ARISTOTLE:

On the Heavens

THE QUESTION of the nature of this Whole, whether it is of infinite magnitude or its total bulk is limited, must be left until later.[1] We have now to speak of its formally distinct parts,[2] and we may start from this, that all natural bodies and magnitudes are capable of moving of themselves in space; for nature we have defined as the principle of motion in them.[3] Now all motion in space (locomotion) is either straight or circular or a compound of the two, for these are the only simple motions, the reason being that the straight and circular lines are the only simple magnitudes. By "circular motion" I mean motion around the centre, by "straight," motion up and down. "Up" means away from the centre, "down" towards the centre. It follows that all simple locomotion is either away from the centre or towards the centre or around the centre. This appears to follow consistently on what was said at the beginning: body was completed by the number three, and so now is its motion.

Of bodies some are simple, and some are compounds of the simple. By "simple" I mean all bodies which contain a principle of natural motion, like fire and earth and their kinds,[4] and the other bodies of the same order. Hence motions also must be similarly divisible, some simple and others compound in one way or another; simple bodies will have simple motions and composite

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From Aristotle, *On the Heavens,* translated by W. K. C. Guthrie, Loeb Classical Library, Harvard University Press, 1939, lines 268b 11–269a 32, 270a 15–270b 25, 271b 1-10, 271b 28–272a 20, 276a 18–276b 22, 278b 5–279a 18, 286b 10–287a 22, 296a 24–298b 20. Reprinted by kind permission of the publishers, Harvard University Press. From Aristotle, *Metaphysics,* translated by John Warrington, Everyman Library, Book Λ, Chapter 8. Reprinted by kind permission of the publishers, E. P. Dutton and Co., Inc.

1. It is taken up on pp. 92-94.

2. *i.e.* the elements, which are the "immediate" parts of the whole, the rest being parts of parts (Simpl.). The elements are also the *summa genera* or ultimate distinctions of kind among bodies (Stocks).

3. *Phys.* ii. 1. 192 b 20.

4. This mention of the "kinds" of an element is probably a reference to the *Timaeus* (58C ff.), where there are said to be different varieties of each element, all pure but owing their differences to the different sizes of their elementary pyramids. (I owe this suggestion to Professor Cornford). There seems no point in Stocks's demand for "a variety of movement corresponding to variety of kind."

bodies composite motions, though the movement may be according to the prevailing element in the compound.[5]

If we take these premises, (*a*) that there is such a thing as simple motion, (*b*) that circular motion is simple, (*c*) that simple motion is the motion of a simple body (for if a composite body moves with a simple motion, it is only by virtue of a simple body prevailing and imparting its direction to the whole), then it follows that there exists a simple body naturally so constituted as to move in a circle in virtue of its own nature. By force it can be brought to move with the motion of another, different body, but not naturally, if it is true that each of the simple bodies has one natural motion only. Moreover, granted that (*a*) unnatural motion is the contrary of natural, (*b*) a thing can have only one contrary, then circular motion, seeing it is one of the simple motions,[6] must, if it is not the motion natural to the moved body, be contrary to its nature. Suppose now that the body which is moving in a circle be fire or some other of the four elements, then its natural motion must be contrary to the circular. But a thing can have only one contrary, and the contrary of upward is downward, and *vice versa*. Suppose on the other hand that this body which is moving in a circle contrary to its own nature is something other than the elements, there must be some other motion which is natural to it. But that is impossible: for if the motion were upward, the body would be fire or air, if downward, water or earth.

