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# CHAPTER I.

## NATURE OF A RIVER OR STREAM—WHENCE IT IS SUPPLIED—WHAT BECOMES OF IT.

**A Stream.**—In learning Physical Geography we should carefully take notice of the various appearances of nature around us, and, starting from the *village* or *town* where the school is situated, gradually enlarge our range of observation from the fields and skies around us, to the *county* in which we live; and make the lessons there learnt serve as explanation of the Physical Geography of the *country*, as a whole, and of the *continent* to which it belongs, as well as of the *world* altogether. We should thus make the *known* a stepping-stone to the *unknown*. The two great avenues, or ways leading up to knowledge, are *Observation* and *Experiment*. In the former we carefully note what takes place in nature; and by study find out the *reason why* things are as they are; in the latter we arrange matters for ourselves, so as to produce what effects we desire. In other words, by observation we reason from *effects* to *causes*, in experiment we reason from *causes* to *effects*. Thus, if we go into the fields and notice how the rain that falls into the ground drains away into ditches, and that the ditches empty themselves into streams, and the streams flow into rivers; we find from *observation* what is the source whence rivers are supplied. From the known effects of rainfall we thus learn the cause of rivers.

If, on the other hand, we boil a kettle of water, and let the steam come out into the room and condense into white clouds of aqueous moisture, we make an experiment, knowing that cold condenses moisture into steam, and thus prove what we might have thought was true from the observation that when the cold of night comes on the moisture held in the air is condensed by it into mist and fog.

We first observe and then, if possible, make experiments; and if the result of our experiment be the same as the effect which we have observed, we may conclude that the causes which we laid down for the effect were the right ones. We shall not be always able, however, to experiment, and in Physical Geography it will be mainly by *observation* alone that we can learn the reasons of things. But every pond is a picture or image of a lake; its little islets represent the larger islands of our lakes, seas, and oceans; every hill is a representation of the mountains of the globe; the streamlets tell us in little what the larger rivers are; and the winds, rain, snow, hail, dew and mist of our own village skies are the same as those of the atmosphere generally. If we learn the causes and effects of the one, we shall learn those of the other.

Let us go into the fields on a rainy day. We notice that some of the rain soaks into the ground, and is lost to sight for a time; whereas, if there be a heavy shower, some of the rainfall runs off the surface into the lower levels of the ground, to form pools or run along the furrows into the ditches, while the rest is taken up by the roots of the grass and vegetables. Of that which disappears for a time, part drains into the ditches also with the surface waters; while another portion sinks deeper to come out again to the surface at lower levels. It will depend on the character of the rocks as to how much sinks into the soil, and how far; for some rocks will allow water to pass through them more easily than others. Thus sand, gravel, chalk and vegetable mould allow the rains to pass through them very rapidly; hard compact rocks, such as limestones and sandstones, offer resistance to the passage; while clays almost altogether prevent any passing through them. We are therefore obliged to lay down drain pipes to carry off the water from clay lands, while such would do more harm than good in what are called dry, warm soils, such as chalk, hills, gravel, and sand.

As soon as the water has reached the ditches it flows along them from higher to lower levels; and this will be the case throughout the whole course of a stream and river; the waters will always flow down the slopes from the higher levels, until at length they reach the lowest level, or that of the sea; the land being generally above this dead level. As the rains run into the ditches they wash away some yortion of the loose surface soil, and this again the waters in the ditches carry into the streams, and the streams into the rivers, and thence into the sea, so that the great effect cf the rains is to wash off the land little by little, and spread it out as sand, mud and silt on the floors of the seas and oceans.

So, when you walk by the river side, you will notice that the river bottom is covered with sand and mud; and, if the river be strong and deep, even pebbles, gravel and stones are carried along by the waters. And you will also notice that the river is at a lower level than the land on either side, as though it had eaten out its way through the rocks, over and through which it winds its way. If the river be low, as it is after dry seasons, its current will be slow and weak to carry away the sand and mud; but after long wet weather its speed and strength are greater—so you learn that the broader and deeper the current the greater its power to transport or carry away its burden. And you will further notice that if the river flow through a nearly level district, its power is also very weak; but if it fall down a sharp slope it runs more rapidly and strongly. In a canal, which is an artificial river, there is little or no slope, so there is little or no current at all; this therefore does not wear away its bottom or sides.

## Exercise.

(1). *What are the two great roads to knowledge of natural appearances?*
(2). *Of what are a ditch, pond, and rock in a pond, a picture in Physical Geography?*
(3). *What becomes of the rain that falls on the ground?*
(4). *What is the general effect of rivers on a country?*
(5). *Upon what do the strength and speed of a river depend?*

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**Parts of a River.**—When we stand upon the banks of a river or stream we notice that the water is flowing in a certain direction to the sea, from some higher level. If we were to follow the stream one way it would lead us to its end; if in an other, to its beginning or *source*—now a river may be said to have many beginnings or sources, but we generally take that one which is the farthest removed from its end or mouth, as *the* source. The sources are of various kinds:

(1.) In hilly and mountainous districts the waters that have fallen as rains, or melted as snows, either run off the surface at once, and make the sources of the river: or they sink through the chalk, sand and gravel till they come to some rock, such as clay, granite, or other hard rock, which will not allow them passage. They then flow over the top of these impervious rocks till they come to a lower level in the sides of the hill or valley, gushing out there as a little or large spring.

Such springs as these therefore very often only flow during wet seasons; but at other times the rains sinking into the rocks cut out great caverns, and fill them with water, and then the spring does not cease to flow during the dry season, because it is fed from the cavern within the mountains. The best place to find these caverns is in mountains made of limestone, because that is easily dissolved out by the rains; and Derbyshire is very famous for such kinds of caverns, and rivers flowing from them.

(2.) But sometimes the river begins from level ground, which is therefore boggy, or marshy; and from a large, wet surface of this kind the waters slowly find their way to a slope, and commence their course in rivers. Such rivers are of course generally slow, as they rise at low levels, and have not much slope to fall down; for the higher a river rises the more rapid must be its current—at any rate till it has reached more level ground. This is the slow character of the rivers that rise in the east of England where the ground is level or nearly so: they are also very winding, as they have not force to cut out a straight path for themselves as swifter waters do.

(3.) But in some other countries where the mountains are high enough to have snow on their summit, it stands near the top all the year round; and where this snow accumulates in bason-shaped valleys until by pressure it becomes changed into ice we have glaciers or ice rivers. These melt at the ends farthest removed from the mountain cradles in which they were formed, and thus give rise to rivers such as the Rhone and Rhine of Europe rising in Mt. St. Gothard in the Alps.

(4.) I dare say if you look round the country you will find some large pond or lake with a stream coming out of it: from this you may learn that *Lakes* are another source of rivers. The largest river of the world—the Mississippi—thus rises in a small lake, which is therefore termed a source-lake.

Travellers have taken more notice about the sources of rivers than their importance justifies; these are of very little or no practical consequence.

In our walk by the river side we must have found out that the river had a *bed* or *channel:* this is generally a single one, but in rivers that are subject to floods from heavy rains and melting snows there may be two beds, one in which the river generally flows, and a wider one in which the flooded river finds its way. This is well seen in the Jordan "which overflows *all* its banks at the time of harvest." These banks are generally called *right* and *left*, as they would be to any one going *down* the stream ; for, as the river winds about so we could not well call its banks north, south, east or west.

(5.) If you have in your neighbourhood a pond into which a stream or large ditch empties itself you can fancy the pond is the sea and the stream then may be said to have its *mouth* where it joins the waters of the pond. When the mouth of a river is wide and the tide comes up it, the mouth is called an *Estuary*, which means a tide-mouth or a river-mouth, up and down which the flow and ebb of the tide take place. Such rivers are the very best for commerce, as the tide takes up and brings down the laden ships with imports and exports as it swells in and out of the channel. This is why London on the Thames and Liverpool on the Mersey are so well situated. The Thames in itself is a not very important river—it is the tide which makes it so useful.

As we go by the river side we see other streams empty into it; these are called *Feeders*, as they feed the main current, or *Tributaries*, as they pay the *tribute* of their waters to the main stream. They should never be called branches, for a branch goes *out* of a tree, and these do not go out of but into the river. Of course the more of these a river has the greater is the volume of water it takes to the sea, and therefore the greater is its velocity and the wider is the area drained by the river as a whole. Some rivers, as the Nile in (Egypt) have no tributaries at all; others, as the Thames, have a great many.

(6.) But a river may have *branches*. Thus many rivers branch out or divide, especially at their mouths.

The further the river gets from its source and the nearer it gets to the sea, the less of course as a rule is its speed; so that at length it has not force enough to carry out the mud, silt and sand, it has brought with it, and drops these down in its bed. As a consequence the bed gets silted up, and the channel blocked, so that the waters find other courses to the sea. Each of these fresh channels is filled by a real river *branch*, and the flat, moist land at the mouth is called a *Delta*. The name is taken from the Greek letter △ delta, which is of the shape of a triangle, the general shape the land assumes. One side has the sea facing it, and the other two sides are made by the river branches that spread out the widest, and there may be many branches between. You can find out for yourselves on the map the great rivers which have deltas, and you will see they are the Rhine, Rhone, Volga, Po and Danube, in Europe: the Ganges and Indus in Asia; the Nile in Africa; the Mississippi, in N. America; and the Orinoco in S. America. Such districts are mostly very unhealthy, from the foul air rising from the decaying vegetables brought down by the low rivers and laid down or deposited in the delta.

(7.) We have thus seen the *sources* of rivers *whence they are supplied*, namely, from rains, melting snows, or melting ice; and we have also found out what becomes of them, namely, that they generally go into the seas and oceans. In the next chapter we shall see that they came from these at first, so the waters that flow through our fields and towns are never idle or at rest; they are always either trickling through the ground, or flowing over its surface, or being carried up by the heat of the sun into the skies to make clouds, to fall again as rain and trickle through the ground, or flow over it once more.

But all rivers do not thus flow into the main ocean; some flow into great inland lakes cut off from the seas and oceans; but even then the sun raises the water again in mist and cloud, and it has to do the same work, and these rivers go the same round as their brothers that flow directly into the seas. You will see this on the map by looking at the Volza and Ural flowing into the Caspian Sea, and also in many smaller rivers. They may also flow into a lake first, and this may then empty itself by a river into the sea or ocean, as in the case of the rivers that flow through the great chain of lakes in Canada.

Moreover, in hot countries some rivers dry up in their course or flow into the sands of the deserts.

## Exercise.

(1). *Name the parts of a river.*
(2). *What sources may rivers spring from?*
(3). *What is the bed of a river?*
(4). *How do you name the banks of a river?*
(5). *What is an Estuary?*
(6). *What is a tributary or feeder?*
(7). *What is a river branch?*
(8). *What is a delta?*
(9). *Name some rivers with deltas.*
(10). *Whence are rivers supplied?*
(11). *What becomes of the waters of a river?*

## CHAPTER II.

### EVAPORATION—CONDENSATION—RAIN—SNOW—HAIL—DEW—MIST.

**Evaporation.**—When we hang wet clothes upon a line they become dry. We do not see the water dry up or evaporate, for it passes away in such small portions that these are not visible if it be warm weather. Now, we know the clothes dry best on *dry, warm* days: so the two great necessries for this *evaporation*, or turning the water into vapour, are *heat* and a *dry state of the atmosphere*, or wind. If the weather be moist the vapour hangs about in "reek," or "mist," or "steam," or "fog;" and then it is visible. In fact, the air is like a sponge; it will take up the moisture, and if it be warm it will hold a great deal. Of course the evaporation will be the greatest therefore in warm countries, and over sheets of water, as over rivers, lakes, seas and oceans; as well as over the moist surface of the ground. This vapour rises up with the warm air into the higher parts of the atmosphere, where it is much colder than below, and the winds carry it from one place to another.

You can see and feel this on your own bodies: when you get into a perspiration or sweat the moisture passes away from your skin and makes the air moist around you. The sun is therefore daily taking up millions of tons of water by evaporation, and the air is everywhere, except over what are called the Rain, less Regions of the earth, and very cold climates laden with more or less of aqueous moisture.

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**Condensation.**—If it has as much as it will hold the air is said to be saturated, which means full; and if in this state the heat or temperature rise then it will hold still more; but if the temperature fall it will not hold so much; so some has to fall or become condensed. The word *dense* means *heavy;* and *condense* is to make heavy; all the while the moisture was in the invisible state in the air; it was very light, but when it condenses it becomes heavy by little particles joining together to make small drops and fall as rain, dew, &c.

Let us make an experiment to show that cold will thus condense some of the invisible moisture in the air, and make it fall, or become deposited. Now, the air in the schoolroom on a warm summer day will have unseen vapour of water in it. Draw a bucket of water from a deep well, and bring a glass full of it into the room. This water is very cold and makes the glass cold; and the glass chills the air all round the outside of it; and when this air has become thus cold it will no longer hold all the vapour it held before, but some drops down and falls on the outside of the glass, where you can see it like dew.

We will make another experiment to show that if the temperature be *raised*, the air will take up more moisture in an invisible state, than when it was cold. On a cold day, if a boy stand at the door, or on the outside of the school, the cold condenses the moisture in the air he breathes out, and we see his "breath." Let such a boy come near the fire, and the "steam" or "mist" disappears.

You have thus learnt that evaporation is turning a liquid into a vapour by heat; and that condensation is the opposite or turning invisible into visible moisture, or a vapour into a liquid by cold, for if you breathe upon a cold slate the beads of moisture will gather and form liquid drops.

### Exercise.

(1). *What do you mean by evaporation?*
(2). *What are the essentials to evaporation?*
(3). *What do you mean by condensation?*
(4). *What are the essentials to condensation?*

---

**Rain.**—We generally see the blue sky more or less covered with clouds, especially in the winter weather. The invisible moisture takes up the sun's heat, becomes partially cooled or condensed at great heights, owing to the cold there; and gives us either the very high, light clouds, curled like wisps of straw, making what is called a *mackerel sky* from the likeness to the marks on a mackerel's back; or if the clouds are lower they are more like heaps of wool. They are black seen from beneath because they stop the light of the sun on the other side of them; white on their edges because they reflect the sun's beams; and red, purple, slate, green, violet and other tints, when the sun's rays partly come through them, according to what colours of the sun's light pass through; for the sun's light is many-coloured as you have seen in a rainbow. If the clouds are still lower they do not gather in wisps or heaps, but are mixed up with the air around, and make what we call true rain clouds, such as you see all round you on a wet day.

Anything, then, which will make these clouds colder will make the vapour drop down in little beads of rain at a height in the air; and as the little beads drop to the earth the wind will blow them about, and they will join and run into each other, and make larger and larger drops, until they reach the earth. We can therefore say that the great cause of rain is cold air coming near warm, moist air. This cold air is generally brought by winds from another part of the earth's surface which is not so warm. Sometimes, also, the wind drives the moist air and clouds against the hills and mountains, and as the air or clouds try to pass over the tops, driven by the pressure behind, it mounts higher and higher into colder and colder layers until it becomes condensed and rain falls from it. The high parts of the earth therefore have more rain than the low as a rule. We see this very well in England; for the wettest parts are in Cumberland and Westmoreland among the mountains of those counties, in Derbyshire around the Peak, and among the mountains of Wales and Devon and Cornwall. Of course, as the rain falls it leaves the winds drier and drier, and so we find as we go from the sea or shore line up the country, or towards the interior of the continents, that the rainy days become less and less, and the quantity of rainfall also decreases. We note also the same thing in the amount of rainfall in passing from the equator or tropics, or hot parts of the earth, towards the poles or colder parts. For as more moisture is taken up the greater the heat; so more falls in those parts when it is condensed or cooled by winds or mountain tops. If we were to measure what falls we should find that around the equator 100 inches, or above 8ft., falls in a year; but in our own country only about one-third or 33 inches fall in the same time. That is if the rain did not run off and into the ground, nor dry up, it would be about 2ft. over a man's head in the tropics, and up to our middle in England at the end of a year. You will notice that with us the rain falls during the whole year, so our grass keeps pretty green all the year, but in warmer countries it falls only once or twice in the year, at the rainy seasons, these seasons extending over a considerable period, and between these the ground is parched, and nothing will grow.

### Exercise.

(1). *What different kinds of clouds are there?*
(2). *What makes these condense into rain?*
(3). *What kinds of countries are most subject to rainfall and why?*
(4). *What parts of England are wettest?*
(5). *After what law does the rainfall of a country diminish?*

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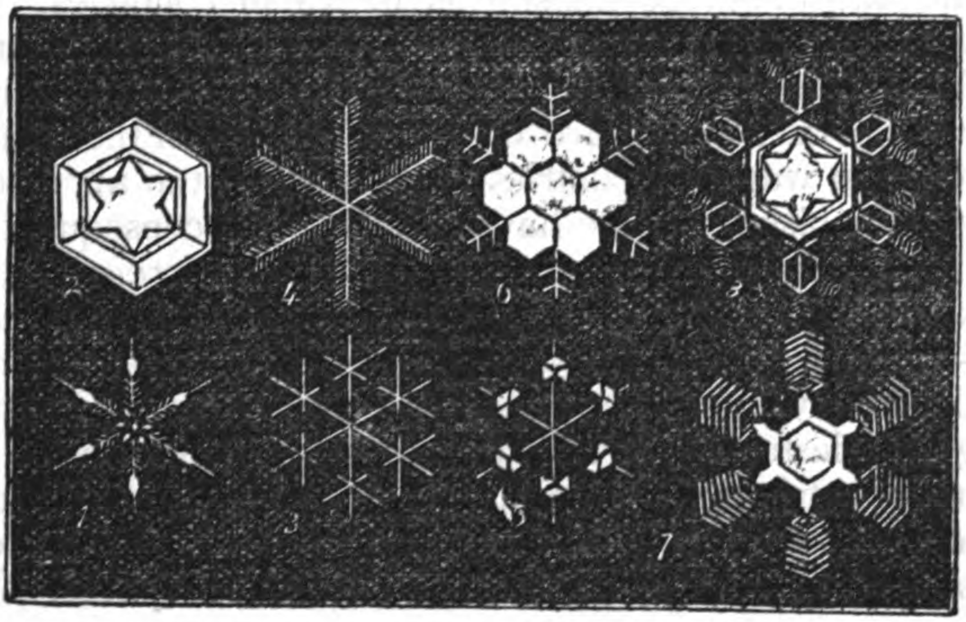
**Snow.**—If you look at the window-panes or on the twigs of the trees, or at the fields in winter time, you will see these are frozen. And if you look closely you will see there are all kinds of beautiful shapes taken by the frozen moisture. We call these forms crystals which means regular figures or shapes, and if you could go high enough up in the air where the moisture is freezing you would find the air full of these frozen crystals. But as these are made of ice they are heavier than the air where they are formed, and so they drop to the ground. and in doing so the wind blows them about, and they run into each other, and their beautiful forms are marred. The plan upon which all these snow crystals is built up is that of a hexagon or figure of the form of the cell of a honey-comb of a bee, in which the diagonals all cross each other at angles of 60 deg.



**Common Forms assumed by Snow Crystals.**

All round the poles within the districts called the frigid zones, the snow lies at the sea level, and forms a snow-cap over all the land during the whole year. But as we proceed towards the Equator or the warmer regions, the snow that falls during the winter melts in the summer except at elevations where it is colder. In other words, the *snow line*, as it is termed, or the line of *perpetual congelation*, or constant freezing, rises higher as we go towards the tropics where it is about 16,000ft. high.

**Hail.** Examine the hailstones that fall during one of those short, sharp, hailstorms which visit us in summer and autumn. You will notice that they are rounded and are like frozen rain. This is a rather difficult subject, since electricity has a deal to do with the formation of hail, and it is again not easy to account for the angular shapes of the large hailstones that fall in severe hailstorms in warm countries. It would appear, however, that while the raindrops are falling they sometimes pass through layers or currents of air, which are cold enough to turn them into ice. In warmer countries than our own the air holds more moisture, as we have said before; consequently the stones are much larger and more irregular in shape. It will be noted that hailstorms are very local —that is, confined to very limited districts, but within these they are sometimes very destructive, breaking glass, destroying fruit, flowers, and foliage; and in hot countries even animal life. The reason why they are limited in range is because electrical disturbances of the air can only take place over small spaces.

## Exercise.

(1). *What is snow*
(2). *What is the snowline, and how high is it at the tropics?*
(3). *Why do we not see snow crystals perfect in England?*
(4). *What is hail?*
(5). *Why is the storm local and not general in hailstorms?*

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**Dew.**—On a fine clear night, without wind, after a warm day, let us go into the fields. We shall find the grass wet with dew. If we take a blade of this and examine it in the light we shall see that it is beaded over with very small, clear, glassy-looking gems or drops of water. This has gently fallen upon the grassy covering of the earth, and on the leaves of the trees, but most likely we should find the gravel walks quite dry.

To understand this let us go back to our experiment with the glass of water taken from a well and brought into a warm room. We saw that this cold glass chilled the air of the room around it, and caused the moisture, which this film of air round the glass held, to be condensed and deposited upon the glass. Let the glass represent the surface of the ground; this rapidly absorbs or sucks in the heat of the sun during the day, and as rapidly parts with the heat during the night. It thus becomes a cooled surface, and chills the air just over it as the glass did: the moisture in this chilled air is thus condensed, and falls as minute bubbles of dew, which collect on all the rough parts of the grass, leaves, twigs, &c. This dew sometimes make a very beautiful beaded lace in autumn. There is a spider which makes long threads of cobweb, reaching from hedge to hedge across the road—fine gossamer spun by the finest lacemaker in the world. This catches the dewdrops as they form and fall, and when the sun shines on these the white light becomes split up into all the colours of the rainbow.

We said you must go out to collect the dew on a *clear* night, *without wind, after a warm day*. For if the night be cloudy there will be no dew, since the heat which the earth's surface gives out will be reflected or sent back by the clouds to warm the air over the earth. And if there be wind this will mix together the cold film of air at the surface below with the warmer air above. And if the day has not been warm the air of course will not be nearly *saturated* or filled with aqueous moisture. These are then the conditions for the formation of dew—that is the three things, without which we cannot have it.

The dew is a very important source of supply of moisture to plants in hot countries where rain falls only at certain seasons; and here it is very copious, as the air being hot it is highly charged with moisture, or is near the point of saturation. By a wise providence dew falls more abundantly on grass and growing vegetables than on any other objects.

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**Mist.**—If you look across the waters of a lake, wide river or sea; or if you look down from a hill or mountain-side at early morning, you will see that the surface of the earth is wrapped in a heavy mist or fog. This is the vapour which is partly condensed above the cold surface of the ground; but, as soon as the sun rises and shines down upon this thin mantle it vanishes away; for the air, becoming warmer, will take up more moisture in the invisible form. On the mountain sides it seems to roll up the valleys and towards the summits, where it meets with colder air than that below, being warmed by the sun. Mist is therefore a kind of thin cloud near the surface of the earth, or on the flanks of a mountain. If it be mixed with the smoke of chimneys as in our large towns it then becomes fog, which may be so thick as to stop all but the red light of the sun coming through it. This is seen too often in London, and those who go up in a balloon tell us there is always more or less of mist hanging over the River Thames below them.

**Exercise.**

(1). *What is dew?*
(2). *What are the conditions for its formation?*
(3). *What is mist?*
(4). *What is fog?*

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## CHAPTER III.

THE ATMOSPHERE. ITS COMPOSITION, WINDS.

**The Atmosphere.**—Besides the liquid ocean, which covers part of the surface of the earth, the whole earth is surrounded by a fluid ocean of a much lighter and thinner character, called the air or atmosphere. We can see how much lighter this is than water, for if we took a square tube an inch wide, and one inch broad, or a square inch in section, 34 feet of this would hold a column of water, which would weigh 15lbs, or have a pressure at the bottom of 15lbs. to the square inch. But if we took air instead of water the column would have to be 200 miles high—that is, we are living at the bottom of a fluid ocean, 200 miles deep. Now, what proofs have we of the existence of this ocean? When you carry a flag or wave a sheet of paper to and fro, you feel there is something resisting the motion, just as when you move a board to and fro through the water.

(2). If you put a lighted candle under a closed vessel it goes out after a little while; so there was something which first allowed the light to burn, and which being used up stopped the combustion. For if when the flame is just going out you raise the edge of the glass vessel a little, the flame will become bright again, air being necessary to combustion.

(3). If you take a bladder half full of air and hold it before the fire, till it becomes warmed, it swells up; so there was something inside at first, for you cannot heat nothing, and *turn* it into *something*.

(4). If you take a delicate balance and weigh a bag full of air, you will find it has weight; therefore it is matter.

Now, matter must be in one of these three physical states or forms: *solid*, *liquid*, or *gas*. As you know, air is the latter, but it is not all one gas of the same kind, but a mixture of two or more, and a quantity of aqueous vapour.

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**Composition.**—We could prove this by two experiments; we could make two gases and mix them together in the same proportions as the chemist says they have in the air; and then we should find this artificial mixture could be breathed, and would keep a flame burning, and behave in every respect like common air.

Or, we could take some common air and divide it into two separate parts, and thus find both the properties and proportions of the two separate gases.

But this would be hard for you to understand, and in some cases the teacher would not have means to do it with; so you must have faith in the labours of others.* But, first, let us say the two gases in the air are called *Oxygen* and *Nitrogen.*

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**Oxygen.**—This is the part that is useful, and without it no animal could live. It clears our blood when we breathe it, and so is the great life sustainer. It is also the great supporter of combustion: that is, by it substances are enabled to burn; and that is the reason why we use the bellows, namely, to pour in copious supplies of oxygen to the glowing fuel.

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**Nitrogen.**—This keen, life-giving, fire-sustaining oxygen, would, unless diluted or weakened by nitrogen, which will not sustain life or combustion, make animals breathe, and fires burn so rapidly, that the former would die from their exhaustion, and the latter would set fire to the grates, walls and houses, and the great globe itself. But it is mixed with four times its

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* The teacher can, at the outlay of a few pence, procure a little binoxide of manganese, and heat this in a Florence flask over a lamp when oxygen will be copiously given off. He may then show the properties of the gas by plunging into the stream of issuing oxygen, a match which has been kindled and blown out, when the match will take fire and burn with great brilliancy. By doing the same with ammonia nitrite, nitrogen will be given off, and he may show that this will put out a light plunged into it. By taking a tumbler and wetting it inside, and sprinkling iron filings over the moist surface, and leaving the inverted tumbler in a saucer of water for a day or two, the oxygen of the air confined within the tumbler will combine with the iron to make iron rust. (Ferric oxide, $Fe_2, O_3$), and nitrogen will be left. The properties of this can be demonstrated to the class as before.

own bulk of nitrogen, which has no active properties in itself, but is of service to weaken the action of the oxygen.

