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《气象学》

北京师联教育科学研究所 编



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# METEOROLOGY

by Aristotle

translated by E. W. Webster

## Book I

### 1

WE have already discussed the first causes of nature, and all natural motion, also the stars ordered in the motion of the heavens, and the physical element-enumerating and specifying them and showing how they change into one another-and becoming and perishing in general. There remains for consideration a part of this inquiry which all our predecessors called meteorology. It is concerned with events that are natural, though their order is less perfect than that of the first of the elements of bodies. They take place in the region nearest to the motion of the stars. Such are the milky way, and comets, and the movements of meteors. It studies also all the affections we may call common to air and water, and the kinds and

parts of the earth and the affections of its parts. These throw light on the causes of winds and earthquakes and all the consequences the motions of these kinds and parts involve. Of these things some puzzle us, while others admit of explanation in some degree. Further, the inquiry is concerned with the falling of thunderbolts and with whirlwinds and fire-winds, and further, the recurrent affections produced in these same bodies by concretion. When the inquiry into these matters is concluded let us consider what account we can give, in accordance with the method we have followed, of animals and plants, both generally and in detail. When that has been done we may say that the whole of our original undertaking will have been carried out.

After this introduction let us begin by discussing our immediate subject.

## 2

We have already laid down that there is one physical element which makes up the system of the bodies that move in a circle, and besides this four bodies owing their existence to the four principles, the motion of these latter bodies being of two kinds: either from the centre or to the centre. These four bodies are fire, air, water, earth. Fire occupies the highest place among them all, earth the

lowest, and two elements correspond to these in their relation to one another, air being nearest to fire, water to earth. The whole world surrounding the earth, then, the affections of which are our subject, is made up of these bodies. This world necessarily has a certain continuity with the upper motions: consequently all its power and order is derived from them. (For the originating principle of all motion is the first cause. Besides, that element is eternal and its motion has no limit in space, but is always complete; whereas all these other bodies have separate regions which limit one another.) So we must treat fire and earth and the elements like them as the material causes of the events in this world (meaning by material what is subject and is affected), but must assign causality in the sense of the originating principle of motion to the influence of the eternally moving bodies.

### 3

Let us first recall our original principles and the distinctions already drawn and then explain the 'milky way' and comets and the other phenomena akin to these.

Fire, air, water, earth, we assert, originate from one another, and each of them exists potentially in each, as all things do that can be resolved into a common and ultimate substrate.

The first difficulty is raised by what is called the air. What are we to take its nature to be in the world surrounding the earth? And what is its position relatively to the other physical elements. (For there is no question as to the relation of the bulk of the earth to the size of the bodies which exist around it, since astronomical demonstrations have by this time proved to us that it is actually far smaller than some individual stars. As for the water, it is not observed to exist collectively and separately, nor can it do so apart from that volume of it which has its seat about the earth: the sea, that is, and rivers, which we can see, and any subterranean water that may be hidden from our observation.) The question is really about that which lies between the earth and the nearest stars. Are we to consider it to be one kind of body or more than one? And if more than one, how many are there and what are the bounds of their regions?

We have already described and characterized the first element, and explained that the whole world of the upper motions is full of that body.

This is an opinion we are not alone in holding: it appears to be an old assumption and one which men have held in the past, for the word ether has long been used to denote that element. Anaxagoras, it is true, seems to me to think that the word means the same as fire. For he thought that the upper regions were full of fire, and that men referred to those regions when they spoke of ether. In the

latter point he was right, for men seem to have assumed that a body that was eternally in motion was also divine in nature; and, as such a body was different from any of the terrestrial elements, they determined to call it 'ether'.

For the same opinions appear in cycles among men not once nor twice, but infinitely often.

Now there are some who maintain that not only the bodies in motion but that which contains them is pure fire, and the interval between the earth and the stars air: but if they had considered what is now satisfactorily established by mathematics, they might have given up this puerile opinion. For it is altogether childish to suppose that the moving bodies are all of them of a small size, because they so to us, looking at them from the earth.

This a matter which we have already discussed in our treatment of the upper region, but we may return to the point now.

If the intervals were full of fire and the bodies consisted of fire every one of the other elements would long ago have vanished.

However, they cannot simply be said to be full of air either; for even if there were two elements to fill the space between the earth and the heavens, the air would far exceed the quantity required to maintain its proper proportion to the other elements. For the bulk of the earth (which includes the whole volume of water) is infinitesimal in comparison with the whole world that surrounds it.

Now we find that the excess in volume is not proportionately great where water dissolves into air or air into fire. Whereas the proportion between any given small quantity of water and the air that is generated from it ought to hold good between the total amount of air and the total amount of water. Nor does it make any difference if any one denies that the elements originate from one another, but asserts that they are equal in power. For on this view it is certain amounts of each that are equal in power, just as would be the case if they actually originated from one another.

So it is clear that neither air nor fire alone fills the intermediate space.

It remains to explain, after a preliminary discussion of difficulties, the relation of the two elements air and fire to the position of the first element, and the reason why the stars in the upper region impart heat to the earth and its neighbourhood. Let us first treat of the air, as we proposed, and then go on to these questions.