Furthermore, circular motion must be primary.[7] That which is complete is prior in nature to the incomplete, and the circle is a complete figure, whereas no straight line can be so. An infinite straight line cannot, for to be complete it would have to have an end or completion, nor yet a finite, for all finite lines have something beyond them: any one of them is capable of being extended. Now if (*a*) a motion which is prior to another is the motion of a body prior in nature, (*b*) circular motion is prior to rectilinear, (*c*) rectilinear motion is the motion of the simple bodies (as *e.g.* fire moves in a straight line upwards and earthy bodies move downwards towards the centre), then circular motion also must of necessity be the motion of some simple body. (We have already

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5. In saying "bodies which contain a principle of natural motion," A. is not thinking of natural beings in the wide sense defined in *Phys.* ii, where the term includes plants and animals, but in the more restricted sense of the elements only. Strictly speaking (ἀκριβέστερον, Simpl.), only these can be said to have a principle of natural motion (the motion of a simple natural substance left to itself), since the motions of plants and animals are determined by the life-principle in them, which again is dependent on their possessing a certain complicated structure. Hence Simpl. is probably right in saying that even the phrase "composite bodies" in this sentence refers to the popular elements, earth, water, etc., as they appear to the senses. We never see them in a perfectly pure form, but they each conform to the natural motions of the pure element, because that prevails sufficiently in the compound to govern the direction of the whole. The argument however does not require that it be limited to these. It could at least include inanimate compounds of the elements (*e.g.* metals), and where the clause occurs again (269 a 28), Simpl. himself illustrates it by the example of a man falling off a roof.

6. This caution is necessary because, if circular motion were composite, then the axiom "one thing one contrary" could not be applied. A composite motion would be neither natural to a simple body nor directly contrary to its nature, but only, as Simpl. says, "not according to its nature."

7. This is demonstrated also, from similar premises but more fully, in *Phys.* viii, 9.

made the reservation that the motion of composite bodies is determined by whatever simple body predominates in the mixture.) From all these premises therefore it clearly follows that there exists some physical substance besides the four in our sublunary world, and moreover that it is more divine than, and prior to, all these. . . .

With equal reason we may regard it as ungenerated and indestructible, and susceptible neither to growth nor alteration. (*a*) Everything that is generated comes into being out of an opposite and a substrate, and is destroyed only if it has a substrate, and through the agency of an opposite, and passes into its opposite, as has been explained in our first discussions.[8] (*b*) Opposites have opposite motions. (*c*) There cannot be an opposite to the body under discussion, because there cannot be an opposite motion to the circular. It looks then as if nature had providently abstracted from the class of opposites that which was to be ungenerated and indestructible, because generation and destruction take place among opposites. Moreover anything which is subject to growth [or diminution] grows [or diminishes] in consequence of substance of the same kind being added to it and dissolving into its matter;[9] but this body has no such matter. And if it is subject neither to growth nor to destruction, the same train of thought leads us to suppose that it is not subject to alteration either. Alteration is movement in respect of quality, and the temporary or permanent states of quality, health and disease for example, do not come into being without changes of affection. But all physical bodies which possess changing affections may be seen to be subject also to growth and diminution. Such are, for example, the bodies of animals and plants and their parts, and also those of the elements. If then the body whose natural motion is circular cannot be subject to growth or diminution, it is a reasonable supposition that it is not subject to alteration either.

From what has been said it is clear why, if our hypotheses are to be trusted, the primary body of all is eternal, suffers neither growth nor diminution, but is ageless, unalterable and impassive. I think too that the argument bears out experience and is borne out by it. All men have a conception of gods, and all assign the highest place to the divine, both barbarians and Hellenes, as many as believe in gods, supposing, obviously, that immortal is closely linked with immortal. It could not, they think, be otherwise. If then—and it is true—there is something divine, what we have said about the primary bodily substance is well said. The truth of it is also clear from the evidence of the senses, enough at least to warrant the assent of human faith; for throughout all past time, according to the records handed down from generation to generation,[10] we find no trace of change either in the whole of the outermost heaven or in

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8. A.'s reference is to the *Physics* (i, 7-9), but the point is perhaps put most concisely in *Met.* Λ 1069b 2-9.

9. *i.e.* growth and diminution are really only particular examples of generation and destruction (Simpl.).