---

**Other Constituents.**—Besides the two gases given above, which *constitute* pure air, or are its *constituents*, air generally contains, as we have already seen, quantities of aqueous vapour. This, beside serving the purposes we mentioned in Chap. I. of giving rain, snow, hail, dew, mist, &c., is very important on account of its action on the *light* and *heat* of the sun. Perfectly dry air would be transparent to light. It would also let heat rays go through it without change; but aqueous vapour reflects the light or scatters it about in all directions, and absorbs the heat to radiate or give it out again into space. So if it were not for the aqueous vapour in the air we should only be in the light when fully exposed to the sun, and behind every object between us and the sun we should be in black shadow or darkness. And we should also not have the air warmed by the sun's heat passing through it as we do now.

Besides this action on light and heat the air is the medium or vehicle, or carrier, or bridge, or means by which *sound*, reaches our ears. For if you take a bell jar and exhaust the air from it we do not hear a bell which is made to ring in it, for there is nothing to carry the vibrations of the bell to the ear.

In addition to the oxygen, nitrogen, and aqueous vapour, the air contains other gases which result from combustion in large towns, and from decay of animal and vegetable matters. These have very hard names and strange properties; but the most common and important is carbonic anhydride, which is a combination of carbon and oxygen. Now, you may think of carbon as charcoal, or as that which will burn like coal, coke, the greater part of wood, fat, &c. When any of these substances are set on fire, a poisonous gas, carbonic anhydride, is set free. The same gas is given off by all animals when breathing out the air from their lungs. So in time the combustion and respiration that are always going on would poison this fluid ocean, at the bottom of which we live, and all animals would die; but this is prevented by a beautiful plan or contrivance, for while the animals breathe in oxygen and breathe out carbonic anhydride the plants through their leaves breathe in carbonic anhydride and breathe out oxygen. The one kingdom thus keeps in check the other.

### Exercise.

(1). *What is the air?*

(2). *What are its composition and weight?*

(3). *What proofs are there that we live surrounded by an atmosphere?*

(4). *What constituents besides oxygen and nitrogen are commonly found in the air?*

(5). *How do the vegetable and animal kingdoms keep each other in check?*

---

**Winds.**—Wind is air in motion. The air is set in motion by its becoming heated in any one part. You see this when you light a fire; at first there is no draught up the chimney, but when the fire is lit the air in the chimney is made lighter than the air in the room, and so it rises while the heavier air in the room rushes towards the fire to fill up the empty space. This in turn becomes heated, and so you get a wind up the chimney. The same thing occurs in nature; the sun shines upon the earth's surface in some districts and makes it warm; this heats the air above it, which thus becomes lighter, and rises while colder, heavier air rushes in from colder surfaces to fill its place, thus causing a wind to blow. Be sure you do not mistake the sun's action in this respect; do not think that the sun shines on the air and makes *it* warm in warm countries, and that thus the air becoming lighter rises, for we have already said the air mostly lets the sun's heat go through it without stopping it. It is the earth's heated surface that heats the air above it. *All winds are then caused by the unequal distribution of temperature.* These are of different kinds.

---

1. **Permanent Winds,** or those which blow over the earth's surface, constantly in the same direction. The chief of them are the *Trade* winds. Let E.E. be the earth's equator, P the pole, the sun heats the surface more near the equator than elsewhere, and the air above it becomes lighter and rises. To fill its place colder, heavier, air rushes in from the poles from north or south, as shown by the arrows. This gives us north and sound winds in these parts. But everything at the earth's surface, and the air with it, spins round once in 24 hours. Now, as the earth is about 24,000 miles round at the equator, the air is going with the earth at the equator at the rate of 1,000 miles an hour. But anywhere further north and south the circle passed through in one revolution is smaller than at the equator, so the air there travels at a less rate. The winds coming in therefore from north and south are travelling to places which have a

quicker rate of going to the east than from whence they came. They therefore lag behind or fall off to the west. If you were in a boat rowing to the east, three miles an hour, and the wind was blowing against you at four miles an hour, you would not get on at all, but would lag behind at the rate of 4 — 3 = 1 mile an hour. So these north and south winds lag to the west and have now two motions, one to the north or south, the other to the west, as shown by the arrows. They cannot therefore go in both these directions except by going between them or to the S.W., and N.W., towards the equator. But when winds blowing to the S.W. and N.W. meet they join in one current to the west, toward the equator, as shown in the fig.

And thus we get easterly winds all round the equator and for some distance on either side of it there are the surface trade winds. We find such therefore blowing across the Atlantic Ocean from the west coast of Africa to America, and across the Pacific from the west coast of America to the east coast of Asia. Of course over the land the direction of the mountain chains will interfere and make them less regular in direction.

---

2. **Land and Sea Breezes.**—One would think that water would soon become heated, as we so often boil it upon the fire; but, really, it is one of the slowest substances to take up or absorb heat, or to become cold when once heated, That is, it is a bad absorber and a bad radiator. But the rocks of the earth's surface are much better absorbers and radiators of heat. When the sun is shining you feel the sand or

rock hot to the hand, but if you plunge it into water equally exposed, the hand then feels cold, which is a proof of this. As the sun therefore shines upon the surface of an island or shore-line in warm countries during the day this surface becomes more heated than that of the ocean; the air above the land therefore becomes more heated than that over the sea, and rises, while colder, heavier air rushes in from the water to fill its place. We thus get sea-breezes, or breezes from the sea. But at night-time the reverse takes place; then the earth rapidly cools, and the water slowly gives off its heat; the air therefore over the ocean becomes lighter than that over the land, and rises while colder, heavier air from the land rushes in to supply its place, and we have land breezes, or breezes from the land.

---

3. **Monsoons.**—The same thing takes place on a large scale over the Indian Ocean. In the hot season of the northern hemisphere, from April to October, the land in India becomes heated, and the air above it rises, while the colder, heavier air over the Indian Ocean rushes in to fill its place, giving us for six months breezes from the south west. In the hot season of the southern hemisphere the air over South Africa becomes more heated than that over the Indian Ocean. The air over South Africa therefore rises, and colder heavier air from the Indian Ocean rushes in to fill its place, and we get monsoons from the north east, lasting from October to April.

4. **Local Winds.**—Besides these permanent and periodical winds we have local winds depending

upon local circumstances, such as the direction of mountain chains. Among these are the **Simoom** of the Sahara, or desert of North Africa, which are hot dry winds which will dry up the water in the skins carried by travellers in caravans. The same wind under other names is also known in Egypt and Arabia, and even across the Mediterranean in Spain and Italy where they are called the **Scirocco.** These are so drying and irritating, that the Spanish have a proverb, " Never ask a man a favour while the Scirocco blows ;"—like our proverb, " Never ask a man a favour till he has had his dinner."

### Exercise.

(1). *What is wind?*
(2). *Into what two classes may we divide winds?*
(3). *Describe the Trade Winds?*
(4). *What are Land and Sea Breezes, and how are they formed?*
(5). *What are Monsoons?*
(6). *What local winds do you know of?*
(7). *What are the Simoom and Scirocco?*
(8). *What are Local Winds?*

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## CHAPTER IV

### Rivers &c.

**River Basin.**—When we spoke of rivers in Chapter I. we explained that a river-bed or channel was the course along which the river flowed. But evidently this is not all the surface that is drained by the river, since streams, and brooks, and rivulets, and tributaries, come in from all sides to supply the main river. We therefore need such a term as River Basin to point out the whole surface or district drained by any one river system, or main river and its tributaries. We could mark out all the river basins of the world, or of a particular country, by colouring all the surface around the main course of the stream and its tributaries.

---

**Watershed.**—The boundaries of these basins, separating one from another, would be called lines of watershed, because these districts would be the parts where the water was shed, or divided into two directions—on one side into one river basin, and on the opposite into another. A very good picture of a watershed is given by the ridge of the roof of a house; this divides or sheds the rainfall into two opposite directions. One of these might be a larger one than the other, as you see, when there is one or more stories to the house on one side than on the other. And so there may be one long slope, as it is called on one side of a watershed, and a short, steep *counterslope*, as it is called, on the other. This is very well seen in South America, where the watershed is made by the Andes Mts., where the long slope is towards the east, and where we thus get the long rivers Amazon, Orinoco, and La Plata, while on the other side, or the short counterslope we have very small rivers. Of course the slope and the counterslope may be of about the same size as in the Pennine Chain running through the six northern counties of England, where we have rivers of about the same size flowing to the east and west. Another example of the same kind is to be seen in Italy with the Apennines, forming, as it were, the backbone of the Peninsula.

Though the watershed is generally an elevated region as implied above, it is not always so. Sometimes it is very low ground; indeed, even a bog or marsh, from which the water slowly flows in opposite directions. Capital instances of this are afforded by the watershed between the rivers Leontes and Orontes in Cœle (Hollow), Syria, and in the watershed between one of the tributaries of the Orinoco, and one of those of the Amazon. Here the ground is so flat that the waters are almost stagnant, and turned one way into one river, or the other way into the other by such a slight disturbing cause as opposite winds.

Our own country affords us a remarkable instance of the watershed not being in an elevated region. The rivers which flow northward into the Thames on the right hand, and those flowing south into the English channel, in the counties of Kent, Sussex, Surrey, Hampshire, and Berkshire, do not in either case rise on the slope of the North and South Downs, but in the weald or flat low plain between these chalk hills, and have scooped out for themselves channels through the soft chalk and sand.

## Exercises.

(1.) *What is a River Basin?*
(2.) *What is a Watershed?*
(3.) *Of what kinds of district maya watershed consist?*
(4.) *Name some of the river basins of England.*

**River Basins of England.**—It now remains to point out the boundaries of the great river basins of our own country. These include those of the Thames, Severn, Yorkshire Ouse, the rivers of the Wash, those of the east and south coasts. The best notion that can be given of these is to illustrate them by section maps with a key of explanations. These should be carefully studied time after time by the student until the details are committed to memory; and then further impressed on the mind by being drawn on slate and paper from memory.

---

## The Basin of the Thames.

This occupies an area of 5,500 square miles.

The Thames rises in the Cotteswold Hills, in Gloucestershire, and after flowing through that county and between Oxford, Buckingham, Middlesex, Essex on the left bank, and Berks, Surrey, and Kent on the right bank, in a course of 200 miles empties itself by a wide estuary or tidal river mouth into the German Ocean, at what is called the Nore between Kent and Essex.

The course is slow, as the river and its tributaries rise at only slight elevations, and hence much of its utility for purposes of inland navigation by means of barges. Again, owing to the fine sweep of the tide which bears ships 60 miles to London Bridge the lower course is well suited for commerce. The watershed is marked by the Cotteswold Hills, the North Downs, Chiltern Hills, and Essex Hills.

## The Basin of the Severn.

This occupies an area of 5,900 square miles.

The river rises in Mt. Plynlimmon on the eastern side, and flows through Montgomeryshire, Shropshire, Worcester, and Gloucester, draining Central Wales. The river is less navigable than the preceding, owing to shallows, and the mouth is subject to a Bore or Ægre, which is a rush of tidal water, dangerous to boats and small craft: the rise at Chepstow being 60ft. for high tide.

The watershed is marked out by the Welsh mountains—the Wrekin, Edge Hills, Malvern Hills, and Forest of Dean.

The tributaries of the Severn are the Teme on the right bank and the Stour and Avon on the left bank. The river sweeps round in a great arc convex to the north-east.

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## The Basin of the Humber.

This includes the united valleys of the Ouse and Trent, with their tributaries. The estuary is shallow, and the navigation difficult on this account, and because of the Ægre or Bore. The area of the Ouse drainage is 4,800 square miles; that of the Trent, 4,000; total area, 8,800 square miles, which is therefore the largest in England, The Ouse is 150 miles long, the Trent 120. The watershed of the Ouse proper is formed by the Yorkshire Moors and Wolds in the east and the Pennine chain in the west; that of the Trent is the Staffordshire Moors, the Peak district, and the Lincoln Wolds.


**MOUNTAINS.**

I North Downs.
II Cotteswold Hills
III Edge Hill.
IV Chiltern Hills.
V Essex Hills.

**TRIBUTARIES.**

1 Thames
2 Colne.
3 Cherwell.
4 Thame.

**TRIBUTARIES, *Con.***

5 Kennet.
6 Windrush.
7 Wey.
8 Lea.
9 Mole.
10 Medway.
11 Brent.

**COUNTIES.**

K. Kent.
S. Sussex.

**COUNTIES, *Con.***

H. Hampshire.
W. Wiltshire.
E. Essex.
M. Middlesex.
H. Hereford.
Be. Berkshire.
Bu. Buckingham.
O. Oxford.
G. Gloucestershire


**MOUNTAINS.**

I Plinlimmon.
II Staffordshire Hls
III Edgehill.
IV Dean Forest
V Malvern Hills.
VI The Wrekin.

**RIVERS.**

1 Teme.
2 Stour.
3 Severn.
4 Avon.
5 Wye.
6 Upper Avon.

**COUNTIES.**

M. Montgomery. W. Worcestershire. St Stafford. H. Hereford.
Sh. Shropshire. G. Gloucestershire. Mh. Monmouth. R. Radnor.

## THAMES.

This has been called the king of British rivers, because of the beauty of its banks, and its importance owing to the situation of London with its gigantic commerce on its tidal mouth or estuary.

It rises in the South-eastern slopes of the Cotteswold Hills, in Gloucestershire, and flows with a general easterly course through Gloucestershire, through a part of Wiltshire, and between Berkshire on the right bank, and Oxfordshire and Buckinghamshire on the left. It next divides Surrey on the south side from Middlesex on the north, and Kent from Essex.

The reputed source of the river is at Thames Head, which is situated three miles from Cirencester to the south-west. Others consider the river Thames is formed by the junction of the Churn with the Isis, or Thame, near Lechlade; the united river being increased by the Colne, Leach, and Cole. The upper part of its course is through a rather level country, but this contains Farringdon Hill. After receiving the Windrush and the Wenlock, the river reaches Oxford, where the Cherwell joins it. It next reaches Abingdon, near which is the celebrated Vale of the White Horse, bounded on the south by a waving range of hills, partly wooded and partly bare. Below Wallingford, the Thames flows in a narrow valley having the Chiltern Hills on the north in Buckinghamshire. The river next reaches Reading, and then flows past Henley, Marlow, and Maidenhead, till it reaches Windsor, with the Royal Castle of Windsor on the right bank. Near are Cooper's Hill and Runnymede. At the latter place the famous Magna Charta was signed by King John.

Flowing past Staines and Chertsey, the river reaches Hampton Court and Twickenham, the latter the residence of the poet Pope.

Next come Richmond, and Kew Gardens, and then the Metropolis.

Below London Bridge are Greenwich with its Palace and Observatory; Woolwich, and its Arsenal; Gravesend, and Tilbury Fort; until at the Nore Light, $45\frac{1}{2}$ miles below London Bridge, the waters mingle with those of the ocean.

Besides the tributaries already mentioned, there are

| On the right bank. | On the left bank. |
|---|---|
| The Colne. | The Kennet. |
| New River. | Loddon. |
| Lea, and | Wey, and |
| Roding. | Mole. |

The whole length of the river is 215 miles, and the area of the basin drained by the main river and its tributaries, is about 6,000 square miles, or nearly one-eighth of all England.

The elevation of its source at Thames Head is only 375 feet above the level of the sea, so that it has a very gentle slope throughout, and this is especially the case in the lowest part of its course. This is an important point, as it assists the navigation of the river. At London Bridge, it is only 4 feet 3 inches above the sea; and below London Bridge, it has a fall of only 1 inch in a mile.

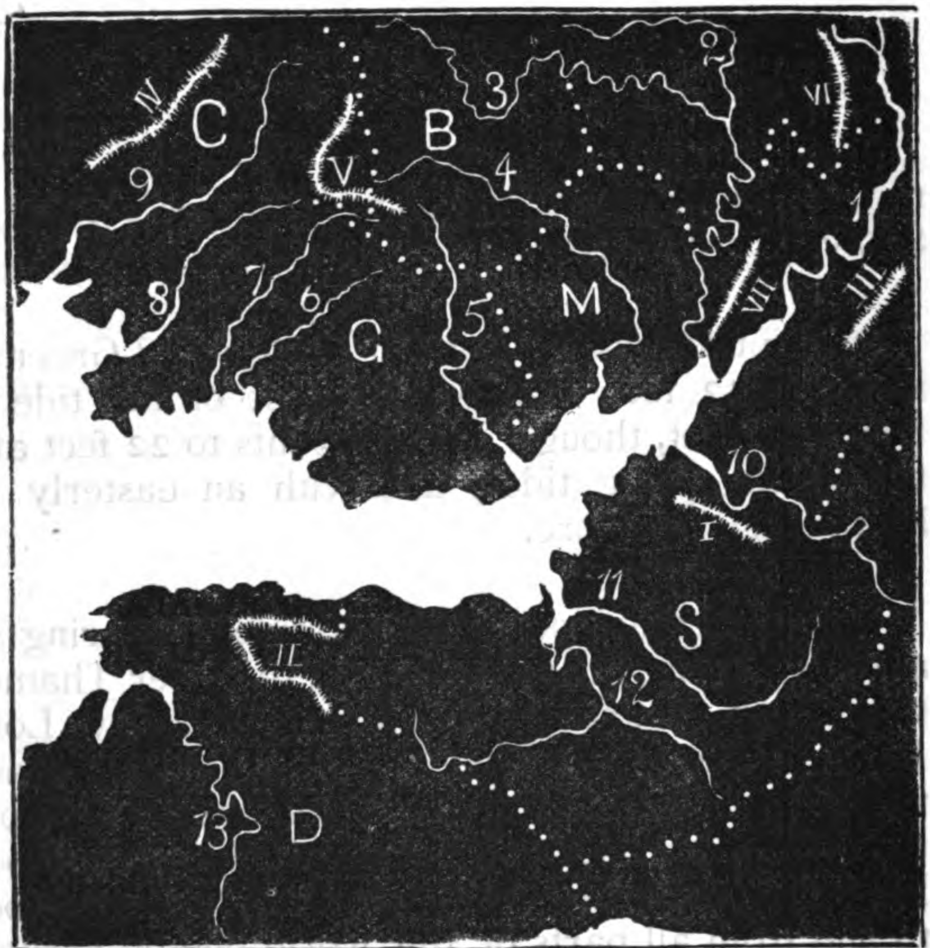
The breadth of the river at London is nearly 300 yards; but it of course widens as it proceeds towards the sea, being nearly 500 yards at Woolwich, and 800 yards at Gravesend.

Its depth between London Bridge and Greenwich, is about 12 feet, the average rise of the tide here being 17 feet, though this amounts to 22 feet at the top of the spring tides, and with an easterly wind blowing up the Nore.

The hydraulic power of the tide in bearing ships and their burdens up and down the river Thames at the mouth to and from the docks below London Bridge is very great and important. Thousands of tons burden are thus shifted every day at comparatively little expense, making the sight of the Pool or Port of London crowded as it is with shipping bound to and from all parts of the world one of unrivalled interest and importance. This is further increased by the ship building establishments on the banks themselves.

**Exercise.**

(1) *Tell what you know of the Basin of the Thames.*
(2) *Tell what you know of the Basin of the Severn.*
(3) *Tell what you know of the Basin of the Humber.*
(4) *Name the Tributaries of the Thames.*
(5) *Where is the reputed source of the Thames?*
(6) *Name the principal towns past which the Thames flows.*




| MOUNTAINS. | RIVERS. | RIVERS *Con.* |
|---|---|---|
| I Mendip Hills. | 1 Severn. | 11 Brue. |
| II Exmoor. | 2 Lug. | 12 Parrett. |
| III Cotteswold Hills. | 3 Wye. | 13 Taw. |
| IV Epynt Hills. | 4 Usk. | **COUNTIES.** |
| V Black Mountains. | 5 Taff. | C. Carmarthen |
| VI Malvern Hills. | 6 Neath. | B. Brecknock. |
| VII Dean Forest. | 7 Tawy. | G. Glamorgan. |
| | 8 Burry. | M. Monmouth. |
| | 9 Towey. | D. Devon. |
| | 10 Avon. | S. Somerset. |

## THE SEVERN.

This river rises in the eastern side of Plynlimmon, on the south-west border of Montgomeryshire.

It flows at first in a great arc, to the north-east then south, and lastly to the south-west, into the Bristol Channel.

The whole course of the river is 200 miles around this semicircular sweep; but the straight line from its source to its north is only 80 miles long.

It passes in its course, through Montgomeryshire, Shropshire, Worcestershire, and Gloucestershire, in the order first named.

The first part of its course is through a narrow valley, having a considerable fall; so that many cascades are here met with. The valley opens out at Llanidloes to one or two miles in width, having on the south-east the Plynlimmon Hills (five peaks in all), and on the north-west the Berwyn Mts.

This valley opens out into the broad rich plain of Shrewsbury.

The river next passes by the western base of the Wrekin.

In Worcestershire it passes by Stourport and Worcester; and after entering Gloucestershire, it passes by Tewkesbury and Gloucester.

From the last town the river increases in breadth, and the beauty of its banks becomes greater.

Its principal tributaries are the Teme on the right bank, and the Upper Avon and Frome on the left.

In the lower part of its course it flows through a valley twelve miles broad, bounded on the east by the Cotteswold Hills, and on the west by the Malvern Hills.

The whole area drained by the river Severn is 4,500 square miles. from which it takes large marly deposits into the British Channel.

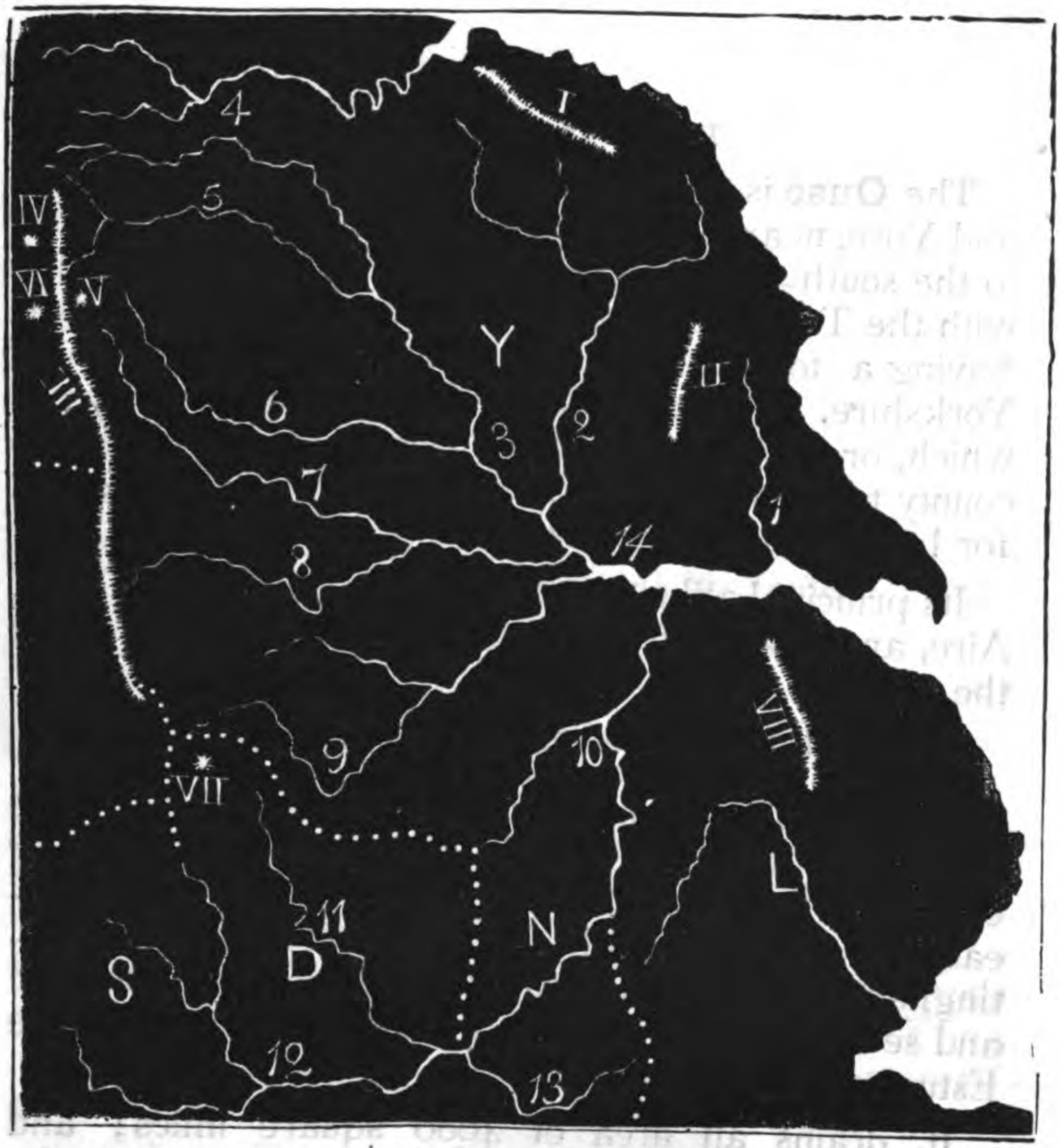
The tide enters the mouth of the river with great force, being known as a "bore," or "ægre," which is frequently nine feet in height, and dangerous to small boats,. The rise of the tide at the mouth is sometimes 50 feet.

The river is navigable for 160 miles above its mouth; and is connected by canals with the Thames and other rivers of England.

There are not many large towns on the river Severn, but on the Avon flowing into the mouth of the Severn on the eastern side is Bristol, one of the largest trading ports in the Kingdom.

The lower course of the river is apt to become flooded under excessive and long continued rains when the surface waters cannot be carried off quickly enough.

Some of the wheat agricultural districts of the kingdom are to be found within the valley of this river.




| MOUNTAINS. | RIVERS. | RIVERS *Con.* |
|---|---|---|
| I York Moors. | 1 Hull. | 11 Derwent. |
| II York Wolds. | 2 Derwent. | 12 Dove. |
| III Pennine Chain. | 3 Ouse. | 13 Soar. |
| IV Whernside. | 4 Swale. | 14 Humber. |
| V Penygant. | 5 Ure. | **COUNTIES.** |
| VI Inglebury. | 6 Wharfe. | Y. Yorkshire |
| VII The Peak. | 7 Aire. | L. Lincolnshire |
| VIII Lincolnshire Wolds | 8 Calder. | N. Nottingham |
| | 9 Don. | D. Derby |
| | 10 Trent. | S. Staffordshire |

THE OUSE, AND TRENT.

The **Ouse** is formed by the junction of the Swale and Yore, near Boroughbridge, in Yorkshire. It flows to the south-east; and eight miles from Goole, unites with the Trent, to form the Estuary of the Humber; having a total course, through the single county of Yorkshire, of sixty miles, for the last forty-five of which, or at least as far up the river as York, the county town, it is navigable for large vessels; and for barges as far up as Linton.

Its principal affluents or tributaries are the Whare, Aire, and Don from the west, and the Derwent from the north.

It flows through the great plain of Yorkshire.

