evident not only that there is not, but also that there could never come to be, any bodily mass whatever outside the circumference. The world as a whole, therefore, includes all its appropriate matter, which is, as we saw, natural perceptible body. So that neither are there now, nor have there ever been, nor can there ever be formed more heavens than one, but this heaven of ours is one and unique and complete.

It is therefore evident that there is also no place or void or time outside the heaven. For in every place body can be present; and void is said to be that in which the presence of body, though not actual, is possible; and time is the number of movement. But in the absence of natural body there is no movement, and outside the heaven, as we have shown, body neither exists nor can come to exist. It is clear then that there is neither place, nor void, nor time, outside the heaven. Hence whatever is there, is of such a nature as not to occupy any place, nor does time age it; nor is there any change in any of the things which lie beyond the outermost motion; they continue through their entire duration unalterable and unmodified, living the best and most selfsufficient of lives. As a matter of fact, this word 'duration' possessed a divine significance for the ancients, for the fulfilment which includes the period of life of any creature, outside of which no natural development can fall, has been called its duration. On the same principle the fulfilment of the whole heaven, the fulfilment which includes all time and infinity, is 'duration'−a name based upon the fact that it is always−duration immortal and divine. From it derive the being and life which other things, some more or less articulately but others feebly, enjoy. So, too, in its discussions concerning the divine, popular philosophy often propounds the view that whatever is divine, whatever is primary and supreme, is necessarily unchangeable. This fact confirms what we have said. For there is nothing else stronger than it to move it−since that would mean more divine−and it has no defect and lacks none of its proper excellences. Its unceasing movement, then, is also reasonable, since everything ceases to move when it comes to

its proper place, but the body whose path is the circle has one and the same place for starting−point and goal.

10

Having established these distinctions, we may now proceed to the question whether the heaven is ungenerated or generated, indestructible or destructible. Let us start with a review of the theories of other thinkers; for the proofs of a theory are difficulties for the contrary theory. Besides, those who have first heard the pleas of our adversaries will be more likely to credit the assertions which we are going to make. We shall be less open to the charge of procuring judgement by default. To give a satisfactory decision as to the truth it is necessary to be rather an arbitrator than a party to the dispute.

That the world was generated all are agreed, but, generation over, some say that it is eternal, others say that it is destructible like any other natural formation. Others again, with Empedliocles of Acragas and Heraclitus of Ephesus, believe that there is alternation in the destructive process, which takes now this direction, now that, and continues without end.

Now to assert that it was generated and yet is eternal is to assert the impossible; for we cannot reasonably attribute to anything any characteristics but those which observation detects in many or all instances. But in this case the facts point the other way: generated things are seen always to be destroyed. Further, a thing whose present state had no beginning and which could not have been other than it was at any previous moment throughout its entire duration, cannot possibly be changed. For there will have to be some cause of change, and if this had been present earlier it would have made possible another condition of that to which any other condition was impossible. Suppose that the world was formed out of elements which were formerly otherwise conditioned than as they are now. Then (1) if their condition was always so and could not have been otherwise, the world could never have come into being. And (2) if the world did come into being, then, clearly, their condition must have been capable of change and not eternal: after combination therefore they will be dispersed, just as in the past after dispersion they came into combination, and this process either has been, or could have been, indefinitely repeated. But if this is so, the world cannot be indestructible, and it does not matter whether the change of condition has actually occurred or remains a possibility.

Some of those who hold that the world, though indestructible, was yet generated, try to support their case by a parallel which is illusory. They say that in their statements about its generation they are doing what geometricians do when they construct their figures, not implying that the universe really had a beginning, but for didactic reasons facilitating understanding by exhibiting the object, like the figure, as in course of formation. The two cases, as we said, are not parallel; for, in the construction of the figure, when the various steps are completed the required figure forthwith results; but in these other demonstrations what results is not that which was required. Indeed it cannot be so; for antecedent and consequent, as assumed, are in contradiction. The ordered, it is said, arose out of the unordered; and the same thing cannot be at the same time both ordered and unordered; there must be a process and a lapse of time separating the two states. In the figure, on the other hand, there is no temporal separation. It is clear then that the universe cannot be at once eternal and generated.

To say that the universe alternately combines and dissolves is no more paradoxical than to make it eternal but varying in shape. It is as if one were to think that there was now destruction and now existence when from a child a man is generated, and from a man a child. For it is clear that when the elements come together the result is not a chance system and combination, but the very same as before−especially on the view of those who hold this theory, since they say that the contrary is the cause of each state. So that if the totality of body, which is a continuum, is now in this order or disposition and now in that, and if the combination of the whole is a world or heaven, then it will not be the world that comes into being and is destroyed, but only its dispositions.

If the world is believed to be one, it is impossible to suppose that it should be, as a whole, first generated and then

destroyed, never to reappear; since before it came into being there was always present the combination prior to it, and that, we hold, could never change if it was never generated. If, on the other hand, the worlds are infinite in number the view is more plausible. But whether this is, or is not, impossible will be clear from what follows. For there are some who think it possible both for the ungenerated to be destroyed and for the generated to persist undestroyed. (This is held in the Timaeus, where Plato says that the heaven, though it was generated, will none the less exist to eternity.) So far as the heaven is concerned we have answered this view with arguments appropriate to the nature of the heaven: on the general question we shall attain clearness when we examine the matter universally.

11

We must first distinguish the senses in which we use the words 'ungenerated' and 'generated', 'destructible' and 'indestructible'. These have many meanings, and though it may make no difference to the argument, yet some confusion of mind must result from treating as uniform in its use a word which has several distinct applications. The character which is the ground of the predication will always remain obscure.

The word 'ungenerated' then is used (a) in one sense whenever something now is which formerly was not, no process of becoming or change being involved. Such is the case, according to some, with contact and motion, since there is no process of coming to be in contact or in motion. (b) It is used in another sense, when something which is capable of coming to be, with or without process, does not exist; such a thing is ungenerated in the sense that its generation is not a fact but a possibility. (c) It is also applied where there is general impossibility of any generation such that the thing now is which then was not. And 'impossibility' has two uses: first, where it is untrue to say that the thing can ever come into being, and secondly, where it cannot do so easily, quickly, or well. In the same way the word 'generated' is used, (a) first, where what formerly was not afterwards is, whether a process of becoming was or was not involved, so long as that which then was not, now is; (b) secondly, of anything capable of existing, 'capable' being defined with reference either to truth or to facility; (c) thirdly, of anything to which the passage from not being to being belongs, whether already actual, if its existence is due to a past process of becoming, or not yet actual but only possible. The uses of the words 'destructible' and 'indestructible' are similar. 'Destructible' is applied (a) to that which formerly was and afterwards either is not or might not be, whether a period of being destroyed and changed intervenes or not; and (b) sometimes we apply the word to that which a process of destruction may cause not to be; and also (c) in a third sense, to that which is easily destructible, to the 'easily destroyed', so to speak. Of the indestructible the same account holds good. It is either (a) that which now is and now is not, without any process of destruction, like contact, which without being destroyed afterwards is not, though formerly it was; or (b) that which is but might not be, or which will at some time not be, though it now is. For you exist now and so does the contact; yet both are destructible, because a time will come when it will not be true of you that you exist, nor of these things that they are in contact. Thirdly (c) in its most proper use, it is that which is, but is incapable of any destruction such that the thing which now is later ceases to be or might cease to be; or again, that which has not yet been destroyed, but in the future may cease to be. For indestructible is also used of that which is destroyed with difficulty.

This being so, we must ask what we mean by 'possible' and 'impossible'. For in its most proper use the predicate 'indestructible' is given because it is impossible that the thing should be destroyed, i.e. exist at one time and not at another. And 'ungenerated' also involves impossibility when used for that which cannot be generated, in such fashion that, while formerly it was not, later it is. An instance is a commensurable diagonal. Now when we speak of a power to move or to lift weights, we refer always to the maximum. We speak, for instance, of a power to lift a hundred talents or walk a hundred stades−though a power to effect the maximum is also a power to effect any part of the maximum−since we feel obliged in defining the power to give the limit or maximum. A thing, then, which is within it. If, for example, a man can lift a hundred talents, he can also lift two, and if he can walk a hundred stades, he can also walk two. But the power is of the maximum, and a thing said, with reference to its maximum, to be incapable of so much is also incapable of any greater amount. It is, for instance, clear that a

person who cannot walk a thousand stades will also be unable to walk a thousand and one. This point need not trouble us, for we may take it as settled that what is, in the strict sense, possible is determined by a limiting maximum. Now perhaps the objection might be raised that there is no necessity in this, since he who sees a stade need not see the smaller measures contained in it, while, on the contrary, he who can see a dot or hear a small sound will perceive what is greater. This, however, does not touch our argument. The maximum may be determined either in the power or in its object. The application of this is plain. Superior sight is sight of the smaller body, but superior speed is that of the greater body.

12

Having established these distinctions we car now proceed to the sequel. If there are thing! capable both of being and of not being, there must be some definite maximum time of their being and not being; a time, I mean, during which continued existence is possible to them and a time during which continued nonexistence is possible. And this is true in every category, whether the thing is, for example, 'man', or 'white', or 'three cubits long', or whatever it may be. For if the time is not definite in quantity, but longer than any that can be suggested and shorter than none, then it will be possible for one and the same thing to exist for infinite time and not to exist for another infinity. This, however, is impossible.

Let us take our start from this point. The impossible and the false have not the same significance. One use of 'impossible' and 'possible', and 'false' and 'true', is hypothetical. It is impossible, for instance, on a certain hypothesis that the triangle should have its angles equal to two right angles, and on another the diagonal is commensurable. But there are also things possible and impossible, false and true, absolutely. Now it is one thing to be absolutely false, and another thing to be absolutely impossible. To say that you are standing when you are not standing is to assert a falsehood, but not an impossibility. Similarly to say that a man who is playing the harp, but not singing, is singing, is to say what is false but not impossible. To say, however, that you are at once standing and sitting, or that the diagonal is commensurable, is to say what is not only false but also impossible. Thus it is not the same thing to make a false and to make an impossible hypothesis, and from the impossible hypothesis impossible results follow. A man has, it is true, the capacity at once of sitting and of standing, because when he possesses the one he also possesses the other; but it does not follow that he can at once sit and stand, only that at another time he can do the other also. But if a thing has for infinite time more than one capacity, another time is impossible and the times must coincide. Thus if a thing which exists for infinite time is destructible, it will have the capacity of not being. Now if it exists for infinite time let this capacity be actualized; and it will be in actuality at once existent and non−existent. Thus a false conclusion would follow because a false assumption was made, but if what was assumed had not been impossible its consequence would not have been impossible.

Anything then which always exists is absolutely imperishable. It is also ungenerated, since if it was generated it will have the power for some time of not being. For as that which formerly was, but now is not, or is capable at some future time of not being, is destructible, so that which is capable of formerly not having been is generated. But in the case of that which always is, there is no time for such a capacity of not being, whether the supposed time is finite or infinite; for its capacity of being must include the finite time since it covers infinite time.

It is therefore impossible that one and the same thing should be capable of always existing and of always not−existing. And 'not always existing', the contradictory, is also excluded. Thus it is impossible for a thing always to exist and yet to be destructible. Nor, similarly, can it be generated. For of two attributes if B cannot be present without A, the impossibility A of proves the impossibility of B. What always is, then, since it is incapable of ever not being, cannot possibly be generated. But since the contradictory of 'that which is always capable of being' 'that which is not always capable of being'; while 'that which is always capable of not being' is the contrary, whose contradictory in turn is 'that which is not always capable of not being', it is necessary that the contradictories of both terms should be predicable of one and the same thing, and thus that, intermediate between

what always is and what always is not, there should be that to which being and not−being are both possible; for the contradictory of each will at times be true of it unless it always exists. Hence that which not always is not will sometimes be and sometimes not be; and it is clear that this is true also of that which cannot always be but sometimes is and therefore sometimes is not. One thing, then, will have the power of being, and will thus be intermediate between the other two.

Expresed universally our argument is as follows. Let there be two attributes, A and B, not capable of being present in any one thing together, while either A or C and either B or D are capable of being present in everything. Then C and D must be predicated of everything of which neither A nor B is predicated. Let E lie between A and B; for that which is neither of two contraries is a mean between them. In E both C and D must be present, for either A or C is present everywhere and therefore in E. Since then A is impossible, C must be present, and the same argument holds of D.

Neither that which always is, therefore, nor that which always is not is either generated or destructible. And clearly whatever is generated or destructible is not eternal. If it were, it would be at once capable of always being and capable of not always being, but it has already been shown that this is impossible. Surely then whatever is ungenerated and in being must be eternal, and whatever is indestructible and in being must equally be so. (I use the words 'ungenerated' and 'indestructible' in their proper sense, 'ungenerated' for that which now is and could not at any previous time have been truly said not to be; 'indestructible' for that which now is and cannot at any future time be truly said not to be.) If, again, the two terms are coincident, if the ungenerated is indestructible, and the indestructible ungenearted, then each of them is coincident with 'eternal'; anything ungenerated is eternal and anything indestructible is eternal. This is clear too from the definition of the terms, Whatever is destructible must be generated; for it is either ungenerated, or generated, but, if ungenerated, it is by hypothesis indestructible. Whatever, further, is generated must be destructible. For it is either destructible or indestructible, but, if indestructible, it is by hypothesis ungenerated.

If, however, 'indestructible' and 'ungenerated' are not coincident, there is no necessity that either the ungenerated or the indestructible should be eternal. But they must be coincident, for the following reasons. The terms 'generated' and 'destructible' are coincident; this is obvious from our former remarks, since between what always is and what always is not there is an intermediate which is neither, and that intermediate is the generated and destructible. For whatever is either of these is capable both of being and of not being for a definite time: in either case, I mean, there is a certain period of time during which the thing is and another during which it is not. Anything therefore which is generated or destructible must be intermediate. Now let A be that which always is and B that which always is not, C the generated, and D the destructible. Then C must be intermediate between A and B. For in their case there is no time in the direction of either limit, in which either A is not or B is. But for the generated there must be such a time either actually or potentially, though not for A and B in either way. C then will be, and also not be, for a limited length of time, and this is true also of D, the destructible. Therefore each is both generated and destructible. Therefore 'generated' and 'destructible' are coincident. Now let E stand for the ungenerated, F for the generated, G for the indestructible, and H for the destructible. As for F and H, it has been shown that they are coincident. But when terms stand to one another as these do, F and H coincident, E and F never predicated of the same thing but one or other of everything, and G and H likewise, then E and G must needs be coincident. For suppose that E is not coincident with G, then F will be, since either E or F is predictable of everything. But of that of which F is predicated H will be predicable also. H will then be coincident with G, but this we saw to be impossible. And the same argument shows that G is coincident with E.

