

Young Folks' Library, Volume XI (of 20) eBook

Young Folks' Library, Volume XI (of 20)

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NOTE.

The publishers' acknowledgments are due to Messrs. Houghton, Mifflin & Co., for permission to use "America and the Old World," by L. Agassiz; to Messrs. D.C. Heath & Co. for permission to use "Some Records of the Rocks," by Professor N.S. Shaler; and to Professor E.S. Holden for permission to use "What is Evolution?" and "An Astronomer's Voyage to Fairy Land."

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AND ONE HUNDRED AND SIXTY-FOUR BLACK AND WHITE ILLUSTRATIONS IN THE TEXT.

THE MARVELS OF NATURE

By Edward S. Holden, M.A., Sc.D. LL.D.

The Earth, the Sea, the Sky, and their wonders—these are the themes of this volume. The volume is so small, and the theme so vast! Men have lived on the earth for hundreds of the sands of years; and its wonders have increased, not diminished, with their experience.

To our barbarous ancestors of centuries ago, all was mystery—the thunder, the rainbow, the growing corn, the ocean, the stars. Gradually and by slow steps they learned to house themselves in trees, in caves, in huts, in houses; to find a sure supply of food; to provide a stock of serviceable clothing. The arts of life were born; tools were invented; the priceless boon of fire was received; tribes and clans united for defence; some measure of security and comfort was attained.

With security and comfort came leisure; and the mind of early Man began curiously to inquire the meaning of the mysteries with which he was surrounded. That curious inquiry was the birth of Science. Art was born when some far-away ancestor, in an idle hour, scratched on a bone the drawing of two of his reindeer fighting, or carved on the walls of his cave the image of the mammoth that he had but lately slain with his spear and arrows.

In a mind that is completely ignorant there is no wonder. Wonder is the child of knowledge—of partial and imperfect knowledge, to be sure, but still, of knowledge. The very first step in Science is to make an inventory of external Nature (and by and by of the faculties of the mind that thinks). The second step is to catalogue similar appearances together. It is a much higher flight to seek the causes of likenesses thus discovered.

A few of the chapters of this volume are items in a mere catalogue of wonders, and deserve their place by accurate and eloquent description. Most of them, however, represent higher stages of insight. In the latter, Nature is viewed not only with the eye of the observer, but also with the mind's eye, curious to discover the reasons for things seen. The most penetrating inward inquiry accompanies the acutest external observation in such chapters as those of Darwin and Huxley, here reprinted.

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Now, the point not to be overlooked is this: to Darwin and Huxley, as to their remote and uncultured ancestors, the World—the Earth, the Sea, the Sky—is full of wonders and of mysteries, but the wonders are of a higher order. The problems of the thunder and of the rainbow as they presented themselves to the men of a thousand generations ago, have been fully solved: but the questions; what is the veritable nature of electricity, exactly how does it differ from light, are still unanswered. And what are simple problems like these to the questions: what is love; why do we feel a sympathy with this person, an antipathy for that; and others of the sort? Science has made almost infinite advances since pre-historic man first felt the feeble current of intellectual curiosity amid his awe of the storm; it has still to grow almost infinitely before anything like a complete explanation even of external Nature is achieved.

Suppose that, at some future day, all physical and mechanical laws should be found to be direct consequences of a single majestic law, just as all the motions of the planets are (but—are they?) the direct results of the single law of gravitation. Gravitation will, probably, soon be explained in terms of some remoter cause, but the reason of that single and ultimate law of the universe which we have imagined would still remain unknown. Human knowledge will always have limits, and beyond those limits there will always be room for mystery and wonder. A complete and exhaustive explanation of the world is inconceivable, so long as human powers and capacities remain at all as they now are.

It is important to emphasize such truths, especially in a book addressed to the young. When a lad hears for the first time that an astronomer, by a simple pointing of his spectroscope, can determine with what velocity a star is approaching the earth, or receding from it, or when he hears that the very shape of the revolving masses of certain stars can be calculated from simple measures of the sort, he is apt to conclude that Science, which has made such astounding advances since the days of Galileo and Newton, must eventually reach a complete explanation of the entire universe. The conclusion is not unnatural, but it is not correct. There are limits beyond which Science, in this sense, cannot go. Its scope is limited. Beyond its limits there are problems that it cannot solve, mysteries that it cannot explain.

At the present moment, for example, the nature of Force is unknown. A weight released from the hand drops to the earth. Exactly what is the nature of the force with which the earth attracts it? We do not know, but it so happens that it is more than likely that an explanation will be reached in our own day. Gravity will be explained in terms of some more general forces. The mystery will be pushed back another step, and yet another and another. But the progress is not indefinite. If all the mechanical actions of the entire universe were to be formulated as the results of a single law or cause, the cause of that cause would be still to seek, as has been said.

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We have every right to exult in the amazing achievements of Science; but we have not understood them until we realize that the universe of Science has strict limits, within which all its conquests must necessarily be confined. Humility, and not pride, is the final lesson of scientific work and study.

* * * * *

The choice of the selections printed in this volume has been necessarily limited by many hampering conditions, that of mere space being one of the most harassing. Each of the chapters might readily be expanded into a volume. Volumes might be added on topics almost untouched here. It has been necessary to pass over almost without notice matters of surpassing interest and importance: Electricity and its wonderful and new applications; the new Biology, with its views upon such fundamental questions as the origins of life and death; modern Astronomy, with its far-reaching pronouncements upon the fate of universes. All these can only be touched lightly, if at all. It is the chief purpose of this volume to point the way towards the most modern and the greatest conclusions of Science, and to lay foundations upon which the reading of a life-time can be laid.

[Illustration: Signature: Edward S. Holden]

United states military Academy, west point, January 1, 1902.

WONDERS OF EARTH, SEA, AND SKY

WHAT THE EARTH'S CRUST IS MADE OF

(From the world's foundations.)

By Agnes GIBERNE.

"Stand still and consider the wondrous works of God."

[Illustration]

What is the earth made of—this round earth upon which we human beings live and move?

A question more easily asked than answered, as regards a very large portion of it. For the earth is a huge ball nearly eight thousand miles in diameter, and we who dwell on the outside have no means of getting down more than a very little way below the surface. So it is quite impossible for us to speak positively as to the inside of the earth, and what it is made of. Some people believe the earth's inside to be hard and solid,

while others believe it to be one enormous lake or furnace of fiery melted rock. But nobody really knows.

This outside crust has been reckoned to be of many different thicknesses. One man will say it is ten miles thick, and another will rate it at four hundred miles. So far as regards man's knowledge of it, gained from mining, from boring, from examination of rocks, and from reasoning out all that may be learned from these observations, we shall allow an ample margin if we count the field of geology to extend some twenty miles downwards from the highest mountain-tops. Beyond this we find ourselves in a land of darkness and conjecture.

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Twenty miles is only one four-hundredth part of the earth's diameter—a mere thin shell over a massive globe. If the earth were brought down in size to an ordinary large school globe, a piece of rough brown paper covering it might well represent the thickness of this earth-crust, with which the science of geology has to do. And the whole of the globe, this earth of ours, is but one tiny planet in the great Solar System. And the centre of that Solar System, the blazing sun, though equal in size to more than a million earths, is yet himself but one star amid millions of twinkling stars, scattered broadcast through the universe. So it would seem at first sight that the field of geology is a small field compared with that of astronomy....

With regard to the great bulk of the globe little can be said. Very probably it is formed through and through of the same materials as the crust. This we do not know. Neither can we tell, even if it be so formed, whether the said materials are solid and cold like the outside crust, or whether they are liquid with heat. The belief has been long and widely held that the whole inside of the earth is one vast lake or furnace of melted fiery-hot material, with only a thin cooled crust covering it. Some in the present day are inclined to question this, and hold rather that the earth is solid and cold throughout, though with large lakes of liquid fire here and there, under or in her crust, from which our volcanoes are fed....

The materials of which the crust is made are many and various; yet, generally speaking, they may all be classed under one simple word, and that word is—*Rock*.

It must be understood that, when we talk of rock in this geological sense, we do not only mean hard and solid stone, as in common conversation. Rock may be changed by heat into a liquid or “molten” state, as ice is changed by heat to water. Liquid rock may be changed by yet greater heat to vapor, as water is changed to steam, only we have in a common way no such heat at command as would be needed to effect this. Rock may be hard or soft. Rock maybe chalky, clayey, or sandy. Rock may be so close-grained that strong force is needed to break it; or it may be so porous—so full of tiny holes—that water will drain through it; or it may be crushed and crumbled into loose grains, among which you can pass your fingers.

The cliffs above our beaches are rock; the sand upon our seashore is rock; the clay used in brick-making is rock; the limestone of the quarry is rock; the marble of which our mantel-pieces are made is rock. The soft sandstone of South Devon, and the hard granite of the north of Scotland, are alike rock. The pebbles in the road are rock; the very mould in our gardens is largely composed of crumbled rock. So the word in its geological sense is a word of wide meaning.

Now the business of the geologist is to read the history of the past in these rocks of which the earth's crust is made. This may seem a singular thing to do, and I can assure you it is not an easy task.

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For, to begin with, the history itself is written in a strange language, a language which man is only just beginning to spell out and understand. And this is only half the difficulty with which we have to struggle.

If a large and learned book were put before you and you were set to read it through, you would perhaps, have no insurmountable difficulty, with patience and perseverance, in mastering its meaning.

But how if the book were first chopped up into pieces, if part of it were flung away out of reach, if part of it were crushed into a pulp, if the numbering of the pages were in many places lost, if the whole were mixed up in confusion, and if *then* you were desired to sort, and arrange, and study the volume?

Picture to yourself what sort of a task this would be, and you will have some idea of the labors of the patient geologist.

Rocks may be divided into several kinds or classes. For the present moment it will be enough to consider the two grand divisions—*Stratified rocks* and *Unstratified rocks*.

Unstratified rocks are those which were once, at a time more or less distant, in a melted state from intense heat, and which have since cooled into a half *crystallized* state; much the same as water, when growing colder, cools and crystallizes into ice. Strictly speaking, ice is rock, just as much as granite and sandstone are rock. Water itself is of the nature of rock, only as we commonly know it in the liquid state we do not commonly call it so.

[Illustration: UNSTRATIFIED ROCK.—A VOLCANIC BLOCK.]

“Crystallization” means those particular forms or shapes in which the particles of a liquid arrange themselves, as that liquid hardens into a solid—in other words, as it freezes. Granite, iron, marble, are frozen substances, just as truly as ice is a frozen substance; for with greater heat they would all become liquid like water. When a liquid freezes, there are always crystals formed, though these are not always visible without the help of a microscope. Also the crystals are of different shapes with different substances.

If you examine the surface of a puddle or pond, when a thin covering of ice is beginning to form, you will be able to see plainly the delicate sharp needle-like forms of the ice crystals. Break a piece of ice, and you will find that it will not easily break just in any way that you may choose, but it will only split along the lines of these needle-like crystals. This particular mode of splitting in a crystallized rock is called the *cleavage* of that rock.

Crystallization may take place either slowly or rapidly, and either in the open air or far below ground. The lava from a volcano is an example of rock which has crystallized

rapidly in the open air; and granite is an example of rock which has crystallized slowly underground beneath great pressure.

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Stratified rocks, on the contrary, which make up a very large part of the earth's crust, are not crystallized. Instead of having cooled from a liquid into a solid state, they have been slowly *built up*, bit by bit and grain upon grain, into their present form, through long ages of the world's history. The materials of which they are made were probably once, long, long ago, the crumbings from granite and other crystallized rocks, but they show now no signs of crystallization.

[Illustration: SECTION OF STRATIFIED ROCKS.

a. Conglomerate. b. Pebbly Sandstone, c. Thin-bedded Sandstone, d. Shelly Sandstone, e. Shale. f. Limestone.]

They are called "stratified" because they are in themselves made up of distinct layers, and also because they lie thus one upon another in layers, or *strata*, just as the leaves of a book lie, or as the bricks of a house are placed.

Throughout the greater part of Europe, of Asia, of Africa, of North and South America, of Australia, these rocks are to be found, stretching over hundreds of miles together, north, south, east, and west, extending up to the tops of some of the earth's highest mountains, reaching down deep into the earth's crust. In many parts if you could dig straight downwards through the earth for thousands of feet, you would come to layer after layer of these stratified rocks, one kind below another, some layers thick, some layers thin, here a stratum of gravel, there a stratum of sandstone, here a stratum of coal, there a stratum of clay.

But how, when, where, did the building up of all these rock-layers take place?

[Illustration: THE BEACH IN THE FOREGROUND IS A ROCKY SHELF, THE REMNANT OF THE CLIFF WHICH ONCE EXTENDED OUT TO THE ISLAND.]

People are rather apt to think of land and water on the earth as if they were fixed in one changeless form,—as if every continent and every island were of exactly the same shape and size now that it always has been and always will be.

Yet nothing can be further from the truth. The earth-crust is a scene of perpetual change, of perpetual struggle, of perpetual building up, of perpetual wearing away.

The work may go on slowly, but it does go on. The sea is always fighting against the land, beating down her cliffs, eating into her shores, swallowing bit by bit of solid earth; and rain and frost and inland streams are always busily at work, helping the ocean in her work of destruction. Year by year and century by century it continues. Not a country in the world which is bordered by the open sea has precisely the same coast-line that it had one hundred years ago; not a land in the world but parts each century with masses of its material, washed piecemeal away into the ocean.

Is this hard to believe? Look at the crumbling cliffs around old England's shores. See the effect upon the beach of one night's fierce storm. Mark the pathway on the cliff, how it seems to have crept so near the edge that here and there it is scarcely safe to tread; and very soon, as we know, it will become impassable. Just from a mere accident, of course,—the breaking away of some of the earth, loosened by rain and frost and wind. But this is an accident which happens daily in hundreds of places around the shores.

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Leaving the ocean, look now at this river in our neighborhood, and see the slight muddiness which seems to color its waters. What from? Only a little earth and sand carried off from the banks as it flowed,—very unimportant and small in quantity, doubtless, just at this moment and just at this spot. But what of that little going on week after week, and century after century, throughout the whole course of the river, and throughout the whole course of every river and rivulet in our whole country and in every other country. A vast amount of material must every year be thus torn from the land and given to the ocean. For the land's loss here is the ocean's gain.

And, strange to say, we shall find that this same ocean, so busily engaged with the help of its tributary rivers in pulling down land, is no less busily engaged with their help in building it up.

You have sometimes seen directions upon a vial of medicine to “shake” before taking the dose. When you have so shaken the bottle the clear liquid grows thick; and if you let it stand for awhile the thickness goes off, and a fine grain-like or dust-like substance settles down at the bottom—the settlement or *sediment* of the medicine. The finer this sediment, the slower it is in settling. If you were to keep the liquid in gentle motion, the fine sediment would not settle down at the bottom. With coarser and heavier grains the motion would have to be quicker to keep them supported in the water.

Now it is just the same thing with our rivers and streams. Running water can support and carry along sand and earth, which in still water would quickly sink to the bottom; and the more rapid the movement of the water, the greater is the weight it is able to bear.

This is plainly to be seen in the case of a mountain torrent. As it foams fiercely through its rocky bed it bears along, not only mud and sand and gravel, but stones and even small rocks, grinding the latter roughly together till they are gradually worn away, first to rounded pebbles, then to sand, and finally to mud. The material thus swept away by a stream, ground fine, and carried out to sea—part being dropped by the way on the river-bed—is called *detritus*, which simply means *worn-out* material.

[Illustration: A MOUNTAIN TORRENT.]

The tremendous carrying-power of a mountain torrent can scarcely be realized by those who have not observed it for themselves. I have seen a little mountain-stream swell in the course of a heavy thunderstorm to such a torrent, brown and turbid with earth torn from the mountainside, and sweeping resistlessly along in its career a shower of stones and rock-fragments. That which happens thus occasionally with many streams is more or less the work all the year round of many more.

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As the torrent grows less rapid, lower down in its course, it ceases to carry rocks and stones, though the grinding and wearing away of stones upon the rocky bed continues, and coarse gravel is borne still upon its waters. Presently the widening stream, flowing yet more calmly, drops upon its bed all such coarser gravel as is not worn away to fine earth, but still bears on the lighter grains of sand. Next the slackening speed makes even the sand too heavy a weight, and that in turn falls to line the river-bed, while the now broad and placid stream carries only the finer particles of mud suspended in its waters. Soon it reaches the ocean, and the flow being there checked by the incoming ocean-tide, even the mud can no longer be held up, and it also sinks slowly in the shallows near the shore, forming sometimes broad mud-banks dangerous to the mariner.

This is the case only with smaller rivers. Where the stream is stronger, the mud-banks are often formed much farther out at sea; and more often still the river-detritus is carried away and shed over the ocean-bed, beyond the reach of our ken. The powerful rush of water in earth's greater streams bears enormous masses of sand and mud each year far out into the ocean, there dropping quietly the gravel, sand, and earth, layer upon layer at the bottom of the sea. Thus pulling down and building up go on ever side by side; and while land is the theatre oftentimes of decay and loss, ocean is the theatre oftentimes of renewal and gain.

Did you notice the word "sediment" used a few pages back about the settlement at the bottom of a medicine-vial?

There is a second name given to the Stratified Rocks, of which the earth's crust is so largely made up. They are called also *Sedimentary Rocks*.

The reason is simply this. The Stratified Rocks of the present day were once upon a time made up out of the sediment stolen first from land and then allowed to settle down on the sea-bottom.

Long, long ago, the rivers, the streams, the ocean, were at work, as they are now, carrying away rock and gravel, sand and earth. Then, as now, all this material, borne upon the rivers, washed to and fro by the ocean, settled down at the mouths of rivers or at the bottom of the sea, into a sediment, one layer forming over another, gradually built up through long ages. At first it was only a soft, loose, sandy or muddy sediment, such as you may see on the seashore, or in a mud-bank. But as the thickness of the sediment increased, the weight of the layers above gradually pressed the lower layers into firm hard rocks; and still, as the work of building went on, these layers were, in their turn, made solid by the increasing weight over them. Certain chemical changes had also a share in the transformation from soft mud to hard rock, which need not be here considered.



All this has through thousands of years been going on. The land is perpetually crumbling away; and fresh land under the sea is being perpetually built up, from the very same materials which the sea and the rivers have so mercilessly stolen from continents and islands. This is the way, if geologists rightly judge, in which a very large part of the enormous formations of Stratified or Sedimentary Rocks have been made.

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[Illustration: VIEW IN A CANON.]

So far is clear. But now we come to a difficulty.

The Stratified Rocks, of which a very large part of the continents is made, appear to have been built up slowly, layer upon layer, out of the gravel, sand, and mud, washed away from the land and dropped on the shore of the ocean.

[Illustration: SEA CLIFFS SHOWING A SERIES OF STRATIFIED ROCKS.]

You may see these layers for yourself as you walk out into the country. Look at the first piece of bluff rock you come near, and observe the clear pencil-like markings of layer above layer—not often indeed lying *flat*, one over another, and this must be explained later, but however irregularly slanting, still plainly visible. You can examine these lines of stratification on the nearest cliff, the nearest quarry, the nearest bare headland, in your neighborhood.

But how can this be? If all these stratified rocks are built on the floor of the ocean out of material taken *from* the land, how can we by any possibility find such rocks *upon* the land? In the beds of rivers we might indeed expect to see them, but surely nowhere else save under ocean waters.

Yet find them we do. Through England, through the two great world-continent, they abound on every side. Thousands of miles in unbroken succession are composed of such rocks.

Stand with me near the seashore, and let us look around. Those white chalk cliffs—they, at least, are not formed of sand or earth. True, and the lines of stratification are in them very indistinct, if seen at all; yet they too are built up of sediment of a different kind, dropping upon ocean's floor. See, however, in the rough sides of yonder bluff the markings spoken of, fine lines running alongside of one another, sometimes flat, sometimes bent or slanting, but always giving the impression of layer piled upon layer. Yet how can one for a moment suppose that the ocean-waters ever rose so high?

Stay a moment. Look again at yonder white chalk cliff, and observe a little way below the top a singular band of shingles, squeezed into the cliff, as it were, with chalk below and earth above.

That is believed to be an old sea-beach. Once upon a time the waters of the sea are supposed to have washed those shingles, as now they wash the shore near which we stand, and all the white cliff must have lain then beneath the ocean.

Geologists were for a long while sorely puzzled to account for these old sea-beaches, found high up in the cliffs around our land in many different places.

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They had at first a theory that the sea must once, in far back ages, have been a great deal higher than it is now. But this explanation only brought about fresh difficulties. It is quite impossible that the level of the sea should be higher in one part of the world than in another. If the sea around England were then one or two hundred feet higher than it is now, it must have been one or two hundred feet higher in every part of the world where the ocean-waters have free flow. One is rather puzzled to know where all the water could have come from, for such a tremendous additional amount. Besides, in some places remains of sea-animals are found in mountain heights, as much as two or three thousand feet above the sea-level—as, for instance, in Corsica. This very much increases the difficulty of the above explanation.

So another theory was started instead, and this is now generally supposed to be the true one. What if instead of the whole ocean having been higher, parts of the land were lower? England at one time, parts of Europe at another time, parts of Asia and America at other times, may have slowly sunk beneath the ocean, and after long remaining there have slowly risen again.

This is by no means so wild a supposition as it may seem when first heard, and as it doubtless did seem when first proposed. For even in the present day these movements of the solid crust of our earth are going on. The coasts of Sweden and Finland have long been slowly and steadily rising out of the sea, so that the waves can no longer reach so high upon those shores as in years gone by they used to reach. In Greenland, on the contrary, land has long been slowly and steadily sinking, so that what used to be the shore now lies under the sea. Other such risings and sinkings might be mentioned, as also many more in connection with volcanoes and earthquakes, which are neither slow nor steady, but sudden and violent.

So it becomes no impossible matter to believe that, in the course of ages past, all those wide reaches of our continents and islands, where sedimentary rocks are to be found, were each in turn, at one time or another, during long periods, beneath the rolling waters of the ocean....

* * * * *

These built-up rocks are not only called “Stratified,” and “Sedimentary.” They have also the name of *Aqueous Rock*, from the Latin word *aqua*, *water*; because they are believed to have been formed by the action of the water.

They have yet another and fourth title, which is, *Fossiliferous Rocks*.

Fossils are the hardened remains of animals and vegetables found in rocks. They are rarely, if ever, seen in unstratified rocks; but many layers of stratified rocks abound in these remains. Whole skeletons as well as single bones, whole tree-trunks as well as single leaves, are found thus embedded in rock-layers, where in ages past the animal or

plant died and found a grave. They exist by thousands in many parts of the world, varying in size from the huge skeleton of the elephant to the tiny shell of the microscopic animalcule.

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[Illustration: FOSSIL OF CARBONIFEROUS FERN.]

Fossils differ greatly in kind. Sometimes the entire shell or bone is changed into stone, losing all its animal substance, but retaining its old outline and its natural markings. Sometimes the fossil is merely the hardened impress of the outside of a shell or leaf, which has dented its picture on soft clay, and has itself disappeared, while the soft clay has become rock, and the indented picture remains fixed through after-centuries. Sometimes the fossil is the cast of the inside of a shell; the said shell having been filled with soft mud, which has taken its exact shape and hardened, while the shell itself has vanished. The most complete description of fossil is the first of these three kinds. It is wonderfully shown sometimes in fossil wood, where all the tiny cells and delicate fibres remain distinctly marked as of old, only the whole woody substance has changed into hard stone.

[Illustration: FOOTPRINTS FROM TRIASSIC SANDSTONE OF CONNECTICUT.]

But although the fossil remains of quadrupeds and other land-animals are found in large quantities, their number is small compared with the enormous number of fossil sea-shells and sea-animals.

[Illustration: FOSSIL FOOTPRINTS.]

Land-animals can, as a rule, have been so preserved, only when they have been drowned in ponds or rivers, or mired in bogs and swamps, or overtaken by frost, or swept out to sea.

Sea-animals, on the contrary, have been so preserved on land whenever that land has been under the sea; and this appears to have been the case, at one or another past age, with the greater part of our present continents. These fossil remains of sea-animals are discovered in all quarters of the world, not only on the seashore but also far inland, not only deep down underground but also high up on the tops of lofty mountains—a plain proof that over the summits of those mountains the ocean must once have rolled, and this not for a brief space only, but through long periods of time. And not on the mountain-summit only are these fossils known to abound, but sometimes in layer below layer of the mountain, from top to bottom, through thousands of feet of rock.

[Illustration: FOSSIL SHELLS.]

This may well seem puzzling at first sight. Fossils of sea-creatures on a mountain-top are startling enough; yet hardly so startling as the thought of fossils *inside* that mountain. How could they have found their way thither?

The difficulty soon vanishes, if once we clearly understand that all these thousands of feet of rock were built up slowly, layer after layer, when portions of the land lay deep

under the sea. Thus *each separate layer* of mud or sand or other material became in its turn the *top layer*, and was for the time the floor of the ocean, until further droppings of material out of the waters made a fresh layer, covering up the one below.

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While each layer was thus in succession the top layer of the building, and at the same time the floor of the ocean, animals lived and died in the ocean, and their remains sank to the bottom, resting upon the sediment floor. Thousands of such dead remains disappeared, crumbling into fine dust and mingling with the waters, but here and there one was caught captive by the half-liquid mud, and was quickly covered and preserved from decay. And still the building went on, and still layer after layer was placed, till many fossils lay deep down beneath the later-formed layers; and when at length, by slow or quick upheaval of the ground, this sea-bottom became a mountain, the little fossils were buried within the body of that mountain. So wondrously the matter appears to have come about.

* * * * *

Another difficulty with respect to the stratified rocks has to be thought of. All these layers or deposits of gravel, sand, or earth, on the floor of the ocean, would naturally be horizontal—that is, would lie flat, one upon another. In places the ocean-floor might slant, or a crevice or valley or ridge might break the smoothness of the deposit. But though the layers might partake of the slant, though the valley might have to be filled, though the ridge might have to be surmounted, still the general tendency of the waves would be to level the dropping deposits into flat layers.

Then how is it that when we examine the strata of rocks in our neighborhood, wherever that neighborhood may be, we do not find them so arranged? Here, it is true, the lines for a space are nearly horizontal, but there, a little way farther on, they are perpendicular; here they are bent, and there curved; here they are slanting, and there crushed and broken.

This only bears out what has been already said about the Book of Geology. It *has* been bent and disturbed, crushed and broken.

Great powers have been at work in this crust of our earth. Continents have been raised, mountains have been upheaved, vast masses of rock have been scattered into fragments. Here or there we may find the layers arranged as they were first laid down; but far more often we discover signs of later disturbance, either slow or sudden, varying from a mere quiet tilting to a violent overturn.

[Illustration: EXAMPLE OF DISTURBANCE OF THE EARTH'S LAYERS.]

So the Book of Geology is a torn and disorganized volume, not easy to read.

Yet, on the other hand, these very changes which have taken place are a help to the geologist.

It may seem at first sight as if we should have an easier task, if the strata were all left lying just as they were first formed, in smooth level layers, one above another. But if it were so, we could know very little about the lower layers.

We might indeed feel sure, as we do now, that the lowest layers were the oldest and the top layers the newest, and that any fossils found in the lower layers must belong to an age farther back than any fossils found in the upper layers.

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So much would be clear. And we might dig also and burrow a little way down, through a few different kinds of rock, where they were not too thick. But that would be all. There our powers would cease.

Now how different. Through the heavings and tiltings of the earth's crust, the lower layers are often pushed quite up to the surface, so that we are able to examine them and their fossils without the least difficulty, and very often without digging underground at all.

You must not suppose that the real order of the rocks is changed by these movements, for generally speaking it is not. The lower kinds are rarely if ever found placed over the upper kinds; only the ends of them are seen peeping out above ground.

It is as if you had a pile of copy-books lying flat one upon another, and were to put your finger under the lowest and push it up. All those above would be pushed up also, and perhaps they would slip a little way down, so that you would have a row of *edges* showing side by side, at very much the same height. The arrangement of the copy-books would not be changed, for the lowest would still be the lowest in actual position; but a general tilting or upheaval would have taken place.

Just such a tilting or upheaval has taken place again and again with the rocks forming our earth-crust. The edges of the lower rocks often show side by side with those of higher layers.

But geologists know them apart. They are able to tell confidently whether such and such a rock, peeping out at the earth's surface, belongs really to a lower or a higher kind. For there is a certain sort of order followed in the arrangement of rock-layers all over the earth, and it is well known that some rocks are never found below some other rocks, that certain particular kinds are never placed above certain other kinds. Thus it follows that the fossils found in one description of rock, must be the fossils of animals which lived and died before the animals whose fossil remains are found in another neighboring rock, just because this last rock-layer was built upon the ocean-floor above and therefore later than the other.

All this is part of the foreign language of geology—part of the piecing and arranging of the torn volume. Many mistakes are made; many blunders are possible; but the mistakes and blunders are being gradually corrected, and certain rules by which to read and understand are becoming more and more clear.

It has been already said that unstratified rocks are those which have been at some period, whether lately or very long ago, in a liquid state from intense heat, and which have since cooled, either quickly or slowly, crystallizing as they cooled.

Unstratified Rocks may be divided into two distinct classes.

[Illustration: SECTION OF A LAVA BOMB.]

First.—Volcanic Rocks, such as lava. These have been quickly cooled at the surface of the earth, or not far below it.

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Secondly.—Plutonic Rocks, such as granite. These have been slowly cooled deep down in the earth under heavy pressure.

There is also a class of rocks, called metamorphic rocks, including some kinds of marble. These are, strictly speaking, crystalline rocks, and yet they are arranged in something like layers. The word “metamorphic” simply means “transformed.” They are believed to have been once stratified rocks, perhaps containing often the remains of animals; but intense heat has later transformed them into crystalline rocks, and the animal remains have almost or quite vanished.

[Illustration: LAVA-STREAM ON VESUVIUS.]

Just as the different kinds of Stratified Rocks are often called Aqueous Rocks, or rocks formed by the action of water—so these different kinds of Unstratified Rocks are often called Igneous Rocks, or rocks formed by the action of fire—the name being taken from the Latin word for fire. The Metamorphic Rocks are sometimes described as “Aqueo-igneous,” since both water and fire helped in the forming of them.

It was at one time believed, as a matter of certainty, that granite and such rocks belonged to a period much farther back than the periods of the stratified rocks. That is to say, it was supposed that fire-action had come first and water-action second; that the fire-made rocks were all formed in very early ages, and that only water-made rocks still continued to be formed. So the name of Primary Rocks, or First Rocks, was given to the granites and other such rocks, and the name of Secondary Rocks to all water-built rocks; while those of the third class were called Transition Rocks, because they seemed to be a kind of link or stepping-stone in the change from the First to the Second Rocks.

The chief reason for the general belief that fire-built rocks were older than water-built ones was, that the former are as a rule found to lie *lower* than the latter. They form, as it were, the basement of the building, while the top-stories are made of water-built rocks.

Many still believe that there is much truth in the thought. It is most probable, so far as we are able to judge, that the *first-formed* crust of rocks all over the earth was of cooled and crystallized material. As these rocks were crumbled and wasted by the ocean, materials would have been supplied for the building-up of rocks, layer upon layer.

But this is conjecture. We cannot know with any certainty the course of events so far back in the past. And geologists are now able to state with tolerable confidence that, however old many of the granites may be, yet a large amount of the fire-built rocks are no older than the water-built rocks which lie over them.

So by many geologists the names of Primary, Transition, and Secondary Formations are pretty well given up. It has been proposed to give instead to the crystallized rocks of all kinds the name of Underlying Rocks (Hypogene Rocks).

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But if they really do lie under, how can they possibly be of the same age? One would scarcely venture to suppose, in looking at a building, that the cellars had not been finished before the upper floors.

True. In the first instance doubtless the cellars were first made, then the ground-floor, then the upper stories.

When, however, the house was so built, alterations and improvements might be very widely carried on above and below. While one set of workmen were engaged in remodelling the roof, another set of workmen might be engaged in remodelling the kitchens and first floor, pulling down, propping up, and actually rebuilding parts of the lower walls.

This is precisely what the two great fellow-workmen, Fire and Water, are ever doing in the crust of our earth. And if it be objected that such alterations too widely undertaken might result in slips, cracks, and slidings, of ceilings and walls in the upper stories, I can only say that such catastrophes *have* been the result of underground alterations in that great building, the earth's crust....

We see therefore clearly that, although the earliest fire-made rocks may very likely date farther back than the earliest water-made rocks, yet the making of the two kinds has gone on side by side, one below and the other above ground, through all ages up to the present moment.

And just as in the present day water continues its busy work above ground of pulling down and building up, so also fire continues its busy work underground of melting rocks which afterwards cool into new forms, and also of shattering and upheaving parts of the earth-crust.

For there can be no doubt that fiery heat does exist as a mighty power within our earth, though to what extent we are not able to say.

These two fellow-workers in nature have different modes of working. One we can see on all sides, quietly progressing, demolishing land patiently bit by bit, building up land steadily grain by grain. The other, though more commonly hidden from sight, is fierce and tumultuous in character, and shows his power in occasional terrific outbursts.

We can scarcely realize what the power is of the imprisoned fiery forces underground, though even we are not without some witness of their existence. From time to time even our firm land has been felt to tremble with a thrill from some far-off shock; and even in our country is seen the marvel of scalding water pouring unceasingly from deep underground....

Think of the tremendous eruptions of Vesuvius, of Etna, of Hecla, of Mauna Loa. Think of whole towns crushed and buried, with their thousands of living inhabitants. Think of rivers of glowing lava streaming up from regions below ground, and pouring along the surface for a distance of forty, fifty, and even sixty miles, as in Iceland and Hawaii. Think of red-hot cinders flung from a volcano-crater to a height of ten thousand feet. Think of lakes

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of liquid fire in other craters, five hundred to a thousand feet across, huge cauldrons of boiling rock. Think of showers of ashes from the furnace below of yet another, borne so high aloft as to be carried seven hundred miles before they sank to earth again. Think of millions of red-hot stones flung out in one eruption of Vesuvius. Think of a mass of rock, one hundred cubic yards in size, hurled to a distance of eight miles or more out of the crater of Cotopaxi.

[Illustration: HOT WELLS.]

Think also of earthquake-shocks felt through twelve hundred miles of country. Think of fierce tremblings and heavings lasting in constant succession through days and weeks of terror. Think of hundreds of miles of land raised several feet in one great upheaval. Think of the earth opening in scores of wide-lipped cracks, to swallow men and beasts. Think of hot mud, boiling water, scalding stream, liquid rock, bursting from such cracks, or pouring from rents in a mountain-side.

Truly these are signs of a state of things in or below the solid crust on which we live, that may make us doubt the absolute security of "Mother Earth."

Different explanations have been put forward to explain this seemingly fiery state of things underground.

Until lately the belief was widely held that our earth was one huge globe of liquid fire, with only a slender cooled crust covering her, a few miles in thickness.

This view was supported by the fact that heat is found to increase as men descend into the earth. Measurements of such heat-increase have been taken, both in mines and in borings for wells. The usual rate is about one degree more of heat, of our common thermometer, for every fifty or sixty feet of descent. If this were steadily continued, water would boil at a depth of eight thousand feet below the surface; iron would melt at a depth of twenty-eight miles; while at a depth of forty or fifty miles no known substance upon earth could remain solid.

The force of this proof is, however, weakened by the fact that the rate at which the heat increases differs very much in different places. Also it is now generally supposed that such a tremendous furnace of heat—a furnace nearly eight thousand miles in diameter—could not fail to break up and melt so slight a covering shell.

Many believe, therefore, not that the whole interior of the earth is liquid with heat, but that enormous fire-seas or lakes of melted rock exist here and there, under or in the earth-crust. From these lakes the volcanoes would be fed, and they would be the cause of earthquakes and land-upheavals or land-sinkings. There are strong reasons for



supposing that the earth was once a fiery liquid body, and that she has slowly cooled through long ages. Some hold that her centre probably grew solid first from tremendous pressure; that her crust afterwards became gradually cold; and that between the solid crust and the solid inside or "nucleus," a sea of melted rock long existed, the remains of which are still to be found in these tremendous fiery reservoirs.

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The idea accords well with the fact that large numbers of extinct or dead volcanoes are scattered through many parts of the earth. If the above explanation be the right one, doubtless the fire-seas in the crust extended once upon a time beneath such volcanoes, but have since died out or smouldered low in those parts.

A somewhat curious calculation has been made, to illustrate the different modes of working of these two mighty powers—Fire and Water.

The amount of land swept away each year in mud, and borne to the ocean by the River Ganges, was roughly reckoned, and also the amount of land believed to have been upheaved several feet in the great Chilian earthquake.

It was found that the river, steadily working month by month, would require some four hundred years to carry to the sea the same weight of material, which in one tremendous effort was upheaved by the fiery underground forces.

Yet we must not carry this distinction too far. Fire does not always work suddenly, or water slowly; witness the slow rising and sinking of land in parts of the earth, continuing through centuries; and witness also the effects of great floods and storms.

The crust of the earth is made of rock. But what is rock made of?

Certain leading divisions of rocks have been already considered:

The Water-made Rocks;

The Fire-made Rocks, both Plutonic and Volcanic;

The Water-and-Fire-made Rocks.

The first of these—Water-made Rocks—may be subdivided into three classes. These are,—

I. *Flint Rocks*; II. *Clay Rocks*; III. *Lime Rocks*.

This is not a book in which it would be wise to go closely into the mineral nature of rocks. Two or three leading thoughts may, however, be given.

Does it not seem strange that the hard and solid rocks should be in great measure formed of the same substances which form the thin invisible air floating around us?

Yet so it is. There is a certain gas called Oxygen Gas. Without that gas you could not live many minutes. Banish it from the room in which you are sitting, and in a few minutes you will die.

This gas makes up nearly one-quarter by weight of the atmosphere round the whole earth.

The same gas plays an important part in the ocean; for more than three-quarters of water is *oxygen*.

It plays also an important part in rocks; for about half the material of the entire earth's crust is oxygen.

Another chief material in rocks is *silicon*. This makes up one-quarter of the crust, leaving only one-quarter to be accounted for. Silicon mixed with oxygen makes silica or quartz. There are few rocks which have not a large amount of quartz in them. Common flint, sandstones, and the sand of our shores, are made of quartz, and therefore belong to the first class of Silicious or Flint Rocks. Granites and lavas are about one-half quartz. The beautiful stones, amethyst, agate, chalcedony, and jasper, are all different kinds of quartz.

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Another chief material in rocks is a white metal called *aluminium*. United to oxygen it becomes alumina, the chief substance in clay. Rocks of this kind—such as clays, and also the lovely blue gem, sapphire—are called Argillaceous Rocks, from the Latin word for clay, and belong to the second class. Such rocks keep fossils well.

Another is *calcium*. United to oxygen and carbonic acid, it makes carbonate of lime, the chief substance in limestone; so all limestones belong to the third class of Calcareous or Lime Rocks.

Other important materials may be mentioned, such as *magnesium*, *potassium*, *sodium*, *iron*, *carbon*, *sulphur*, *hydrogen*, *chlorine*, *nitrogen*. These, with many more, not so common, make up the remaining quarter of the earth-crust.

Carbon plays as important a part in animal and vegetable life as silicon in rocks. Carbon is most commonly seen in three distinct forms—as charcoal, as black-lead, and as the pure brilliant diamond. Carbon united, in a particular proportion, to oxygen, forms carbonic acid; and carbonic acid united, in a particular proportion, to lime, forms limestone.

Hydrogen united to oxygen forms water. Each of these two gases is invisible alone, but when they meet and mingle they form a liquid.

Nitrogen united to oxygen and to a small quantity of carbonic acid gas forms our atmosphere.

Rocks of pure flint, pure clay, or pure lime, are rarely or never met with. Most rocks are made up of several different substances melted together.

* * * * *

In the fire-built rocks no remains of animals are found, though in water-built rocks they abound. Water-built rocks are sometimes divided into two classes—those which only contain occasional animal remains, and those which are more or less built up of the skeletons of animals.

[Illustration: AMIBA PRINCEPS, ONE OF THE MANY ORDERS OF THE RHIZOPODA CLASS, MAGNIFIED ONE HUNDRED TIMES.]

There are some exceedingly tiny creatures inhabiting the ocean, called Rhizopods. They live in minute shells, the largest of which may be almost the size of a grain of wheat, but by far the greater number are invisible as shells without a microscope, and merely show as fine dust. The rhizopods are of different shapes, sometimes round, sometimes spiral, sometimes having only one cell, sometimes having several cells. In the latter case a separate animal lives in each cell. The animal is of the very simplest

as well as the smallest kind. He has not even a mouth or a stomach but can take in food at any part of his body.

[Illustration: RHIZOPODS (MAGNIFIED).]

These rhizopods live in the oceans in enormous numbers. Tens of millions are ever coming into existence, living out their tiny lives, dying, and sinking to the bottom.

There upon the ocean-floor gather their remains, a heaped-up multitude of minute skeletons or shells, layer forming over layer.

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It was long suspected that the white chalk cliffs of England were built up in some such manner as this through past ages. And now at length proof has been found, in the shape of mud dredged up from the ocean-bottom—mud entirely composed of countless multitudes of these little shells, dropping there by myriads, and becoming slowly joined together in one mass.

Just so, it is believed, were the white chalk cliffs built—gradually prepared on the ocean-floor, and then slowly or suddenly upheaved, so as to become a part of the dry land.

Think what the enormous numbers must have been of tiny living creatures, out of whose shells the wide reaches of white chalk cliffs have been made. Chalk cliffs and chalk layers extend from Ireland, through England and France, as far as to the Crimea. In the south of Russia they are said to be six hundred feet thick. Yet one cubic inch of chalk is calculated to hold the remains of more than one million rhizopods. How many countless millions upon millions must have gone to the whole structure! How long must the work of building up have lasted!

[Illustration: THREE POLYPS OF CORAL.]

These little shells do not always drop softly and evenly to the ocean-floor, to become quietly part of a mass of shells. Sometimes, where the ocean is shallow enough for the waves to have power below, or where land currents can reach, they are washed about, and thrown one against another, and ground into fine powder; and the fine powder becomes in time, through different causes, solid rock.

[Illustration: CORAL POLYP.]

Limestone is made in another way also. In the warm waters of the South Pacific Ocean there are many islands, large and small, which have been formed in a wonderful manner by tiny living workers. The workers are soft jelly-like creatures, called polyps, who labor together in building up great walls and masses of coral.

[Illustration: CORAL ISLAND.]

[Illustration: YOUNG CORAL POLYP ATTACHED TO A ROCK AND EXPANDED.]

They never carry on their work above the surface of the water, for in the air they would die. But the waves break the coral, and heap it up above high-water mark, and carry earth and seeds to drop there till at length a small low-lying island is formed.

The waves not only heap up broken coral, but they grind the coral into fine powder, and from this powder limestone rock is made, just as it is from the powdered shells of rhizopods. The material used by the polyps in building the coral is chiefly lime, which they have the power of gathering out of the water, and the fine coral-powder, sinking to

the bottom, makes large quantities of hard limestone. Soft chalk is rarely, if ever, found near the coral islands.