10. According to Simplicius, it was believed that the astronomical records of the Egyptians went back for 630,000 years, and those of the Babylonians for 1,440,000.

any one of its proper parts. It seems too that the name of this first body has been passed down to the present time by the ancients, who thought of it in the same way as we do, for we cannot help believing that the same ideas recur to men not once nor twice but over and over again. Thus they, believing that the primary body was something different from earth and fire and air and water, gave the name *aither* to the uppermost region, choosing its title from the fact that it "runs always" (ἀεὶ θεῖν) and eternally. . . .

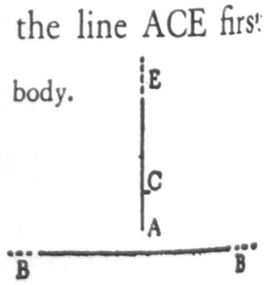
This, then, is now clear, and we must turn to consider the rest of our problems, of which the first is whether there exists any infinite body, as most of the early philosophers believed, or whether that is an impossibility. This is a point whose settlement one way or the other makes no small difference, in fact all the difference, to our investigation of the truth. It is this, one might say, which has been, and may be expected to be, the origin of all the contradictions between those who make pronouncements in natural science, since a small initial deviation from the truth multiplies itself ten-thousandfold as the argument proceeds. . . .

The following arguments make it plain that every body which revolves in a circle must be finite. If the revolving body be infinite, the straight lines radiating from the centre[11] will be infinite. But if they are infinite, the intervening space must be infinite. "Intervening space" I am defining as space beyond which there can be no magnitude in contact with the lines. This must be infinite. In the case of finite lines it is always finite, and moreover it is always possible to take more than any given quantity of it, so that this space is infinite in the sense in which we say that number is infinite, because there exists no greatest number. If then it is impossible to traverse an infinite space, and in an infinite body the space between the radii is infinite, the body cannot move in a circle. But we ourselves see the heaven revolving in a circle, and also we established by argument that circular motion is the motion of a real body.

Again, if a finite time be subtracted from a finite time, the remainder must also be finite and have a beginning. But if the time of the journey has a beginning, so also must the movement, and hence the distance which is traversed. This applies equally to everything else. Let ACE be a straight line infinite in the direction of E, and BB another straight line infinite in both directions. If the line ACE describes a circle about C[12] as centre, it will be expected to cut BB in its revolution for a certain finite time (for the whole time taken by the heaven to complete its revolution is finite, therefore the subtracted time, during which the line in its movement cuts the other, is also finite). There will therefore be a point of time at which the line ACE first

11. That is, the centre of the circular path of the supposed revolving body.

12. So Bekker, with all MSS. but F. Allan reads "A," following F and Simpl. This is more satisfactory, for it adds a needless confusion to the problem to suppose that the line ACE revolves not about its starting-point but about some other point farther along it.



cuts the line BB. But this is impossible. Therefore it is impossible for an infinite body to revolve in a circle. Neither then could the heaven, if it were infinite. . . .

We must now explain why there cannot even be more than one world. This was a question which we noted for consideration, to meet the objection that no general proof has been given that no body whatsoever can exist beyond this world, since the foregoing discussion applied only to those with no definite situation.[13]

All bodies both rest and move naturally and by constraint. A body moves naturally to that place where it rests without constraint, and rests without constraint in that place to which it naturally moves. It moves by constraint to that place in which it rests by constraint, and rests by constraint in that place to which it moves by constraint. Further, if a certain movement is enforced, then its opposite is natural. Thus if it is by constraint that earth moves to the centre here from wherever else it is, its movement thither from here will be natural: and if, having come from there, it remains here without constraint, its movement hither will be natural also. And the natural movement of each is one. Further, all the worlds must be composed of the same bodies, being similar in nature. But at the same time each of these bodies must have the same potentialities, fire, that is to say, and earth, and the bodies intermediate between them; for if the bodies of another world resemble our own in name only, and not in virtue of having the same form, then it would only be in name that the whole which they compose could be pronounced a world. It clearly follows that one of them will be of a nature to move away from the centre, and another towards the centre, seeing that all fire must have the same form as other fire, just as the different portions of fire in this world have the same form; and the same may be said about each of the other simple bodies. The necessity for this emerges clearly from our assumptions about the motions of simple bodies, namely that they are limited in number and that each of the elements has a particular motion assigned to it. Consequently if the motions are the same, the elements also must be the same wherever they are. It must be natural therefore for the particles of earth in another world to move towards the centre of this one also, and for the fire in that world to move towards the circumference of this. This is impossible, for if it were to happen the earth would have to move upwards in its own world and the fire to the centre; and similarly earth from our own world would have to move naturally away from the centre, as it made its way to the centre of the other, owing to the assumed situation of the worlds relatively to each other. Either, in fact, we must deny that the simple bodies of the several worlds have the same natures, or if we