Now the relation of the ungenerated (E) to the generated (F) is the same as that of the indestructible (G) to the destructible (H). To say then that there is no reason why anything should not be generated and yet indestructible or ungenerated and yet destroyed, to imagine that in the one case generation and in the other case destruction occurs once for all, is to destroy part of the data. For (1) everything is capable of acting or being acted upon, of being or not being, either for an infinite, or for a definitely limited space of time; and the infinite time is only a possible alternative because it is after a fashion defined, as a length of time which cannot be exceeded. But

infinity in one direction is neither infinite or finite. (2) Further, why, after always existing, was the thing destroyed, why, after an infinity of not being, was it generated, at one moment rather than another? If every moment is alike and the moments are infinite in number, it is clear that a generated or destructible thing existed for an infinite time. It has therefore for an infinite time the capacity of not being (since the capacity of being and the capacity of not being will be present together), if destructible, in the time before destruction, if generated, in the time after generation. If then we assume the two capacities to be actualized, opposites will be present together. (3) Further, this second capacity will be present like the first at every moment, so that the thing will have for an infinite time the capacity both of being and of not being; but this has been shown to be impossible. (4) Again, if the capacity is present prior to the activity, it will be present for all time, even while the thing was as yet ungenerated and non−existent, throughout the infinite time in which it was capable of being generated. At that time, then, when it was not, at that same time it had the capacity of being, both of being then and of being thereafter, and therefore for an infinity of time.

It is clear also on other grounds that it is impossible that the destructible should not at some time be destroyed. For otherwise it will always be at once destructible and in actuality indestructible, so that it will be at the same time capable of always existing and of not always existing. Thus the destructible is at some time actually destroyed. The generable, similarly, has been generated, for it is capable of having been generated and thus also of not always existing.

We may also see in the following way how impossible it is either for a thing which is generated to be thenceforward indestructible, or for a thing which is ungenerated and has always hitherto existed to be destroyed. Nothing that is by chance can be indestructible or ungenerated, since the products of chance and fortune are opposed to what is, or comes to be, always or usually, while anything which exists for a time infinite either absolutely or in one direction, is in existence either always or usually. That which is by chance, then, is by nature such as to exist at one time and not at another. But in things of that character the contradictory states proceed from one and the same capacity, the matter of the thing being the cause equally of its existence and of its non−existence. Hence contradictories would be present together in actuality.

Further, it cannot truly be said of a thing now that it exists last year, nor could it be said last year that it exists now. It is therefore impossible for what once did not exist later to be eternal. For in its later state it will possess the capacity of not existing, only not of not existing at a time when it exists−since then it exists in actuality−but of not existing last year or in the past. Now suppose it to be in actuality what it is capable of being. It will then be true to say now that it does not exist last year. But this is impossible. No capacity relates to being in the past, but always to being in the present or future. It is the same with the notion of an eternity of existence followed later by non−existence. In the later state the capacity will be present for that which is not there in actuality. Actualize, then, the capacity. It will be true to say now that this exists last year or in the past generally.

Considerations also not general like these but proper to the subject show it to be impossible that what was formerly eternal should later be destroyed or that what formerly was not should later be eternal. Whatever is destructible or generated is always alterable. Now alteration is due to contraries, and the things which compose the natural body are the very same that destroy it.

Book II

1

THAT the heaven as a whole neither came into being nor admits of destruction, as some assert, but is one and eternal, with no end or beginning of its total duration, containing and embracing in itself the infinity of time, we may convince ourselves not only by the arguments already set forth but also by a consideration of the views of those who differ from us in providing for its generation. If our view is a possible one, and the manner of

generation which they assert is impossible, this fact will have great weight in convincing us of the immortality and eternity of the world. Hence it is well to persuade oneself of the truth of the ancient and truly traditional theories, that there is some immortal and divine thing which possesses movement, but movement such as has no limit and is rather itself the limit of all other movement. A limit is a thing which contains; and this motion, being perfect, contains those imperfect motions which have a limit and a goal, having itself no beginning or end, but unceasing through the infinity of time, and of other movements, to some the cause of their beginning, to others offering the goal. The ancients gave to the Gods the heaven or upper place, as being alone immortal; and our present argument testifies that it is indestructible and ungenerated. Further, it is unaffected by any mortal discomfort, and, in addition, effortless; for it needs no constraining necessity to keep it to its path, and prevent it from moving with some other movement more natural to itself. Such a constrained movement would necessarily involve effort the more so, the more eternal it were−and would be inconsistent with perfection. Hence we must not believe the old tale which says that the world needs some Atlas to keep it safe−a tale composed, it would seem, by men who, like later thinkers, conceived of all the upper bodies as earthy and endowed with weight, and therefore supported it in their fabulous way upon animate necessity. We must no more believe that than follow Empedocles when he says that the world, by being whirled round, received a movement quick enough to overpower its own downward tendency, and thus has been kept from destruction all this time. Nor, again, is it conceivable that it should persist eternally by the necessitation of a soul. For a soul could not live in such conditions painlessly or happily, since the movement involves constraint, being imposed on the first body, whose natural motion is different, and imposed continuously. It must therefore be uneasy and devoid of all rational satisfaction; for it could not even, like the soul of mortal animals, take recreation in the bodily relaxation of sleep. An Ixion's lot must needs possess it, without end or respite. If then, as we said, the view already stated of the first motion is a possible one, it is not only more appropriate so to conceive of its eternity, but also on this hypothesis alone are we able to advance a theory consistent with popular divinations of the divine nature. But of this enough for the present.

2

Since there are some who say that there is a right and a left in the heaven, with those who are known as Pythagoreans−to whom indeed the view really belongs−we must consider whether, if we are to apply these principles to the body of the universe, we should follow their statement of the matter or find a better way. At the start we may say that, if right and left are applicable, there are prior principles which must first be applied. These principles have been analysed in the discussion of the movements of animals, for the reason that they are proper to animal nature. For in some animals we find all such distinctions of parts as this of right and left clearly present, and in others some; but in plants we find only above and below. Now if we are to apply to the heaven such a distinction of parts, we must exect, as we have said, to find in it also the distinction which in animals is found first of them all. The distinctions are three, namely, above and below, front and its opposite, right and left−all these three oppositions we expect to find in the perfect body−and each may be called a principle. Above is the principle of length, right of breadth, front of depth. Or again we may connect them with the various movements, taking principle to mean that part, in a thing capable of movement, from which movement first begins. Growth starts from above, locomotion from the right, sensemovement from in front (for front is simply the part to which the senses are directed). Hence we must not look for above and below, right and left, front and back, in every kind of body, but only in those which, being animate, have a principle of movement within themselves. For in no inanimate thing do we observe a part from which movement originates. Some do not move at all, some move, but not indifferently in any direction; fire, for example, only upward, and earth only to the centre. It is true that we speak of above and below, right and left, in these bodies relatively to ourselves. The reference may be to our own right hands, as with the diviner, or to some similarity to our own members, such as the parts of a statue possess; or we may take the contrary spatial order, calling right that which is to our left, and left that which is to our right. We observe, however, in the things themselves none of these distinctions; indeed if they are turned round we proceed to speak of the opposite parts as right and left, a boy land below, front and back. Hence it is remarkable that the Pythagoreans should have spoken of these two principles, right and left, only, to the exclusion of the other four,

which have as good a title as they. There is no less difference between above and below or front and back in animals generally than between right and left. The difference is sometimes only one of function, sometimes also one of shape; and while the distinction of above and below is characteristic of all animate things, whether plants or animals, that of right and left is not found in plants. Further, inasmuch as length is prior to breadth, if above is the principle of length, right of breadth, and if the principle of that which is prior is itself prior, then above will be prior to right, or let us say, since 'prior' is ambiguous, prior in order of generation. If, in addition, above is the region from which movement originates, right the region in which it starts, front the region to which it is directed, then on this ground too above has a certain original character as compared with the other forms of position. On these two grounds, then, they may fairly be criticized, first, for omitting the more fundamental principles, and secondly, for thinking that the two they mentioned were attributable equally to everything.

Since we have already determined that functions of this kind belong to things which possess, a principle of movement, and that the heaven is animate and possesses a principle of movement, clearly the heaven must also exhibit above and below, right and left. We need not be troubled by the question, arising from the spherical shape of the world, how there can be a distinction of right and left within it, all parts being alike and all for ever in motion. We must think of the world as of something in which right differs from left in shape as well as in other respects, which subsequently is included in a sphere. The difference of function will persist, but will appear not to by reason of the regularity of shape. In the same fashion must we conceive of the beginning of its movement. For even if it never began to move, yet it must possess a principle from which it would have begun to move if it had begun, and from which it would begin again if it came to a stand. Now by its length I mean the interval between its poles, one pole being above and the other below; for two hemispheres are specially distinguished from all others by the immobility of the poles. Further, by 'transverse' in the universe we commonly mean, not above and below, but a direction crossing the line of the poles, which, by implication, is length: for transverse motion is motion crossing motion up and down. Of the poles, that which we see above us is the lower region, and that which we do not see is the upper. For right in anything is, as we say, the region in which locomotion originates, and the rotation of the heaven originates in the region from which the stars rise. So this will be the right, and the region where they set the left. If then they begin from the right and move round to the right, the upper must be the unseen pole. For if it is the pole we see, the movement will be leftward, which we deny to be the fact. Clearly then the invisible pole is above. And those who live in the other hemisphere are above and to the right, while we are below and to the left. This is just the opposite of the view of the Pythagoreans, who make us above and on the right side and those in the other hemisphere below and on the left side; the fact being the exact opposite. Relatively, however, to the secondary revolution, I mean that of the planets, we are above and on the right and they are below and on the left. For the principle of their movement has the reverse position, since the movement itself is the contrary of the other: hence it follows that we are at its beginning and they at its end. Here we may end our discussion of the distinctions of parts created by the three dimensions and of the consequent differences of position.

3

Since circular motion is not the contrary of the reverse circular motion, we must consider why there is more than one motion, though we have to pursue our inquiries at a distance−a distance created not so much by our spatial position as by the fact that our senses enable us to perceive very few of the attributes of the heavenly bodies. But let not that deter us. The reason must be sought in the following facts. Everything which has a function exists for its function. The activity of God is immortality, i.e. eternal life. Therefore the movement of that which is divine must be eternal. But such is the heaven, viz. a divine body, and for that reason to it is given the circular body whose nature it is to move always in a circle. Why, then, is not the whole body of the heaven of the same character as that part? Because there must be something at rest at the centre of the revolving body; and of that body no part can be at rest, either elsewhere or at the centre. It could do so only if the body's natural movement were towards the centre. But the circular movement is natural, since otherwise it could not be eternal: for nothing unnatural is eternal. The unnatural is subsequent to the natural, being a derangement of the natural which occurs

in the course of its generation. Earth then has to exist; for it is earth which is at rest at the centre. (At present we may take this for granted: it shall be explained later.) But if earth must exist, so must fire. For, if one of a pair of contraries naturally exists, the other, if it is really contrary, exists also naturally. In some form it must be present, since the matter of contraries is the same. Also, the positive is prior to its privation (warm, for instance, to cold), and rest and heaviness stand for the privation of lightness and movement. But further, if fire and earth exist, the intermediate bodies must exist also: each element stands in a contrary relation to every other. (This, again, we will here take for granted and try later to explain.) these four elements generation clearly is involved, since none of them can be eternal: for contraries interact with one another and destroy one another. Further, it is inconceivable that a movable body should be eternal, if its movement cannot be regarded as naturally eternal: and these bodies we know to possess movement. Thus we see that generation is necessarily involved. But if so, there must be at least one other circular motion: for a single movement of the whole heaven would necessitate an identical relation of the elements of bodies to one another. This matter also shall be cleared up in what follows: but for the present so much is clear, that the reason why there is more than one circular body is the necessity of generation, which follows on the presence of fire, which, with that of the other bodies, follows on that of earth; and earth is required because eternal movement in one body necessitates eternal rest in another.

4

The shape of the heaven is of necessity spherical; for that is the shape most appropriate to its substance and also by nature primary.

First, let us consider generally which shape is primary among planes and solids alike. Every plane figure must be either rectilinear or curvilinear. Now the rectilinear is bounded by more than one line, the curvilinear by one only. But since in any kind the one is naturally prior to the many and the simple to the complex, the circle will be the first of plane figures. Again, if by complete, as previously defined, we mean a thing outside which no part of itself can be found, and if addition is always possible to the straight line but never to the circular, clearly the line which embraces the circle is complete. If then the complete is prior to the incomplete, it follows on this ground also that the circle is primary among figures. And the sphere holds the same position among solids. For it alone is embraced by a single surface, while rectilinear solids have several. The sphere is among solids what the circle is among plane figures. Further, those who divide bodies into planes and generate them out of planes seem to bear witness to the truth of this. Alone among solids they leave the sphere undivided, as not possessing more than one surface: for the division into surfaces is not just dividing a whole by cutting it into its parts, but division of another fashion into parts different in form. It is clear, then, that the sphere is first of solid figures.

If, again, one orders figures according to their numbers, it is most natural to arrange them in this way. The circle corresponds to the number one, the triangle, being the sum of two right angles, to the number two. But if one is assigned to the triangle, the circle will not be a figure at all.

Now the first figure belongs to the first body, and the first body is that at the farthest circumference. It follows that the body which revolves with a circular movement must be spherical. The same then will be true of the body continuous with it: for that which is continuous with the spherical is spherical. The same again holds of the bodies between these and the centre. Bodies which are bounded by the spherical and in contact with it must be, as wholes, spherical; and the bodies below the sphere of the planets are contiguous with the sphere above them. The sphere then will be spherical throughout; for every body within it is contiguous and continuous with spheres.

Again, since the whole revolves, palpably and by assumption, in a circle, and since it has been shown that outside the farthest circumference there is neither void nor place, from these grounds also it will follow necessarily that the heaven is spherical. For if it is to be rectilinear in shape, it will follow that there is place and body and void without it. For a rectilinear figure as it revolves never continues in the same room, but where formerly was body, is now none, and where now is none, body will be in a moment because of the projection at the corners. Similarly,

if the world had some other figure with unequal radii, if, for instance, it were lentiform, or oviform, in every case we should have to admit space and void outside the moving body, because the whole body would not always occupy the same room.

Again, if the motion of the heaven is the measure of all movements whatever in virtue of being alone continuous and regular and eternal, and if, in each kind, the measure is the minimum, and the minimum movement is the swiftest, then, clearly, the movement of the heaven must be the swiftest of all movements. Now of lines which return upon themselves the line which bounds the circle is the shortest; and that movement is the swiftest which follows the shortest line. Therefore, if the heaven moves in a circle and moves more swiftly than anything else, it must necessarily be spherical.