[Illustration: 1. WHITE CORAL. 2. PORTION OF A BRANCH (MAGNIFIED).]

Limestones are formed in the same manner from the grinding up of other sea-shells and fossils, various in kind; the powder becoming gradually united into solid rock.

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There is yet another way in which limestone is made, quite different from all these. Sometimes streams of water have a large quantity of lime in them; and these as they flow will drop layers of lime which harden into rock. Or a lime-laden spring, making its way through the roof of an underground cavern, will leave all kinds of fantastic arrangements of limestone wherever its waters can trickle and drip. Such a cavern is called a "stalactite cave."

* * * * *

So there are different kinds of fossil rock-making. There may be rocks made of other materials, with fossil simply buried in them. There may be rocks made entirely of fossils, which have gathered in masses as they sank to the sea-bottom, and have there become simply and lightly joined together. There may be rocks made of the ground-up powder of fossils, pressed into a solid substance or united by some other substance.

Rocks are also often formed of whole fossils, or stones, or shells, bound into one by some natural soft sticky cement, which has gathered round them and afterwards grown hard, like the cement which holds together the stones in a wall.

The tiny rhizopods (meaning root foot) which have so large a share in chalk and limestone making, are among the smallest and simplest known kinds of animal life.

There are also some very minute forms of vegetable life, which exist in equally vast numbers, called Diatoms. For a long while they were believed to be living animals, like the rhizopods. Scientific men are now, however, pretty well agreed that they really are only vegetables or plants.

The diatoms have each one a tiny shell or shield, not made of lime like the rhizopod-shells, but of flint. Some think that common flint may be formed of these tiny shells.

Again, there is a kind of rock called Mountain Meal, which is entirely made up of the remains of diatoms. Examined under the microscope, thousands of minute flint shields of various shapes are seen. This rock, or earth, is very abundant in many places, and is sometimes used as a polishing powder. In Bohemia there is a layer of it no less than fourteen feet thick. Yet so minute are the shells of which it is composed, that one square inch of rock is said to contain about four thousand millions of them. Each one of these millions is a separate distinct fossil....

* * * * *

[Illustration: SUCCESSION OF BURIED COAL-GROWTHS AND ERECT TREE-STUMPS. SYDNEY, CAPE BRETON.

a. Sandstone, b. Shales, c. Coal-seams, d. Bed containing Roots and Stumps *in situ*.]

If you examine carefully a piece of coal, you will find, more or less clearly, markings like those which are seen in a piece of wood. Sometimes they are very distinct indeed. Coal abounds in impressions of leaves, ferns, and stems, and fossil remains of plants and tree-trunks are found in numbers in coal-seams.

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Coal is a vegetable substance. The wide coal-fields of Britain and other lands are the *fossil* remains of vast forests.

Long ages ago, as it seems, broad and luxuriant forests flourished over the earth. In many parts generation after generation of trees lived and died and decayed, leaving no trace of their existence, beyond a little layer of black mould, soon to be carried away by wind and water. Coal could only be formed where there were bogs and quagmires.

But in bogs and quagmires, and in shallow lakes of low-lying lands, there were great gatherings of slowly-decaying vegetable remains, trees, plants, and ferns all mingling together. Then after a while the low lands would sink and the ocean pouring in would cover them with layers of protecting sand or mud; and sometimes the land would rise again, and fresh forests would spring into life, only to be in their turn overwhelmed anew, and covered by fresh sandy or earthy deposits.

These buried forests lay through the ages following, slowly hardening into the black and shining coal, so useful now to man.

The coal is found thus in thin or thick seams, with other rock-layers between, telling each its history of centuries long past. In one place no less than sixteen such beds of coal are found, one below another, each divided from the next above and the next underneath by beds of clay or sand or shale. The forests could not have grown in the sea, and the earth-layers could not have been formed on land, therefore many land-risings and sinkings must have taken place. Each bed probably tells the tale of a succession of forests....

* * * * *

Before going on to a sketch of the early ages of the Earth's history—ages stretching back long long before the time of Adam—it is needful to think yet for a little longer about the manner in which that history is written, and the way in which it has to be read.

For the record is one difficult to make out, and its style of expression is often dark and mysterious. There is scarcely any other volume in the great Book of Nature, which the student is so likely to misread as this one. It is very needful, therefore, to hold the conclusions of geologists with a light grasp, guarding each with a "perhaps" or a "may be." Many an imposing edifice has been built, in geology, upon a rickety foundation which has speedily given way.

In all ages of the world's history up to the present day, rock-making has taken place—fire-made rocks being fashioned underground, and water-made rocks being fashioned above ground though under water.

Also in all ages different kinds of rocks have been fashioned side by side—limestone in one part of the world, sandstone in another, chalk in another, clay in another, and so on. There have, it is true, been ages when one kind seems to have been the *chief* kind—an age of limestone, or an age of chalk. But even then there were doubtless more rock-buildings going on, though not to so great an extent. On the other hand, there may have been ages during which no limestone was made, or no chalk, or no clay. As a general rule, however, the various sorts of rock-building have probably gone on together. This was not so well understood by early geologists as it is now.

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The difficulty is often great of disentangling the different strata, and saying which was earlier and which later formed.

Still, by close and careful study of the rocks which compose the earth's crust, a certain kind of order is found to exist, more or less followed out in all parts of the world. *When* each layer was formed in England or in America, the geologist cannot possibly say. He can, however, assert, in either place, that a certain mass of rock was formed before a certain other mass in that same place, even though the two may seem to lie side by side; for he knows that they were so placed only by upheaval, and that once upon a time the one lay beneath the other.

The geologist can go further. He can often declare that a certain mass of rock in America and a certain mass of rock in England, quite different in kind, were probably built up at about the same time. How long ago that time was he would be rash to attempt to say; but that the two belong to the same age he has good reason for supposing.

We find rocks piled upon rocks in a certain order, so that we may generally be pretty confident that the lower rocks were first made, and the upper rocks the latest built. Further than this, we find in all the said layers of water-built rocks signs of past life.

As already stated, much of this life was ocean-life, though not all.

Below the sea, as the rock-layers were being formed, bit by bit, of earth dropping from the ocean to the ocean's floor, sea-creatures lived out their lives and died by thousands, to sink to that same floor. Millions passed away, dissolving and leaving no trace behind; but thousands were preserved—shells often, animals sometimes.

Nor was this all. For now and again some part of the sea-bottom was upheaved, slowly or quickly, till it became dry land. On this dry land animals lived again, and thousands of them, too, died, and their bones crumbled into dust. But here and there one was caught in bog or frost, and his remains were preserved till, through lapse of ages, they turned to stone.

Yet again that land would sink, and over it fresh layers were formed by the ocean-waters, with fresh remains of sea-animals buried in with the layers of sand or lime; and once more the sea-bottom would rise, perhaps then to continue as dry land, until the day when man should discover and handle these hidden remains.

Now note a remarkable fact as to these fossils, scattered far and wide through the layers of stratified rock.

In the uppermost and latest built rocks the animals found are the same, in great measure, as those which now exist upon the earth.

Leaving the uppermost rocks, and examining those which lie a little way below, we find a difference. Some are still the same, and others, if not quite the same, are very much like what we have now; but here and there a creature of a different form appears.

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Go deeper still, and the kinds of animals change further. Fewer and fewer resemble those which now range the earth; more and more belong to other species.

Descend through layer after layer till we come to rocks built in earliest ages and not one fossil shall we find precisely the same as one animal living now.

So not only are the rocks built in successive order, stratum after stratum belonging to age after age in the past, but fossil-remains also are found in successive order, kind after kind belonging to past age after age.

Although in the first instance the succession of fossils was understood by means of the succession of rock-layers, yet in the second place the arrangement of rock-layers is made more clear by the means of these very fossils.

A geologist, looking at the rocks in America, can say which there were first-formed, which second-formed, which third-formed. Also, looking at the rocks in England, he can say which there were first-formed, second-formed, third-formed. He would, however, find it very difficult, if not impossible, to say which among any of the American rocks was formed at about the same time as any particular one among the English rocks, were it not for the help afforded him by these fossils.

Just as the regular succession of rock-strata has been gradually learned, so the regular succession of different fossils is becoming more and more understood. It is now known that some kinds of fossils are always found in the oldest rocks, and in them only; that some kinds are always found in the newest rocks, and in them only; that some fossils are rarely or never found lower than certain layers; that some fossils are rarely or never found higher than certain other layers.

So this fossil arrangement is growing into quite a history of the past. And a geologist, looking at certain rocks, pushed up from underground, in England and in America, can say: "These are very different kinds of rocks, it is true, and it would be impossible to say how long the building up of the one might have taken place before or after the other. But I see that in both these rocks there are exactly the same kinds of fossil-remains, differing from those in the rocks above and below. I conclude therefore that the two rocks belong to about the same great age in the world's past history, when the same animals were living upon the earth."

Observing and reasoning thus, geologists have drawn up a general plan or order of strata; and the whole of the vast masses of water-built rocks throughout the world have been arranged in a regular succession of classes, rising step by step from earliest ages up to the present time.

[Illustration]

AMERICA THE OLD WORLD

(FROM GEOLOGICAL SKETCHES.)

BY L. AGASSIZ.

[Illustration]

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First-born among the Continents, though so much later in culture and civilization than some of more recent birth, America, so far as her physical history is concerned, has been falsely denominated the *New World*. Hers was the first dry land lifted out of the waters, hers the first shore washed by the ocean that enveloped all the earth beside; and while Europe was represented only by islands rising here and there above the sea, America already stretched an unbroken line of land from Nova Scotia to the Far West.

In the present state of our knowledge, our conclusions respecting the beginning of the earth's history, the way in which it took form and shape as a distinct, separate planet, must, of course, be very vague and hypothetical. Yet the progress of science is so rapidly reconstructing the past that we may hope to solve even this problem; and to one who looks upon man's appearance upon the earth as the crowning work in a succession of creative acts, all of which have had relation to his coming in the end, it will not seem strange that he should at last be allowed to understand a history which was but the introduction to his own existence. It is my belief that not only the future, but the past also, is the inheritance of man, and that we shall yet conquer our lost birthright.

Even now our knowledge carries us far enough to warrant the assertion that there was a time when our earth was in a state of igneous fusion, when no ocean bathed it and no atmosphere surrounded it, when no wind blew over it and no rain fell upon it, but an intense heat held all its materials in solution. In those days the rocks which are now the very bones and sinews of our mother Earth—her granites, her porphyries, her basalts, her syenites—were melted into a liquid mass. As I am writing for the unscientific reader, who may not be familiar with the facts through which these inferences have been reached, I will answer here a question which, were we talking together, he might naturally ask in a somewhat sceptical tone. How do you know that this state of things ever existed, and, supposing that the solid materials of which our earth consists were ever in a liquid condition, what right have you to infer that this condition was caused by the action of heat upon them? I answer, Because it is acting upon them still; because the earth we tread is but a thin crust floating on a liquid sea of molten materials; because the agencies that were at work then are at work now, and the present is the logical sequence of the past. From artesian wells, from mines, from geysers, from hot springs, a mass of facts has been collected, proving incontestably the heated condition of all substances at a certain depth below the earth's surface; and if we need more positive evidence, we have it in the fiery eruptions that even now bear fearful testimony to the molten ocean seething within the globe and forcing its way but from time to time. The modern progress of

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Geology has led us by successive and perfectly connected steps back to a time when what is now only an occasional and rare phenomenon was the normal condition of our earth; when the internal fires were enclosed by an envelope so thin that it opposed but little resistance to their frequent outbreak, and they constantly forced themselves through this crust, pouring out melted materials that subsequently cooled and consolidated on its surface. So constant were these eruptions, and so slight was the resistance they encountered, that some portions of the earlier rock-deposits are perforated with numerous chimneys, narrow tunnels as it were, bored by the liquid masses that poured out through them and greatly modified their first condition.

[Illustration: IDEAL SECTION OF A VOLCANO IN ACTION.]

The question at once suggests itself, How was even this thin crust formed? what should cause any solid envelope, however slight and filmy when compared to the whole bulk of the globe, to form upon the surface of such a liquid mass? At this point of the investigation the geologist must appeal to the astronomer; for in this vague and nebulous border-land, where the very rocks lose their outlines and flow into each other, not yet specialized into definite forms and substances,—there the two sciences meet. Astronomy shows us our planet thrown off from the central mass of which it once formed a part, to move henceforth in an independent orbit of its own. That orbit, it tells us, passed through celestial spaces cold enough to chill this heated globe, and of course to consolidate it externally. We know, from the action of similar causes on a smaller scale and on comparatively insignificant objects immediately about us, what must have been the effect of this cooling process upon the heated mass of the globe. All substances when heated occupy more space than they do when cold. Water, which expands when freezing, is the only exception to this rule. The first effect of cooling the surface of our planet must have been to solidify it, and thus to form a film or crust over it. That crust would shrink as the cooling process went on; in consequence of the shrinking, wrinkles and folds would arise upon it, and here and there, where the tension was too great, cracks and fissures would be produced. In proportion as the surface cooled, the masses within would be affected by the change of temperature outside of them, and would consolidate internally also, the crust gradually thickening by this process.

[Illustration: A VOLCANO.]

But there was another element without the globe, equally powerful in building it up. Fire and water wrought together in this work, if not always harmoniously, at least with equal force and persistency. I have said that there was a time when no atmosphere surrounded the earth; but one of the first results of the cooling of its crust must have been the formation of an atmosphere, with all the phenomena connected with it,—the

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rising of vapors, their condensation into clouds, the falling of rains, the gathering of waters upon its surface. Water is a very active agent of destruction, but it works over again the materials it pulls down or wears away, and builds them up anew in other forms. As soon as an ocean washed over the consolidated crust of the globe, it would begin to abrade the surfaces upon which it moved, gradually loosening and detaching materials, to deposit them again as sand or mud or pebbles at its bottom in successive layers, one above another. Thus, in analyzing the crust of the globe, we find at once two kinds of rocks, the respective work of fire and water: the first poured out from the furnaces within, and cooling, as one may see any mass of metal cool that is poured out from a smelting-furnace to-day, in solid crystalline masses, without any division into separate layers or leaves; and the latter in successive beds, one over another, the heavier materials below, the lighter above, or sometimes in alternate layers, as special causes may have determined successive deposits of lighter or heavier materials at some given spot.

There were many well-fought battles between geologists before it was understood that these two elements had been equally active in building up the crust of the earth. The ground was hotly contested by the disciples of the two geological schools, one of which held that the solid envelope of the earth was exclusively due to the influence of fire, while the other insisted that it had been accumulated wholly under the agency of water. This difference of opinion grew up very naturally; for the great leaders of the two schools lived in different localities, and pursued their investigations over regions where the geological phenomena were of an entirely opposite character,—the one exhibiting the effect of volcanic eruptions, the other that of stratified deposits. It was the old story of the two knights on opposite sides of the shield, one swearing that it was made of gold, the other that it was made of silver; and almost killing each other before they discovered that it was made of both. So prone are men to hug their theories and shut their eyes to any antagonistic facts, that it is related of Werner, the great leader of the Aqueous school, that he was actually on his way to see a geological locality of especial interest, but, being told that it confirmed the views of his opponents, he turned round and went home again, refusing to see what might force him to change his opinions. If the rocks did not confirm his theory, so much the worse for the rocks,—he would none of them. At last it was found that the two great chemists, fire and water, had worked together in the vast laboratory of the globe, and since then scientific men have decided to work together also; and if they still have a passage at arms occasionally over some doubtful point, yet the results of their investigations are ever drawing them nearer to each other,—since men who study truth, when they reach their goal, must always meet at last on common ground.

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The rocks formed under the influence of heat are called, in geological language, the Igneous, or, as some naturalists have named them, the Plutonic rocks, alluding to their fiery origin, while the others have been called Aqueous or Neptunic rocks, in reference to their origin under the agency of water. A simpler term, however, quite as distinctive, and more descriptive of their structure, is that of the stratified and massive or unstratified rocks. We shall see hereafter how the relative position of these two classes of rocks and their action upon each other enable us to determine the chronology of the earth, to compare the age of her mountains, and, if we have no standard by which to estimate the positive duration of her continents, to say at least which was the first-born among them, and how their characteristic features have been successfully worked out. I am aware that many of these inferences, drawn from what is called "the geological record," must seem to be the work of the imagination. In a certain sense this is true,—for imagination, chastened by correct observation, is our best guide in the study of Nature. We are too apt to associate the exercise of this faculty with works of fiction, while it is in fact the keenest detective of truth.

[Illustration: DIKES.]

Besides the stratified and massive rocks, there is still a third set, produced by the contact of these two, and called, in consequence of the changes thus brought about, the Metamorphic rocks. The effect of heat upon clay is to bake it into slate; limestone under the influence of heat becomes quick-lime, or, if subjected afterwards to the action of water, it is changed to mortar; sand under the same agency is changed to a coarse kind of glass. Suppose, then, that a volcanic eruption takes place in a region of the earth's surface where successive layers of limestone, of clay, and of sandstone, have been previously deposited by the action of water. If such an eruption has force enough to break through these beds, the hot, melted masses will pour out through the rent, flow over its edges, and fill all the lesser cracks and fissures produced by such a disturbance. What will be the effect upon the stratified rocks? Wherever these liquid masses, melted by a heat more intense than can be produced by any artificial means, have flowed over them or cooled in immediate contact with them, the clays will be changed to slate, the limestone will have assumed a character more like marble, while the sandstone will be vitrified. This is exactly what has been found to be the case, wherever the stratified rocks have been penetrated by the melted masses from beneath. They have been themselves partially melted by the contact, and when they have cooled again, their stratification, though still perceptible, has been partly obliterated, and their substance changed. Such effects may often be traced in dikes, which are only the cracks in rocks filled by materials poured into them at some

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period of eruption when the melted masses within the earth were thrown out and flowed like water into any inequality or depression of the surface around. The walls enclosing such a dike are often found to be completely altered by contact with its burning contents, and to have assumed a character quite different from the rocks of which they make a part; while the mass itself which fills the fissure shows by the character of its crystallization that it has cooled more quickly on the outside, where it meets the walls, than at the centre.

The first two great classes of rocks, the unstratified and stratified rocks, represent different epochs in the world's physical history: the former mark its revolutions, while the latter chronicle its periods of rest. All mountains and mountain-chains have been upheaved by great convulsions of the globe, which rent asunder the surface of the earth, destroyed the animals and plants living upon it at the time, and were then succeeded by long intervals of repose, when all things returned to their accustomed order, ocean and river deposited fresh beds in uninterrupted succession, the accumulation of materials went on as before, a new set of animals and plants were introduced, and a time of building up and renewing followed the time of destruction. These periods of revolution are naturally more difficult to decipher than the periods of rest; for they have so torn and shattered the beds they uplifted, disturbing them from their natural relations to each other, that it is not easy to reconstruct the parts and give them coherence and completeness again. But within the last half-century this work has been accomplished in many parts of the world with an amazing degree of accuracy, considering the disconnected character of the phenomena to be studied; and I think I shall be able to convince my readers that the modern results of geological investigation are perfectly sound logical inferences from well-established facts. In this, as in so many other things, we are but "children of a larger growth." The world is the geologist's great puzzle-box; he stands before it like the child to whom the separate pieces of his puzzle remain a mystery till he detects their relation and sees where they fit, and then his fragments grow at once into a connected picture beneath his hand....

When geologists first turned their attention to the physical history of the earth, they saw at once certain great features which they took to be the skeleton and basis of the whole structure. They saw the great masses of granite forming the mountains and mountain-chains, with the stratified rocks resting against their slopes; and they assumed that granite was the first primary agent, and that all stratified rocks must be of a later formation. Although this involved a partial error, as we shall see hereafter when we trace the upheavals of granite even into comparatively modern periods, yet it held an important geological truth also; for, though granite formations are by no means limited to those early periods, they are nevertheless very characteristic of them, and are indeed the foundation-stones on which the physical history of the globe is built.

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Starting from this landmark, the earlier geologists divided the world's history into three periods. As the historian recognizes Ancient History, the Middle Ages, and Modern History as distinct phases in the growth of the human race, so they distinguished between what they called the Primary period, when, as they believed, no life stirred on the surface of the earth; the Secondary or middle period, when animals and plants were introduced, and the land began to assume continental proportions; and the Tertiary period, or comparatively modern geological times, when the physical features of the earth as well as its inhabitants were approaching more nearly to the present condition of things. But as their investigations proceeded, they found that every one of these great ages of the world's history was divided into numerous lesser epochs, each of which had been characterized by a peculiar set of animals and plants, and had been closed by some great physical convulsion, disturbing and displacing the materials accumulated during such a period of rest.

The further study of these subordinate periods showed that what had been called Primary formations, namely, the volcanic or Plutonic rocks formerly believed to be confined to the first geological ages, belonged to all the periods, successive eruptions having taken place at all times, pouring up through the accumulated deposits, penetrating and injecting their cracks, fissures, and inequalities, as well as throwing out large masses on the surface. Up to our own day there has never been a period when such eruptions have not taken place, though they have been constantly diminishing in frequency and extent. In consequence of this discovery, that rocks of igneous character were by no means exclusively characteristic of the earliest times, they are now classified together upon very different grounds from those on which geologists first united them; though, as the name *Primary* was long retained, we still find it applied to them, even in geological works of quite recent date. This defect of nomenclature is to be regretted, as likely to mislead the student, because it seems to refer to time; whereas it no longer signifies the age of the rocks, but simply their character. The name Plutonic or Massive rocks is, however, now almost universally substituted for that of Primary.

A wide field of investigation still remains to be explored by the chemist and the geologist together, in the mineralogical character of the Plutonic rocks, which differs greatly in the different periods. The earlier eruptions seem to have been chiefly granitic, though this must not be understood in too wide a sense, since there are granite formations even as late as the Tertiary period; those of the middle periods were mostly porphyries and basalts; while in the more recent ones, lavas predominate. We have as yet no clew to the laws by which this distribution of volcanic elements in the formation of the earth is regulated;

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but there is found to be a difference in the crystals of the Plutonic rocks belonging to different ages, which, when fully understood may enable us to determine the age of any Plutonic rock by its mode of crystallization; so that the mineralogist will as readily tell you by its crystals whether a bit of stone of igneous origin belongs to this or that period of the world's history, as the palaeontologist will tell you by its fossils whether a piece of rock of aqueous origin belongs to the Silurian or Devonian or Carboniferous deposits.

Although subsequent investigations have multiplied so extensively not only the number of geological periods, but also the successive creations that have characterized them, yet the first general division into three great eras was nevertheless founded upon a broad and true generalization. In the first stratified rocks in which any organic remains are found, the highest animals are fishes, and the highest plants are cryptogams; in the middle periods reptiles come in, accompanied by fern and moss forests; in later times quadrupeds are introduced, with a dicotyledonous vegetation. So closely does the march of animal and vegetable life keep pace with the material progress of the world, that we may well consider these three divisions, included under the first general classification of its physical history, as the three Ages of Nature; the more important epochs which subdivide them may be compared to so many great dynasties, while the lesser periods are the separate reigns contained therein. Of such epochs there are ten, well known to geologists; of the lesser periods about sixty are already distinguished, while many more loom up from the dim regions of the past, just discerned by the eye of science, though their history is not yet unravelled.

Before proceeding further, I will enumerate the geological epochs in their succession, confining myself, however, to such as are perfectly well established, without alluding to those of which the limits are less definitely determined, and which are still subject to doubts and discussions among geologists. As I do not propose to make here any treatise of Geology, but simply to place before my readers some pictures of the old world, with the animals and plants that have inhabited it at various times, I shall avoid, as far as possible, all debatable ground, and confine myself to those parts of my subject which are best known, and can therefore be more clearly presented.

[Illustration: FOSSIL SCORPION.—SILURIAN PERIOD.]

First, we have the Azoic period, *devoid of life*, as its name signifies,—namely, the earliest stratified deposits upon the heated film forming the first solid surface of the earth, in which no trace of living thing has ever been found. Next comes the Silurian period, when the crust of the earth had thickened and cooled sufficiently to render the existence of animals and plants upon it possible, and when the atmospheric conditions necessary to their maintenance

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were already established. Many of the names given to these periods are by no means significant of their character, but are merely the result of accident: as, for instance, that of Silurian, given by Sir Roderick Murchison to this set of beds, because he first studied them in that part of Wales occupied by the ancient tribe of the Silures. The next period, the Devonian, was for a similar reason named after the country of Devonshire in England, where it was first investigated. Upon this follows the Carboniferous period, with the immense deposits of coal from which it derives its name. Then comes the Permian period, named, again, from local circumstances, the first investigation of its deposits having taken place in the province of Permian in Russia. Next in succession we have the Triassic period, so called from the trio of rocks, the red sandstone, Muschel Kalk (shell-limestone), and Keuper (clay), most frequently combined in its formations; the Jurassic, so amply illustrated in the chain of the Jura, where geologists first found the clew to its history; and the Cretaceous period, to which the chalk cliffs of England and all the extensive chalk deposits belong. Upon these follow the so-called Tertiary formations, divided into three periods, all of which have received most characteristic names in this epoch of the world's history we see the first approach to a condition of things resembling that now prevailing, and Sir Charles Lyell has most fitly named its three divisions, the Eocene, Miocene, and Pliocene. The termination of the three words is made from the Greek word *Kainos*, recent; while *Eos* signifies dawn, *Meion* less, and *Pleion* more. Thus Eocene indicates the dawn of recent species, Pliocene their increase, while Miocene, the intermediate term, means less recent. Above these deposits comes what has been called in science the present period,—*the modern times* of the geologist,—that period to which man himself belongs, and since the beginning of which, though its duration be counted by hundreds of thousands of years, there has been no alteration in the general configuration of the earth, consequently no important modification of its climatic conditions, and no change in the animals and plants inhabiting it.

[Illustration: CRUSTACEA.—DEVONIAN PERIOD.]

[Illustration: FISH OF THE DEVONIAN PERIOD.]

[Illustration: FISH OF THE CARBONIFEROUS PERIOD.]

[Illustration: FOSSIL VEGETATION OF CARBONIFEROUS PERIOD.]

[Illustration: FISH OF THE PERMIAN PERIOD.]

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I have spoken of the first of these periods, the Azoic, as having been absolutely devoid of life, and I believe this statement to be strictly true; but I ought to add that there is a difference of opinion among geologists upon this point, many believing that the first surface of our globe may have been inhabited by living beings, but that all traces of their existence have been obliterated by the eruptions of melted materials, which not only altered the character of those earliest stratified rocks, but destroyed all the organic remains contained in them. It will be my object to show, not only that the absence of the climatic and atmospheric conditions essential to organic life, as we understand it, must have rendered the previous existence of any living beings impossible, but also that the completeness of the Animal Kingdom in those deposits where we first find organic remains, its intelligible and coherent connections with the successive creations of all geological times and with the animals now living, afford the strongest internal evidence that we have indeed found in the lower Silurian formations, immediately following the Azoic, the beginning of life upon earth. When a story seems to us complete and consistent from the beginning to the end, we shall not seek for a first chapter, even though the copy in which we have read it be so torn and defaced as to suggest the idea that some portion of it may have been lost. The unity of the work, as a whole, is an incontestable proof that we possess it in its original integrity. The validity of this argument will be recognized, perhaps, only by those naturalists to whom the Animal Kingdom has begun to appear as a connected whole. For those who do not see order in Nature it can have no value.

[Illustration: FOSSILS OF TRIASSIC VEGETATION.]

[Illustration: BIRD OF THE JURASSIC PERIOD.(The Oldest Bird.)]

[Illustration: SKELETON OF BIRD OF THE CRETACEOUS PERIOD.]

[Illustration: SKELETON OF ANIMAL OF THE EOCENE PERIOD.]

For a table containing the geological periods in their succession, I would refer to any modern text-book of Geology, or to an article in the *Atlantic Monthly* for March, 1862, upon "Methods of Study in Natural History," where they are given in connection with the order of introduction of animals upon earth.

Were these sets of rocks found always in the regular sequence in which I have enumerated them, their relative age would be easily determined, for their superposition would tell the whole story: the lowest would, of course, be the oldest, and we might follow without difficulty the ascending series, till we reached the youngest and uppermost deposits. But their succession has been broken up by frequent and violent alterations in the configuration of the globe. Land and water have changed their level,—islands have been transformed to continents,—sea-bottoms have become dry land, and dry land has sunk to form sea-bottoms,—Alps

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and Himalayas, Pyrenees and Apennines, Alleghanies and Rocky Mountains, have had their stormy birthdays since many of these beds have been piled one above another, and there are but few spots on the earth's surface where any number of them may be found in their original order and natural position. When we remember that Europe, which lies before us on the map as a continent, was once an archipelago of islands,—that, where the Pyrenees raise their rocky barrier between France and Spain, the waters of the Mediterranean and Atlantic met,—that, where the British Channel flows, dry land united England and France, and Nature in those days made one country of the lands parted since by enmities deeper than the waters that run between,—when we remember, in short, all the fearful convulsions that have torn asunder the surface of the earth, as if her rocky record had indeed been written on paper, we shall find a new evidence of the intellectual unity which holds together the whole physical history of the globe in the fact that through all the storms of time the investigator is able to trace one unbroken thread of thought from the beginning to the present hour.

[Illustration: SKELETON OF ANIMAL OF THE MIOCENE PERIOD.]

[Illustration: SKELETON OF ANIMAL OF THE PLIOCENE PERIOD.]

The tree is known by its fruits,—and the fruits of chance are incoherence, incompleteness, unsteadiness, the stammering utterance of blind, unreasoning force. A coherence that binds all the geological ages in one chain, a stability of purpose that completes in the beings born to-day an intention expressed in the first creatures that swam in the Silurian ocean or crept upon its shores, a steadfastness of thought, practically recognized by man, if not acknowledged by him, whenever he traces the intelligent connection between the facts of Nature and combines them into what he is pleased to call his system of Geology, or Zooology, or Botany,—these things are not the fruits of chance or of an unreasoning force, but the legitimate results of intellectual power. There is a singular lack of logic, as it seems to me, in the views of the materialistic naturalists. While they consider classification, or, in other words, their expression of the relations between animals or between physical facts of any kind, as the work of their intelligence, they believe the relations themselves to be the work of physical causes. The more direct inference surely is, that, if it requires an intelligent mind to recognize them, it must have required an intelligent mind to establish them. These relations existed before man was created; they have existed ever since the beginning of time; hence, what we call the classification of facts is not the work of his mind in any direct original sense, but the recognition of an intelligent action prior to his own existence.

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There is, perhaps, no part of the world, certainly none familiar to science, where the early geological periods can be studied with so much ease and precision as in the United States. Along their northern borders, between Canada and the United States, there runs the low line of hills known as the Laurentian Hills. Insignificant in height, nowhere rising more than fifteen hundred or two thousand feet above the level of the sea, these are nevertheless the first mountains that broke the uniform level of the earth's surface and lifted themselves above the waters. Their low stature, as compared with that of other more lofty mountain-ranges, is in accordance with an invariable rule, by which the relative age of mountains may be estimated. The oldest mountains are the lowest, while the younger and more recent ones tower above their elders, and are usually more torn and dislocated also. This is easily understood, when we remember that all mountains and mountain-chains are the result of upheavals, and that the violence of the outbreak must have been in proportion to the strength of the resistance. When the crust of the earth was so thin that the heated masses within easily broke through it, they were not thrown to so great a height, and formed comparatively low elevations, such as the Canadian hills or the mountains of Bretagne and Wales. But in later times, when young, vigorous giants, such as the Alps, the Himalayas, or, later still, the Rocky Mountains, forced their way out from their fiery prison-house, the crust of the earth was much thicker, and fearful indeed must have been the convulsions which attended their exit.

[Illustration: A PHYSICAL MAP OF THE UNITED STATES.]

The Laurentian Hills form, then, a granite range, stretching from Eastern Canada to the Upper Mississippi, and immediately along its base are gathered the Azoic deposits, the first stratified beds, in which the absence of life need not surprise us, since they were formed beneath a heated ocean. As well might we expect to find the remains of fish or shells or crabs at the bottom of geysers or of boiling springs, as on those early shores bathed by an ocean of which the heat must have been so intense. Although, from the condition in which we find it, this first granite range has evidently never been disturbed by any violent convulsion since its first upheaval, yet there has been a gradual rising of that part of the continent; for the Azoic beds do not lie horizontally along the base of the Laurentian Hills in the position in which they must originally have been deposited, but are lifted and rest against their slopes. They have been more or less dislocated in this process, and are greatly metamorphized by the intense heat to which they must have been exposed. Indeed, all the oldest stratified rocks have been baked by the prolonged action of heat.

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It may be asked how the materials for those first stratified deposits were provided. In later times, when an abundant and various soil covered the earth, when every river brought down to the ocean, not only its yearly tribute of mud or clay or lime, but the debris of animals and plants that lived and died in its waters or along its banks, when every lake and pond deposited at its bottom in successive layers the lighter or heavier materials floating in its waters and settling gradually beneath them, the process by which stratified materials are collected and gradually harden into rock is more easily understood. But when the solid surface of the earth was only just beginning to form, it would seem that the floating matter in the sea can hardly have been in sufficient quantity to form any extensive deposits. No doubt there was some abrasion even of that first crust; but the more abundant source of the earliest stratification is to be found in the submarine volcanoes that poured their liquid streams into the first ocean. At what rate these materials would be distributed and precipitated in regular strata it is impossible to determine; but that volcanic materials were so deposited in layers is evident from the relative position of the earliest rocks. I have already spoken of the innumerable chimneys perforating the Azoic beds, narrow outlets of Plutonic rock, protruding through the earliest strata. Not only are such funnels filled with the crystalline mass of granite that flowed through them in a liquid state, but it has often poured over their sides, mingling with the stratified beds around. In the present state of our knowledge, we can explain such appearances only by supposing that the heated materials within the earth's crust poured out frequently, meeting little resistance,—that they then scattered and were precipitated in the ocean around, settling in successive strata at its bottom,—that through such strata the heated masses within continued to pour again and again, forming for themselves the chimney-like outlets above mentioned.

Such, then, was the earliest American land,—a long, narrow island, almost continental in its proportions, since it stretched from the eastern borders of Canada nearly to the point where now the base of the Rocky Mountains meets the plain of the Mississippi Valley. We may still walk along its ridge and know that we tread upon the ancient granite that first divided the waters into a northern and southern ocean; and if our imaginations will carry us so far, we may look down toward its base and fancy how the sea washed against this earliest shore of a lifeless world. This is no romance, but the bald, simple truth; for the fact that this granite band was lifted out of the waters so early in the history of the world, and has not since been submerged, has, of course, prevented any subsequent deposits from forming above it. And this is true of all the northern part of the United States. It has been lifted gradually, the beds

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deposited in one period being subsequently raised, and forming a shore along which those of the succeeding one collected, so that we have their whole sequence before us. In regions where all the geological deposits (Silurian, Devonian, carboniferous, permian, triassic, etc.) are piled one upon another, and we can get a glimpse of their internal relations only where some rent has laid them open, or where their ragged edges, worn away by the abrading action of external influences, expose to view their successive layers, it must, of course, be more difficult to follow their connection. For this reason the American continent offers facilities to the geologist denied to him in the so-called Old World, where the earlier deposits are comparatively hidden, and the broken character of the land, intersected by mountains in every direction, renders his investigation still more difficult. Of course, when I speak of the geological deposits as so completely unveiled to us here, I do not forget the sheet of drift which covers the continent from north to south, and which we shall discuss hereafter, when I reach that part of my subject. But the drift is only a superficial and recent addition to the soil, resting loosely above the other geological deposits, and arising, as we shall see, from very different causes.

In this article I have intended to limit myself to a general sketch of the formation of the Laurentian Hills with the Azoic stratified beds resting against them. In the Silurian epoch following the Azoic we have the first beach on which any life stirred; it extended along the base of the Azoic beds, widening by its extensive deposits the narrow strip of land already upheaved. I propose ... to invite my readers to a stroll with me along that beach.

With what interest do we look upon any relic of early human history! The monument that tells of a civilization whose hieroglyphic records we cannot even decipher, the slightest trace of a nation that vanished and left no sign of its life except the rough tools and utensils buried in the old site of its towns or villages, arouses our imagination and excites our curiosity. Men gaze with awe at the inscription on an ancient Egyptian or Assyrian stone; they hold with reverential touch the yellow parchment-roll whose dim, defaced characters record the meagre learning of a buried nationality; and the announcement, that for centuries the tropical forests of Central America have hidden within their tangled growth the ruined homes and temples of a past race, stirs the civilized world with a strange, deep wonder.

To me it seems, that to look on the first land that was ever lifted above the waste of waters, to follow the shore where the earliest animals and plants were created when the thought of God first expressed itself in organic forms, to hold in one's hand a bit of stone from an old sea-beach, hardened into rock thousands of centuries ago, and studded with the beings that once crept upon its surface or were stranded there by some retreating wave, is even of deeper interest to men than the relics of their own race, for these things tell more directly of the thoughts and creative acts of God.

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Standing in the neighborhood of Whitehall, near Lake George, one may look along such a seashore, and see it stretching westward and sloping gently southward as far as the eye can reach. It must have had a very gradual slope, and the waters must have been very shallow; for at that time no great mountains had been uplifted, and deep oceans are always the concomitants of lofty heights. We do not, however, judge of this by inference merely; we have an evidence of the shallowness of the sea in those days in the character of the shells found in the Silurian deposits, which shows that they belonged in shoal waters.

Indeed, the fossil remains of all times tell us almost as much of the physical condition of the world at different epochs as they do of its animal and vegetable population. When Robinson Crusoe first caught sight of the footprint on the sand, he saw in it more than the mere footprint, for it spoke to him of the presence of men on his desert island. We walk on the old geological shores, like Crusoe along his beach, and the footprints we find there tell us, too, more than we actually see in them. The crust of our earth is a great cemetery, where the rocks are tombstones on which the buried dead have written their own epitaphs. They tell us not only who they were and when and where they lived, but much also of the circumstances under which they lived. We ascertain the prevalence of certain physical conditions at special epochs by the presence of animals and plants whose existence and maintenance required such a state of things, more than by any positive knowledge respecting it. Where we find the remains of quadrupeds corresponding to our ruminating animals, we infer not only land, but grassy meadows also, and an extensive vegetation; where we find none but marine animals, we know the ocean must have covered the earth; the remains of large reptiles, representing, though in gigantic size, the half aquatic, half terrestrial reptiles of our own period, indicate to us the existence of spreading marshes still soaked by the retreating waters; while the traces of such animals as live now in sand and shoal waters, or in mud, speak to us of shelving sandy beaches and of mud-flats. The eye of the Trilobite tells us that the sun shone on the old beach where he lived; for there is nothing in nature without a purpose, and when so complicated an organ was made to receive the light, there must have been light to enter it. The immense vegetable deposits in the Carboniferous period announce the introduction of an extensive terrestrial vegetation; and the impressions left by the wood and leaves of the trees show that these first forests must have grown in a damp soil and a moist atmosphere. In short, all the remains of animals and plants hidden in the rocks have something to tell of the climatic conditions and the general circumstances under which they lived, and the study of fossils is to the naturalist a thermometer by which he reads the variations of temperature in past times, a plummet by which he sounds the depths of the ancient oceans,—a register, in fact, of all the important physical changes the earth has undergone.

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But although the animals of the early geological deposits indicate shallow seas by their similarity to our shoal-water animals, it must not be supposed that they are by any means the same. On the contrary, the old shells, crustacea, corals, *etc.*, represent types which have existed in all times with the same essential structural elements, but under different specific forms in the several geological periods. And here it may not be amiss to say something of what are called by naturalists *representative types*.

The statement that different sets of animals and plants have characterized the successive epochs is often understood as indicating a difference of another kind than that which distinguishes animals now living in different parts of the world. This is a mistake. There are so-called representative types all over the globe, united to each other by structural relations and separated by specific differences of the same kind as those that unite and separate animals of different geological periods. Take, for instance, mud-flats or sandy shores in the same latitudes of Europe and America; we find living on each, animals of the same structural character and of the same general appearance, but with certain specific differences, as of color, size, external appendages, *etc.* They represent each other on the two continents. The American wolves, foxes, bears, rabbits, are not the same as the European, but those of one continent are as true to their respective types as those of the other; under a somewhat different aspect they represent the same groups of animals. In certain latitudes, or under conditions of nearer proximity, these differences may be less marked. It is well known that there is a great monotony of type, not only among animals and plants, but in the human races also, throughout the Arctic regions; and some animals characteristic of the high North reappear under such identical forms in the neighborhood of the snow-fields in lofty mountains, that to trace the difference between the ptarmigans, rabbits, and other gnawing animals of the Alps, for instance, and those of the Arctics, is among the most difficult problems of modern science.

And so it is also with the animated world of past ages; in similar deposits of sand, mud, or lime, in adjoining regions of the same geological age, identical remains of animals and plants may be found; while at greater distances, but under similar circumstances, representative species may occur. In very remote regions, however, whether the circumstances be similar or dissimilar, the general aspect of the organic world differs greatly, remoteness in space being thus in some measure an indication of the degree of affinity between different faunae. In deposits of different geological periods immediately following each other, we sometimes find remains of animals and plants so closely allied to those of earlier or later periods that at first sight the specific differences are hardly

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discernible. The difficulty of solving these questions, and of appreciating correctly the differences and similarities between such closely allied organisms, explains the antagonistic views of many naturalists respecting the range of existence of animals, during longer or shorter geological periods; and the superficial way in which discussions concerning the transition of species are carried on, is mainly owing to an ignorance of the conditions above alluded to. My own personal observation and experience in these matters have led me to the conviction that every geological period has had its own representatives, and that no single species has been repeated in successive ages.

The laws regulating the geographical distribution of animals, and their combination into distinct zoological provinces called faunae, with definite limits, are very imperfectly understood as yet; but so closely are all things linked together from the beginning that I am convinced we shall never find the clew to their meaning till we carry on our investigations in the past and the present simultaneously. The same principle according to which animal and vegetable life is distributed over the surface of the earth now, prevailed in the earliest geological periods. The geological deposits of all times have had their characteristic faunae under various zones, their zoological provinces presenting special combinations of animal and vegetable life over certain regions, and their representative types reproducing in different countries, but under similar latitudes, the same groups with specific differences.

Of course, the nearer we approach the beginning of organic life, the less marked do we find the differences to be, and for a very obvious reason. The inequalities of the earth's surface, her mountain-barriers protecting whole continents from the Arctic winds, her open plains exposing others to the full force of the polar blasts, her snug valleys and her lofty heights, her tablelands and rolling prairies, her river-systems and her dry deserts, her cold ocean-currents pouring down from the high North on some of her shores, while warm ones from tropical seas carry their softer influence to others,—in short, all the contrasts in the external configuration of the globe, with the physical conditions attendant upon them, are naturally accompanied by a corresponding variety in animal and vegetable life.