13. κεῖσθαι, as Professor Cornford pointed out to me, is more likely to refer to situation than extent, and this sense fits the context well. In infinite space, bodies (*e.g.* the atoms of Democritus) can have no proper region and hence no natural motion (such as A. is discussing in this and the previous chapters). The view now to be considered is that, even though the whole be not infinite, it may yet contain several *cosmoi,* in each of which the elements will have their definite places as in ours.

admit it we must, as I have said, make the centre and the circumference one for all; and this means that there cannot be more worlds than one. . . .

Now the world must be counted among particulars and things made from matter; but if it is composed, not of a portion of matter, but of all matter whatsoever, then we may admit that its essential nature as "world" and as "this world" are distinct, but nevertheless there will not be another world, nor could there be more than one, for the reason that all the matter is contained in this one.

This therefore remains to be demonstrated, that our own world is composed of the whole sum of natural perceptible body. Let us first establish what we mean by *ouranos,*[14] and in how many senses the word is used, in order that we may more clearly understand the object of our questions. (1) In one sense we apply the word *ouranos* to the substance of the outermost circumference of the world, or to the natural body which is at the outermost circumference of the world; for it is customary to give the name of *ouranos* especially to the outermost and uppermost region, in which also we believe all divinity to have its seat. (2) Secondly we apply it to that body which occupies the next place to the outermost circumference of the world, in which are the moon and the sun and certain of the stars;[15] for these, we say, are in the *ouranos.* (3) We apply the word in yet another sense to the body which is enclosed by the outermost circumference; for it is customary to give the name of *ouranos* to the world as a whole.

The word, then, is used in these three senses, and the whole which is enclosed by the outermost circumference must of necessity be composed of the whole sum of natural perceptible body, for the reason that there is not, nor ever could be, any body outside the heaven. For if there is a natural body beyond the outermost circumference, it must be either simple or composite, and its position there must be either natural or unnatural. It cannot be one of the simple bodies, for (*a*) with regard to the body which revolves it has been shown that it cannot change its place; (*b*) but no more can it be either the body which moves away from the centre or that which settles towards it. They could not be there naturally (for their proper places are elsewhere), but if they are there unnaturally, then this outside region will belong naturally to some other body; for the place which is unnatural to one must be natural to another. But we have seen that there is no other body besides these three. Therefore it is impossible that any of the simple bodies should lie outside the heaven. And if this is true of the simple bodies, it is true also of composite, for where the composite body is the simple bodies must be also. It is equally impossible that a body should ever come to be there, for its coming to be there will be

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14. This is the word which so far in this chapter has been translated "world." Elsewhere in the treatise it is rendered as "world," "heavens" or "sky" according to that one of the three senses here enumerated which A. is employing at any particular moment. In this passage a repetition of the Greek is unavoidable, since no one English word covers all the three senses which *ouranos* is here stated to possess.

15. *i.e.* the planets. The fixed stars are in *ouranos* no. 1.

either natural or unnatural, and it will be either simple or composite, in fact the same argument will recur: it makes no difference whether we ask "Is it there?" or "Can it come to be there?"