Corroborative evidence may be drawn from the bodies whose position is about the centre. If earth is enclosed by water, water by air, air by fire, and these similarly by the upper bodies−which while not continuous are yet contiguous with them−and if the surface of water is spherical, and that which is continuous with or embraces the spherical must itself be spherical, then on these grounds also it is clear that the heavens are spherical. But the surface of water is seen to be spherical if we take as our starting−point the fact that water naturally tends to collect in a hollow place−'hollow' meaning 'nearer the centre'. Draw from the centre the lines AB, AC, and let their extremities be joined by the straight line BC. The line AD, drawn to the base of the triangle, will be shorter than either of the radii. Therefore the place in which it terminates will be a hollow place. The water then will collect there until equality is established, that is until the line AE is equal to the two radii. Thus water forces its way to the ends of the radii, and there only will it rest: but the line which connects the extremities of the radii is circular: therefore the surface of the water BEC is spherical.

It is plain from the foregoing that the universe is spherical. It is plain, further, that it is turned (so to speak) with a finish which no manufactured thing nor anything else within the range of our observation can even approach. For the matter of which these are composed does not admit of anything like the same regularity and finish as the substance of the enveloping body; since with each step away from earth the matter manifestly becomes finer in the same proportion as water is finer than earth.

5

Now there are two ways of moving along a circle, from A to B or from A to C, and we have already explained that these movements are not contrary to one another. But nothing which concerns the eternal can be a matter of chance or spontaneity, and the heaven and its circular motion are eternal. We must therefore ask why this motion takes one direction and not the other. Either this is itself an ultimate fact or there is an ultimate fact behind it. It may seem evidence of excessive folly or excessive zeal to try to provide an explanation of some things, or of everything, admitting no exception. The criticism, however, is not always just: one should first consider what reason there is for speaking, and also what kind of certainty is looked for, whether human merely or of a more cogent kind. When any one shall succeed in finding proofs of greater precision, gratitude will be due to him for the discovery, but at present we must be content with a probable solution. If nature always follows the best course possible, and, just as upward movement is the superior form of rectilinear movement, since the upper region is more divine than the lower, so forward movement is superior to backward, then front and back exhibits, like right and left, as we said before and as the difficulty just stated itself suggests, the distinction of prior and posterior, which provides a reason and so solves our difficulty. Supposing that nature is ordered in the best way possible, this may stand as the reason of the fact mentioned. For it is best to move with a movement simple and unceasing, and, further, in the superior of two possible directions.

6

We have next to show that the movement of the heaven is regular and not irregular. This applies only to the first heaven and the first movement; for the lower spheres exhibit a composition of several movements into one. If the movement is uneven, clearly there will be acceleration, maximum speed, and retardation, since these appear in all irregular motions. The maximum may occur either at the starting−point or at the goal or between the two; and we expect natural motion to reach its maximum at the goal, unnatural motion at the starting−point, and missiles midway between the two. But circular movement, having no beginning or limit or middle in the direct sense of the words, has neither whence nor whither nor middle: for in time it is eternal, and in length it returns upon itself without a break. If then its movement has no maximum, it can have no irregularity, since irregularity is produced by retardation and acceleration. Further, since everything that is moved is moved by something, the cause of the irregularity of movement must lie either in the mover or in the moved or both. For if the mover moved not always with the same force, or if the moved were altered and did not remain the same, or if both were to change, the result might well be an irregular movement in the moved. But none of these possibilities can be conceived as actual in the case of the heavens. As to that which is moved, we have shown that it is primary and simple and ungenerated and indestructible and generally unchanging; and the mover has an even better right to these attributes. It is the primary that moves the primary, the simple the simple, the indestructible and ungenerated that which is indestructible and ungenerated. Since then that which is moved, being a body, is nevertheless unchanging, how should the mover, which is incorporeal, be changed?

It follows then, further, that the motion cannot be irregular. For if irregularity occurs, there must be change either in the movement as a whole, from fast to slow and slow to fast, or in its parts. That there is no irregularity in the parts is obvious, since, if there were, some divergence of the stars would have taken place before now in the infinity of time, as one moved slower and another faster: but no alteration of their intervals is ever observed. Nor again is a change in the movement as a whole admissible. Retardation is always due to incapacity, and incapacity is unnatural. The incapacities of animals, age, decay, and the like, are all unnatural, due, it seems, to the fact that the whole animal complex is made up of materials which differ in respect of their proper places, and no single part occupies its own place. If therefore that which is primary contains nothing unnatural, being simple and unmixed and in its proper place and having no contrary, then it has no place for incapacity, nor, consequently, for retardation or (since acceleration involves retardation) for acceleration. Again, it is inconceivable that the mover should first show incapacity for an infinite time, and capacity afterwards for another infinity. For clearly nothing which, like incapacity, unnatural ever continues for an infinity of time; nor does the unnatural endure as long as the natural, or any form of incapacity as long as the capacity. But if the movement is retarded it must necessarily be retarded for an infinite time. Equally impossible is perpetual acceleration or perpetual retardation. For such movement would be infinite and indefinite, but every movement, in our view, proceeds from one point to another and is definite in character. Again, suppose one assumes a minimum time in less than which the heaven could not complete its movement. For, as a given walk or a given exercise on the harp cannot take any and every time, but every performance has its definite minimum time which is unsurpassable, so, one might suppose, the movement of the heaven could not be completed in any and every time. But in that case perpetual acceleration is impossible (and, equally, perpetual retardation: for the argument holds of both and each), if we may take acceleration to proceed by identical or increasing additions of speed and for an infinite time. The remaining alternative is to say that the movement exhibits an alternation of slower and faster: but this is a mere fiction and quite inconceivable. Further, irregularity of this kind would be particularly unlikely to pass unobserved, since contrast makes observation easy.

That there is one heaven, then, only, and that it is ungenerated and eternal, and further that its movement is regular, has now been sufficiently explained.

7

We have next to speak of the stars, as they are called, of their composition, shape, and movements. It would be most natural and consequent upon what has been said that each of the stars should be composed of that substance in which their path lies, since, as we said, there is an element whose natural movement is circular. In so saying we are only following the same line of thought as those who say that the stars are fiery because they believe the upper body to be fire, the presumption being that a thing is composed of the same stuff as that in which it is situated. The warmth and light which proceed from them are caused by the friction set up in the air by their motion. Movement tends to create fire in wood, stone, and iron; and with even more reason should it have that effect on air, a substance which is closer to fire than these. An example is that of missiles, which as they move are themselves fired so strongly that leaden balls are melted; and if they are fired the surrounding air must be similarly affected. Now while the missiles are heated by reason of their motion in air, which is turned into fire by the agitation produced by their movement, the upper bodies are carried on a moving sphere, so that, though they are not themselves fired, yet the air underneath the sphere of the revolving body is necessarily heated by its motion, and particularly in that part where the sun is attached to it. Hence warmth increases as the sun gets nearer or higher or overhead. Of the fact, then, that the stars are neither fiery nor move in fire, enough has been said.

8

Since changes evidently occur not only in the position of the stars but also in that of the whole heaven, there are three possibilities. Either (1) both are at rest, or (2) both are in motion, or (3) the one is at rest and the other in motion.

(1) That both should be at rest is impossible; for, if the earth is at rest, the hypothesis does not account for the observations; and we take it as granted that the earth is at rest. It remains either that both are moved, or that the one is moved and the other at rest.

(2) On the view, first, that both are in motion, we have the absurdity that the stars and the circles move with the same speed, i.e. that the ace of every star is that of the circle in it moves. For star and circle are seen to come back to the same place at the same moment; from which it follows that the star has traversed the circle and the circle has completed its own movement, i.e. traversed its own circumference, at one and the same moment. But it is difficult to conceive that the pace of each star should be exactly proportioned to the size of its circle. That the pace of each circle should be proportionate to its size is not absurd but inevitable: but that the same should be true of the movement of the stars contained in the circles is quite incredible. For if, on the one and, we suppose that the star which moves on the greater circle is necessarily swifter, clearly we also admit that if stars shifted their position so as to exchange circles, the slower would become swifter and the swifter slower. But this would show that their movement was not their own, but due to the circles. If, on the other hand, the arrangement was a chance combination, the coincidence in every case of a greater circle with a swifter movement of the star contained in it is too much to believe. In one or two cases it might not inconceivably fall out so, but to imagine it in every case alike is a mere fiction. Besides, chance has no place in that which is natural, and what happens everywhere and in every case is no matter of chance.

(3) The same absurdity is equally plain if it is supposed that the circles stand still and that it is the stars themselves which move. For it will follow that the outer stars are the swifter, and that the pace of the stars corresponds to the size of their circles.

Since, then, we cannot reasonably suppose either that both are in motion or that the star alone moves, the remaining alternative is that the circles should move, while the stars are at rest and move with the circles to which they are attached. Only on this supposition are we involved in no absurd consequence. For, in the first place, the quicker movement of the larger circle is natural when all the circles are attached to the same centre. Whenever

bodies are moving with their proper motion, the larger moves quicker. It is the same here with the revolving bodies: for the are intercepted by two radii will be larger in the larger circle, and hence it is not surprising that the revolution of the larger circle should take the same time as that of the smaller. And secondly, the fact that the heavens do not break in pieces follows not only from this but also from the proof already given of the continuity of the whole.

Again, since the stars are spherical, as our opponents assert and we may consistently admit, inasmuch as we construct them out of the spherical body, and since the spherical body has two movements proper to itself, namely rolling and spinning, it follows that if the stars have a movement of their own, it will be one of these. But neither is observed. (1) Suppose them to spin. They would then stay where they were, and not change their place, as, by observation and general consent, they do. Further, one would expect them all to exhibit the same movement: but the only star which appears to possess this movement is the sun, at sunrise or sunset, and this appearance is due not to the sun itself but to the distance from which we observe it. The visual ray being excessively prolonged becomes weak and wavering. The same reason probably accounts for the apparent twinkling of the fixed stars and the absence of twinkling in the planets. The planets are near, so that the visual ray reaches them in its full vigour, but when it comes to the fixed stars it is quivering because of the distance and its excessive extension; and its tremor produces an appearance of movement in the star: for it makes no difference whether movement is set up in the ray or in the object of vision.

(2) On the other hand, it is also clear that the stars do not roll. For rolling involves rotation: but the 'face', as it is called, of the moon is always seen. Therefore, since any movement of their own which the stars possessed would presumably be one proper to themselves, and no such movement is observed in them, clearly they have no movement of their own.

There is, further, the absurdity that nature has bestowed upon them no organ appropriate to such movement. For nature leaves nothing to chance, and would not, while caring for animals, overlook things so precious. Indeed, nature seems deliberately to have stripped them of everything which makes selforiginated progression possible, and to have removed them as far as possible from things which have organs of movement. This is just why it seems proper that the whole heaven and every star should be spherical. For while of all shapes the sphere is the most convenient for movement in one place, making possible, as it does, the swiftest and most selfcontained motion, for forward movement it is the most unsuitable, least of all resembling shapes which are self−moved, in that it has no dependent or projecting part, as a rectilinear figure has, and is in fact as far as possible removed in shape from ambulatory bodies. Since, therefore, the heavens have to move in one lace, and the stars are not required to move themselves forward, it is natural that both should be spherical−a shape which best suits the movement of the one and the immobility of the other.

9

From all this it is clear that the theory that the movement of the stars produces a harmony, i.e. that the sounds they make are concordant, in spite of the grace and originality with which it has been stated, is nevertheless untrue. Some thinkers suppose that the motion of bodies of that size must produce a noise, since on our earth the motion of bodies far inferior in size and in speed of movement has that effect. Also, when the sun and the moon, they say, and all the stars, so great in number and in size, are moving with so rapid a motion, how should they not produce a sound immensely great? Starting from this argument and from the observation that their speeds, as measured by their distances, are in the same ratios as musical concordances, they assert that the sound given forth by the circular movement of the stars is a harmony. Since, however, it appears unaccountable that we should not hear this music, they explain this by saying that the sound is in our ears from the very moment of birth and is thus indistinguishable from its contrary silence, since sound and silence are discriminated by mutual contrast. What happens to men, then, is just what happens to coppersmiths, who are so accustomed to the noise of the smithy that it makes no difference to them. But, as we said before, melodious and poetical as the theory is, it cannot be a true

account of the facts. There is not only the absurdity of our hearing nothing, the ground of which they try to remove, but also the fact that no effect other than sensitive is produced upon us. Excessive noises, we know, shatter the solid bodies even of inanimate things: the noise of thunder, for instance, splits rocks and the strongest of bodies. But if the moving bodies are so great, and the sound which penetrates to us is proportionate to their size, that sound must needs reach us in an intensity many times that of thunder, and the force of its action must be immense. Indeed the reason why we do not hear, and show in our bodies none of the effects of violent force, is easily given: it is that there is no noise. But not only is the explanation evident; it is also a corroboration of the truth of the views we have advanced. For the very difficulty which made the Pythagoreans say that the motion of the stars produces a concord corroborates our view. Bodies which are themselves in motion, produce noise and friction: but those which are attached or fixed to a moving body, as the parts to a ship, can no more create noise, than a ship on a river moving with the stream. Yet by the same argument one might say it was absurd that on a large vessel the motion of mast and poop should not make a great noise, and the like might be said of the movement of the vessel itself. But sound is caused when a moving body is enclosed in an unmoved body, and cannot be caused by one enclosed in, and continuous with, a moving body which creates no friction. We may say, then, in this matter that if the heavenly bodies moved in a generally diffused mass of air or fire, as every one supposes, their motion would necessarily cause a noise of tremendous strength and such a noise would necessarily reach and shatter us. Since, therefore, this effect is evidently not produced, it follows that none of them can move with the motion either of animate nature or of constraint. It is as though nature had foreseen the result, that if their movement were other than it is, nothing on this earth could maintain its character.

That the stars are spherical and are not selfmoved, has now been explained.

10

With their order−I mean the position of each, as involving the priority of some and the posteriority of others, and their respective distances from the extremity−with this astronomy may be left to deal, since the astronomical discussion is adequate. This discussion shows that the movements of the several stars depend, as regards the varieties of speed which they exhibit, on the distance of each from the extremity. It is established that the outermost revolution of the heavens is a simple movement and the swiftest of all, and that the movement of all other bodies is composite and relatively slow, for the reason that each is moving on its own circle with the reverse motion to that of the heavens. This at once leads us to expect that the body which is nearest to that first simple revolution should take the longest time to complete its circle, and that which is farthest from it the shortest, the others taking a longer time the nearer they are and a shorter time the farther away they are. For it is the nearest body which is most strongly influenced, and the most remote, by reason of its distance, which is least affected, the influence on the intermediate bodies varying, as the mathematicians show, with their distance.