But in the Silurian age, when there were no elevations higher than the Canadian hills, when water covered the face of the earth, with the exception of a few isolated portions lifted above the almost universal ocean, how monotonous must have been the conditions of life! And what should we expect to find on those first shores? If we are walking on a sea-beach to-day, we do not look for animals that haunt the forests or roam over the open plains, or for those that live in sheltered valleys or in inland regions or on mountain-heights. We look for Shells, for Mussels and Barnacles, for Crabs, for Shrimps, for Marine Worms, for Star-Fishes and Sea-Urchins, and we may find here and there a fish stranded on the sand or tangled in the seaweed.

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[Illustration]

SOME RECORDS OF THE ROCKS

(FROM A FIRST BOOK IN GEOLOGY.)

BY N.S. SHALER, S.D.[1]

[Footnote 1: Copyright, 1884, by N.S. Shaler.]

[Illustration]

The geologist cannot find his way back in the record of the great stone book, to the far-off day when life began. The various changes that come over rocks from the action of heat, of water, and of pressure, have slowly modified these ancient beds, so that they no longer preserve the frames of the animals that were buried in them.

These old rocks, which are so changed that we cannot any longer make sure that any animals lived in them, are called the "archaeon," which is Greek for ancient. They were probably mud and sand and limestone when first made, but they have been changed to mica schists, gneiss, granite, marble, and other crystalline rocks. When any rock becomes crystalline, the fossils dissolve and disappear, as coins lose their stamp and form when they are melted in the jeweller's gold-pot.

These ancient rocks that lie deepest in the earth are very thick, and must have taken a great time in building; great continents must have been worn down by rain and waves in order to supply the waste out of which they were made. It is tolerably certain that they took as much time during their making as has been required for all the other times since they were formed. During the vast ages of this archaeon the life of our earth began to be. We first find many certain evidences of life in the rocks which lie on top of the archaeon rock, and are known as the Cambrian and Silurian periods. There we have creatures akin to our corals and crabs and worms, and others that are the distant kindred of the cuttle-fishes and of our lamp-shells. There were no backboned animals, that is to say, no land mammals, reptiles, or fishes at this stage of the earth's history. It is not likely that there was any land life except of plants and those forms like the lowest ferns, and probably mosses. Nor is it likely that there were any large continents as at the present time, but rather a host of islands lying where the great lands now are, the budding tops of the continents just appearing above the sea.

Although the life of this time was far simpler than at the present day, it had about as great variety as we would find on our present sea-floors. There were as many different species living at the same time on a given surface.

The Cambrian and Silurian time—the time before the coming of the fishes—must have endured for many million years without any great change in the world. Hosts of species lived and died; half a dozen times or more the life of the earth was greatly changed. New species came much like those that had gone before, and only a little gain here and there was perceptible at any time. Still, at the end of the Silurian, the life of the world had climbed some steps higher in structure and in intelligence.

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[Illustration: FIG. 1. NORTH AMERICA IN CAMBRIAN TIME.]

The next set of periods is known as the Devonian. It is marked by the rapid extension of the fishes; for, although the fishes began in the uppermost Silurian, they first became abundant in this time. These, the first strong-jawed tyrants of the sea, came all at once, like a rush of the old Norman pirates into the peaceful seas of Great Britain. They made a lively time among the sluggish beings of that olden sea. Creatures that were able to meet feebleness were swept away or compelled to undergo great changes, and all the life of the oceans seems to have a spur given to it by these quicker-formed and quicker-willed animals. In this Devonian section of our rocks we have proofs that the lands were extensively covered with forests of low fern trees, and we find the first trace of air-breathing animals in certain insects akin to our dragon-flies. In this stage of the earth's history the fishes grew constantly more plentiful, and the seas had a great abundance of corals and crinoids. Except for the fishes, there were no very great changes in the character of the life from that which existed in the earlier time of the Cambrian and Silurian. The animals are constantly changing, but the general nature of the life remains the same as in the earlier time.

[Illustration: FIG. 2. RANICEPS LYELLI—COAL TIME SALAMANDER.]

In the Carboniferous or coal-bearing age, we have the second great change in the character of the life on the earth. Of the earlier times, we have preserved only the rocks formed in the seas. But rarely do we find any trace of the land life or even of the life that lived along the shores. In this Carboniferous time, however, we have very extensive sheets of rocks which were formed in swamps in the way shown in the earlier part of this book. They constitute our coal-beds, which, though much worn away by rain and sea, still cover a large part of the land surface. These beds of coal grew in the air, and, although the swamps where they were formed had very little animal life in them, we find some fossils which tell us that the life of the land was making great progress; there are new insects, including beetles, cockroaches, spiders, and scorpions, and, what is far more important, there are some air-breathing, back-boned animals, akin to the salamanders and water-dogs of the present day. These were nearly as large as alligators, and of much the same shape, but they were probably born from the egg in the shape of tadpoles and lived for a time in the water as our young frogs, toads, and salamanders do. This is the first step upwards from the fishes to land vertebrates; and we may well be interested in it, for it makes one most important advance in creatures through whose lives our own existence became possible. Still, these ancient woods of the coal period must have had little of the life we now associate with the forests; there were still no birds, no serpents, no true lizards, no suck-giving animals, no flowers, and no fruits. These coal-period forests were sombre wastes of shade, with no sound save those of the wind, the thunder, and the volcano, or of the running streams and the waves on the shores.

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In the seas of the Carboniferous time, we notice that the ancient life of the earth is passing away. Many creatures, such as the trilobites, die out, and many other forms such as the crinoids or sea lilies become fewer in kind and of less importance. These marks of decay in the marine life continue into the beds just after the Carboniferous, known as the Permian, which are really the last stages of the coal-bearing period.

When with the changing time we pass to the beds known as the Triassic, which were made just after the close of the Carboniferous time, we find the earth undergoing swift changes in its life. The moist climate and low lands that caused the swamps to grow so rapidly have ceased to be, and in their place we appear to have warm, dry air, and higher lands.

On these lands of the Triassic time the air-breathing life made very rapid advances. The plants are seen to undergo considerable changes. The ferns no longer make up all the forests, but trees more like the pines began to abound, and insects became more plentiful and more varied.

[Illustration: FIG. 3. CYCAS CIRCINALIS, AKIN TO HIGHEST PLANTS OF COAL TIME.]

Hitherto the only land back-boned animal was akin to our salamanders. Now we have true lizards in abundance, many of them of large size. Some of them were probably plant-eaters, but most were flesh-eaters; some seem to have been tenants of the early swamps, and some dwelt in the forests.

The creatures related to the salamanders have increased in the variety of their forms to a wonderful extent. We know them best by the tracks which they have left on the mud stones formed on the borders of lakes or the edge of the sea. In some places these footprints are found in amazing numbers and perfection. The best place for them is in the Connecticut Valley, near Turner's Falls, Mass. At this point the red sandstone and shale beds, which are composed of thin layers having a total thickness of several hundred feet, are often stamped over by these footprints like the mud of a barnyard. From the little we can determine from these footprints, the creatures seem to have been somewhat related to our frogs, but they generally had tails, and, though provided with four legs, were in the habit of walking on the hind ones alone like the kangaroo. A few of these tracks are shown in the figure on this page.

[Illustration: FIG. 4. FOOT-PRINTS, CONNECTICUT SANDSTONES.]

These strange creatures were of many different species. Some of them must have been six or seven feet high, for their steps are as much as three feet apart, and seem to imply a creature weighing several hundred pounds. Others were not bigger than robins. Strangely enough, we have never found their bones nor the creatures on which they fed, and but for the formation of a little patch of rocks here and there we should not

have had even these footprints to prove to us that such creatures had lived in the Connecticut Valley in this far-off time.

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[Illustration: FIG. 5. FOOT-PRINT, TURNER'S FALLS.]

But these wonderful forms are less interesting than two or three little fossil jaw-bones that prove to us that in this Triassic time the earth now bore another animal more akin to ourselves, in the shape of a little creature that gave suck to its young. Once more life takes a long upward step in this little opossum-like animal, perhaps the first creature whose young was born alive. These little creatures called *Microlestes* or *Dromatherium*, of which only one or two different but related species have been found in England and in North Carolina, appear to have been insect-eaters of about the size and shape of the Australian creature shown in Fig. 7. So far we know it in but few specimens,—altogether only an ounce or two of bones,—but they are very precious monuments of the past.

[Illustration: FIG. 6. DROMATHERIUM SYLVESTRE AND TEETH OF MICROLESTES ANTIQUUS.]

In this Triassic time the climate appears to have been rather dry, for in it we have many extensive deposits of salt formed by the evaporation of closed lakes, of seas, such as are now forming on the bottom of the Dead Sea, and the Great Salt Lake of Utah, and a hundred or more other similar basins of the present day.

[Illustration: FIG. 7. MYRMECOBIUS.]

In the sea animals of this time we find many changes. Already some of the giant lizard-like animals, which first took shape on the land, are becoming swimming-animals. They changed their feet to paddles, which, with the help of a flattened tail, force them through the water.

The fishes on which these great swimming lizards preyed are more like the fishes of our present day than they were before. The trilobites are gone, and of the crinoids only a remnant is left. Most of the corals of the earlier days have disappeared, but the mollusks have not changed more than they did at several different times in the earliest stages of the earth's history.

[Illustration: FIG. 8. ICHTHYOSAURUS AND PLESIOSAURUS.]

After the Trias comes a long succession of ages in which the life of the world is steadily advancing to higher and higher planes; but for a long time there is no such startling change as that which came in the passage from the coal series of rocks to the Trias. This long set of periods is known to geologists as the age of reptiles. It is well named, for the kindred of the lizards then had the control of the land. There were then none of our large fish to dispute their control, so they shaped themselves to suit all the occupations that could give them a chance for a living. Some remained beasts of prey like our alligators, but grew to larger size; some took to eating the plants, and came to

walk on their four legs as our ordinary beasts do, no longer dragging themselves on their bellies as do the lizard and alligator, their lower kindred. Others became flying creatures like our bats, only vastly larger, often with a spread of wing of fifteen or twenty feet. Yet others, even as strangely shaped, dwelt with the sharks in the sea.

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[Illustration: FIG. 9. REPTILES OF JURASSIC PERIOD.]

In this time of the earth's history we have the first bird-like forms. They were feathered creatures, with bills carrying true teeth, and with strong wings; but they were reptiles in many features, having long, pointed tails such as none of our existing birds have. They show us that the birds are the descendants of reptiles, coming off from them as a branch does from the parent tree. The tortoises began in this series of rocks. At first they are marine or swimming forms, the box-turtles coming later. Here too begin many of the higher insects. Creatures like moths and bees appear, and the forests are enlivened with all the important kinds of insects, though the species were very different from those now living.

In the age of reptiles the plants have made a considerable advance. Palms are plenty; forms akin to our pines and firs abound, and the old flowerless group of ferns begins to shrink in size, and no longer spreads its feathery foliage over all the land as before. Still there were none of our common broad-leaved trees; the world had not yet known the oaks, birches, maples, or any of our hard-wood trees that lose their leaves in autumn; nor were the flowering plants, those with gay blossoms, yet on the earth. The woods and fields were doubtless fresh and green, but they wanted the grace of blossoms, plants, and singing-birds. None of the animals could have had the social qualities or the finer instincts that are so common among animals of the present day. There were probably no social animals like our ants and bees, no merry singing creatures; probably no forms that went in herds. Life was a dull round of uncared-for birth, cruel self-seeking, and of death. The animals at best were clumsy, poorly-endowed creatures, with hardly more intelligence than our alligators.

The little thread of higher life begun in the *Microlestes* and *Dromatherium*, the little insect-eating mammals of the forest, is visible all through this time. It held in its warm blood the powers of the time to come, but it was an insignificant thing among the mighty cold-blooded reptiles of these ancient lands. There are several species of them, but they are all small, and have no chance to make headway against the older masters of the earth.

The Jurassic or first part of the reptilian time shades insensibly into the second part, called the Cretaceous, which immediately follows it. During this period the lands were undergoing perpetual changes; rather deep seas came to cover much of the land surfaces, and there is some reason to believe that the climate of the earth became much colder than it had been, at least in those regions where the great reptiles had flourished. It may be that it is due to a colder climate that we owe the rapid passing away of this gigantic reptilian life of the previous age. The reptiles, being cold-blooded, cannot stand even a moderate winter cold, save when they are so small

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that they can crawl deep into crevices in the rocks to sleep the winter away, guarded from the cold by the warmth of the earth. At any rate these gigantic animals rapidly ceased to be, so that by the middle of the Cretaceous period they were almost all gone, except those that inhabited the sea; and at the end of this time they had shrunk to lizards in size. The birds continue to increase and to become more like those of our day; their tails shrink away, their long bills lose their teeth; they are mostly water-birds of large size, and there are none of our songsters yet; still they are for the first time perfect birds, and no longer half-lizard in their nature.

The greatest change in the plants is found in the coming of the broad-leaved trees belonging to the families of our oaks, maples, *etc.* Now for the first time our woods take on their aspect of to-day; pines and other cone-bearers mingle with the more varied foliage of nut-bearing or large-seeded trees. Curiously enough, we lose sight of the little mammals of the earlier time. This is probably because there is very little in the way of land animals of this period preserved to us. There are hardly any mines or quarries in the beds of this age to bring these fossils to light. In the most of the other rocks there is more to tempt man to explore them for coal ores or building stones.

In passing from the Cretaceous to the Tertiary, we enter upon the threshold of our modern world. We leave behind all the great wonders of the old world, the gigantic reptiles, the forests of tree ferns, the seas full of ammonites and belemnites, and come among the no less wonderful but more familiar modern forms. We come at once into lands and seas where the back-boned animals are the ruling beings. The reptiles have shrunk to a few low forms,—the small lizards, the crocodiles and alligators, the tortoises and turtles, and, as if to mark more clearly the banishment of this group from their old empire, the serpents, which are peculiarly degraded forms of reptiles which have lost the legs they once had, came to be the commonest reptiles of the earth.

The first mammals that have no pouches now appear. In earlier times, the suck-giving animals all belonged to the group that contains our opossums, kangaroos, *etc.* These creatures are much lower and feebler than the mammals that have no pouches. Although they have probably been on the earth two or three times as long as the higher mammals, they have never attained any eminent success whatever; they cannot endure cold climates; none of them are fitted for swimming as are the seals and whales, or for flying as the bats, or for burrowing as the moles; they are dull, weak things, which are not able to contend with their stronger, better-organized, higher kindred. They seem not only weak, but unable to fit themselves to many different kinds of existence.

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In the lower part of the Tertiary rocks, we find at once a great variety of large beasts that gave suck to their young. It is likely that these creatures had come into existence in a somewhat earlier time in other lands, where we have not been able to study the fossils; for to make their wonderful forms slowly, as we believe them to have been made, would require a very long time. It is probable that during the Cretaceous time, in some land where we have not yet had a chance to study the rocks, these creatures grew to their varied forms, and that in the beginning of the Tertiary time, they spread into the regions where we find their bones.

Beginning with the Tertiary time, we find these lower kinsmen of man, through whom man came to be. The mammals were marked by much greater simplicity and likeness to each other than they now have. There were probably no monkeys, no horses, no bulls, no sheep, no goats, no seals, no whales, and no bats. All these animals had many-fingered feet. There were no cloven feet like those of our bulls, and no solid feet as our horses have. Their brains, which by their size give us a general idea of the intelligence of the creature, are small; hence we conclude that these early mammals were less intelligent than those of our day.

It would require volumes to trace the history of the growth of these early mammals, and show how they, step by step, came to their present higher state. We will take only one of the simplest of these changes, which happens to be also the one which we know best. This is the change that led to the making of our common horses, which seem to have been brought into life on the continent of North America. The most singular thing about our horses is that the feet have but one large toe or finger, the hoof, the hard covering of which is the nail of that extremity. Now it seems hard to turn the weak, five-fingered feet of the animals of the lower Tertiary—feet which seem to be better fitted for tree-climbing than anything else—into feet such as we find in the horse. Yet the change is brought about by easy stages that lead the successive creatures from the weak and loose-jointed foot of the ancient forms to the solid, single-fingered horse's hoof, which is wonderfully well-fitted for carrying a large beast at a swift speed, and is so strong a weapon of defence that an active donkey can kill a lion with a well-delivered kick.

[Illustration: FIG. 10. FEET OF TERTIARY MAMMALS.]

The oldest of these creatures that lead to the horses is called *Eohippus* or beginning horse. This fellow had on the forefeet four large toes, each with a small hoof and fifth imperfect one, which answered to the thumb. The hind feet had gone further in the change, for they each had but three toes, each with hoofs, the middle-toed hoof larger and longer than the others. A little later toward our day we find another advance in the *Orohippus*, when the little imperfect thumb has disappeared, and there are only four toes on the forefeet and three on the hind.

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Yet later we have the *Mesohippus* or half-way horse. There are still three toes on the hind foot, but one more of the fingers of the forefeet has disappeared. This time it is the little finger that goes, leaving only a small bone to show that its going was by a slow shrinking. The creature now has three little hoofs on each of its feet.

Still nearer our own time comes the *Miohippus*, which shows the two side hoofs on each foot shrinking up so that they do not touch the ground, but they still bear little hoofs. Lastly, about the time of man's coming on the earth, appears his faithful servant, the horse, in which those little side hoofs have disappeared, leaving only two little "splint" bones to mark the place where these side hoofs belong. Thus, step by step, our horses' feet were built up; while these parts were changing, the other parts of the animals were also slowly altering. They were at first smaller than our horses,—some of them not as large as an ordinary Newfoundland dog; others as small as foxes.

[Illustration: FIG. 11. DEVELOPMENT OF HORSES'S FOOT.]

As if to remind us of his old shape, our horses now and then, but rarely, have, in place of the little splint bones above the hoof, two smaller hoofs, just like the foot of *Miohippus*. Sometimes these are about the size of a silver dollar, on the part that receives the shoe when horses are shod.

In this way, by slow-made changes, the early mammals pass into the higher. Out of one original part are made limbs as different as the feet of the horse, the wing of a bat, the paddle of a whale, and the hand of man. So with all the parts of the body the forms change to meet the different uses to which they are put.

At the end of this long promise, which was written in the very first animals, comes man himself, in form closely akin to the lower animals, but in mind immeasurably apart from them. We can find every part of man's body in a little different shape in the monkeys, but his mind is of a very different quality. While his lower kindred cannot be made to advance in intelligence any more than man himself can grow a horse's foot or a bat's wing, he is constantly going higher and higher in his mental and moral growth.

So far we have found but few traces of man that lead us to suppose that he has been for a long geological time on the earth, yet there is good evidence that he has been here for a hundred thousand years or more. It seems pretty clear that he has changed little in his body in all these thousands of generations. The earliest remains show us a large-brained creature, who used tools and probably had already made a servant of fire, which so admirably aids him in his work.

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Besides the development of this wonderful series of animals, that we may call in a certain way our kindred, there have been several other remarkable advances in this Tertiary time, this age of crowning wonders in the earth's history. The birds have gone forward very rapidly; it is likely that there were no songsters at the first part of this period, but these singing birds have developed very rapidly in later times. Among the insects the most remarkable growth is among the ants, the bees, and their kindred. These creatures have very wonderful habits; they combine together for the making of what we may call states, they care for their young, they wage great battles, they keep slaves, they domesticate other insects, and in many ways their acts resemble the doings of man. Coming at about the same time as man, these intellectual insects help to mark this later stage of the earth as the intellectual period in its history. Now for the first time creatures are on the earth which can form societies and help each other in the difficult work of living.

Among the mollusks, the most important change is in the creation of the great, strong swimming squids, the most remarkable creatures of the sea. Some of these have arms that can stretch for fifty feet from tip to tip.

Among the plants, the most important change has been in the growth of flowering plants, which have been constantly becoming more plenty, and the plants which bear fruits have also become more numerous. The broad-leaved trees seem to be constantly gaining on the forests of narrow-leaved cone-bearers, which had in an earlier day replaced the forests of ferns.

In these Tertiary ages, as in the preceding times of the earth, the lands and seas were much changed in their shape. It seems that in the earlier ages the land had been mostly in the shape of large islands grouped close together where the continents now are. In this time, these islands grew together to form the united lands of Europe, Asia, Africa, Australia, and the twin American continents; so that, as life rose higher, the earth was better fitted for it. Still there were great troubles that it had to undergo. There were at least two different times during the Tertiary age termed glacial periods, times when the ice covered a large part of the northern continents, compelling life of all sorts to abandon great regions, and to find new places in more southern lands. Many kinds of animals and plants seem to have been destroyed in these journeys; but these times of trial, by removing the weaker and less competent creatures, made room for new forms to rise in their places. All advance in nature makes death necessary, and this must come to races as well as to individuals if the life of the world is to go onward and upward.

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Looking back into the darkened past, of which we yet know but little compared with what we would like to know, we can see the great armies of living beings led onward from victory to victory toward the higher life of our own time. Each age sees some advance, though death overtakes all its creatures. Those that escape their actual enemies or accident, fall a prey to old age: volcanoes, earthquakes, glacial periods, and a host of other violent accidents sweep away the life of wide regions, yet the host moves on under a control that lies beyond the knowledge of science. Man finds himself here as the crowning victory of this long war. For him all this life appears to have striven. In his hands lies the profit of all its toil and pain. Surely this should make us feel that our duty to all these living things, that have shared in the struggle that has given man his elevation, is great, but above all, great is our duty to the powers that have been placed in our bodies and our minds.

[Illustration: A GLACIER.]

THE PITCH LAKE IN THE WEST INDIES

(FROM AT LAST.)

BY C. KINGSLEY.

[Illustration: COOLIE AND NEGRO.]

The Pitch Lake, like most other things, owes its appearance on the surface to no convulsion or vagary at all, but to a most slow, orderly, and respectable process of nature, by which buried vegetable matter, which would have become peat, and finally brown coal, in a temperate climate, becomes, under the hot tropic soil, asphalt and oil, continually oozing up beneath the pressure of the strata above it....

* * * * *

As we neared the shore, we perceived that the beach was black with pitch; and the breeze being off the land, the asphalt smell (not unpleasant) came off to welcome us. We rowed in, and saw in front of a little row of wooden houses a tall mulatto, in blue policeman's dress, gesticulating and shouting to us. He was the ward policeman, and I found him (as I did all the colored police) able and courteous, shrewd and trusty. These police are excellent specimens of what can be made of the negro, or half-negro, if he be but first drilled, and then given a responsibility which calls out his self-respect. He was warning our crew not to run aground on one or other of the pitch reefs, which here take the place of rocks. A large one, a hundred yards off on the left, has been almost all dug away, and carried to New York or to Paris to make asphalt-pavement.

[Illustration: THE POLICE STATION.]

The boat was run ashore, under his directions, on a spit of sand between the pitch; and when she ceased bumping up and down in the muddy surf, we scrambled out into a world exactly the hue of its inhabitants of every shade, from jet black to copper-brown. The pebbles on the shore were pitch. A tide-pool close by was enclosed in pitch; a four-eyes was swimming about in it, staring up at us; and when we hunted him, tried to escape, not by diving, but by jumping on shore on the pitch, and scrambling off between our legs. While the policeman, after profoundest courtesies, was gone to get a mule-cart to take us up to the lake, and planks to bridge its water channels, we took a look round at this oddest of corners of the earth.

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In front of us was the unit of civilization,—the police-station, wooden, on wooden stilts (as all well-built houses are here), to insure a draught of air beneath them. We were, of course, asked to come in and sit down, but preferred looking about, under our umbrellas; for the heat was intense. The soil is half pitch, half brown earth, among which the pitch sweals in and out as tallow sweals from a candle. It is always in slow motion under the heat of the tropic sun; and no wonder if some of the cottages have sunk right and left in such a treacherous foundation. A stone or brick house could not stand here; but wood and palm-thatch are both light and tough enough to be safe, let the ground give way as it will.

The soil, however, is very rich. The pitch certainly does not injure vegetation, though plants will not grow actually in it. The first plants which caught our eyes were pine-apples, for which La Brea is famous. The heat of the soil, as well as the air, brings them to special perfection. They grow about anywhere, unprotected by hedge or fence; for the negroes here seem honest enough, at least toward each other; and at the corner of the house was a bush worth looking at, for we had heard of it for many a year. It bore prickly, heart-shaped pods an inch long, filled with seeds coated with a red waxy pulp.

This was a famous plant—*Bixa orellana Roucou*; and that pulp was the well-known annatto dye of commerce. In England and Holland it is used merely, I believe, to color cheeses, but in the Spanish Main to color human beings. The Indian of the Orinoco prefers paint to clothes; and when he has “roucoued” himself from head to foot, considers himself in full dress, whether for war or dancing. Doubtless he knows his own business best from long experience. Indeed, as we stood broiling on the shore, we began somewhat to regret that European manners and customs prevented our adopting the Guaraon and Arrawak fashion.

[Illustration: THE MULE-CART.]

The mule-cart arrived; the lady of the party was put into it on a chair, and slowly bumped and rattled past the corner of Dundonald Street—so named after the old sea-hero, who was, in his life-time, full of projects for utilizing this same pitch—and up in pitch road, with a pitch gutter on each side.

The pitch in the road has been, most of it, laid down by hand, and is slowly working down the slight incline, leaving pools and ruts full of water, often invisible, because covered with a film of brown pitch-dust, and so letting in the unwary walker over his shoes. The pitch in the gutter-bank is in its native place, and as it spues slowly out of the soil into the ditch in odd wreaths and lumps, we could watch, in little, the process which has produced the whole deposit—probably the whole lake itself.

A bullock-cart, laden with pitch, came jolting down past us, and we observed that the lumps, when the fracture is fresh, have all a drawn out look; that the very air bubbles in

them, which are often very numerous, are all drawn out likewise, long and oval, like the air-bubbles in some ductile lavas.

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On our left, as we went on, the bush was low, all of yellow cassia and white Hibiscus, and tangled with lovely convolvulus-like creepers, Ipomoea and Echites, with white, purple or yellow flowers. On the right were negro huts and gardens, fewer and fewer as we went on,—all rich with fruit trees, especially with oranges, hung with fruit of every hue; and beneath them, of course, the pine-apples of La Brea. Everywhere along the road grew, seemingly wild here, that pretty low tree, Cashew, with rounded yellow-veined leaves and little green flowers, followed by a quaint pink and red-striped pear, from which hangs, at the larger and lower end, a kidney-shaped bean, which bold folk eat when roasted; but woe to those who try it when raw; for the acrid oil blisters the lips, and even while the beans are roasting the fumes of the oil will blister the cook's face if she holds it too near the fire.

As we went onward up the gentle slope (the rise is one hundred and thirty-eight feet in rather more than a mile), the ground became more and more full of pitch, and the vegetation poorer and more rushy, till it resembled, on the whole, that of an English fen. An Ipomoea or two, and a scarlet flowered dwarf Heliconia, kept up the tropic type, as does a stiff brittle fern about two feet high. We picked the weeds, which looked like English mint or basil, and found that most of them had three longitudinal nerves in each leaf, and were really Melastomas, though dwarfed into a far meaner habit than that of the noble forms we saw at Chaguanas, and again on the other side of the lake. On the right, too, in a hollow, was a whole wood of Groogroo palms, gray stemmed, gray leaved, and here and there a patch of white or black Roseau rose gracefully eight or ten feet high among the reeds.

The plateau of pitch now widened out, and the whole ground looked like an asphalt pavement, half overgrown with marsh-loving weeds, whose roots feed in the sloppy water which overlies the pitch. But, as yet, there was no sign of the lake. The incline, though gentle, shuts off the view of what is beyond. This last lip of the lake has surely overflowed, and is overflowing still, though very slowly. Its furrows all curve downward; and it is, in fact, as one of our party said, "a black glacier." The pitch, expanding under the burning sun of day, must needs expand most toward the line of least resistance—that is, downhill; and when it contracts again under the coolness of night, it contracts, surely, from the same cause, more downhill than uphill; and so each particle never returns to the spot whence it started, but rather drags the particles above it downward toward itself. At least, so it seemed to us. Thus may be explained the common mistake which is noticed by Messrs. Wall and Sawkins in their admirable description of the lake.

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“All previous descriptions refer the bituminous matter scattered over the La Brea district, and especially that between the village and the lake, to streams which have issued at some former epoch from the lake, and extended into the sea. This supposition is totally incorrect, as solidification would probably have ensued before it had proceeded one-tenth of the distance; and such of the asphalt as has undoubtedly escaped from the lake has not advanced more than a few yards, and always presents the curved surfaces already described, and never appears as an extended sheet.”

Agreeing with this statement as a whole, I nevertheless cannot but think it probable that a great deal of the asphalt, whether it be in large masses or in scattered veins, may be moving very slowly down hill, from the lake to the sea, by the process of expansion by day and contraction by night, and may be likened to a caterpillar, or rather caterpillars innumerable, progressing by expanding and contracting their rings, having strength enough to crawl down hill, but not strength enough to back up hill again.

At last we surmounted the last rise, and before us lay the famous lake—not at the bottom of a depression, as we expected, but at the top of a rise, whence the ground slopes away from it on two sides, and rises from it very slightly on the two others. The black pool glared and glittered in the sun. A group of islands, some twenty yards wide, were scattered about the middle of it. Beyond it rose a double forest of Moriche fan-palms; and to the right of them high wood with giant Mombins and undergrowth of Cocorite—a paradise on the other side of the Stygian pool.

[Illustration: THE PITCH LAKE.]

We walked, with some misgivings, on to the asphalt, and found it perfectly hard. In a few steps we were stopped by a channel of clear water, with tiny fish and water-beetles in it; and, looking round, saw that the whole lake was intersected with channels, so unlike anything which can be seen elsewhere that it is not easy to describe them.

Conceive a crowd of mushrooms, of all shapes, from ten to fifty feet across, close together side by side, their tops being kept at exactly the same level, their rounded rims squeezed tight against each other; then conceive water poured on them so as to fill the parting seams, and in the wet season, during which we visited it, to overflow the tops somewhat. Thus would each mushroom represent, tolerably well, one of the innumerable flat asphalt bosses, which seem to have sprung up each from a separate centre, while the parting seams would be of much the same shape as those in the asphalt, broad and shallow at top, and rolling downward in a smooth curve, till they are at bottom mere cracks from two to ten feet deep. Whether these cracks actually close up below, and the two contiguous masses of pitch become one, cannot be seen. As far as the eye goes down, they are two, though pressed close

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to each other. Messrs. Wall and Sawkins explain the odd fact clearly and simply. The oil, they say, which the asphalt contains when it rises first, evaporates in the sun, of course most on the outside of the heap, leaving a thorough coat of asphalt, which has, generally, no power to unite with the corresponding coat of the next mass. Meanwhile Mr. Manross, an American gentleman, who has written a very clever and interesting account of the lake, seems to have been so far deceived by the curved and squeezed edges of these masses that he attributes to each of them a revolving motion, and supposes that the material is continually passing from the centre to the edges, when it “rolls under,” and rises again in the middle. Certainly the strange stuff looks, at the first glance, as if it were behaving in this way; and certainly, also, his theory would explain the appearance of sticks and logs in the pitch. But Messrs. Wall and Sawkins say that they have observed no such motion: nor did we; and I agree with them, that it is not very obvious to what force, or what influence, it could be attributable. We must, therefore, seek some other way of accounting for the sticks—which utterly puzzled us, and which Mr. Manross well describes as “numerous pieces of wood, which, being involved in the pitch, are constantly coming to the surface. They are often several feet in length, and five or six inches in diameter. On reaching the surface they generally assume an upright position, one end being detained in the pitch, while the other is elevated by the lifting of the middle. They may be seen at frequent intervals over the lake, standing up to the height of two or even three feet. They look like stumps of trees protruding through the pitch; but their parvenu character is curiously betrayed by a ragged cap of pitch which invariably covers the top, and hangs down like hounds’ ears on either side.”

Whence do they come? Have they been blown on to the lake, or left behind by man? or are they fossil trees, integral parts of the vegetable stratum below which is continually rolling upward? or are they of both kinds? I do not know. Only this is certain, as Messrs. Wall and Sawkins have pointed out, that not only “the purer varieties of asphalt, such as approach or are identical with asphalt glance, have been observed” (though not, I think, in the lake itself) “in isolated masses, where there was little doubt of their proceeding from ligneous substances of larger dimensions, such as roots and pieces of trunks and branches,” but, moreover, that “it is also necessary to admit a species of conversion by contact, since pieces of wood included accidentally in the asphalt, for example, by dropping from overhanging vegetation, are often found partially transformed into the material.” This is a statement which we verified again and again, as we did the one which follows, namely, that the hollow bubbles which abound on the surface of the pitch “generally contain traces of the lighter portion of vegetation,” and “are manifestly derived from leaves, etc., which are blown about the lake by the wind, and are covered with asphalt, and, as they become asphalt themselves, give off gases which form bubbles round them.”

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But how is it that those logs stand up out of the asphalt, with asphalt caps and hounds' ears (as Mr. Manross well phrases it) on the tops of them?

We pushed on across the lake, over the planks which the negroes laid down from island to island. Some, meanwhile, preferred a steeple-chase with water-jumps, after the fashion of the midshipmen on a certain second visit to the lake. How the negroes grinned delight and surprise at the vagaries of English lads—a species of animal altogether new to them; and how they grinned still more when certain staid and portly dignitaries caught the infection, and proved by more than one good leap that they too had been English school-boys—alas! long, long ago.

So, whether by bridging, leaping, or wading, we arrived at the little islands, and found them covered with a thick, low scrub; deep sedge, and among them Pinguins, like huge pine-apples without the apple; gray wild-pines, parasites on Matapalos, which, of course, have established themselves, like robbers and vagrants as they are, everywhere; a true holly, with box-like leaves; and a rare cocoa-plum, very like the holly in habit, which seems to be all but confined to these little patches of red earth, afloat on the pitch. Out of the scrub, when we were there, flew off two or three night-jars, very like our English species, save that they had white in the wings; and on the second visit one of the midshipmen, true to the English boy's bird's-nesting instinct, found one of their eggs, white-spotted, in a grass nest.

Passing these little islands, which are said (I know not how truly) to change their places and number, we came to the very fountains of Styx, to that part of the lake where the asphalt is still oozing up.

As the wind set toward us, we soon became aware of an evil smell—petroleum and sulphureted hydrogen at once—which gave some of us a headache. The pitch here is yellow and white with sulphur foam; so are the water-channels; and out of both water and pitch innumerable bubbles of gas arise, loathsome to the smell. We became aware that the pitch was soft under our feet. We left the impression of our boots; and if we had stood still awhile, we should soon have been ankle-deep. No doubt there are spots where, if a man stayed long enough, he would be slowly and horribly engulfed. "But," as Mr. Manross says truly, "in no place is it possible to form those bowl-like depressions round the observer described by former travellers." What we did see is that the fresh pitch oozes out at the lines of least resistance, namely, in the channels between the older and more hardened masses, usually at the upper ends of them, so that one may stand on pitch comparatively hard, and put one's hand into pitch quite liquid, which is flowing softly out, like some ugly fungoid growth, such as may be seen in old wine-cellar, into the water. One such pitch-fungus had grown several yards in length in the three weeks between our first and second visit; and on another, some of our party performed exactly the same feat as Mr. Manross.

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“In one of the star-shaped pools of water, some five feet deep, a column of pitch had been forced perpendicularly up from the bottom. On reaching the surface of the water it had formed a sort of centre-table, about four feet in diameter, but without touching the sides of the pool. The stem was about a foot in diameter. I leaped out on this table, and found that it not only sustained my weight, but that the elasticity of the stem enabled me to rock it from side to side. Pieces torn from the edges of this table sank readily, showing that it had been raised by pressure, and not by its buoyancy.”

True, though strange; but stranger still did it seem to us when we did at last what the negroes asked us, and dipped our hands into the liquid pitch, to find that it did not soil the fingers. The old proverb that one cannot touch pitch without being defiled happily does not stand true here, or the place would be intolerably loathsome. It can be scraped up, moulded into any shape you will, wound in a string (as was done by one of the midshipmen) round a stick, and carried off; but nothing is left on the hand save clean gray mud and water. It may be kneaded for an hour before the mud be sufficiently driven out of it to make it sticky. This very abundance of earthy matter it is which, while it keeps the pitch from soiling, makes it far less valuable than it would be were it pure.

It is easy to understand whence this earthy matter (twenty or thirty per cent) comes. Throughout the neighborhood the ground is full, to the depth of hundreds of feet, of coaly and asphaltic matter. Layers of sandstone or of shale containing this decayed vegetable alternate with layers which contain none; and if, as seems probable, the coaly matter is continually changing into asphalt and oil, and then working its way upward through every crack and pore, to escape from the enormous pressure of the superincumbent soil, it must needs carry up with it innumerable particles of the soils through which it passes.

In five minutes we had seen, handled, and smelt enough to satisfy us with this very odd and very nasty vagary of tropic nature; and as we did not wish to become faint and ill between the sulphureted hydrogen and the blaze of the sun reflected off the hot black pitch, we hurried on over the water-furrows, and through the sedge-beds to the farther shore—to find ourselves, in a single step, out of an Inferno into a Paradise.

[Illustration]

A STALAGMITE CAVE

(FROM THE VOYAGE OF THE CHALLENGER.)

BY SIR C. WYVILLE THOMSON, KT., LL.D., ETC.

[Illustration]

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I think the Painter's Vale cave is the prettiest of the whole. The opening is not very large. It is an arch over a great mass of debris forming a steep slope into the cave, as if part of the roof of the vault had suddenly fallen in. At the foot of the bank of debris one can barely see in the dim light the deep clear water lying perfectly still and reflecting the roof and margin like a mirror. We clambered down the slope, and as the eye became more accustomed to the obscurity the lake stretched further back. There was a crazy little punt moored to the shore, and after lighting candles Captain Nares rowed the Governor back into the darkness, the candles throwing a dim light for a time—while the voices became more hollow and distant—upon the surface of the water and the vault of stalactite, and finally passing back as mere specks into the silence.

[Illustration: A GUIDE.]

After landing the Governor on the opposite side, Captain Nares returned for me, and we rowed round the weird little lake. It was certainly very curious and beautiful; evidently a huge cavity out of which the calcareous sand had been washed or dissolved, and whose walls, still to a certain extent permeable, had been hardened and petrified by the constant percolation of water charged with carbonate of lime. From the roof innumerable stalactites, perfectly white, often several yards long and coming down to the delicacy of knitting-needles, hung in clusters; and wherever there was any continuous crack in the roof or wall, a graceful, soft-looking curtain of white stalactite fell, and often ended, much to our surprise. Deep in the water Stalagmites also rose up in pinnacles and fringes through the water, which was so exquisitely still and clear that it was something difficult to tell where the solid marble tracery ended, and its reflected image began. In this cave, which is a considerable distance from the sea, there is a slight change of level with the tide sufficient to keep the water perfectly pure. The mouth of the cave is overgrown with foliage, and every tree is draped and festooned with the fragrant *Jasminum gracile*, mingled not unfrequently with the "poison ivy" (*Rhus toxicodendron*). The Bermudians, especially the dark people, have a most exaggerated horror of this bush. They imagine that if one touch it or rub against it he becomes feverish, and is covered with an eruption. This is no doubt entirely mythical. The plant is very poisonous, but the perfume of the flower is rather agreeable, and we constantly plucked and smelt it without its producing any unpleasant effect. The tide was with us when we regained the Flats Bridge, and the galley shot down the rapid like an arrow, the beds of scarlet sponges and the great lazy trepangs showing perfectly clearly on the bottom at a fathom depth.

[Illustration: FIG. 1. CALCAREOUS CONCRETION SIMULATING A FOSSIL PALM-STEM, BOAZ ISLAND, BERMUDAS.]

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Every here and there throughout the islands there are groups of bodies of very peculiar form projecting from the surface of the limestone where it has been weathered. These have usually been regarded as fossil palmetto stumps, the roots of trees which have been overwhelmed with sand and whose organic matter has been entirely removed and replaced by carbonate of lime. Fig. 1 represents one of the most characteristic of these from a group on the side of the road in Boaz Island. It is a cylinder a foot in diameter and six inches or so high; the upper surface forms a shallow depression an inch deep surrounded by a raised border; the bottom of the cup is even, and pitted over with small depressions like the marks of rain-drops on sand; the walls of the cylinder seem to end a few inches below the surface of the limestone in a rounded boss, and all over this there are round markings or little cylindrical projections like the origins of rootlets. The object certainly appears to agree even in every detail with a fossil palm-root, and as the palmetto is abundant on the islands and is constantly liable to be destroyed by and ultimately enveloped in a mass of moving sand, it seemed almost unreasonable to question its being one. Still something about the look of these things made me doubt, with General Nelson, whether they were fossil palms, or indeed whether they were of organic origin at all; and after carefully examining and pondering over several groups of them, at Boaz Island, on the shore at Mount Langton, and elsewhere, I finally came to the conclusion that they were not fossils, but something totally different.

[Illustration: FIG. 2. CALCAREOUS CONCRETION IN AEOLIAN LIMESTONE, BERMUDAS.]

[Illustration: FIG. 3. CALCAREOUS CONCRETION IN AEOLIAN LIMESTONE, BERMUDAS.]

[Illustration: FIG. 4. CALCAREOUS CONCRETION, BERMUDAS.]

[Illustration: FIG. 5. CALCAREOUS CONCRETION IN AEOLIAN LIMESTONE, BERMUDAS.]

The form given in Fig. 1 is the most characteristic, and probably by far the most common; but very frequently one of a group of these, one which is evidently essentially the same as the rest and formed in the same way, has an oval or an irregular shape (Figs. 2, 3, and 4). In these we have the same raised border, the same scars on the outside, the same origins of root-like fibres, and the same pitting of the bottom of the shallow cup; but their form precludes the possibility of their being tree-roots. In some cases (Fig. 5), a group of so-called "palm-stems" is inclosed in a space surrounded by a ridge, and on examining it closely this outer ridge is found to show the same leaf-scars and traces of rootlets as the "palm-stems" themselves. In some cases very irregular honey-combed figures are produced which the examination of a long series of intermediate forms shows to belong to the same category (Fig. 6).

[Illustration: FIG. 6. CONCRETIONS IN AEOLIAN ROCKS, BERMUDAS.]

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In the caves in the limestone, owing to a thread of water having found its way in a particular direction through the porous stone of the roof, a drop falls age after age on one spot on the cave-floor, accurately directed by the stalactite which it is all the time creating. The water contains a certain proportion of carbonate of lime, which is deposited as stalagmite as the water evaporates, and thus a ring-like crust is produced at a little distance from the spot where the drop falls. When a ring is once formed, it limits the spread of the drop, and determines the position of the wall bounding the little pool made by the drop. The floor of the cave gradually rises by the accumulation of sand and travertine, and with it rise the walls and floor of the cup by the deposit of successive layers of stalagmite produced by the drop percolating into the limestone of the floor which hardens it still further, but in this peculiar symmetrical way. From the floor and sides of the cup the water oozes into the softer limestone around and beneath; but, as in all these limestones, it does not ooze indiscriminately, but follows certain more free paths. These become soon lined and finally blocked with stalagmite, and it is these tubes and threads of stalagmite which afterwards in the pseudo-fossil represent the diverging rootlets.