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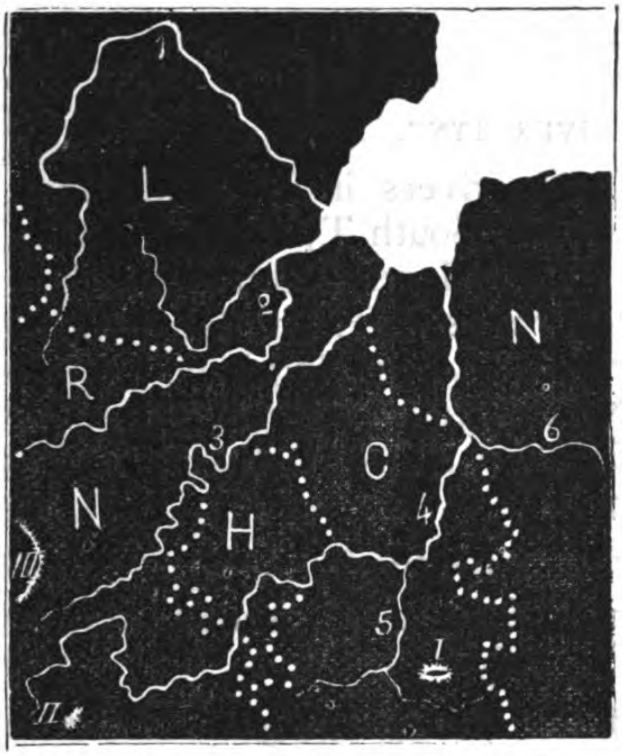
The **Trent** rises in Staffordshire, four miles to the west of the town of Burslem, and flows in an irregular course, at first south-east, then east, and finally north-east and north, through the counties of Derby, Nottingham, and Lincoln. After a course of one hundred and seventy miles, it unites with the Ouse to form the Estuary of the Humber.

It drains an area of 4080 square miles; and receives the Dove, Derwent, Idle, and Tarn, from the left; and the Thame, Soar, and Devon, from the right bank.

The Trent is navigable by vessels of two hundred tons to Gainsborough, and by barges to Burton.

It forms part of the boundary between Nottinghamshire, and Lincolnshire, and falls into the Humber at Trent Falls.

Its navigable importance is much increased by a series of canals.




**MOUNTAINS.**

I Gogmagog Hills
II Chiltern Hills.
III Central Tableland.

**RIVERS.**

1 Witham.
2 Welland.
3 Nen.
4 Ouse.
5 Cam.
6 Little Ouse.

**COUNTIES.**

N. Norfolk.
C. Cambridge.
L. Lincoln.
H. Huntingdon.
N. Northampton.
R Rutland.

**MOUNTAINS.**

I Pennine Chain. II Cross Fell. III Cheviot Hills.

**RIVERS.**

1 Alne.
2 Coquet.
3 Wansbeck.
4 Tyne.
5 Wear.
6 Tees.

**COUNTIES.**

N. Northumberland.
D. Durham.
Y. York.

## THE RIVER TYNE.

This is the name of two rivers in England—the North and South Tyne. The South Tyne rises in the most eastern corner of Cumberland, and flows to the north to within three or four miles of Haltwhistle, when it takes an easterly direction, and having been joined near Hexham by the North Tyne, the united stream passes Newcastle and falls into the sea between South Shields and Tynemouth.

On the river Tyne are situated the following towns:

Haltwhistle, Hexham, Newcastle, Gateshead, North Shields, South Shields, and Tynemouth.

The whole course of the river, taking the South Tyne and the united stream together, is about eighty miles.

The North Tyne rises on the South-west borders of Northumberland and Carter Fell, whence it flows south-east and south-south-east, till it falls into the South Tyne, a little above Hexham.

These rivers flow through a country of mountain, heath, and barren uncultivated wastes.

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The **Wear.** This river rises in the west corner of the county of Durham, which it never quits till it discharges its waters into the North Sea. It first flows to the east to Bishop Auckland; then to the north-east, nearly encircling the city of Durham; and at Sunderland falls into the sea after a total course of about seventy miles.

On the Wear are situated the following towns;

Durham in the middle valley of, and Sunderland at the mouth of the river.

The **Tees** rises near Cross Fell in Cumberland, and flows at first to the south-east, and to the north-east, making the southern limit to the county of Durham, to its mouth in the North Sea, where it forms an Estuary, ten miles below Stockton, of a considerable extent. Its whole course is between seventy and eighty miles, the last fifteen or twenty of which are extremely winding.

On the river Tees are the following towns:

Barnard Castle, Stockton and Middlesborough the later at the mouth on the Yorkshire side.

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THE RIVERS OF THE WASH.

The **Witham** rises in the northern borders of Rutlandshire, and flows in a very circuitous way, first north to Lincoln, then to the east, and then south-east, falling into the Wash about five miles below Boston.

The Fosdyke Canal, originally constructed by the Romans connects it with the Trent, and it is navigable to Lincoln, or for a distance of about thirty-eight miles.

On the Witham are the following towns:

Boston near the mouth, and Lincoln in the middle valley.

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The **Welland** rises near Market Harborough on the borders of Northamptonshire and Leicestershire. It flows to the north-east past Rockingham and Stamford, and forms the boundary between the counties of Northampton and Rutland; and falls into the Wash at Fosdyke Bridge, near the mouth of the

Witham. Its navigation, which is practicable to Market Deeping naturally, is continued by a canal to Stamford.

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The **Nen** or **Nene** is formed by two streams in Northamptonshire, one which rises near Arbury Hill, to the south-west of Daventry. On their junction at Northampton, the Nen becomes navigable, and flows to the north-east, forming part of the boundary between the counties of Northamptonshire and Huntingdonshire. After a course of about ninety miles, it empties itself into the Wash. Important improvements have recently been made in its channel.

### Exercise.

(1). *What do you know of the Yorkshire Ouse?*
(2). *What do you know of the Trent?*
(3). *Name the rivers of the Wash?*
(4). *Describe the course of the Welland?*
(5). *Describe the course of the Witham?*
(6). *Describe the course of the Nen?*

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THE ACTION OF WAVES; SEA-BEACHES;
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# PHYSICAL GEOGRAPHY.

## *SECOND YEAR.*

### CHAPTER I.

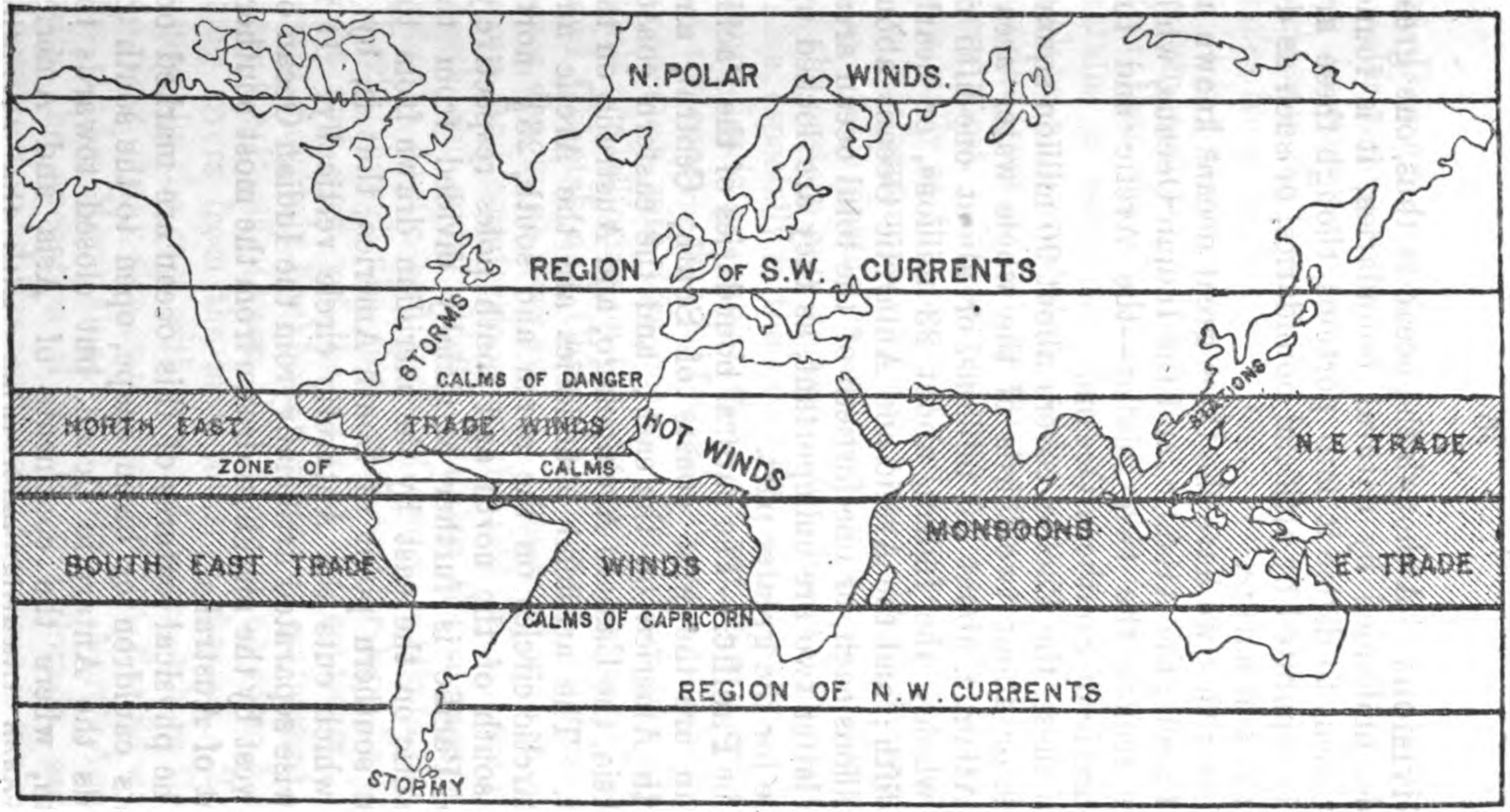
#### THE OCEAN—ITS EXTENT AND DIVISIONS, DEPTH, SALTNESS, AND CURRENTS.

**The Ocean.**—The surface of the globe is made up of land and water. The land is divided into two great land masses or immense islands—the Old and the New Worlds. But the water, being moveable in its particles, and nowhere entirely surrounded by land, cannot be thus divided, but forms one great whole.

If you look at the globe, having your eye fixed upon England as the centre of the hemisphere turned towards you, it will be noticed that nearly all the land of the surface is around England as a centre. This half of the surface may be well called, therefore, the Land Hemisphere, as it includes all North America, Europe, and Africa, and the greater portion of Asia and South America. Now look at the other half, and you will find that it only contains of land, Australia and the islands between it and Asia, together with the tapering portion of South America. This has been well called, therefore, the Water Hemisphere.


To put it in another light: of the whole surface of 197 million square miles on the globe, one-half, or 98½ million square miles, make up each hemisphere, but of this, 49½ millions, or one-half, is land in the Land Hemisphere, and only 2½ millions out of 98½ millions is land in the Water Hemisphere; or, 145 out of 197 millions of the whole surface are water, and 52 millions land.

It will also be seen that if we take a northern and a southern hemisphere, the greater part of the water is the southern, and the greater part of the land is the northern hemisphere; or, the land in the northern hemisphere is 39 millions, and the water about 59 millions; while the land in the southern hemisphere is only 13 millions, and the water 86 millions of square miles.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**Divisions.**—Although the ocean is thus one great whole, undivided by natural boundaries, it is found convenient to divide it into portions, though these are partly separated by artificial boundaries, or such as do not exist in nature.

Doing this, we have the three great oceans known as the Pacific, the Atlantic, and the Indian Oceans, while there remain the two smaller—the Arctic and the Antarctic or Southern Oceans.

Of these, the Pacific covers about 90 million square miles, or about two-thirds of the whole water area; the Atlantic, about 26 millions, or about one-fifth of the whole; the Indian, about 23 millions, or nearly one-fifth; and the Arctic and Antarctic Oceans about 3 millions each, or one-fortieth of the total ocean area. The latter two are unimportant, as they are locked up in ice for the greater part.

The **Pacific.**—The natural boundaries of the Pacific Ocean are the west coasts of South, Central, and North America on the east; and the eastern coasts of Asia, the Eastern Archipelago, and Australia on the west. The artificial boundaries are the Arctic and Antarctic circles on the north and south, $23\frac{1}{2}°$ north and south of the north and south poles respectively. The Pacific is further artificially divided from the Atlantic on the east by the meridian drawn from the most southern point of South America, that is, by a line which cuts the Antarctic circle vertically. It is likewise separated artificially from the Indian Ocean on the west by the meridian drawn from the most southern point of Australia.

The physical features of this ocean are marked out by its cauldron or basin shape, open to the south towards the Antarctic Ocean, but closed towards the north, where the continents of Asia and America approach towards each other, with the exception of Behring Strait, only 60 miles wide. This vast cauldron-shaped basin is thus circular in shape, except on the open southern border, and measures 10,000 miles across in the longest part from east to west, and 9,000 miles from the Arctic to the Antarctic circles.

It is studded with small islands of coral of volcanic origin, and the bed is sinking. This is proved by the fact that the depth of water outside the coral reefs attains in some instances 3000 feet, and the coral polype, an animal that builds the coral, can only live in depths from 30 feet to 30 fathoms, or 180 feet at the very most. These reefs must therefore have sunk gradually as they were added to above, and therefore the platform upon which they are built must have sunk too. This sinking is still further proved by the rising of the eastern and western shore-lines in America and Asia, especially in the case of South America. As the shore-line is so regular, there are very few indentations of the coast—that is, few inland seas, gulfs, or bays connected with this ocean. The principal are the Gulf of California on the east, and the Seas of Japan and Okhotsk and China on the west. It has, moreover, few large river systems connected with it, as the slope and counterslope of the Old World are to the north and south chiefly, draining the surface waters into the Arctic and Indian Oceans; while in the New World, though the slope and counterslope lie to the east and west, yet the axis of the continent, or its great mountain backbone and line of watershed, is so near the Pacific Ocean that there is no room for any long rivers from the mountains to the sea. This is especially the case with South America, where there is no river of any size emptying into the Pacific west of the Andes Mountains; and even in North America, with the exception of the River Colorado, and the Sacramento and Frazer Rivers, the same is the case.

In Asia, on the other hand, we have the Yang-tse-kiang, the Hoang-ho or Yellow River, and the Sagalien discharging their waters into this ocean.

The **Atlantic** is the best known of all the oceans, as it lies between the civilised and commercial peoples of Europe and the United States. Its natural boundaries are the continents of Africa and Europe on the east, and the two Americas on the west. Its artificial boundaries are the meridian of the extreme point of South America, dividing it from the Pacific on the west, and the meridian of the most southern part of Africa, separating it from the Indian Ocean on the east. Besides it has the Antarctic and Arctic circles on the south and north respectively, dividing it from the oceans of the same name.

Its length is therefore the same as the width of the Pacific, but its breadth from east to west is much less than the length of the Pacific. It is open both to the north and south; and instead of being basin shaped, is more like that of a long and narrow but very deep trough, bent partly on itself in the middle.

Its coast-line is more indented in the northern part of it than the Pacific, and opens out into the large areas of the Caribbean Sea and Gulf of Mexico between the two Americas, and Baffin's Bay, Hudson Bay, and Davis' Strait in the north; while on the eastern side it has the largest inland sea in the world—the Mediterranean, between Europe and Africa, with its subdivisions the Black Sea and Sea of Azov.

Farther north, but still upon the eastern side, are the English Channel, Irish Sea, St. George's Channel, North Sea or German Ocean, and the Baltic Sea. It lies open, therefore, in all directions, being directly connected with the Indian and Pacific Oceans; and, moreover, it penetrates far into the land masses, with the exception of the compact continents of South America and Africa.

Its breadth is generally given as measured along three lines:

(1) From West Africa to Cape Florida, 3600 miles.
(2) " " Brazil, 1500 miles.
(3) From Scandinavia to Greenland, 800 miles.

Among the islands, which are not so numerous as large and important, are the British Isles, Iceland, the islands of the Baltic and Mediterranean Seas; Cape de Verde, Azores, and Madeira Islands groups; St. Helena and Ascension Islands,—all on the eastern side; and the West Indies, Newfoundland, and Falkland Islands on the western side.

The **Indian** Ocean lies to the south of Asia, and has for its natural boundaries Arabia, Persia, Affghanistan, and India on the north; the Eastern Archipelago and Australia on the east; and part of the east coast of Africa on the west. Towards the south it is open to the Antarctic Ocean, from which it is artificially divided by the Antarctic circle; while it is separated from the Atlantic on the west and the Pacific on the east by the meridians drawn from the most southern points of Africa and Australia respectively. It is therefore neither basin nor trough shaped, but makes an irregular oblong, with a length of about 5500 miles and a breadth of 4500.

The only indentations of the coast are on the north, Africa and Australia being compact in structure. These are the Red Sea between Arabia and Africa, the Arabian Sea between India and Africa, and the Bay of Bengal between India and Malaya and Further India. It has numerous and large islands, among which are those making the Eastern Archipelago, between Asia and Australia, such as Sumatra, Java, Borneo, Celebes, Papua or New Guinea, etc.; while to the south of India there is Ceylon, and Madagascar off the east coast of South Africa. Besides are a few oceanic islands of coral formation and small size, such as the Laccadives and the Maldives, the Nicobar and Andamân Islands, Bourbon, Mauritius, and a few others.

The principal rivers draining into the Indian Ocean are the united rivers of the Tigris and Euphrates, forming the Shat-el-Arab, emptying into the Persian Gulf; and the rivers of India, namely, the Indus, flowing into the Arabian Sea, and the Ganges and Brahmapootra into the Bay of Bengal. Besides are the smaller rivers of Southern India, the Godavery, Kistna, Cauvery, Tapty, etc.

The **Arctic** Ocean is nearly circular in shape, being artificially bounded by the Arctic circle. It has numerous large but almost uninhabited islands off the northern coast of North America, together with Greenland, which may be a peninsula or island, but which has never been rounded in the north. Off the coasts of North Europe and Asia are the islands of Spitzbergen and Nova Zembla.

The principal rivers draining into the Arctic Ocean are the Mackenzie and Coppermine Rivers in America; the Petchora, Mezen, and Northern Dwina in Europe; and the Yenesei, Obi, and Lena in North Asia.

The **Antarctic** Ocean is still less known than the Arctic, but is supposed to be occupied to a great extent by an Antarctic continent, as ships have sailed from east to west for many hundreds of miles along the border of an ice-locked continent.

**Depth.**—As a general rule, it may be stated that the depression of the ocean bed is about the same as the elevation of the land, and though greater depths than the greatest height of the mountain peaks of the aerial surface have been occasionally obtained, yet these observations are subject to suspicion, as the sounding lines were doubtless carried out of a perpendicular direction by deep sea currents.

The Atlantic is the only ocean which has yet been systematically sounded, but here very complete observations have been taken; and as a result, we find the surface of the floors of the ocean presents the same physical features of mountains and plains that we find on the surface of the dry land. The results of the most recent researches give us the following information:—


A section taken across the Atlantic, from the Peak of Teneriffe on the east to St. Thomas Island on the west, gives an oblique line across the North Atlantic. From this it will be seen that this part of the Atlantic is divided into an eastern and a western basin, while the floor rises between on an elevation known as the Dolphin Rise. The deepest portion of the eastern basin is 18,900 feet, and that of the western basin is 18,150, the Dolphin Rise between being only 11,400 feet deep.

Here it will be noted that the temperature of the water gradually sinks to near the freezing point, 32° Fahr., the line of 36° being nearly horizontal.

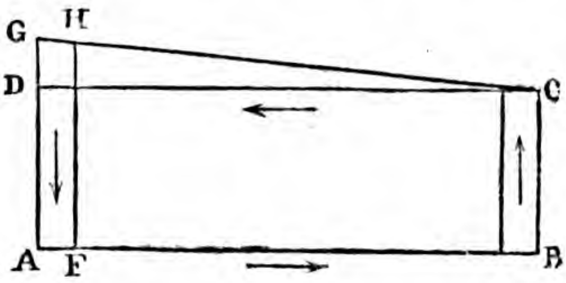
The section shown gives a picture of the elevation of the floor of the ocean over which it is taken; but this is not made to scale, for the width is so great compared with the depth, that if the section were made in proportion, an immensely long line would have to be employed to represent the length of the section. See page 11.

An area has been surveyed from the island of St. Thomas in the south to that of Bermuda in the north; and here the greatest reliable depth, off St. Thomas, was reached, amounting to 23,250 feet, when the pressure of 4¾ tons to the square inch was recorded From this section it will be seen that the Bermudas rise nearly three miles from the floor of the ocean; and yet this base of the island was once near the surface, as the island rests on a coral formation, so that the floor must have been gradually sinking while the coral polypes were as gradually building up the island. Soundings have been taken from the island of Bermuda, off the coast of the United States, to Halifax, where the greatest depth was about half-way, and was 16,800 feet.

**Saltness.**—The degree of saltness of the sea depends on the amount of evaporation and the inflow of fresh water from rivers. Thus, in the Black Sea, more fresh water is brought in by rain and rivers than is carried off by evaporation, while in the Grecian Archipelago outside, the opposite is the case; and this gives rise to currents between one and the other. The Baltic Sea, also, is less salt than the North Sea outside; in the Gulf of Bothnia the water is often so little salt as to be quite drinkable. In the Red Sea, on the contrary, the waters at the head of the gulf are much salter from evaporation than outside—no fresh water flowing into it in return; and this would fill up with salt in time, if it were not for the currents from the difference of densities thus produced. The Mediterranean for similar reasons is salter than the Atlantic outside.

In the southern hemisphere there is more water than in the northern, or less land; and as a consequence there is less condensation into rain, so the southern oceans are salter than the northern. As there is more evaporation in the tropics also, the water is salter there than towards the poles. The largest constituent present in sea water as an impurity is common salt, to the extent of between 2 and 3 parts in 100; and besides there are many constituents of rocks brought down by rivers, such as certain forms of lime, magnesia, etc., out of which the shell-fish and corals make their inside and outside skeletons.

**Currents.**—These are movements of the ocean waters in a more or less horizontal direction, as distinguished from waves, which are more or less vertical. Currents might under certain circumstances be caused, as in lochs, and inlets, and inland seas, by three causes:—(1) Surface winds; (2) difference of saltness; (3) difference of temperature. Thus let D A B C be a trough representing the water in an inland sea; if a surface wind blow from C to D, it will tend to raise the water higher at D than at C. The column of water




F A G H will now press more heavily than a column at C B, consequently a current will pass from the place of greater pressure to that of a less along the bottom from A to B, while surface currents pass from C to D, thus establishing a complete circulation. This is seen in the ingoing and outgoing currents in many inland seas and inlets.

Anything which would make the column of water at F A G H heavier than the rest of the trough would equally establish a current from this point. This would be the case if the water were *salter* at that point, since it would then be heavier; or if it were *colder*, in which case also it would be heavier. All these cases occur in such inland seas as the Baltic and Red Sea; but it is *cold* alone which is concerned in setting up the great oceanic circulation.

Suppose our trough now represents the ocean—each end one pole, and the middle the equator. Now put a bar of heated metal across the middle, to represent the sun's action at the equator, and lumps of ice at the two poles, or what are called freezing mixtures, such as ice and salt, to represent the cold at the poles. The cold, heavy water at the ends will sink and flow along the bottom towards the middle, while, to take its place, top surface waters will flow from the middle to the ends to make up for what has flowed away. This may be seen if you put coloured powder into the water, for the currents will then be visible.

Or if you were to take a round tub and put into the middle of it a freezing mixture, currents would flow at the bottom from the middle, representing the pole, to the outside, representing the equator; and from the outside on the surface to the centre.

This is exactly what takes place on the earth; there is a constant inflow of warm water to the polar basins from the equator to the north and south on the surface; and a constant outflow of cold water from the polar basins towards the equator on the floor of the oceans; so, if we sound deep enough, we always come to water near the freezing point, even under the equator.

The fact that the bottom waters of the oceans have a definite movement, however slow, towards the equator, is indicated by the icebergs crossing the Gulf Stream off the banks of Newfoundland, and being carried to the south of it; and this can only be by the southerly movement of the deeper layers of water in which the lower part of the iceberg is floating, which carries it along, against the action in the opposite direction of the upper current. Again, the broken end of the Atlantic Telegraph Cable of 1865 was buoyed, but the 'buoy having got adrift, was found to have travelled nearly due south a distance of 600 nautical miles in seventy-six days in opposition to the Gulf Stream,' by the action of the underflow upon the long rope suspended in it. Again, on the west side of the Atlantic, off the United States line, there is a cold band of water between the shore-line and the Gulf Stream, which surges up from the bottom on its way to the equator from the poles; and the same is the case off the east coast of Asia, between the shore-line and the Gulf Stream of the Pacific.

A deep-sea sounding chart of the North Atlantic Ocean shows the lines through which there is the same winter temperature. From these trending to the north, or towards the pole, it will be seen that there must be warm winds or warm waters stretching right across the Atlantic from Newfoundland to Ireland, a breadth of 1700 miles, and proceeding towards the Arctic regions, to make these great bends, or the lines of equal temperature. This is a proof of the existence of the great inflow of warm water to the poles from the equator. And this drift is not a mere surface one, or it would not retain its heat; and soundings show that off the Faroe Isles it is 600 fathoms deep, and that in very high latitudes it reaches to 60 and 80 fathoms, whereas the true Gulf Stream cools down to the temperature of the air above it before it reaches England. Moreover, floating bodies which have been carried into the Atlantic by the true Gulf Stream have been often transported by this inflow to the Arctic Ocean and to Ireland, the Orkney and Shetland Islands, and even to Spitzbergen.

The general north and south direction which the bottom and surface waters have in proceeding from the equator to the poles is modified by the difference of velocity of rotation which the earth's surface has at different latitudes. All water going from the equator towards the poles goes to places with a less rotation; such water therefore has a tendency to go east as well as north. On the contrary, all water on the floor of the ocean going from the poles to the equator has a tendency to lag behind to the west. As a consequence of this, surface currents trend to the east, and polar currents to the west.

The principal currents, or the Equatorials of the Atlantic and Pacific, running from east to west, are caused by the trade winds and evaporation. In the Atlantic, this divides off Cape St. Roque in South America, splitting up into the Brazil Current, which, under the name of the South Connecting Current, flows round again into the Equatorial in the south. The northern branch follows the coast of South America, and rounds the Gulf of Mexico, and issues out as the Florida Current or Gulf Stream, flowing under the latter name past the seaboard of the United States, trending more and more to the east, and then by Rennel's Current re-entering the Equatorial. Between it and the United States coast is the Polar Current from both sides of Greenland.

The Equatorial of the Pacific divides into the

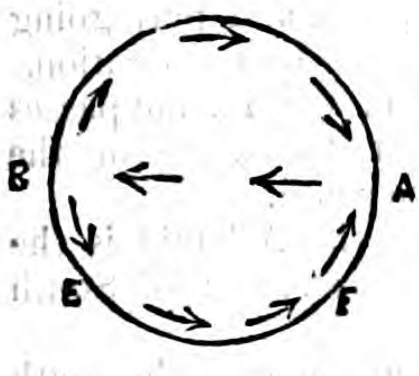
Australian Current and the Black Stream of Japan, traversing the North Pacific as the Gulf Stream does the Atlantic.