11

With regard to the shape of each star, the most reasonable view is that they are spherical. It has been shown that it is not in their nature to move themselves, and, since nature is no wanton or random creator, clearly she will have given things which possess no movement a shape particularly unadapted to movement. Such a shape is the sphere, since it possesses no instrument of movement. Clearly then their mass will have the form of a sphere. Again, what holds of one holds of all, and the evidence of our eyes shows us that the moon is spherical. For how else should the moon as it waxes and wanes show for the most part a crescent−shaped or gibbous figure, and only at one moment a half−moon? And astronomical arguments give further confirmation; for no other hypothesis accounts for the crescent shape of the sun's eclipses. One, then, of the heavenly bodies being spherical, clearly the rest will be spherical also.

12

There are two difficulties, which may very reasonably here be raised, of which we must now attempt to state the probable solution: for we regard the zeal of one whose thirst after philosophy leads him to accept even slight indications where it is very difficult to see one's way, as a proof rather of modesty than of overconfidence.

Of many such problems one of the strangest is the problem why we find the greatest number of movements in the intermediate bodies, and not, rather, in each successive body a variety of movement proportionate to its distance from the primary motion. For we should expect, since the primary body shows one motion only, that the body which is nearest to it should move with the fewest movements, say two, and the one next after that with three, or some similar arrangement. But the opposite is the case. The movements of the sun and moon are fewer than those of some of the planets. Yet these planets are farther from the centre and thus nearer to the primary body than they, as observation has itself revealed. For we have seen the moon, half−full, pass beneath the planet Mars, which vanished on its shadow side and came forth by the bright and shining part. Similar accounts of other stars are given by the Egyptians and Babylonians, whose observations have been kept for very many years past, and from whom much of our evidence about particular stars is derived. A second difficulty which may with equal justice be raised is this. Why is it that the primary motion includes such a multitude of stars that their whole array seems to defy counting, while of the other stars each one is separated off, and in no case do we find two or more attached to the same motion?

On these questions, I say, it is well that we should seek to increase our understanding, though we have but little to go upon, and are placed at so great a distance from the facts in question. Nevertheless there are certain principles on which if we base our consideration we shall not find this difficulty by any means insoluble. We may object that we have been thinking of the stars as mere bodies, and as units with a serial order indeed but entirely inanimate; but should rather conceive them as enjoying life and action. On this view the facts cease to appear surprising. For it is natural that the best−conditioned of all things should have its good without action, that which is nearest to it should achieve it by little and simple action, and that which is farther removed by a complexity of actions, just as with men's bodies one is in good condition without exercise at all, another after a short walk, while another requires running and wrestling and hard training, and there are yet others who however hard they worked themselves could never secure this good, but only some substitute for it. To succeed often or in many things is difficult. For instance, to throw ten thousand Coan throws with the dice would be impossible, but to throw one or two is comparatively easy. In action, again, when A has to be done to get B, B to get C, and C to get D, one step or two present little difficulty, but as the series extends the difficulty grows. We must, then, think of the action of the lower stars as similar to that of animals and plants. For on our earth it is man that has the greatest variety of actions−for there are many goods that man can secure; hence his actions are various and directed to ends beyond them−while the perfectly conditioned has no need of action, since it is itself the end, and action always requires two terms, end and means. The lower animals have less variety of action than man; and plants perhaps have little action and of one kind only. For either they have but one attainable good (as indeed man has), or, if several, each contributes directly to their ultimate good. One thing then has and enjoys the ultimate good, other things attain to it, one immediately by few steps, another by many, while yet another does not even attempt to secure it but is satisfied to reach a point not far removed from that consummation. Thus, taking health as the end, there will be one thing that always possesses health, others that attain it, one by reducing flesh, another by running and thus reducing flesh, another by taking steps to enable himself to run, thus further increasing the number of movements, while another cannot attain health itself, but only running or reduction of flesh, so that one or other of these is for such a being the end. For while it is clearly best for any being to attain the real end, yet, if that cannot be, the nearer it is to the best the better will be its state. It is for this reason that the earth moves not at all and the bodies near to it with few movements. For they do not attain the final end, but only come as near to it as their share in the divine principle permits. But the first heaven finds it immediately with a single movement, and the bodies intermediate between the first and last heavens attain it indeed, but at the cost of a multiplicity of movement.

As to the difficulty that into the one primary motion is crowded a vast multitude of stars, while of the other stars each has been separately given special movements of its own, there is in the first place this reason for regarding the arrangement as a natural one. In thinking of the life and moving principle of the several heavens one must regard the first as far superior to the others. Such a superiority would be reasonable. For this single first motion has to move many of the divine bodies, while the numerous other motions move only one each, since each single planet moves with a variety of motions. Thus, then, nature makes matters equal and establishes a certain order, giving to the single motion many bodies and to the single body many motions. And there is a second reason why the other motions have each only one body, in that each of them except the last, i.e. that which contains the one star, is really moving many bodies. For this last sphere moves with many others, to which it is fixed, each sphere being actually a body; so that its movement will be a joint product. Each sphere, in fact, has its particular natural motion, to which the general movement is, as it were, added. But the force of any limited body is only adequate to moving a limited body.

The characteristics of the stars which move with a circular motion, in respect of substance and shape, movement and order, have now been sufficiently explained.

13

It remains to speak of the earth, of its position, of the question whether it is at rest or in motion, and of its shape.

I. As to its position there is some difference of opinion. Most people−all, in fact, who regard the whole heaven as finite−say it lies at the centre. But the Italian philosophers known as Pythagoreans take the contrary view. At the centre, they say, is fire, and the earth is one of the stars, creating night and day by its circular motion about the centre. They further construct another earth in opposition to ours to which they give the name counterearth. In all this they are not seeking for theories and causes to account for observed facts, but rather forcing their observations and trying to accommodate them to certain theories and opinions of their own. But there are many others who would agree that it is wrong to give the earth the central position, looking for confirmation rather to theory than to the facts of observation. Their view is that the most precious place befits the most precious thing: but fire, they say, is more precious than earth, and the limit than the intermediate, and the circumference and the centre are limits. Reasoning on this basis they take the view that it is not earth that lies at the centre of the sphere, but rather fire. The Pythagoreans have a further reason. They hold that the most important part of the world, which is the centre, should be most strictly guarded, and name it, or rather the fire which occupies that place, the 'Guardhouse of Zeus', as if the word 'centre' were quite unequivocal, and the centre of the mathematical figure were always the same with that of the thing or the natural centre. But it is better to conceive of the case of the whole heaven as analogous to that of animals, in which the centre of the animal and that of the body are different. For this reason they have no need to be so disturbed about the world, or to call in a guard for its centre: rather let them look for the centre in the other sense and tell us what it is like and where nature has set it. That centre will be something primary and precious; but to the mere position we should give the last place rather than the first. For the middle is what is defined, and what defines it is the limit, and that which contains or limits is more precious than that which is limited, see ing that the latter is the matter and the former the essence of the system.

II. As to the position of the earth, then, this is the view which some advance, and the views advanced concerning its rest or motion are similar. For here too there is no general agreement. All who deny that the earth lies at the centre think that it revolves about the centre, and not the earth only but, as we said before, the counter−earth as well. Some of them even consider it possible that there are several bodies so moving, which are invisible to us owing to the interposition of the earth. This, they say, accounts for the fact that eclipses of the moon are more frequent than eclipses of the sun: for in addition to the earth each of these moving bodies can obstruct it. Indeed, as in any case the surface of the earth is not actually a centre but distant from it a full hemisphere, there is no more difficulty, they think, in accounting for the observed facts on their view that we do not dwell at the centre, than on the common view that the earth is in the middle. Even as it is, there is nothing in the observations to suggest that

we are removed from the centre by half the diameter of the earth. Others, again, say that the earth, which lies at the centre, is 'rolled', and thus in motion, about the axis of the whole heaven, So it stands written in the Timaeus.

III. There are similar disputes about the shape of the earth. Some think it is spherical, others that it is flat and drum−shaped. For evidence they bring the fact that, as the sun rises and sets, the part concealed by the earth shows a straight and not a curved edge, whereas if the earth were spherical the line of section would have to be circular. In this they leave out of account the great distance of the sun from the earth and the great size of the circumference, which, seen from a distance on these apparently small circles appears straight. Such an appearance ought not to make them doubt the circular shape of the earth. But they have another argument. They say that because it is at rest, the earth must necessarily have this shape. For there are many different ways in which the movement or rest of the earth has been conceived.

The difficulty must have occurred to every one. It would indeed be a complacent mind that felt no surprise that, while a little bit of earth, let loose in mid−air moves and will not stay still, and more there is of it the faster it moves, the whole earth, free in midair, should show no movement at all. Yet here is this great weight of earth, and it is at rest. And again, from beneath one of these moving fragments of earth, before it falls, take away the earth, and it will continue its downward movement with nothing to stop it. The difficulty then, has naturally passed into a common place of philosophy; and one may well wonder that the solutions offered are not seen to involve greater absurdities than the problem itself.

By these considerations some have been led to assert that the earth below us is infinite, saying, with Xenophanes of Colophon, that it has 'pushed its roots to infinity',−in order to save the trouble of seeking for the cause. Hence the sharp rebuke of Empedocles, in the words 'if the deeps of the earth are endless and endless the ample ether−such is the vain tale told by many a tongue, poured from the mouths of those who have seen but little of the whole. Others say the earth rests upon water. This, indeed, is the oldest theory that has been preserved, and is attributed to Thales of Miletus. It was supposed to stay still because it floated like wood and other similar substances, which are so constituted as to rest upon but not upon air. As if the same account had not to be given of the water which carries the earth as of the earth itself! It is not the nature of water, any more than of earth, to stay in mid−air: it must have something to rest upon. Again, as air is lighter than water, so is water than earth: how then can they think that the naturally lighter substance lies below the heavier? Again, if the earth as a whole is capable of floating upon water, that must obviously be the case with any part of it. But observation shows that this is not the case. Any piece of earth goes to the bottom, the quicker the larger it is. These thinkers seem to push their inquiries some way into the problem, but not so far as they might. It is what we are all inclined to do, to direct our inquiry not by the matter itself, but by the views of our opponents: and even when interrogating oneself one pushes the inquiry only to the point at which one can no longer offer any opposition. Hence a good inquirer will be one who is ready in bringing forward the objections proper to the genus, and that he will be when he has gained an understanding of all the differences.

Anaximenes and Anaxagoras and Democritus give the flatness of the earth as the cause of its staying still. Thus, they say, it does not cut, but covers like a lid, the air beneath it. This seems to be the way of flat−shaped bodies: for even the wind can scarcely move them because of their power of resistance. The same immobility, they say, is produced by the flatness of the surface which the earth presents to the air which underlies it; while the air, not having room enough to change its place because it is underneath the earth, stays there in a mass, like the water in the case of the water−clock. And they adduce an amount of evidence to prove that air, when cut off and at rest, can bear a considerable weight.

Now, first, if the shape of the earth is not flat, its flatness cannot be the cause of its immobility. But in their own account it is rather the size of the earth than its flatness that causes it to remain at rest. For the reason why the air is so closely confined that it cannot find a passage, and therefore stays where it is, is its great amount: and this amount great because the body which isolates it, the earth, is very large. This result, then, will follow, even if the earth is spherical, so long as it retains its size. So far as their arguments go, the earth will still be at rest.

In general, our quarrel with those who speak of movement in this way cannot be confined to the parts; it concerns the whole universe. One must decide at the outset whether bodies have a natural movement or not, whether there is no natural but only constrained movement. Seeing, however, that we have already decided this matter to the best of our ability, we are entitled to treat our results as representing fact. Bodies, we say, which have no natural movement, have no constrained movement; and where there is no natural and no constrained movement there will be no movement at all. This is a conclusion, the necessity of which we have already decided, and we have seen further that rest also will be inconceivable, since rest, like movement, is either natural or constrained. But if there is any natural movement, constraint will not be the sole principle of motion or of rest. If, then, it is by constraint that the earth now keeps its place, the so−called 'whirling' movement by which its parts came together at the centre was also constrained. (The form of causation supposed they all borrow from observations of liquids and of air, in which the larger and heavier bodies always move to the centre of the whirl. This is thought by all those who try to generate the heavens to explain why the earth came together at the centre. They then seek a reason for its staying there; and some say, in the manner explained, that the reason is its size and flatness, others, with Empedocles, that the motion of the heavens, moving about it at a higher speed, prevents movement of the earth, as the water in a cup, when the cup is given a circular motion, though it is often underneath the bronze, is for this same reason prevented from moving with the downward movement which is natural to it.) But suppose both the 'whirl' and its flatness (the air beneath being withdrawn) cease to prevent the earth's motion, where will the earth move to then? Its movement to the centre was constrained, and its rest at the centre is due to constraint; but there must be some motion which is natural to it. Will this be upward motion or downward or what? It must have some motion; and if upward and downward motion are alike to it, and the air above the earth does not prevent upward movement, then no more could air below it prevent downward movement. For the same cause must necessarily have the same effect on the same thing.

Further, against Empedocles there is another point which might be made. When the elements were separated off by Hate, what caused the earth to keep its place? Surely the 'whirl' cannot have been then also the cause. It is absurd too not to perceive that, while the whirling movement may have been responsible for the original coming together of the art of earth at the centre, the question remains, why now do all heavy bodies move to the earth. For the whirl surely does not come near us. Why, again, does fire move upward? Not, surely, because of the whirl. But if fire is naturally such as to move in a certain direction, clearly the same may be supposed to hold of earth. Again, it cannot be the whirl which determines the heavy and the light. Rather that movement caused the pre−existent heavy and light things to go to the middle and stay on the surface respectively. Thus, before ever the whirl began, heavy and light existed; and what can have been the ground of their distinction, or the manner and direction of their natural movements? In the infinite chaos there can have been neither above nor below, and it is by these that heavy and light are determined.