It is plain, then, from what has been said, that there is not, nor do the facts allow there to be, any bodily mass beyond the heaven. The world in its entirety is made up of the whole sum of available matter (for the matter appropriate to it is, as we saw, natural perceptible body), and we may conclude that there is not now a plurality of worlds, nor has there been, nor could there be. This world is one, solitary and complete. It is clear in addition that there is neither place nor void nor time beyond the heaven; for (*a*) in all place there is a possibility of the presence of body, (*b*) void is defined as that which, although at present not containing body, can contain it, (*c*) time is the number of motion, and without natural body there cannot be motion. It is obvious then that there is neither place nor void nor time outside the heaven, since it has been demonstrated that there neither is nor can be body there. . . .

The shape of the heaven must be spherical. That is most suitable to its substance, and is the primary shape in nature. But let us discuss the question of what is the primary shape, both in plane surfaces and in solids. Every plane figure is bounded either by straight lines or by a circumference; the rectilinear is bounded by several lines, the circular by one only. Thus since in every genus the one is by nature prior to the many, and the simple to the composite, the circle must be the primary plane figure. Also, if the term "perfect" is applied, according to our previous definition, to that outside which no part of itself can be found,[16] and addition to a straight line is always possible, to a circle never, the circumference of the circle must be a perfect line: granted therefore that the perfect is prior to the imperfect, this argument too demonstrates the priority of the circle to other figures. By the same reasoning the sphere is the primary solid, for it alone is bounded by a single surface, rectilinear solids by several. The place of the sphere among solids is the same as that of the circle among plane figures. Even those who divide bodies up into surfaces and generate them out of surfaces[17] seem to agree with this, for the sphere is the one solid which they do not divide, holding that it has only one surface, not a plurality; for their division into surfaces does not mean division in the manner of one cutting a whole into its parts, but division into elements specifically different.[18]

It is clear, then, that the sphere is the first solid figure, and it would also

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16. This is not quite the same as the definition of "perfect" at *Phys.* iii. 207 a 8, to which Stocks refers (οὗ μηδὲν ἔξω, τοῦτο τέλειον. *Cf.* also *Met.* 1055 a 12). In order to bring the two into agreement, Allan would omit the words τῶν αὑτοῦ, but the evidence of Simpl. is strongly in favour of retaining them.

17. The theory of Plato in the *Timaeus*.

18. *i.e.* it is not that a sphere is indivisible, but any division of it can only be into parts belonging to the same kind (*sc.* body) as the whole, whereas the "division" which these thinkers are seeking means theoretical analysis into elements of a simpler kind—solid bodies into surfaces and surfaces into lines. Thus a cube can be "divided" into six rectangles, a rectangle into four lines, but no similar analysis can be made of a sphere, if it has only one surface bounding it.

be most natural to give it that place if one ranked figures according to number, the circle corresponding to one and the triangle to two, on account of its two right angles—for if one gives unity to the triangle, the circle will cease to be a figure. But the primary figure belongs to the primary body, and the primary body is that which is at the farthest circumference, hence it, the body which revolves in a circle, must be spherical in shape.

The same must be true of the body which is contiguous[19] to it, for what is contiguous to the spherical is spherical, and also of those bodies which lie nearer the centre, for bodies which are surrounded by the spherical and touch it at all points must themselves be spherical, and the lower bodies are in contact with the sphere above. It is, then, spherical through and through, seeing that everything in it is in continuous contact with the spheres.

Again, since it is an observed fact, and assumed in these arguments, that the whole revolves in a circle, and it has been shown that beyond the outermost circumference there is neither void nor place, this provides another reason why the heaven must be spherical. For if it is bounded by straight lines, that will involve the existence of place, body, and void. A rectilinear body revolving in a circle will never occupy the same space, but owing to the change in position[20] of the corners there will at one time be no body where there was body before, and there will be body again where now there is none. It would be the same if it were of some other shape whose radii were unequal, that of a lentil or an egg for example. All will involve the existence of place and void outside the revolution, because the whole does not occupy the same space throughout. . . .