[Illustration: A STALAGMITE CAVE.]

Sometimes when two or more drops fall from stalactites close to one another the cups coalesce (Figs. 2, 3, and 4); sometimes one drop or two is more frequent than the other, and then we have the form shown in Figs. 3 and 4; sometimes many drops irregularly scattered form a large pool with its raised border, and a few drops more frequent and more constant than the rest grow their "palmetto stems" within its limit (Fig. 5); and sometimes a number of drops near one another make a curious regular pattern, with the partitions between the recesses quite straight (Fig. 6).

I have already referred to the rapid denudation which is going on in these islands, and to the extent to which they have been denuded within comparatively recent times. The floors of caves, from their being cemented into a nearly homogeneous mass by stalagmitic matter, are much harder than the ordinary porous blown limestone; and it seems that in many cases, after the rocks forming the walls and roof have been removed, disintegration has been at all events temporarily arrested by the floor. Where there is a flat surface of rock exposed anywhere on the island, it very generally bears traces of having been at one time the floor of a cave; and as the weather-wearing of the surface goes on, the old concretionary structures are gradually brought out again, the parts specially hardened by a localized slow infiltration of lime resist integration longest and project above the general surface. Often a surface of weathered rock is so studded with these symmetrical concretions, that it is hard to believe that one is not looking at the calcified stumps of a close-growing grove of palms.

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[Illustration]

THE BIG TREES OF CALIFORNIA

(FROM STUDIES SCIENTIFIC AND SOCIAL.)

BY ALFRED RUSSEL WALLACE.

[Illustration]

In the popular accounts of these trees it is usual to dwell only on the dimensions of the very largest known specimens, and sometimes even to exaggerate these. Even the smaller full-grown trees, however, are of grand dimensions, varying from fourteen to eighteen feet in diameter, at six feet above the ground, and keeping nearly the same thickness for perhaps a hundred feet. In the south Calaveras grove, where there are more than a thousand trees, the exquisite beauty of the trunks is well displayed by the numerous specimens in perfect health and vigor. The bark of these trees, seen at a little distance, is of a bright orange brown tint, delicately mottled with darker shades, and with a curious silky or plush-like gloss, which gives them a richness of color far beyond that of any other conifer. The tree which was cut down soon after the first discovery of the species, the stump of which is now covered with a pavilion, is twenty-five feet in diameter at six feet above the ground, but this is without the thick bark, which would bring it to twenty-seven feet when alive. A considerable portion of this tree still lies where it fell, and at one hundred and thirty feet from the base I found it to be still twelve and a half feet in diameter (or fourteen feet with the bark), while at the extremity of the last piece remaining, two hundred and fifteen feet from its base, it is six feet in diameter, or at least seven feet with the bark. The height of this tree when it was cut down is not recorded, but as one of the living trees is more than three hundred and sixty feet high, it is probable that this giant was not much short of four hundred feet.

[Illustration: THE "MOTHER OF THE FOREST."]

In the accompanying picture the dead tree in the centre is that from which the bark was stripped, which was erected in the Crystal Palace and unfortunately destroyed by fire. It is called the "Mother of the Forest." The two trees nearer the foreground are healthy, medium-sized trees, about fifteen feet diameter at six feet above the ground.

The huge decayed trunk called "Father of the Forest," which has fallen perhaps a century or more, exhibits the grandest dimensions of any known tree. By measuring its remains, and allowing for the probable thickness of the bark, it seems to have been about thirty-five feet diameter near the ground, at ninety feet up fifteen feet, and even at a height of two hundred and seventy feet, it was nine feet in diameter. It is within the hollow trunk of this tree that a man on horse-back can ride—both man and horse being

rather small; but the dimensions undoubtedly show that it was considerably larger than the “Pavilion tree,” and that it carried its huge dimensions to a greater altitude; and although this does not prove it to have been much taller, yet it was in all probability more than four hundred feet in height.

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[Illustration]

Very absurd statements are made to visitors as to the antiquity of these trees, three or four thousand years being usually given as their age. This is founded on the fact that while many of the large Sequoias are greatly damaged by fire, the large pines and firs around them are quite uninjured. As many of these pines are assumed to be near a thousand years old, the epoch of the "great fire" is supposed to be earlier still, and as the Sequoias have not outgrown the fire-scars in all that time, they are supposed to have then arrived at their full growth. But the simple explanation of these trees alone having suffered so much from fire is, that their bark is unusually thick, dry, soft, and fibrous, and it thus catches fire more easily and burns more readily and for a longer time than that of the other coniferae. Forest fires occur continually, and the visible damage done to these trees has probably all occurred in the present century. Professor C.B. Bradley, of the University of California, has carefully counted the rings of annual growth on the stump of the "Pavilion tree," and found them to be twelve hundred and forty; and after considering all that has been alleged as to the uncertainty of this mode of estimating the age of a tree, he believes that in the climate of California, in the zone of altitude where these trees grow, the seasons of growth and repose are so strongly marked that the number of annual rings gives an accurate result.

Other points that have been studied by Professor Bradley are, the reason why there are so few young trees in the groves, and what is the cause of the destruction of the old trees. To take the last point first, these noble trees seem to be singularly free from disease or from decay due to old age. All the trees that have been cut down are solid to the heart, and none of the standing trees show any indications of natural decay. The only apparent cause for their overthrow is the wind, and by noting the direction of a large number of fallen trees it is found that the great majority of them lie more or less towards the south. This is not the direction of the prevalent winds, but many of the tallest trees lean towards the south, owing to the increased growth of their topmost branches towards the sun. They are then acted upon by violent gales, which loosen their roots, and whatever the direction of the wind that finally overthrows them, they fall in the direction of the over-balancing top weight. The young trees grow spiry and perfectly upright, but as soon as they overtop the surrounding trees and get the full influence of the sun and wind, the highest branches grow out laterally, killing those beneath their shade, and thus a dome-shaped top is produced. Taking into consideration the health and vigor of the largest trees, it seems probable that, under favorable conditions of shelter from violent winds, and from a number of trees around them of nearly equal height, big trees might be produced far surpassing in height and bulk any that have yet been discovered. It is to be hoped that if any such are found to exist in the extensive groves of these trees to the south of those which are alone accessible to tourists, the Californian Government will take steps to reserve a considerable tract containing them, for the instruction and delight of future generations.

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The scarcity of young Sequoias strikes every visitor, the fact being that they are only to be found in certain favored spots. These are, either where the loose debris of leaves and branches which covers the ground has been cleared away by fire, or on the spots where trees have been uprooted. Here the young trees grow in abundance, and serve to replace those that fall. The explanation of this is, that during the long summer drought the loose surface debris is so dried up that the roots of the seedling Sequoias perish before they can penetrate the earth beneath. They require to germinate on the soil itself, and this they are enabled to do when the earth is turned up by the fall of a tree, or where a fire has cleared off the debris. They also flourish under the shade of the huge fallen trunks in hollow places, where moisture is preserved throughout the summer. Most of the other conifers of these forests, especially the pines, have much larger seeds than the Sequoias, and the store of nourishment in these more bulky seeds enables the young plants to tide over the first summer's drought. It is clear, therefore, that there are no indications of natural decay in these forest giants. In every stage of their growth they are vigorous and healthy, and they have nothing to fear except from the destroying hand of man.

[Illustration: REDWOOD TREE WITH TRIPLE TRUNK.]

Destruction from this cause is, however, rapidly diminishing both the giant Sequoia and its near ally the noble redwood (*Sequoia sempervirens*), a tree which is more beautiful in foliage and in some other respects more remarkable than its brother species, while there is reason to believe that under favorable conditions it reaches an equally phenomenal size. It once covered almost all the coast ranges of central and northern California, but has been long since cleared away in the vicinity of San Francisco, and greatly diminished elsewhere. A grove is preserved for the benefit of tourists near Santa Cruz, the largest tree being two hundred and ninety-six feet high, twenty-nine feet diameter at the ground and fifteen feet at six feet above it. One of these trees having a triple trunk is here figured from a photograph. Much larger trees, however, exist in the great forests of this tree in the northern part of the State; but these are rapidly being destroyed for the timber, which is so good and durable as to be in great demand. Hence Californians have a saying that the redwood is too good a tree to live. On the mountains a few miles east of the Bay of San Francisco, there are a number of patches of young redwoods, indicating where large trees have been felled, it being a peculiarity of this tree that it sends up vigorous young plants from the roots of old ones immediately around the base. Hence in the forests these trees often stand in groups arranged nearly in a circle, thus marking out the size of the huge trunks of their parents. It is from this quality that the tree has been named

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sempervirens, or ever flourishing. Dr. Gibbons, of Alameda, who has explored all the remains of the redwood forests in the neighborhood of Oakland, kindly took me to see the old burnt-out stump of the largest tree he had discovered. It is situated about fifteen hundred feet above the sea, and is thirty-four feet in diameter at the ground. This is as large as the very largest specimens of the *Sequoia gigantea*, but it may have spread out more at the base and have been somewhat smaller above, though this is not a special characteristic of the species.

[Illustration]

WHAT IS EVOLUTION?

(FROM THE ATLANTIC MONTHLY, MARCH, '93.)

BY PROFESSOR E.S. HOLDEN.

[Illustration]

I was once trying to tell a boy, a friend of mine, what the scientific men mean by the long word *Evolution*, and to give him some idea of the plan of the world. I wanted an illustration of something that had grown—evolved, developed—from small beginnings up through more and more complicated forms, till it had reached some very complete form. I could think of no better example than the railway by which we were sitting. The trains were running over the very track where a wagon-road had lately been, and before that a country cart-track, and before that a bridle-path, and before that again a mere trail for cattle. So I took the road for an example, and tried to show my boy how it had grown from little things by slow degrees according to laws; and if you like, I will try to tell it again.

Just as one can go further and further back, and always find a bird to be the parent of the egg, and an egg to be the parent of that bird, so in the history of this road of ours; we may go back and back into the past, always finding something earlier, which is the cause of the something later. The earth, the planets, and the sun were all a fiery mist long ago. And in that mist, and in what came before it, we may look for the origin of things as they are. But we must begin somewhere. Let us begin with the landscape as we see it now,—hills, valleys, streams, mountains, grass,—but with only a single tree.

We will not try to say how the tree came there. At least, we will not try just yet. When we are through with the story you can say just as well as I can.

Suppose, then, a single oak-tree stood just on that hillside thousands and thousands of years ago. Grass was growing everywhere, and flowers, too. The seeds came with the winds. Year after year the oak-tree bore its acorns, hundreds and hundreds of them,



and they fell on the grass beneath and rolled down the smooth slopes, and sprouted as best they could,—most of them uselessly so far as producing trees were concerned,—but each one did its duty and furnished its green sprout, and died if it found no nourishment.

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All the hundreds of acorns rolled down the slopes, Not one rolled up; and here was a *law*,—the law of gravitation,—in full activity. There were scores of other laws active, too; for evolution had gone a long way when we had an earth fit to be lived on, and hills in their present shape, and a tree bearing acorns that would reproduce their kind. But ever since the fiery mist this simple law of gravitation has been acting, binding the whole universe together, making a relationship between each clod and every other clod, and forcing every stone, every acorn, and every rain-drop to move down and not up.

Just as this law operates,—continuously, silently, inexorably,—so every other law makes itself felt in its own sphere. Gravitation is simple. The law according to which an acorn makes an oak—and not a pine-tree is complex. But the laws of Nature are all alike, and if we understand the simple ones, we can at least partly comprehend the more complex. They are nothing but fixed habits on a large scale.

So the acorns fell year by year and sprouted; and one out of a thousand found good soil, and was not wasted, and made a tree. And so all around (below) the tree with which we started there grew a grove of oaks like it, in fact its children; and finally the original trees died, but not without having left successors.

First of all, the green hillside is smooth and untrodden. There is nothing but grass and flowers, borne there by the winds, which leave no track. There is no animal life even in this secluded spot save the birds, and they too leave no track. By and by there comes a hard winter, or a dearth of food, and a pair of stray squirrels emigrate from their home in the valley below; and the history of our hill and its woods begins. Mere chance decides the choice of the particular oak-tree in which the squirrels make their home. From the foot of this tree they make excursions here and there for their store of winter food,—acorns and the like,—and they leave little paths on the hillside from tree to tree.

The best-marked paths run to the places where there are the most acorns. A little later on there are more squirrels in the colony,—the young of the parent pair, and other colonists from the valley. The little tracks become plainer and plainer.

Later still come other wild animals in search of food,—squirrels will do. The wild animals do not remain in the colony (there are too few squirrels, and they are too hard to catch), but they pass through it, sometimes by day but oftenest by night.

You might think it was perfectly a matter of chance along which path a bear or a wolf passed, but it was not. He *could* walk anywhere on the hillside; and sometimes he would be found far out of the paths that the squirrels had begun. But usually, when he was in no haste, he took the easiest path. The easiest one was that which went between the bushes and not through them; along the hillside and not straight up it; around the big rocks and not over them. The wolves and bears and foxes have new and different wants when they come; and they break new paths to the springs where

they drink, to the shade where they lie, to the hollow trees where the bees swarm and store the wild honey.

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But the squirrels were the first surveyors of these tracks. The bears and wolves are the engineers, who change the early paths to suit their special convenience.

By and by the Indian hunter comes to follow the wild game. He, too, takes the easiest trail, the path of least resistance; and he follows the track to the spring that the deer have made, and he drinks there. He is an animal as they are, and he satisfies his animal wants according to the same law that governs them.

After generations of hunters, Indians, and then white men, there comes a man on horseback looking for a house to live in. He, too, follows along the easiest paths and stops at the spring; and near by he finds the place he is looking for. Soon he returns, driving before him herds of cattle and flocks of sheep, which spread over the grassy glades to feed. But everywhere they take the easiest place, the old paths, from the shady tree to the flowing spring. After awhile the hillside is plainly marked with these sheep trails. You can see them now whenever you go into the country, on every hillside.

Soon there are neighbors who build their homes in the next valley, and a good path must be made between the different houses.

A few days' work spent in moving the largest stones, in cutting down trees, and in levelling off a few steep slopes, makes a trail along which you can gallop your horse.

Things move fast now,—history begins to be made quickly as soon as man takes a hand in it. Soon the trail is not enough: it must be widened so that a wagon-load of boards for a new house can be carried in (for the settler has found a wife). After the first cart-track is made to carry the boards and shingles in, a better road will be needed to haul firewood and grain out (for the wants of the new family have increased, and things must be bought in the neighboring village with money, and money can only be had by selling the products of the farm). By and by the neighborhood is so well inhabited that it is to the advantage of the villages all around it to have good and safe and easy roads there; and the road is declared a public one, and it is regularly kept in repair and improved at the public expense. Do not forget the squirrels of long ago. They were the projectors of this road. Their successors use it now,—men and squirrels alike,—and stop at the spring to drink, and under the huge oaks to rest.

A few years more, and it becomes to the advantage of all to have a railway through the valley and over the hillside. Then a young surveyor, just graduated from college, comes with his chain-men and flag-men, and finds that the squirrels, and bears, and hunters, and all the rest have picked out the easiest way for him long centuries ago. He makes his map, and soon the chief engineer and the president of the road drive along in a buggy with a pair of fast horses (frightening the little squirrels off their road-way and into their holes), and the route of the Bear Valley and Quercus Railway is finally selected, and here it is. See! there comes a train along the track. This is the way a railway route

grew out of a squirrel path. There are thousands of little steps, but you can trace them, or imagine them, as well as I can tell you.

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It is the same all over the world. Stanley cut a track through the endless African forests. But it lay between the Pygmy villages, along the paths they had made, and through the glades where they fought their battles with the storks.

Sometimes the first road is a river—the track is already cut. Try to find out where the settlements in America were in the very early days—before 1800. You will find them along the Hudson, the Juanita, the St. Lawrence, the James, the Mississippi Rivers. But when these are left, men follow the squirrel-tracks and bear-tracks, or the paths of hunters, or the roads of Roman soldiers. It is a standing puzzle to little children why all the great rivers flow past the great towns. (Why do they?) The answer to that question will tell you why the great battles are fought in the same regions; why Egypt has been the coveted prize of a dozen different conquerors (it is the gateway of the East); why our Civil War turned on the possession of the Mississippi River. It is the roadways we fight for, the ways in and out, whether they be land or water. Of course, we really fought for something better than the mere possession of a roadway, but to get what we fought for we had to have the roadway first.

The great principle at the bottom of everything in Nature is that the fittest survives: or, as I think it is better to say it, in any particular conflict or struggle that thing survives which is the fittest to survive *in this particular struggle*. This is Mr. Darwin's discovery, —or one of them,—and the struggle for existence is a part of the great struggle of the whole universe, and the laws of it make up the methods of Evolution—of Development.

It is clear now, is it not, how the railway route is the direct descendant of the tiny squirrel track between two oaks? The process of development we call Evolution, and you can trace it all around you. Why are your skates shaped in a certain way? Why is your gun rifled? Why have soldiers two sets of (now) useless buttons on the skirts of their coats? (I will give you three guesses for this, and the hint that you must think of cavalry soldiers.) Why are eagles' wings of just the size that they are? These and millions of like questions are to be answered by referring to the principle of development.

Sometimes it is hard to find the clew. Sometimes the development has gone so far, and the final product has become so complex and special, that it takes a good deal of thinking to find out the real reasons. But they *can* be found, whether they relate to a fashion, to one of the laws of our country, or to the colors on a butterfly's wing.

There is a little piece of verse intended to be comic, which, on the contrary, is really serious and philosophical, if you understand it. Learn it by heart, and apply it to all kinds and conditions of things, and see if it does not help you to explain them to yourself....

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“And Man grew a thumb for that he had need of it,
And developed capacities for prey.
For the fastest men caught the most animals,
And the fastest animals got away from the most men.
Whereby all the slow animals were eaten,
And all the slow men starved to death.”

[Illustration]

HOW THE SOIL IS MADE

(FROM THE FORMATION OF VEGETABLE MOULD.)

BY CHARLES DARWIN.

[Illustration: W]

Worms have played a more important part in the history of the world than most persons would at first suppose. In almost all humid countries they are extraordinarily numerous, and for their size possess great muscular power. In many parts of England a weight of more than ten tons (10,516 kilogrammes) of dry earth annually passes through their bodies and is brought to the surface on each acre of land; so that the whole superficial bed of vegetable mould passes through their bodies in the course of every few years. From the collapsing of the old burrows the mould is in constant though slow movement, and the particles composing it are thus rubbed together. By these means fresh surfaces are continually exposed to the action of the carbonic acid in the soil, and of the humus-acids which appear to be still more efficient in the decomposition of rocks. The generation of the humus-acids is probably hastened during the digestion of the many half-decayed leaves which worms consume. Thus the particles of earth, forming the superficial mould, are subjected to conditions eminently favorable for their decomposition and disintegration. Moreover, the particles of the softer rocks suffer some amount of mechanical trituration in the muscular gizzards of worms, in which small stones serve as mill-stones.

[Illustration: DIAGRAM OF THE ALIMENTARY CANAL OF AN EARTH-WORM.]

The finely levigated castings, when brought to the surface in a moist condition, flow during rainy weather down any moderate slope; and the smaller particles are washed far down even a gently inclined surface. Castings when dry often crumble into small pellets and these are apt to roll down any sloping surface. Where the land is quite level and is covered with herbage, and where the climate is humid so that much dust cannot be blown away, it appears at first sight impossible that there should be any appreciable amount of sub-aerial denudation; but worm castings are blown, especially while moist

and viscid, in one uniform direction by the prevalent winds which are accompanied by rain. By these several means the superficial mould is prevented from accumulating to a great thickness; and a thick bed of mould checks in many ways the disintegration of the underlying rocks and fragments of rock.

[Illustration: A WORM CASTING, FROM NICE. (Natural Size.)]

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The removal of worm-castings by the above means leads to results which are far from insignificant. It has been shown that a layer of earth, $\frac{1}{2}$ of an inch in thickness, is in many places annually brought to the surface per acre; and if a small part of this amount flows, or rolls, or is washed, even for a short distance, down every inclined surface, or is repeatedly blown in one direction, a great effect will be produced in the course of ages. It was found by measurements and calculations that on a surface with a mean inclination of 9 deg. 26', 2.4 cubic inches of earth which had been ejected by worms crossed, in the course of a year, a horizontal line one yard in length; so that two hundred and forty cubic inches would cross a line one hundred yards in length. This latter amount in a damp state would weigh eleven and one-half pounds. Thus, a considerable weight of earth is continually moving down each side of every valley, and will in time reach its bed. Finally, this earth will be transported by the streams flowing in the valleys into the ocean, the great receptacle for all matter denuded from the land. It is known from the amount of sediment annually delivered into the sea by the Mississippi, that its enormous drainage-area must on an average be lowered .00263 of an inch each year; and this would suffice in four and a half million years to lower the whole drainage-area to the level of the seashore. So that if a small fraction of the layer of fine earth, $\frac{1}{2}$ of an inch in thickness, which is annually brought to the surface by worms, is carried away, a great result cannot fail to be produced within a period which no geologist considers extremely long.

[Illustration: SECTION THROUGH ONE OF THE DRUIDICAL STONES AT STONEHENGE, SHOWING HOW MUCH IT HAD SUNK INTO THE GROUND.

(Scale, $\frac{1}{2}$ inch to 1 foot.)]

Archaeologists ought to be grateful to worms, as they protect and preserve for an indefinitely long period every object, not liable to decay, which is dropped on the surface of the land, by burying it beneath their castings. Thus, also, many elegant and curious tessellated pavements and other ancient remains have been preserved; though no doubt the worms have in these cases been largely aided by earth washed and blown from the adjoining land, especially when cultivated. The old tessellated pavements have, however, often suffered by having subsided unequally from being unequally undermined by the worms. Even old massive walls may be undermined and subside; and no building is in this respect safe, unless the foundations lie six or seven feet beneath the surface, at a depth at which worms cannot work. It is probable that many monoliths and some old walls have fallen down from having been undermined by worms.

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Worms prepare the ground in an excellent manner for the growth of fibrous-rooted plants and for seedlings of all kinds. They periodically expose the mould to the air, and sift it so that no stones larger than the particles which they can swallow are left in it. They mingle the whole intimately together, like a gardener who prepares fine soil for his choicest plants. In this state it is well fitted to retain moisture and to absorb all soluble substances, as well as for the process of nitrification. The bones of dead animals, the harder parts of insects, the shells of land mollusks, leaves, twigs, *etc.*, are before long all buried beneath the accumulated castings of worms, and are thus brought in a more or less decayed state within reach of the roots of plants. Worms likewise drag an infinite number of dead leaves and other parts of plants into their burrows, partly for the sake of plugging them up and partly as food.

The leaves which are dragged into the burrows as food, after being torn into the finest shreds, partially digested and saturated with the intestinal and urinary secretions, are commingled with much earth. This earth forms the dark-colored, rich humus which almost everywhere covers the surface of the land with a fairly well-defined layer or mantle. Von Hensen placed two worms in a vessel eighteen inches in diameter, which was filled with sand, on which fallen leaves were strewed; and these were soon dragged into their burrows to a depth of three inches. After about six weeks an almost uniform layer of sand, a centimetre (.4 inch) in thickness, was converted into humus by having passed through the alimentary canals of these two worms. It is believed by some persons that worm-burrows, which often penetrate the ground almost perpendicularly to a depth of five or six feet, materially aid in its drainage; notwithstanding that the viscid castings piled over the mouths of the burrows prevent or check the rain-water directly entering them. They allow the air to penetrate deeply into the ground. They also greatly facilitate the downward passage of roots of moderate size; and these will be nourished by the humus with which the burrows are lined. Many seeds owe their germination to having been covered by castings; and others buried to a considerable depth beneath accumulated castings lie dormant, until at some future time they are accidentally uncovered and germinate.

[Illustration: A WORM CASTING FROM SOUTH INDIA. (Natural Size.)]

Worms are poorly provided with sense-organs, for they cannot be said to see, although they can just distinguish between light and darkness; they are completely deaf, and have only a feeble power of smell; the sense of touch alone is well developed. They can, therefore, learn little about the outside world, and it is surprising that they should exhibit some skill in lining their burrows with their castings and with leaves, and in the case of some species in piling up their castings

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into tower-like constructions. But it is far more surprising that they should apparently exhibit some degree of intelligence instead of a mere blind, instinctive impulse, in their manner of plugging up the mouths of their burrows. They act in nearly the same manner as would a man, who had to close a cylindrical tube with different kinds of leaves, petioles, triangles of paper, etc., for they commonly seize such objects by their pointed ends. But with thin objects a certain number are drawn in by their broader ends. They do not act in the same unvarying manner in all cases, as do most of the lower animals; for instance, they do not drag in leaves by their foot-stalks, unless the basil part of the blade is as narrow as the apex, or narrower than it.

* * * * *

When we behold a wide, turf-covered expanse, we should remember that its smoothness, on which so much of its beauty depends, is mainly due to all the inequalities having been slowly levelled by worms. It is a marvellous reflection that the whole of the superficial mould over any such expanse has passed, and will again pass, every few years through the bodies of worms. The plough is one of the most ancient and most valuable of man's inventions; but long before he existed the land was in fact regularly ploughed, and, still continues to be thus ploughed by earth-worms. It may be doubted whether there are many other animals which have played so important a part in the history of the world, as have these lowly organized creatures. Some other animals, however, still more lowly organized, namely, corals, have done far more conspicuous work in having constructed innumerable reefs and islands in the great oceans; but these are almost confined to the tropical zones.

[Illustration]

ZOOeLOGICAL MYTHS

(FROM FACTS AND FICTIONS OF ZOOeLOGY.)

BY ANDREW WILSON.

[Illustration]

When the country swain, loitering along some lane, comes to a standstill to contemplate, with awe and wonder, the spectacle of a mass of the familiar "hair-eels" or "hair-worms" wriggling about in a pool, he plods on his way firmly convinced that, as he has been taught to believe, he has just witnessed the results of the transformation of some horse's hairs into living creatures. So familiar is this belief to people of professedly higher culture than the countryman, that the transformation just alluded to

has to all, save a few thinking persons and zoologists, become a matter of the most commonplace kind. When some quarrymen, engaged in splitting up the rocks, have succeeded in dislodging some huge mass of stone, there may sometimes be seen to hop from among the debris a lively toad or frog, which comes to be regarded by the excavators with feelings akin to those of superstitious wonder and amazement. The animal may or may not be captured; but the fact is duly chronicled in the

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local newspapers, and people wonder for a season over the phenomenon of a veritable Rip Van Winkle of a frog, which to all appearance, has lived for “thousands of years in the solid rock.” Nor do the hair-worm and the frog stand alone in respect of their marvellous origin. Popular zoology is full of such marvels. We find unicorns, mermaids, and mermen; geese developed from the shell-fish known as “barnacles”; we are told that crocodiles may weep, and that sirens can sing—in short, there is nothing so wonderful to be told of animals that people will not believe the tale. Whilst, curiously enough, when they are told of veritable facts of animal life, heads begin to shake and doubts to be expressed, until the zooologist despairs of educating people into distinguishing fact from fiction, and truth from theories and unsupported beliefs. The story told of the old lady, whose youthful acquaintance of seafaring habits entertained her with tales of the wonders he had seen, finds, after all, a close application in the world at large. The dame listened with delight, appreciation, and belief, to accounts of mountains of sugar and rivers of rum, and to tales of lands where gold and silver and precious stones were more than plentiful. But when the narrator descended to tell of fishes that were able to raise themselves out of the water in flight, the old lady’s credulity began to fancy itself imposed upon; for she indignantly repressed what she considered the lad’s tendency to exaggeration, saying, “Sugar mountains may be, and rivers of rum may be, but fish that flee ne’er can be!” Many popular beliefs concerning animals partake of the character of the old lady’s opinions regarding the real and fabulous; and the circumstance tells powerfully in favor of the opinion that a knowledge of our surroundings in the world, and an intelligent conception of animal and plant life, should form part of the school-training of every boy and girl, as the most effective antidote to superstitions and myths of every kind.

[Illustration: FLYING FISH.]

The tracing of myths and fables is a very interesting task, and it may, therefore, form a curious study, if we endeavor to investigate very briefly a few of the popular and erroneous beliefs regarding lower animals. The belief regarding the origin of the hair-worms is both widely spread and ancient. Shakespeare tells us that

“Much, is breeding
Which, like the courser’s hair, hath, yet but life,
And not a serpent’s poison.”

The hair-worms certainly present the appearance of long, delicate black hairs, which move about with great activity amidst the mud of pools and ditches. These worms, in the early stages of their existence, inhabit the bodies of insects, and may be found coiled up within the grasshopper, which thus gives shelter to a guest exceeding many times the length of the body of its host. Sooner or later the hair-worm, or *Gordius aquaticus* as the naturalist terms

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it, leaves the body of the insect, and lays its eggs, fastened together in long strings, in water. From each egg a little creature armed with minute hooks is produced, and this young hair-worm burrows its way into the body of some insect, there to repeat the history of its parent. Such is the well-ascertained history of the hair-worm, excluding entirely the popular belief in its origin. There certainly does exist in science a theory known as that of “spontaneous generation,” which, in ancient times, accounted for the production of insects and other animals by assuming that they were produced in some mysterious fashion out of lifeless matter. But not even the most ardent believer in the extreme modification of this theory which holds a place in modern scientific belief, would venture to maintain the production of a hair-worm by the mysterious vivification of an inert substance such as a horse’s hair.

The expression “crocodile’s tears” has passed into common use, and it therefore may be worth while noting the probable origin of this myth. Shakespeare, with that wide extent of knowledge which enabled him to draw similes from every department of human thought, says that

“Gloster’s show
Beguiles him, as the mournful crocodile
With sorrow snares relenting passengers.”

The poet thus indicates the belief that not only do crocodiles shed tears, but that sympathizing passengers, turning to commiserate the reptile’s woes, are seized and destroyed by the treacherous creatures. That quaint and credulous old author—the earliest writer of English prose—Sir John Mandeville, in his “Voiage,” or account of his “Travile,” published about 1356—in which, by the way, there are to be found accounts of not a few wonderful things in the way of zoological curiosities—tells us that in a certain “contre and be all yonde, ben great plenty of Crokodilles, that is, a manner of a long Serpent as I have seyed before.” He further remarks that “these Serpents slew men,” and devoured them, weeping; and he tells us, too, that “whan thei eaten thei meven (move) the over jowe (upper jaw), and nought the nether (lower) jowe: and thei have no tonge (tongue).” Sir John thus states two popular beliefs of his time and of days prior to his age, namely, that crocodiles move their upper jaws, and that a tongue was absent in these animals.

[Illustration: CROCODILE.]

As regards the tears of the crocodile, no foundation of fact exists for the belief in such sympathetic exhibitions. But a highly probable explanation may be given of the manner in which such a belief originated. These reptiles unquestionably emit very loud and singularly plaintive cries, compared by some travellers to the mournful howling of dogs. The earlier and credulous travellers would very naturally associate tears with these

cries, and, once begun, the supposition would be readily propagated, for error and myth are ever plants of quick growth. The

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belief in the movement of the upper jaw rests on apparent basis of fact. The lower jaw is joined to the skull very far back on the latter, and the mouth-opening thus comes to be singularly wide; whilst, when the mouth opens, the skull and upper jaw are apparently observed to move. This is not the case, however; the apparent movement arising from the manner in which the lower jaw and the skull are joined together. The belief in the absence of the tongue is even more readily explained. When the mouth is widely opened, no tongue is to be seen. This organ is not only present, but is, moreover, of large size; it is, however, firmly attached to the floor of the mouth, and is specially adapted, from its peculiar form and structure, to assist these animals in the capture and swallowing of their prey.

One of the most curious fables regarding animals which can well be mentioned, is that respecting the so-called “Bernicle” or “Barnacle Geese,” which by the naturalists and educated persons of the Middle Ages were believed to be produced by those little Crustaceans named “Barnacles.” With the “Barnacles” every one must be familiar who has examined the floating driftwood of the sea-beach, or who has seen ships docked in a seaport town. A barnacle is simply a kind of crab enclosed in a triangular shell, and attached by a fleshy stalk to fixed objects. If the barnacle is not familiar to readers, certain near relations of these animals must be well known, by sight at least, as amongst the most familiar denizens of our sea-coast. These latter are the “Sea-Acorn,” or Balani, whose little conical shells we crush by hundreds as we walk over the rocks at low-water mark; whilst every wooden pile immersed in the sea becomes coated in a short time with a thick crust of the “Sea-Acorns.” If we place one of these little animals, barnacle, or sea-acorn—the latter wanting the stalk of the former—in its native waters, we shall observe a beautiful little series of feathery plumes to wave backward and forward, and ever and anon to be quickly withdrawn into the secure recesses of the shell. These organs are the modified feet of the animal, which not only serve for sweeping food-particles into the mouth, but act also as breathing-organs. We may, therefore, find it a curious study to inquire through what extraordinary transformation and confusion of ideas such an animal could be credited with giving origin to a veritable goose; and the investigation of the subject will also afford a singularly apt illustration of the ready manner in which the fable of one year or period becomes transmitted and transformed into the secure and firm belief of the next.

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We may begin our investigation by inquiring into some of the opinions which were entertained on this subject and ventilated by certain old writers. Between 1154 and 1189 Giraldus Cambrensis, in a work entitled "Topographia Hiberniae," written in Latin, remarks concerning "many birds which are called Bernacae: against nature, nature produces them in a most extraordinary way. They are like marsh geese, but somewhat smaller. They are produced from fir timber tossed along the sea, and are at first like gum. Afterward they hang down by their beaks, as if from a seaweed attached to the timber, surrounded by shells, in order to grow more freely," Giraldus is here evidently describing the barnacles themselves. He continues: "Having thus, in process of time, been clothed with a strong coat of feathers, they either fall into the water or fly freely away into the air. They derive their food and growth from the sap of the wood or the sea, by a secret and most wonderful process of alimentation. I have frequently, with my own eyes, seen more than a thousand of these small bodies of birds, hanging down on the seashore from one piece of timber, enclosed in shells, and already formed." Here, again, our author is speaking of the barnacles themselves, with which he naturally confuses the geese, since he presumes the Crustaceans are simply geese in an undeveloped state. He further informs his readers that, owing to their presumably marine origin, "bishops and clergymen in some parts of Ireland do not scruple to dine off these birds at the time of fasting, because they are not flesh, nor born of flesh," although for certain other and theological reasons, not specially requiring to be discussed in the present instance, Giraldus disputes the legality of this practice of the Hibernian clerics.

In the year 1527 appeared "The Hystory and Croniclis of Scotland, with the cosmography and dyscription thair of, compilit be the noble Clerk Maister Hector Boece, Channon of Aberdene." Boece's "History" was written in Latin; the title we have just quoted being that of the English version of the work (1540), which title further sets forth that Boece's work was "Translait laitly in our vulgar and commoun langage be Maister Johne Bellenden, Archedene of Murray, And Imprentit in Edinburgh, be me Thomas Davidson, prenter to the Kyngis nobyll grace." In this learned work the author discredits the popular ideas regarding the origin of the geese. "Some men belevis that thir clakis (geese) growis on treis be the nebbis (bills). Bot thair opinoun is vane. And becaus the nature and procreatioun of thir clakis is strange, we have maid na lytyll laboure and deligence to serche ye treuth and verite yairof, we have salit (sailed) throw ye seis quhare thir clakis ar bred, and I fynd be gret experience, that the nature of the seis is mair relevant caus of thair procreatioun than ony uthir thyng." According to Boece, then, "the nature of the seis" formed the chief element

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in the production of the geese, and our author proceeds to relate how “all treis (trees) that ar casein in the seis be proces of tyme apperis first wormeetin (worm-eaten), and in the small boris and hollis (holes) thairof growis small worms.” Our author no doubt here alludes to the ravages of the *Teredo*, or ship-worm, which burrows into timber, and with which the barnacles themselves are thus confused. Then he continues, the “wormis” first “schaw (show) thair heid and feit, and last of all thay schaw thair plumis and wyngis. Finaly, quhen thay ar cumyn to the just mesure and quantite of geis, thay fle in the aire as othir fowlis dois, as was notably provyn, in the yeir of God ane thousand iii hundred lxxxx, in sicht of mony pepyll, besyde the castell of Petslego.” On the occasion referred to, Boece tells us that a great tree was cast on shore, and was divided, by order of the “laird” of the ground, by means of a saw. Wonderful to relate, the tree was found not merely to be riddled with a “multitude of wormis,” throwing themselves out of the holes of the tree, but some of the “wormis” had “baith heid, feit, and wyngis,” but, adds the author, “they had no fedderis (feathers).”

Unquestionably, either “the scientific use of the imagination” had operated in this instance in inducing the observers to believe that in this tree, riddled by the ship-worms and possibly having barnacles attached to it, they beheld young geese; or Boece had construed the appearances described as those representing the embryo stages of the barnacle geese.

Boece further relates how a ship named the *Christofir* was brought to Leith, and was broken down because her timbers had grown old and failing. In these timbers were beheld the same “wormeetin” appearances, “all the hollis thairof” being “full of geis.” Boece again most emphatically rejects the idea that the “geis” were produced from the wood of which the timbers were composed, and once more proclaims his belief that the “nature of the seis resolvit in geis” may be accepted as the true and final explanation of their origin. A certain “Maister Alexander Galloway” had apparently strolled with the historian along the sea-coast, the former giving “his mynd with maist ernst besynes to serche the verite of this obscure and mysty dowlis.” Lifting up a piece of tangle, they beheld the seaweed to be hanging full of mussel-shells from the root to the branches. Maister Galloway opened one of the mussel-shells, and was “mair astonis than afore” to find no fish therein, but a perfectly shaped “foule, smal and gret,” as corresponded to the “quantity of the shell.” And once again Boece draws the inference that the trees or wood on which the creatures are found have nothing to do with the origin of the birds; and that the fowls are begotten of the “occeane see, quhilk,” concludes our author, “is the caus and production of mony wonderful thingis.”

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More than fifty years after the publication of Boece's "History," old Gerard of London, the famous "master in chirurgerie" of his day, gave an account of the barnacle goose, and not only entered into minute particulars of its growth and origin, but illustrated its manner of production by means of the engraver's art of his day. Gerard's "Herball," published in 1597, thus contains, amongst much that is curious in medical lore, a very quaint piece of zoological history. He tells us that "in the north parts of Scotland, and the Hands adjacent, called Orchades (Orkneys)," are found "certaine trees, whereon doe growe certaine shell fishes, of a white colour tending to russet; wherein are contained little living creatures: which shels in time of maturitie doe open, and out of them grow those little living foules whom we call Barnakles, in the north of England Brant Geese, and in Lancashire tree Geese; but the other that do fall upon the land, perish, and come to nothing: thus much by the writings of others, and also from the mouths of people of those parts, which may," concludes Gerard, "very well accord with truth."

Not content with hearsay evidence, however, Gerard relates what his eyes saw and hands touched. He describes how on the coasts of a certain "small Hand in Lancashire called Pile of Foulders" (probably Peel Island), the wreckage of ships is cast up by the waves, along with the trunks and branches "of old and rotten trees." On these wooden rejectamenta "a certaine spume or froth" grows, according to Gerard. This spume "in time breedeth unto certaine shels, in shape like those of the muscle, but sharper pointed, and of a whitish color." This description, it may be remarked, clearly applies to the barnacles themselves. Gerard then continues to point out how, when the shell is perfectly formed, it "gapeth open, and the first thing that appeereth is the foresaid lace or string"—the substance described by Gerard as contained within the shell—"next come the legs of the Birde hanging out; and as it groweth greater, it openeth the shell by degrees, till at length it is all come forth, and hangeth only by the bill; in short space after it commeth to full maturitie, and falleth into the sea, where it gathereth feathers, and groweth to a foule, bigger than a Mallard, and lesser than a Goose, having blacke legs and bill or beake, and feathers blacke and white ... which the people of Lancashire call by no other name than a tree Goose."

[Illustration: FIG. 1. THE BARNACLE TREE. (From Gerard's "Herball.")]

Accompanying this description is the engraving of the barnacle tree (Fig. 1) bearing its geese progeny. From the open shells in two cases, the little geese are seen protruding, whilst several of the fully-fledged fowls are disporting themselves in the sea below. Gerard's concluding piece of information, with its exordium, must not be omitted. "They spawn," says the wise apothecary, "as it were, in March or Aprill; the Geese are found in

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Maie or June, and come to fulnesse of feathers in the moneth after. And thus hauing, through God's assistance, discoursed somewhat at large of Grasses, Herbes, Shrubs, Trees, Mosses, and certaine excrescences of the earth, with other things moe incident to the Historic thereof, we conclude and end our present volume, with this woonder of England. For which God's name be euer honored and praised." It is to be remarked that Gerard's description of the goose-progeny of the barnacle tree exactly corresponds with the appearance of the bird known to ornithologists as the "barnacle-goose"; and there can be no doubt that, skilled as was this author in the natural history lore of his day, there was no other feeling in his mind than that of firm belief in and pious wonder at the curious relations between the shells and their fowl-offspring. Gerard thus attributes the origin of the latter to the barnacles. He says nothing of the "wormeetin" holes and burrows so frequently mentioned by Boece, nor would he have agreed with the latter in crediting the "nature of the occeane see" with their production, save in so far as their barnacle-parents lived and existed in the waters of the ocean.

The last account of this curious fable which we may allude to in the present instance is that of Sir Robert Moray, who, in his work entitled "A Relation concerning Barnacles," published in the *Philosophical Transactions* of the Royal Society in 1677-78, gives a succinct account of these crustaceans and their bird-progeny. Sir Robert is described as "lately one of his Majesties Council for the Kingdom of Scotland," and we may therefore justly assume his account to represent that of a cultured, observant person of his day and generation. The account begins by remarking that the "most ordinary trees" found in the western islands of Scotland "are Firr and Ash." "Being," continues Sir Robert, "in the Island of East (Uist), I saw lying upon the shore a cut of a large Firr tree of about 2-1/2 foot diameter, and 9 or 10 foot long; which had lain so long out of the water that it was very dry: And most of the shells that had formerly cover'd it, were worn or rubb'd off. Only on the parts that lay next the ground, there still hung multitudes of little Shells; having within them little Birds, perfectly shap'd, supposed to be Barnacles." Here again the description applies to the barnacles; the "little birds" they are described as containing being of course the bodies of the shell-fish.

"The Shells," continues the narrator, "hang at the Tree by a Neck longer than the Shell;" this "neck" being represented by the stalk of the barnacle. The neck is described as being composed "of a kind of filmy substance, round, and hollow, and creased, not unlike the Wind-pipe of a Chicken; spreading out broadest where it is fastened to the Tree, from which it seems to draw and convey the matter which serves for the growth and vegetation of the Shell and the little Bird within it."