It is to these causes that most writers pay attention: but there are some, Anaximander, for instance, among the ancients, who say that the earth keeps its place because of its indifference. Motion upward and downward and sideways were all, they thought, equally inappropriate to that which is set at the centre and indifferently related to every extreme point; and to move in contrary directions at the same time was impossible: so it must needs remain still. This view is ingenious but not true. The argument would prove that everything, whatever it be, which is put at the centre, must stay there. Fire, then, will rest at the centre: for the proof turns on no peculiar property of earth. But this does not follow. The observed facts about earth are not only that it remains at the centre, but also that it moves to the centre. The place to which any fragment of earth moves must necessarily be the place to which the whole moves; and in the place to which a thing naturally moves, it will naturally rest. The reason then is not in the fact that the earth is indifferently related to every extreme point: for this would apply to any body, whereas movement to the centre is peculiar to earth. Again it is absurd to look for a reason why the earth remains at the centre and not for a reason why fire remains at the extremity. If the extremity is the natural place of fire, clearly earth must also have a natural place. But suppose that the centre is not its place, and that the reason of its remaining there is this necessity of indifference−on the analogy of the hair which, it is said, however great the tension, will not break under it, if it be evenly distributed, or of the men who, though exceedingly hungry and thirsty, and both equally, yet being equidistant from food and drink, is therefore bound to stay where he is−even

so, it still remains to explain why fire stays at the extremities. It is strange, too, to ask about things staying still but not about their motion,−why, I mean, one thing, if nothing stops it, moves up, and another thing to the centre. Again, their statements are not true. It happens, indeed, to be the case that a thing to which movement this way and that is equally inappropriate is obliged to remain at the centre. But so far as their argument goes, instead of remaining there, it will move, only not as a mass but in fragments. For the argument applies equally to fire. Fire, if set at the centre, should stay there, like earth, since it will be indifferently related to every point on the extremity. Nevertheless it will move, as in fact it always does move when nothing stops it, away from the centre to the extremity. It will not, however, move in a mass to a single point on the circumference−the only possible result on the lines of the indifference theory−but rather each corresponding portion of fire to the corresponding part of the extremity, each fourth part, for instance, to a fourth part of the circumference. For since no body is a point, it will have parts. The expansion, when the body increased the place occupied, would be on the same principle as the contraction, in which the place was diminished. Thus, for all the indifference theory shows to the contrary, earth also would have moved in this manner away from the centre, unless the centre had been its natural place.

We have now outlined the views held as to the shape, position, and rest or movement of the earth.

14

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 move about the centre or as 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 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. That the centre of the earth is the goal of their movement is indicated by the fact that heavy bodies moving towards the earth do not parallel but so as to make equal angles, and thus to a single centre, that of the earth. 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 infinite 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 observations made as the shapes change 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. Only they attribute the downward movement to constraint, and it is better to keep to the truth and say that the reason of this motion is that a thing which possesses weight is naturally endowed with a centripetal movement. When the mixture, then, was merely potential, the things that were separated off moved similarly from every side towards the centre. Whether the parts which came together at the centre were distributed at the extremities evenly, or in some other way, makes no difference. 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. In this we have also the solution of a possible difficulty. The earth, it might be argued, is at the centre and spherical in shape: if, then, a weight many times that of the earth were added to one hemisphere, the centre of the earth and of the whole will no longer be coincident. So that either the earth will not stay still at the centre, or if it does, it will be at rest without having its centre at the place to which it is still its nature to move. Such is the difficulty. A short consideration will give us an easy answer, if we first give precision to our postulate that any body endowed with weight, of whatever size, moves towards the centre. Clearly it will not stop when its edge touches the centre. The greater quantity must prevail until the body's centre occupies the centre. For that is the goal of its impulse. Now it makes no difference whether we apply this to a clod or common fragment of earth or to the earth as a whole. The fact indicated does not depend upon degrees of size but applies universally to everything that has the centripetal impulse. Therefore earth in motion, whether in a mass or in fragments, necessarily continues to move until it occupies the centre equally every way, the less being forced to equalize itself by the greater owing to the forward drive of the impulse.

If the earth was generated, then, it must have been formed in this way, and so clearly its generation was spherical; and if it is ungenerated and has remained so always, its character must be that which the initial generation, if it had occurred, would have given it. But the spherical shape, necessitated by this argument, follows also from the fact that the motions of heavy bodies always make equal angles, and are not parallel. This would be the natural form of movement towards what is naturally spherical. Either then the earth is spherical or it is at least naturally spherical. And it is right to call anything that which nature intends it to be, and which belongs to it, rather than that which it is by constraint and contrary to nature. The evidence of the senses further corroborates this. How else would eclipses of the moon show segments shaped as we see them? As it is, the shapes which the moon itself each month shows are of every kind straight, gibbous, and concave−but in eclipses the outline is always curved: and, since it is the interposition of the earth that makes the eclipse, the form of this line will be caused by the form of the earth's surface, which is therefore spherical. Again, our observations of the stars make it evident, not only that the earth is circular, but also that it is a circle of no great size. For quite a small change of position to south or north causes a manifest alteration of the horizon. There is much change, I mean, in the stars which are overhead, and the stars seen are different, as one moves northward or southward. Indeed there are some stars seen in Egypt and in the neighbourhood of Cyprus which are not seen in the northerly regions; and stars, which in the north are never beyond the range of observation, in those regions rise and set. All of which goes to show not only that the earth is circular in shape, but also that it is a sphere of no great size: for otherwise the effect of so slight a change of place would not be quickly apparent. Hence one should not be too sure of the incredibility of the view of those

who conceive that there is continuity between the parts about the pillars of Hercules and the parts about India, and that in this way the ocean is one. As further evidence in favour of this they quote the case of elephants, a species occurring in each of these extreme regions, suggesting that the common characteristic of these extremes is explained by their continuity. Also, those mathematicians who try to calculate the size of the earth's circumference arrive at the figure 400,000 stades. This indicates not only that the earth's mass is spherical in shape, but also that as compared with the stars it is not of great size.

Book III

1

WE have already discussed the first heaven and its parts, the moving stars within it, the matter of which these are composed and their bodily constitution, and we have also shown that they are ungenerated and indestructible. Now things that we call natural are either substances or functions and attributes of substances. As substances I class the simple bodies−fire, earth, and the other terms of the series−and all things composed of them; for example, the heaven as a whole and its parts, animals, again, and plants and their parts. By attributes and functions I mean the movements of these and of all other things in which they have power in themselves to cause movement, and also their alterations and reciprocal transformations. It is obvious, then, that the greater part of the inquiry into nature concerns bodies: for a natural substance is either a body or a thing which cannot come into existence without body and magnitude. This appears plainly from an analysis of the character of natural things, and equally from an inspection of the instances of inquiry into nature. Since, then, we have spoken of the primary element, of its bodily constitution, and of its freedom from destruction and generation, it remains to speak of the other two. In speaking of them we shall be obliged also to inquire into generation and destruction. For if there is generation anywhere, it must be in these elements and things composed of them.

This is indeed the first question we have to ask: is generation a fact or not? Earlier speculation was at variance both with itself and with the views here put forward as to the true answer to this question. Some removed generation and destruction from the world altogether. Nothing that is, they said, is generated or destroyed, and our conviction to the contrary is an illusion. So maintained the school of Melissus and Parmenides. But however excellent their theories may otherwise be, anyhow they cannot be held to speak as students of nature. There may be things not subject to generation or any kind of movement, but if so they belong to another and a higher inquiry than the study of nature. They, however, had no idea of any form of being other than the substance of things perceived; and when they saw, what no one previously had seen, that there could be no knowledge or wisdom without some such unchanging entities, they naturally transferred what was true of them to things perceived. Others, perhaps intentionally, maintain precisely the contrary opinion to this. It has been asserted that everything in the world was subject to generation and nothing was ungenerated, but that after being generated some things remained indestructible while the rest were again destroyed. This had been asserted in the first instance by Hesiod and his followers, but afterwards outside his circle by the earliest natural philosophers. But what these thinkers maintained was that all else has been generated and, as they said, 'is flowing away, nothing having any solidity, except one single thing which persists as the basis of all these transformations. So we may interpret the statements of Heraclitus of Ephesus and many others. And some subject all bodies whatever to generation, by means of the composition and separation of planes.

Discussion of the other views may be postponed. But this last theory which composes every body of planes is, as the most superficial observation shows, in many respects in plain contradiction with mathematics. It is, however, wrong to remove the foundations of a science unless you can replace them with others more convincing. And, secondly, the same theory which composes solids of planes clearly composes planes of lines and lines of points, so that a part of a line need not be a line. This matter has been already considered in our discussion of movement, where we have shown that an indivisible length is impossible. But with respect to natural bodies there are impossibilities involved in the view which asserts indivisible lines, which we may briefly consider at this point.

For the impossible consequences which result from this view in the mathematical sphere will reproduce themselves when it is applied to physical bodies, but there will be difficulties in physics which are not present in mathematics; for mathematics deals with an abstract and physics with a more concrete object. There are many attributes necessarily present in physical bodies which are necessarily excluded by indivisibility; all attributes, in fact, which are divisible. There can be nothing divisible in an indivisible thing, but the attributes of bodies are all divisible in one of two ways. They are divisible into kinds, as colour is divided into white and black, and they are divisible per accidens when that which has them is divisible. In this latter sense attributes which are simple are nevertheless divisible. Attributes of this kind will serve, therefore, to illustrate the impossibility of the view. It is impossible, if two parts of a thing have no weight, that the two together should have weight. But either all perceptible bodies or some, such as earth and water, have weight, as these thinkers would themselves admit. Now if the point has no weight, clearly the lines have not either, and, if they have not, neither have the planes. Therefore no body has weight. It is, further, manifest that their point cannot have weight. For while a heavy thing may always be heavier than something and a light thing lighter than something, a thing which is heavier or lighter than something need not be itself heavy or light, just as a large thing is larger than others, but what is larger is not always large. A thing which, judged absolutely, is small may none the less be larger than other things. Whatever, then, is heavy and also heavier than something else, must exceed this by something which is heavy. A heavy thing therefore is always divisible. But it is common ground that a point is indivisible. Again, suppose that what is heavy or weight is a dense body, and what is light rare. Dense differs from rare in containing more matter in the same cubic area. A point, then, if it may be heavy or light, may be dense or rare. But the dense is divisible while a point is indivisible. And if what is heavy must be either hard or soft, an impossible consequence is easy to draw. For a thing is soft if its surface can be pressed in, hard if it cannot; and if it can be pressed in it is divisible.

Moreover, no weight can consist of parts not possessing weight. For how, except by the merest fiction, can they specify the number and character of the parts which will produce weight? And, further, when one weight is greater than another, the difference is a third weight; from which it will follow that every indivisible part possesses weight. For suppose that a body of four points possesses weight. A body composed of more than four points will superior in weight to it, a thing which has weight. But the difference between weight and weight must be a weight, as the difference between white and whiter is white. Here the difference which makes the superior weight heavier is the single point which remains when the common number, four, is subtracted. A single point, therefore, has weight.

Further, to assume, on the one hand, that the planes can only be put in linear contact would be ridiculous. For just as there are two ways of putting lines together, namely, end to and side by side, so there must be two ways of putting planes together. Lines can be put together so that contact is linear by laying one along the other, though not by putting them end to end. But if, similarly, in putting the lanes together, superficial contact is allowed as an alternative to linear, that method will give them bodies which are not any element nor composed of elements. Again, if it is the number of planes in a body that makes one heavier than another, as the Timaeus explains, clearly the line and the point will have weight. For the three cases are, as we said before, analogous. But if the reason of differences of weight is not this, but rather the heaviness of earth and the lightness of fire, then some of the planes will be light and others heavy (which involves a similar distinction in the lines and the points); the earthplane, I mean, will be heavier than the fire−plane. In general, the result is either that there is no magnitude at all, or that all magnitude could be done away with. For a point is to a line as a line is to a plane and as a plane is to a body. Now the various forms in passing into one another will each be resolved into its ultimate constituents. It might happen therefore that nothing existed except points, and that there was no body at all. A further consideration is that if time is similarly constituted, there would be, or might be, a time at which it was done away with. For the indivisible now is like a point in a line. The same consequences follow from composing the heaven of numbers, as some of the Pythagoreans do who make all nature out of numbers. For natural bodies are manifestly endowed with weight and lightness, but an assemblage of units can neither be composed to form a body nor possess weight.

2

The necessity that each of the simple bodies should have a natural movement may be shown as follows. They manifestly move, and if they have no proper movement they must move by constraint: and the constrained is the same as the unnatural. Now an unnatural movement presupposes a natural movement which it contravenes, and which, however many the unnatural movements, is always one. For naturally a thing moves in one way, while its unnatural movements are manifold. The same may be shown, from the fact of rest. Rest, also, must either be constrained or natural, constrained in a place to which movement was constrained, natural in a place movement to which was natural. Now manifestly there is a body which is at rest at the centre. If then this rest is natural to it, clearly motion to this place is natural to it. If, on the other hand, its rest is constrained, what is hindering its motion? Something, which is at rest: but if so, we shall simply repeat the same argument; and either we shall come to an ultimate something to which rest where it is or we shall have an infinite process, which is impossible. The hindrance to its movement, then, we will suppose, is a moving thing−as Empedocles says that it is the vortex which keeps the earth still−: but in that case we ask, where would it have moved to but for the vortex? It could not move infinitely; for to traverse an infinite is impossible, and impossibilities do not happen. So the moving thing must stop somewhere, and there rest not by constraint but naturally. But a natural rest proves a natural movement to the place of rest. Hence Leucippus and Democritus, who say that the primary bodies are in perpetual movement in the void or infinite, may be asked to explain the manner of their motion and the kind of movement which is natural to them. For if the various elements are constrained by one another to move as they do, each must still have a natural movement which the constrained contravenes, and the prime mover must cause motion not by constraint but naturally. If there is no ultimate natural cause of movement and each preceding term in the series is always moved by constraint, we shall have an infinite process. The same difficulty is involved even if it is supposed, as we read in the Timaeus, that before the ordered world was made the elements moved without order. Their movement must have been due either to constraint or to their nature. And if their movement was natural, a moment's consideration shows that there was already an ordered world. For the prime mover must cause motion in virtue of its own natural movement, and the other bodies, moving without constraint, as they came to rest in their proper places, would fall into the order in which they now stand, the heavy bodies moving towards the centre and the light bodies away from it. But that is the order of their distribution in our world. There is a further question, too, which might be asked. Is it possible or impossible that bodies in unordered movement should combine in some cases into combinations like those of which bodies of nature's composing are composed, such, I mean, as bones and flesh? Yet this is what Empedocles asserts to have occurred under Love. 'Many a head', says he, 'came to birth without a neck.' The answer to the view that there are infinite bodies moving in an infinite is that, if the cause of movement is single, they must move with a single motion, and therefore not without order; and if, on the other hand, the causes are of infinite variety, their motions too must be infinitely varied. For a finite number of causes would produce a kind of order, since absence of order is not proved by diversity of direction in motions: indeed, in the world we know, not all bodies, but only bodies of the same kind, have a common goal of movement. Again, disorderly movement means in reality unnatural movement, since the order proper to perceptible things is their nature. And there is also absurdity and impossibility in the notion that the disorderly movement is infinitely continued. For the nature of things is the nature which most of them possess for most of the time. Thus their view brings them into the contrary position that disorder is natural, and order or system unnatural. But no natural fact can originate in chance. This is a point which Anaxagoras seems to have thoroughly grasped; for he starts his cosmogony from unmoved things. The others, it is true, make things collect together somehow before they try to produce motion and separation. But there is no sense in starting generation from an original state in which bodies are separated and in movement. Hence Empedocles begins after the process ruled by Love: for he could not have constructed the heaven by building it up out of bodies in separation, making them to combine by the power of Love, since our world has its constituent elements in separation, and therefore presupposes a previous state of unity and combination.