For ourselves, let us first state whether the earth is in motion or at rest. Some, as we have said, make it one of the stars, whereas others put it at the centre but describe it as winding and moving about the pole as its axis. But the impossibility of these explanations is clear if we start from this, that if the earth moves, whether at the centre or at a distance from it, its movement must be enforced: it is not the motion of the earth itself, for otherwise each of its parts would have the same motion, but as it is their motion is invariably in a straight line towards the centre. The motion therefore, being enforced and unnatural, could not be eternal; but the order of the world is eternal.

Secondly, all the bodies which move with the circular movement are observed to lag behind and to move with more than one motion, with the exception of the primary sphere: the earth therefore must have a similar double motion, whether it move around the centre or as situated at it. But if this were so, there would have to be passings and turnings of the fixed stars. Yet these are not observed to take place: the same stars always rise and set at the same places on the earth.[21]

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19. I do not translate συνεχής consistently as = "continuous," because Aristotle does not seem to be consistent in his use of it. It seems better to keep "continuous" to represent the strict sense of συνεχής.

20. For παράλλαξις *cf.* Plato, *Tim.* 22 D and *Politicus* 269 E.

21. The criticism depends on the analogy with the planets, following which A. assumes that if the earth moved with a motion of its own, as well as being carried round in the motion of

Thirdly, the natural motion of the earth as a whole, like that of its parts, is towards the centre of the Universe: that is the reason why it is now lying at the centre. It might be asked, since the centre of both is the same point, in which capacity the natural motion of heavy bodies, or parts of the earth, is directed towards it; whether as centre of the Universe or of the earth. But it must be towards the centre of the Universe that they move, seeing that light bodies like fire, whose motion is contrary to that of the heavy, move to the extremity of the region which surrounds the centre.[22] It so happens that the earth and the Universe have the same centre, for the heavy bodies do move also towards the centre of the earth, yet only incidentally, because it has its centre at the centre of the Universe. As evidence that they move also towards the centre of the earth, we see that weights moving towards the earth do not move in parallel lines but always at the same angles to it:[23] therefore they are moving towards the same centre, namely that of the earth. It is now clear that the earth must be at the centre and immobile. To our previous reasons we may add that heavy objects, if thrown forcibly upwards in a straight line, come back to their starting-place, even if the force hurls them to an unlimited distance.

From these considerations it is clear that the earth does not move, neither does it lie anywhere but at the centre. In addition the reason for its immobility

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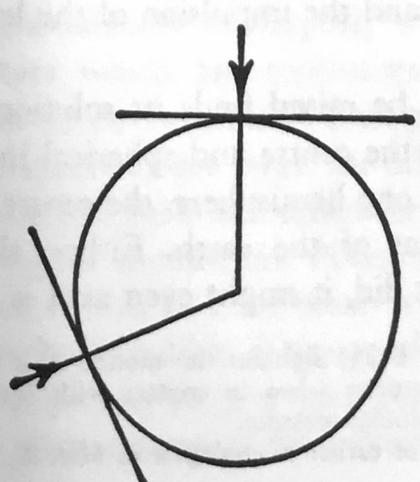
the first heaven, its proper motion would be in the plane of the ecliptic and not of the equator. Were this so, the fixed stars would exhibit to our eyes the irregularities which he describes by the words παρόδους καὶ τροπάς; the pole-star would appear to describe a circle in the sky, and the stars would not rise and set as they do. (For the senses of τροπαί, see Heath, *Aristarchus*, p. 33, n. 3. He discusses the present passage *o.c.* p. 241.) The objection is lodged against both the planetary theory and Plato's theory of motion at the centre. If we may accept Prof. Cornford's suggestion (*Plato's Cosmology*, pp. 132 ff.), Plato would reply that he had expressly limited the motion in the ecliptic (= motion of the Different) to the seven planetary circles, and that the motion of the earth, caused by its soul, was independent and around the same axis as the motion of the Same, only in the reverse direction to cancel it.