Since water is generated from air, and air from water, why are clouds not formed in the upper air? They ought to form there the more, the further from the earth and the colder that region is. For it is neither appreciably near to the heat of the stars, nor to the rays relected from the earth. It is these that dissolve any formation by their heat and so prevent clouds from forming near the earth. For



clouds gather at the point where the reflected rays disperse in the infinity of space and are lost. To explain this we must suppose either that it is not all air which water is generated, or, if it is produced from all air alike, that what immediately surrounds the earth is not mere air, but a sort of vapour, and that its vaporous nature is the reason why it condenses back to water again. But if the whole of that vast region is vapour, the amount of air and of water will be disproportionately great. For the spaces left by the heavenly bodies must be filled by some element. This cannot be fire, for then all the rest would have been dried up. Consequently, what fills it must be air and the water that surrounds the whole earth-vapour being water dissolved.

After this exposition of the difficulties involved, let us go on to lay down the truth, with a view at once to what follows and to what has already been said. The upper region as far as the moon we affirm to consist of a body distinct both from fire and from air, but varying degree of purity and in kind, especially towards its limit on the side of the air, and of the world surrounding the earth. Now the circular motion of the first element and of the bodies it contains dissolves, and inflames by its motion, whatever part of the lower world is nearest to it, and so generates heat. From another point of view we may look at the motion as follows. The body that lies below the circular motion of the heavens is, in a sort, matter, and is

potentially hot, cold, dry, moist, and possessed of whatever other qualities are derived from these. But it actually acquires or retains one of these in virtue of motion or rest, the cause and principle of which has already been explained. So at the centre and round it we get earth and water, the heaviest and coldest elements, by themselves; round them and contiguous with them, air and what we commonly call fire. It is not really fire, for fire is an excess of heat and a sort of ebullition; but in reality, of what we call air, the part surrounding the earth is moist and warm, because it contains both vapour and a dry exhalation from the earth. But the next part, above that, is warm and dry. For vapour is naturally moist and cold, but the exhalation warm and dry; and vapour is potentially like water, the exhalation potentially like fire. So we must take the reason why clouds are not formed in the upper region to be this: that it is filled not with mere air but rather with a sort of fire.

However, it may well be that the formation of clouds in that upper region is also prevented by the circular motion. For the air round the earth is necessarily all of it in motion, except that which is cut off inside the circumference which makes the earth a complete sphere. In the case of winds it is actually observable that they originate in marshy districts of the earth; and they do not seem to blow above the level of the highest mountains. It is the revolution of the heaven which carries the air with it and causes its circular motion, fire

being continuous with the upper element and air with fire. Thus its motion is a second reason why that air is not condensed into water.

But whenever a particle of air grows heavy, the warmth in it is squeezed out into the upper region and it sinks, and other particles in turn are carried up together with the fiery exhalation. Thus the one region is always full of air and the other of fire, and each of them is perpetually in a state of change.

So much to explain why clouds are not formed and why the air is not condensed into water, and what account must be given of the space between the stars and the earth, and what is the body that fills it.

As for the heat derived from the sun, the right place for a special and scientific account of it is in the treatise about sense, since heat is an affection of sense, but we may now explain how it can be produced by the heavenly bodies which are not themselves hot.

We see that motion is able to dissolve and inflame the air; indeed, moving bodies are often actually found to melt. Now the sun's motion alone is sufficient to account for the origin of terrestrial warmth and heat. For a motion that is to have this effect must be rapid and near, and that of the stars is rapid but distant, while that of the moon is near but slow, whereas the sun's motion combines both conditions in a sufficient degree. That most heat should be generated where the sun is present is easy to understand

if we consider the analogy of terrestrial phenomena, for here, too, it is the air that is nearest to a thing in rapid motion which is heated most. This is just what we should expect, as it is the nearest air that is most dissolved by the motion of a solid body.

This then is one reason why heat reaches our world. Another is that the fire surrounding the air is often scattered by the motion of the heavens and driven downwards in spite of itself.

Shooting-stars further suffice to prove that the celestial sphere is not hot or fiery: for they do not occur in that upper region but below: yet the more and the faster a thing moves, the more apt it is to take fire. Besides, the sun, which most of all the stars is considered to be hot, is really white and not fiery in colour.

#### 4

Having determined these principles let us explain the cause of the appearance in the sky of burning flames and of shooting-stars, and of 'torches', and 'goats', as some people call them. All these phenomena are one and the same thing, and are due to the same cause, the difference between them being one of degree.