It will be noted that in the case of the two great oceans, the Atlantic and the Pacific, each is again subdivided into a northern and a southern half; these we name the North Atlantic Ocean, the South Atlantic Ocean, and the North Pacific Ocean and the South Pacific. In these instances the equator is the artificial boundary-line in question.

In the case, however, of the Indian Ocean, the continent of Asia occupies the area corresponding to the North Atlantic and the North Pacific, and here we have only a Southern Ocean corresponding to the South Atlantic and the South Pacific.

The Atlantic and Pacific can be represented by a basin or a bowl. If a gentle breath be forced across the surface of water in the basin, it will ruffle this, and cause a surface current in the direction of the arrows along the diameter of the basin.

This surface current represents the Equatorial Currents of the Atlantic and of the Pacific flowing from east to west, and helped on by the trade winds blowing in the same direction. When, however, the water in the basin has struck the sides on the left, it is divided into two currents, one going round in the direction of the hands of a watch, and the other in the opposite direction, as represented by the arrows in the figure. This really divides our basin into two corresponding halves.




Here we have represented the halves of the Atlantic and Pacific Oceans north and south of the equator.

The Equatorial Currents of these oceans, after flowing for some thousands of miles, at length approach the shore-lines of the continents, represented in the figure by the sides of the basin. In the case of the Atlantic. it will be the shore-line of South America off Cape St. Roque; in the case of the Pacific, it will be the islands of the Eastern Archipelago between Asia and Australia. In each instance, therefore, the waters are divided into two currents, one going northward and the other southward. In both instances, likewise, the current going to the north will be bent round farther and farther to the east, just as in the basin in the figure. This will be helped by the direction of the shore-line of North America in the case of the Atlantic, and of Asia in the case of the Pacific. Each of these shore-lines trends to the north-east.

In the Atlantic we thus get the Florida Current and the Gulf Stream; in the Pacific, the corresponding Black Stream of Japan.

Each of these having crossed the ocean, through and on the surface of which it flows, becomes slower, cooler, and thinner, until it is finally lost—part of its waters going on with the general inflow of warm surface water from the equator to the poles, and part going to the equator to make up for the loss by evaporation.

On the south, the Equatorial of the Pacific passes by the coast of Australia under the name of the Australian Current, flowing to the south.

The corresponding current of the Atlantic is the Brazil Current, flowing along the east coast of South America.

Besides these currents there is also one off the south coast of Africa, known as the Mozambique Current, from its being found off that coast; and another known as the Agulhas Current, from its passing by Cape Agulhas in South Africa.

A current is also found which flows in from the south-west, first as a drift or mere surface motion of little depth from the Antarctic Ocean. This becomes changed into a current proper off the west coast of South America, being known there as the Peruvian Current, from flowing past the coast of Peru. Its course is to the north into the great Equatorial of the Pacific.

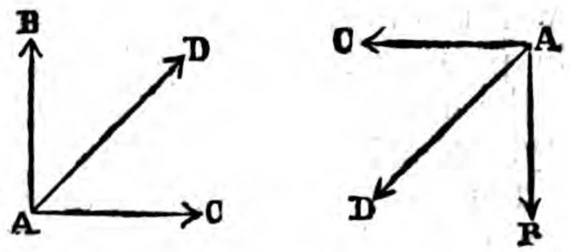
It will be thus seen that the North Atlantic and North Pacific Oceans have a system of circulation complete in themselves, and that the central portions are surrounded by water moving, roughly speaking, in a circle, and leaving a quiet portion, known in each case as a Sarghasso, or weedy sea, in the centre.

All the currents to which we have yet referred are currents of warm water. We have stated that the cold water in passing from the poles to the equator travels along the floor of the oceans on account of its greater density. But it is evident that if the channels along which it passes are of little depth, or if the waters be dammed up by shelving shore-lines, the cold currents may come even to the surface. This is true in many parts of the Atlantic, especially off the east and west coasts of Greenland, where we meet with cold currents of water, or Polar Currents as they are termed, even at the surface. These bring with them great quantities of ice, which they carry on towards the equator, or the west coast of Iceland with frightful effect.

Just as the warm waters, in coming from the equator to the poles, trend more and more to the east, so the cold currents travelling in the opposite direction, in going from the poles to the equator, trend more and more to the west.

This is the reason why we find the cold currents of the North Atlantic flowing by the coast-line of the United States, between the Gulf Stream and the main-land, making the climate there much colder than it otherwise would be. This course is continued until the southern point of Florida is reached, where the current flows through the strait between Florida and the Bahama Islands into the Gulf of Mexico, while the Florida warm current is coming out of the same gulf into the open Atlantic; that is, the two currents flow by each other, and the colder one, being the heavier also, underlies the Gulf Stream at this point, thus occupying by far the greater part of the passage.

The reason why the general north and south directions of the warm and cold currents is changed to a more easterly and westerly direction may be understood from the following figures.




A B represents the northerly direction of the warm surface waters from the equator to the North Pole.

At A, the water at the equator is travelling with the earth in an easterly direction, at the rate of one thousand miles an hour. As it goes from A to B, it reaches places which are travelling from west to east at a less rate than this; but it still keeps up for a time part of its excess of easterly direction, so that it is really trying to go in two directions, to the north and to the east, as represented by the lines A B and A C.

It can only follow out these two directions by going between them, or along the line A D. This is seen in the easterly trend of the Gulf Stream.

On the contrary, in travelling from the poles to the equator, A B represents the general south direction of the cold water on the floor of the ocean. At A there is little velocity of rotation; that is, the water is going with the earth from west to east at a slow rate. But in passing from A to B, it comes to parts of the earth's surface which are going from west to east at a more rapid rate. It therefore lags behind, dragging, as it were, from east to west, and hence it is forced to go along both A B and A C. This it can only do by going between A B and A C along A D; that is, the water gets a westerly trend, as seen in the Polar Currents of the North Atlantic.

The same laws are obeyed in the southern half of the Atlantic and Pacific Oceans, but of course everything is the reverse of the preceding, as the pupil may demonstrate for himself by drawing corresponding diagrams.

### Exercise I

(1.) What is the extent of the earth's surface?
(2.) How much of this is land, and how much water?
(3.) What is the land hemisphere?
(4.) How much land is there in the water hemisphere?

### Exercise II.

(1.) Divide the waters of the globe into oceans.
(2.) Give the area of each of these.
(3.) Name the boundaries of each ocean.
(4.) Name the characteristics of each ocean.

### Exercise III.

(1.) Compare the Atlantic and the Pacific Oceans.
(2.) Name the inland seas of the Atlantic.
(3.) Name the inland seas of the Pacific.
(4.) Name the inland seas of the Indian Ocean.

### Exercise IV.

(1.) Name some islands in the Atlantic.
(2.) Name some islands in the Pacific.
(3.) Name some islands in the Indian Ocean.

### Exercise V.

(1.) Name some rivers flowing into the Atlantic.
(2.) Name some rivers flowing into the Pacific.
(3.) Name some rivers flowing into the Indian Ocean.

### Exercise VI.

(1.) What do you know of the depth of the ocean?
(2.) Name some parts of the ocean which are very salt.
(3.) Name some parts of the ocean which are brackish.
(4.) What are the causes of these respectively?

### Exercise VII.

(1.) What are ocean currents?
(2.) What are the causes of these?
(3.) Show by a basin of water how system of currents may be established.

### Exercise VIII.

(1.) Explain how the general north and south directions of ocean currents are modified.
(2.) What are the currents of the Atlantic?
(3.) What are the currents of the Pacific?

## CHAPTER II.

### ACTION OF WAVES—SEA BEACHES.

**Waves.**—When the wind blows across the water parallel with the surface, it ripples the upper face of the water, but if it blow against it at any angle it raises it up into waves. Waves are vertical ridges and troughs, having in theory no motion of translation—that is, no power to transport anything in a horizontal direction. Thus, if you watch a wave rolling in to the shore, you will notice that when it comes to a piece of floating sea-weed, cork, etc., it passes under it, or the object rises to the crest and falls back into the trough seaward, without being at once carried to the shore. Of course the true waves are more or less changed into currents and drifts when dammed up in narrow channels; and so, as a rule, after, it may be, tossing to and fro in the waters, the waves, assisted by a flowing tide, generally do strand any floating object. These wave motions of the water are strictly confined to the upper surface; at a depth of about 60 to 600 feet all is positively still; and hence the ooze or mud brought up from depths, when put under the microscope, shows us beautiful shells, in many cases as perfect as the day the living tenants died and dropped them to the bottom,—every corner, spine, and delicate fluting being preserved. But along the shore-line where the breakers beat, we find the waves are powerful instruments of destruction of the rocks; constantly pounding and grinding away, until not even the hardest rocks can withstand their sapping and undermining. The hardest rocks are split up by fissures and natural joints, and the water penetrates these; and when the battering power of the waves beats against them, the blocks are loosened and detached, while the air is sucked in and out of the cavities behind the sea face, and the sand and gravel act like chisels and graving tools to wear down the surface still more. The final effect is, that the waves act like a great planing tool, bringing cliff and shore down to one dead level, and turning what was hill and mountain into a plain just beneath the level of the sea. Every coast in the world will show this; if it be a bold cliff of the hardest rock, caves are beaten out of it along the line of high-water level, and every now and then large portions of the cliff are undermined, and for a time the fallen mass acts as a rampart against the waves;—but for a time only. The rocks at length become rounded and smaller and smaller, being carried by the retreating tide farther and farther from the spot on which they fell; or they become less, till at last they are ground into pebbles, and gravel, and sand, and finally into fine mud and silt.

This is well seen along the east and south coasts of England, where in Yorkshire, Norfolk, Suffolk, Essex, and Kent, many villages and towns are now beneath the sea. In other instances the people have had to continually retreat as the sea gained upon them, as at Cromer on the east coast. At Sherringham also, in 50 years, the sea made such encroachments that there was a depth of 30 feet of water where before a cliff of 50 feet high with houses on it had existed.

All this matter is carried away and spread on the floor of the adjacent seas, and hence the patches of mud between Cornwall and Ireland, and the sandbanks in other parts, especially the great Dogger Bank, which covers one-fifth of the area of the German Ocean. The rate of encroaching on the land, of course, varies with the hardness of the rocks and with the elevation of the cliffs. Thus soft rocks, like chalk, soon wear beneath the action of the waves; and hence at such places as

Brighton and other towns on the chalk, the sea is obliged to be kept back by groins or jetties, which are piles driven into the pebbles and chalk bed, which are carried out vertically from the shore, and serve as supports for the accumulation of beach against them, thus interposing a ridge of shingle between the waves and the cliff. If, again, the cliffs be high, the amount of rocks that fall is very great, and the time taken to remove them and spread them as sand and silt upon the ocean floor is of course very great also; but when the land slopes inland, the progress of encroachment is often very rapid indeed.

'The sea-shore after a storm presents a scene of infinite grandeur. It shows the exhibition of gigantic force, which impresses the mind with the presence of power as sublime as the waterfall or the thunder.

'Long before the waves reach the shore they may be said to feel the bottom, as the water becomes more shallow, for they increase in height, but lessen in length.

'Finally, the wave becomes higher and more pointed; it takes on an unstable form that it cannot retain, and so totters and becomes crested with foam, then breaks with great violence, and continuing to break, is gradually lessened in bulk until it ends in a fringed margin.'—John Scott Russell's *Theory of Waves.*

The motion of waves of the sea can be understood by the student observing the similar motion of the tops of trees or of a field of corn when a fresh breeze is blowing. These rise and fall, while the tree-trunks and corn-stalks themselves remain rooted to the spot. The size, form, length, and swiftness of waves depend on the wind, and the width and depth of the channel in which the waves arise. Thus, out in the mid ocean, the waves make long undulations, which succeed each other by pretty equal spaces between them, but nearer shore these long waves break up into shorter ones.

Again, if the wind be blowing off the land, the waves are at first very small, but become longer and higher as we proceed from the land, breaking with the greatest violence on the opposite shore, if this be near. The writer has remarked this many times on the south coast of England. Here, if the wind be from the north across the English Channel, the sea may be as smooth as glass under the lee or shelter of the land, but in going across the Channel the waves become higher and longer, until off the opposite coast of France they are of very considerable height; while the very reverse, of course, happens when the wind is blowing in the opposite direction.

The depth of the water also exerts an important effect on the waves. In deep water the motion is less resisted by friction, but in shallow channels the waves drag at the bottom, and thus fall forward on the land, just as a man would do if he were pulled backwards by the feet.

The same thing may be noticed in narrow channels, —the wider the sweep of water, the more rapidly the wave motion goes forward, but the narrower the extent, the more the waves drag at the sides, and become increased in height and diminished in length and swiftness. This is the reason why mariners avoid the shore in heavy wind-storms, and seek safety in the open ocean.

In these narrow and shallow channels, moreover, if the wind be blowing fresh, the crests of the waves do not pass on so rapidly as the wind, and the latter breaks the edges into white foam; very often, too, the gusts of wind strike the already formed waves at an angle, and raise up on these waves other waves, like those it forms on the level surface of the sea, and thus wave on wave is produced.

The motion does not cease with the stilling of the wind, for all the particles of water are moveable on each other, and each wave acts like a pendulum, which continues to swing when it has been raised from the lowest position, even after the hand that moved it is withdrawn.

If a rockbound coast, or outlying sandbanks, or coral reefs stand in the way of the waves, these break up into surf, rolling on the strand with a loud roar and dreadful violence. Many coast-lines are thus not to be approached by ships, which are obliged to stand off shore, while their cargoes are landed or embarked by means of boats which are constructed to make way through the surf. As an example of this, we have the shore along the eastern side of Southern India, so that persons wishing to disembark at Madras are carried by peculiar boats right through the surf; and the same is the case on many parts of the western coast of South America.

If a harbour opens towards that quarter from which the winds are most prevalent and violent, we are frequently obliged to protect it by a breakwater constructed across the mouth, leaving passages between the extremities of the breakwater and the land for ships to come in and go out. An example of this is afforded by the famous breakwater at Plymouth, in which 40 million cubic feet of rock have been used up.

'The billows sleep
Within the shelter of a wondrous pile
Of man's best workmanship—that new made isle,
That marble isle—brought piecemeal from the shore
To break the weltering waves and check their savage roar.'

The vertical rise and fall of water in waves may be illustrated to the class by the teacher fastening one end of a cord to a fixed point in the school, and shaking the other end violently. The cord will be seen to divide itself into loops or troughs and crests, and though no one point in the rope travels from the hand to the fixed point, yet the wave motions are transmitted in that direction.

The result of the action of waves on coast-lines is to eat away the shore-lines of continents, and strew these on the floor of the ocean. Of course the harder rocks, such as granite, resist the agency the longer, but all alike have finally to give way to the sapping and undermining to which they are subjected. Thus, on the east coast of England, the land is eaten away at the rate of one to six yards every year, according to the character of the shore, and the same is true of the chalk cliffs of the south coast of the country; and the same may be said of the vast masses of coral formations in various parts of the world,—all are broken and ground down in time.

'The long ocean swell being suddenly impeded by the coral barrier, lifts itself in one great continuous ridge of deep-blue water, which, rushing over, falls on the edge of the reef in an unbroken cataract of dazzling white foam. Each line of breaker runs often one or two miles in length without any gap in its length. The unbroken wave of the surf, with its regular thunder sound, as each succeeding swell falls first on the outer edge of the surf, is almost deafening, yet so deep-toned as not to interfere with the slightest nearer and sharper sound. Both the sound and sight are such as to impress one with the fact of standing in the presence of an awful majesty and power.'

**Beaches.**—Any one who has taken a walk by the seaside, except on such flat coasts as those around the Wash, must have been struck by the ridges of pebbles and shingle that have been cast up by the waves. These are termed Beaches, and consist of more or less rounded pebbles worn down from the rocks that have been undermined by the waves from the adjacent cliffs.

Thus, on shores where the rocks are slaty, the pebbles will be more or less flat, with rounded edges; but near chalk cliffs they will be angular near the base of the cliffs, being, in fact, the flints little worn, but more and more rounded as you walk to the sea, where they have been longer waterworn, till at low tide they give place to sand.

These beaches are continually shifting under the action of the waves—after a storm the ridge will be very high and steep at the top of the tide, while in calm weather there is only a long low slope from high to low water-mark.

**Raised Beaches.**—Very often it will be noticed that inside, towards the land from the beach or ridge raised by the last tide, there may be one or several other ridges, where the waters now never reach. These may even be found many feet, even hundreds of feet, above the present level of the waters. Of course, wherever we meet with them, we know the waters once came; so they are a proof either that the waters have sunk to a lower level, or that the land has been raised to a higher. The latter is the true cause, and is one that is constantly going on in one part of the earth or another. This takes place suddenly or slowly. Thus in 1835, after an earthquake in South America, a district larger than the British Isles and France was raised up four or five feet along the west coast, showing 'beds of dead mussels and shellfish, and withered sea-weed still adhering to the rocks.' Mr. Darwin has found beds of sea-shells in South America among the Andes Mountains, 1300 feet above the level of the sea; and these beds were met with for 1200 miles from north to south on the east coast, and 2000 miles along the west coast.

There are many raised beaches in Scandinavia, some 200 feet above the level of the Baltic, and 70 miles from it; in fact, there are traces of the rise of land above the sea over a breadth of country of 1000 miles.

The great earthquake in Chili, in South America, which occurred in 1822, afforded a remarkable instance of elevation of the coast-line, and the creation of a raised sea-beach above the level of the sea at the present time.

The shock of this earthquake was felt along the west coast of South America for a distance of 1200 miles from north to south, and over a breadth of 100 miles from east to west, between the Andes and the Pacific Ocean. Many flourishing towns were greatly injured, and at the port of Valparaiso the shore was found to be raised 3 feet above its former level. A large part of the sea-bed was likewise elevated, and remained after the earthquake high and dry at high water, leaving beds of oysters and mussels and other shell-fish.

It is calculated that in the upheaval a total area of 100,000 square miles of land was permanently elevated, so that the soundings on the coast were all altered, the depth of water being less than before.

Besides this newly raised beach, other more ancient lines of sea-beach, made up of shingle and shells, are seen running parallel with the shore, of which one is 50 feet above the level of the sea.

## QUESTIONS.

### Exercise I.

(1.) What is a wave?

(2.) How can you prove that there is little or no motion of translation in a wave?

(3.) What circumstances modify the length, height, size, and velocity of waves?

### Exercise II.

(1.) Illustrate wave motions by means of a cord.

(2.) Do the same by means of a corn-field or tree-tops moving under a breeze.

(3.) What makes waves break on the shore?

### Exercise III.

(1.) Contrast these with waves made by winds blowing off the shore.

(2.) What is the action of waves on coast-lines?

(3.) What agency tends to raise shore-lines?

### Exercise IV.

(1.) Give instances of wearing away of shore lines.

(2.) Give instances of upheaval of shore-lines.

(3.) Name some rocks that are easily worn down by water.

(4.) Name some rocks that are with difficulty worn down by water.

### Exercise V.

(1.) What becomes of the material taken away by waves?

(2.) Why does not the motion of waves penetrate very deep below the surface of the water?

(3.) What is surf? Give illustrations.

### Exercise VI.

(1.) What differences are there between waves in the mid ocean and those in channels?

(2.) What are the causes of waves?

(3.) What are the effects of waves?

### Exercise VII.

(1.) What parts of our own coast-line are most acted on by waves?

(2.) What is the reason of this?

(3.) What would be the final result of wave-action if there were no earthquakes or volcanoes?

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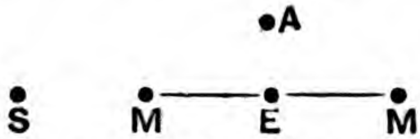
## CHAPTER III.

### THE PHENOMENA OF THE TIDES.

When we walk by the seaside, we notice that there is a margin which is alternately covered and uncovered by the sea—bounded by the low water-mark below, and the high water-mark above. Observation would teach us that it takes the water about six hours to go from the low to the high water-mark, so the tides alternate at about that interval.

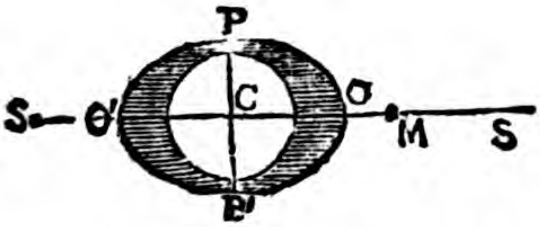
Closer observation would show that these high and low water-marks are not always the same, but that sometimes the water goes down lower, and then, also, it comes up higher than it does at other tides. The sailors and fishermen would tell you that in the former case these were spring tides, and you would notice, of course, that the margin of shore exposed was the greatest; but there are also neap tides, when the margin is the least, or when the tide neither rises (flows) so high nor falls (ebbs) so low as the spring tides. If you kept your eyes open, you would also find out that the spring tides occurred about the time of new and full moon. Observation would thus teach you much. Now let us understand what we have seen. Plainly, this tide is a rising and falling of the water; and as plainly, the moon has something to do with it. What are the circumstances, then, when it is new or full moon? This may be seen in the diagram, where M and M′ represent the moon going round the earth, E, at new and full moon respectively. It will then be noticed that the sun and moon are in the same straight line, whereas in any other position of the moon, as at A, this would not be so. Now suppose the earth were covered all over with water, that there was no dry land. You have all seen how a loadstone will draw iron filings to it, even from a distance—this is attraction. Now there is also an attraction, though of a different kind, which all matter has upon all other matter. So the sun in the diagram is attracting the moon and the earth, and the earth is attracting the moon, and, indeed, they are all attracting each other. In this attraction that body which is the largest and heaviest attracts most, and the nearer a body is to another the more it attracts it. Well, the sun is very much larger than the moon, so the sun attracts the earth for this reason more than the moon does. On the other hand, the moon is very much nearer the earth than the sun is, so the moon for this reason attracts the earth more than the sun does. When we strike a balance, we find the moon is after all the more powerful of the two. Now the earth has a side turned towards the moon and one turned from her, and there is a distance of 8000 miles between these two points, or each is 4000 miles from the earth's centre. The moon will attract, therefore, that side of the earth turned towards her more than she attracts the centre, and she will attract the centre more than the side turned from her, on account of these differences of distance.




If the water, then, cover all the earth, the water turned towards the moon will be attracted more than the earth's centre, and will rise up in a ridge a few feet high; this gives a high tide on one side of the globe, and a low tide at two other points from which the water has been drawn. But there is also a high tide on the opposite side of the globe; for the moon attracts the earth's centre more than she does the water turned from her, on account of difference of distance, so she pulls the earth as it were bodily forward a few feet, while the waters lag behind, and make a crest or high tide.

If the earth and moon were stationary, this state of things would be constant; but the earth is turning round on itself, spinning on its axis like a top, so the crest under the moon seems to pass round in the opposite direction to that in which the earth spins or rotates. That is, the earth goes round from west to east, and the crest passes round the earth from east to west. Now it will take twenty-four hours before the same spot is presented to the moon again, so it will take twenty-four hours till the crest of that wave passes over the same spot. But there is the crest on the opposite side of the earth to remember; so high tide will occur about every twelve hours, and the low tides occur half time between these, or it takes six hours for the tide to flow or ebb. This is not quite correct, because the moon does not stand still; but while the earth is spinning round once, the moon has gone a little way on her path, so the earth has to turn a little more than once round to bring the same spot once more exactly beneath her; and this makes the time for the ebb and flow rather more than six hours.

Now, for the explanation of the spring and neap tides. When the sun and moon are in the same straight line—that is, when the moon is either at M or M′—both are pulling in the same line to make high tides opposite each other; hence the spring tides. These are very high, and, of course, at the intermediate places very low. But when the moon is in her quarters at A, and in the opposite position, the moon is making a high tide where the sun is making a low tide, so they partly undo each other's work. There is then at the neap tide neither a very high nor a very low tide. Now be sure you do not become confused, and think that the spring tides are very high and the neap tides very low; but remember that the spring tides are *very high and very low*, and the neap tides *not* very high *nor* very low.




The preceding is a general statement of the phenomena or appearances presented by the Tides, but there are many circumstances modifying their action which it will be necessary to explain. Among the first of these is—

The **Lagging of the Tides.**—We can tell very accurately when the moon is just opposite any particular part of the earth's surface. Such a point is then said to be under the meridian of the moon. It is here that we ought accordingly to find the crest of the high tide, but in reality the crest of the tidal wave does not reach this point for two or three hours after it has passed from under the moon in the earth's daily or diurnal rotation on its axis from west to east. Thus at Ushant, off the north-west coast of France, if the meridian of that point be under the moon at twelve o'clock, it is not till three o'clock that the high tide is perceived. This is because it takes some time to set the water in action in raising up the crest, and this action keeps on for some time after the cause is withdrawn. You can understand this by thinking of the similar effect of the sun in causing the seasons. The hottest time of the year is not on the longest day, and when the sun is most nearly vertical overhead, but some time after this, as in the month of July in the northern hemisphere. So again the coldest day is not on the shortest, but some time after, as in the month of January in the northern hemisphere.

Again, the tides do not rise and fall always to the same extent respectively at spring and neap tides, but sometimes we have extreme spring tides, when the rise and fall are greater than the average of spring tides, and at other times we have more limited neap tides, when the rise and fall are less than the average of neap tides.

This is because the moon is not always at the same distance from the earth. That point of time when the moon is nearest the earth is called her perigee, and it is then that the highest tides take place, since the attraction of the moon on the earth is dependent on her distance from us. It might be thought that the difference of distance between the moon at perigee, and her distance at apogee, when she is farthest removed from us, would make but little difference on the relative rise and fall of the tides, as this difference of distance is but small; but it must be remembered that the attraction does not vary as the distance, but inversely as the *square* of the distance.

This may be explained by reference to the following figures :—

| | | | | |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | etc. |
| 1 | $\frac{1}{2^2}$ | $\frac{1}{3^2}$ | $\frac{1}{4^2}$ | etc. |
| 1 | $\frac{1}{4}$ | $\frac{1}{9}$ | $\frac{1}{16}$ | etc. |

Here the first row of figures may be taken to represent varying distances of the moon from the earth.

The second row of figures shows that the attraction then varies inversely as the squares of those distances, and the third row gives the value of the second row of figures.

In this calculation we leave out of sight the action of the sun, as that is only about one-third of that of the moon.

Again, we have supposed that the earth was covered all over with an ocean of water, and that there were no continents or land masses disturbing our simple arrangements. In that case, if the moon were always over the equator, there would be a crest or high tide directly under the moon, and this would decrease to either pole, so that the highest tides would be at points on the equator, and there would be constantly low tide at the poles.