22. *Sc.* the upward motion of fire is upward in relation to the Universe (*i.e.* towards its extremity), not in relation to itself. Simpl. thinks that "the region which surrounds the centre" is the region occupied by the air, *i.e.* immediately surrounding the earth. Fire moves to the outer extremity of this region. It is true that if Aristotle simply means the circumference of the Universe, the phrase is unusually elaborate.

23. *I.e.* at right angles to a tangent. Stocks explains the Greek as meaning that the angles at each side of the line of fall of any one body are equal. But does it not more naturally mean that the angles made by one falling body with the earth are similar to those made by another? See Fig.



is clear from our discussions. If it is inherent in the nature of earth to move from all sides to the centre (as observation shows), and of fire to move away from the centre towards the extremity, it is impossible for any portion of earth to move from the centre except under constraint; for one body has one motion and a simple body a simple motion, not two opposite motions, and motion from the centre is the opposite of motion towards it. If then any particular portion is incapable of moving from the centre, it is clear that the earth itself as a whole is still more incapable, since it is natural for the whole to be in the place towards which the part has a natural motion. If then it cannot move except by the agency of a stronger force, it must remain at the centre. This belief finds further support in the assertions of mathematicians about astronomy: that is, the observed phenomena—the shifting of the figures by which the arrangement of the stars is defined—are consistent with the hypothesis that the earth lies at the centre. This may conclude our account of the situation and the rest or motion of the earth.

Its shape must be spherical. For every one of its parts has weight until it reaches the centre, and thus when a smaller part is pressed on by a larger, it cannot surge round it,[24] but each is packed close to, and combines with, the other until they reach the centre. To grasp what is meant we must imagine the earth as in the process of generation in the manner which some of the natural philosophers describe (except that they make external compulsion responsible for the downward movement: let us rather substitute the true statement that this takes place because it is the nature of whatever has weight to move towards the centre). In these systems, when the mixture existed in a state of potentiality,[25] the particles in process of separation were moving from every side alike towards the centre. Whether or not the portions were evenly distributed at the extremities, from which they converged towards the centre, the same result will be produced. It is plain, first, that if particles are moving from all sides alike towards one point, the centre, the resulting mass must be similar on all sides; for if an equal quantity is added all round, the extremity must be at a constant distance from the centre. Such a shape is a sphere. But it will make no difference to the argument even if the portions of the earth did not travel uniformly from all sides towards the centre. A greater mass must always drive on a smaller mass in front of it, if the inclination of both is to go as far as the centre, and the impulsion of the less heavy by the heavier persists to that point.

A difficulty which might be raised finds its solution in the same considerations. If, the earth being at the centre and spherical in shape, a weight many times its own were added to one hemisphere, the centre of the Universe would no longer coincide with that of the earth. Either, therefore, it would not remain at the centre, or, if it did, it might even as it is be at rest although not

24. The verb (*cf. Phys.* iv. 216 b 25) signifies the motion of a wave, and Simpl. notes that the behaviour of the less heavy particles when in contact with the heavier is being contrasted with the behaviour of liquids under similar pressure.

25. Compare the language used of earlier cosmologies in *Met.* Λ, 1069 b 20-23.

occupying the centre, *i.e.* though in a situation where it is natural for it to be in motion. That then is the difficulty. But it is not hard to understand, if we make a little further effort and define the manner in which we suppose any magnitude, possessed of weight, to travel towards the centre. Not, clearly, to the extent of only touching the centre with its edge: the larger portion must prevail until it possesses the centre with its own centre, for its impulse extends to that point. It makes no difference whether we posit this of any chance portion or clod, or of the earth as a whole, for the fact as explained does not depend on smallness or greatness, but applies to everything which has an impulse towards the centre. Therefore whether the earth moved as a whole or in parts, it must have continued in motion until it occupied the centre evenly all round, the smaller portions being equalized by the greater under the forward pressure of their common impulse.