These arguments make it plain that every body has its natural movement, which is not constrained or contrary to its nature. We go on to show that there are certain bodies whose necessary impetus is that of weight and lightness.

Of necessity, we assert, they must move, and a moved thing which has no natural impetus cannot move either towards or away from the centre. Suppose a body A without weight, and a body B endowed with weight. Suppose the weightless body to move the distance CD, while B in the same time moves the distance CE, which will be greater since the heavy thing must move further. Let the heavy body then be divided in the proportion CE: CD (for there is no reason why a part of B should not stand in this relation to the whole). Now if the whole moves the whole distance CE, the part must in the same time move the distance CD. A weightless body, therefore, and one which has weight will move the same distance, which is impossible. And the same argument would fit the case of lightness. Again, a body which is in motion but has neither weight nor lightness, must be moved by constraint, and must continue its constrained movement infinitely. For there will be a force which moves it, and the smaller and lighter a body is the further will a given force move it. Now let A, the weightless body, be moved the distance CE, and B, which has weight, be moved in the same time the distance CD. Dividing the heavy body in the proportion CE:CD, we subtract from the heavy body a part which will in the same time move the distance CE, since the whole moved CD: for the relative speeds of the two bodies will be in inverse ratio to their respective sizes. Thus the weightless body will move the same distance as the heavy in the same time. But this is impossible. Hence, since the motion of the weightless body will cover a greater distance than any that is suggested, it will continue infinitely. It is therefore obvious that every body must have a definite weight or lightness. But since 'nature' means a source of movement within the thing itself, while a force is a source of movement in something other than it or in itself qua other, and since movement is always due either to nature or to constraint, movement which is natural, as downward movement is to a stone, will be merely accelerated by an external force, while an unnatural movement will be due to the force alone. In either case the air is as it were instrumental to the force. For air is both light and heavy, and thus qua light produces upward motion, being propelled and set in motion by the force, and qua heavy produces a downward motion. In either case the force transmits the movement to the body by first, as it were, impregnating the air. That is why a body moved by constraint continues to move when that which gave the impulse ceases to accompany it. Otherwise, i.e. if the air were not endowed with this function, constrained movement would be impossible. And the natural movement of a body may be helped on in the same way. This discussion suffices to show (1) that all bodies are either light or heavy, and (2) how unnatural movement takes place.

From what has been said earlier it is plain that there cannot be generation either of everything or in an absolute sense of anything. It is impossible that everything should be generated, unless an extra−corporeal void is possible. For, assuming generation, the place which is to be occupied by that which is coming to be, must have been previously occupied by void in which no body was. Now it is quite possible for one body to be generated out of another, air for instance out of fire, but in the absence of any pre−existing mass generation is impossible. That which is potentially a certain kind of body may, it is true, become such in actuality, But if the potential body was not already in actuality some other kind of body, the existence of an extra−corporeal void must be admitted.

3

It remains to say what bodies are subject to generation, and why. Since in every case knowledge depends on what is primary, and the elements are the primary constituents of bodies, we must ask which of such bodies are elements, and why; and after that what is their number and character. The answer will be plain if we first explain what kind of substance an element is. An element, we take it, is a body into which other bodies may be analysed, present in them potentially or in actuality (which of these, is still disputable), and not itself divisible into bodies different in form. That, or something like it, is what all men in every case mean by element. Now if what we have described is an element, clearly there must be such bodies. For flesh and wood and all other similar bodies contain potentially fire and earth, since one sees these elements exuded from them; and, on the other hand, neither in potentiality nor in actuality does fire contain flesh or wood, or it would exude them. Similarly, even if there were only one elementary body, it would not contain them. For though it will be either flesh or bone or something else, that does not at once show that it contained these in potentiality: the further question remains, in what manner it becomes them. Now Anaxagoras opposes Empedocles' view of the elements. Empedocles says that fire and earth

and the related bodies are elementary bodies of which all things are composed; but this Anaxagoras denies. His elements are the homoeomerous things, viz. flesh, bone, and the like. Earth and fire are mixtures, composed of them and all the other seeds, each consisting of a collection of all the homoeomerous bodies, separately invisible; and that explains why from these two bodies all others are generated. (To him fire and aither are the same thing.) But since every natural body has it proper movement, and movements are either simple or mixed, mixed in mixed bodies and simple in simple, there must obviously be simple bodies; for there are simple movements. It is plain, then, that there are elements, and why.

4

The next question to consider is whether the elements are finite or infinite in number, and, if finite, what their number is. Let us first show reason or denying that their number is infinite, as some suppose. We begin with the view of Anaxagoras that all the homoeomerous bodies are elements. Any one who adopts this view misapprehends the meaning of element. Observation shows that even mixed bodies are often divisible into homoeomerous parts; examples are flesh, bone, wood, and stone. Since then the composite cannot be an element, not every homoeomerous body can be an element; only, as we said before, that which is not divisible into bodies different in form. But even taking 'element' as they do, they need not assert an infinity of elements, since the hypothesis of a finite number will give identical results. Indeed even two or three such bodies serve the purpose as well, as Empedocles' attempt shows. Again, even on their view it turns out that all things are not composed of homocomerous bodies. They do not pretend that a face is composed of faces, or that any other natural conformation is composed of parts like itself. Obviously then it would be better to assume a finite number of principles. They should, in fact, be as few as possible, consistently with proving what has to be proved. This is the common demand of mathematicians, who always assume as principles things finite either in kind or in number. Again, if body is distinguished from body by the appropriate qualitative difference, and there is a limit to the number of differences (for the difference lies in qualities apprehended by sense, which are in fact finite in number, though this requires proof), then manifestly there is necessarily a limit to the number of elements.

There is, further, another view−that of Leucippus and Democritus of Abdera−the implications of which are also unacceptable. The primary masses, according to them, are infinite in number and indivisible in mass: one cannot turn into many nor many into one; and all things are generated by their combination and involution. Now this view in a sense makes things out to be numbers or composed of numbers. The exposition is not clear, but this is its real meaning. And further, they say that since the atomic bodies differ in shape, and there is an infinity of shapes, there is an infinity of simple bodies. But they have never explained in detail the shapes of the various elements, except so far to allot the sphere to fire. Air, water, and the rest they distinguished by the relative size of the atom, assuming that the atomic substance was a sort of master−seed for each and every element. Now, in the first place, they make the mistake already noticed. The principles which they assume are not limited in number, though such limitation would necessitate no other alteration in their theory. Further, if the differences of bodies are not infinite, plainly the elements will not be an infinity. Besides, a view which asserts atomic bodies must needs come into conflict with the mathematical sciences, in addition to invalidating many common opinions and apparent data of sense perception. But of these things we have already spoken in our discussion of time and movement. They are also bound to contradict themselves. For if the elements are atomic, air, earth, and water cannot be differentiated by the relative sizes of their atoms, since then they could not be generated out of one another. The extrusion of the largest atoms is a process that will in time exhaust the supply; and it is by such a process that they account for the generation of water, air, and earth from one another. Again, even on their own presuppositions it does not seem as if the clements would be infinite in number. The atoms differ in figure, and all figures are composed of pyramids, rectilinear the case of rectilinear figures, while the sphere has eight pyramidal parts. The figures must have their principles, and, whether these are one or two or more, the simple bodies must be the same in number as they. Again, if every element has its proper movement, and a simple body has a simple movement, and the number of simple movements is not infinite, because the simple motions are only two and the number of places is not infinite, on these grounds also we should have to deny that the number of elements is

infinite.

5

Since the number of the elements must be limited, it remains to inquire whether there is more than one element. Some assume one only, which is according to some water, to others air, to others fire, to others again something finer than water and denser than air, an infinite body−so they say−bracing all the heavens.

Now those who decide for a single element, which is either water or air or a body finer than water and denser than air, and proceed to generate other things out of it by use of the attributes density and rarity, all alike fail to observe the fact that they are depriving the element of its priority. Generation out of the elements is, as they say, synthesis, and generation into the elements is analysis, so that the body with the finer parts must have priority in the order of nature. But they say that fire is of all bodies the finest. Hence fire will be first in the natural order. And whether the finest body is fire or not makes no difference; anyhow it must be one of the other bodies that is primary and not that which is intermediate. Again, density and rarity, as instruments of generation, are equivalent to fineness and coarseness, since the fine is rare, and coarse in their use means dense. But fineness and coarseness, again, are equivalent to greatness and smallness, since a thing with small parts is fine and a thing with large parts coarse. For that which spreads itself out widely is fine, and a thing composed of small parts is so spread out. In the end, then, they distinguish the various other substances from the element by the greatness and smallness of their parts. This method of distinction makes all judgement relative. There will be no absolute distinction between fire, water, and air, but one and the same body will be relatively to this fire, relatively to something else air. The same difficulty is involved equally in the view elements and distinguishes them by their greatness and smallness. The principle of distinction between bodies being quantity, the various sizes will be in a definite ratio, and whatever bodies are in this ratio to one another must be air, fire, earth, and water respectively. For the ratios of smaller bodies may be repeated among greater bodies.

Those who start from fire as the single element, while avoiding this difficulty, involve themselves in many others. Some of them give fire a particular shape, like those who make it a pyramid, and this on one of two grounds. The reason given may be−more crudely−that the pyramid is the most piercing of figures as fire is of bodies, or−more ingeniously−the position may be supported by the following argument. As all bodies are composed of that which has the finest parts, so all solid figures are composed of pryamids: but the finest body is fire, while among figures the pyramid is primary and has the smallest parts; and the primary body must have the primary figure: therefore fire will be a pyramid. Others, again, express no opinion on the subject of its figure, but simply regard it as the of the finest parts, which in combination will form other bodies, as the fusing of gold−dust produces solid gold. Both of these views involve the same difficulties. For (1) if, on the one hand, they make the primary body an atom, the view will be open to the objections already advanced against the atomic theory. And further the theory is inconsistent with a regard for the facts of nature. For if all bodies are quantitatively commensurable, and the relative size of the various homoeomerous masses and of their several elements are in the same ratio, so that the total mass of water, for instance, is related to the total mass of air as the elements of each are to one another, and so on, and if there is more air than water and, generally, more of the finer body than of the coarser, obviously the element of water will be smaller than that of air. But the lesser quantity is contained in the greater. Therefore the air element is divisible. And the same could be shown of fire and of all bodies whose parts are relatively fine. (2) If, on the other hand, the primary body is divisible, then (a) those who give fire a special shape will have to say that a part of fire is not fire, because a pyramid is not composed of pyramids, and also that not every body is either an element or composed of elements, since a part of fire will be neither fire nor any other element. And (b) those whose ground of distinction is size will have to recognize an element prior to the element, a regress which continues infinitely, since every body is divisible and that which has the smallest parts is the element. Further, they too will have to say that the same body is relatively to this fire and relatively to that air, to others again water and earth.

The common error of all views which assume a single element is that they allow only one natural movement, which is the same for every body. For it is a matter of observation that a natural body possesses a principle of movement. If then all bodies are one, all will have one movement. With this motion the greater their quantity the more they will move, just as fire, in proportion as its quantity is greater, moves faster with the upward motion which belongs to it. But the fact is that increase of quantity makes many things move the faster downward. For these reasons, then, as well as from the distinction already established of a plurality of natural movements, it is impossible that there should be only one element. But if the elements are not an infinity and not reducible to one, they must be several and finite in number.

6

First we must inquire whether the elements are eternal or subject to generation and destruction; for when this question has been answered their number and character will be manifest. In the first place, they cannot be eternal. It is a matter of observation that fire, water, and every simple body undergo a process of analysis, which must either continue infinitely or stop somewhere. (1) Suppose it infinite. Then the time occupied by the process will be infinite, and also that occupied by the reverse process of synthesis. For the processes of analysis and synthesis succeed one another in the various parts. It will follow that there are two infinite times which are mutually exclusive, the time occupied by the synthesis, which is infinite, being preceded by the period of analysis. There are thus two mutually exclusive infinites, which is impossible. (2) Suppose, on the other hand, that the analysis stops somewhere. Then the body at which it stops will be either atomic or, as Empedocles seems to have intended, a divisible body which will yet never be divided. The foregoing arguments show that it cannot be an atom; but neither can it be a divisible body which analysis will never reach. For a smaller body is more easily destroyed than a larger; and a destructive process which succeeds in destroying, that is, in resolving into smaller bodies, a body of some size, cannot reasonably be expected to fail with the smaller body. Now in fire we observe a destruction of two kinds: it is destroyed by its contrary when it is quenched, and by itself when it dies out. But the effect is produced by a greater quantity upon a lesser, and the more quickly the smaller it is. The elements of bodies must therefore be subject to destruction and generation.

Since they are generated, they must be generated either from something incorporeal or from a body, and if from a body, either from one another or from something else. The theory which generates them from something incorporeal requires an extra−corporeal void. For everything that comes to be comes to be in something, and that in which the generation takes place must either be incorporeal or possess body; and if it has body, there will be two bodies in the same place at the same time, viz. that which is coming to be and that which was previously there, while if it is incorporeal, there must be an extra−corporeal void. But we have already shown that this is impossible. But, on the other hand, it is equally impossible that the elements should be generated from some kind of body. That would involve a body distinct from the elements and prior to them. But if this body possesses weight or lightness, it will be one of the elements; and if it has no tendency to movement, it will be an immovable or mathematical entity, and therefore not in a place at all. A place in which a thing is at rest is a place in which it might move, either by constraint, i.e. unnaturally, or in the absence of constraint, i.e. naturally. If, then, it is in a place and somewhere, it will be one of the elements; and if it is not in a place, nothing can come from it, since that which comes into being and that out of which it comes must needs be together. The elements therefore cannot be generated from something incorporeal nor from a body which is not an element, and the only remaining alternative is that they are generated from one another.