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Sir Robert Moray therefore agrees in respect of the manner of nourishment of the barnacles with the opinion of Giraldus already quoted. The author goes on to describe the “Bird” found in every shell he opened; remarking that “there appeared nothing wanting as to the internal parts, for making up a perfect Sea-fowl: every little part appearing so distinctly, that the whole looked like a large Bird seen through a concave or diminishing Glass, colour and feature being everywhere so clear and neat.” The “Bird” is most minutely described as to its bill, eyes, head, neck, breast, wings, tail, and feet, the feathers being “everywhere perfectly shaped, and blackish-coloured. All being dead and dry,” says Sir Robert, “I did not look after the Internal parts of them,” a statement decidedly inconsistent with his previous assertion as to the perfect condition of the “internal parts”; and he takes care to add, “nor did I ever see any of the little Birds alive, nor met with anybody that did. Only some credible persons,” he concludes, “have assured me they have seen some as big as their fist.”

[Illustration: FIG. 2. BARNACLE TREE. (From Munster’s “Cosmography.”)]

This last writer thus avers that he saw little birds within the shells he clearly enough describes as those of the barnacles. We must either credit Sir Robert with describing what he never saw, or with misconstruing what he did see. His description of the goose corresponds with that of the barnacle goose, the reputed progeny of the shells; and it would, therefore, seem that this author, with the myth at hand, saw the barnacles only with the eyes of a credulous observer, and thus beheld, in the inside of each shell—if, indeed, his research actually extended thus far—the reproduction in miniature of a goose, with which, as a mature bird, he was well acquainted.

On p. 157 is a woodcut, copied from Munster’s “Cosmography” (1550), a very popular book in its time, showing the tree with its fruit, and the geese which are supposed to have just escaped from it.

This historical ramble may fitly preface what we have to say regarding the probable origin of the myth. By what means could the barnacles become credited with the power of producing the well-known geese? Once started, the progress and growth of the myth are easily accounted for. The mere transmission of a fable from one generation or century to another is a simply explained circumstance, and one exemplified by the practices of our own times. The process of accretion and addition is also well illustrated in the perpetuation of fables; since the tale is certain to lose nothing in its historical journey, but, on the contrary, to receive additional elaboration with increasing age. Professor Max Mueller, after discussing various theories of the origin of the barnacle myth, declares in favor of the idea that confusion of language and alteration of names lie at the root of the error. The learned author of the “Science

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of Language” argues that the true barnacles were named, properly enough, Bernaculae, and lays stress on the fact that Bernicle geese were first caught in Ireland. That country becomes *Hibernia* in Latin, and the Irish geese were accordingly named Hibernicae, or Hiberniculae. By the omission of the first syllable—no uncommon operation for words to undergo—we obtain the name Berniculae for the geese, this term being almost synonymous with the name Bernaculae already applied, as we have seen, to the barnacles. Bernicle geese and bernicle shells, confused in name, thus became confused in nature; and, once started, the ordinary process of growth was sufficient to further intensify, and render more realistic, the story of the bernicle tree and its wonderful progeny.

By way of a companion legend to that of the barnacle tree, we may select the story of the “Lamb Tree” of Cathay, told by Sir John Mandeville, whose notes of travel regarding crocodiles’ tears, and other points in the conformation of these reptiles, have already been referred to. Sir John, in that chapter of his work which treats “Of the Contries and Yles that ben bezonde the Lond of Cathay; and of the Frutes there,” etc., relates that in Cathay “there growethe a manner of Fruyt, as thoughe it were Gowrdes: and whan thei ben ripe, men kutten (cut) hem a to (them in two), and men fyndem with inne a lytylle Best (beast), in Flessche in Bon and Blode (bone and blood) as though it were a lytylle Lomb (lamb) with outen wolfe (without wool). And men eaten both the Frut and the Best; and that,” says Sir John, “is a great marveylle. Of that frut,” he continues, “I have eten; alle thoughe it were wondirfulle”—this being added, no doubt, from an idea that there might possibly be some stay-at-home persons who would take Sir John’s statement *cum grano salis*. “But,” adds this worthy “knyght of Ingolond,” “I knowe wel that God is marveyllous in His Werkes.” Not to be behind the inhabitants of Cathay in a tale of wonders, the knight related to these Easterns “als gret a marveylle to hem that is amonges us; and that was of the Bernakes. For I tolde him hat in oure Countree weren Trees that beren a Fruyt, that becomen Briddes (birds) fleeynge: and tho that fellen in the Water lyven (live); and thei that fallen on the Erthe dyen anon: and thei ben right gode to mannes mete (man’s meat). And here had thei als gret marvayle,” concludes Sir John, “that sume of hem trowed it were an impossible thing to be.” Probably the inhabitants of Cathay, knowing their own weakness as regards the lamb tree, might possess a fellow-feeling for their visitor’s credulity, knowing well, from experience, the readiness with which a “gret marvayle” could be evolved and sustained.

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Passing from the sphere of the mythical and marvellous as represented in mediaeval times, we may shortly discuss a question, which, of all others, may justly claim a place in the records of Zooological curiosities—namely, the famous and oft-repeated story of the “Toad from the solid rock,” as the country newspapers style the incident. Regularly, year by year, and in company with the reports of the sea-serpent’s reappearance, we may read of the discoveries of toads and frogs in situations and under circumstances suggestive of a singular vitality on the part of the amphibians, of more than usual credulity on the part of the hearers, or of a large share of inventive genius in the narrators of such tales. The question possesses for every one a certain degree of interest, evoked by the curious and strange features presented on the face of the tales. And it may therefore not only prove an interesting but also a useful study, if we endeavor to arrive at some just and logical conceptions of these wonderful narrations.

[Illustration]

Instances of the discovery of toads and frogs in solid rocks need not be specially given; suffice it to say, that these narratives are repeated year by year with little variation. A large block of stone or face of rock is detached from its site, and a toad or frog is seen hereafter to be hopping about in its usual lively manner. The conclusion to which the bystanders invariably come is that the animal must have been contained within the rock, and that it was liberated by the dislodgement of the mass. Now, in many instances, cases of the appearance of toads during quarrying operations have been found, on close examination, to present no evidence whatever that the appearance of the animals was due to the dislodgement of the stones. A frog or toad may be found hopping about among some recently formed debris, and the animal is at once seized upon and reported as having emerged from the rocks into the light of day. There is in such a case not the slightest ground for supposing any such thing; and the animal may more reasonably be presumed to have simply hopped into the debris from its ordinary habitat. But laying aside narratives of this kind, which lose their plausibility under a very commonplace scrutiny, there still exist cases, reported in an apparently exact and truthful manner, in which these animals have been alleged to appear from the inner crevices of rocks after the removal of large masses of the formations. We shall assume these latter tales to contain a plain, unvarnished statement of what was observed, and deal with the evidence they present on this footing.

[Illustration: A TOAD.]

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One or two notable examples of such verified tales are related by Smellie, in his "Philosophy of Natural History." Thus, in the "Memoirs of the French Academy of Sciences" for 1719, a toad is described as having been found in the heart of an elm tree; and another is stated to have been found in the heart of an old oak tree, in 1731, near Nantz. The condition of the trees is not expressly stated, nor are we afforded any information regarding the appearance of the toads—particulars of considerable importance in view of the suggestions and explanations to be presently brought forward. Smellie himself, while inclined to be sceptical in regard to the truth or exactness of many of the tales told of the vitality of toads, regards the matter as affording food for reflection, since he remarks, "But I mean not to persuade, for I cannot satisfy myself; all I intend is, to recommend to those gentlemen who may hereafter chance to see such rare phenomena, a strict examination of every circumstance that can throw light upon a subject so dark and mysterious; for the vulgar, ever inclined to render uncommon appearances still more marvellous, are not to be trusted."

This author strikes the key-note of the inquiry in his concluding words, and we shall find that the explanation of the matter really lies in the clear understanding of what are the probabilities, and what the actual details, of the cases presented for consideration. We may firstly, then, glance at a few of the peculiarities of the frogs and toads, regarded from a zoological point of view. As every one knows, these animals emerge from the egg in the form of little fish-like "tadpoles," provided with outside gills, which are soon replaced by inside gills, resembling those of fishes. The hind legs are next developed, and the fore limbs follow a little later; whilst, with the development of lungs, and the disappearance of the gills and tail, the animal leaves the water, and remains for the rest of its life an air-breathing, terrestrial animal. Then, secondly, in the adult frog or toad, the naturalist would point to the importance of the skin as not only supplementing, but, in some cases, actually supplanting the work of the lungs as the breathing organ. Frogs and toads will live for months under water, and will survive the excision of the lungs for like periods; the skin in such cases serving as the breathing surface. A third point worthy of remembrance is included in the facts just related, and is implied in the information that these animals can exist for long periods without food, and with but a limited supply of air. We can understand this toleration on the part of these animals when we take into consideration their cold-blooded habits, which do not necessitate, and which are not accompanied by, the amount of vital activity we are accustomed to note in higher animals. And, as a last feature in the purely scientific history of the frogs and toads, it may be remarked that these animals are known

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to live for long periods. One pet toad is mentioned by a Mr. Arscott as having attained, to his knowledge, the age of thirty-six years; and a greater age still might have been recorded of this specimen, but for the untoward treatment it sustained at the hands, or rather beak, of a tame raven. In all probability it may be safely assumed that, when the conditions of life are favorable, these creatures may attain a highly venerable age—regarding the lapse of time from a purely human and interested point of view.

We may now inquire whether or not the foregoing considerations may serve to throw any light upon the tales of the quarryman. The first point to which attention may be directed is that involved in the statement that the amphibian has been imprisoned in a *solid* rock. Much stress is usually laid on the fact that the rock was solid; this fact being held to imply the great age, not to say antiquity, of the rock and its supposed tenant. The impartial observer, after an examination of the evidence presented, will be inclined to doubt greatly the justification for inserting the adjective “solid”; for usually no evidence whatever is forthcoming as to the state of the rock prior to its removal. No previous examination of the rock is or can be made, from the circumstance that no interest can possibly attach to its condition until its removal reveals the apparent wonder it contained, in the shape of the live toad. And it is equally important to note that we rarely, if ever, find mention of any examination of the rock being made subsequently to the discovery. Hence, a first and grave objection may be taken to the validity of the supposition that the rock was solid, and it may be fairly urged that on this supposition the whole question turns and depends. For if the rock cannot be proved to have been impermeable to and barred against the entrance of living creatures, the objector may proceed to show the possibility of the toad having gained admission, under certain notable circumstances, to its prison-house.

The frog or toad in its young state, and having just entered upon its terrestrial life, is a small creature, which could, with the utmost ease, wriggle into crevices and crannies of a size which would almost preclude such apertures being noticed at all. Gaining access to a roomier crevice or nook within, and finding there a due supply of air, along with a dietary consisting chiefly of insects, the animal would grow with tolerable rapidity, and would increase to such an extent that egress through its aperture of entrance would become an impossibility. Next, let us suppose that the toleration of the toad’s system to starvation and to a limited supply of air is taken into account, together with the fact that these creatures will hibernate during each winter, and thus economize, as it were, their vital activity and strength; and after the animal has thus existed for a year or two—no doubt under singularly hard conditions—let us

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imagine that the rock is split up by the wedge and lever of the excavator. We can then readily enough account for the apparently inexplicable story of "the toad in the rock." "There is the toad and here is the solid rock," say the gossips. "There is an animal which has singular powers of sustaining life under untoward conditions, and which, in its young state, could have gained admittance to the rock through a mere crevice," says the naturalist in reply. Doubtless, the great army of the unconvinced may still believe in the tale as told them; for the weighing of evidence and the placing *pros* and *cons* in fair contrast are not tasks of congenial or wonted kind in the ordinary run of life. Some people there will be who will believe in the original solid rock and its toad, despite the assertion of the geologists that the earliest fossils of toads appear in almost the last-formed rocks, and that a live toad in rocks of very ancient age—presuming, according to the popular belief, that the animal was enclosed when the rock was formed—would be as great an anomaly and wonder as the mention, as an historical fact, of an express train or the telegraph in the days of the patriarchs. In other words, the live toad which hops out of an Old Red Sandstone rock must be presumed, on the popular belief, to be older by untold ages than the oldest fossil frogs and toads. The reasonable mind, however, will ponder and consider each feature of the case, and will rather prefer to countenance a supposition based on ordinary experience, than an explanation brought ready-made from the domain of the miraculous; whilst not the least noteworthy feature of these cases is that included in the remark of Smellie, respecting the tendency of uneducated and superstitious persons to magnify what is uncommon, and in his sage conclusion that as a rule such persons in the matter of their relations "are not to be trusted."

But it must also be noted that we possess valuable evidence of a positive and direct kind bearing on the duration of life in toads under adverse circumstances. As this evidence tells most powerfully against the supposition that the existence of those creatures can be indefinitely prolonged, it forms of itself a veritable court of appeal in the cases under discussion. The late Dr. Buckland, curious to learn the exact extent of the vitality of the toad, caused, in the year 1825, two large blocks of stone to be prepared. One of the blocks was taken from the oolite limestone, and in this first stone twelve cells were excavated. Each cell was one foot deep and five inches in diameter. The mouth of each cell was grooved so as to admit of two covers being placed over the aperture; the first or lower cover being of glass, and the upper one of slate. Both covers were so adapted that they could be firmly luted down with clay or putty; the object of this double protection being that the slate cover could be raised so as to inspect the contained object through the closed glass cover without admitting air. In the second or sandstone block, a series of twelve cells was also excavated; these latter cells being, however, of smaller size than those of the limestone block, each cell being only six inches in depth by five inches in diameter. These cells were likewise fitted with double covers.

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On November 26th, 1825, a live toad—kept for some time previously to insure its being healthy—was placed in each of the twenty-four cells. The largest specimen weighed 1185 grains, and the smallest 115 grains. The stones and the immured toads were buried on the day mentioned, three feet deep, in Dr. Buckland's garden. There they lay until December 10th, 1826, when they were disinterred and their tenants examined. All the toads in the smaller cells of the sandstone block were dead, and from the progress of decomposition it was inferred that they had succumbed long before the date of disinterment. The majority of the toads in the limestone block were alive, and, curiously enough, one or two had actually increased in weight. Thus, No. 5, which at the commencement of its captivity had weighed 1185 grains, had increased to 1265 grains; but the glass cover of No. 5's cell was found to be cracked. Insects and air must therefore have obtained admittance and have afforded nourishment to the imprisoned toad; this supposition being rendered the more likely by the discovery that in one of the cells, the covers of which were also cracked and the tenant of which was dead, numerous insects were found. No. 9, weighing originally 988 grains, had increased during its incarceration to 1116 grains; but No. 1, which in the year 1825 had weighed 924 grains, was found in December, 1826, to have decreased to 698 grains; and No. 11, originally weighing 936 grains, had likewise disagreed with the imprisonment, weighing only 652 grains when examined in 1826.

At the period when the blocks of stone were thus prepared, four toads were pinned up in holes five inches deep and three inches in diameter, cut in the, stem of an apple-tree; the holes being firmly plugged with tightly fitting wooden plugs. These four toads were found to be dead when examined along with the others in 1826; and of four others enclosed in basins made of plaster of Paris, and which were also buried in Dr. Buckland's garden, two were found to be dead at the end of a year, their comrades being alive, but looking starved and meagre. The toads which were found alive in the limestone block in December, 1826, were again immured and buried, but were found to be dead, without leaving a single survivor, at the end of the second year of their imprisonment.

These experiments may fairly be said to prove two points. They firstly show that under circumstances even of a favorable kind when compared with the condition popularly believed in—namely, that of being enclosed in a *solid* rock—the limit of the toad's life may be assumed to be within two years; this period being no doubt capable of being extended when the animal gains a slight advantage, exemplified by the admission of air and insect-food. Secondly, we may reasonably argue that these experiments show that toads when rigorously treated, like other animals, become starved and meagre, and by no means resemble the lively, well-fed animals reported as having emerged from an imprisonment extending, in popular estimation, through periods of inconceivable duration.

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These tales are, in short, as devoid of actual foundation as are the modern beliefs in the venomous properties of the toad, or the ancient beliefs in the occult and mystic powers of various parts of its frame when used in incantations. Shakespeare, whilst attributing to the toad venomous qualities, has yet immortalized it in his famous simile by crediting it with the possession of a “precious jewel.” But even in the latter case the animal gets but scant justice; for science strips it of its poetical reputation, and in this, as in other respects, shows it, despite fable and myth, to be zoologically an interesting, but otherwise a commonplace member of the animal series.

[Illustration]

ON A PIECE OF CHALK

A LECTURE TO WORKING MEN.

(Delivered in England.)

BY T.H. HUXLEY.

[Illustration: A CHALK CLIFF.]

If a well were to be sunk at our feet in the midst of the city of Norwich, the diggers would very soon find themselves at work in that white substance almost too soft to be called rock, with which we are all familiar as “chalk.”

Not only here, but over the whole county of Norfolk, the well-sinker might carry his shaft down many hundred feet without coming to the end of the chalk; and, on the sea-coast, where the waves have pared away the face of the land which breasts them, the scarped faces of the high cliffs are often wholly formed of the same material. Northward, the chalk may be followed as far as Yorkshire; on the south coast it appears abruptly in the picturesque western bays of Dorset, and breaks into the Needles of the Isle of Wight; while on the shores of Kent it supplies that long line of white cliffs to which England owes her name of Albion.

Were the thin soil which covers it all washed away, a curved band of white chalk, here broader, and there narrower, might be followed diagonally across England from Lulworth in Dorset, to Flamborough Head in Yorkshire—a distance of over two hundred and eighty miles as the crow flies.

From this band to the North Sea, on the east, and the Channel, on the south, the chalk is largely hidden by other deposits; but, except in the Weald of Kent and Sussex, it enters into the very foundation of all the south-eastern counties.

Attaining, as it does in some places, a thickness of more than a thousand feet, the English chalk must be admitted to be a mass of considerable magnitude. Nevertheless, it covers but an insignificant portion of the whole area occupied by the chalk formation of the globe, which has precisely the same general character as ours, and is found in detached patches, some less, and others more extensive, than the English.

Chalk occurs in north-west Ireland; it stretches over a large part of France—the chalk which underlies Paris being, in fact, a continuation of that of the London basin; it runs through Denmark and Central Europe, and extends southward to North Africa; while eastward, it appears in the Crimea and in Syria, and may be traced as far as the shores of the Sea of Aral, in Central Asia.

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If all the points at which true chalk occurs were circumscribed, they would lie within an irregular oval about three thousand miles in long diameter—the area of which would be as great as that of Europe, and would many times exceed that of the largest existing inland sea—the Mediterranean.

Thus the chalk is no unimportant element in the masonry of the earth's crust, and it impresses a peculiar stamp, varying with the conditions to which it is exposed, on the scenery of the districts in which it occurs. The undulating downs and rounded coombs, covered with sweet-grassed turf, of our inland chalk country, have a peacefully domestic and mutton-suggesting prettiness, but can hardly be called either grand or beautiful. But on our southern coasts, the wall-sided cliffs, many hundred feet high, with vast needles and pinnacles standing out in the sea, sharp and solitary enough to serve as perches for the wary cormorant, confer a wonderful beauty and grandeur upon the chalk headlands. And in the East, chalk has its share in the formation of some of the most venerable of mountain ranges, such as the Lebanon.

* * * * *

What is this wide-spread component of the surface of the earth? and whence did it come?

You may think this no very hopeful inquiry. You may not unnaturally suppose that the attempt to solve such problems as these can lead to no result, save that of entangling the inquirer in vague speculations, incapable of refutation and of verification.

If such were really the case, I should have selected some other subject than a "piece of chalk" for my discourse. But, in truth, after much deliberation, I have been unable to think of any topic which would so well enable me to lead you to see how solid is the foundation upon which some of the most startling conclusions of physical science rest.

A great chapter of the history of the world is written in the chalk. Few passages in the history of man can be supported by such an overwhelming mass of direct and indirect evidence as that which testifies to the truth of the fragment of the history of the globe, which I hope to enable you to read, with your own eyes, to-night.

[Illustration: MICROSCOPIC SECTION OF CHALK.

(Magnified nearly 300 times.)

1. Textularia. 2. Globigerina. 3. Rotalia. 4. Coccoliths.]

Let me add, that few chapters of human history have a more profound significance for ourselves. I weigh my words well when I assert, that the man who should know the true history of the bit of chalk which every carpenter carries about in his breeches' pocket, though ignorant of all other history, is likely, if he will think his knowledge out to its

ultimate results, to have a truer, and therefore a better, conception of this wonderful universe, and of man's relation to it, than the most learned student who is deep-read in the records of humanity and ignorant of those of nature.

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The language of the chalk is not hard to learn, not nearly so hard as Latin, if you only want to get at the broad features of the story it has to tell; and I propose that we now set to work to spell that story out together.

We all know that if we “burn” chalk, the result is quicklime. Chalk, in fact, is a compound of carbonic acid gas and lime; and when you make it very hot, the carbonic acid flies away and the lime is left.

By this method of procedure we see the lime, but we do not see the carbonic acid. If, on the other hand, you were to powder a little chalk and drop it into a good deal of strong vinegar, there would be a great bubbling and fizzing, and, finally, a clear liquid, in which no sign of chalk would appear. Here you see the carbonic acid in the bubbles; the lime, dissolved in the vinegar, vanishes from sight. There are a great many other ways of showing that chalk is essentially nothing but carbonic acid and quicklime. Chemists enunciate the result of all the experiments which prove this, by stating that chalk is almost wholly composed of “carbonate of lime.”

It is desirable for us to start from the knowledge of this fact, though it may not seem to help us very far toward what we seek. For carbonate of lime is a widely-spread substance, and is met with under very various conditions. All sorts of limestones are composed of more or less pure carbonate of lime. The crust which is often deposited by waters which have drained through limestone rocks, in the form of what are called stalagmites and stalactites, is carbonate of lime. Or, to take a more familiar example, the fur on the inside of a tea-kettle is carbonate of lime; and, for anything chemistry tells us to the contrary, the chalk might be a kind of gigantic fur upon the bottom of the earth-kettle, which is kept pretty hot below.

Let us try another method of making the chalk tell us its own history. To the unassisted eye chalk looks simply like a very loose and open kind of stone. But it is possible to grind a slice of chalk down so thin that you can see through it—until it is thin enough, in fact, to be examined with any magnifying power that may be thought desirable. A thin slice of the fur of a kettle might be made in the same way. If it were examined microscopically, it would show itself to be a more or less distinctly laminated mineral substance, and nothing more.

But the slice of chalk presents a totally different appearance when placed under the microscope. The general mass of it is made up of very minute granules; but, imbedded in this matrix, are innumerable bodies, some smaller and some larger, but, on a rough average, not more than a hundredth of an inch in diameter, having a well-defined shape and structure. A cubic inch of some specimens of chalk may contain hundreds of thousands of these bodies, compacted together with incalculable millions of the granules.

[Illustration: CHALK.

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(Magnified nearly 100 diameters.)]

The examination of a transparent slice gives a good notion of the manner in which the components of the chalk are arranged, and of their relative proportions. But, by rubbing up some chalk with a brush in water and then pouring off the milky fluid, so as to obtain sediments of different degrees of fineness, the granules and the minute rounded bodies may be pretty well separated from one another, and submitted to microscopic examination, either as opaque or as transparent objects. By combining the views obtained in these various methods, each of the rounded bodies may be proved to be a beautifully-constructed calcareous fabric, made up of a number of chambers, communicating freely with one another. The chambered bodies are of various forms. One of the commonest is something like a badly-grown raspberry, being formed of a number of nearly globular chambers of different sizes congregated together. It is called Globigerina, and some specimens of chalk consist of little else than Globigerinae and granules.

[Illustration: GLOBIGERINA.]

Let us fix our attention upon the Globigerina. It is the spoor of the game we are tracking. If we can learn what it is and what are the conditions of its existence, we shall see our way to the origin and past history of the chalk.

A suggestion which may naturally enough present itself is, that these curious bodies are the result of some process of aggregation which has taken place in the carbonate of lime; that, just as in winter, the rime on our windows simulates the most delicate and elegantly arborescent foliage—proving that the mere mineral matter may, under certain conditions, assume the outward form of organic bodies—so this mineral substance, carbonate of lime, hidden away in the bowels of the earth, has taken the shape of these chambered bodies. I am not raising a merely fanciful and unreal objection. Very learned men, in former days, have even entertained the notion that all the formed things found in rocks are of this nature; and if no such conception is at present held to be admissible, it is because long and varied experience has now shown that mineral matter never does assume the form and structure we find in fossils. If anyone were to try to persuade you that an oyster-shell (which is also chiefly composed of carbonate of lime) had crystallized out of sea-water, I suppose you would laugh at the absurdity. Your laughter would be justified by the fact that all experience tends to show that oyster-shells are formed by the agency of oysters, and in no other way. And if there were no better reasons, we should be justified, on like grounds, in believing that Globigerina is not the product of anything but vital activity.

Happily, however, better evidence in proof of the organic nature of the Globigerinae than that of analogy is forthcoming. It so happens that calcareous skeletons, exactly similar to the Globigerinae of the chalk, are being formed, at the present moment, by minute living creatures, which flourish in multitudes, literally more numerous than the sands of

the sea-shore, over a large extent of that part of the earth's surface which is covered by the ocean.

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The history of the discovery of these living Globigerinae, and of the part which they play in rock-building, is singular enough. It is a discovery which, like others of no less scientific importance, has arisen, incidentally, out of work devoted to very different and exceedingly practical interests.

When men first took to the sea, they speedily learned to look out for shoals and rocks; and the more the burthen of their ships increased, the more imperatively necessary it became for sailors to ascertain with precision the depth of the waters they traversed. Out of this necessity grew the use of the lead and sounding-line; and, ultimately, marine-surveying, which is the recording of the form of coasts and of the depth of the sea, as ascertained by the sounding-lead, upon charts.

At the same time, it became desirable to ascertain and to indicate the nature of the sea-bottom, since this circumstance greatly affects its goodness as holding ground for anchors. Some ingenious tar, whose name deserves a better fate than the oblivion into which it has fallen, attained this object by “arming” the bottom of the lead with a lump of grease, to which more or less of the sand or mud, or broken shells, as the case might be, adhered, and was brought to the surface. But, however well adapted such an apparatus might be for rough nautical purposes, scientific accuracy could not be expected from the armed lead, and to remedy its defects (especially when applied to sounding in great depths) Lieutenant Brooke, of the American Navy, some years ago invented a most ingenious machine, by which a considerable portion of the superficial layer of the sea-bottom can be scooped out and brought up, from any depth to which the lead descends.

In 1853, Lieutenant Brooke obtained mud from the bottom of the North Atlantic, between Newfoundland and the Azores, at a depth of more than ten thousand feet, or two miles, by the help of this sounding apparatus. The specimens were sent for examination to Ehrenberg of Berlin, and to Bailey of West Point, and those able microscopists found that this deep-sea mud was almost entirely composed of the skeletons of living organisms—the greater proportion of these being just like the Globigerinae already known to occur in chalk.

Thus far, the work had been carried on simply in the interests of science, but Lieutenant Brooke’s method of sounding acquired a high commercial value, when the enterprise of laying down the telegraph-cable between this country and the United States was undertaken. For it became a matter of immense importance to know, not only the depth of the sea over the whole line, along which the cable was to be laid, but the exact nature of the bottom, so as to guard against chances of cutting or fraying the strands of that costly rope. The Admiralty consequently ordered Captain Dayman, an old friend and shipmate of mine, to ascertain the depth over the whole line of the cable, and to bring

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back specimens of the bottom. In former days, such a command as this might have sounded very much like one of the impossible things which the young prince in the Fairy Tales is ordered to do before he can obtain the hand of the princess. However, in the months of June and July, 1857, my friend performed the task assigned to him with great expedition and precision, without, so far as I know, having met with any reward of that kind. The specimens of Atlantic mud which he procured were sent to me to be examined and reported upon.

The result of all these operations is, that we know the contours and the nature of the surface-soil covered by the North Atlantic, for a distance of seventeen hundred miles from east to west, as well as we know that of any part of the dry land.

It is a prodigious plain—one of the widest and most even plains in the world. If the sea were drained off, you might drive a wagon all the way from Valentia, on the west coast of Ireland, to Trinity Bay in Newfoundland. And, except upon one sharp incline about two hundred miles from Valentia, I am not quite sure that it would even be necessary to put the skid on, so gentle are the ascents and descents upon that long route. From Valentia the road would lie down-hill for about two hundred miles to the point at which the bottom is now covered by seventeen hundred fathoms of sea-water. Then would come the central plain, more than a thousand miles wide, the inequalities of the surface of which would be hardly perceptible, though the depth of water upon it now varies from ten thousand to fifteen thousand feet; and there are places in which Mont Blanc might be sunk without showing its peak above water. Beyond this, the ascent on the American side commences, and gradually leads, for about three hundred miles, to the Newfoundland shore.

Almost the whole of the bottom of this central plain (which extends for many hundred miles in a north and south direction) is covered by a fine mud, which, when brought to the surface, dries into a grayish white friable substance. You can write with this on a black-board, if you are so inclined; and, to the eye, it is quite like very soft, grayish chalk. Examined chemically, it proves to be composed almost wholly of carbonate of lime; and if you make a section of it, in the same way as that of the piece of chalk was made, and view it with the microscope, it presents innumerable Globigerinae embedded in a granular matrix.

Thus this deep-sea mud is substantially chalk. I say substantially, because there are a good many minor differences; but as these have no bearing on the question immediately before us—which is the nature of the Globigerinae of the chalk—it is unnecessary to speak of them.

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Globigerinae of every size, from the smallest to the largest, are associated together in the Atlantic mud, and the chambers of many are filled by a soft animal matter. This soft substance is, in fact, the remains of the creature to which the Globigerina shell, or rather skeleton, owes its existence—and which is an animal of the simplest imaginable description. It is, in fact, a mere particle of living jelly, without defined parts of any kind—without a mouth, nerves, muscles, or distinct organs, and only manifesting its vitality to ordinary observation by thrusting out and retracting from all parts of its surface long filamentous processes, which serve for arms and legs. Yet this amorphous particle, devoid of everything which, in the higher animals, we call organs, is capable of feeding, growing, and multiplying; of separating from the ocean the small proportion of carbonate of lime which is dissolved in sea-water; and of building up that substance into a skeleton for itself, according to a pattern which can be imitated by no other known agency.

The notion that animals can live and flourish in the sea, at the vast depths from which apparently living Globigerinae have been brought up, does not agree very well with our usual conceptions respecting the conditions of animal life; and it is not so absolutely impossible as it might at first sight appear to be, that the Globigerinae of the Atlantic sea-bottom do not live and die where they are found.

[Illustration: DIATOM OOZE DREDGED FROM A DEPTH OF 1950 FEET.

(Magnified nearly 300 diameters.)]

As I have mentioned, the soundings from the great Atlantic plain are almost entirely made up of Globigerinae, with the granules which have been mentioned, and some few other calcareous shells; but a small percentage of the chalky mud—perhaps at most some five per cent of it—is of a different nature, and consists of shells and skeletons composed of silex, or pure flint. These siliceous bodies belong partly to the lowly vegetable organisms which are called Diatomaceae, and partly to the minute and extremely simple animals, termed Radiolaria. It is quite certain that these creatures do not live at the bottom of the ocean, but at its surface—where they may be obtained in prodigious numbers by the use of a properly constructed net. Hence it follows that these siliceous organisms, though they are not heavier than the lightest dust, must have fallen, in some cases, through fifteen thousand feet of water, before they reached their final resting-place on the ocean floor. And, considering how large a surface these bodies expose in proportion to their weight, it is probable that they occupy a great length of time in making their burial journey from the surface of the Atlantic to the bottom.

[Illustration: RADIOLARIA. (*a.* Natural size. *b.* One-third natural size.)]

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But if the Radiolaria and Diatoms are thus rained upon the bottom of the sea, from the superficial layer of its waters in which they pass their lives, it is obviously possible that the Globigerinae may be similarly derived; and if they were so, it would be much more easy to understand how they obtain their supply of food than it is at present. Nevertheless, the positive and negative evidence all points the other way. The skeletons of the full-grown, deep-sea Globigerinae are so remarkably solid and heavy in proportion to their surface as to seem little fitted for floating; and, as a matter of fact, they are not to be found along with the Diatoms and Radiolaria, in the uppermost stratum of the open ocean.

It has been observed, again, that the abundance of Globigerinae, in proportion to other organisms of like kind, increases with the depth of the sea; and that deep-water Globigerinae are larger than those which live in the shallower parts of the sea; and such facts negative the supposition that these organisms have been swept by currents from the shallows into the deeps of the Atlantic.

It therefore seems to be hardly doubtful that these wonderful creatures live and die at the depths in which they are found.[1]

[Footnote 1: During the cruise of H.M.S. Bull-dog, commanded by Sir Leopold M'Clintock, in 1860, living star-fish were brought up, clinging to the lowest part of the sounding-line, from a depth of 1260 fathoms, midway between Cape Farewell, in Greenland, and the Rockall banks. Dr. Wallich ascertained that the sea-bottom at this point consisted of the ordinary Globigerina ooze, and that the stomachs of the star-fishes were full of Globigerinae. This discovery removes all objections to the existence of living Globigerinae at great depths, which are based upon the supposed difficulty of maintaining animal life under such conditions; and it throws the burden of proof upon those who object to the supposition that the Globigerinae live and die where they are found.]

However, the important points for us are, that the living Globigerinae are exclusively marine animals, the skeletons of which abound at the bottom of deep seas; and that there is not a shadow of reason for believing that the habits of the Globigerinae of the chalk differed from those of the existing species. But if this be true, there is no escaping the conclusion that the chalk itself is the dried mud of an ancient deep sea.

In working over the soundings collected by Captain Dayman, I was surprised to find that many of what I have called the "granules" of that mud were not, as one might have been tempted to think at first, the mere powder and waste of Globigerinae, but that they had a definite form and size. I termed these bodies "*coccoliths*" and doubted their organic nature. Dr. Wallich verified my observation, and added the interesting discovery that, not unfrequently, bodies similar to these "*coccoliths*" were aggregated together into spheroids, which he termed "*coccospheres*." So far as we knew, these bodies, the

nature of which is extremely puzzling and problematical, were peculiar to the Atlantic soundings.

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But, a few years ago, Mr. Sorby, in making a careful examination of the chalk by means of thin sections and otherwise, observed, as Ehrenberg had done before him, that much of its granular basis possesses a definite form. Comparing these formed particles with those in the Atlantic soundings, he found the two to be identical; and thus proved that the chalk, like the soundings, contains these mysterious coccoliths and coccospheres. Here was a further and a most interesting confirmation, from internal evidence, of the essential identity of the chalk with modern deep-sea mud. Globigerinae, coccoliths, and coccospheres are found as the chief constituents of both, and testify to the general similarity of the conditions under which both have been formed.[2]

[Footnote 2: I have recently traced out the development of the “coccoliths” from a diameter of 1/7000th of an inch up to their largest size (which is about 1/1600th), and no longer doubt that they are produced by independent organisms, which, like the Globigerinae, live and die at the bottom of the sea.]

The evidence furnished by the hewing, facing, and superposition of the stones of the Pyramids, that these structures were built by men, has no greater weight than the evidence that the chalk was built by Globigerinae; and the belief that those ancient pyramid-builders were terrestrial and air-breathing creatures like ourselves, is not better based than the conviction that the chalk-makers lived in the sea.

But as our belief in the building of the Pyramids by men is not only grounded on the internal evidence afforded by these structures, but gathers strength from multitudinous collateral proofs, and is clinched by the total absence of any reason for a contrary belief; so the evidence drawn from the Globigerinae that the chalk is an ancient sea-bottom, is fortified by innumerable independent lines of evidence; and our belief in the truth of the conclusion to which all positive testimony tends, receives the like negative justification from the fact that no other hypothesis has a shadow of foundation.

It may be worth while briefly to consider a few of these collateral proofs that the chalk was deposited at the bottom of the sea.

The great mass of the chalk is composed, as we have seen, of the skeletons of Globigerinae, and other simple organisms, imbedded in granular matter. Here and there, however, this hardened mud of the ancient sea reveals the remains of higher animals which have lived and died, and left their hard parts in the mud, just as the oysters die and leave their shells behind them, in the mud of the present seas.

[Illustration: UPPER SILURIAN CORALS AND CRUSTACEANS.]

There are, at the present day, certain groups of animals which are never found in fresh waters, being unable to live anywhere but in the sea. Such are the corals; those corallines which are called Polyzoa; those creatures which fabricate the lamp-shells,

and are called Brachiopoda; the pearly Nautilus, and all animals allied to it; and all the forms of sea-urchins and star-fishes.

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Not only are all these creatures confined to salt water at the present day, but, so far as our records of the past go, the conditions of their existence have been the same: hence, their occurrence in any deposit is as strong evidence as can be obtained, that that deposit was formed in the sea. Now the remains of animals of all the kinds which have been enumerated occur in the chalk, in greater or less abundance; while not one of those forms of shell-fish which are characteristic of fresh water has yet been observed in it.

When we consider that the remains of more than three thousand distinct species of aquatic animals have been discovered among the fossils of the chalk, that the great majority of them are of such forms as are now met with only in the sea, and that there is no reason to believe that any one of them inhabited fresh water—the collateral evidence that the chalk represents an ancient sea-bottom acquires as great force as the proof derived from the nature of the chalk itself. I think you will now allow that I did not overstate my case when I asserted that we have as strong grounds for believing that all the vast area of dry land at present occupied by the chalk was once at the bottom of the sea, as we have for any matter of history whatever; while there is no justification for any other belief.

[Illustration: CRETACEOUS NAUTILUS.]

No less certain is it that the time during which the countries we now call southeast England, France, Germany, Poland, Russia, Egypt, Arabia, Syria, were more or less completely covered by a deep sea, was of considerable duration.

We have already seen that the chalk is, in places, more than a thousand feet thick. I think you will agree with me that it must have taken some time for the skeletons of the animalcules of a hundredth of an inch in diameter to heap up such a mass as that. I have said that throughout the thickness of the chalk the remains of other animals are scattered. These remains are often in the most exquisite state of preservation. The valves of the shell-fishes are commonly adherent; the long spines of some of the sea-urchins, which would be detached by the smallest jar, often remain in their places. In a word, it is certain that these animals have lived and died when the place which they now occupy was the surface of as much of the chalk as had then been deposited; and that each has been covered up by the layer of Globigerina mud, upon which the creatures imbedded a little higher up have, in like manner, lived and died. But some of these remains prove the existence of reptiles of vast size in the chalk sea. These lived their time, and had their ancestors and descendants, which assuredly implies time, reptiles being of slow growth.

There is more curious evidence, again, that the process of covering up, or, in other words, the deposit of Globigerina skeletons, did not go on very fast. It is demonstrable that an animal of the cretaceous sea might die, that its skeleton might lie uncovered upon the sea-bottom long enough to lose all its outward coverings and appendages by

putrefaction; and that, after this had happened, another animal might attach itself to the dead and naked skeleton, might grow to maturity, and might itself die before the calcareous mud had buried the whole.

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Cases of this kind are admirably described by Sir Charles Lyell. He speaks of the frequency with which geologists find in the chalk a fossilized sea-urchin to which is attached the lower valve of a Crania. This is a kind of shell-fish, with a shell composed of two pieces, of which, as in the oyster, one is fixed and the other free.

“The upper valve is almost invariably wanting, though occasionally found in a perfect state of preservation in the white chalk at some distance. In this case, we see clearly that the sea-urchin first lived from youth to age, then died and lost its spines, which were carried away. Then the young Crania adhered to the bared shell, grew and perished in its turn; after which, the upper valve was separated from the lower, before the Echinus became enveloped in chalky mud.”

A specimen in the Museum of Practical Geology, in London, still further prolongs the period which must have elapsed between the death of the sea-urchin and its burial by the Globigerinae. For the outward face of the valve of a Crania, which is attached to a sea-urchin (*Micraster*), is itself overrun by an incrusting coralline, which spreads thence over more or less of the surface of the sea-urchin. It follows that, after the upper valve of the Crania fell off, the surface of the attached valve must have remained exposed long enough to allow of the growth of the whole coralline, since corallines do not live imbedded in the mud.

The progress of knowledge may, one day, enable us to deduce from such facts as these the maximum rate at which the chalk can have accumulated, and thus to arrive at the minimum duration of the chalk period. Suppose that the valve of the Crania upon which a coralline has fixed itself in the way just described is so attached to the sea-urchin that no part of it is more than an inch above the face upon which the sea-urchin rests. Then, as the coralline could not have fixed itself if the Crania had been covered up with chalk-mud, and could not have lived had itself been so covered, it follows, that an inch of chalk mud could not have accumulated within the time between the death and decay of the soft parts of the sea-urchin and the growth of the coralline to the full size which it has attained. If the decay of the soft parts of the sea-urchin; the attachment, growth to maturity, and decay of the Crania; and the subsequent attachment and growth of the coralline, took a year (which is a low estimate enough), the accumulation of the inch of chalk must have taken more than a year: and the deposit of a thousand feet of chalk must, consequently, have taken more than twelve thousand years.

The foundation of all this calculation is, of course, a knowledge of the length of time the Crania and the coralline needed to attain their full size; and, on this head, precise knowledge is at present wanting. But there are circumstances which tend to show that nothing like an inch of chalk has accumulated during the life of a Crania; and, on any probable estimate of the length of that life, the chalk period must have had a much longer duration than that thus roughly assigned to it.

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Thus, not only is it certain that the chalk is the mud of an ancient sea-bottom; but it is no less certain that the chalk sea existed during an extremely long period, though we may not be prepared to give a precise estimate of the length of that period in years. The relative duration is clear, though the absolute duration may not be definable. The attempt to affix any precise date to the period at which the chalk sea began or ended its existence, is baffled by difficulties of the same kind. But the relative age of the cretaceous epoch may be determined with as great ease and certainty as the long duration of that epoch.

You will have heard of the interesting discoveries recently made, in various parts of Western Europe, of flint implements, obviously worked into shape by human hands, under circumstances which show conclusively that man is a very ancient denizen of these regions.

It has been proved that the old populations of Europe, whose existence has been revealed to us in this way, consisted of savages, such as the Esquimaux are now; that, in the country which is now France, they hunted the reindeer, and were familiar with the ways of the mammoth and the bison. The physical geography of France was in those days different from what it is now—the river Somme, for instance, having cut its bed a hundred feet deeper between that time and this; and it is probable that the climate was more like that of Canada or Siberia than that of Western Europe.

The existence of these people is forgotten even in the traditions of the oldest historical nations. The name and fame of them had utterly vanished until a few years back; and the amount of physical change which has been effected since their day renders it more than probable that, venerable as are some of the historical nations, the workers of the chipped flints of Hoxne or of Amiens are to them, as they are to us, in point of antiquity.

But, if we assign to these hoar relics of long-vanished generations of men the greatest age that can possibly be claimed for them, they are not older than the drift, or boulder clay, which, in comparison with the chalk, is but a very juvenile deposit. You need go no further than your own seaboard for evidence of this fact. At one of the most charming spots on the coast of Norfolk, Cromer, you will see the boulder clay forming a vast mass, which lies upon the chalk, and must consequently have come into existence after it. Huge boulders of chalk are, in fact, included in the clay, and have evidently been brought to the position they now occupy by the same agency as that which has planted blocks of syenite from Norway side by side with them.