If then the earth has come into being, this must have been the manner of its generation, and it must have grown in the form of a sphere: if on the other hand it is ungenerated and everlasting, it must be the same as it would have been had it developed as the result of a process. Besides this argument for the spherical shape of the earth, there is also the point that all heavy bodies fall at similar angles, not parallel to each other; this naturally means that their fall is towards a body whose nature is spherical. Either then it *is* spherical, or at least it is natural for it to be so, and we must describe each thing by that which is its natural goal or its permanent state, not by any enforced or unnatural characteristics.

Further proof is obtained from the evidence of the senses. (i) If the earth were not spherical, eclipses of the moon would not exhibit segments of the shape which they do. As it is, in its monthly phases the moon takes on all varieties of shape—straight-edged, gibbous and concave—but in eclipses the boundary is always convex. Thus if the eclipses are due to the interposition of the earth, the shape must be caused by its circumference, and the earth must be spherical. (ii) Observation of the stars also shows not only that the earth is spherical but that it is of no great size, since a small change of position on our part southward or northward visibly alters the circle of the horizon, so that the stars above our heads change their position considerably, and we do not see the same stars as we move to the North or South. Certain stars are seen in Egypt and the neighbourhood of Cyprus, which are invisible in more northerly lands, and stars which are continuously visible in the northern countries are observed to set in the others. This proves both that the earth is spherical and that its periphery is not large, for otherwise such a small change of position could not have had such an immediate effect. For this reason those who imagine that the region around the Pillars of Heracles joins on to the regions of India, and that in this way the ocean is one, are not, it would seem, suggesting anything utterly incredible. They produce also in support of their contention the fact that elephants are a species found at the extremities of both lands, arguing that this phenomenon at the extremes is due to communication

between the two. Mathematicians who try to calculate the circumference put it at 400,000 stades.[26]

From these arguments we must conclude not only that the earth's mass is spherical but also that it is not large in comparison with the size of the other stars.

Metaphysics

The Number of Eternal Moving Principles

WE MUST NOT forget to ask whether it is necessary to recognize one or more than one eternal and unchangeable substance. If there are more than one, what is their number? It is worth remarking that our predecessors have expressed no clear opinion on this subject. The Ideal theory does not discuss it; for those who believe in Ideas identify them with numbers, treating these sometimes as unlimited, sometimes (though with insufficient proof) as limited by the number 10.

We must, however, discuss the subject, beginning with the earlier premises and distinctions. The first principle or primary being is not movable, either in itself or accidentally, but produces the primary eternal and single motion. Now (*a*) that which is moved is moved by something; (*b*) the prime mover must be in itself immovable; (*c*) eternal motion requires an eternal cause; and (*d*) we see that in addition to the simple spatial movement of the universe[27] (which we say is produced by the primary immovable substance) there are other eternal[28] spatial movements (viz. those of the planets). *Therefore* each of *these* movements must likewise be caused by a substance which is immovable in itself and eternal. For the nature of the stars[29] is eternal, being a kind of substance; the mover is eternal and prior to the moved; and only substance can be prior to substance. Evidently, then, there must be as many such substances as there are motions of the stars; and they must be by nature eternal, immovable in themselves, and without magnitude, for the reason before mentioned.[30]

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26. *I.e.* 9987 geographical miles. Prantl (p. 319) remarks that this is the oldest recorded calculation of the earth's circumference. He quotes the following estimates for comparison: Archimedes 7495 geogr. miles; Eratosthenes and Hipparchus 6292; Posidonius 5992 or 4494; present day 5400. (The present-day figure in English miles is 24,902.)

This passage of Aristotle is said to have provided a stimulus to the voyage of Columbus. (Ross, *Aristotle,* p. 96, n. 3.)

27. *I.e.* the apparent daily motion of the whole heavens.

28. They are eternal; for a body which moves in a circle is eternal and unresting, as I have shown in the physical treatises [*Physics,* viii. 8, 9; *De Coelo,* i. 2; ii. 3-8].—(A.)

29. The word here includes the fixed stars and the planets.

30. Chapter vii.