The explanation of these and many other phenomena is this. When the sun warms the earth the evaporation which takes place is necessarily of two kinds, not of one only as some think. One kind is

rather of the nature of vapour, the other of the nature of a windy exhalation. That which rises from the moisture contained in the earth and on its surface is vapour, while that rising from the earth itself, which is dry, is like smoke. Of these the windy exhalation, being warm, rises above the moister vapour, which is heavy and sinks below the other. Hence the world surrounding the earth is ordered as follows. First below the circular motion comes the warm and dry element, which we call fire, for there is no word fully adequate to every state of the fumid evaporation: but we must use this terminology since this element is the most inflammable of all bodies. Below this comes air. We must think of what we just called fire as being spread round the terrestrial sphere on the outside like a kind of fuel, so that a little motion often makes it burst into flame just as smoke does: for flame is the ebullition of a dry exhalation. So whenever the circular motion stirs this stuff up in any way, it catches fire at the point at which it is most inflammable. The result differs according to the disposition and quantity of the combustible material. If this is broad and long, we often see a flame burning as in a field of stubble: if it burns lengthwise only, we see what are called 'torches' and 'goats' and shooting-stars. Now when the inflammable material is longer than it is broad sometimes it seems to throw off sparks as it burns. (This happens because matter catches fire at the sides in small portions but continuously with the main body.) Then it is called a

'goat'. When this does not happen it is a 'torch'. But if the whole length of the exhalation is scattered in small parts and in many directions and in breadth and depth alike, we get what are called shooting-stars.

The cause of these shooting-stars is sometimes the motion which ignites the exhalation. At other times the air is condensed by cold and squeezes out and ejects the hot element; making their motion look more like that of a thing thrown than like a running fire. For the question might be raised whether the 'shooting' of a 'star' is the same thing as when you put an exhalation below a lamp and it lights the lower lamp from the flame above. For here too the flame passes wonderfully quickly and looks like a thing thrown, and not as if one thing after another caught fire. Or is a 'star' when it 'shoots' a single body that is thrown? Apparently both cases occur: sometimes it is like the flame from the lamp and sometimes bodies are projected by being squeezed out (like fruit stones from one's fingers) and so are seen to fall into the sea and on the dry land, both by night and by day when the sky is clear. They are thrown downwards because the condensation which propels them inclines downwards. Thunderbolts fall downwards for the same reason: their origin is never combustion but ejection under pressure, since naturally all heat tends upwards.

When the phenomenon is formed in the upper region it is due to the

combustion of the exhalation. When it takes place at a lower level it is due to the ejection of the exhalation by the condensing and cooling of the moisture evaporation: for this latter as it condenses and inclines downward contracts, and thrusts out the hot element and causes it to be thrown downwards. The motion is upwards or downwards or sideways according to the way in which the evaporation lies, and its disposition in respect of breadth and depth. In most cases the direction is sideways because two motions are involved, a compulsory motion downwards and a natural motion upwards, and under these circumstances an object always moves obliquely. Hence the motion of 'shooting-stars' is generally oblique.

So the material cause of all these phenomena is the exhalation, the efficient cause sometimes the upper motion, sometimes the contraction and condensation of the air. Further, all these things happen below the moon. This is shown by their apparent speed, which is equal to that of things thrown by us; for it is because they are close to us, that these latter seem far to exceed in speed the stars, the sun, and the moon.

Sometimes on a fine night we see a variety of appearances that form in the sky: 'chasms' for instance and 'trenches' and blood-red

colours. These, too, have the same cause. For we have seen that the upper air condenses into an inflammable condition and that the combustion sometimes takes on the appearance of a burning flame, sometimes that of moving torches and stars. So it is not surprising that this same air when condensing should assume a variety of colours. For a weak light shining through a dense air, and the air when it acts as a mirror, will cause all kinds of colours to appear, but especially crimson and purple. For these colours generally appear when fire-colour and white are combined by superposition. Thus on a hot day, or through a smoky, medium, the stars when they rise and set look crimson. The light will also create colours by reflection when the mirror is such as to reflect colour only and not shape.

These appearances do not persist long, because the condensation of the air is transient.

'Chasms' get their appearance of depth from light breaking out of a dark blue or black mass of air. When the process of condensation goes further in such a case we often find 'torches' ejected. When the 'chasm' contracts it presents the appearance of a 'trench'.

In general, white in contrast with black creates a variety of colours; like flame, for instance, through a medium of smoke. But by day the sun obscures them, and, with the exception of crimson, the colours are not seen at night because they are dark.

These then must be taken to be the causes of 'shooting-stars' and



the phenomena of combustion and also of the other transient appearances of this kind.

6

Let us go on to explain the nature of comets and the 'milky way', after a preliminary discussion of the views of others.

Anaxagoras and Democritus declare that comets are a conjunction of the planets approaching one another and so appearing to touch one another.

Some of the Italians called Pythagoreans say that the comet is one of the planets, but that it appears at great intervals of time and only rises a little above the horizon. This is the case with Mercury too; because it only rises a little above the horizon it often fails to be seen and consequently appears at great intervals of time.

A view like theirs was also expressed by Hippocrates of Chios and his pupil Aeschylus. Only they say that the tail does not belong to the comet itself, but is occasionally assumed by it on its course in certain situations, when our sight is reflected to the sun from the moisture attracted by the comet. It appears at greater intervals than the other stars because it is slowest to get clear of the sun and has been left behind by the sun to the extent of the whole of its circle before it reappears at the same point. It gets clear of the sun