The chalk, then, is certainly older than the boulder clay. If you ask how much, I will again take you no further than the same spot upon your own coasts for evidence. I have spoken of the boulder clay and drift as resting upon the chalk. That is not strictly true. Interposed between the chalk and the drift is a comparatively insignificant layer, containing vegetable matter. But that layer tells a wonderful history. It is full of stumps of trees standing as they grew. Fir-trees are there with their cones, and hazel-bushes

with their nuts; there stand the stools of oak and yew trees, beeches and alders. Hence this stratum is appropriately called the “forest-bed.”

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It is obvious that the chalk must have been upheaved and converted into dry land before the timber trees could grow upon it. As the bolls of some of these trees are from two to three feet in diameter, it is no less clear that the dry land thus formed remained in the same condition for long ages. And not only do the remains of stately oaks and well-grown firs testify to the duration of this condition of things, but additional evidence to the same effect is afforded by the abundant remains of elephants, rhinoceroses, hippopotamuses, and other great wild beasts, which it has yielded to the zealous search of such men as the Rev. Mr. Gunn.

When you look at such a collection as he has formed, and bethink you that these elephantine bones did veritably carry their owners about, and these great grinders crunch, in the dark woods of which the forest-bed is now the only trace, it is impossible not to feel that they are as good evidence of the lapse of time as the annual rings of the tree-stumps.

Thus there is a writing upon the wall of cliffs at Cromer, and whoso runs may read it. It tells us, with an authority which cannot be impeached, that the ancient sea-bed of the chalk sea was raised up, and remained dry land, until it was covered with forest, stocked with the great game whose spoils have rejoiced your geologists. How long it remained in that condition cannot be said; but "the whirligig of time brought its revenges" in those days as in these. That dry land, with the bones and teeth of generations of long-lived elephants, hidden away among the gnarled roots and dry leaves of its ancient trees, sank gradually to the bottom of the icy sea, which covered it with huge masses of drift and boulder clay. Sea-beasts, such as the walrus, now restricted to the extreme north, paddled about where birds had twittered among the topmost twigs of the fir-trees. How long this state of things endured we know not, but at length it came to an end. The upheaved glacial mud hardened into the soil of modern Norfolk. Forests grew once more, the wolf and the beaver replaced the reindeer and the elephant; and at length what we call the history of England dawned.

Thus you have, within the limits of your own county, proof that the chalk can justly claim a very much greater antiquity than even the oldest physical traces of mankind. But we may go further and demonstrate, by evidence of the same authority as that which testifies to the existence of the father of men, that the chalk is vastly older than Adam himself.

The Book of Genesis informs us that Adam, immediately upon his creation, and before the appearance of Eve, was placed in the garden of Eden. The problem of the geographical position of Eden has greatly vexed the spirits of the learned in such matters, but there is one point respecting which, so far as I know, no commentator has ever raised a doubt. This is, that of the four rivers which are said to run out of it, Euphrates and Hiddekel are identical with the rivers now known by the names of Euphrates and Tigris.

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But the whole country in which these mighty rivers take their origin, and through which they run, is composed of rocks which are either of the same age as the chalk, or of later date. So that the chalk must not only have been formed, but, after its formation, the time required for the deposit of these later rocks, and for their upheaval into dry land, must have elapsed, before the smallest brook which feeds the swift stream of "the great river, the river of Babylon," began to flow.

* * * * *

Thus, evidence which cannot be rebutted, and which need not be strengthened, though if time permitted I might indefinitely increase its quantity, compels you to believe that the earth, from the time of the chalk to the present day, has been the theatre of a series of changes as vast in their amount as they were slow in their progress. The area on which we stand has been first sea and then land, for at least four alternations; and has remained in each of these conditions for a period of great length.

Nor have these wonderful metamorphoses of sea into land, and of land into sea, been confined to one corner of England. During the chalk period, or "cretaceous epoch," not one of the present great physical features of the globe was in existence. Our great mountain ranges, Pyrenees, Alps, Himalayas, Andes, have all been upheaved since the chalk was deposited, and the cretaceous sea flowed over the sites of Sinai and Ararat.

All this is certain, because rocks of cretaceous or still later date have shared in the elevatory movements which gave rise to these mountain chains; and may be found perched up, in some cases, many thousand feet high upon their flanks. And evidence of equal cogency demonstrates that, though in Norfolk the forest-bed rests directly upon the chalk, yet it does so, not because the period at which the forest grew immediately followed that at which the chalk was formed, but because an immense lapse of time, represented elsewhere by thousands of feet of rock, is not indicated at Cromer.

I must ask you to believe that there is no less conclusive proof that a still more prolonged succession of similar changes occurred before the chalk was deposited. Nor have we any reason to think that the first term in the series of these changes is known. The oldest sea-beds preserved to us are sands, and mud, and pebbles, the wear and tear of rocks which were formed in still older oceans.

But, great as is the magnitude of these physical changes of the world, they have been accompanied by a no less striking series of modifications in its living inhabitants.

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All the great classes of animals, beasts of the field, fowls of the air, creeping things, and things which dwell in the waters, flourished upon the globe long ages before the chalk was deposited. Very few, however, if any, of these ancient forms of animal life were identical with those which now live. Certainly not one of the higher animals was of the same species as any of those now in existence. The beasts of the field, in the days before the chalk, were not our beasts of the field, nor the fowls of the air such as those which the eye of man has seen flying, unless his antiquity dates infinitely further back than we at present surmise. If we could be carried back into those times, we should be as one suddenly set down in Australia before it was colonized. We should see mammals, birds, reptiles, fishes, insects, snails, and the like, clearly recognizable as such, and yet not one of them would be just the same as those with which we are familiar, and many would be extremely different.

From that time to the present, the population of the world has undergone slow and gradual, but incessant, changes. There has been no grand catastrophe—no destroyer has swept away the forms of life of one period, and replaced them by a totally new creation; but one species has vanished and another has taken its place; creatures of one type of structure have diminished, those of another have increased, as time has passed on. And thus, while the differences between the living creatures of the time before the chalk and those of the present day appear startling, if placed side by side, we are led from one to the other by the most gradual progress, if we follow the course of Nature through the whole series of those relics of her operations which she has left behind.

[Illustration: SKELETON OF THE PTERODACTYL.]

And it is by the population of the chalk sea that the ancient and the modern inhabitants of the world are most completely connected. The groups which are dying out flourish, side by side, with the groups which are now the dominant forms of life.

Thus the chalk contains remains of those flying and swimming reptiles, the pterodactyl, the ichthyosaurus, and the plesiosaurus, which are found in no later deposits, but abounded in preceding ages. The chambered shells called ammonites and belemnites, which are so characteristic of the period preceding the cretaceous, in like manner die with it.

[Illustration: THE SKELETON OF THE ICHTHYOSAURUS.]

[Illustration: THE SKELETON OF THE PLESIOSAURUS.]

[Illustration: AMMONITES.]

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But, among these fading remainders of a previous state of things, are some very modern forms of life, looking like Yankee peddlers among a tribe of red Indians. Crocodiles of modern type appear; bony fishes, many of them very similar to existing species, almost supplant the forms of fish which predominate in more ancient seas; and many kinds of living shell-fish first become known to us in the chalk. The vegetation acquires a modern aspect. A few living animals are not even distinguishable as species from those which existed at that remote epoch. The Globigerina of the present day, for example, is not different specifically from that of the chalk; and the same may be said of many other Foraminifera. I think it probable that critical and unprejudiced examination will show that more than one species of much higher animals have had a similar longevity; but the only example which I can at present give confidently is the snake's-head lamp-shell (*Terebratulina caput serpentis*), which lives in our English seas and abounded (as *Terebratulina striata* of authors) in the chalk.

[Illustration: BELEMNITES.]

[Illustration: TEREBRATULINA.]

The longest line of human ancestry must hide its diminished head before the pedigree of this insignificant shell-fish. We Englishmen are proud to have an ancestor who was present at the Battle of Hastings. The ancestors of *Terebratulina caput serpentis* may have been present at a battle of Ichthyosauria in that part of the sea which, when the chalk was forming, flowed over the site of Hastings. While all around has changed, this *Terebratulina* has peacefully propagated its species from generation to generation, and stands to this day as a living testimony to the continuity of the present with the past history of the globe.

* * * * *

Up to this moment I have stated, so far as I know, nothing but well-authenticated facts, and the immediate conclusions which they force upon the mind.

But the mind is so constituted that it does not willingly rest in facts and immediate causes, but seeks always after a knowledge of the remoter links in the chain of causation.

Taking the many changes of any given spot of the earth's surface, from sea to land, and from land to sea, as an established fact, we cannot refrain from asking ourselves how these changes have occurred. And when we have explained them—as they must be explained—by the alternate slow movements of elevation and depression which have affected the crusts of the earth, we go still further back, and ask, Why these movements?



I am not certain that any one can give you a satisfactory answer to that question. Assuredly I cannot. All that can be said for certain is, that such movements are part of the ordinary course of nature, inasmuch as they are going on at the present time. Direct proof may be given, that some parts of the land of the northern hemisphere are at this moment insensibly rising and others insensibly sinking; and there is indirect but perfectly satisfactory proof, that an enormous area now covered by the Pacific has been deepened thousands of feet since the present inhabitants of that sea came into existence.

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Thus there is not a shadow of a reason for believing that the physical changes of the globe, in past times, have been effected by other than natural causes.

Is there any more reason for believing that the concomitant modifications in the forms of the living inhabitants of the globe have been brought about in any other ways?

Before attempting to answer this question, let us try to form a distinct mental picture of what has happened in some special case.

The crocodiles are animals which, as a group, have a very vast antiquity. They abounded ages before the chalk was deposited; they throng the rivers in warm climates at the present day. There is a difference in the form of the joints of the backbone, and in some minor particulars, between the crocodiles of the present epoch and those which lived before the chalk; but, in the cretaceous epoch, as I have already mentioned, the crocodiles had assumed the modern type of structure. Notwithstanding this, the crocodiles of the chalk are not identically the same as those which lived in the times called "older tertiary," which succeeded the cretaceous epoch; and the crocodiles of the older tertiaries are not identical with those of the newer tertiaries, nor are these identical with existing forms. I leave open the question whether particular species may have lived on from epoch to epoch. But each epoch has had its peculiar crocodiles; though all, since the chalk, have belonged to the modern type, and differ simply in their proportions and in such structural particulars as are discernible only to trained eyes.

How is the existence of this long succession of different species of crocodiles to be accounted for?

Only two suppositions seem to be open to us—either each species of crocodile has been specially created, or it has arisen out of some pre-existing form by the operation of natural causes.

Choose your hypothesis; I have chosen mine. I can find no warranty for believing in the distinct creation of a score of successive species of crocodiles in the course of countless ages of time. Science gives no countenance to such a wild fancy; nor can even the perverse ingenuity of a commentator pretend to discover this sense, in the simple words in which the writer of Genesis records the proceeding of the fifth and sixth days of the Creation.

On the other hand, I see no good reason for doubting the necessary alternative, that all these varied species have been evolved from pre-existing crocodilian forms by the operation of causes as completely a part of the common order of nature as those which have effected the changes of the inorganic world.

Few will venture to affirm that the reasoning which applies to crocodiles loses its force among other animals or among plants. If one series of species has come into existence

by the operation of natural causes, it seems folly to deny that all may have arisen in the same way.

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A small beginning has led us to a great ending. If I were to put the bit of chalk with which we started into the hot but obscure flame of burning hydrogen, it would presently shine like the sun. It seems to me that this physical metamorphosis is no false image of what has been the result of our subjecting it to a jet of fervent, though nowise brilliant, thought to-night. It has become luminous, and its clear rays, penetrating the abyss of the remote past, have brought within our ken some stages of the evolution of the earth. And in the shifting "without haste, but without rest" of the land and sea, as in the endless variation of the forms assumed by living beings, we have observed nothing but the natural product of the forces originally possessed by the substance of the universe.

[Illustration]

A BIT OF SPONGE

(Written on Scotland.)

(FROM GLIMPSES OF NATURE.)

BY A. WILSON.

[Illustration]

This morning, despite the promise of rain over-night, has broken with all the signs and symptoms of a bright July day. The Firth is bathed in sunlight, and the wavelets at full tide are kissing the strand, making a soft musical ripple as they retire, and as the pebbles run down the sandy slope on the retreat of the waves. Beyond the farthest contact of the tide is a line of seaweed dried and desiccated, mixed up with which, in confusing array, are masses of shells, and such *olla podrida* of the sea.

Tossed up at our very feet is a dried fragment of sponge, which doubtless the unkind waves tore from its rocky bed. It is not a large portion of sponge this, but its structure is nevertheless to be fairly made out, and some reminiscences of its history gleaned, for the sake of occupying the by no means "bad half-hour" before breakfast. "What is a sponge?" is a question which you may well ask as a necessary preliminary to the understanding of its personality.

[Illustration: A SPONGE ATTACHED TO ITS ROCKY BED.]

The questionings of childhood and the questionings of science run in precisely similar grooves. "What is it?" and "How does it live?" and "Where does it come from?" are equally the inquiries of childhood, and of the deepest philosophy which seeks to determine the whole history of life. This morning, we cannot do better than follow in the



footsteps of the child, and to the question, "What is a sponge?" I fancy science will be able to return a direct answer. First of all, we may note that a sponge, as we know it in common life, is the horny skeleton or framework which was made by, and which supported, the living parts. These living parts consist of minute masses of that living jelly to which the name of *protoplasm* has been applied. This, in truth, is the universal matter of life. It is the one substance with which life everywhere is associated, and as we see it simply in the sponge, so also we behold it (only in more complex guise) in the man. Now, the living parts of this dried cast-away sponge were found both in its interior and on its surface. They lined the canals that everywhere permeate the sponge-substance, and microscopic examination has told us a great deal about their nature.

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[Illustration: FIG. 1. DEVELOPMENT OF A SPONGE (*Olynthus*). 1. The egg. 2, 3, and 4. The process of egg-division. 5 and 6. The gastrula-stage. 7. The perfect sponge.]

For, whether found in the canals of the sponge themselves, or embedded in the sponge-substance, the living sponge-particles are represented each by a semi-independent mass of protoplasm. So that the first view I would have you take of the sponge as a living mass, is, that it is a colony and not a single unit. It is composed, in other words, of aggregated masses of living particles, which bud out one from the other, and manufacture the supporting skeleton we know as “the sponge of commerce” itself. Under the microscope, these living sponge-units appear in various guises and shapes. Some of them are formless, and, as to shape, ever-altering masses, resembling that familiar animalcule of our pools we know as the *Amoeba*. These members of the sponge-colony form the bulk of the population. They are embedded in the sponge substance; they wander about through the meshes of the sponge; they seize food and flourish and grow; and they probably also give origin to the “eggs” from which new sponges are in due course produced.

More characteristic however, are certain units of this living sponge-colony which live in the lining membrane of the canals. In point of fact, a sponge is a kind of Venice, a certain proportion of whose inhabitants, like those of the famous Queen of the Adriatic herself, live on the banks of the waterways. Just as in Venice we find the provisions for the denizens of the city brought to the inhabitants by the canals, so from the water, which, as we shall see, is perpetually circulating through a sponge, the members of the sponge-colony receive their food.

Look, again, at the sponge-fragment which lies before us. You perceive half a dozen large holes or so, each opening on a little eminence, as it were. These apertures, bear in mind, we call *oscula*. They are the exits of the sponge-domain. But a close inspection of a sponge shows that it is riddled with finer and smaller apertures. These latter are the *pores*, and they form the entrances to the sponge-domain.

On the banks of the canal you may see growing plentifully in summer time a green sponge, which is the common fresh-water species. Now, if you drop a living specimen of this species into a bowl of water, and put some powdered indigo into the water, you may note how the currents are perpetually being swept in by the pores and out by the oscula. In every living sponge this perpetual and unceasing circulation of water proceeds. This is the sole evidence the unassisted sight receives of the vitality of the sponge-colony, and the importance of this circulation in aiding life in these depths, to be fairly carried out cannot readily be over-estimated.

[Illustration: WHERE SPONGES GROW.]

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Let us now see how this circulation is maintained. Microscopically regarded, we see here and there, in the sides of the sponge-passages, little chambers and recesses which remind one of the passing-places in a narrow canal. Lining these chambers, we see living sponge-units of a type different from the shapeless specks we noted to occur in the meshes of the sponge substance itself. The units of the recesses each consist of a living particle, whose free extremity is raised into a kind of collar, from which projects a lash-like filament known as a flagellum.

This lash is in constant movement. It waves to and fro in the water, and the collection of lashes we see in any one chamber acts as a veritable brush, which by its movement not only sweeps water in by the pores, but sends it onwards through the sponge, and in due time sends it out by the bigger holes, or oscula. This constant circulation in the sponge discharges more than one important function. For, as already noted, it serves the purpose of nutrition, in that the particles on which sponge-life is supported are swept into the colony.

Again, the fresh currents of water carry with them the oxygen gas which is a necessity of sponge existence, as of human life; while, thirdly, waste matters, inevitably alike in sponge and in man as the result of living, are swept out of the colony, and discharged into the sea beyond. Our bit of sponge has thus grown from a mere dry fragment into a living reality. It is a community in which already, low as it is, the work of life has come to be discharged by distinct and fairly specialized beings.

The era of new sponge-life is inaugurated by means of egg-development, although there exists another fashion (that of gemmules or buds) whereby out of the parental substance young sponges are produced. A sponge-egg develops, as do all eggs, in a definite cycle. It undergoes division (Fig. 1); its one cell becomes many; and its many cells arrange themselves first of all into a cup-like form (5, 6 and 7), which may remain in this shape if the sponge is a simple one, or become developed into the more complex shape of the sponges we know.

In every museum you may see specimens of a beautiful vase-like structure seemingly made of spun-glass. This is a flinty sponge, the "Venus flower-basket," whose presence in the sponge family redeems it from the charge that it contains no things of beauty whatever. So, too, the rocks are full of fossil-sponges, many of quaint form. Our piece of sponge, as we may understand, has yet other bits of history attached to it.... Meanwhile, think over the sponge and its ways, and learn from it that out of the dry things of life, science weaves many a fairy tale.

[Illustration]

THE GREATEST SEA-WAVE EVER KNOWN

(FROM LIGHT SCIENCE IN LEISURE HOURS.)

BY R.A. PROCTOR.

[Illustration]

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August 13th, 1868, one of the most terrible calamities which has ever visited a people befell the unfortunate inhabitants of Peru. In that land earthquakes are nearly as common as rain storms are with us; and shocks by which whole cities are changed into a heap of ruins are by no means infrequent. Yet even in Peru, "the land of earthquakes," as Humboldt has termed it, no such catastrophe as that of August, 1868, had occurred within the memory of man. It was not one city which was laid in ruins, but a whole empire. Those who perished were counted by tens of thousands, while the property destroyed by the earthquake was valued at millions of pounds sterling.

Although so many months have passed since this terrible calamity took place, scientific men have been busily engaged, until quite recently, in endeavoring to ascertain the real significance of the various events which were observed during and after the occurrence of the earthquake. The geographers of Germany have taken a special interest in interpreting the evidence afforded by this great manifestation of Nature's powers. Two papers have been written recently on the great earthquake of August 13th, 1868—one by Professor von Hochsteter, the other by Herr von Tschudi, which present an interesting account of the various effects, by land and by sea, which resulted from the tremendous upheaving force to which the western flanks of the Peruvian Andes were subjected on that day. The effects on land, although surprising and terrible, only differ in degree from those which have been observed in other earthquakes. But the progress of the great sea-wave which was generated by the upheaval of the Peruvian shores and propagated over the whole of the Pacific Ocean differs altogether from any earthquake phenomena before observed. Other earthquakes have indeed been followed by oceanic disturbances; but these have been accompanied by terrestrial motions, so as to suggest the idea that they had been caused by the motion of the sea-bottom or of the neighboring land. In no instance has it ever before been known that a well-marked wave of enormous proportions should have been propagated over the largest ocean tract on our globe by an earth-shock whose direct action was limited to a relatively small region, and that region not situated in the centre, but on one side of the wide area traversed by the wave.

We propose to give a brief sketch of the history of this enormous sea-wave. In the first place, however, it may be well to remind the reader of a few of the more prominent features of the great shock to which this wave owed its origin.

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It was at Arequipa, at the foot of the lofty volcanic mountain Misti, that the most terrible effects of the great earthquake were experienced. Within historic times Misti has poured forth no lava streams, but that the volcano is not extinct is clearly evidenced by the fact that in 1542 an enormous mass of dust and ashes was vomited forth from its crater. On August 13th. 1868, Misti showed no signs of being disturbed. So far as the volcanic neighbor was concerned, the forty-four thousand inhabitants of Arequipa had no reason to anticipate the catastrophe which presently befell them. At five minutes past five an earthquake shock was experienced, which, though severe, seems to have worked little mischief. Half a minute later, however, a terrible noise was heard beneath the earth; a second shock more violent than the first was felt, and then began a swaying motion, gradually increasing in intensity. In the-course of the first minute this motion had become so violent that the inhabitants ran in terror out of their houses into the streets and squares. In the next two minutes the swaying movement had so increased that the more lightly built houses were cast to the ground, and the flying people could scarcely keep their feet. "And now," says Von Tschudi, "there followed during two or three minutes a terrible scene. The swaying motion which had hitherto prevailed changed into fierce vertical upheaval. The subterranean roaring increased in the most terrifying manner; then were heard the heart-piercing shrieks of the wretched people, the bursting of walls, the crashing fall of houses and churches, while over all rolled thick clouds of a yellowish-black dust, which, had they been poured forth many minutes longer, would have suffocated thousands." Although the shocks had lasted but a few minutes, the whole town was destroyed. Not one building remained uninjured, and there were few which did not lie in shapeless heaps of ruins.

At Tacna and Arica the earth-shock was less severe, but strange and terrible phenomena followed it. At the former place a circumstance occurred the cause and nature of which yet remain a mystery. About three hours after the earthquake—in other words, at about eight o'clock in the evening—an intensely brilliant light made its appearance above the neighboring mountains. It lasted for fully half an hour, and has been ascribed to the eruption of some as yet unknown volcano.

At Arica the sea-wave produced even more destructive effects than had been caused by the earthquake. About twenty minutes after the first earth-shock the sea was seen to retire, as if about to leave the shores wholly dry; but presently its waters returned with tremendous force. A mighty wave, whose length seemed immeasurable, was seen advancing like a dark wall upon the unfortunate town, a large part of which was overwhelmed by it. Two ships, the Peruvian corvette America, and the United States "double-ender" Wateree, were carried nearly half a mile to the north of Arica beyond the railroad which runs to Tacna, and there left stranded high and dry. This enormous wave was considered by the English vice-consul at Arica to have been fully fifty feet in height.

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At Chala three such waves swept in after the first shocks of earthquake. They overflowed nearly the whole of the town, the sea passing more than half a mile beyond its usual limits.

At Islay and Iquique similar phenomena were manifested. At the former town the lava flowed in no less than five times, and each time with greater force. Afterward the motion gradually diminished, but even an hour and a half after the commencement of this strange disturbance the waves still ran forty feet above the ordinary level. At Iquique the people beheld the intruding wave while it was still a great way off. A dark blue mass of water some fifty feet in height was seen sweeping in upon the town with inconceivable rapidity. An island lying before the harbor was completely submerged by the great wave, which still came rushing on black with the mud and slime it had swept from the sea-bottom. Those who witnessed its progress from the upper balconies of their houses, and presently saw its black mass rushing close beneath their feet, looked on their safety as a miracle. Many buildings were indeed washed away, and in the low-lying parts of the town there was a terrible loss of life. After passing far inland, the wave slowly returned sea-ward, and, strangely enough, the sea, which elsewhere heaved and tossed for hours after the first great wave had swept over it, here came soon to rest.

At Callao a yet more singular instance was afforded of the effect which circumstances may have upon the motion of the sea after a great earthquake has disturbed it. In former earthquakes Callao has suffered terribly from the effects of the great sea-wave. In fact, on two occasions the whole town has been destroyed, and nearly all its inhabitants have been drowned, through the inrush of precisely such waves as flowed into the ports of Arica and Chala. But upon this occasion the centre of subterranean disturbance must have been so situated that either the wave was diverted from Callao, or, more probably, two waves reached Callao from different sources and at different times, so that the two undulations partly counteracted each other. Certain it is that, although the water retreated strangely from the coast near Callao, insomuch that a wide tract of the sea-bottom was uncovered, there was no intruding wave comparable with those described above. The sea afterward rose and fell in an irregular manner, a circumstance confirming the supposition that the disturbance was caused by two distinct oscillations. Six hours after the occurrence of the earth-shock the double oscillations seemed for a while to have worked themselves into unison, for at this time three considerable waves rolled in upon the town. But clearly these waves must not be compared with those which in other instances had made their appearance within half an hour of the earth-throes. There is little reason to doubt that if the separate oscillations had re-enforced each other earlier, Callao would have been completely destroyed. As it was, a considerable amount of mischief was effected; but the motion of the sea presently became irregular again, and so continued until the morning of August 14th, when it began to ebb with some regularity. But during the 14th there were occasional renewals of the irregular motion, and several days elapsed before the regular ebb and flow of the sea were resumed.

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Such were among the phenomena presented in the region where the earthquake itself was felt. It will be seen at once that within this region, or rather along that portion of the sea-coast which falls within the central region of disturbance, the true character of the sea-wave generated by the earthquake could not be recognized. If a rock fall from a lofty cliff into a comparatively shallow sea, the water around the place where the rock has fallen is disturbed in an irregular manner. The sea seems at one place to leap up and down; elsewhere one wave seems to beat against another, and the sharpest eye can detect no law in the motion of the seething waters. But presently, outside the scene of disturbance, a circular wave is seen to form, and if the motion of this wave be watched it is seen to present the most striking contrast with the turmoil and confusion at its centre. It sweeps onward and outward in a regular undulation. Gradually it loses its circular figure (unless the sea-bottom happens to be unusually level), showing that although its motion is everywhere regular, it is not everywhere equally swift. A wave of this sort, though incomparably vaster, swept swiftly away on every side from the scene of the great earthquake near the Peruvian Andes. It has been calculated that the width of this wave varied from one million to five million feet, or, roughly, from two hundred to one thousand miles, while, when in mid-Pacific, the length of the wave, measured along its summit in a widely-curved path from one side to another of the great ocean, cannot have been less than eight thousand miles.

[Illustration: OVER A LARGE PORTION OF ITS COURSE ITS PASSAGE WAS UNNOTED.]

We cannot tell how deep-seated was the centre of subterranean action; but there can be no doubt it was very deep indeed, because otherwise the shock felt in towns separated from each other by hundreds of miles could not have been so nearly contemporaneous. Therefore the portion of the earth's crust upheaved must have been enormous, for the length of the region where the direct effects of the earthquake were perceived is estimated by Professor von Hochsteter at no less than two hundred and forty miles. The breadth of the region is unknown, because the slope of the Andes on one side and the ocean on the other concealed the motion of the earth's crust.

The great ocean-wave swept, as we have said, in all directions around the scene of the earth-throe. Over a large part of its course its passage was unnoted, because in the open sea the effects even of so vast an undulation could not be perceived. A ship would slowly rise as the crest of the great wave passed under her, and then as slowly sink again. This may seem strange, at first sight, when it is remembered that in reality the great sea-wave we are considering swept at the rate of three or four hundred sea-miles an hour over the larger part of the Pacific. But when the true character of ocean-waves is understood,

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when it is remembered that there is no transference of the water itself at this enormous rate, but simply a transmission of motion (precisely as when in a high wind waves sweep rapidly over a cornfield, while yet each cornstalk remains fixed in the ground), it will be seen that the effects of the great sea-wave could only be perceived near the shore. Even there, as we shall presently see, there was much to convey the impression that the land itself was rising and falling rather than that the deep was moved. But among the hundreds of ships which were sailing upon the Pacific when its length and breadth were traversed by the great sea-wave, there was not one in which any unusual motion was perceived.

In somewhat less than three hours after the occurrence of the earthquake the ocean-wave inundated the port of Coquimbo, on the Chilean seaboard, some eight hundred miles from Arica. An hour or so later it had reached Constitucion, four hundred and fifty miles farther south; and here for some three hours the sea rose and fell with strange violence. Farther south, along the shore of Chile, even to the island of Chiloe, the shore-wave travelled, though with continually diminishing force, owing, doubtless, to the resistance which the irregularities of the shore opposed to its progress.

The northerly shore-wave seems to have been more considerable; and a moment's study of a chart of the two Americas will show that this circumstance is highly significant. When we remember that the principal effects of the land-shock were experienced within that angle which the Peruvian Andes form with the long north-and-south line of the Chilean and Bolivian Andes, we see at once that, had the centre of the subterranean action been near the scene where the most destructive effects were perceived, no sea-wave, or but a small one, could have been sent toward the shores of North America. The projecting shores of northern Peru and Ecuador could not have failed to divert the sea-wave toward the west; and though a reflected wave might have reached California, it would only have been after a considerable interval of time, and with dimensions much less than those of the sea-wave which travelled southward. When we see that, on the contrary, a wave of even greater proportions travelled toward the shores of North America, we seem forced to the conclusion that the centre of the subterranean action must have been so far to the west that the sea-wave generated by it had a free course to the shores of California.

Be this as it may, there can be no doubt that the wave which swept the shores of Southern California, rising upward of sixty feet above the ordinary sea-level, was absolutely the most imposing of all the indirect effects of the great earthquake. When we consider that even in San Pedro Bay, fully five thousand miles from the centre of disturbance, a wave twice the height of an ordinary house rolled in with unspeakable violence only a few hours after the occurrence of the earth-throe, we are most strikingly impressed with the tremendous energy of the earth's movement.

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Turning to the open ocean, let us track the great wave on its course past the multitudinous islands which dot the surface of the Pacific.

The inhabitants of the Sandwich Islands, which lie about six thousand three hundred miles from Arica, might have imagined themselves safe from any effects which could be produced by an earthquake taking place so far away from them. But on the night between August 13th and 14th, the sea around this island group rose in a surprising manner, insomuch that many thought the islands were sinking, and would shortly subside altogether beneath the waves. Some of the smaller islands, indeed, were for a time completely submerged. Before long, however, the sea fell again, and as it did so the observers "found it impossible to resist the impression that the islands were rising bodily out of the water." For no less than three days this strange oscillation of the sea continued to be experienced, the most remarkable ebbs and floods being noticed at Honolulu, on the island of Woahoo.

But the sea-wave swept onward far beyond these islands.

At Yokohama, in Japan, more than ten thousand five hundred miles from Arica, an enormous wave poured in on August 14th, but at what hour we have no satisfactory record. So far as distance is concerned, this wave affords most surprising evidence of the stupendous nature of the disturbance to which the waters of the Pacific Ocean had been subjected. The whole circumference of the earth is but twenty-five thousand miles, so that this wave had travelled over a distance considerably greater than two-fifths of the earth's circumference. A distance which the swiftest of our ships could not traverse in less than six or seven weeks had been swept over by this enormous undulation in the course of a few hours.

More complete details reach us from the Southern Pacific.

Shortly before midnight the Marquesas Isles and the low-lying Tuamotu group were visited by the great wave, and some of these islands were completely submerged by it. The lonely Opara Isle, where the steamers which run between Panama and New Zealand have their coaling station, was visited at about half-past eleven in the evening by a billow which swept away a portion of the coal depot. Afterward great waves came rolling in at intervals of about twenty minutes, and several days elapsed before the sea resumed its ordinary ebb and flow.

It was not until about half-past two on the morning of August 14th that the Samoa Isles (sometimes called the Navigator Islands) were visited by the great wave. The watchmen startled the inhabitants from their sleep by the cry that the sea was about to overwhelm them; and already, when the terrified people rushed from their houses, the sea was found to have risen far above the highest water-mark. But it presently began to sink again, and then commenced a series of oscillations, which lasted for several days, and were of a very remarkable nature. Once in every quarter

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of an hour the sea rose and fell, but it was noticed that it rose twice as rapidly as it sank. This peculiarity is well worth remarking. The eminent physicist Mallet speaks thus (we follow Lyell's quotation) about the waves which traverse an open sea: "The great sea-wave, advancing at the rate of several miles in a minute, consists, in the deep ocean, of a long, low swell of enormous volume, having an equal slope before and behind, and that so gentle that it might pass under a ship without being noticed. But when it reaches the edge of soundings, its front slope becomes short and steep, while its rear slope is long and gentle." On the shores visited by such a wave, the sea would appear to rise more rapidly than it sank. We have seen that this happened on the shores of the Samoa group, and therefore the way in which the sea rose and fell on the days following the great earthquake gave significant evidence of the nature of the sea-bottom in the neighborhood of these islands. As the change of the great wave's figure could not have been quickly communicated, we may conclude with certainty that the Samoan Islands are the summits of lofty mountains, whose sloping sides extend far toward the east.

This conclusion affords interesting evidence of the necessity of observing even the seemingly trifling details of important phenomena.

The wave which visited the New Zealand Isles was altogether different in character, affording a noteworthy illustration of another remark of Mallet's. He says that where the sea-bottom slopes in such a way that there is water of some depth close inshore, the great wave may roll in and do little damage; and we have seen that so it happened in the case of the Samoan Islands. But he adds that, "where the shore is shelving there will be first a retreat of the water, and then the wave will break upon the beach and roll far in upon the land." This is precisely what happened when the great wave reached the eastern shores of New Zealand, which are known to shelve down to very shallow water, continuing far away to sea toward the east.

At about half-past three on the morning of August 14th the water began to retreat in a singular manner from the port of Littleton, on the eastern shores of the southernmost of the New Zealand Islands. At length the whole port was left entirely dry, and so remained for about twenty minutes. Then the water was seen returning like a wall of foam ten or twelve feet in height, which rushed with a tremendous noise upon the port and town. Toward five o'clock the water again retired, very slowly as before, not reaching its lowest ebb until six. An hour later a second huge wave inundated the port. Four times the sea retired and returned with great power at intervals of about two hours. Afterward the oscillation of the water was less considerable, but it had not wholly ceased until August 17th, and only on the 18th did the regular ebb and flow of the tide recommence.

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Around the Samoa group the water rose and fell once in every fifteen minutes, while on the shores of New Zealand each oscillation lasted no less than two hours. Doubtless the different depths of water, the irregular conformation of the island groups, and other like circumstances, were principally concerned in producing these singular variations. Yet they do not seem fully sufficient to account for so wide a range of difference. Possibly a cause yet unnoticed may have had something to do with the peculiarity. In waves of such enormous extent it would be quite impossible to determine whether the course of the wave motion was directed full upon a line of shore or more or less obliquely. It is clear that in the former case the waves would seem to follow each other more swiftly than in the latter, even though there were no difference in their velocity.

Far on beyond the shores of New Zealand the great wave coursed, reaching at length the coast of Australia. At dawn of August 14th Moreton Bay was visited by five well-marked waves. At Newcastle, on the Hunter River, the sea rose and fell several times in a remarkable manner, the oscillatory motion commencing at half-past six in the morning. But the most significant evidence of the extent to which the sea-wave travelled in this direction was afforded at Port Fairy, Belfast, South Victoria. Here the oscillation of the water was distinctly perceived at midday on August 14th; and yet, to reach this point, the sea-wave must not only have travelled on a circuitous course nearly equal in length to half the circumference of the earth, but must have passed through Bass's Straits, between Australia and Van Diemen's Land, and so have lost a considerable portion of its force and dimensions. When we remember that had not the effects of the earth-shock on the water been limited by the shores of South America, a wave of disturbance equal in extent to that which travelled westward would have swept toward the east, we see that the force of the shock was sufficient to have disturbed the waters of an ocean covering the whole surface of the earth. For the sea-waves which reached Yokohama in one direction and Port Fairy in another had each traversed a distance nearly equal to half the earth's circumference; so that if the surface of the earth were all sea, waves setting out in opposite directions from the centre of disturbance would have met each other at the antipodes of their starting-point.

It is impossible to contemplate the effects which followed the great earthquake—the passage of a sea-wave of enormous volume over fully one third of the earth's surface, and the force with which, on the farthest limits of its range, the wave rolled in upon shores more than ten thousand miles from its starting-place—without feeling that those geologists are right who deny that the subterranean forces of the earth are diminishing in intensity. It may be difficult, perhaps, to look on the effects

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which are ascribed to ancient earth-throes without imagining for a while that the power of modern earthquakes is altogether less. But when we consider fairly the share which time had in those ancient processes of change, when we see that while mountain ranges were being upheaved or valleys depressed to their present position, race after race, and type after type appeared on the earth, and lived out the long lives which belong to races and to types, we are recalled to the remembrance of the great work which the earth's subterranean forces are still engaged upon. Even now continents are being slowly depressed or upheaved; even now mountain ranges are being raised to a new level, tablelands are in process of formation, and great valleys are being gradually scooped out. It may need an occasional outburst, such as the earthquake of August, 1868, to remind us that great forces are at work beneath the earth's surface. But, in reality, the signs of change have long been noted. Old shore-lines shift their place, old soundings vary; the sea advances in one place and retires in another; on every side Nature's plastic hand is at work modelling and remodelling the earth, in order that it may always be a fit abode for those who are to dwell upon it.

[Illustration]

THE PHOSPHORESCENT SEA

(FROM STUDIES OF ANIMATED NATURE.)

BY W.S. DALLAS.

[Illustration]

It is not merely on land that this phenomenon of phosphorescence is to be seen in living forms. Among marine animals, indeed, it is a phenomenon much more general, much more splendid, and, we may add, much more familiar to those who live on our coasts. There must be many in the British Isles who have never had the opportunity of seeing the light of the glow-worm, but there can be few of those who have frequented in summer any part of our coasts, who have never seen that beautiful greenish light which is then so often visible, especially on our southern shores, when the water is disturbed by the blade of an oar or the prow of a boat or ship. In some cases, even on our own shores, the phenomenon is much more brilliant, every rippling wave being crested with a line of the same peculiar light, and in warmer seas exhibitions of this kind are much more common. It is now known that this light is due to a minute living form, to which we will afterward return.

But before going on to speak in some detail of the organisms to which the phosphorescence of the sea is due, it will be as well to mention that the kind of

phosphorescence just spoken of is only one mode in which the phenomenon is exhibited on the ocean. Though sometimes the light is shown in continuous lines whenever the surface is disturbed, at other times, and, according to M. de Quatrefages, more commonly, the light appears only in minute sparks, which, however numerous, never coalesce. "In the little channel known as the Sund de Chausez," he writes, "I have seen on a dark night each stroke of the oar kindle, as it were, myriads of stars, and the wake of the craft appeared in a manner besprinkled with diamonds." When such is the case the phosphorescence is due to various minute animals, especially crustaceans; that is, creatures which, microscopically small as they are, are yet constructed more or less on the type of the lobster or cray-fish.

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At other times, again, the phosphorescence is still more partial. "Great domes of pale gold with long streamers," to use the eloquent words of Professor Martin Duncan, "move slowly along in endless succession; small silvery disks swim, now enlarging and now contracting, and here and there a green or bluish gleam marks the course of a tiny, but rapidly rising and sinking globe. Hour after hour the procession passes by, and the fishermen hauling in their nets from the midst drag out liquid light, and the soft sea jellies, crushed and torn piecemeal, shine in every clinging particle. The night grows dark, the wind rises and is cold, and the tide changes; so does the luminosity of the sea. The pale spectres below the surface sink deeper, and are lost to sight, but the increasing waves are tinged here and there with green and white, and often along a line, where the fresh water is mixing with the salt in an estuary, there is a brightness so intense that boats and shores are visible.... But if such sights are to be seen on the surface, what must not be the phosphorescence of the depths! Every sea-pen is glorious in its light, in fact, nearly every eight-armed Alcyonarian is thus resplendent, and the social *Pyrosoma*, bulky and a free swimmer, glows like a bar of hot metal with a white and green radiance."

Such accounts are enough to indicate how varied and how general a phenomenon is the phosphorescence of the sea. To take notice of one tithe of the points of interest summed up in the paragraph just quoted would occupy many pages, and we must therefore confine the attention to a few of the most interesting facts relating to marine phosphorescence.

We will return to that form of marine luminosity to which we first referred: what is known as the general or diffused phosphorescence of the sea. From this mode of describing it the reader must not infer that the surface of the ocean is ever to be seen all aglow in one sheet of continuous light. So far, at least, as was ever observed by M. de Quatrefages, who studied this phenomenon carefully and during long periods on the coasts of Brittany and elsewhere, no light was visible when the surface of the sea was perfectly still. On the other hand, when the sea exhibits in a high degree the phenomenon of diffused phosphorescence no disturbance can be too slight to cause the water to shine with that peculiar characteristic gleam. Drop but a grain of sand upon its surface, and you will see a point of light marking the spot where it falls, and from that point as a centre a number of increasing wavelets, each clearly defined by a line of light, will spread out in circles all around.

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The cause of this diffused phosphorescence was long the subject of curiosity, and was long unknown, but more than a hundred years ago (in 1764) the light was stated by M. Kigaut to proceed from a minute and very lowly organism, now known as *Noctiluca miliaris*; and subsequent researches have confirmed this opinion. This Noctiluca is a spherical form of not more than one-fiftieth of an inch in size, with a slight depression or indentation at one point, marking the position of a mouth leading to a short digestive cavity, and having close beside it a filament, by means of which it probably moves about. The sphere is filled with protoplasm, in which there is a nucleus and one or more gaps, or “vacuoles.” Such is nearly all the structure that can be discerned with the aid of the microscope in this simple organism.

Nevertheless, this lowly form is the chief cause of that diffused phosphorescence which is sometimes seen over a wide extent of the ocean. How innumerable the individuals belonging to this species must therefore be, may be left to the imagination. Probably the Noctiluca is not rivalled in this respect even by microscopic unicellular algae which compose the “red snow.”

By filtering sea-water containing Noctilucae its light can be concentrated, and it has been found that a few teaspoonfuls will then yield light enough to enable one to read holding a book at the ordinary distance from the eyes—about ten inches.

A singular and highly remarkable case of diffused marine phosphorescence was observed by Nordenskiöld during his voyage to Greenland in 1883. One dark night, when the weather was calm and the sea smooth, his vessel was steaming across a narrow inlet called the Igaliko Fjord, when the sea was suddenly observed to be illumined in the rear of the vessel by a broad but sharply-defined band of light, which had a uniform, somewhat golden sheen, quite unlike the ordinary bluish-green phosphorescence of the sea. The latter kind of light was distinctly visible at the same time in the wake of the vessel. Though the steamer was going at the rate of from five to six miles an hour, the remarkable sheet of light got nearer and nearer. When quite close, it appeared as if the vessel were sailing in a sea of fire or molten metal. In the course of an hour the light passed on ahead, and ultimately it disappeared in the remote horizon. The nature of this phenomenon Nordenskiöld is unable to explain; and unfortunately he had not the opportunity of examining it with the spectroscope.