But the moon is not always directly over the equator, but is sometimes $28\frac{1}{2}°$ on either side of it. If the moon, therefore, be north of the equator, the tide then will be higher in the northern than in the southern hemisphere; and if, on the contrary, the moon be on the south side of the equator, the tide will be higher in the southern than in the northern hemisphere. But the most important agency affecting the tides is the character of the sea bottom, and the depth and width of the sweep of water along which the tidal wave passes. The general direction ought to be from the east to the west, as the earth is revolving in the opposite direction, and this we find to be the case in the open Pacific. But in the Indian Ocean, the tidal wave, in sweeping on from the west coast of Australia to the Cape of Good Hope, not only thus moves from east to west, but also from south to north, along the Indian Ocean, making a great arc. That is, if it is high water at twelve o'clock off South Australia, in another twelve hours the crest of the tidal wave will have reached both the east coast of Africa and the island of Ceylon, off the southern point of India, travelling in a great arc or portion of a circle.

Again, the tidal wave after passing the Cape of Good Hope not only passes to the west to reach Cape Horn, but proceeds northwards along the Atlantic, travelling most rapidly in the central deeper portions, and more slowly along the west coast of Africa and the east coast of America. It thus makes a great arc, of which the extremities in another twelve hours rest upon the American and African coast-lines.

In the deeper parts of the ocean the rise and fall are very slight, but on the shore-lines, where the wave is changed more or less by the nature of the channels into a drift or current, the height increases. Thus, at St. Helena, in the Atlantic Ocean, the rise is only about 3 feet, but at the mouth of the river Wye, where the Bristol Channel is shaped like a funnel, the height is often 50 feet. At London and Beachy Head it is about 18 feet, but lower down the English Channel, where the sweep is wider, it is only 9 feet, as off the Isle of Wight, and 7 feet off Weymouth.

The rate of movement also varies with the depth and width, being nearly a thousand miles an hour across the open Pacific. The tidal wave, again, takes only fifteen hours to sweep along the Atlantic Ocean from south to north, or from the Cape of Good Hope to the British Islands, but when it reaches the latter it divides into three branches.

1. Of these, one goes eastward up the English Channel, taking about eight hours to reach the mouth of the Thames.

2. Another passes through St. George's Channel into the Irish Sea, meeting

3. The principal branch, which passes along the west

coasts of Ireland and Scotland, rounding the latter; and passing along the east coasts of Scotland and England, to reach the mouth of the river Thames in about twenty hours. In the last-mentioned instance it will be noticed that the direction has been north, east, and south in different parts of its course, while the tide rises highest in such funnel-shaped bays and inlets as the Bay of Fundy in the United States, and the Bristol Channel on our own shores. There is, on the other hand, little or no tide at all in inland seas, such as the Mediterranean and Black Seas. This is, of course, because they are shut off by their narrow mouths from the advancing tide-wave, and because of their small size, which does not allow room for the moon to act on their waters before she has passed over them.

**Winds.**—Tides are to a great extent modified in their height by strong winds. If the wind blow against the tide, or in the opposite direction to that of the tidal wave, the height is diminished; and the contrary is the case if the wind blow with the tidal wave.

This is sometimes seen with damaging effect in the river Thames, when the banks are overflowed by high tides, aided by strong winds, and great destruction of property takes place. 'When by reason of great drought in summer, or extreme frosts in winter, the springs are low and the fresh waters less than usual, the tides may hold up longer than the times noted in the table; also, when strong north-westerly or northerly winds blow, which bring in an extraordinary flood from the northern seas, and keep it up longer than at other times. So, on the contrary, when the winds blow hard on the opposite points of the compass, or when we have much rain and great freshets (floods of river water), the tides hold out not so long as the times shown in the table, the freshets overpowering and checking them soon.'—FLAMSTEAD.

**The Bore.**—Some rivers are very subject to sudden and violent risings of the crest of the tidal wave. These have estuaries, or are tidal rivers with open mouths, and the mouths are directed towards the approach of the tidal wave. The estuaries are also shaped like a funnel, the shores approaching nearer and nearer to each other until the proper river banks are reached.

It will be perhaps useful to write down these usual conditions for a bore in a tabulated form.

1. There must be an estuary.
2. This must open outwards towards the sea.
3. The open mouth is directed towards the approach of the tidal wave.

All these conditions are fulfilled by the mouth of the Wye at Chepstow. The Bristol Channel forms a funnel-shaped inlet, with its open end directed to the west, so as to catch the tidal wave passing between England and Ireland. At all times there is a great rise and fall of the tide, or an extreme number of feet between high and low tide in this channel; but at times there is a bore, or, as it is there termed, an *æger* or *ægre*, at certain times.

When this sweeps up the mouth of the Wye or Severn, it dashes the boats near the shore on to the banks with great damage, so that the fishermen are accustomed to warn each other when they see the crest coming up the river by the cry, *Ware æger!* and then those who hear the cry at once make for the middle of the river, where there is deepest water, and therefore less friction of the wave against the bottom.

This bore is also met with at the mouth of the Hooghly, in India.

The river Ganges branches before it enters the Bay of Bengal, forming a delta at its mouth. One of these river branches is known as the Hooghly, and is the means by which Calcutta is approached by trading ships. The mouth of the Hooghly is directed towards the south, and as the tidal wave in moving westward from South Australia sweeps to the north up the Bay of Bengal, it finds the open mouth of the Hooghly in full front of it. It therefore rushes up this, becoming dammed up more and more as the shores approach, and hence many ships are frequently lost by being carried by the advancing wave on to the land, where they are left stranded.

**Uses of the Tides.**—We have already seen that the waves are constantly wearing away the shore-lines of continents and islands, sapping and undermining their foundations, and afterwards rounding the broken fragments and grinding them to pebbles, sand, silt, and mud.

It has also been pointed out that the ocean currents further assist this action by transporting the materials thus worn away to deeper parts of the ocean, until these drop on the floor of the ocean-bed to form the future continents.

But the tides also are concerned in this work. These 'sift' the matter held in suspension in the water, since the motion of the tides is one that reaches from the surface of the waters to the greatest depths of the ocean.

Moreover, the sea is kept pure and supplied with oxygen from the air by means of the various motions to which it is subject. If it were not for this, the upper layers of the water of the ocean would be supplied with the oxygen so necessary to animal marine life, but the great depths would have none, or would be loaded with the foul air given off by living and decaying animals. If this latter were the case, animal life at great depths would soon cease to exist. But from the greatest depths yet sounded, abundant traces of various forms of animal life have been obtained, and these living creatures are supplied with oxygen from the air by means of the constant interchange going on in the waters of the ocean. In this the tides take an important share of work.

Another great use of the tides is to serve man as a motive power in heaving his heavily-laden ships up and down the tidal rivers, as they carry exports and imports to and from the different trading nations of the earth. This is a subject of vast importance, as would readily be seen if you stood on the shores of the Mersey, Clyde, or Thames, and saw the ships coming in with the high tide to Liverpool, Glasgow, and London, and going out with the ebb.

At the same time the tide up these estuaries becomes changed into a current, more or less, as the waters become dammed up by the shores approaching each other, and so the tide serves to 'scour' the beds and carry out with the ebb the sewage that is thrown into the river. Sometimes this 'scouring' action works in an injurious manner, by tearing away the foundations of the piers of the bridges, so that many of the London Bridges across the Thames become weakened thereby.

Vast sums of money have been spent on the mouth of the Clyde in building works to help this scouring action of the tide, and excellent results have been produced. The bed of the river here has become so much deepened of late years, that now very much larger ships can enter the river than before, and large profits are being made out of the money that has been thus spent.

Seeing this, an attempt is about to be made to widen the mouth and bed of the river Mersey, so as to let the tide sweep up it, to enable ships to approach near Manchester. At the present time about ten million tons of goods, chiefly raw cotton and other imports, are landed at Liverpool every year, and of this quantity about four millions are carried by rail to Manchester, where the raw material is made up into manufactured goods. If the Irwell be made navigable, the greater proportion of this heavy goods traffic will be carried by water, and, of course, water carriage is vastly cheaper than that by land, and unloading would be avoided.

**Tide-Tables.**—As many harbours are so shallow that there is sufficient water to allow heavily-laden ships and steamers to enter in and pass out only at high water, it is very necessary that captains of vessels should know for any day in the year, and for any hour in the day or night, what may be the state of the tide.

If, for instance, ships or steamers should start from the south coast of England, or from London, for the French ports in the English Channel without making allowances for the state of the tide in these French ports, they would frequently have to wait outside of the port after reaching it until the tide had risen sufficiently for them to enter the harbour.

Calculations are therefore made, and tables drawn up, for each port in a trading country, stating for each day in the year the time of high and low tide.

You would see how necessary this is in some ports for at low tide the harbour is sometimes quite empty of water and a mere mud flat, while in very few ports indeed can a heavily-laden ship enter at low tide, unless the harbour has been deepened or long piers run out at vast expense.

**Appearances of the Tide.**—The aspect of the shore at high and low water is very different. At high tide the channel, or arm of the sea, or the open ocean, at which we are gazing, appears to be fuller of water than at other times. This is really the case to the extent of the difference in vertical height between high and low tide water-marks.

The sea also appears fresher and fuller of life and motion with a rising than with a falling tide. This is known to the sailor; and he is led to expect a lowering of a storm, both in wind and waves, after the top of the tide is reached.

We see this greater power of the tide at its height also in the size of the boulders covering the sea-shore. Near high water-mark these are large, and the waves throw them up in high ridges or sea-beaches; but as we go from the top of the high water-mark towards the level of low tide, these boulders become smaller and smaller, until they are mere gravel, and at last sand. This is the reason why such extensive sand-wastes are often to be met with on sea-shores, as off Brighton, on the south coast of England.

In other places the sand-wastes are even more extensive, but not bounded by sea-beaches of shingle, the rocks from which the boulders were worn being some miles distant on other parts of the coast.

The margin covered and uncovered by the rising and falling tides has a life of its own. The rocks are generally covered with long brown sea-weed, in the shelter of which, when lapped by the waters, numerous marine animals live, such as crabs, limpets, periwinkles, shrimps, prawns; and the young fry of soles, plaice, and other fishes swim about.

This kind of life, both animal and vegetable, is different from that found at greater depths, so the rising and falling tides are one cause of the great varieties of marine life.

The shores of tideless seas are not therefore so pleasant as those where the difference of scene and life are met with where tides are observed.

In building piers and jetties along the sea-coast for harbours and landing-quays, and for keeping the shingle from being washed away in storms, we take advantage of the low tides to carry on our operations. It is at such times, too, that large quantities of sand and gravel can be removed for making mortar for building purposes, as well as for mending roads and gravel walks; and in some places on the sea-shore the difference between spring tides and neap tides is very important to hundreds of labourers employed in this work.

In other places, as at Scarborough, on the coast of Yorkshire, the rocks which form the bed of the sea contain embedded in them large rounded boulders, which have been dropped there when the now hard rocks were merely soft mud. At times of low tide many men are employed in picking out these hard boulders to mend the roads with, and as the tide in rising and falling wears away the softer bedding rock, each tide exposes fresh quantities of these boulders.

One of the most marked effects of tides on some coasts is the drifting work they perform, as they change into currents by being dammed up by narrowing shores. This is well seen on parts of the south coast of England, as off the coasts of Sussex and Kent. The mouth of the English Channel is widest towards the west, and the Channel contracts towards the Straits of Dover. The tide which comes up-channel thus becomes converted into a drift from the west to the east; and thus, if a ship breaks up in wreck, her cargo generally becomes washed ashore to the east of the point where she broke up.

This fact is taken advantage of in getting rid of the sewage. The latter is carried to the east end of the coast towns, and is carried by the tide still farther to the east, and away from the front of the town, where it would be a nuisance and source of danger to health.

A very good example of this is afforded at Brighton, where the main outfall for the sewage is at the eastern extremity of the town.

If projecting points of land, such as rocky ledges, run out to sea, these generally have deeper water on that side which is exposed to the drift thus formed out of the tide proper; and such natural projections afford capital foundations for harbour works, being strengthened and raised by artificial works. It is in this way that many of the natural and artificial harbours of our coasts have been formed or improved.

The low tides are also frequently taken advantage of by the farmer, who collects at these times large quantities of sea-weed torn up and drifted by storms, and this serves as excellent manure when placed in heaps to ferment. Thousands of tons of sea-weed are thus annually collected on different parts of the coast, and these contain many salts extremely useful for the growth of plants. In other parts the sea-weeds are collected, dried, and burnt, and out of the ashes thus formed valuable chemical products are derived.

If you live upon the sea-coast, it is to be hoped that you will carefully watch the tides, and see that what is here stated is true. One object of these lessons is to give you knowledge that you might not be able to acquire for yourselves; but a still more important object is to teach you to *observe*, to use your eyes for yourselves, and employ your thinking powers to make you understand what you see. For there are many people who have lived on the sea-shore all their lives, but who have never asked themselves what are the *causes*, the *effects*, and the appearances of the tides they have seen daily.

## QUESTIONS

### Exercise I

(1.) What differences are to be noted in the sea-shore at high and low tides?

(2.) What are the differences between spring and neap tides?

(3.) At what times do the spring and neap tides respectively take place?

### Exercise II.

(1.) Draw a diagram of the relative positions of the sun, moon, and earth.

(2.) Point out on this the positions of the moon at spring and neap tides respectively.

(3.) What does attraction of gravity vary with?

### Exercise III.

(1.) Why should there be two high and two low tides every twenty-four hours?

(2.) What do you mean by the *lagging of the tides?*

(3.) What is the cause of that?

### Exercise IV.

(1.) What do you mean by the law of attraction varying inversely as the square of the distance?

(2.) How are tides affected by the ocean bottom?

(3.) Point out the march of the tidal wave from Australia to the mouth of the Thames.

### Exercise V.

(1.) What are the three routes of the tidal wave round Britain?

(2.) What time is taken by that up the English Channel?

(3.) What time is taken by that round Scotland?

### Exercise VI.

(1.) Why is the tide so high at the Bay of Fundy?

(2.) Why is the tide so low at St. Helena?

(3.) Name some part of the English coast where there is a high tide.

(4.) Why does the height of the tide vary in the Thames?

### Exercise VII.

(1.) What do you mean by a bore?

(2.) What are the conditions for the occurrence of a bore?

(3.) What are the effects of a bore?

(4.) Name some rivers where bores are met with.

### Exercise VIII.

(1.) Of what use are tides?

(2.) Name some towns that derive benefits from the tides.

(3.) How could Manchester be brought nearer the sea?

(4.) What is a tide-table?

### Exercise IX.

(1.) How do people take advantage of the low tides on some parts of the coast?

(2.) How is the tide concerned in the making or improving of harbours?

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# PREFACE.

In writing this book the Author has endeavoured to follow out the expressed intentions of the Education Department as regards scientific teaching in elementary schools, by describing fully the special portion of Physical Geography allotted to the third year in the *simplest possible language*, and by giving explicit directions for actual illustrations; his great aim being to enable the scholar to form ***true ideas*** and to exercise his powers of ***observation.***

**J. W.**

*Feb.*, 1877.

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# PHYSICAL GEOGRAPHY.

## THIRD YEAR.

## INTRODUCTION.

1. We suppose that you who are about to study this little book, have carefully gone through the special portions of Physical Geography allotted by the Education Department to the first and second years. At least, we must take it for granted that you are well acquainted, both practically and theoretically, with the nature of a river or stream, how it is supplied, and what becomes of it.

2. You have also been informed of the manner in which water is evaporated and condensed, how clouds are formed, the different kinds of clouds, and also of the formation of rain, snow, hail, dew, and mist.

3. The atmosphere surrounding this globe on which we live, and rendering it habitable, next claimed your attention. Winds were shown to be air in a state of motion produced by its rarefaction in some places, and consequent inrush of cooler air to fill up the vacuum. The air itself was shown to be composed mainly of nitrogen and oxygen gas, and the properties of each were demonstrated to you.

4. We trust also that you have thoroughly understood how tiny streams trickling down the mountain slopes gradually become larger and larger, receiving accessions on both sides, and ultimately discharge their contents into the sea. Watersheds, *i.e.*, elevated tracts of the earth forming the head-quarters, so to speak, of nearly all rivers, were next pointed out—how they divide river basins and affect also the virtual configuration of countries; and, further, we hope this portion of the subject was fully exemplified to you by careful and thorough study of the river basins of England.

5. So far you have been made acquainted with the physical or natural aspect of *land* and *air*. You then proceeded to the study of the other great natural division of the earth's surface, viz., water, its immense extent, its divisions, its depth, its saltness, its motions and effect upon the land, wearing it gradually away and depositing the sediment in strata at the bottom of its bed, and also its great influence upon the climates of the various countries of the world.

6. You see, then, that in the first and second years you were directed to study the surface of the earth, and the air enveloping it, *i.e.*, Physical Geography in a limited sense of the term; you have, as it were, taken a general survey of this great globe-house, and have made a rough inventory of its external features.

7. But besides this, it is thought advisable that you should supplement this local knowledge, so to speak, by a more extended course of study of the earth as a whole—its form, size, and motion; day and night; the seasons, how they depend upon the relative positions of the earth and sun. Then you are to direct your attention to the nearest heavenly body, viz., the moon, her distance, dimensions, and motions; concluding the course with a general survey of the planetary system.

8. When this is accomplished—and we shall endeavour to make your progress easy, interesting, and instructive—we trust you will not rest content with the elementary knowledge thus obtained, but that you will persevere in the study of science, and will search carefully and dig deeply into the inexhaustible and intensely interesting treasury of Nature, so bountifully spread around us.

9. What we specially want you to do in studying this book is, to *think* over a small portion at a time, making actual experiments with such things as you can conveniently obtain; and above all to exercise your powers of observation. When you see the tiny stream swollen into an impetuous torrent rushing wildly past, ask yourself, Why and whence this change? Or as you see the rays of the sun gradually removing the misty mantle of the hills, reason with yourself as to the formation of the mist, the effect of the sun's rays, and so on. If you proceed in this way, every walk in the fields or by the river side or across the mountains will be a thousand times more vividly interesting—in fact, every step you take will furnish you with matter for elevating thought.

## I. THE EARTH.

10. In accordance with the syllabus sketched in par 7, we commence with the earth. What is the earth? What shape is it? How large is it? How far away is it from the sun and the moon? Such queries as these will naturally present themselves to your mind. It is our duty to answer them for you, or rather to lead you to answer them yourself; that is, we shall ask you to observe a number of *facts* about the earth. From these *facts* you will naturally infer some conclusions, or *inductions*. This is what is termed the inductive method of teaching.

11. To begin: we will suppose you live in a town, and if we asked you where you lived, most likely you would give the number of a certain *house* in a certain *street*, or the name of your house. Very well. Now, all the houses and streets around your home are grouped together, and called a *town;* the town, again, with the outlying towns and country, form in England what is called a *county;* and, further, a number of such counties make up the *country* in which we live.

12. Proceeding further, and referring to the map, we find that two other countries adjoin England, viz., Scotland and Wales. The three countries make up the Kingdom of Great Britain. To the east of Great Britain we find many other countries, inhabited by people speaking many different languages. All these countries make up the *continent* of Europe.

13. Proceeding still further, we see the continent of

Africa to the south, and that of Asia and the island-continent of Australia to the east, of Europe; while to the west, separated by the great Atlantic Ocean, is the continent of America.

14. All these continents and islands, with the seas around them, are the earth; the vast magnitude of which you will have already *inferred* from the facts given.

15. You know your *house* is only one among thousands that form the *town*, the town again is very small compared with the *county*, while it takes many counties to make up a *country*, which is but a portion of a *continent;* the latter, nevertheless, is only a part of the *land* on the *globe*, and it must be remembered that besides the land there is three times as much *water;* the land comprising only a fourth part of the surface of the globe.

We will first advert to

### 1. The Form or Shape of the Earth.

16. **The earth is round.** How do we know that the earth is round? We shall try to show you. Wherever you live you see the earth and sky apparently meeting together in the distance. If you live in a town, the roofs of the houses in streets at a distance seem to touch the sky; or if you live in an open flat country, the same apparent meeting is observed, but much further away. The same is seen in mountainous or hilly districts, the tops of the ridges and the sky seem to meet as if there were no more land in that direction. But if you proceed to the place where this apparent meeting occurs, you will find there are more mountains or hills, valleys or plains, while the sky and earth seem to meet much further off than before. But if you were to go on further, you

would find that the *horizon* (as the line where the earth and sky apparently meet is called) would be still as far off as at first; and you would begin to doubt whether the sky and earth did meet after all.

17. But supposing you went on until at last you left the mountains far behind, and you were traversing a vast plain. The horizon would of course appear much further from you than it did when you were among the mountains, but on proceeding to where you thought the limit was, the horizon would still be as far as ever from you.

18. Still keeping on, we will suppose that at length you arrived at the sea-shore. You have before you the great wide expanse of water stretching away as far as you can see. You look at the surface and think it is *quite* flat. In fact you know that water will not and cannot possibly *remain* otherwise than flat or level *of itself*. You see also the horizon far away in the hazy distance, and you think that if you could but go as far you would at last arrive at the place where the earth and sky do really meet.

19. Let us suppose you can go. You embark. The sails are unfurled; the ship, speeding on before the wind, soon brings you to where you thought the limiting line was. But no, the further you go the further the horizon recedes from you, so that it is evidently useless to proceed.

20. You return, and look towards the land. You know that the mountains you crossed are in that direction, but you cannot see even their summits. And yet if we were to ask you what sort of surface the earth has, we have no doubt you would at once say it is flat, the sea and the plain especially; as to the mountains, after all they seem to be simply heaps upon a flat surface; and so you would infer that the earth's surface is flat.

21. But the heading of this chapter asserts that the earth is round. Well, you say, I cannot see that the earth is round. Everything seems to prove to me that the earth is flat. Wait a moment. You may even *see* that the earth is round; and if you will carefully attend we will give you a few proofs of the earth's rotundity. Now for

22. **Proof number 1.** Referring to your imaginary voyage, we will suppose that you were looking towards the shore from the "crow's nest" at the mast-head. You expected to see the mountains which you knew were in that direction, inasmuch as you had travelled straight from them across the plain to the sea-shore. And yet you could only see a few miles of the plain. Why could you not see the mountains? In reality the surface of the plain is not flat, as it appeared to you when you crossed it, but curved. The mountains certainly do lie beyond the plain in that direction, but the *curvature of the plain prevented you from seeing them.*

23. But if you land, and travel a few miles across the plain, the mountains will again gradually appear to your view, and when near enough you see them fully.

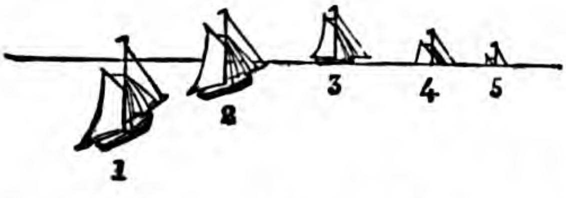
24. How can we account for this? If the surface of the plain between the sea and the mountains were really flat, you ought to have seen the mountains from the ship, although perhaps not very clearly because of the distance; if not with the eye at least with a telescope. But no, not even with a telescope could you see them; nothing but the surface of the plain apparently meeting the sky. Therefore it must be the curvature of the surface of the plain that prevented you from seeing the mountains beyond.

25. **Proof number 2.** We will now turn *towards* the sea. Standing on the shore we notice a ship (*a*) nearing the harbour. There it is in full view—hull, masts,

and flag. Further away, we see another ship (*b*), evidently of the same kind and size, but the *greater portion of its hull* seems concealed by the water. Further still, we notice another ship (*c*), of which the *masts* and flag only are visible, the whole of the hull apparently sunk in the water. Looking carefully along the horizon, we see more ships. We now leave the shore.

26. Returning in an hour or two we look again at the ships. We see ship *a* close by the shore; the *whole* of the hull of ship *b* is visible; the *greater portion* of the hull of ship *c* is also visible, as well as its masts and flag; while just emerging from the horizon, rising as it were out of the water, are the flags and masts of another ship (*d*). Why could we not see the flag of the last ship before? Because it was hidden from our view by the curvature of the surface of the sea, which at first also concealed portions of the hulls of ships *b* and *c*.

27. Now if the surface of the sea were really flat, we could have seen the *hulls*, if not the masts, of *all* the vessels the first time. So that nothing but the curvature of the surface of the sea prevented us from seeing ship *d* the first time; the same cause also rendered portions of the hulls of ships *b* and *c* invisible.




Ships sailing away *from* the land also present the same appearances. In the above figure, although the five ships are evidently of the same kind and size, the same gradual disappearance of the vessels is observable.

28. **Proof number 3.** **Ships have sailed round the**

world, and have come back to the same place by sailing in the *same general direction.*

29. Now if the earth were flat, ships would have to sail in a *different direction* in order to come back again to the place whence they started.

30. Ships can only sail right round the globe in a general eastern and western direction, because both the polar seas are unnavigable. But if you were to make the journey partly by land and partly by water, you would come back to the very place you started from simply by keeping the same direction.

31. Suppose, then, we start from London due east. Embarking at the Docks, you would proceed along the Thames across the German Ocean to Holland. Thence traversing Prussia, Russia, and Siberia, crossing the northern end of the Gulf of Tartary and Saghalien Island, we arrive at the shores of the Sea of Okotsck. Crossing this sea, and passing over the southern end of the Kamschatka peninsula, skirting the Aleutian Isles, you would land in British Columbia. Then setting out still eastward, you would cross British America, arriving at length on the coast of Labrador, near the northern end of the island of Newfoundland. Then embarking and crossing the Atlantic, the vessel would enter Bristol Channel. Landing at Bristol, and continuing your journey still eastward, you would at last arrive at London, having travelled completely round the globe, and thus proving in the clearest possible manner that *the earth is round from east to west and vice versâ.*

32. This being proved, how can we demonstrate that the earth is round from north to south? If we *knew* it to be round from east to west only, the earth might be of the form of a cylinder. It is true that we cannot circumnavigate the globe in a northern or southern direction, because of the ice surrounding the poles;

but if we travel a considerable distance from north to south, or *vice versâ*, many stars fully visible to us when we started, gradually disappear below the horizon, while new stars become visible above the horizon in the opposite part of the heavens.