7

We must, therefore, turn to the question, what is the manner of their generation from one another? Is it as Empedocles and Democritus say, or as those who resolve bodies into planes say, or is there yet another possibility? (1) What the followers of Empedocles do, though without observing it themselves, is to reduce the generation of elements out of one another to an illusion. They make it a process of excretion from a body of what

was in it all the time−as though generation required a vessel rather than a material−so that it involves no change of anything. And even if this were accepted, there are other implications equally unsatisfactory. We do not expect a mass of matter to be made heavier by compression. But they will be bound to maintain this, if they say that water is a body present in air and excreted from air, since air becomes heavier when it turns into water. Again, when the mixed body is divided, they can show no reason why one of the constituents must by itself take up more room than the body did: but when water turns into air, the room occupied is increased. The fact is that the finer body takes up more room, as is obvious in any case of transformation. As the liquid is converted into vapour or air the vessel which contains it is often burst because it does not contain room enough. Now, if there is no void at all, and if, as those who take this view say, there is no expansion of bodies, the impossibility of this is manifest: and if there is void and expansion, there is no accounting for the fact that the body which results from division cfpies of necessity a greater space. It is inevitable, too, that generation of one out of another should come to a stop, since a finite quantum cannot contain an infinity of finite quanta. When earth produces water something is taken away from the earth, for the process is one of excretion. The same thing happens again when the residue produces water. But this can only go on for ever, if the finite body contains an infinity, which is impossible. Therefore the generation of elements out of one another will not always continue.

(2) We have now explained that the mutual transformations of the elements cannot take place by means of excretion. The remaining alternative is that they should be generated by changing into one another. And this in one of two ways, either by change of shape, as the same wax takes the shape both of a sphere and of a cube, or, as some assert, by resolution into planes. (a) Generation by change of shape would necessarily involve the assertion of atomic bodies. For if the particles were divisible there would be a part of fire which was not fire and a part of earth which was not earth, for the reason that not every part of a pyramid is a pyramid nor of a cube a cube. But if (b) the process is resolution into planes, the first difficulty is that the elements cannot all be generated out of one another. This they are obliged to assert, and do assert. It is absurd, because it is unreasonable that one element alone should have no part in the transformations, and also contrary to the observed data of sense, according to which all alike change into one another. In fact their explanation of the observations is not consistent with the observations. And the reason is that their ultimate principles are wrongly assumed: they had certain predetermined views, and were resolved to bring everything into line with them. It seems that perceptible things require perceptible principles, eternal things eternal principles, corruptible things corruptible principles; and, in general, every subject matter principles homogeneous with itself. But they, owing to their love for their principles, fall into the attitude of men who undertake the defence of a position in argument. In the confidence that the principles are true they are ready to accept any consequence of their application. As though some principles did not require to be judged from their results, and particularly from their final issue! And that issue, which in the case of productive knowledge is the product, in the knowledge of nature is the unimpeachable evidence of the senses as to each fact.

The result of their view is that earth has the best right to the name element, and is alone indestructible; for that which is indissoluble is indestructible and elementary, and earth alone cannot be dissolved into any body but itself. Again, in the case of those elements which do suffer dissolution, the 'suspension' of the triangles is unsatisfactory. But this takes place whenever one is dissolved into another, because of the numerical inequality of the triangles which compose them. Further, those who hold these views must needs suppose that generation does not start from a body. For what is generated out of planes cannot be said to have been generated from a body. And they must also assert that not all bodies are divisible, coming thus into conflict with our most accurate sciences, namely the mathematical, which assume that even the intelligible is divisible, while they, in their anxiety to save their hypothesis, cannot even admit this of every perceptible thing. For any one who gives each element a shape of its own, and makes this the ground of distinction between the substances, has to attribute to them indivisibility; since division of a pyramid or a sphere must leave somewhere at least a residue which is not sphere or a pyramid. Either, then, a part of fire is not fire, so that there is a body prior to the element−for every body is either an element or composed of elements−or not every body is divisible.

8

In general, the attempt to give a shape to each of the simple bodies is unsound, for the reason, first, that they will not succeed in filling the whole. It is agreed that there are only three plane figures which can fill a space, the triangle, the square, and the hexagon, and only two solids, the pyramid and the cube. But the theory needs more than these because the elements which it recognizes are more in number. Secondly, it is manifest that the simple bodies are often given a shape by the place in which they are included, particularly water and air. In such a case the shape of the element cannot persist; for, if it did, the contained mass would not be in continuous contact with the containing body; while, if its shape is changed, it will cease to be water, since the distinctive quality is shape. Clearly, then, their shapes are not fixed. Indeed, nature itself seems to offer corroboration of this theoretical conclusion. Just as in other cases the substratum must be formless and unshapen−for thus the 'all−receptive', as we read in the Timaeus, will be best for modelling−so the elements should be conceived as a material for composite things; and that is why they can put off their qualitative distinctions and pass into one another. Further, how can they account for the generation of flesh and bone or any other continuous body? The elements alone cannot produce them because their collocation cannot produce a continuum. Nor can the composition of planes; for this produces the elements themselves, not bodies made up of them. Any one then who insists upon an exact statement of this kind of theory, instead of assenting after a passing glance at it, will see that it removes generation from the world.

Further, the very properties, powers, and motions, to which they paid particular attention in allotting shapes, show the shapes not to be in accord with the bodies. Because fire is mobile and productive of heat and combustion, some made it a sphere, others a pyramid. These shapes, they thought, were the most mobile because they offer the fewest points of contact and are the least stable of any; they were also the most apt to produce warmth and combustion, because the one is angular throughout while the other has the most acute angles, and the angles, they say, produce warmth and combustion. Now, in the first place, with regard to movement both are in error. These may be the figures best adapted to movement; they are not, however, well adapted to the movement of fire, which is an upward and rectilinear movement, but rather to that form of circular movement which we call rolling. Earth, again, they call a cube because it is stable and at rest. But it rests only in its own place, not anywhere; from any other it moves if nothing hinders, and fire and the other bodies do the same. The obvious inference, therefore, is that fire and each several element is in a foreign place a sphere or a pyramid, but in its own a cube. Again, if the possession of angles makes a body produce heat and combustion, every element produces heat, though one may do so more than another. For they all possess angles, the octahedron and dodecahedron as well as the pyramid; and Democritus makes even the sphere a kind of angle, which cuts things because of its mobility. The difference, then, will be one of degree: and this is plainly false. They must also accept the inference that the mathematical produce heat and combustion, since they too possess angles and contain atomic spheres and pyramids, especially if there are, as they allege, atomic figures. Anyhow if these functions belong to some of these things and not to others, they should explain the difference, instead of speaking in quite general terms as they do. Again, combustion of a body produces fire, and fire is a sphere or a pyramid. The body, then, is turned into spheres or pyramids. Let us grant that these figures may reasonably be supposed to cut and break up bodies as fire does; still it remains quite inexplicable that a pyramid must needs produce pyramids or a sphere spheres. One might as well postulate that a knife or a saw divides things into knives or saws. It is also ridiculous to think only of division when allotting fire its shape. Fire is generally thought of as combining and connecting rather than as separating. For though it separates bodies different in kind, it combines those which are the same; and the combining is essential to it, the functions of connecting and uniting being a mark of fire, while the separating is incidental. For the expulsion of the foreign body is an incident in the compacting of the homogeneous. In choosing the shape, then, they should have thought either of both functions or preferably of the combining function. In addition, since hot and cold are contrary powers, it is impossible to allot any shape to the cold. For the shape given must be the contrary of that given to the hot, but there is no contrariety between figures. That is why they have all left the cold out, though properly either all or none should have their distinguishing figures. Some of them, however, do attempt to explain this power, and they contradict themselves. A body of large particles, they say, is cold because

instead of penetrating through the passages it crushes. Clearly, then, that which is hot is that which penetrates these passages, or in other words that which has fine particles. It results that hot and cold are distinguished not by the figure but by the size of the particles. Again, if the pyramids are unequal in size, the large ones will not be fire, and that figure will produce not combustion but its contrary.

From what has been said it is clear that the difference of the elements does not depend upon their shape. Now their most important differences are those of property, function, and power; for every natural body has, we maintain, its own functions, properties, and powers. Our first business, then, will be to speak of these, and that inquiry will enable us to explain the differences of each from each.

Book IV

1

WE have now to consider the terms 'heavy' and 'light'. We must ask what the bodies so called are, how they are constituted, and what is the reason of their possessing these powers. The consideration of these questions is a proper part of the theory of movement, since we call things heavy and light because they have the power of being moved naturally in a certain way. The activities corresponding to these powers have not been given any name, unless it is thought that 'impetus' is such a name. But because the inquiry into nature is concerned with movement, and these things have in themselves some spark (as it were) of movement, all inquirers avail themselves of these powers, though in all but a few cases without exact discrimination. We must then first look at whatever others have said, and formulate the questions which require settlement in the interests of this inquiry, before we go on to state our own view of the matter.

Language recognizes (a) an absolute, (b) a relative heavy and light. Of two heavy things, such as wood and bronze, we say that the one is relatively light, the other relatively heavy. Our predecessors have not dealt at all with the absolute use, of the terms, but only with the relative. I mean, they do not explain what the heavy is or what the light is, but only the relative heaviness and lightness of things possessing weight. This can be made clearer as follows. There are things whose constant nature it is to move away from the centre, while others move constantly towards the centre; and of these movements that which is away from the centre I call upward movement and that which is towards it I call downward movement. (The view, urged by some, that there is no up and no down in the heaven, is absurd. There can be, they say, no up and no down, since the universe is similar every way, and from any point on the earth's surface a man by advancing far enough will come to stand foot to foot with himself. But the extremity of the whole, which we call 'above', is in position above and in nature primary. And since the universe has an extremity and a centre, it must clearly have an up and down. Common usage is thus correct, though inadequate. And the reason of its inadequacy is that men think that the universe is not similar every way. They recognize only the hemisphere which is over us. But if they went on to think of the world as formed on this pattern all round, with a centre identically related to each point on the extremity, they would have to admit that the extremity was above and the centre below.) By absolutely light, then, we mean that which moves upward or to the extremity, and by absolutely heavy that which moves downward or to the centre. By lighter or relatively light we mean that one, of two bodies endowed with weight and equal in bulk, which is exceeded by the other in the speed of its natural downward movement.

2

Those of our predecessors who have entered upon this inquiry have for the most part spoken of light and heavy things only in the sense in which one of two things both endowed with weight is said to be the lighter. And this treatment they consider a sufficient analysis also of the notions of absolute heaviness, to which their account does not apply. This, however, will become clearer as we advance. One use of the terms 'lighter' and 'heavier' is that which is set forth in writing in the Timaeus, that the body which is composed of the greater number of identical

parts is relatively heavy, while that which is composed of a smaller number is relatively light. As a larger quantity of lead or of bronze is heavier than a smaller−and this holds good of all homogeneous masses, the superior weight always depending upon a numerical superiority of equal parts−in precisely the same way, they assert, lead is heavier than wood. For all bodies, in spite of the general opinion to the contrary, are composed of identical parts and of a single material. But this analysis says nothing of the absolutely heavy and light. The facts are that fire is always light and moves upward, while earth and all earthy things move downwards or towards the centre. It cannot then be the fewness of the triangles (of which, in their view, all these bodies are composed) which disposes fire to move upward. If it were, the greater the quantity of fire the slower it would move, owing to the increase of weight due to the increased number of triangles. But the palpable fact, on the contrary, is that the greater the quantity, the lighter the mass is and the quicker its upward movement: and, similarly, in the reverse movement from above downward, the small mass will move quicker and the large slower. Further, since to be lighter is to have fewer of these homogeneous parts and to be heavier is to have more, and air, water, and fire are composed of the same triangles, the only difference being in the number of such parts, which must therefore explain any distinction of relatively light and heavy between these bodies, it follows that there must be a certain quantum of air which is heavier than water. But the facts are directly opposed to this. The larger the quantity of air the more readily it moves upward, and any portion of air without exception will rise up out of the water.

So much for one view of the distinction between light and heavy. To others the analysis seems insufficient; and their views on the subject, though they belong to an older generation than ours, have an air of novelty. It is apparent that there are bodies which, when smaller in bulk than others, yet exceed them in weight. It is therefore obviously insufficient to say that bodies of equal weight are composed of an equal number of primary parts: for that would give equality of bulk. Those who maintain that the primary or atomic parts, of which bodies endowed with weight are composed, are planes, cannot so speak without absurdity; but those who regard them as solids are in a better position to assert that of such bodies the larger is the heavier. But since in composite bodies the weight obviously does not correspond in this way to the bulk, the lesser bulk being often superior in weight (as, for instance, if one be wool and the other bronze), there are some who think and say that the cause is to be found elsewhere. The void, they say, which is imprisoned in bodies, lightens them and sometimes makes the larger body the lighter. The reason is that there is more void. And this would also account for the fact that a body composed of a number of solid parts equal to, or even smaller than, that of another is sometimes larger in bulk than it. In short, generally and in every case a body is relatively light when it contains a relatively large amount of void. This is the way they put it themselves, but their account requires an addition. Relative lightness must depend not only on an excess of void, but also an a defect of solid: for if the ratio of solid to void exceeds a certain proportion, the relative lightness will disappear. Thus fire, they say, is the lightest of things just for this reason that it has the most void. But it would follow that a large mass of gold, as containing more void than a small mass of fire, is lighter than it, unless it also contains many times as much solid. The addition is therefore necessary.

Of those who deny the existence of a void some, like Anaxagoras and Empedocles, have not tried to analyse the notions of light and heavy at all; and those who, while still denying the existence of a void, have attempted this, have failed to explain why there are bodies which are absolutely heavy and light, or in other words why some move upward and others downward. The fact, again, that the body of greater bulk is sometimes lighter than smaller bodies is one which they have passed over in silence, and what they have said gives no obvious suggestion for reconciling their views with the observed facts.

But those who attribute the lightness of fire to its containing so much void are necessarily involved in practically the same difficulties. For though fire be supposed to contain less solid than any other body, as well as more void, yet there will be a certain quantum of fire in which the amount of solid or plenum is in excess of the solids contained in some small quantity of earth. They may reply that there is an excess of void also. But the question is, how will they discriminate the absolutely heavy? Presumably, either by its excess of solid or by its defect of void. On the former view there could be an amount of earth so small as to contain less solid than a large mass of fire. And similarly, if the distinction rests on the amount of void, there will be a body, lighter than the absolutely light, which nevertheless moves downward as constantly as the other moves upward. But that cannot be so, since the

absolutely light is always lighter than bodies which have weight and move downward, while, on the other hand, that which is lighter need not be light, because in common speech we distinguish a lighter and a heavier (viz. water and earth) among bodies endowed with weight. Again, the suggestion of a certain ratio between the void and the solid in a body is no more equal to solving the problem before us. The manner of speaking will issue in a similar impossibility. For any two portions of fire, small or great, will exhibit the same ratio of solid to void, but the upward movement of the greater is quicker than that of the less, just as the downward movement of a mass of gold or lead, or of any other body endowed with weight, is quicker in proportion to its size. This, however, should not be the case if the ratio is the ground of distinction between heavy things and light. There is also an absurdity in attributing the upward movement of bodies to a void which does not itself move. If, however, it is the nature of a void to move upward and of a plenum to move downward, and therefore each causes a like movement in other things, there was no need to raise the question why composite bodies are some light and some heavy; they had only to explain why these two things are themselves light and heavy respectively, and to give, further, the reason why the plenum and the void are not eternally separated. It is also unreasonable to imagine a place for the void, as if the void were not itself a kind of place. But if the void is to move, it must have a place out of which and into which the change carries it. Also what is the cause of its movement? Not, surely, its voidness: for it is not the void only which is moved, but also the solid.