If we come now to consider the more partial phosphorescence of the sea, we find that it is due to animals belonging to almost every group of marine forms—to Echinoderms, or creatures of the sea-urchin and star-fish type, to Annelid worm, to Medusidae, or jelly-fish, as they are popularly called, including the “great domes” and the “silvery disks” of the passage above quoted from Professor Martin Duncan, to Tunicates, among which is the Pyrosoma, to Mollusks, Crustaceans, and in very many cases to Actinozoa, or forms belonging to the type of the sea anemone and the coral polyp.

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Of these we will single out only a few for more special notice.

Many of the Medusidae, or jelly-fish, possess the character of which we are speaking. In some cases the phosphorescence is spontaneous among them, but in others it is not so; the creature requires to be irritated or stimulated in some way before it will emit the light. It is spontaneous, for example, in the *Pelagia phosphorea*, but not in the allied *Pelagia noctiluca*, a very common form in the Mediterranean.

In both of the jelly-fishes just mentioned the phosphorescence, when displayed at all, is on the surface of the swimming disk, and this is most commonly the case with the whole group. Sometimes, however, the phosphorescence is specially localized. In some forms, as in *Thaumantius pilosella* and other members of the same genus, it is seen in buds at the base of tentacles given off from the margin of the swimming-bell. In other cases it is situated in certain internal organs, as in the canals which radiate from the centre to the margin of the bell, or in the ovaries. It is from this latter seat that the phosphorescence proceeds in *Oceania pilata*, the form which gives out such a light that Ehrenberg compared it to a lamp-globe lighted by a flame.

The property of emitting a phosphorescent light, sometimes spontaneously and sometimes on being stimulated, is likewise exemplified in the Ctenophora, a group resembling the Medusidae in the jelly-like character of their bodies, but more closely allied in structure to the Actinozoa. But we will pass over these cases in order to dwell more particularly on the remarkable tunicate known as *Pyrosoma*, a name indicative of its phosphorescent property, being derived from two Greek words signifying fire-body. As shown in the illustration *Pyrosoma* is not a single creature, but is composed of a whole colony of individuals, each of which is represented by one of the projections on the surface of the tube, closed at one end, which they all combine to form. The free end on the exterior contains the mouth, while there is another opening in each individual toward the interior of the tube. Such colonies, which swim about by the alternate contraction and dilatation of the individuals composing them, are pretty common in the Mediterranean, where they may attain the length of perhaps fourteen inches, with a breadth of about three inches. In the ocean they may reach a much greater size. Mr. Moseley, in his "Notes of a Naturalist on the Challenger," mentions a giant specimen which he once caught in the deep-sea trawl, a specimen four feet in length and ten inches in diameter, with "walls of jelly about an inch in thickness."

[Illustration: A. PYROSOMA. B. PONITON. (Magnified.)]

The same naturalist states that the light emitted by this compound form is the most beautiful of all kinds of phosphorescence. When stimulated by a touch, or shake, or swirl of the water, it "gives out a globe of bluish light, which lasts for several seconds, as the animal drifts past several feet beneath the surface, and then suddenly goes out." He adds that on the giant specimen just referred to he wrote his name with his finger as

it lay on the deck in a tub at night, and in a few seconds he had the gratification of seeing his name come out in “letters of fire.”

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Among mollusks, the best known instance of phosphorescence is in the rock-boring *Pholas*, the luminosity of which after death is mentioned by Pliny. But it is not merely after death that *Pholas* becomes luminous—a phenomenon perfectly familiar even in the case of many fish, especially the herring and mackerel. It was long before the luminosity of the living animal was known, but this is now a well-ascertained fact; and Panceri, an Italian naturalist, recently dead, has been able to discover in this, as in several other marine phosphorescent forms, the precise seat of the light-giving bodies, which he has dissected out again and again for the sake of making experiments in connection with this subject.

A more beautiful example of a phosphorescent mollusk is presented by a sea-slug called *Phyllirhoe bucephala*. This is a creature of from one and a half to two inches in length, without a shell in the adult stage, and without even gills. It breathes only by the general surface of the body. It is common enough in the Mediterranean, but is not easy to see, as it is almost perfectly transparent, so that it cannot be distinguished without difficulty, by day at least, from the medium in which it swims. By night, however, it is more easily discerned, in consequence of its property of emitting light. When disturbed or stimulated in any way, it exhibits a number of luminous spots of different sizes irregularly distributed all over it, but most thickly aggregated on the upper and under parts. These phosphorescent spots, it is found, are not on the surface, but for the most part represent so many large cells which form the terminations of nerves, and are situated underneath the transparent cuticle. The spots shine with exceptional brilliancy when the animal is withdrawn from the water and stimulated by a drop of ammonia.

Among the Annelid worms a species of *Nereis*, or sea-centipedes, has earned by its phosphorescent property the specific name of *noctiluca* (night-shining), and the same property is very beautifully shown in *Polynoe*, a near ally of the familiar sea-mouse. M. de Quatrefages speaks with enthusiasm of the beauty of the spectacle presented by this latter form when examined under a microscope magnifying to the extent of a hundred diameters. He then found, as he did in the great majority of cases which he studied, that the phosphorescence was confined to the motor muscles, and was manifested solely when these were in the act of contracting, manifested, too, not in continuous lines along the course of the muscles, but in rows of brilliant points.

More interesting than the Annelids, however, are the Alcyonarian Actinozoa. The Actinozoa have already been described as formed on the type of the sea-anemone and the coral polyp, that is, they are all animals with a radiate structure, attached to one end, and having their only opening at the other end, which is surrounded by tentacles. In the Alcyonarian forms belonging to this great group these tentacles are always eight in number, and fringed on both sides. Moreover, these forms are almost without exception compound. Like the *Pyrosoma*, they have a common life belonging to a whole stock or colony, as well as an individual life.

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Now, throughout this sub-division of the Actinozoa phosphorescence is a very general phenomenon. Professor Moseley, already quoted as a naturalist accompanying the Challenger expedition, informs us that "all the Alcyonarians dredged by the Challenger in deep water were found to be brilliantly phosphorescent when brought to the surface."

Among these Alcyonarians are the sea-pens mentioned in the quotation above made from Professor Martin Duncan. Each sea-pen is a colony of Alcyonarians, and the name is due to the singular arrangement of the individuals upon the common stem. This stem is supported internally by a coral rod, but its outer part is composed of fleshy matter belonging to the whole colony. The lower portion of it is fixed in the muddy bottom of the sea, but the upper portion is free, and gives off a number of branches, on which the individual polyps are seated. The whole colony thus has the appearance of a highly ornamental pen.

There is one British species, *Pennatula phosphorea*, which is found in tolerably deep water, and is from two to four inches in length. The specific name again indicates the phosphorescent quality belonging to it. When irritated, it shines brilliantly, and the curious thing is that the phosphorescence travels gradually on from polyp to polyp, starting from the point at which the irritation is applied. If the lower part of the stem is irritated, the phosphorescence passes gradually upwards along each pair of branches in succession; but if the top is irritated the phosphorescence will pass in the same way downwards. When both top and bottom are irritated simultaneously two luminous currents start at once, and, meeting in the middle, usually become extinguished there; but on one occasion Panceri found that the two crossed, and each completed its course independently of the other. Those of our readers who have had opportunities of making or seeing experiments with the sensitive plant (*Mimosa pudica*) will be reminded of the way in which, when that plant is irritated, the influence travels regularly on from pinnules to pinnules and pinnae to pinnae.

In all the cases mentioned the phenomenon of phosphorescence is exhibited by invertebrate animals; but though rare, it is not an unknown phenomenon even in living vertebrates. In a genus of deep-sea fishes called Stomias, Gunther mentions that a "series of phosphorescent dots run along the lower side of the head, body, and tail." Several other deep-sea fishes, locally phosphorescent, seem to have been dredged up by the French ship *Talisman* in its exploring cruise off the west coast of Northern Africa in 1883. During the same expedition, a number of deep-sea phosphorescent crustaceans were dredged up, the phosphorescence being in some cases diffused over the whole body, in other cases localized to particular areas. In deep-sea forms the phenomenon is, in fact, so common, as to have given rise to the theory that in the depths of the ocean, where the light of the sun cannot penetrate, the phosphorescence of various organisms diffuse a light which limits the domain of absolute darkness.

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So much by way of illustration regarding the phosphorescence exhibited by animals, terrestrial and marine; but it ought to be noticed that there are also a few cases in which the same phenomenon is to be witnessed in plants. These are not so numerous as was at one time supposed, the property having been mistakenly ascribed to some plants not really luminous.

[Illustration: A PHOSPHORESCENT SEA.]

In some instances the mistake appears to have been due to a subjective effect produced by brilliantly colored (red or orange) flowers, such as the great Indian cress, the orange lily, the sunflower, and the marigold. The fact that such flowers do give out in the dusk sudden flashes of light has often been stated on the authority of a daughter of Linnaeus, subsequently backed by the assertions of various other observers. But most careful observers seem to be agreed that the supposed flashes of light are in reality nothing else than a certain dazzling of the eyes.

In another case, in which a moss, *Schistostega osmundacea*, has been stated to be phosphorescent, the effect is said to be really due to the refraction and reflection of light by minute crystals scattered over its highly cellular leaves, and not to be produced at all where the darkness is complete.

Among plants, genuine phosphorescence is to be found chiefly in certain fungi, the most remarkable of which is *Rhizomorpha subterranea*, which is sometimes to be seen ramifying over the walls of dark, damp mines, caverns, or decayed towers, and emitting at numerous points a mild phosphorescent light, which is sometimes bright enough to allow of surrounding objects being distinguished by it. The name of “vegetable glow-worm” has sometimes been applied to this curious growth.

Among other phosphorescent fungi are several species of *Agaricus*, including the *A. olearius* of Europe, *A. Gardneri* of Brazil, and *A. lampas* of Australia, and besides the members of this genus, *Thelaphora caerulea*, which is the cause of the phosphorescent light sometimes to be seen on decaying wood—the “touchwood” which many boys have kept in the hope of seeing this light displayed. The milky juice of a South American *Euphorbia* (*E. phosphorea*) is stated by Martins to be phosphorescent when gently heated. But phosphorescence is evidently not so interesting and important a phenomenon in the vegetable as it is in the animal kingdom.

The whole phenomenon is one that gives rise to a good many questions which it is not easy to answer, and this is especially true in the case of animal phosphorescence. What is the nature of the light? What are the conditions under which it is manifested? What purpose does it serve in the animal economy?

As to the nature of the light, the principal question is whether it is a direct consequence of the vital activity of the organism in which it is seen, of such a nature that no further

explanation can be given of it, any more than we can explain why a muscle is contracted under the influence of a nerve-stimulus; or whether it is due to some chemical process more or less analogous to the burning of a candle.

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The fact of luminosity appearing to be in certain cases directly under the control of the creature in which it is found, and the fact of its being manifested in many forms, as M. de Quatrefages found, only when muscular contraction was taking place, would seem to favor the former view. On the other hand, it is against this view that the phosphorescence is often found to persist after the animal is dead, and even in the phosphorescent organs for a considerable time after they have been extracted from the body of the animal. In the glow-worm the light goes on shining for some time after the death of the insect, and even when it has become completely extinguished it can be restored for a time by the application of a little moisture. Further, both Matteucci and Phipson found that when the luminous substance was extracted from the insect it would keep on glowing for thirty or forty minutes.

In Pholas the light is still more persistent, and it is found that when the dead body of this mollusk is placed in honey, it will retain for more than a year the power of emitting light when plunged in warm water.

The investigations of recent years have rendered it more and more probable that the light exhibited by phosphorescent organisms is due to a chemical process somewhat analogous to that which goes on in the burning of a candle. This latter process is one of rapid oxidation. The particles of carbon supplied by the oily matter that feeds the candle become so rapidly combined with oxygen derived from the air that a considerable amount of light, along with heat, is produced thereby. Now, the phenomenon of phosphorescence in organic forms, whether living or dead, appears also to be due to a process of oxidation, but one that goes on much more slowly than in the case of a lighted candle. It is thus more closely analogous to what is observed in the element phosphorus itself, which owes its name (meaning "light-bearer") to the fact that when exposed to the air at ordinary temperatures it glows in the dark, in consequence of its becoming slowly combined with oxygen.

At one time it was believed that the presence of oxygen was not necessary to the exhibition of phosphorescence in organic forms, but it has now been placed beyond doubt that this is a mistake. Oxygen has been proved to be indispensable, and hence we see a reason for the luminous organs in the glow-worm being so intimately connected, as above mentioned, with the air-tubes that ramify through the insect.

This fact of itself might be taken as a strong indication of the chemical nature of the process to which phosphorescence is due. But the problem has been made the subject of further investigations which have thrown more light upon it. It was long known that there were various inorganic bodies besides phosphorus which emitted a phosphorescent light in the dark, at least after being exposed to the rays of the sun; but it was not till quite recently that any organic compound was known to phosphoresce at ordinary temperatures.

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This discovery was made by a Polish chemist, named Bronislaus Radziszewski, who followed it up with a long series of experiments on the phosphorescence of organic compounds, by which he was able to determine the conditions under which that phenomenon was exhibited. In all the substances investigated by him in which phosphorescence was introduced he found that three conditions were essential to its production: (1) that oxygen should be present; (2) that there should be an alkaline reaction in the phosphorescing mixture—that is, a reaction such as is produced on acids and vegetable coloring matters by potash, soda, and the other alkalies; and (3) that some kind of chemical action should take place.

He found, moreover, that among the organic compounds that could be made to phosphoresce under these conditions were nearly all the fixed and ethereal oils. With reference to the phosphorescence of animals, this observation is important, for it has been shown in a great many cases that a fatty substance forms the main constituent in their luminous organs. This has long been known to be the case in the luminous insects belonging to the Lampyridae and Elateridae, as well as in the luminous centipedes; and the researches of Panceri, already referred to, on the luminous organs of many marine forms have shown that it holds good with regard to these also.

We may, therefore, conclude that substances fitted to phosphoresce under the conditions determined by the experiments of Radziszewski are generally, and probably universally, present in the luminous organs of phosphorescent animals. Now, what is to be said as to the occurrence of these conditions? The access of oxygen is in all cases easy to account for, but it must also be shown how the alkaline reaction is to be produced. We need not expect to find in animal organisms potash, soda, ammonia, and the other common alkalies; but it was established by experiment that the alkaline organic compounds cholin and neurin, which are present in animal tissues, would also serve to bring about the phenomenon of phosphorescence in the substances on which the experiments were made.

Accordingly, it seems fair to conclude that when all these conditions for the production of phosphorescence in a chemical laboratory are present in animal organisms, the phenomenon, when observed in these, is exactly of the same nature as that which is produced artificially. By that it is meant that animal phosphorescence is attended, like the artificial phenomenon, by a slow chemical action, or in other words, that the phosphorescent light is due to a gradual process of oxidation.

One curious circumstance has been discovered which lends still further probability to this explanation. It was mentioned above that among phosphorescent plants there are several species of *Agaricus*. Now, from one species of this genus, though not indeed one of the phosphorescent species (from *A. muscarius*) there has been extracted a principle called *amanitia*, which is found to be identical with cholin. In the light of the results derived from the investigations just referred to it is reasonable to draw the conclusion that, if sought for, this principle would likewise be found in the

phosphorescent species in which the other conditions of phosphorescence are also present.

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On this theory of the production of the phenomenon now under consideration, the effect of shaking or of vital action in giving rise to or intensifying the exhibition of the light is accounted for by the fact that by these means fresh supplies of oxygen are brought into contact with the phosphorescent substance. The effect of ammonia on the light emitted by the sea-slug *Phyllirhoe bucephala*, is also fully explained, ammonia being one of those alkaline substances which are so directly favorable to the exhibition of the phenomenon.

Nor is it difficult to account for the control which in some cases insects appear to have over the luminosity of the phosphorescent organs, exhibiting and withdrawing the light at will. It is not necessary to suppose that this is an immediate effect, a conversion of nerve force into light, and a withdrawal of that force. The action of the creature's will may be merely in maintaining or destroying the conditions under which the light is manifested. It may, for example, have the power of withdrawing the supply of oxygen, and this supposition receives some countenance from the observation cited from Kirby and Spence on the two captured glow-worms, one of which withdrew its light, while the other kept it shining, but while doing so had the posterior extremity of the abdomen in constant motion. But the animal may also have the power in another way of affecting the chemical conditions of the phenomenon. It may, for example, have the power of increasing or diminishing by some nervous influence the supply of the necessary alkaline ingredient.

But if animal phosphorescence is really due to a process of slow oxidation, there is one singular circumstance to be noted in connection with it. Oxidation is a process that is normally accompanied by the development of heat. Even where no light is produced an increase of temperature regularly takes place when substances are oxidized. We ought, then, to expect such a rise of temperature when light is emitted by the phosphorescent organs of animals. But the most careful observations have shown that nothing of the kind can be detected. It was with a view to test this that Panceri dissected out the luminous organs of so many specimens of *Pholas*. He selected this mollusk because it was so abundant in the neighborhood of Naples, where, his experiments were made; and in making his experiments he made use of a thermopile, an apparatus by which, with the aid of electricity, much smaller quantities of heat can be indicated than by means of the most delicate thermometer. The organs remained luminous long after they were extracted, but no rise in temperature whatever could be found to accompany the luminosity. Many experiments upon different animals were made with similar negative results by means of the thermometer.

The only explanation of this that can be given is probably to be found in the fact that the chemical process ascertained to go on in the phosphorescence of organic compounds on which experiments were made in the laboratory is an extremely slow one.

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The so-called phosphorescence of most inorganic bodies is one of a totally different nature from that exhibited in organic forms. The diamond shines for a time in the dark after it has been exposed to the sun; so do pieces of quartz when rubbed together, and powdered fluor-spar when heated shines with considerable brilliancy. Various artificial compounds, such as sulphide of calcium (Canton's phosphorus, as it is called from the discoverer), sulphate of barium (Bologna stone, or Bologna phosphorus), sulphide of strontium, *etc.*, after being illuminated by the rays of the sun, give out in the dark a beautiful phosphorescence, green, blue, violet, orange, red, according to circumstances. The luminous paint which has recently attracted so much attention is of the same nature. In these cases what we have is either a conversion of heat rays into light rays (as in the powdered fluor-spar), or the absorption and giving out again of sun-rays. In the latter case the phenomenon is essentially the same as fluorescence, in which the dark rays of the solar spectrum beyond the violet are made visible.

But we must now return to the other questions that have been started in relation to phosphorescence in animals. There has been much speculation as to the object of this light, and to the purposes it serves in Nature. Probably no general answer can be given to this question. It is no doubt impossible to show why so many animals have been endowed with this remarkable property; but we may consider some of the effects which the possession of it has in different cases.

In the first place, it will undoubtedly serve in many cases to afford light to enable the animal to see by, and in the Lampyridae it would seem that the degree of luminosity is related to the development of the vision. In that family, according to the Rev. H.S. Gorham, the eyes are developed, as a rule, in inverse proportion to the luminosity. Where there is an ample supply of this kind of light the eyes are small, but where the light is insignificant the eyes are large by way of compensation. And moreover, where both eyes and light are small, then the antennae are large and feathery, so that the deficiency in the sense of sight is made up for by an unusual development in the organs of touch.

But it is none the less certain that the presence of this light cannot always be designed to serve this purpose, for many of the animals so endowed are blind. The phosphorescent centipedes are without eyes, like all the other members of the genus (*Geophilus*) to which they belong, and probably the majority of phosphorescent marine forms are likewise destitute of organs of sight.

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Another suggestion is that the light derived from these marine forms, and especially from deep-sea Alcyonarians, is what enables the members of the deep-sea fauna that are possessed of eyes (which are always enormously enlarged) to see. Such is the suggestion of Dr. Carpenter, Sir Wyville Thomson, and Mr. Gwyn Jeffries; and it is possible that this actually is one of the effects of the phosphorescent property. But if so, it remains to inquire how the forms endowed with it came to be possessed of a power useful in that way to other forms, but not to themselves. According to the Darwinian doctrine of development, the powers that are developed in different organisms by the process of natural selection are such as are useful to themselves and not to others, unless incidentally.

This consideration has led to another suggestion, namely, that the property of phosphorescence serves as a protection to the forms possessing it, driving away enemies in one way or another: it may be by warning them of the fact that they are unpalatable food, as is believed to be the case with the colors of certain brilliantly-colored caterpillars; it may be in other ways. In Kirby and Spence one case is recorded in which the phosphorescence of the common phosphorescent centipede (*Geophilus electricus*) was actually seen apparently to serve as a means of defence against an enemy. "Mr. Shepherd," says that authority, "once noticed a scarabeus running round the last-mentioned insect when shining, as if wishing, but afraid to attack it." In the case of the jelly-fishes, it has been pointed out that their well-known urticating or stinging powers would make them at least unpleasant, if not dangerous, food for fishes; and that consequently the luminosity by which so many of them are characterized at night may serve at once as a warning to predatory fishes and as a protection to themselves. The experience of the unpleasant properties of many phosphorescent animals may likewise have taught fishes to avoid all forms possessing this attribute, even though many of them might be quite harmless.

Lastly, it has been suggested that the phosphorescence in the female glow-worm may be designed to attract the male; and that it will actually have this effect may readily be taken for granted. Observation shows that the male glow-worm is very apt to be attracted by a light. Gilbert White of Selborne mentions that they, attracted by the light of the candles, came into his parlor. Another observer states that by the same light he captured as many as forty male glow-worms in one night.

[Illustration]

COMETS

(FROM MARVELS OF THE HEAVENS.)

BY CAMILLE FLAMMARION.



“Je viens vous annoncer une grande nouvelle:
Nous l'avons, en dormant, madame, echappe belle.
Un monde pres de nous a passe tout du long,
Est chu tout au travers de notre tourbillon;
Et s'il eut en chemin rencontre notre terre,
Elle eut ete brisee en morceaux comme verre.”

MOLIERE.

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[Illustration]

This announcement of Trissontin's to Philaminte, who begins the parody on the fears caused by the appearance of comets, would not have been a parody four or five centuries ago. These tailed bodies, which suddenly come to light up the heavens, were for long regarded with terror, like so many warning signs of divine wrath. Men have always thought themselves much more important than they really are in the universal order; they have had the vanity to pretend that the whole creation was made for them, whilst in reality the whole creation does not suspect their existence. The Earth we inhabit is only one of the smallest worlds; and therefore it can scarcely be for it alone that all the wonders of the heavens, of which the immense majority remains hidden from it, were created. In this disposition of man to see in himself the centre and the end of everything, it was easy indeed to consider the steps of nature as unfolded in his favor; and if some unusual phenomenon presented itself, it was considered to be without doubt a warning from Heaven. If these illusions had had no other result than the amelioration of the more timorous of the community one would regret these ages of ignorance; but not only were these fancied warnings of no use, seeing that once the danger passed, man returned to his former state; but they also kept up among people imaginary terrors, and revived the fatal resolutions caused by the fear of the end of the world.

When one fancies the world is about to end,—and this has been believed for more than a thousand years,—no solicitude is felt in the work of improving this world; and, by the indifference or disdain into which one falls, periods of famine and general misery are induced which at certain times have overtaken our community. Why use the wealth of a world which is going to perish? Why work, be instructed, or rise in the progress of the sciences or arts? Much better to forget the world, and absorb one's self in the barren contemplation of an unknown life. It is thus that ages of ignorance weigh on man, and thrust him further and further into darkness, while Science makes known by its influence on the whole community, its great value, and the magnitude of its aim.

The history of a comet would be an instructive episode of the great history of the heavens. In it could be brought together the description of the progressive movement of human thought, as well as the astronomical theory of these extraordinary bodies. Let us take, for example, one of the most memorable and best-known comets, and give an outline of its successive passages near the Earth. Like the planetary worlds, Comets belong to the solar system, and are subject to the rule of the Star King. It is the universal law of gravitation which guides their path; solar attraction governs them, as it governs the movement of the planets and the small satellites. The chief point of difference between them and the planets is, that their

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orbits are very elongated; and, instead of being nearly circular, they take the elliptical form. In consequence of the nature of these orbits, the same comet may approach very near the Sun, and afterwards travel from it to immense distances. Thus, the period of the Comet of 1680 has been estimated at three thousand years. It approaches the Sun, so as to be nearer to it than our Moon is to us, whilst it recedes to a distance 853 times greater than the distance of the Earth from the Sun. On the 17th of December, 1680, it was at its perihelion—that is, at its greatest proximity to the Sun; it is now continuing its path beyond the Neptunian orbit. Its velocity varies according to its distance from the solar body. At its perihelion it travels thousands of leagues per minute; at its aphelion it does not pass over more than a few yards. Its proximity to the Sun in its passage near that body caused Newton to think that it received a heat twenty-eight thousand times greater than that we experience at the summer solstice; and that this heat being two thousand times greater than that of red-hot iron, an iron globe of the same dimensions would be fifty thousand years entirely losing its heat. Newton added that in the end comets will approach so near the Sun that they will not be able to escape the preponderance of its attraction, and that they will fall one after the other into this brilliant body, thus keeping up the heat which it perpetually pours out into space. Such is the deplorable end assigned to comets by the author of the “*Principia*,” an end which makes De la Bretonne say to Retif: “An immense comet, already larger than Jupiter, was again increased in its path by being blended with six other dying comets. Thus displaced from its ordinary route by these slight shocks, it did not pursue its true elliptical orbit; so that the unfortunate thing was precipitated into the devouring centre of the Sun.” “It is said,” added he, “that the poor comet, thus burned alive, sent forth dreadful cries!”

[Illustration: A COMET]

It will be interesting, then, in a double point of view, to follow a comet in its different passages in sight of the Earth. Let us take the most important in astronomical history—the one whose orbit has been calculated by Edmund Halley, and which was named after him. It was in 1682 that this comet appeared in its greatest brilliancy, accompanied with a tail which did not measure less than thirty-two millions of miles. By the observation of the path which it described in the heavens, and the time it occupied in describing it, this astronomer calculated its orbit, and recognized that the comet was the same as that which was admired in 1531 and 1607, and which ought to have reappeared in 1759. Never did scientific prediction excite a more lively interest. The comet returned at the appointed time; and on the 12th of March, 1759, reached its perihelion. Since the year 12 before the Christian era, it had presented itself twenty-four times to the Earth. It was principally from the astronomical annals of China that it was possible to follow it up to this period.

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Its first memorable appearance in the history of France is that of 837, in the reign of Louis le Debonnaire. An anonymous writer of chronicles of that time, named "The Astronomer," gave the following details of this appearance, relative to the influence of the comet on the imperial imagination:

"During the holy days of the solemnization of Easter, a phenomenon ever fatal, and of gloomy foreboding, appeared in the heavens. As soon as the Emperor, who paid attention to these phenomena, received the first announcement of it, he gave himself no rest until he had called a certain learned man and myself before him. As soon as I arrived, he anxiously asked me what I thought of such a sign; I asked time of him, in order to consider the aspects of the stars, and to discover the truth by their means, promising to acquaint him on the morrow; but the Emperor, persuaded that I wished to gain time, which was true, in order not to be obliged to announce anything fatal to him, said to me: 'Go on the terrace of the palace and return at once to tell me what you have seen, for I did not see this star last evening, and you did not point it out to me; but I know that it is a comet; tell me what you think it announces to me.' Then scarcely allowing me time to say a word, he added: 'There is still another thing you keep back; it is that a change of reign and the death of a prince are announced by this sign.' And as I advanced the testimony of the prophet, who said: 'Fear not the signs of the heavens as the nations fear them,' the prince with his grand nature, and the wisdom which never forsook him, said, 'We must not only fear Him who has created both us and this star. But as this phenomenon may refer to us, let us acknowledge it as a warning from Heaven.'"

Louis le Debonnaire gave himself and his court to fasting and prayer, and built churches and monasteries. He died three years later, in 840, and historians have profited by this slight coincidence to prove that the appearance of the comet was a harbinger of death. The historian, Raoul Glader, added later: "These phenomena of the universe are never presented to man without surely announcing some wonderful and terrible event."

Halley's comet again appeared in April, 1066, at the moment when William the Conqueror invaded England. It was pretended that it had the greatest influence on the fate of the battle of Hastings, which delivered over the country to the Normans.

A contemporary poet, alluding probably to the English diadem with which William was crowned, had proclaimed in one place, "that the comet had been more favorable to William than nature had been to Caesar; the latter had no hair, but William had received some from the comet." A monk of Malmesbury apostrophized the comet in these terms: "Here thou art again, thou cause of the tears of many mothers! It is long since I have seen thee, but I see thee now, more terrible than ever; thou threatenest my country with complete ruin!"

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In 1455, the same comet made a more memorable appearance still. The Turks and Christians were at war, the West and the East seemed armed from head to foot—on the point of annihilating each other. The crusade undertaken by Pope Calixtus III. against the invading Saracens, was waged with redoubled ardor on the sudden appearance of the star with the flaming tail. Mahomet II. took Constantinople by storm, and raised the siege of Belgrade. But the Pope having put aside both the curse of the comet, and the abominable designs of the Mussulmans, the Christians gained the battle, and vanquished their enemies in a bloody fight. The *Angelus* to the sound of bells dates from these ordinances of Calixtus III. referring to the comet.

In his poem on astronomy, Daru, of the French Academy, describes this episode in eloquent terms:

“Un autre Mahomet a-t-il d’un bras puissant
Aux murs de Constantine arbore le croissant:
Le Danube etonne se trouble au bruit des armes,
La Grece est dans les fers, l’Europe est en alarmes;
Et pour comble d’horreur, l’astre au visage ardent
De ses ailes de feu va couvrir l’Occident.
Au pied de ses autels, qu’il ne saurait defendre,
Calixte, l’oeil en pleurs, le front convert de cendre,
Conjure la comete, objet de tant d’effroi:
Regarde vers les cieux, pontife, et leve-toi!
L’astre poursuit sa course, et le fer d’Huniade
Arrete le vainqueur, qui tombe sous Belgrade.
Dans les cieux cependant le globe suspendu,
Par la loi generale a jamais retenu,
Ignore les terreurs, l’existence de Rome,
Et la Terre peut-etre, et jusqu’au nom de l’homme,
De l’homme, etre credule, atome ambitieux,
Qui tremble sous un pretre et qui lit dans les cieux.”

This ancient comet witnessed many revolutions in human history, at each of its appearances, even in its later ones, in 1682, 1759, 1835; it was also presented to the Earth under the most diverse aspects, passing through a great variety of forms, from the appearance of a curved sabre, as in 1456, to that of a misty head, as in its last visit. Moreover, this is not an exception to the general rule, for these mysterious stars have had the gift of exercising a power on the imagination which plunged it in ecstasy or trouble. Swords of fire, bloody crosses, flaming daggers, spears, dragons, fish, and other appearances of the same kind, were given to them in the middle ages and the Renaissance.

Comets like those of 1577 appear, moreover, to justify by their strange form the titles with which they are generally greeted. The most serious writers were not free from this

terror. Thus, in a chapter on celestial monsters, the celebrated surgeon, Ambroise Pare, described the comet of 1528 under the most vivid and frightful colors: "This comet was so horrible and dreadful that it engendered such great terror to the people, that they died, some with fear, others with illness. It appeared to be of immense length, and of blood color; at its head was seen the figure of a curved arm, holding a large sword in the hand as if it wished to strike. At the point of the sword there were three stars, and on either side was seen a great number of hatchets, knives, and swords covered with blood, amongst which were numerous hideous human faces, with bristling beards and hair."

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The imagination has good eyes when it exerts itself. The great and strange variety of cometary aspects is described with exactitude by Father Souciet in his Latin poem on comets. "Most of them," says he, "shine with fires interlaced like thick hair, and from this they have taken the name of comets. One draws after it the twisted folds of a long tail; another appears to have a white and bushy beard; this one throws a glimmer similar to that of a lamp burning during the night; that one, O Titan! represents thy resplendent face; and this other, O Phoebe! the form of thy nascent horns. There are some which bristle with twisted serpents. Shall I speak of those armies which have sometimes appeared in the air? of those clouds which follow as it were along a circle, or which resemble the head of Medusa? Have there not often been seen figures of men or savage animals?

"Often, in the gloom of night, lighted up by these sad fires, the horrible sound of arms is heard, the clashing of swords which meet in the clouds, the ether furiously resounding with fearful din which crush the people with terror. All comets have a melancholy light, but they have not all the same color. Some have a leaden color; others that of flame or brass. The fires of some have the redness of blood; others resemble the brightness of silver. Some again are azure; others have the dark and pale color of iron. These differences come from the diversity of the vapors which surround them, or from the different manner in which they receive the Sun's rays. Do you not see in our fires, that various kinds of wood produce different colors? Pines and firs give a flame mixed with thick smoke, and throw out little light. That which rises from sulphur and thick bitumen is bluish. Lighted straw gives out sparks of a reddish color. The large olive, laurel, ash of Parnassus, etc., trees which always retain their sap, throw a whitish light similar to that of a lamp. Thus, comets whose fires are formed of different materials, each take and preserve a color which is peculiar to them."

Instead of being a cause of fear and terror, the variety and variability of the aspect of comets ought rather to indicate to us the harmlessness of their nature.

[Illustration]

THE TOTAL SOLAR ECLIPSE OF 1883

AN ASTRONOMERS VOYAGE TO FAIRY-LAND.

(FROM THE ATLANTIC MONTHLY, MAY, 1890.)

BY PROF. E.S. HOLDEN.

[Illustration]

In 1883 calculations showed that a solar eclipse of unusually long duration (5 minutes, 20 seconds) would occur in the South Pacific Ocean. The track of the eclipse lay south

of the equator, but north of Tahiti. There were in fact only two dots of coral islands on the charts in the line of totality, Caroline Island, and one hundred and fifty miles west Flint Island (longitude 150 west, latitude 10 south). Almost nothing was known of either of these minute points. The station of the party under my charge (sent out by the United States government under the direction of the National Academy of Sciences) was to be Caroline Islands.

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Every inch of that island (seven miles long, a mile or so broad) is familiar now; but it is almost ludicrous to recollect with what anxiety we pored over the hydrographic charts and sailing instructions of the various nations, to find some information, however scanty, about the spot which was to be our home for nearly a month. All that was known was that this island had formerly been occupied as a guano station. There was a landing *then*.

After the *personnel* of the party had been decided on, there were the preparations for its subsistence to be looked out for. How to feed seventeen men for twenty-one days? Fortunately the provisions that we took, and the fresh fish caught for us by the natives, just sufficed to carry us through with comfort and with health.

In March of 1883 we sailed from New York, and about the same time a French expedition left Europe bound for the same spot. From New York to Panama, from Panama to Lima, were our first steps. Here we joined the United States steamship *Hartford*, Admiral Farragut's flagship, and the next day set sail for our destined port,—if a coral reef surrounded by a raging surf can be called a port. About the same time a party of French observers under Monsieur Janssen, of the Paris Academy of Sciences, left Panama in the *Eclaireur*.

[Illustration: BIRD'S EYE VIEW OF THE CAROLINE ISLANDS.]

It was an ocean race of four thousand miles due west. The station Caroline Islands was supposed to be more desirable than Flint Island. Admiral Wilkes's expedition had lain off the latter several days without being able to land on account of the tremendous surf, so that it was eminently desirable to "beat the Frenchman," as the sailors put it. With this end in view our party had secured (through a member of the National Academy in Washington) the verbal promise of the proper official of the Navy Department that the *Hartford's* orders should read "to burn coal as necessary." The last obstacle to success was thus removed. We were all prepared, and now the ship would take us speedily to our station.

Imagine our feelings the next day after leaving Callao, when the commanding officer of the *Hartford* opened his sealed orders. They read (dated Washington, in February), "To arrive at Caroline Islands (in April) with full coal-bunkers!"

Officialism could go no further. Here was an expedition sent on a slow-sailing ship directly through the regions of calms for four thousand miles. It was of no possible use to send the expedition at all unless it arrived in time. And here were our orders "to arrive with full coal-bunkers."

Fortunately we had unheard-of good-luck. The trade-wind blew for us as it did for the *Ancient Mariner*, and we sped along the parallel of 12 deg. south at the rate of one hundred and fifty miles a day under sail, while the *Eclaireur* was steaming for thirty days

a little nearer the equator in a dead calm. We arrived off the island just in time, with not a day to spare. It was a narrow escape, and a warning to all of us never to sail again under sealed orders unless we knew what was under the seal.

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Here we were, then, lying off the island and scanning its sparse crown of cocoanut palms, looking for a French flag among their wavy tufts. There was none in sight. We were the winners in the long race. Directly a whale-boat was lowered, and rowed around the white fringe of tremendous surf that broke ceaselessly against the vertical wall of coral rock. There was just one narrow place where the waves rolled into a sort of cleft and did not break. Here was the “landing,” then.

Landing was an acrobatic feat. In you went on the crest of a wave, pointing for the place where the blue seas did not break into white. An instant after, you were in the quiet water inside of the surf. Jump out everybody and hold the boat! Then it was pick up the various instruments, and carry them for a quarter of a mile to high-water mark and beyond, over the sharp points of the reef.

In one night we were fairly settled; in another the Hartford had sailed away, leaving us in our fairy paradise, where the corals and the fish were of all the brilliant hues of the rainbow, and where the whiteness of the sand, the emerald of the lagoon, and the turquoise of the ocean made a picture of color and form never to be forgotten.

But where are the Frenchmen? The next morning there is the *Eclaireur* lying a mile or so out, and there is a boat with the bo’sun—*maitre d’equipage*—pulling towards the surf. I wade out to the brink. He halloes:

“Where is the landing, then?”

“*Mais ici*”—Right here,—I say.

“Yes, that’s all very well for *persons*, but where do you land *les bagages*?”

“*Mais ici*” I say again, and he says, “*Diable!*”

But all the same he lands both persons and baggage in a neat, sailor-like way. In a couple of days our two parties of fifty persons had taken possession of this fairy isle. Observatories go up, telescopes, spectroscopes, photographic cameras are pointed and adjusted. The eventful day arrives. Everything is successful. Then comes the Hartford and takes us away, and a few days later comes the *Eclaireur*, and the Frenchmen are gone. The little island is left there, abandoned to the five natives who tend the sickly plantation of cocoa-palms, and live from year to year with no incident but the annual visit of “the blig” (Kanaka for brig), which brings their store of ship biscuit and molasses.

[Illustration: “OBSERVATORIES GO UP.”]

Think of their stupendous experience! For years and years they have lived like that in the marvellous, continuous charm of the silent island. The “blig” had come and gone

away this year, and there will be no more disturbance and discord for a twelve-month longer.

“Surely, surely, slumber is more sweet than toil, the shore
Than labor in the deep mid-ocean, wind, and wave, and oar,
Then rest ye, brother mariners, we will not wander more!”

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Not so! for here comes a great warship out of the East under a press of canvas. What event is this? See! she clews up her light sails and fires an eleven-inch gun! One of those guns of Mobile Bay. Then swarms out the starboard watch, one hundred and sixty strong, and a fleet of boats brings ashore these pale astronomers with those useless tubes that they point at the sky every night. But there are useful things too; cooking-stoves, and lumber, and bricks.

What is all this? No sooner are these established than comes another ship and fires its gun! and another set of hardy sailormen pours out, and here is another party of madmen with tubes,—yes, and with cooking-stoves and lumber, too. Then comes the crowning, stupendous, and unspeakable event. The whole sun is hidden and the heavens are lighted up with pearly streamers! In the name of all the Polynesian gods, what is the meaning of all this?

And then in a few days all these are gone. All the madmen. They have taken away the useless tubes, but they have left their houses standing. Their splendid, priceless, precious cook-stoves are here. See! here is a frying-pan! here are empty tin cans! and a keg of nails! They must have forgotten all this, madmen as they are!

And the little island sinks back to its quiet and its calm. The lagoon lies placid like a mirror. The slow sea breaks eternally on the outer reef. The white clouds sail over day by day. The seabirds come back to their haunts,—the fierce man-of-war birds, the gentle, soft-eyed tern. But we, whose island home was thus invaded—are we the same? Was this a dream? Will it happen again next year? every year? What indeed was it that happened,—or in fact, did it happen at all? Is it not a dream, indeed?

If we left those peaceful Kanakas to their dream, we Americans have brought ours away with us. Who will forget it? Which of us does not wish to be in that peaceful fairyland once more? That is the personal longing. But we have all come back, each one with his note-books full; and in a few weeks the stimulus of accustomed habit has taken possession of us again. Right and wrong are again determined by “municipal sanctions.” We have become useful citizens once more. Perhaps it is just as well. We should have been poor poets, and we do not forget. So ends the astronomer’s voyage to fairyland.

[Illustration]

HALOS—PARHELIA—THE SPECTRE OF THE BROCKEN, ETC

(FROM THE ATMOSPHERE.)

BY CAMILLE FLAMMARION.

[Illustration]

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Treatises on meteorology have not, up to the present day, classified with sufficient regularity the divers optical phenomena of the air. Some of these phenomena have, however, been seen but rarely, and have not been sufficiently studied to admit of their classification. We have examined the common phenomenon of the rainbow and we have seen that it is due to the refraction and reflection of light on drops of water, and that it is seen upon the opposite side of the sky to the sun in day-time, or the moon at night. We are now about to consider an order of phenomena which are of rarer occurrence, but which have this property in common with the rainbow, *viz.*, that they take place also upon the side of the sky opposite to the sun. These different optical effects are classed together under the name of *anthelia* (from Greek, opposite to, and Greek, the sun). The optical phenomena which occur on the same side as, or around the sun, such as halos, parhelia, *etc.*, will be dealt with later on.

Before coming to the anthelia, properly so called, or to the colored rings which appear around a shadow, it is as well first to note the effects produced on the clouds and mists that are facing the sun when it rises or sets.

Upon high mountains, the shadow of the mountain is often seen thrown either upon the surface of the lower mists or upon the neighboring mountains, and projected opposite to the sun almost horizontally. I once saw the shadow of the Righi very distinctly traced upon Mount Pilate, which is situated to the west of the Righi, on the other side of the Lake of Lucerne. This phenomenon occurs a few minutes after sunrise, and the triangular form of Righi is delineated in a shape very easy to recognize.

The shadow of Mont Blanc is discerned more easily at sunset. MM. Bravais and Martins, in one of their scientific ascents, noticed it under specially favorable circumstances, the shadow being thrown upon the snow-covered mountains, and gradually rising in the atmosphere until it reached a height of 1 deg., still remaining quite visible. The air above the cone of the shadow was tinted with that rosy purple which is seen, in a fine sunset, coloring the lofty peaks. "Imagine," says Bravais, "the other mountains also projecting, at the same moment, their shadows into the atmosphere, the lower parts dark and slightly greenish, and above each of these shadows the rosy surface, with the deeper rose of the belt which separates it from them; add to this the regular contour of the cones of the shadow, principally at the upper edge, and lastly, the laws of perspective causing all these lines to converge the one to the other toward the very summit of the shadow of Mont Blanc; that is to say, to the point of the sky where the shadows of our own selves were; and even then one will have but a faint idea of the richness of the meteorological phenomenon displayed before our eyes for a few instants. It seemed as though an invisible being was seated upon a throne surrounded by fire, and that angels with glittering wings were kneeling before him in adoration."