33. Now if the earth were flat we should always see the *same* stars wherever we might be—that is, a star seen from say London in the northern hemisphere,

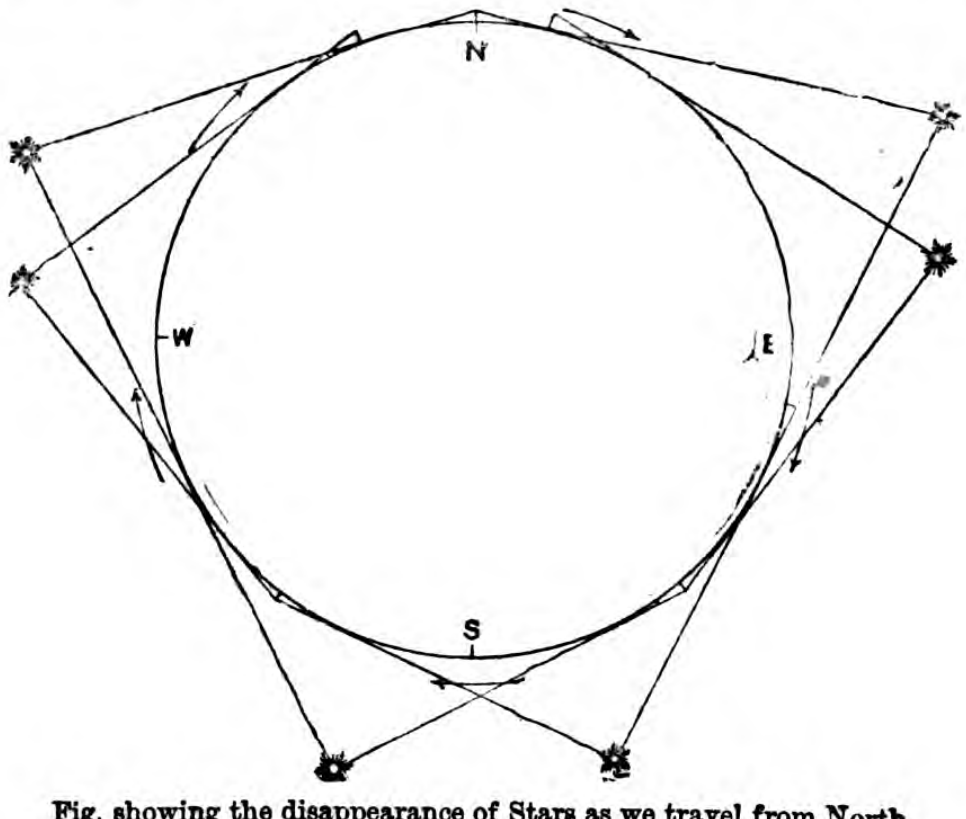



Fig. showing the disappearance of Stars as we travel from North to South, or *vice versâ.*

would be also visible at Cape Town in the southern hemisphere. This is not the case, and the curvature of the earth will appear evident from the above figure. Therefore we conclude that *the earth is round from north to south.*

34. And whatsoever direction we may take we shall arrive at the same conclusion, *i.e.*, that the earth is round in that direction. And since this is true what

soever direction we may take, we justly conclude that *the earth as a whole is round.*

35. **Proof number 4.** If the earth were flat the sun would rise and set upon all the countries of the world at the same time. This, we know, is not the case. For instance, when the sun rises on England it has just set on New Zealand. The distance of 15° makes a difference of one hour in the local time of places 15° east or west of each other. (*Vide*, par. 94.)

36. **And lastly.** In an eclipse of the moon caused by the earth passing between the sun and the moon, the shadow of the earth is always circular. This corroborates all the preceding proofs of the earth's rotundity. The fact that some portions of the earth's surface rise four or five miles above the general level does not make any appreciable difference in the general appearance of the earth. It is well known that there are mountains in the moon much higher than those upon the earth; yet the moon always appears round, both to the naked eye and when viewed through a telescope.

37. We have now, we hope, given you indisputable proofs of the assertion that the earth is round, not flat. Having thus settled this important question, we will proceed to consider—

38. **The exact shape of the earth.** It has been found that the earth is not an exact sphere or globe, but that it is compressed or flattened a little at both ends—*i.e.*, the poles, forming what is termed an *oblate spheroid.* The difference, however, is so slight that for all practical purposes we can assume the earth to be a round body.

### 2. The Size of the Earth.

39. **The circumference of the earth** is nearly 25,000 miles. Whenever numbers are given you should always

compare them with something you really know, in order to form the clearest possible idea of what they express. Thus if you were to walk five miles an hour for five hours every day, it would take you 1,000 days, or more than three years, to go *once* round the earth.

40. **The diameter of the earth** is nearly 8,000 miles. So that the circumference of the earth or of any spherical body is about three times the diameter. This is very important for you to remember, for if you know the one, you can easily find the other. As a practical illustration, take a piece of string. Find the centre of a round table and mark it thus ×. Pass the string over this mark right from one side of the table to the other, and cut off the ends if it is too long. Now take another piece. Measure round the table. You will find the latter (the circumference) is about three times as long as the former (the diameter).

41. The diameter of a circle is a line drawn through the centre from one side to the other. The diameter of the earth is a line *supposed* to be drawn *through* the centre of the earth from one side to the other.

42. Now in a circle all diameters are equal; but in the earth the diameter drawn from the north to the south pole (*i.e.*, the *Polar Diameter*) is less by 26 miles than that drawn from the equator, (*i.e.*, the *Equatorial Diameter*); the former being 7,899 miles, the latter 7,925 miles, while the mean diameter is $7899 + 7925 \div 2 = 7{,}912$ miles.

43. The earth, then, is compressed, as it were, at the poles, and bulges out a little (very little indeed in comparison to its magnitude) at the equator. So that if you take an orange to represent the earth, you must not compress it at the poles so as to show this bulging out at the equator, since it is quite inappreciable in any globe that we may use, being only $\frac{1}{300}$ of the whole diameter.

44. **The area** of the earth's surface has been computed to be more than 197,000,000 square miles; of which, water occupies 145,000,000, and land 52,000,000 —*i.e.*, there is nearly three times as much water as land. The preponderance of water is mostly in the southern hemisphere, which may be called the water hemisphere, while land predominates in the northern hemisphere.

45. Now you must try to form as clear an idea as possible of the great size of the earth. Compare the numbers given with known distances. If you do this at the outset, you will be enabled to form more definite ideas of the size, etc., of other heavenly bodies vastly greater than the earth.

46. Another word as to representations of the world by means of globes, etc., which are very apt to mislead you. For instance, you know there are some mountains on the earth more than four miles in height. If you were asked to represent a range of mountains of this height on a school globe, most likely you would make quite a little ridge about half an inch or so in height. Now what is the distance of the sea-level (which is taken as the basis of all measurements of height or depth) from the centre of the earth? The diameter is nearly 8,000 miles; the radius or the distance from the centre is 4,000 miles; that is, a mountain four miles high will be $\frac{1}{1000}$th part of the distance from the surface to the centre of the earth. Now, supposing the diameter of the globe is 12 inches, the radius will be 6 inches, and the height of the range will be shown by $\frac{1}{1000}$th part of 6 inches, or about $\frac{1}{166}$th part of an inch. The height of the range in question, then, would be represented by the thickness of a piece of paper pasted on the surface of the globe.

47. Or if you were asked to represent, say, the bed of the Atlantic, using the same globe, we dare say you

would cut out quite a little trench, while, in reality, taking off the paper cover would be amply sufficient to show depths of between four and five miles.

48. It is only in this way that you can form even a faint conception of the immense sizes, distances, etc., of the heavenly bodies. The great point in all comparisons is to take a number of which you can form a clear and definite idea.

### 3. Motions of the Earth.

49. We have by this time, we hope, enabled you to form a good idea of the form and size of the earth. And now we will consider the *motions of the earth.* Motions of the earth! you exclaim, I am sure the author is making a mistake. He must mean the motions of the sun or the moon, for I am quite sure that the earth does not move. I do not see or feel it move. Places on its surface (*e.g.*, the school, the wood) are always in the same position, neither nearer nor further than they always were, and yet this section is to treat of the motions of the earth. As to the sun or the moon, I know they do move, for have I not seen them rise and set many and many a time?

50. Wait a moment. In the first place, you say that you do not see or feel the earth move. You have, we suppose, travelled on the railway. Did you *feel* yourself moving? No. Looking through the window, what did you *see?* You saw the trees, houses, and fields, etc., apparently moving rapidly past you in the opposite direction, while you almost thought yourself at rest. But you knew very well it was the train that was moving, and not the trees and the houses. Therefore it would be quite absurd for you to assert that the train was at rest because you did not *feel* it moving forward, or that the houses and trees did really move in the opposite direction because you *saw* them apparently

moving. *Therefore the earth itself may be moving although you do not see or feel it moving.*

51. You said also that places on the earth's surface, such as the school, etc., are always in the same position; the wood, where you delight to ramble, is no further from the school than it always was, and therefore you think the earth does not move.

52. Let us take another railway journey. Let the train represent the earth, and you in one corner and another boy in the opposite corner of the compartment, the school and the wood, *i.e.*, their relative positions. Now is it necessary in order to prove that the train is moving that you or the other boy should move at all, *i.e.*, change your relative position? Of course not. The train moves whether you sit still in the same place or whether you change your place, and it is quite absurd to think that to prove the train is really moving you and the other boy should be moving. *In the same way the earth may be moving although places on its surface do not move.*

### 4. The Revolution of the Earth.

53. Let us apply pars. 50, 51, and 52 to the earth. We have said that the earth *may be moving* although you do not see or feel it moving, and although you do not see or feel the school, etc., moving. But does it move? And if it does, how can we know that it does?

54. But first let us ask you, does the sun move? Certainly, you say, because we *see* the sun *rising* in the east and *moving* gradually across the heavens, and at length *setting* in the west. And the moon? Yes, the moon also moves. And the stars? Well, yes, the stars also.

55. Very well. You remember that the line where the earth's surface and the sky appear to meet is called

the *horizon.* Therefore when the sun, etc., *rise* they appear *above* the horizon; when they *set* they sink *below* the horizon, *i.e.*, supposing they do really move.

56. Now let us make an actual experiment to illustrate these results, supposing that the earth does not move, but that the sun, etc., moves round it. Place a ball near the edge of a table or desk, to represent the earth. Insert a pin or a needle to represent yourself *looking at the sun* rising and setting. Now imagine your eye to be the sun, and the edge of the table the horizon. Bend your head so that your eye (*the sun*) is below the level of the table (*the horizon*). Raise your head gradually. As soon as your eye (*the sun*) is on a level with the surface of the table (*the horizon*), you can just see the pin stuck in the top of the ball. Move your head slowly in a semi-circle from one side of the table to the other, keeping your eye on the pin. When your eye (*the sun*) is right overhead it is *noon*, and when it is again just descending below the level of the table's surface, you lose sight of the pin; *i.e.*, the pin (*yourself*) sees your eye (*the sun*) *setting.*

57. We have thus illustrated the rising and setting of the sun, supposing the earth to be at rest. The movements of the sun after all may be only *apparent*, as in the case of the trees, houses, etc., seen from a train in motion. May it not be the sun that is really at rest while the earth is moving, the same way as we *know* it is the train that is moving and not the trees, etc? In other words, supposing the sun to be at rest, would the revolution of the earth round the sun cause the same effects, *i.e.*, still show what we call sunset and sunrise? Let us see.

58. Place a small lamp or candle near the edge of a table or desk to represent the sun. Your head will represent the earth; your eye, the position of an ob-

server on the earth's surface. Bend your head below the level of the surface of the table (*the horizon*), and raise it gradually in a semi-circle as before. When on a level with the surface of the table, the lamp's (*the sun's*) rays will then first fall upon your head (*the earth*), *i.e.*, you see the *sun rise*. When right above the lamp, the rays of the lamp (*sun*) will fall more direct upon your head (*the earth*) than at any other time; consequently it is *noon*. Moving your head still forward when just descending below the surface of the table, your head (*the earth*) receives the last rays of the lamp (*the sun*), and when below the edge does not see it at all; *i.e.*, the *sun has set*.

59. Therefore the *rising* and *setting* of the sun, as it is called, may be caused either by the sun travelling round the earth, or by the earth revolving round the sun. (Of course, as will be hereafter shown in par. 77, the apparent rising and setting of the sun is really due to the earth's rotation. The two preceding illustrations simply show that the rising and setting of the sun are not necessarily due to the sun moving round the earth, but may be the result of the earth moving round the sun.)

60. The former is *apparently* the case, and nearly everybody three or four hundred years ago believed that the earth was still, and that the sun and other heavenly bodies moved around it. Yet no educated person believes so now. But how can we know which is true? We have no direct evidence (generally speaking), as in the case of the mountains or the ships (pars. 22, 25). One way is by analogy, *i.e.*, finding out the movements of other heavenly bodies, and then inferring the fact that since the earth belongs to the same system, its motions will be similar. We find that the other planets move regularly round the sun, and since the earth is also a planet, we naturally

infer that the earth also revolves round the sun, and the more so since we know that some of these planets are many times larger than the earth.

61. You must also remember that the sun is a million and a half times larger than the earth. Now which would be the more natural, for a comparatively small globe (*the earth*) to revolve round an immensely larger one (*the sun*), or the latter round the former?

62. The velocity of the earth in its revolution round the sun is nearly 1,000 miles a minute,—which does not appear incredible when the vast magnitude of the earth is considered; but if the sun revolved round the earth, it (*the sun*) would have to travel at the rate of more than 1,000,000 miles per second, while the nearest star would be speeding through space at the rate of over 400,000,000 miles per second, which defies belief.

63. If the sun really does move round the earth (in comparison with the latter), it would be as if a great furnace, many miles in extent, were to revolve round a small piece of meat. Since it must be one of the two, would it not be a thousand times more natural, more in accordance with what we know of the order of creation, for the comparatively smaller earth to travel round the great sun?

64. Finally, the question is definitely settled by applying to the sun and the earth the universal principle of attraction, present in all bodies; and the larger the body the greater its attractive power. Just as the moon, which is much smaller than, and near to, the earth, is attracted to the earth so that it revolves around it, even so are the earth itself and all the planets attracted to the sun; and (in accordance with a principle which will be fully explained in a subsequent section) compelled, so to speak, to revolve around it in consequence of its preponderating attractive power.

65. *It is, then, satisfactorily proved that the earth moves, and, further, that it moves round the sun.*

66. Before proceeding to the consideration of such questions as how does the earth move? etc., let us remind you that the sun, the earth, the moon—in short, all heavenly bodies, are situate in space. You have seen an orange on the table. That orange rests on, or is supported by, the table. You roll it over to the edge, and it falls to the floor. It does not stop half-way; it must be supported by something else, and so, the floor being the nearest place of rest, it falls to the floor. Tie a piece of string round the orange, and take hold of the other end. Now let it roll over the edge. It does not fall to the floor. Why? The string holds it. It is *suspended* in the air by means of the string. Let go the string, and both string and orange fall to the ground.

67. You have, we suppose, seen a balloon floating in the air. You do not see anything holding it up as in the case of the orange. Higher and higher it rises, until it is out of sight. The earth, too, moves in space like the balloon in the air. You know why the latter rises above the surface of the earth; it is full of gas, much lighter than the air in which it floats. But the earth does not move in space because there is anything in it keeping it up. It is kept up, so to speak, by the attraction of the sun, which is so powerful that it makes not only the earth but all the planets to revolve around it. Twist one end of the string round your forefinger. Whirl the orange round. The orange is made to revolve round your finger by means of the string. In like manner the earth is influenced by the sun's attraction, and made to revolve round it.

68. Now, reverting to a railway journey, when you look out of the window, you see the trees, etc., apparently moving in the *opposite* direction. Suppos-

ing the train is moving from west to east, the trees, etc., will appear to be moving from east to west. And so it is with the world. We see the sun, etc., apparently moving across the heavens, from east to west, while in reality it is the earth that is moving from west to east.

69. Thus far we have proved (1) *that the earth is round*, (2) *that it is situate in space*, (3) *that it moves*, (4) *that it moves round the sun*, (5) *that it is the sun's attraction that causes the revolution of the earth*, (6) *that the earth moves from west to east.*

### The Earth's Rotation.

70. The next query naturally will be, How does the earth move? Does it turn over and over like a ball on the table, or does it move along like a carriage wheel with the break on?

71. We will suppose the earth's motion is similar to the latter, *i.e.*, the earth moves round the sun without turning over and over like a ball. Take an orange or a ball, to represent the earth. Stick a long needle right through it. Place a lamp in the middle of the table, to represent the sun. Now stick a pin or a small needle, first of all in the middle of the side of the orange opposite the lamp, to represent an observer on the surface of the earth, looking at the sun. By means of the long needle *draw* the orange *along* the table right round the lamp. Then the pin (*you*) is in full view of the lamp (*the sun*) all the time (*year*); *i.e.*, it would be always day. This we know very well is not the case in any part of the earth, so that evidently this illustration is not true.

72. Take the pin out and stick it in the middle of the dark side of the orange, and *draw* the orange round the lamp as before. This time the pin (*you*) would not be in sight of the lamp (*the sun*) at all; *i.e.*,

you would be in continual darkness. But you know this is not the case in any part of the world.

73. All over the world there is alternate darkness and light. But we have shown by the two preceding experiments that this alternation of darkness and light would not be produced if the earth simply moved along like a carriage wheel with the break on. If this were the case one half of the world would be *always lighted up* and the other half would be in *perpetual darkness*. It is quite evident, then, that the earth must be moving, not simply along its orbit, but in some other way as well, in order to produce this regular change from light to darkness experienced all over the world.

74. Let us try to find out what other motion is necessary to produce this alternation of light and darkness. Insert a pin in the middle of the orange, to represent yourself at the equator. Suppose, while moving the orange round the lamp as before, we *turn the orange itself round* the needle stuck through it. The pin is now in the light and darkness alternately. Take it out and stick it somewhere else in the orange. Turn the orange round as before, and you have the same result—light and darkness alternately. This, therefore, is just the motion necessary to produce alternate light and darkness. The orange represents the *earth*, the long needle stuck through it the earth's *axis*, and the turning of the orange round the needle the rotation of the earth on its axis.

75. Thus we have established a most important fact, viz., that in revolving round the sun *the earth turns on its own axis*. And what is the earth's axis? You must not think there is an immense needle or rod stuck right through the earth as the needle through the orange. No, the earth's axis is an *imaginary* line round which we conceive the earth turns. Its ends

are called poles; so there are two poles, viz., the north and south pole.

76. Watch a top spinning. It spins so fast that it seems at rest, but you know it is spinning its best then. Now imagine a line drawn through the top from the point of the nail to its upper surface. Such a line would be the top's axis. And as the top seems to spin round this line, so the earth seems to spin round its axis.

## 6. Day and Night.

77. Now let us consider the effects of the earth's rotation more closely. We shall use the lamp (*sun*), the orange (*earth*) with the needle stuck through it (*the axis*), the points where the needle pierces the orange (*the poles, the top one the north pole and the bottom one the south pole*). At first, hold the needle upright. You see that the side opposite the lamp is lighted up, while the other side is dark. In the former it is *day*, in the latter it is *night*. You will further notice that on account of the roundness of the orange, exactly one-half of it is lighted up at the same time, the other half being dark. Turning the orange slowly round, you will see that the illuminated side gets gradually darkened, while the dark side is just as gradually lighted up, until at length the whole of the side previously lighted up is now in darkness, while the other side previously dark is now illuminated.

78. *Therefore the earth's rotation on its axis causes day and night* by presenting alternate sides to the sun

79. Now tie a bit of thread round the orange half way between its poles. The thread represents the *equator*, which is an imaginary line passing round the earth exactly midway between the poles. Suppose yourself at the equator watching the sun *rising*. You would see it rising right to the east, and *apparently*

ascending higher and higher until at *noon* it is right over your head. In twelve hours' time it will have *set* in the west. You watch again and see it rise exactly twelve hours after you last saw it.

80. Now we have proved that the sun's motion is only apparent, and since twenty-four hours have elapsed between two consecutive *risings* of the sun, the earth (which really moves) must have taken twenty-four hours to turn once round its axis.

81. *The earth*, therefore, *rotates upon its axis once in twenty-four hours.*

82. Further, as we mentioned before, the sun's apparent motion is from east to west. In reality, the earth moves from west to east while the sun is stationary. Therefore the sun rises earlier to countries east than it does to those west; when it is dawning on England it is noon at Calcutta, and midnight in Lower California.

## II. EXPLANATION OF TERMS.

83. Before proceeding further, it is necessary that you should be familiarized with the technical terms used in treating of the earth, etc.

### 1. Cardinal Points.

84. First of all, before we can fix the *position* of places, we must know their distance and *direction* from the place of observation. Or in drawing maps or representations of the whole or part of the earth's surface, if we have no fixed points to guide us in determining the *direction* of places whose positions we wish to denote, our maps will necessarily be very inaccurate. Such points are absolutely necessary, and are termed *Cardinal Points*, or points of the compass, *i.e.*, north, south, east, and west, with intermediate points, north-

east, south-west, etc. One of these points being known at any place, the *direction* of all other places may be easily ascertained. For instance, if you were asked in what direction Bristol lies from London, you would say west, and so on. You have already seen that the sun rises in the east and sets in the west. This you may use as a basis to find all other points. If you look at the sun at noon, you are facing the south, while the north of course is in the opposite direction.

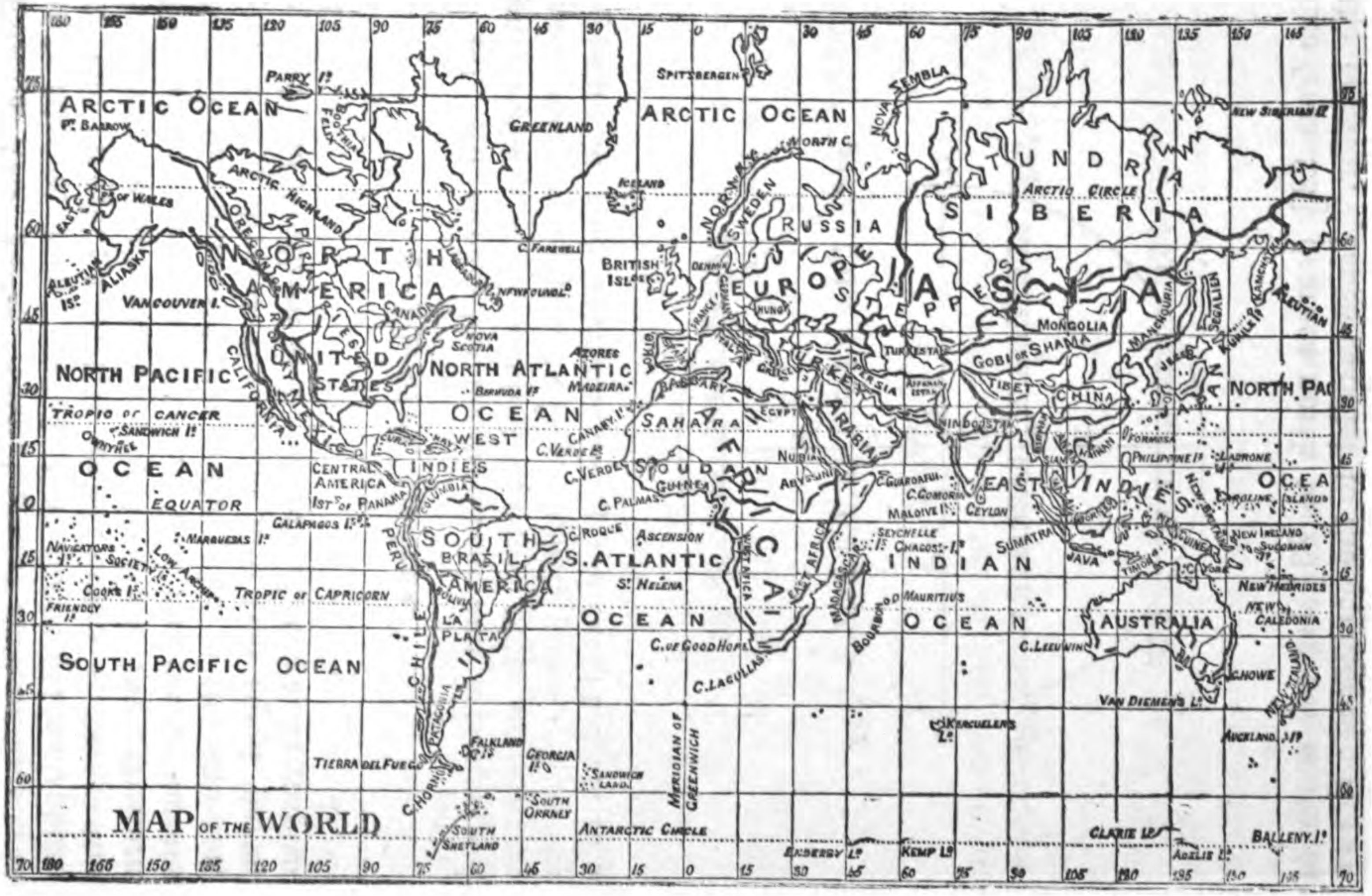
85. It is absolutely necessary for sailors at sea and travellers in desert places to know in what direction they are travelling. So long as the sun is visible it may be easily determined, but when it is obscured they have resource to an instrument called the *compass*, which is nothing more than a magnetized needle so adjusted upon a pivot that it can turn freely in any direction. Since this needle always points nearly due north, the sailor or traveller can easily find out in which direction they are going. At the bottom of the box is a circular piece of paper with the cardinal and intermediate points marked on it.

## 2. Maps.

86. In maps or representations of the whole or portions of the earth's surface (unless otherwise specified), the top of the map is the north, the bottom the south, the right hand the east, and the left hand the west. On the opposite page is a map of the world on the cylindrical or Mercator's projection.