Similar difficulties are involved in all other methods of distinction, whether they account for the relative lightness and heaviness of bodies by distinctions of size, or proceed on any other principle, so long as they attribute to each the same matter, or even if they recognize more than one matter, so long as that means only a pair of contraries. If there is a single matter, as with those who compose things of triangles, nothing can be absolutely heavy or light: and if there is one matter and its contrary−the void, for instance, and the plenum−no reason can be given for the relative lightness and heaviness of the bodies intermediate between the absolutely light and heavy when compared either with one another or with these themselves. The view which bases the distinction upon differences of size is more like a mere fiction than those previously mentioned, but, in that it is able to make distinctions between the four elements, it is in a stronger position for meeting the foregoing difficulties. Since, however, it imagines that these bodies which differ in size are all made of one substance, it implies, equally with the view that there is but one matter, that there is nothing absolutely light and nothing which moves upward (except as being passed by other things or forced up by them); and since a multitude of small atoms are heavier than a few large ones, it will follow that much air or fire is heavier than a little water or earth, which is impossible.

3

These, then, are the views which have been advanced by others and the terms in which they state them. We may begin our own statement by settling a question which to some has been the main difficulty−the question why some bodies move always and naturally upward and others downward, while others again move both upward and downward. After that we will inquire into light and heavy and of the various phenomena connected with them. The local movement of each body into its own place must be regarded as similar to what happens in connexion with other forms of generation and change. There are, in fact, three kinds of movement, affecting respectively the size, the form, and the place of a thing, and in each it is observable that change proceeds from a contrary to a contrary or to something intermediate: it is never the change of any chance subject in any chance direction, nor, similarly, is the relation of the mover to its object fortuitous: the thing altered is different from the thing increased, and precisely the same difference holds between that which produces alteration and that which produces increase. In the same manner it must be thought that produces local motion and that which is so moved are not fortuitously related. Now, that which produces upward and downward movement is that which produces weight and lightness, and that which is moved is that which is potentially heavy or light, and the movement of each body to its own place is motion towards its own form. (It is best to interpret in this sense the common statement of the older writers that 'like moves to like'. For the words are not in every sense true to fact. If one were to remove the earth to where the moon now is, the various fragments of earth would each move not towards it but to the place in which it now is. In general, when a number of similar and undifferentiated bodies are moved with the same

motion this result is necessarily produced, viz. that the place which is the natural goal of the movement of each single part is also that of the whole. But since the place of a thing is the boundary of that which contains it, and the continent of all things that move upward or downward is the extremity and the centre, and this boundary comes to be, in a sense, the form of that which is contained, it is to its like that a body moves when it moves to its own place. For the successive members of the scries are like one another: water, I mean, is like air and air like fire, and between intermediates the relation may be converted, though not between them and the extremes; thus air is like water, but water is like earth: for the relation of each outer body to that which is next within it is that of form to matter.) Thus to ask why fire moves upward and earth downward is the same as to ask why the healable, when moved and changed qua healable, attains health and not whiteness; and similar questions might be asked concerning any other subject of aletion. Of course the subject of increase, when changed qua increasable, attains not health but a superior size. The same applies in the other cases. One thing changes in quality, another in quantity: and so in place, a light thing goes upward, a heavy thing downward. The only difference is that in the last case, viz. that of the heavy and the light, the bodies are thought to have a spring of change within themselves, while the subjects of healing and increase are thought to be moved purely from without. Sometimes, however, even they change of themselves, ie. in response to a slight external movement reach health or increase, as the case may be. And since the same thing which is healable is also receptive of disease, it depends on whether it is moved qua healable or qua liable to disease whether the motion is towards health or towards disease. But the reason why the heavy and the light appear more than these things to contain within themselves the source of their movements is that their matter is nearest to being. This is indicated by the fact that locomotion belongs to bodies only when isolated from other bodies, and is generated last of the several kinds of movement; in order of being then it will be first. Now whenever air comes into being out of water, light out of heavy, it goes to the upper place. It is forthwith light: becoming is at an end, and in that place it has being. Obviously, then, it is a potentiality, which, in its passage to actuality, comes into that place and quantity and quality which belong to its actuality. And the same fact explains why what is already actually fire or earth moves, when nothing obstructs it, towards its own place. For motion is equally immediate in the case of nutriment, when nothing hinders, and in the case of the thing healed, when nothing stays the healing. But the movement is also due to the original creative force and to that which removes the hindrance or off which the moving thing rebounded, as was explained in our opening discussions, where we tried to show how none of these things moves itself. The reason of the various motions of the various bodies, and the meaning of the motion of a body to its own place, have now been explained.

4

We have now to speak of the distinctive properties of these bodies and of the various phenomena connected with them. In accordance with general conviction we may distinguish the absolutely heavy, as that which sinks to the bottom of all things, from the absolutely light, which is that which rises to the surface of all things. I use the term 'absolutely', in view of the generic character of 'light' and 'heavy', in order to confine the application to bodies which do not combine lightness and heaviness. It is apparent, I mean, that fire, in whatever quantity, so long as there is no external obstacle moves upward, and earth downward; and, if the quantity is increased, the movement is the same, though swifter. But the heaviness and lightness of bodies which combine these qualities is different from this, since while they rise to the surface of some bodies they sink to the bottom of others. Such are air and water. Neither of them is absolutely either light or heavy. Both are lighter than earth−for any portion of either rises to the surface of it−but heavier than fire, since a portion of either, whatever its quantity, sinks to the bottom of fire; compared together, however, the one has absolute weight, the other absolute lightness, since air in any quantity rises to the surface of water, while water in any quantity sinks to the bottom of air. Now other bodies are severally light and heavy, and evidently in them the attributes are due to the difference of their uncompounded parts: that is to say, according as the one or the other happens to preponderate the bodies will be heavy and light respectively. Therefore we need only speak of these parts, since they are primary and all else consequential: and in so doing we shall be following the advice which we gave to those whose attribute heaviness to the presence of plenum and lightness to that of void. It is due to the properties of the elementary bodies that a body which is regarded as light in one place is regarded as heavy in another, and vice versa. In air, for instance, a talent's weight

of wood is heavier than a mina of lead, but in water the wood is the lighter. The reason is that all the elements except fire have weight and all but earth lightness. Earth, then, and bodies in which earth preponderates, must needs have weight everywhere, while water is heavy anywhere but in earth, and air is heavy when not in water or earth. In its own place each of these bodies has weight except fire, even air. Of this we have evidence in the fact that a bladder when inflated weighs more than when empty. A body, then, in which air preponderates over earth and water, may well be lighter than something in water and yet heavier than it in air, since such a body does not rise in air but rises to the surface in water.

The following account will make it plain that there is an absolutely light and an absolutely heavy body. And by absolutely light I mean one which of its own nature always moves upward, by absolutely heavy one which of its own nature always moves downward, if no obstacle is in the way. There are, I say, these two kinds of body, and it is not the case, as some maintain, that all bodies have weight. Different views are in fact agreed that there is a heavy body, which moves uniformly towards the centre. But is also similarly a light body. For we see with our eyes, as we said before, that earthy things sink to the bottom of all things and move towards the centre. But the centre is a fixed point. If therefore there is some body which rises to the surface of all things−and we observe fire to move upward even in air itself, while the air remains at rest−clearly this body is moving towards the extremity. It cannot then have any weight. If it had, there would be another body in which it sank: and if that had weight, there would be yet another which moved to the extremity and thus rose to the surface of all moving things. In fact, however, we have no evidence of such a body. Fire, then, has no weight. Neither has earth any lightness, since it sinks to the bottom of all things, and that which sinks moves to the centre. That there is a centre towards which the motion of heavy things, and away from which that of light things is directed, is manifest in many ways. First, because no movement can continue to infinity. For what cannot be can no more come−to−be than be, and movement is a coming to−be in one place from another. Secondly, like the upward movement of fire, the downward movement of earth and all heavy things makes equal angles on every side with the earth's surface: it must therefore be directed towards the centre. Whether it is really the centre of the earth and not rather that of the whole to which it moves, may be left to another inquiry, since these are coincident. But since that which sinks to the bottom of all things moves to the centre, necessarily that which rises to the surface moves to the extremity of the region in which the movement of these bodies takes place. For the centre is opposed as contrary to the extremity, as that which sinks is opposed to that which rises to the surface. This also gives a reasonable ground for the duality of heavy and light in the spatial duality centre and extremity. Now there is also the intermediate region to which each name is given in opposition to the other extreme. For that which is intermediate between the two is in a sense both extremity and centre. For this reason there is another heavy and light; namely, water and air. But in our view the continent pertains to form and the contained to matter: and this distinction is present in every genus. Alike in the sphere of quality and in that of quantity there is that which corresponds rather to form and that which corresponds to matter. In the same way, among spatial distinctions, the above belongs to the determinate, the below to matter. The same holds, consequently, also of the matter itself of that which is heavy and light: as potentially possessing the one character, it is matter for the heavy, and as potentially possessing the other, for the light. It is the same matter, but its being is different, as that which is receptive of disease is the same as that which is receptive of health, though in being different from it, and therefore diseasedness is different from healthiness.

5

A thing then which has the one kind of matter is light and always moves upward, while a thing which has the opposite matter is heavy and always moves downward. Bodies composed of kinds of matter different from these but having relatively to each other the character which these have absolutely, possess both the upward and the downward motion. Hence air and water each have both lightness and weight, and water sinks to the bottom of all things except earth, while air rises to the surface of all things except fire. But since there is one body only which rises to the surface of all things and one only which sinks to the bottom of all things, there must needs be two other bodies which sink in some bodies and rise to the surface of others. The kinds of matter, then, must be as numerous as these bodies, i.e. four, but though they are four there must be a common matter of all−particularly if

they pass into one another−which in each is in being different. There is no reason why there should not be one or more intermediates between the contraries, as in the case of colour; for 'intermediate' and 'mean' are capable of more than one application.

Now in its own place every body endowed with both weight and lightness has weightwhereas earth has weight everywhere−but they only have lightness among bodies to whose surface they rise. Hence when a support is withdrawn such a body moves downward until it reaches the body next below it, air to the place of water and water to that of earth. But if the fire above air is removed, it will not move upward to the place of fire, except by constraint; and in that way water also may be drawn up, when the upward movement of air which has had a common surface with it is swift enough to overpower the downward impulse of the water. Nor does water move upward to the place of air, except in the manner just described. Earth is not so affected at all, because a common surface is not possible to it. Hence water is drawn up into the vessel to which fire is applied, but not earth. As earth fails to move upward, so fire fails to move downward when air is withdrawn from beneath it: for fire has no weight even in its own place, as earth has no lightness. The other two move downward when the body beneath is withdrawn because, while the absolutely heavy is that which sinks to the bottom of all things, the relatively heavy sinks to its own place or to the surface of the body in which it rises, since it is similar in matter to it.

It is plain that one must suppose as many distinct species of matter as there are bodies. For if, first, there is a single matter of all things, as, for instance, the void or the plenum or extension or the triangles, either all things will move upward or all things will move downward, and the second motion will be abolished. And so, either there will be no absolutely light body, if superiority of weight is due to superior size or number of the constituent bodies or to the fullness of the body: but the contrary is a matter of observation, and it has been shown that the downward and upward movements are equally constant and universal: or, if the matter in question is the void or something similar, which moves uniformly upward, there will be nothing to move uniformly downward. Further, it will follow that the intermediate bodies move downward in some cases quicker than earth: for air in sufficiently large quantity will contain a larger number of triangles or solids or particles. It is, however, manifest that no portion of air whatever moves downward. And the same reasoning applies to lightness, if that is supposed to depend on superiority of quantity of matter. But if, secondly, the kinds of matter are two, it will be difficult to make the intermediate bodies behave as air and water behave. Suppose, for example, that the two asserted are void and plenum. Fire, then, as moving upward, will be void, earth, as moving downward, plenum; and in air, it will be said, fire preponderates, in water, earth. There will then be a quantity of water containing more fire than a little air, and a large amount of air will contain more earth than a little water: consequently we shall have to say that air in a certain quantity moves downward more quickly than a little water. But such a thing has never been observed anywhere. Necessarily, then, as fire goes up because it has something, e.g. void, which other things do not have, and earth goes downward because it has plenum, so air goes to its own place above water because it has something else, and water goes downward because of some special kind of body. But if the two bodies are one matter, or two matters both present in each, there will be a certain quantity of each at which water will excel a little air in the upward movement and air excel water in the downward movement, as we have already often said.

6

The shape of bodies will not account for their moving upward or downward in general, though it will account for their moving faster or slower. The reasons for this are not difficult to see. For the problem thus raised is why a flat piece of iron or lead floats upon water, while smaller and less heavy things, so long as they are round or long−a needle, for instance−sink down; and sometimes a thing floats because it is small, as with gold dust and the various earthy and dusty materials which throng the air. With regard to these questions, it is wrong to accept the explanation offered by Democritus. He says that the warm bodies moving up out of the water hold up heavy bodies which are broad, while the narrow ones fall through, because the bodies which offer this resistance are not numerous. But this would be even more likely to happen in air−an objection which he himself raises. His reply to the objection is feeble. In the air, he says, the 'drive' (meaning by drive the movement of the upward moving

bodies) is not uniform in direction. But since some continua are easily divided and others less easily, and things which produce division differ similarly in the case with which they produce it, the explanation must be found in this fact. It is the easily bounded, in proportion as it is easily bounded, which is easily divided; and air is more so than water, water than earth. Further, the smaller the quantity in each kind, the more easily it is divided and disrupted. Thus the reason why broad things keep their place is because they cover so wide a surface and the greater quantity is less easily disrupted. Bodies of the opposite shape sink down because they occupy so little of the surface, which is therefore easily parted. And these considerations apply with far greater force to air, since it is so much more easily divided than water. But since there are two factors, the force responsible for the downward motion of the heavy body and the disruption−resisting force of the continuous surface, there must be some ratio between the two. For in proportion as the force applied by the heavy thing towards disruption and division exceeds that which resides in the continuum, the quicker will it force its way down; only if the force of the heavy thing is the weaker, will it ride upon the surface.

We have now finished our examination of the heavy and the light and of the phenomena connected with them.

THE END