## 3. Hemispheres.

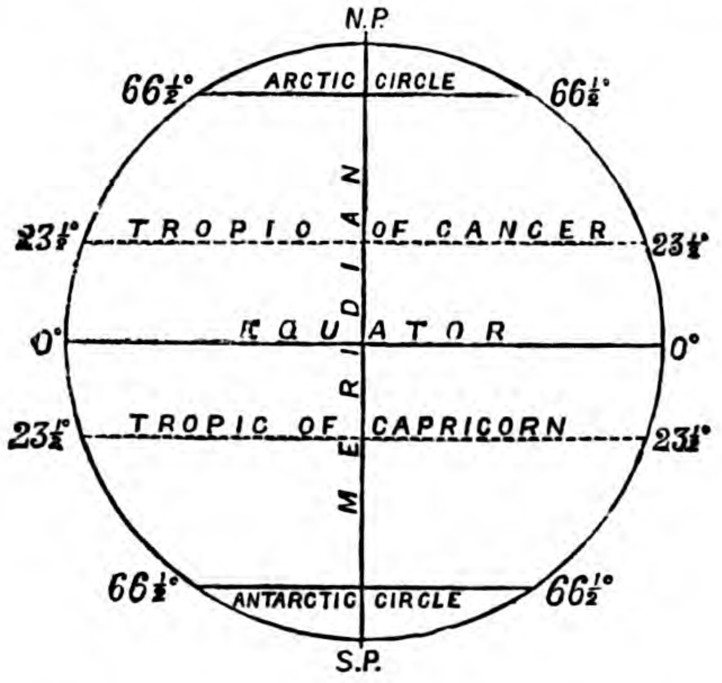
87. Since the earth is a round body, one circle would only represent half of it; we therefore use two contiguous circles, the right hand circle showing


MAP OF THE WORLD
ARCTIC OCEAN
NORTH AMERICA
UNITED STATES
CANADA
GREENLAND
NORTH PACIFIC
NORTH ATLANTIC OCEAN
WEST INDIES
CENTRAL AMERICA
SOUTH AMERICA
BRAZIL
PERU
CHILE
LA PLATA
PATAGONIA
S. ATLANTIC OCEAN
SOUTH PACIFIC OCEAN
EQUATOR
TROPIC OF CANCER
TROPIC OF CAPRICORN
ANTARCTIC CIRCLE
MERIDIAN OF GREENWICH
EUROPE
RUSSIA
SWEDEN
NORWAY
BRITISH ISLES
ICELAND
SPITZBERGEN
NOVA ZEMBLA
ASIA
SIBERIA
TUNDRA
ARCTIC CIRCLE
STEPPES
MONGOLIA
MANCHOURIA
CHINA
TIBET
GOBI OR SHAMA
HINDOSTAN
ARABIA
TURKESTAN
AFRICA
SAHARA
SOUDAN
EGYPT
NUBIA
ABYSSINIA
EAST AFRICA
MADAGASCAR
INDIAN OCEAN
EAST INDIES
SUMATRA
JAVA
AUSTRALIA
VAN DIEMEN'S LD
NEW ZEALAND
NEW HEBRIDES
NEW CALEDONIA
CEYLON
MAURITIUS
BOURBON
ST HELENA
ASCENSION
C. OF GOOD HOPE
C. LAGULLAS
C. VERDE
C. PALMAS
C. ROQUE
C. HORN
TIERRA DEL FUEGO
FALKLAND IS
SOUTH GEORGIA
SOUTH SHETLAND
SOUTH ORKNEY
KERGUELEN'S LD
AUCKLAND IS
BALLENY IS
KEMP LD
ENDERBY LD
CLARIE LD
ADELIE LD
GALAPAGOS IS
MARQUESAS IS
SANDWICH IS
VANCOUVER I.
ALASKA
ALEUTIAN IS
NEW SIBERIAN IS
SEGALIEN
KAMSCHATKA
KURILE IS
PHILIPPINE IS
FORMOSA
LADRONE
CAROLINE ISLANDS
NEW GUINEA
NEW IRELAND
SOLOMON
C. YORK
C. LEEUWIN
LD HOWE
ARCTIC HIGHLANDS
PARRY IS
PT BARROW
NEWFOUNDLD
NOVA SCOTIA
C. FAREWELL
AZORES
MADEIRA
BERMUDA IS
CANARY IS
C. VERDE IS
NORTH C.
SEYCHELLE
CHAGOS IS
MALDIVE IS
C. COMORIN
C. GUARDAFUI
IST OF PANAMA
NAVIGATORS IS
SOCIETY IS
LOW ARCH.
COOK'S IS
FRIENDLY IS
OWHYHEE

Europe, Asia, Africa, Australia, and surrounding seas and islands, being called the *Eastern* Hemisphere or Old World; the left hand circle showing the American continent, etc., and called the Western Hemisphere or New World. The line drawn across both circles midway between the poles is the equator, and it also divides the world into two equal parts, named the *Northern* and *Southern Hemispheres* respectively.

### 4. Degrees, Circles.

88. All circles for geographical and astronomical purposes are divided into 360 equal parts or *degrees;* each degree is equal to 69½ English miles. The sun appears to pass overhead along the earth's orbit in a




line from 23½ degrees north to 23½ degrees south of the equator. Lines parallel to the equator are drawn through these points. The northern line is the *Tropic* *of Cancer*, the southern the *Tropic of Capricorn.* At the same distances from the poles are drawn two other parallel lines, called the *Arctic* (*north*) and *Antarctic* (*south*) *Circles.*

### 5. Zones.

89. The portions of the earth included between these circles are termed *zones* or belts; that between the Tropic of Cancer on the north and the Tropic of Capricorn on the south being called the *Torrid Zone,* because the sun is always vertical in some part of it; therefore the Torrid Zone includes the hottest parts of the earth. This zone extends for about 1,600 miles north and 1,600 miles south of the Equator. In the spaces between the Tropic of Cancer and the Arctic Circle in the northern hemisphere, and the Tropic of Capricorn and the Antarctic Circle in the southern, the sun is never seen directly overhead, and his rays fall more or less obliquely; consequently the heat is not so intense as in the Torrid Zone. They are therefore termed *Temperate Zones.* The North Temperate Zone extends for 3,000 miles north of the Torrid Zone; the South Temperate the same distance south. These zones contain above half the earth's surface. The spaces included in the Arctic and Antarctic Circles are termed the *North* and *South Frigid Zones* respectively.

### 6. Ecliptic.

90. The plane of the earth's orbit, as will be hereafter explained, is inclined to the plane of the equator at an angle of 23½ degrees. If, therefore, we draw a line cutting the equator at that angle, it will meet the tropics north and south. Such a line is called the *Ecliptic,* and the points where it cuts the equator are called the *Equinoctial Points,* because when they are

opposite the sun day and night are of equal duration all over the world. This takes place twice a year, viz., on March 21st and September 21st.

### 7. Latitude, Longitude.

91. Besides these *Greater Circles*, as the equator and ecliptic are called, and the *Lesser Circles*, viz., the tropics, Arctic and Antarctic circles, other lines are drawn from the north to the south poles cutting the equator at right angles. These lines are called *Meridians*, because it is midday at the same time at all places on the same meridian on one side of the earth, while on the other side it is midnight. Circles are also drawn parallel to the equator, gradually decreasing to a point at the poles. These lines are called parallels of *Latitude*, while the meridians drawn from pole to pole are called *Longitude*.

92. It is by means of these lines that we can fix the position of places on the earth's surface, for the latitude of a place shows its distance north or south of the equator, while its longitude shows its distance east or west of a given fixed meridian; that of Great Britain being the meridian of Greenwich, that of France Paris, etc.

93. We have said that all circles are divided into 360 degrees; each degree (denoted by a small circle thus ) is again divided into 60 minutes, denoted thus ′; each minute into 60 seconds, denoted thus ″, etc.; so that 22° 4′ 16″ reads twenty-two degrees four minutes and sixteen seconds. Lines of latitude, although decreasing in size as they approach the poles, are necessarily parallel, so that all degrees of latitude are necessarily equal. On the other hand degrees of longitude decrease gradually from the equator (where it measures 69½ English miles, *i.e.*, equal to a degree

of latitude) to either pole. At London, for instance, a degree of longitude measures only about 43 miles.

94. Since, then, the earth rotates upon its axis once in twenty-four hours, in one hour it moves 15 degrees (360÷24=15). So that 15 degrees in distance is equal to one hour in time. And since the earth's rotation is from west to east, it is evident that the sun will rise earlier to places east of a given place and later to places west of that place. We can thus find the longitude of any place by the difference between the local time of that place and that of Greenwich; and the longitude is west or east as the time is earlier or later. Thus when it is 6 a.m. at Greenwich it is noon at Calcutta, *i.e.*, six hours later, or ninety degrees east. In Lower California it would be 12 p.m., six hours earlier, or ninety degrees west.

95. Reverting to the consideration of the earth's revolution and rotation, the former was indirectly proved in par. 60. Although the facts there given necessitated the belief that the earth does move round the sun, they did not refer at all to the time taken by the earth to complete its revolution. How can this be determined? The following fact not only determines the time but also substantiates all the preceding arguments.

96. It is well known that different stars are seen at different times of the year. Let us notice the stars appearing over our heads in summer. We do not see the *same stars* in the *same place* until the *following* summer. Now since the *same stars* are not seen in the *same place* in more or less than a year, we conclude that the earth takes a year to come back to the same place in the heavens, or, in other words, *the earth revolves round the sun once a year.*

97. And just as the earth's rotation marks off day and night, the revolution of the earth round the sun

marks a year. And so, as an eminent writer remarks, the "earth is our great time-keeper."

### 8. The Plane of the Equator and the Plane of the Ecliptic.

98. In par. 79 you were directed to tie a piece of thread round the orange to represent the equator. If we cut the orange in two, the flat surface of each half would be at right angles to the needle. This surface is called the *Plane of the Equator*, and is at right angles to the earth's axis. Now get a circular vessel nearly full of water. Put a saucer or small plate containing a piece of candle or a small lamp in the middle, to represent the sun. Near the side immerse the orange up to the thread, holding it upright by means of the long needle, so that the plane of the equator and the surface of the water will be in the same plane, and at right angles to the axis of the orange (*earth*). Move the orange round the lamp as directed in par. 71. The path of the orange in the water will represent the earth's orbit, and the level surface of the water will show what is termed the *Plane of the Ecliptic*, which we suppose to be in a line with the Plane of the Equator; in which case the earth's axis is perpendicular.

### 9. Degree of Inclination.

99. Now let us notice the effect of this coincidence of planes on the alternation of day and night. The axis being upright, no part of the earth's surface would change its *degree of inclination* to the sun, and consequently day and night would be of equal duration all the year round. But we know they are only equal at the equator, and that the farther we go north or south of the equator the greater is the difference in the length of day and night, until at the poles the sun is visible above the horizon for six months, but never

rises at all during the following six months. In England, for instance, in summer the days are long, and the nights short, while in winter the reverse is the case.

100. How can we account for this inequality in the duration of day and night? We have seen that so long as the earth's axis is perpendicular to the plane of its orbit, the days and nights are necessarily equal all the year round. But they are not equal. The earth's axis, then, is not perpendicular to the plane

of its orbit; *i.e.*, it must be *inclined*. (See accompanying figure of terrestrial globe.) The angle of inclination necessary to produce the inequality of day and night is 23½ degrees, and it is this oblique position of the earth's axis to the plane of its orbit that causes the varying length of day and night at different seasons of the year.

101. Let us illustrate this. Recurring to the illustration (par. 71), instead of holding the orange upright, suppose we incline the needle (*axis*) a little to the right away from the lamp (*sun*). You now see that the point at the top (*north pole*) of the orange is in darkness, that at the bottom (*south pole*) is lighted up. Now turn the orange round (to show the *rotation of the earth*), and you will see that although exactly half the orange is always lighted up, the part round the needle at the top (*north pole*) never comes into the lighted up half at all, while the opposite part (*south pole*) is never in the dark half; that is, so long as the earth remained in that position, it was always night at the north pole and day at the south pole.

### 10. Circle of Illumination.

102. Keeping it still in the same place, put a pin in the thread line (*equator*) just where the line between the light and dark halves of the orange cuts it. (This line is called the *Circle of Illumination*, and of course is continually changing at the rate of 15 degrees an hour.) Turn the orange round as before, and you will see that it is just as long in the light as it is in the dark; *i.e.*, the day and night are equal in that place. Remove the pin nearer the top, say half-way, and you will find that it takes longer to go round the dark than the light side; *i.e.*, the night is longer than the day. Now put the pin in the corresponding position in the lower half (*southern hemisphere*), and in this case you see it is longer in the light than in the dark; *i.e.*, the day is longer than the night. If you put the pin close to the needle at the top of the north pole, you will find that so long as the orange is in that position, the pin is in the dark; while if you put the pin in the opposite part (*south pole*) it is always lighted up.

103. In this position, then, the days and nights are equal at the equator, while the days get gradually shorter and the nights longer as you approach the north pole, and the reverse as you approach the south pole.

## III. THE SEASONS.

104. The obliqueness of the earth's axis, then, fully accounts for the varying duration of day and night in different parts of the world.

105. We have illustrated this point on the supposition that the earth only rotated upon its axis. We have proved to you that the earth revolves round the sun. And its motion is such that its axis always points in the same direction, and is therefore parallel to itself in every part of its orbit.

106. Since, therefore, the earth's axis is not perpendicular but oblique, the effect of the sun upon the earth must be very different. In the former case, day and night would be equal all the year round, and there would be no change of seasons; in the latter case, day and night are unequal (except at or near the equator), and a regular succession of seasons takes place.

107. These facts, then, lead us to infer that the different seasons are caused by the varying lengths of day and night at different periods of the year. Thus in summer days are long, in winter they are short; therefore, it must be that the long days make it summer, and short days winter; for in the former the sun is longer *above* than below the horizon, and therefore heat accumulates as it were; in the latter the sun is longer *below* than above the horizon—*i.e.*, the nights are so much longer than the day that the heat imparted during the short day is lost during the long night.

108. You know there are four seasons, at least in

the temperate zones, viz., spring, summer, autumn, and winter. In equatorial countries, we may say two, viz., the wet and dry seasons. We propose to consider and illustrate the relative position of the earth and the sun during the year, showing how the seasons are due to the obliqueness of the earth's axis, and consequent variation in the length of day and night.

109. The earth in its revolution round the sun is not always at the same distance from it, its mean distance being 91,000,000 miles. Its orbit, then, is not circular but elliptical, being nearest to the sun in summer and farthest in winter. The difference in distance, however, is quite inappreciable, and does not affect the earth enough to be included among the causes of the change of seasons.

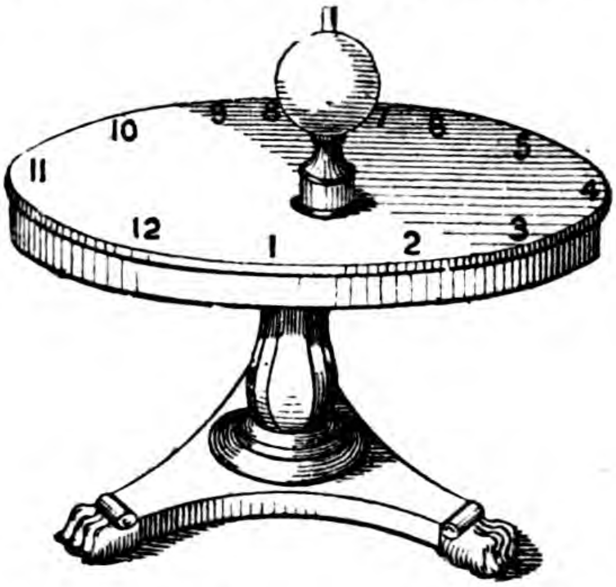
### 1. Equinoxes.

110. Place a small lamp or candle in the centre of a round table. Stick a long needle through a ball, in such a manner that the flame of the lamp will be in a line with the middle of the ball when upright. Incline the top a little to the right and move it right round the lamp, keeping the top end of the needle pointing in the same direction. During the revolution the ball's (*earth's*) axis will be parallel to the lamp's (*sun's*) axis twice; *i.e.*, each of the poles will be equally distant from the sun. Twice a year, then, day and night will be equal all over the world. This, we know, takes place about March 21st, and September 23rd, the former, in the northern hemisphere, being termed the *Vernal* or *Spring Equinox*, the latter the *Autumnal Equinox*.

111. Let us now consider the earth's *annual motion* more closely. To form clear and definite ideas, instead of an orange or ball to represent the earth, you should get an artificial globe, with the greater and

lesser circles, at least, marked. A thin iron rod or long needle should be passed through the centre, to show the earth's axis. This rod should stick out at each end, so that you can turn the globe round by means of the upper end, while the lower end rests on the table. The lower end should be long enough to make the middle of the globe to be in a line with the centre of the lamp representing the sun.

112. You have already been told that the earth's orbit is elliptical, and is situate in an imaginary plane passing through the centre of the sun, called the *plane of the*




*ecliptic.* It is so called because there can be no eclipses except when the moon is in or very near it. You have also seen that the earth's axis is not perpendicular to the plane of its orbit, but oblique at an angle of $23\frac{1}{2}°$, and further that the poles always point in the same direction in the heavens, so that the earth's axis is parallel to itself in all parts of its orbit. Bearing these facts in mind, you will be able to make the illustrations more accurate, and so form clearer ideas of the vicissitudes of the *seasons.*

113. You must imagine yourself an observer in

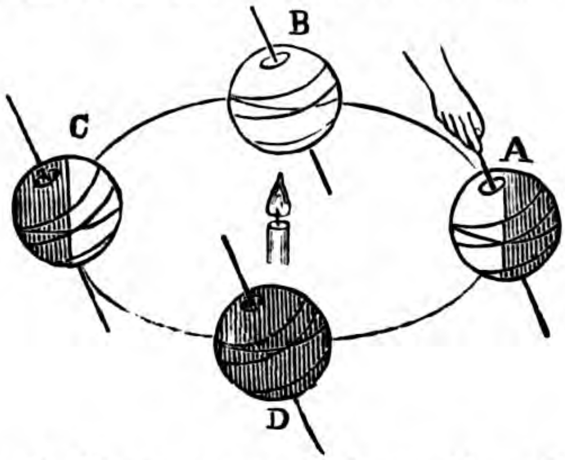
space right above the plane of the ecliptic, of which the sun is the centre, and in which the orbit of the earth lies. In these illustrations you should get a *low* round table, so that you may look down on the globe and the lamp. Draw a line round the edge of the table, to represent the earth's orbit. Of course you must not think that the surface of the table actually represents the plane of the ecliptic; you must imagine a plane passing through the centre of the lamp (*sun*) and the globe (*earth*). The same remark applies to the line showing the earth's orbit. Divide this line into twelve equal parts, representing the twelve months, and write the figure 1 on the mark nearly opposite the lamp on the nearest side of the table, then 2, 3, 4, etc., up to twelve.

114. Inclining the needle a little to the right, and moving the globe round the lamp to represent the revolution of the earth round the sun, you will see that the two ends of the needle are at the same distance from the lamp twice, thus illustrating what we showed before (par. 110), that at two opposite points in its orbit the poles are equi-distant from the sun; that is, the earth neither inclines to nor declines from the sun. Consequently the *circle of illumination* will pass through the poles twice a year, viz., on March 21st and September 23rd; and this being the case, day and night are equal all over the world. Hence these points are called *Equinoxes;* the former, the *Vernal* or *Spring Equinox;* the latter, the *Autumnal Equinox*—*i.e.*, in the northern hemisphere.

### 2. Spring—Autumn.

115. To begin: Place the lamp in the centre of the table, and the globe on mark 1 (March 22nd). Holding he globe by means of the needle at the north pole,

incline it a little to the right. This shows the inclination of the earth's axis to the plane of the ecliptic. Looking *down* on the globe. you see that exactly half the Arctic circle is in the light and half in darkness; that is, the circle of illumination passes right through the poles. Move the globe slowly to the next mark 2 (April). By this time more than half the Arctic circle is in the light, or, in other words, the north pole *inclines* a little *to* the sun, while the south pole *declines from* it exactly as much. Move the globe to the next mark 3 (May), and you see that nearly all the Arctic circle is within the circle of illumination; that is, the north pole inclines more and more to the sun, while




the south pole declines as much from it. So that the days have been gradually getting longer in the northern hemisphere, and shorter in the southern. Consequently, heat gradually accumulates as it were in the northern hemisphere, and as gradually diminishes in the southern hemisphere. Hence it is *spring* in the former, and *autumn* in the latter. (See fig.—D.)

### 3. Summer—Winter.

116. Proceeding further, the circle of illumination takes in more and more of the Arctic circle, until on arriving at mark 4 (June 21st; *vide* fig.) the whole of

the Arctic circle is in the light; and, consequently, June 21st is the longest day in the northern and the shortest in the southern hemisphere. The heat which had gradually accumulated in the northern hemisphere, as gradually diminished in the southern hemisphere, so that it is *summer* in the former, and *winter* in the latter; and this point in the earth's orbit is called the *summer solstice* (see fig.—A) in the northern hemisphere, and *winter solstice* in the southern hemisphere.

117. Now move the globe slowly to mark 5 (July). Instead of the north pole inclining more and more to the sun as before, the reverse is the case; while the south pole, instead of declining as heretofore, now inclines a little to the sun. Looking at the Arctic circle, you see that it is not all within the circle of illumination, but about as much as in May. Move the globe still further to mark 6 (August), and you see that the north pole declines still more from the sun, while the south pole inclines just as much to it; and if you notice very closely, you will see that just as much of the Arctic circle is in the light as was the case in April.

118. Therefore it is *summer* in the northern and *winter* in the southern hemisphere.

119. Moving the globe still further to mark 7 (Sept. 23rd), the north pole has gradually declined from the sun until on Sept. 23rd the circle of illumination passes through the poles as on March 21st; consequently day and night are equal all over the world. The earth then is at the *autumnal equinox* (see fig.—B), and its course from March to June is marked by the gradual inclination of the north pole to the sun, and corresponding declination of the south pole from it. From June to September just the reverse; that is, gradual declination of the north pole from the sun, and corresponding inclination of the south pole—*i.e.*, spring

gradually merging into summer, and summer into autumn in the northern hemisphere; autumn gradually merging into winter, and winter into spring in the southern hemisphere.

120. Proceeding further, we see that the north pole declines still more from the sun until at mark 10 (Dec. 21st) the whole of the Arctic circle is in darkness; that is, *autumn* in the northern hemisphere is gradually merging into winter, and therefore this point is called the *winter solstice* (see fig.—c), while in the southern hemisphere *spring* is gradually merging into *summer*.

121. Then from mark 10 to mark 1—*i.e.*, Dec. 21st to March 21st—the north pole inclines more and more to the sun until on March 22nd the circle of illumination again passes through the poles. From December to March then is *winter* in the northern, and *summer* in the southern hemisphere.

122. We hope that you have observed the north pole very carefully during this illustration of the earth's revolution round the sun, as the change of seasons depends entirely upon its inclination and declination from the sun, and consequent varying length of day and night. The longer the day the more heat accumulates, and the longer the night the more heat is lost; so that we have long days and short nights in summer, but short days and long nights in winter.

## IV. THE MOON.

123. We have now to direct your attention to the moon, the nearest of all the heavenly bodies, and with the exception of the sun, the most useful to us.

### 1. Does the Moon move?

124. In paragraph 64 the earth's motion was shown to be apparent only. Now what of the moon? Look at

it some evening at a certain time, and notice the stars near it. Take a piece of paper and draw a small circle to represent the moon. Now mark, as well as you can, the relative position of the stars around it. You must be careful to show the star-groups *nearest* to the moon very clearly, so that they may be readily recognised on further reference. On the following evening, at the same hour, observe the moon again and make a similar sketch of its position among the stars. Compare the two drawings. The star-groups nearest to the moon in the first drawing are seen considerably to the east of it in the second, while those nearest the moon in the latter are some distance to the west of it in the former. So that the moon has apparently moved a considerable distance to the east among the stars. But has it really moved? You say the sun appears to move, but it has been proved that it does not move. The moon also appears to move, but it may be that its motion, like that of the sun, is only apparent.

125. How can we determine this? The sun's motion has been proved to be apparent only by observing it with reference to other planets besides the earth, and since we find that it does not change its position with regard to these, we reasonably conclude that the sun does not move. In the same manner, by observing the relative positions of the moon and other heavenly bodies, we conclude that the moon not only appears to move, but does actually move; and further, that its motion is eastward like that of the earth.

## 2. How does the Moon move

126. Having thus proved that the moon really moves, the next question is, how does it move? Does it move round the sun in an orbit parallel to that of

the earth, or does it move directly round the earth as centre? We can determine this by noticing its *phases*.

127. You know that at one time the moon is round or "full moon;" at another time "half moon;" at another "new moon." Now, the moon is about 240,000 miles from the earth. Suppose it to be always that distance further from the sun than the earth. Then it would be the same as the exterior planets, *i.e.*, it would always appear round or full. But we know very well it is not always full, but "waxes" and "wanes" alternately.

128. So that these *phases* cannot be produced if the moon revolves round the sun in an orbit parallel to that of the earth. Therefore we conclude that the moon does not move directly round the sun, and so we infer that it moves round the earth as centre, accompanying it in its revolution round the sun.

129. But will this account for and produce the various phases of the moon? Let us see. Place the lamp and globe on the table as before, to represent the sun and the earth. Get a small ball of thread or wool; unwind a little to suspend the ball by. This ball will represent the moon. We must here remind you that the moon has no light of its own, but simply reflects the light of the sun: if it had light of its own it would always appear round like the sun. You must imagine that you can see only the lighted-up part of the ball. Now let us notice the effects of the sun's rays on the moon *as seen from the earth*.

130. Suspend the ball (*moon*) exactly between the globe (*earth*) and the lamp (*sun*). The half of the ball (*moon*) opposite the lamp (*sun*) will be illuminated, the half opposite the globe (*earth*) will be dark; *i.e.*, no moon will be visible from the earth at that time (*new*, see fig.) Move the ball slowly round. After a little, you

see a thin crescent of light (*i.e.*, *horned;* see fig.). Half the moon is of course lighted up as at first, but only a very small portion of this light is seen from the earth. Move it a little further round, and place your eye where the globe is. You can only see half of the light side, *i.e.*, half moon (*first qr.;* see fig.). Proceeding still further, you see three-fourths of the light side (*gibbous;* see fig.), and at length you see the whole of the illuminated side, *i,e.*, full moon (see fig.).

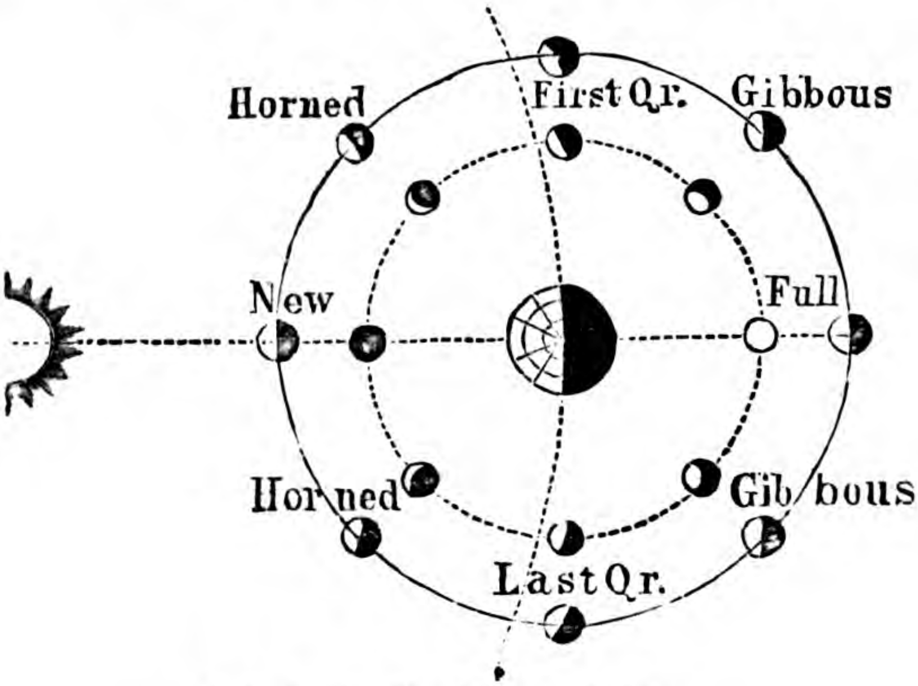



Fig. showing the phases of the Moon.

131. In moving then from "new" to "full" the part of the illuminated side seen from the earth increased gradually, *i.e.*, the moon "waxed" from new to "full."

132. We have now illustrated the moon's motions and appearance in half its orbit, from "new" to "full." Let us consider it from "full" to "new." The lighted-up side appears to decrease gradually as we move the ball slowly round, being "gibbous" (see

fig.) at the point opposite "horned." Moving it still further, it becomes "half-moon" (*last qr.;* see fig.), then "horned," while at "new moon" the whole of the side opposite the earth is dark. The inside figures in the diagram referred to show the moon as seen from the earth—the outside as seen from the sun. In the former, the portion of the lighted-up side seen from the earth increases and decreases alternately, although exactly half the moon is always lighted up.

133. So that in moving from "full" to "new" the part of the moon's illuminated side seen from the earth decreased gradually, *i.e.*, the moon "waned" from "full" to "new."

134. The appearance of the ball in revolving round the globe is exactly the same as that of the moon, so that the moon must revolve round the earth as the earth revolves round the sun.

135. Further it has been found that the moon rotates on its axis, not once a day like the earth, but that it takes as long to rotate once on its axis as it does to revolve once round the earth, viz., in 29½ days. And since it turns only once upon its axis, the lunar days will be as long as 29½ of our days of twelve hours each; the lunar nights will be equally long. During the former, the sun's rays will be constantly pouring, as it were, on one half the moon's surface for nearly 250 hours, and the heat thus accumulated will be very great, but will be almost if not entirely lost during the equally long night.

### 3. Eclipse of the Sun.

136. We have now proved that the moon revolves directly round the earth, and rotates on its axis in nearly the same time. Let us illustrate eclipses of the sun and moon.

137. Suspend the ball representing the moon be-

tween the lamp and the globe near the latter. You see that the dark side of the moon is towards the earth, *i.e.*, it is "new" moon (see fig.). Notice the shadow cast by the ball on the globe. You see that it consists of a dark centre, surrounded by a lighter shade. This lighter shade is called the *penumbra.*

138. Remove the globe, and place your eye where the darker portion of the shadow was. You cannot see the lamp, that is, there is a *total eclipse* of the sun in that part of the earth where the dark portion of the moon's shadow falls. Now place your eye in the position of the penumbra. You can just see part of the

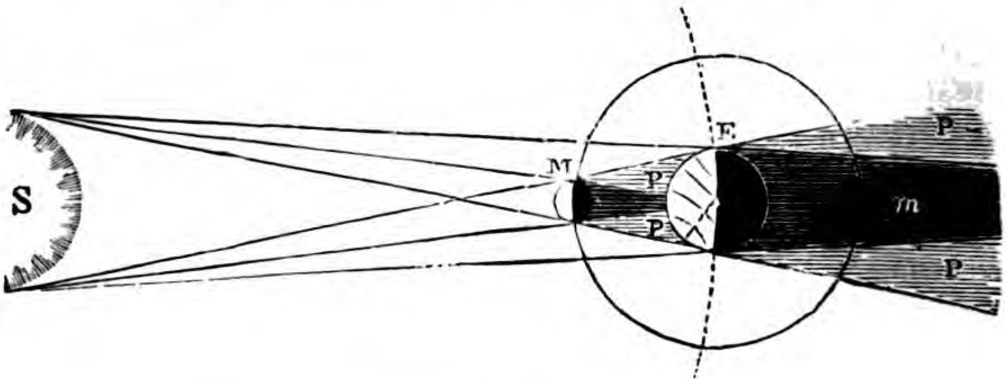



Fig. showing Eclipses of the Sun and Moon.

lamp, that is, in all places within the penumbra there is a *partial eclipse* of the sun ; while if you place your eye anywhere outside the penumbra, you can see the whole of the lamp, that is, there is no eclipse in places outside the moon's shadow.

139. Now move the ball further away from the globe, so that the shadow is not long enough to reach the globe; remove the globe and place your eye exactly opposite the middle of the moon. You do not see all the lamp, you only see a ring as it were of light surrounding the ball. This is called an *annular eclipse.*

140. So that when the moon is between the earth

and the sun, *i.e.* " new moon," (see fig.—M) we have, *total, partial* or *annular eclipses of the sun.*

4. Eclipse of the Moon.

141. Now remove the ball and let the lamp's rays fall on the globe. Notice the shadow cast by the globe. Move the ball round; when it enters the globe's shadow it is waxing into "full." But when in the shadow, the lamp's rays are prevented from shining upon it by the globe, and as the moon has no light of its own, we cannot see it while passing through the earth's shadow, that is, there is an *eclipse of the moon.*

142. So that when the moon is on the side of the earth farthest away from the sun, *i.e.*, at "full moon" (see fig.—*m*) there is or ought to be an *eclipse* of the moon, but when between the earth and sun, *i.e.*, at "new moon" there is or ought to be an eclipse of the sun.

143. Then if the plane of the moon's orbit coincides with the plane of the ecliptic at each "new moon" (*i.e.*, when the moon passes between the earth and the sun), there will be an eclipse of the sun, and at each "full moon" (*i.e.*, when the earth is between the moon and the sun), there will be an eclipse of the moon. So that we would have two eclipses, one of the sun and one of the moon, every 29½ days.

144. Is this the case? No. We have no more than four or five eclipses in a year, while if the planes of the moon's orbit and that of the ecliptic coincide, we ought to have twenty-four eclipses, twelve of the sun and twelve of the moon. But we know this is not the case. For instance, this year (1877) there will be only five eclipses—three total eclipses of the moon and two partial eclipses of the sun; the latter invisible at Greenwich. Total eclipses

of the sun are of very rare occurrence, none having been visible in London since the year 1715.

145. The fact is, the plane of the moon's orbit does not coincide with the plane of the ecliptic, but cuts it at an angle of 5°. The points at which these planes cut each other are called *nodes*, and the line between them, the *line of nodes*. Eclipses of the sun or moon can only happen when the moon passes through or near one of these nodes, and then only when it is in a line with the earth and sun.

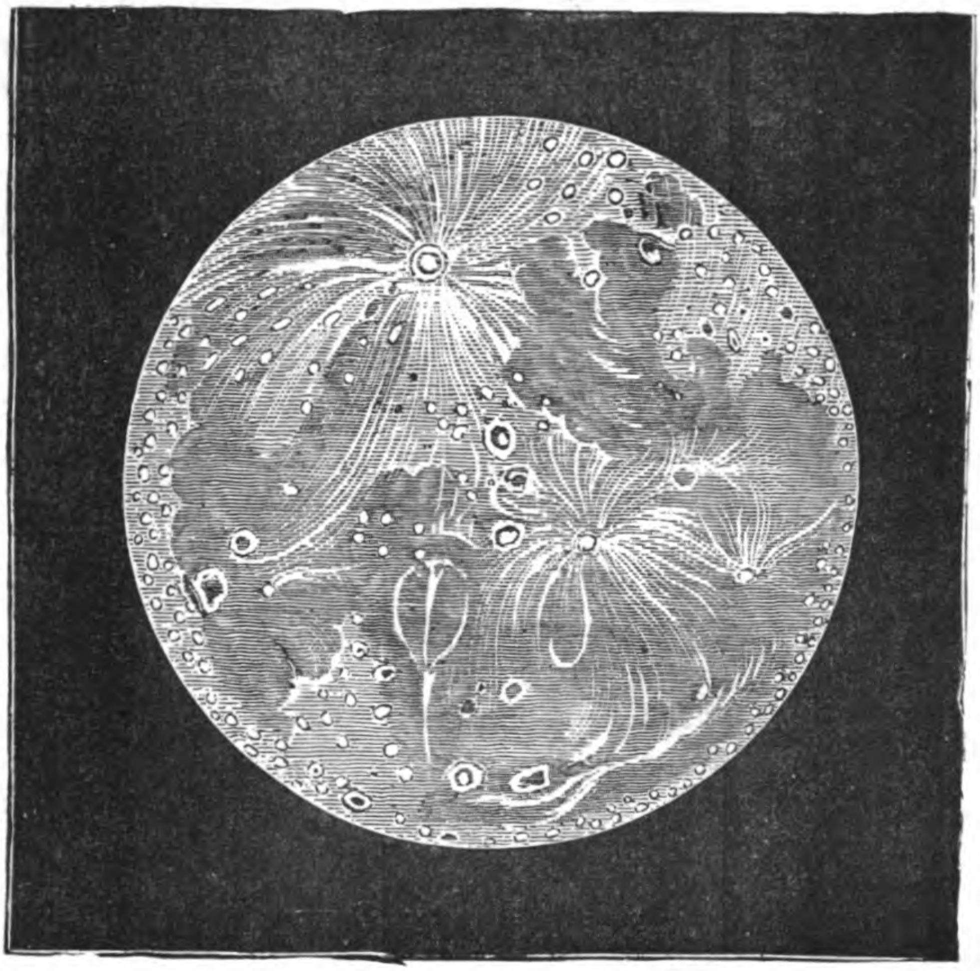
### 5. The Appearance, Distance, and Dimensions of the Moon.

146. Having thus considered the moon in its relation to the earth and sun, let us now examine it more closely as to its appearance, distance, and dimensions.

147. First its *appearance*. To the naked eye some portions of it seem dark, so that its surface appears mottled. These dark spots have given rise to many fanciful stories, and in olden times were thought to be seas. But on looking through a telescope, the whole surface seems to be covered with mountains, isolated peaks and continuous ranges, varying in height from hundreds to tens of thousands of feet, enclosing deep valleys and level plains. No water has been seen, no sign of vegetation, even no air, and consequently no clouds, rain, snow, or dew.

148. But the most remarkable features are the circular ranges of mountains rising in height from a few hundred to twenty or thirty thousand feet, enclosing plains of from one or two to forty or fifty miles in diameter, and in the centre an isolated cone rising to a considerable height. These circular ranges are thought to be huge craters of immense extinct volcanoes, and are seen in almost all parts of the moon.

149. The bright places seen with the naked eye are the elevated portion of the moon's surface; the darker parts are the plains and valleys. The light reflected by the moon is only about $\frac{1}{250000}$ of that of the sun.



Telescopic appearance of the Moon.

150. We always see the same side of the moon, which proves that it takes just as long to turn once on its axis as it does to revolve once round the earth. For if it did not rotate at all we should see both sides alternately, or if it rotated upon its axis either slower or quicker than it actually does, we should see both

sides, or one side and part of the other. But its rotation once in $29\frac{1}{2}$ days keeps the same side always towards the earth.

151. To an observer on the moon, the earth would look about thirteen times as large as we see the moon, and it would also show the same phases as the moon. We can see the light of the sun reflected from the earth on the moon if we look at the latter with a telescope about eight or ten days after "new moon."

152. Now how far do you think the moon is? You know the earth's diameter is 8,000 miles; the distance of the moon from the earth is thirty times the earth's diameter, or 240,000 miles.

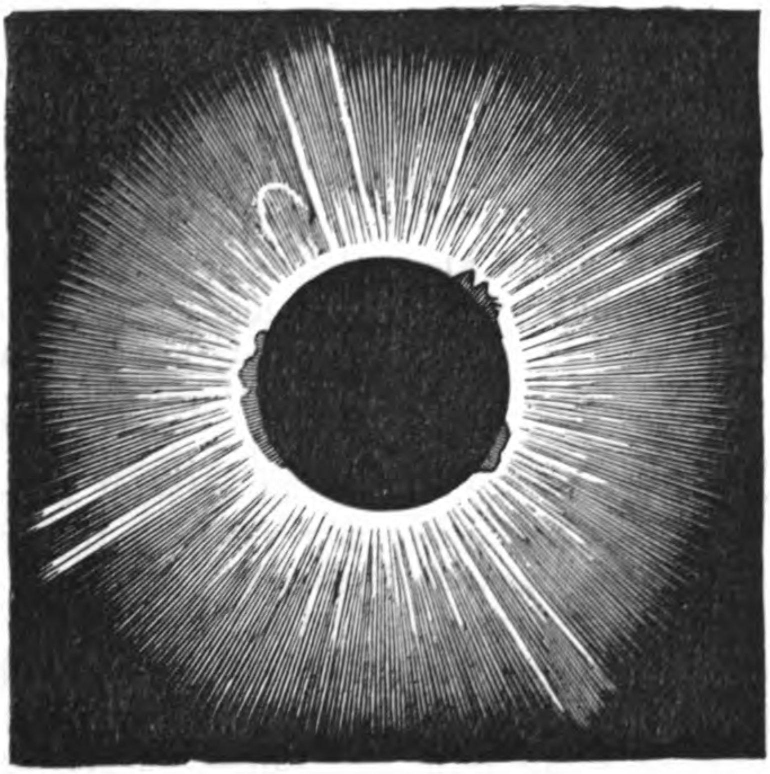
153. The moon's diameter is a little over 2,000 miles, or a fourth less than the earth's, and its superficial area is about 15,000,000 square miles, or thirteen times less than the earth's, which is 197,000,000 square miles.

## V. PLANETARY SYSTEM.

154. In the preceding chapters we have shown how the earth revolves round the sun, while the moon revolves directly round the earth, and indirectly in company with the earth round the sun. Besides the earth and moon there are many other bodies revolving round the sun as centre. These bodies, like the earth, are called *planets*, while other smaller bodies, like the moon, that revolve directly round some of the planets, are called *satellites* or moons. All these bodies form what is called the *planetary system*, and of this system the sun is the centre; it is, therefore, also called the *solar system*. Before proceeding to consider it more closely, we shall first direct your attention to the sun, and present you with a few facts relating to that great luminary.

## 1. The Sun.

155. First its distance. Its mean distance is 91,000,000 miles. Supposing a steamer travelling at the rate of 200 miles a day, it would take 13,000 years to travel from the earth to the sun. Its diameter, which is deduced from its distance, is about 150,000 miles. Its magnitude is such that it would require a million and a half of globes equal in size to our earth to form



Halo or Aureole round the Sun during Eclipse.

a body equal to the sun, which is 500 times greater than all the planets together. This, then, is the key-note, as it were, to all the grand, regular, unceasing movements of the planets; the common centre (*the sun*) having such immense attractive power, keeping the furthest planet in its orbit as easily as a ball is held by the string when whirled round the finger.

156. Now as to its heat and light. The great sun is not a cool body like the earth, but is a globe of the most intense heat—we might say a globe of fire, the hardest metals existing only in a vapoury or gaseous state. This immense heat and accompanying light is distributed all over the solar system, rendering the various planets habitable. The sun thus shines by its own light, and is always seen of a globular form; unlike the moon, which is a dark, cool body of itself, and although it gives light, you would not for a moment think of asserting that it gives out heat also. But the sun gives both heat and light. Its rays have been analyzed, and it has been found that the red rays are the conveyers of heat, and the yellow rays of light. By means of the spectroscope learned men are able to tell us what the sun and other bodies are made of. They tell us that many of the metals found on the earth exist also in the sun, but not in a solid state—the intense heat decomposing everything into vapour or gas.

157. You cannot and must not attempt to look at the sun with the naked eye, nor yet with the common telescope, or very serious consequences might ensue. In examining the sun, darkened glasses and special apparatus have to be used. But sometimes when just setting you can look at it. The round globe that you see is not all there is of the sun—you see only the central denser part, which is called the *photosphere*. The lighter vapours, called the *chromosphere* and *coronal atmosphere*, spread out into space for hundreds of thousands of miles, and we can only see them during an eclipse of the sun. (See fig., page 53.)

## 2. Sun-spots—Faculæ.

158. We have already proved that the sun's motion from east to west is only apparent; but although the sun does not revolve in an orbit, yet it rotates on its axis. How can we prove this? Very easily. Place the lamp in the middle of the table, to represent the sun. Dip your finger in the ink and make one or two spots on the globe of the lamp. Now imagine yourself to be the earth. Walk round the table, to represent the revolution of the earth. Keep your eye on the largest spot on the globe of the lamp. Stand exactly opposite it. Now move round to the right, and you see that the spot has moved apparently to the left, and it is out of sight when you have gone a fourth of the distance round the table. You go round, and it just appears when you are at the opposite side. So that the spot is in view only half the distance round the table.

159. Now there are dark spots often seen on the sun's surface, called *sun-spots;* the parts near them, called *faculæ*, being extremely bright. We will suppose the sun does not move, and after fixing upon one of the largest of these spots we examine it. According to the above illustration this spot ought to be seen from the earth for six months, and then disappear for the other six months. Is this the case? No. For if a large sun-spot be closely observed it will be seen to travel right across the sun from east to west in about twelve and a half days, disappearing on its western side, and twelve and a half days after, it will again appear on its eastern side, thus proving most clearly that the sun has turned round on its axis in that time.

160. So that *the sun rotates on its axis in about twenty-five days.*

## 3. General Arrangement of the Solar System.

161. Having thus considered both separately and relatively the three most important (to us) bodies in the solar system, viz., the earth, the moon, and the sun, we shall now direct your attention to the general arrangement of the system, and to the other members of the solar family, so to speak. As it is very difficult to represent the various movements of the heavenly bodies by means of such simple apparatus as the orange, ball, and lamp, you must try to form some idea of the same by means of drawings. In the centre of a sheet of drawing or other paper not ruled, draw a small circle, to represent the sun, and mark it with the letter S. With S as centre describe another circle, to represent the orbit of the earth (E). Then a small circle round E, to show the moon's (M) orbit.

162. Now you can easily see that if there were any bodies revolving round the sun nearer to it than the earth, their orbits would be *inside* that of the earth, while the orbits of bodies further off from the sun than the earth would be *outside* that of the earth.

163. You have been told that all bodies revolving directly round the sun like the earth are called *planets.* Therefore those planets whose orbits are inside that of the earth may be called *interior planets;* while those whose orbits are outside that of the earth may be called *exterior planets.*

164. Some of these planets have moons which revolve round them as our moon does round the earth.

165. But besides the sun, the planets and their moons, which all move in regular paths or orbits nearly in the same plane (that of the ecliptic), there are other luminous bodies called *comets*, some of which seem to revolve round the sun in very eccentric orbits ; others seem to pay a flying visit, as it were, to the solar

system, and then plunge into the vast regions of space, probably never to return.

### 4. Interior Planets.

166. Let us first take the interior planets, that is, those whose orbits are inside that of the earth. There are two interior planets, viz., Mercury and Venus.

167. *Mercury* is the nearest planet to the sun yet discovered.* It revolves round the sun in eighty-eight days at a distance of 37,000,000 miles. Its diameter is 3,200 miles. It is not often seen with the naked eye, because of its nearness to the sun. It rotates on its axis in about twenty-four hours, and goes through the same changes as our moon.

168. The next is *Venus*, revolving round the sun in 224 days at a distance of 68,000,000 miles. Its diameter is 7,700 miles, and it rotates on its axis in twenty-three hours and ten minutes; consequently the length of day and night is nearly the same as on the earth. Venus is the brightest of all the planets, and is called the morning and evening star, according to the time it is visible. Its least distance from the earth, *i.e.*, when it is in a line with and between the earth and the sun, is 27,000,000 miles, and its greatest distance, *i.e.*, when it is on the other side of the sun, and in a line with the earth and the sun, is 163,000,000 miles. Like Mercury and our moon, it presents different appearances or phases. This proves that the two planets are cool bodies like the earth, and only reflect the light of the sun.

169. Both Venus and Mercury pass between the earth and the sun, and cause eclipses. As in the case of the moon, these only happen when the planet is passing through or near one of its nodes. When this

* Some assert that there is a planet, named *Vulcan*, nearer to the sun than Mercury.

s the case, the dark body of the planet is seen passing across the sun's disc. This is called the *transit* of Venus, or Mercury; the last transit of the former took place in 1874, the next will happen in 1882, and again in the year 1987.

170. Next in order is the *Earth*, which has already been described, but for the sake of comparison we shall repeat a few facts. Its diameter is nearly 8,000 miles, and it revolves round the sun in 365¼ days at a mean distance of about 91,000,000 miles. Its diurnal motion on its own axis is performed in twenty-three hours fifty-six minutes.

### 5 Exterior Planets.

171. Then we have the *exterior* planets, *i.e.*, those whose orbits are outside that of the earth.

172. The nearest of the exterior planets is *Mars*, which revolves round the sun in one year and ten months, at a distance of 145,000,000 miles. Its diameter is 4,200 miles, or more than half that of the earth. It can be easily distinguished by its peculiar redness, which is due to its dense atmosphere. I rotates on its axis in twenty-four hours forty minutes. It is 50,000,000 miles distant from the earth when nearest, and 240,000,000 when farthest. White spots are seen at its poles and disappear alternately. These are supposed to be snows covering its poles in winter and melted away in summer. It moves at the rate of 55,000 miles an hour.

173. Next are the *Asteroids*, a number (about 150) of small planets revolving between the orbits of Mars and Jupiter. The principal are *Ceres*, *Pallas*, *Juno*, and *Vesta*, but from their comparative smallness, are scarcely ever to be seen with the naked eye.

174. Beyond the Asteroids is *Jupiter*, revolving

round the sun in about twelve years at a distance of 476,000,000 miles. Jupiter is the largest planet in the solar system, its diameter being about 87,000 miles. Its polar diameter is less than its equatorial by about 6,000 miles. When examined through a telescope various spots are seen, from the movements of which its time of rotation has been determined. It is crossed by several dark belts which are continually varying in breadth and number; sometimes only one is seen; at other times the whole surface seems covered with them. They are supposed to be openings in the clouds which envelope the body of the planet. Jupiter is attended by four moons or satellites. All these, except the fourth, cause eclipses, and are themselves eclipsed at each revolution round the planet. Its axis is nearly perpendicular to the plane of its orbit, so there can be scarcely any change of seasons. In size it is 14,000 times larger than our earth.

175. We next come to *Saturn*, which revolves round the sun in 29½ years, at a distance of 872,000,000 miles. Its diameter is about 72,000 miles, or nine times the earth's diameter, and it rotates on its axis in 10½ hours. Its axis is inclined to the plane of its orbit, at an angle of 26½°, so the seasons are similar to ours. It has eight moons, which are rarely eclipsed or cause eclipses like those of Jupiter. But the most remarkable feature of Saturn is the immense luminous triple ring which surrounds it, yet does not touch its surface. They are thousands of miles in breadth, but only 138 miles in thickness, and in certain positions can scarcely be seen.

176. The next planet is *Uranus*, or Herschel, who discovered it in 1781. It is about eighty times larger than the earth, and takes 83½ years to travel round the sun, from which it is 1,800,000,000 miles distant.

177. Then, further still, at the immense distance of

2,800,000,000 miles from the sun, is the most distant planet yet discovered, *Neptune*, about the size of Uranus, and revolving round the sun in about 160 years.

### 6. Comets, Meteorites, Falling Stars.

178. As before stated, there are other bodies in the solar system, known as *comets, falling stars, meteorites.* Comets are known by a reddish bright nucleus, and an immense tail many millions of miles long, or enveloped in mist, as it were; in the centre of which the bright nucleus is distinctly seen. Some, as Eucke's and Halley's comets, belong to the solar system, moving round the sun in very eccentric orbits, and generally in a different direction to the planets.

179. We daresay you have seen what is termed a *falling star* or *meteor*. These *meteors* are little bodies scattered in groups in the space occupied by the solar system, travelling round the sun in elliptical orbits and in a different direction to the planets. Two of these groups or *showers* are seen in August and November, when the earth happens to go through them. Being attracted by the earth, they rush towards it at the rate of over a thousand miles a minute. Entering our atmosphere, heat is developed by friction; they become visible, *i.e.*, begin to burn, at a height of seventy-four miles; but such is the intense heat generated, that they are generally changed into vapour and disappear at a height of about fifty miles. The larger meteors, however, are not entirely burnt up, but fall on the earth's surface as *meteorites* or *aerolites.* These have been examined and found to consist chiefly of metallic iron and various compounds of silica; the proportion of iron varying from 95 to 1 per cent.

180. In representing the solar system, the *relative distance* of each planet from the sun ought to be considered. On, say, a black-board, mark off a square of

forty inches. In the centre draw a small circle to represent the *sun*. With a radius of half an inch describe a circle from centre S; this will show *Mercury's* orbit. One inch from S, *Venus'* orbit; $1\frac{1}{3}$ inch, the *Earth's;* 2 inches, *Mars';* $6\frac{4}{5}$ inches, *Jupiter's;* between Mars and Jupiter, the *Asteroids;* $12\frac{1}{2}$ inches, *Saturn's;* 27 inches, *Uranus';* $39\frac{1}{5}$ inches, *Neptune's.*

181. Now take another board to show their *relative diameters*, by perpendicular lines. At the bottom of the board draw a horizontal line. Draw lines of the various lengths indicated perpendicular to this line. *Mercury*, $1\frac{1}{2}$ inches. *Venus*, $3\frac{3}{4}$ inches. *Earth*, 4 inches. *Mars*, $2\frac{1}{2}$ inches. *Jupiter*, $44\frac{1}{4}$ inches. *Saturn*, 36 inches. *Uranus*, $16\frac{1}{2}$ inches. *Neptune*, $18\frac{1}{4}$ inches. The diameter of the *sun* would be relatively shown by a line 427 inches in height, that is, the line representing the sun's diameter would be more than three times the length of all the others put together.

182. Combining both relative magnitude and distance, Sir John Herschel gives the following illustration:—In the centre of a level plot of about $2\frac{1}{2}$ miles in diameter place a 2 ft. globe, to represent the *Sun:* a grain of mustard-seed revolving in a circle 164 ft. in diameter (*i.e.*, 82 ft. from the centre) will represent *Mercury:* a pea, in a circle of 284 ft. in diameter, will represent *Venus:* another pea at a distance of 215 ft., the *Earth:* a large pin's head in a circle of 654 ft., *Mars:* grains of sand in orbits of from 1000 to 1,200 ft., the *Asteroids:* an orange, in a circle of about half a mile across, *Jupiter:* a small orange in a circle of four-fifths of a mile, *Saturn:* a small plum in a circle of more than $1\frac{1}{2}$ miles, *Uranus:* a good-sized plum in a circle of about $2\frac{1}{2}$ miles in diameter, *Neptune.*

183. As a closing illustration we will give in a tabular form the time in which light, travelling at the rate of 192,000 miles per second, would pass from the sun to the various planets :—

| | | | | | |
|---|---|---|---|---|---|
| From the Sun to | | Mercury | in | $3\frac{1}{3}$ | minutes. |
| ,, | ,, | Venus | ,, | $5\frac{4}{5}$ | ,, |
| ,, | ,, | Earth | ,, | 8 | ,, |
| ,, | ,, | Mars | ,, | $12\frac{1}{2}$ | ,, |
| ,, | ,, | Flora, the nearest of the Asteroids | ,, | 19 | ,, |
| ,, | ,, | Maximiliana, the most distant Asteroid | ,, | $24\frac{1}{2}$ | ,, |
| ,, | ,, | Jupiter | ,, | 43 | ,, |
| ,, | ,, | Saturn | ,, | $78\frac{1}{2}$ | ,, |
| ,, | ,, | Uranus | ,, | 158 | ,, |
| ,, | ,, | Neptune | ,, | 249 | ,, |
| ,, | ,, | Nearest fixed star | ,, | $3\frac{1}{2}$ | years. |
| ,, | ,, | More distant fixed stars | ,, | 50,000 | years. |

184. A singular fact as regards the relative distances of the planets was discovered by Titius, and is known by the name of *Bode's-law*. Thus, putting 0 first, then 3, then doubling each succeeding figure :—

0   3   6   12   24   48   96

and adding four to each:

4   7   10   16   28   52   100

these figures show very nearly the relative distances of the planets from the sun. Of course there is no large planet answering to the fifth figure (28), the space between the fourth and sixth being occupied by the Asteroids.

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