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Among the natural phenomena which now attract our attention, but fail to excite our surprise, there are some which possess the characteristics of a supernatural intervention. The names which they have received still bear witness to the terror which they once inspired; and even to-day, when science has stripped them of their marvellous origin, and explained the causes of their production, these phenomena have retained a part of their primitive importance, and are welcomed by the *savant* with as much interest as when they were attributed to divine agency. Out of a large and very diverse number, I will first select the *Spectre of the Brocken*.

The Brocken is the highest mountain in the picturesque Hartz chain, running through Hanover, being three hundred and thirty feet above the level of the sea.

One of the best descriptions of this phenomenon is given by the traveller Hane, who witnessed it on the 23d of May, 1797. After having ascended no less than thirty miles to the summit, he had the good fortune at last to contemplate the object of his curiosity. The sun rose at about four o'clock, the weather being fine, and the wind driving off to the west the transparent vapors which had not yet had time to be condensed into clouds. About a quarter-past four, Hane saw in this direction a human figure of enormous dimensions. A gust of wind nearly blowing off his hat at that moment, he raised his hand to secure it, and the colossal figure imitated his action. Hane, noticing this, at once made a stooping movement, and this was also reproduced by the spectre. He then called another person to him, and placing themselves in the very spot where the apparition was first seen, the pair kept their eyes fixed on the Achtermannshohe, but saw nothing. After a short interval, however, two colossal figures appeared, which repeated the gestures made by them, and then disappeared.

Some few years ago, in the summer of 1862, a French artist, M. Stroobant, witnessed and carefully sketched this phenomenon, which is drawn in full-page illustration, opposite p. 272. He had slept at the inn of the Brocken, and rising at two in the morning, he repaired to the plateau upon the summit in the company of a guide. They reached the highest point just as the first glimmer of the rising sun enabled them to distinguish clearly objects at a great distance. To use M. Stroobant's own words, "My guide, who had for some time appeared to be walking in search of something, suddenly led me to an elevation whence I had the singular privilege of contemplating for a few instants the magnificent effect of mirage, which is termed the Spectre of the Brocken. The appearance is most striking. A thick mist, which seemed to emerge from the clouds like an immense curtain, suddenly rose to the west of the mountain, a rainbow was formed, then certain indistinct shapes were delineated. First, the large tower of the inn was reproduced upon a gigantic scale; after that we saw our two selves in a more vague and less exact shape, and these shadows were in each instance surrounded by the colors of the rainbow, which served as a frame to this fairy picture. Some tourists who were staying at the inn had seen the sun rise from their windows, but no one had witnessed the magnificent spectacle which had taken place on the other side of the mountain."

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Sometimes these spectres are surrounded by colored concentric arcs. Since the beginning of the present century, treatises on meteorology designate, under the name of the *Ulloa circle*, the pale external arch which surrounds the phenomenon, and this same circle has sometimes been called the “white rainbow.” But it is not formed at the same angular distance as the rainbow, and, although pale, it often envelops a series of interior colored arcs.

[Illustration: “THE SPECTRE OF THE BROCKEN”]

Ulloa, being in company with six fellow-travellers upon the Pambamarca at daybreak one morning, observed that the summit of the mountain was entirely covered with thick clouds, and that the sun, when it rose, dissipated them, leaving only in their stead light vapors, which it was almost impossible to distinguish. Suddenly, in the opposite direction to where the sun was rising, “each of the travellers beheld, at about seventy feet from where he was standing, his own image reflected in the air as in a mirror. The image was in the centre of three rainbows of different colors, and surrounded at a certain distance by a fourth bow with only one color. The inside color of each bow was carnation or red, the next shade was violet, the third yellow, the fourth straw color, the last green. All these bows were perpendicular to the horizon; they moved in the direction of, and followed, the image of the person they enveloped as with a glory.” The most remarkable point was that, although the seven spectators were standing in a group, each person only saw the phenomenon in regard to his own person, and was disposed to disbelieve that it was repeated in respect to his companions. The extent of the bows increased continually and in proportion to the height of the sun; at the same time their colors faded away, the spectre became paler and more indistinct, and finally the phenomenon disappeared altogether. At the first appearance the shape of the bows was oval, but toward the end they became quite circular. The same apparition was observed in the polar regions by Scoresby, and described by him. He states that the phenomenon appears whenever there is mist and at the same time shining sun. In the polar seas, whenever a rather thick mist rises over the ocean, an observer, placed on the mast, sees one or several circles upon the mist.

[Illustration: THE ULLOA CIRCLE.]

These circles are concentric, and their common centre is in the straight line joining the eye of the observer to the sun, and extended from the sun toward the mist. The number of circles varies from one to five; they are particularly numerous and well colored when the sun is very brilliant and the mist thick and low. On July 23, 1821, Scoresby saw four concentric circles around his head. The colors of the first and of the second were very well defined; those of the third, only visible at intervals, were very faint, and the fourth only showed a slight greenish tint.

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The meteorologist Kaemtzt has often observed the same fact in the Alps. Whenever this shadow was projected upon a cloud, his head appeared surrounded by a luminous aureola.

To what action of light is this phenomenon due? Bouguer is of opinion that it must be attributed to the passage of light through icy particles. Such, also, is the opinion of De Saussure, Scoresby, and other meteorologists.

In regard to the mountains, as we cannot assure ourselves directly of the fact by entering the clouds, we are reduced to conjecture. The aerostat traversing the clouds completely, and passing by the very point where the apparition is seen, affords one an opportunity of ascertaining the state of the cloud. This observation I have been able to make, and so to offer an explanation of the phenomenon.

As the balloon sails on, borne forward by the wind, its shadow travels either on the ground or on the clouds. This shadow is, as a rule, black, like all others; but it frequently happens that it appears alone on the surface of the ground, and thus appears luminous. Examining this shadow by the aid of a telescope, I have noticed that it is often composed of a dark nucleus and a penumbra of the shape of an aureola. This aureola, frequently very large in proportion to the diameter of the central nucleus, eclipses it to the naked eye, so that the whole shadow appears like a nebulous circle projected in yellow upon the green ground of the woods and meadows. I have noticed, too, that this luminous shadow is generally all the more strongly marked in proportion to the greater humidity of the surface of the ground.

Seen upon the clouds, this shadow sometimes presents a curious aspect. I have often, when the balloon emerged from the clouds into the clear sky, suddenly perceived, at twenty or thirty yards' distance, a second balloon distinctly delineated, and apparently of a grayish color, against the white ground of the clouds. This phenomenon manifests itself at the moment when the sun re-appears. The smallest details of the car can be made out clearly, and our gestures are strikingly reproduced by the shadow.

[Illustration: THE SHADOW OF THE BALLOON WAS SEEN BY US.]

On April 15, 1868, at about half-past three in the afternoon, we emerged from a stratum of clouds, when the shadow of the balloon was seen by us, surrounded by colored concentric circles, of which the car formed the centre. It was very plainly visible upon a yellowish white ground. A first circle of pale blue encompassed this ground and the car in a kind of ring. Around this ring was a second of a deeper yellow, then a grayish red zone, and lastly as the exterior circumference, a fourth circle, violet in hue, and imperceptibly toning down into the gray tint of the clouds. The slightest details were clearly discernible—net, robes, and instruments. Every one of our gestures was instantaneously reproduced by the aerial spectres. The anthelion remained

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upon the clouds sufficiently distinct, and for a sufficiently long time, to permit of my taking a sketch in my journal and studying the physical condition of the clouds upon which it was produced. I was able to determine directly the circumstances of its production. Indeed, as this brilliant phenomenon occurred in the midst of the very clouds which I was traversing, it was easy for me to ascertain that these clouds were not formed of frozen particles. The thermometer marked 2 deg. above zero. The hygrometer marked a maximum of humidity experienced, namely, seventy-seven at three thousand seven hundred and seventy feet, and the balloon was then at four thousand six hundred feet, where the humidity was only seventy-three. It is therefore certain that this is a phenomenon of the diffraction of light simply produced by the vesicles of the mist.

The name of diffraction is given to all the modifications which the luminous rays undergo when they come in contact with the surface of bodies. Light, under these circumstances, is subject to a sort of deviation, at the same time becoming decomposed, whence result those curious appearances in the shadows of objects which were observed for the first time by Grimaldi and Newton.

The most interesting phenomena of diffraction are those presented by *gratings*, as are technically denominated the systems of linear and very narrow openings situated parallel to one another and at very small intervals. A system of this kind may be realized by tracing with a diamond, for instance, on a pane of glass equidistant lines very close together. As the light would be able to pass in the interstices between the strokes, whereas it would be stopped in the points corresponding to those where the glass was not smooth, there is, in reality, an effect produced as if there were a series of openings very near to each other. A hundred strokes, about 1/25th of an inch in length, may thus be drawn without difficulty. The light is then decomposed in spectra, each overlapping the other. It is a phenomenon of this kind which is seen when we look into the light with the eye half closed; the eyelashes in this case, acting as a net-work or grating. These net-works may also be produced by reflection, and it is to this circumstance that are due the brilliant colors observed when a pencil of luminous rays is reflected on a metallic surface regularly striated.

To the phenomena of gratings must be attributed, too, the colors, often so brilliant, to be seen in mother-of-pearl. This substance is of a laminated structure; so much so, that in carving it the different folds are often cut in such a way as to form a regular net-work upon the surface. It is, again, to a phenomenon of this sort that are due the rainbow hues seen in the feathers of certain birds, and sometimes in spiders' webs. The latter, although very fine, are not simple, for they are composed of a large number of pieces joined together by a viscous substance, and thus constitute a kind of net-work.

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If the sun is near the horizon, and the shadow of the observer falls upon the grass, upon a field of corn, or other surface covered with dew, there is visible an aureola, the light of which is especially bright about the head, but which diminishes from below the middle of the body. This light is due to the reflection of light by the moist stubble and the drops of dew. It is brighter about the head, because the blades that are near where the shadow of the head falls expose to it all that part of them which is lighted up, whereas those farther off expose not only the part which is lighted up, but other parts which are not, and this diminishes the brightness in proportion as their distance from the head increases. The phenomenon is seen whenever there is simultaneously mist and sun. This fact is easily verified upon a mountain. As soon as the shadow of a mountaineer is projected upon a mist, his head gives rise to a shadow surrounded by a luminous aureola.

[Illustration: FOG-BOW SEEN FROM THE MATTERHORN.]

The Illustrated London News of July 8, 1871, illustrates one of these apparitions, "The Fog-Bow, seen from the Matterhorn," observed by E. Whymper in this celebrated region of the Alps. The observation was taken just after the catastrophe of July 14, 1865; and by a curious coincidence, two immense white aerial crosses projected into the interior of the external arc. These two crosses were no doubt formed by the intersection of circles, the remaining parts of which were invisible. The apparition was of a grand and solemn character, further increased by the silence of the fathomless abyss into which the four ill-fated tourists had just been precipitated.

[Illustration]

Other optical appearances of an analogous kind are manifested under different conditions. Thus, for instance, if any one, turning his back to the sun, looks into water, he will perceive the shadow of his head, but always very much deformed. At the same time he will see starting from this very shadow what seem to be luminous bodies, which dart their rays in all directions with inconceivable rapidity, and to a great distance. These luminous appearances—these aureola rays—have, in addition to the darting movement, a rapid rotary movement around the head.

[Illustration]

THE PLANET VENUS

BY AGNES M. CLERKE.

I.

HESPERUS AND PHOSPHOR.

[Illustration]

The radiant planet that hangs on the skirts of dusk and dawn

“like a jewel in an Ethiop’s ear,”

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has been known and sung by poets in all ages. Its supremacy over the remainder of the starry host is recognized in the name given it by the Arabs, those nomad watchers of the skies, for while they term the moon “El Azhar,” “the Brighter One,” and the sun and moon together “El Azharan,” “the Brighter Pair,” they call Venus “Ez Zahra,” the bright or shining one *par excellence*, in which sense the same word is used to describe a flower. This “Flower of Night” is supposed to be no other than the white rose into which Adonis was changed by Venus in the fable which is the basis of all early Asiatic mythology. The morning and evening star is thus the celestial symbol of that union between earth and heaven in the vivifying processes of nature, typified in the love of the goddess for a mortal.

The ancient Greeks, on the other hand, not unnaturally took the star, which they saw alternately emerging from the effulgence of the rising and setting sun, in the east and in the west, for two distinct bodies, and named it differently according to the time of its appearance. The evening star they called Hesperus, and from its place on the western horizon, fabled an earthly hero of that name, the son of Atlas, who from the slopes of that mountain on the verge of the known world used to observe the stars until eventually carried off by a mighty wind, and so translated to the skies. These divine honors were earned by his piety, wisdom, and justice as a ruler of men, and his name long shed a shimmering glory over those Hesperidean regions of the earth, where the real and unreal touched hands in the mystical twilight of the unknown.

But the morning star shone with a different significance as the herald of the day, the torchbearer who lights the way for radiant Aurora on her triumphal progress through the skies. Hence he was called Eosphorus, or Phosphorus, the bearer of the dawn, translated into Latin as Lucifer, the Light-bearer. The son of Eos, or Aurora, and the Titan Astraeus, he was of the same parentage as the other multitude of the starry host, to whom a similar origin was ascribed, and from whom in Greek mythology he was evidently believed to differ only in the superior order of his brightness. Homer, who mentions the planet in the following passage:

“But when the star of Lucifer appeared,
The harbinger of light, whom following close,
Spreads o’er the sea the saffron-robed morn.”

(LORD DERBY’S “Iliad.”)

recognizes no distinction between those celestial nomads, the planets, “wandering stars,” as the Arabs call them, which visibly change their position relatively to the other stars, and the latter, whose places on the sphere are apparently fixed and immutable. In this he and his compatriots were far behind the ancient Egyptians, who probably derived their knowledge from still earlier speculators in Asia, for they not only observed the movements of some at least of the planets, but believed that Mercury and Venus

revolved as satellites round the sun, which in its turn circled round our lesser world. Pythagoras is said to have been the first to identify Hesperus with Phosphor, as the

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“Silver planet both of eve and morn,”

and by Plato the same fact is recognized. The other planets, all of which had, according to him, been originally named in Egypt and Syria, have each its descriptive title in his nomenclature. Thus the innermost, “the Star of Mercury,” is called Stilbon, “the Sparkler,” Mars, Pyroeis, “the Fiery One,” while Jupiter, the planet of the slowest course but one, is designated as Phaeton, and Saturn, the tardiest of all, Phaenon. These names were in later times abandoned in favor of those of the divinities to whom they were respectively dedicated, unalterably associated now with the days of the week, over which they have been selected to preside.

The Copernican theory, which once and forever “brushed the cobwebs out of the sky,” by clearing away the mists of pre-existing error, first completely explained the varying positions of the Shepherd’s star, irradiating the first or last watch of night, according to her alternate function as the follower or precursor of the sun. As she travels on a path nearer to him by more than twenty-five and a half million miles than that of the earth, she is seen by us on each side of him in turn after passing behind or in front of him. The points at which her orbit expands most widely to our eyes—an effect of course entirely due to perspective, as her distance from the sun is not then actually increased—are called her eastern and western elongations; that at which she passes by the sun on the hither side her inferior, and on the farther side her superior conjunction. At both conjunctions she is lost to our view, since she accompanies the sun so closely as to be lost in his beams, rising and setting at the same time, and travelling with him in his path through the heavens during the day. When at inferior conjunction, or between us and the sun, she turns her dark hemisphere to us like the new moon, and would consequently be invisible in any case, but when in the opposite position, shows us her illuminated face, and is literally a day star, invisible only because effaced by the solar splendor. It is as she gradually separates from him, after leaving this latter position, circling over that half of her orbit which lies to the east of him, that she begins to come into view as an evening star, following him at a greater and greater distance, and consequently setting later, until she attains her greatest eastern elongation, divided from the sun about 45 deg. of his visible circuit through the heavens, and consequently remaining above the horizon for some four hours after him. From this point she again appears to draw nearer to him until she passes on his hither side in inferior conjunction, from which she emerges on the opposite side to the westward, and begins to shine as a morning star, preceding him on his track, at a gradually increasing distance, until attaining her greatest westward elongation, and finally completing her cycle by returning to superior conjunction once more in a period of about five hundred and eighty-four days.

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Venus is thus Hesperus or Vesper, the evening star, when following the sun as she passes from beyond him in superior conjunction to inferior conjunction where she is nearest to the earth. As she again leaves him behind in her course from this point to the opposite one of superior conjunction, she appears in her second aspect as Phosphorus or Lucifer, "the sun of morning," and herald of the day, shining as

"The fair star
That gems the glittering coronet of morn."

II.

THE PHASES OF VENUS.

But the changes in the aspect of Venus due to her varying positions in her orbit are not confined to those which cause her to oscillate with a pendulum movement eastward and westward from the sun. The discovery that she undergoes phases exactly like those of the moon, followed that of the existence of Jupiter's satellites as the second great result achieved by the use of the telescope in the hands of Galileo. The fact that the planets were intrinsically dark bodies revolving round the sun, and reflecting its light, as he and Copernicus had maintained, thus received a further ocular demonstration. The Florentine astronomer describes in a letter to a friend how the planet, after emerging from superior conjunction as a morning star, gradually loses her rotundity on the side remote from the luminary, changing first to a half sphere and then to a waning crescent; until, after passing through the stage of absolute extinction when intervening between us and the sun, she re-appears as a morning star, and undergoes the same series of transformations in inverse order. The revelation was indeed so novel and unexpected, that when the slight deformation of the planet's shape was first detected by him, he did not venture to announce it in plain terms but veiled it, according to the prevailing fashion of the time, under a Latin anagram. His celebrated sentence—

"Haec immatura a me jam frustra leguntur."

("Those incomplete observations are as yet read by me in vain.")

forms, by transposing the letters, the more definite statement,

"Cynthiae figuras aemulatur Mater Amorum."

("The mother of the loves imitates the aspects of Diana.")

that is to say, Venus vies with the phases of the moon. The discovery was an important one from its bearing on popular superstition ascribing to the planets special influences on human affairs, for since they were thus shown to transmit to us only borrowed light, belief in their beneficent or malefic powers over man's destinies received a rude shock.

[Illustration: THE PHASES OP VENUS.]

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Galileo's announcement, published in September, 1610, when only a slight flattening of the planet's disk was visible, received absolute confirmation in the ensuing months, as she completed her full half-circle of change on February 24th of the following year, and consequently exhibited herself to him in all her varying aspects. It was the first time they had been looked upon by a human eye, since its unaided powers do not enable it to discern them, although one exception to this rule is said to have existed. This was the case of the Swiss mathematician Gauss, who, when a child, on being shown the crescent star through the telescope, exclaimed to his mother that it "was turned wrong"; the inference being that he recognized the reversal of the image in the field of the glass. If it were indeed so, he deserves to rank with the Siberian savage, who described the eclipses, or Jupiter's satellites; or the shoemaker of Breslau, who could see and declare the positions of those minute orbs.

The phases exhibited to us by Venus are due to her moving in an orbit within that of the earth, at one side of which she is between us and the sun, while at the other this position is exactly reversed. We may compare her to a performer in a great celestial circus, lit by a central chandelier, and ourselves to spectators in an external ring, from which we see her at one time facing us with the light full on her, at the opposite point in complete shadow, and at the intermediate ones in varying degrees of illumination according to our changing views of her. The same illustration may serve to show why Venus is brightest, not when full, since she is then beyond the sun, and at the farthest possible point from us, but when she approaches us at inferior conjunction, more nearly by over one hundred and thirty million miles, and still shows us a crescent of her illuminated surface, before passing into the last phase of total obscuration. When actually nearest to us she is absolutely invisible, being then, like the new moon, between us and the sun. Her varying degrees of brilliancy, even when in the same phase, are thus accounted for by her alternate retreat from and advance towards us as she circles round the sun. Completing, as she does, her revolution in about seven months and a half, she would of course go through the whole series of her metamorphoses in that time, were the earth, from which we observe them, a fixed point. Their protraction instead, over a term of five hundred and eighty-four days, or more than nineteen months, is due to the simultaneous motion of the earth in the same direction, over her larger orbit in a longer period, causing the same relative position of the sister planet to recur only as often as she overtakes her in her career. Thus the hour and minute hands of a watch, moving at different rates of speed after meeting on the dial plate at twelve o'clock, will not again come together until five minutes past one, when the swifter

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paced of the two will have completed a revolution and a twelfth. But were we to retard the motion of the latter, reducing it to only twice that of its companion, they would always meet at the figure twelve, as it would exactly complete two circuits while the hour hand was performing one. Venus thus overtakes and passes the earth once in five hundred and eighty-four days, or nearly two and a half of her own years, constituting what is called her synodic period of apparent revolution as seen from this globe. She thus presents to us all the phases undergone by our own satellite during a lunar month, passing from new to full, and *vice versa*, through the various intervening gradations of form.

The phases of Venus are amongst the most beautiful subjects for observation in a moderate telescope, as her silver bow, gradually brightening in the evening dusk, or fading in the dawn,

“On a bed of daffodil sky,”

is, after the two greater luminaries that rule the day and night, the most brilliant object in the heavens.

III.

THE SILVER CROWN.

The parallel between Venus and

“That orb'd maiden with fire laden,
Whom mortals call the moon,”

is carried a stage further. Most of us are familiar with the spectacle in which the Ancient Egyptians saw symbolized Horus on the lap of Isis, but which we more prosaically term “the old moon in the new moon’s arms.” The strongly illuminated half circle next the sun is then seen embracing with its horns a dusky sphere, contrasting with it as tarnished silver does with the newly burnished metal. The same phenomenon is occasionally, though very rarely, exhibited by Venus, while close to the sun at inferior conjunction, when the shadowy form of the full orb is seen to shine dimly within her crescent with what is termed “the ashen light.” More wonderful still, this “glimmering sphere” is then crowned, as with a silver halo, by a thin luminous arch, forming a secondary sickle facing the one nearest the sun, and doubtless due to the refraction of his rays round the globe of the planet, through the upper regions of her twilight atmosphere. This spectacle was first observed by the Jesuit Ricciolo, an opponent of the Copernican theory, on January 9th, 1643. He describes the planet as ruddy near the sun, yellowish in the middle, and of

greenish blue on the side remote from the sun; while he also noted the bow of light limiting the dark hemisphere. Scarcely daring to trust his own eyesight, he ascribed these appearances, although he recorded them, to illusory reflection in the telescope.

[Illustration: VENUS AT HER GREATEST BRILLIANCY.]

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They were again seen, however, by Derham about 1715, and six years later by Kirch, in Berlin, who has the following entry in his diary for Saturday, June 29, 1721:—"I found Venus in a region where the sky was not very clear. The planet was narrow, and I seemed to see its dark side, though this is almost incredible. The diameter of Venus was 65", and its sickle seemed to tremble in the atmospheric vapors." Again, on March 8th, 1726, he records a similar observation. "We observed Venus with the twenty-six foot telescope. I perceived her dark side, and its edge seemed to describe a smaller circle than that of the light side, as is the case of the moon." This effect is due to irradiation, that is to say, to the glare from a bright surface, giving a deceptive enlargement to its apparent area. He again saw the dark side of the planet in October, 1759, as did Harding at Goettingen, with Herschel's ten-foot reflector, on January 24th, 1806. This latter observer saw it on this occasion stand out against the background of the sky as of a pale ashen green, while on February 28th following, it seemed to him of a pale reddish gray, like the color of the eclipsed moon.

That the latter body should send to us from her nocturnal shadows sufficient light to be visible is easily explicable, since she is then flooded with earth-light reflected on her from a surface thirteen and one-half times greater than her own, and probably casting on her an illumination transcending our full moonlight in the same proportion. But the secondary light of Venus admits of no such explanation, since earth-light on her surface, diminished by 1/12000th part compared to what it is on that of the moon, would be quite insufficient to render her visible to our eyes. The phenomenon was therefore adduced as an argument for the habitability of the planets by Gruithuisen, of the Munich Observatory, who, writing early in this century, suggested that the ashen light of Venus might be due to general illuminations in celebration by her inhabitants of some periodically recurring festivity. The materials for a flare-up on so grand a scale would, he thought, exist in abundance, as he conjectured the vegetation of our planetary neighbor to be more luxuriant than that of our Brazilian forests. The phosphorescence of the Aphroditean oceans, warm and teeming with life, as they are held to be by Zollner, was advanced as an explanatory hypothesis, with scarcely more plausibility, by Professor Safarik, while others have resorted to the supposition of atmospheric or electrical luminosity producing on a large scale some such display as that of the aurora borealis.

Professor Vogel, of Berlin, who himself saw part of the night-side of Venus, in its semi-obscure in November, 1871, ascribed its visibility to a twilight effect caused by a very extensive atmosphere. The light thus transmitted to us by aerial diffusion and giving the ashen light, is reflected sunlight, while that sent by the luminous arc on its edge is direct sunlight, refracted, or bent round to us, from behind the planet. The silver selvedge of the dawn edging the dark limb may consequently be the brightest part of the broken nimbus that then seems to surround her.

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A similar appearance is observed during transits of Venus, when she passes directly between us and the actual solar disk. A silver thread is then seen encircling that side of the planet which has not yet entered on the face of the sun or "a shadowy nebulous ring," as it was described by Mr. Macdonnell at Eden, surrounds the whole planetary disk when two-thirds of it have passed the solar edge. As it moves off it, the same aureole again becomes visible, testifying to the existence of an atmosphere of considerable extent exterior to the sharply outlined surface ordinarily visible. The shimmering haze of reflected sunlight which perpetually enfolds her is only made apparent to us under exceptional circumstances which cut off some portion of her more immediate light, just as we see the motes in the air illuminated by a candle if we hide the actual flame from our eyes. The perennial twilight which seems to reign over the nocturnal hemisphere of Venus may compensate, perhaps, for the want of a satellite to modify its darkness.

The great prolongation at other times of the horns of her crescent, so as to embrace almost her entire circumference with a tenuous ring of light, is doubtless due to the same cause, as their visibility should otherwise be limited to a half segment of a circle. The regions thus shining to us are obviously those on which the sun has not yet set, his appearance above the horizon being prolonged, as in our own case, by refraction, though to a much larger extent. The magnitude of the sun's disk as seen from Venus, a third larger than it appears to us, is also adducted by Mr. Proctor in his posthumous work, "The Old and the New Astronomy," edited and completed by Mr. A.C. Ranyard, as an element in extending the illumination of Venus to more than a hemisphere of her surface. As his diameter there is $44\frac{1}{4}$ deg., a zone of more than 22 deg. wide outside the sunward hemisphere is he thinks illuminated by direct though partial sunlight, the orb being throughout this tract still partially above the horizon.

[Illustration: GEOGRAPHICAL ASPECT OF VENUS.]

[Illustration]

THE STARS

(FROM STARLAND.)

BY SIR ROBERT S. BALL.

[Illustration]

The group of bodies which cluster around our sun forms a little island, so to speak, in the extent of infinite space. We may illustrate this by a map in which we shall endeavor to show the stars placed at their proper relative distances. We first open the compasses one inch, and thus draw a little circle to represent the path of the earth. We

are not going to put in all the planets. We take Neptune, the outermost, at once. To draw its path I open the compasses to thirty inches, and draw a circle with that radius. That will do for our solar system, though the comets no doubt will roam beyond these limits. To complete our map we ought of course to put in some stars.

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There are a hundred million to choose from, and we shall begin with the brightest. It is often called the Dog Star, but astronomers know it better as Sirius. Let us see where it is to be placed on our map. Sirius is beyond Neptune, so it must be outside somewhere. Indeed, it is a good deal further off than Neptune; so I try at the edge of the drawing-board; I have got a method of making a little calculation that I do not intend to trouble you with, but I can assure you that the results it leads me to are quite correct; they show me that this board is not big enough. But could a board which was big enough fit into this lecture theatre? Here, again, I make my little calculations, and I find that there would not be room for a board sufficiently great; in fact, if I put the sun here at one end, with its planets around it? Sirius would be too near on the same scale if it were at the further corner. The board would have to go out through the wall of the theatre, out through London. Indeed, big as London is, it would not be large enough to contain the drawing-board that I should require. It would have to stretch about twenty miles from where we are now assembled. We may therefore dismiss any hope of making a practical map of our system on this scale if Sirius is to have its proper place. Let us, then, take some other star. We shall naturally try with the nearest of all. It is one that we do not know in this part of the world, but those that live in the southern hemisphere are well acquainted with it. The name of this star is Alpha Centauri. Even for this star we should require a drawing three or four miles long if the distance from the earth to the sun is to be taken as one inch. You see what an isolated position our sun and his planets occupy. The members of the family are all close together, and the nearest neighbors are situated at enormous distances. There is a good reason for this separation. The stars are very pretty and perfectly harmless to us where they are at present situated. They might be very troublesome neighbors if they were very much closer to our system. It is therefore well they are so far off; they would be constantly making disturbances in the sun's family if they were near at hand. Sometimes they would be dragging us into unpleasantly great heat by bringing us too close to the sun, or producing a coolness by pulling us away from the sun, which would be quite as disagreeable.

The Stars are Suns.

We are about to discuss one of the grandest truths in the whole of nature. We have had occasion to see that this sun of ours is a magnificent globe immensely larger than the greatest of his planets, while the greatest of these planets is immensely larger than this earth; but now we are to learn that our sun is, indeed, only a star not nearly so bright as many of those which shine over our heads every night. We are comparatively close to the sun, so that we are able to enjoy his beautiful light and cheering heat.

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Each of those other myriads of stars is a sun, and the splendor of those distant suns is often far greater than that of our own. We are, however, so enormously far from them that they appear dwindled down to insignificance. To judge impartially between our sun or star and such a sun or star as Sirius we should stand halfway between the two; it is impossible to make a fair estimate when we find ourselves situated close to one star and a million times as far from the other. After allowance is made for the imperfections of our point of view, we are enabled to realize the majestic truth that the sun is no more than a star, and that the other stars are no less than suns. This gives us an imposing idea of the extent and magnificence of the universe in which we are situated. Look up at the sky at night—you will see a host of stars; try to think that every one of them is itself a sun. It may probably be that those suns have planets circling round them, but it is hopeless for us to expect to see such planets. Were you standing on one of those stars and looking towards our system, you would not perceive the sun to be the brilliant and gorgeous object that we know so well. If you could see him at all, he would merely seem like a star, not nearly as bright as many of those you can see at night. Even if you had the biggest of telescopes to aid your vision, you could never discern from one of these bodies the planets which surround the sun, no astronomer in the stars could see Jupiter, even if his sight were a thousand times as powerful as any sight or telescope that we know. So minute an object as our earth would, of course, be still more hopelessly beyond the possibility of vision.

The Number of the Stars.

To count the stars involves a task which lies beyond the power of man to accomplish. Even without the aid of any telescope, we can see a great multitude of stars from this part of the world. There are also many constellations in the southern hemisphere which never appear above our horizon. If, however, we were to go to the equator, then, by waiting there for a twelve-month, all the stars in the heavens would have been successively exposed to view. An astronomer, Houzeau, with the patience to count them, enumerated about six thousand. This is the naked-eye estimate of the star-population of the heavens; but if instead of relying on unaided vision, you get the assistance of a little telescope, you will be astounded at the enormous multitude of stars which are disclosed.

[Illustration: FIG 1. THE GREAT BEAR AND THE POLE.]

An ordinary opera-glass or binocular is a very useful instrument for looking at the stars in the heavens. If you employ an instrument of this sort, you will be amazed to find that the heavens teem with additional hosts of stars that your unaided vision would never have given you knowledge of. Any part of the sky may be observed; but, just to give an illustration, I shall take one special region, namely, that of the

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Great Bear (Fig. 1). The seven well-known stars are here shown, four of which form a sort of oblong, while the other three represent the tail. I would like you to make this little experiment. On a fine clear night, count how many stars there are within this oblong; they are all very faint, but you will be able to see a few, and, with good sight, and on a clear night, you may see perhaps ten. Next take your opera-glass and sweep it over the same region; if you will carefully count the stars it shows, you will find fully two hundred; so that the opera-glass has, in this part of the sky, revealed nearly twenty times as many stars as could be seen without its aid. As six thousand stars can be seen by the eye all over the heavens, we may fairly expect that twenty times that number—that is to say, one hundred and twenty thousand stars—could be shown by the opera-glass over the entire sky. Let us go a step further, and employ a telescope, the object-glass of which is three inches across. This is a useful telescope to have, and, if a good one, will show multitudes of pleasing objects, though an astronomer would not consider it very powerful. An instrument like this, small enough to be carried in the hand, has been applied to the task of enumerating the stars in the northern half of the sky, and three hundred and twenty thousand stars were counted. Indeed, the actual number that might have been seen with it is considerably greater, for when the astronomer Argelander made this memorable investigation he was unable to reckon many of the stars in localities where they lay very close together. This grand count only extended to half the sky, and, assuming that the other half is as richly inlaid with stars, we see that a little telescope like that we have supposed will, when swept over the heavens, reveal a number of stars which exceeds that of the population of any city in England except London. It exhibits more than one hundred times as many stars as our eyes could possibly reveal. Still, we are only at the beginning of the count; the very great telescopes add largely to the number. There are multitudes of stars which in small instruments we cannot see, but which are distinctly visible from our great observatories. That telescope would be still but a comparatively small one which would show as many stars in the sky as there are people living in the mighty city of London; and with the greatest instruments, the tale of stars has risen to a number far greater than that of the entire population of Great Britain.

In addition to those stars which the largest telescopes show us, there are myriads which make their presence evident in a wholly different way. It is only in quite recent times that an attempt has been made to develop fully the powers of photography in representing the celestial objects. On a photographic plate which has been exposed to the sky in a great telescope the stars are recorded by thousands. Many of these may, of course, be observed with a good telescope,

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but there are not a few others which no one ever saw in a telescope, which apparently no one ever could see, though the photograph is able to show them. We do not, however, employ a camera like that which the photographer uses who is going to take your portrait. The astronomer's plate is put into his telescope, and then the telescope is turned towards the sky. On that plate the stars produce their images, each by its own light. Some of these images are excessively faint, but we give a very long exposure of an hour or two hours; sometimes as much as four hours' exposure is given to a plate so sensitive that a mere fraction of a second would sufficiently expose it during the ordinary practice of taking a photograph in daylight. We thus afford sufficient time to enable the fainter objects to indicate their presence upon the sensitive film. Even with an exposure of a single hour a picture exhibiting sixteen thousand stars has been taken by Mr. Isaac Roberts, of Liverpool. Yet the portion of the sky which it represents is only one ten-thousandth part of the entire heavens. It should be added that the region which Mr. Roberts has photographed is furnished with stars in rather exceptional profusion.

Here, at last, we have obtained some conception of the sublime scale on which the stellar universe is constructed. Yet even these plates cannot represent all the stars that the heavens contain. We have every reason for knowing that with larger telescopes, with more sensitive plates, with more prolonged exposures, ever fresh myriads of stars will be brought within our view.

You must remember that every one of these stars is truly a sun, a lamp, as it were, which doubtless gives light to other objects in its neighborhood as our sun sheds light upon this earth and the other planets. In fact, to realize the glories of the heavens you should try to think that the brilliant points you see are merely the luminous points of the otherwise invisible universe.

Standing one fine night on the deck of a Cunarder we passed in open ocean another great Atlantic steamer. The vessel was near enough for us to see not only the light from the mast-head but also the little beams from the several cabin ports; and we could see nothing of the ship herself. Her very existence was only known to us by the twinkle of these lights. Doubtless her passengers could see, and did see, the similar lights from our own vessel, and they probably drew the correct inference that these lights indicated a great ship.

Consider the multiplicity of beings and objects in a ship: the captain and the crew, the passengers, the cabins, the engines, the boats, the rigging, and the stores. Think of all the varied interests there collected and then reflect that out on the ocean, at night, the sole indication of the existence of this elaborate structure was given by the few beams of light that happened to radiate from it. Now raise your eyes to the stars; there are the twinkling

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lights. We cannot see what those lights illuminate, we can only conjecture what untold wealth of non-luminous bodies may also lie in their vicinity; we may, however, feel certain that just as the few gleaming lights from a ship are utterly inadequate to give a notion of the nature and the contents of an Atlantic steamer, so are the twinkling stars utterly inadequate to give even the faintest conception of the extent and the interest of the universe. We merely see self-luminous bodies, but of the multitudes of objects and the elaborate systems of which these bodies are only the conspicuous points we see nothing and we know very little. We are, however, entitled to infer from an examination of our own star—the sun—and of the beautiful system by which it is surrounded, that these other suns may be also splendidly attended. This is quite as reasonable a supposition as that a set of lights seen at night on the Atlantic Ocean indicates the existence of a fine ship.

The Clusters of Stars.

On a clear night you can often see, stretching across the sky, a track of faint light, which is known to astronomers as the “Milky Way.” It extends below the horizon, and then round the earth to form a girdle about the heavens. When we examine the Milky Way with a telescope we find, to our amazement, that it consists of myriads of stars, so small and so faint that we are not able to distinguish them individually; we merely see the glow produced from their collective rays. Remembering that our sun is a star, and that the Milky Way surrounds us, it would almost seem as if our sun were but one of the host of stars which form this cluster.

There are also other clusters of stars, some of which are exquisitely beautiful telescopic spectacles. I may mention a celebrated pair of these objects which lies in the constellation of Perseus. The sight of them in a great telescope is so imposing that no one who is fit to look through a telescope could resist a shout of wonder and admiration when first they burst on his view. But there are other clusters. Here is a picture of one which is known as the “Globular Cluster in the Centaur” (Fig. 2). It consists of a ball of stars, so far off that, however large these several suns may actually be, they have dwindled down to extremely small points of light. A homely illustration may serve to show the appearance which a globular cluster presents in a good telescope. I take a pepper-caster, and on a sheet of white paper I begin to shake out the pepper until there is a little heap at the centre and other grains are scattered loosely about. Imagine that every one of those grains of pepper was to be transformed into a tiny electric light, and then you have some idea of what a cluster of stars would look like when viewed through a telescope of sufficient power. There are multitudes of such groups scattered through the depths of space. They require our biggest telescopes to show them adequately. We have seen that our sun is a star, being only one of a magnificent cluster that forms the Milky Way. We have also seen that there are other groups scattered through the

length and depth of space. It is thus we obtain a notion of the rank which our earth holds in the scheme of things celestial.

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[Illustration: FIG. 2. GLOBULAR CLUSTER IN THE CENTAUR.]

The Rank of the Earth as a Globe in Space.

Let me give an illustration with the view of explaining more fully the nature of the relation which the earth bears to the other globes which abound through space, and you must allow me to draw a little upon my imagination. I shall suppose that the mails of our country extend not only over this globe, but that they also communicate with other worlds; that postal arrangements exist between Mars and the earth, between the sun and Orion—in fact, everywhere throughout the whole extent of the universe. We shall consider how our letters are to be addressed. Let us take the case of Mr. John Smith, merchant, who lives at 1001, Piccadilly; and let us suppose that Mr. John Smith's business transactions are of such an extensive nature that they reach not only all over this globe, but away throughout space. I shall suppose that the firm has a correspondent residing—let us say in the constellation of the Great Bear; and when this man of business wants to write to Mr. Smith from these remote regions, what address must he put upon the letter, so that the Postmaster-General of the universe shall make no mistake about its delivery? He will write as follows:—

MR. JOHN SMITH,
1001 Piccadilly,
London,
England,
Europe,
Earth,
Near the Sun,
Milky Way,
The Universe.

Let us now see what the several lines of this address mean. Of course we put down the name of Mr. John Smith in the first line, and then we will add “1001 Piccadilly” for the second; but as the people in the Great Bear are not likely to know where Piccadilly is, we shall add “London” underneath. As even London itself cannot be well known everywhere, it is better to write “England.” This would surely find Mr. John Smith from any post-office on this globe. From other globes, however, the supreme importance of England may not be so immediately recognized, and therefore it is as well to add another line, “Europe.” This ought to be sufficient, I think, for any post-office in the solar system. Europe is big enough to be visible from Mars or Venus, and should be known to the post-office people there, just as we know and have names for the continents on Mars. But further away there might be a little difficulty; from Uranus and Neptune the different regions on our earth can never have been distinguished, and therefore we must add another line to indicate the particular globe of the solar system which contains Europe. Mark Twain tells us that there was always one thing in astronomy which specially puzzled him, and that was to know how we found out the names of the stars.

We are, of course, in hopeless ignorance of the name by which this earth is called among other intelligent beings elsewhere who can see it. I can only adopt the title of "Earth," and therefore I add this line. Now our address is so complete that from anywhere

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in the solar system—from Mercury, from Jupiter, or Neptune—there ought to be no mistake about the letter finding its way to Mr. John Smith. But from his correspondent in the Great Bear this address would be still incomplete; they cannot see our earth from there, and even the sun himself only looks like a small star—like one, in fact, of thousands of stars elsewhere. However, each star can be distinguished, and our sun may, for instance, be recognized from the Great Bear by some designation. We shall add the line “Near the Sun,” and then I think that from this constellation, or from any of the other stars around us, the address of Mr. John Smith may be regarded as complete. But Mr. Smith’s correspondence may be still wider. He may have an agent living in the cluster of Perseus or on some other objects still fainter and more distant; then “Near the Sun” is utterly inadequate as a concluding line to the address, for the sun, if it can be seen at all from thence, will be only of the significance of an excessively minute star, no more to be designated by a special name than are each of the several leaves on the trees of a forest. What this distant correspondent will be acquainted with is not the earth or the sun but only the cluster of stars among which the sun is but a unit. Again we use our own name to denote the cluster, and we call it the “Milky Way.” When we add this line, we have made the address of Mr. John Smith as complete as circumstances will permit. I think a letter posted to him anywhere ought to reach its destination. To perfect it, however, we will finish up with one line more—“The Universe.”

The Distances of the Stars.

I must now tell you something about the distances of the stars. I shall not make the attempt to explain fully how astronomers make such measurements, but I will give you some notion of how it is done. You may remember I showed you how we found the distance of a globe that was hung from the ceiling. The principle of the method for finding the distance of a star is somewhat similar, except that we make the two observations not from the two ends of a table, not even from opposite sides of the earth, but from two opposite points on the earth’s orbit, which are therefore at a distance of one hundred and eighty-six million miles. Imagine that on Midsummer Day, when standing on the earth here, I measure with a piece of card the angle between the star and the sun. Six months later, on Midwinter Day, when the earth is at the opposite point of its orbit, I again measure the angle between the same star and the sun, and we can now determine the star’s distance by making a triangle. I draw a line a foot long, and we will take this foot to represent one hundred and eighty-six million miles, the distance between the two stations; then placing the cards at the corners, I rule the two sides and complete the triangle, and the star must be at the remaining corner; then I measure the sides of the triangle, and how many feet they contain,

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and recollecting that each foot corresponds to one hundred and eighty-six million miles, we discover the distance of the star. If the stars were comparatively near us, the process would be a very simple one; but, unfortunately, the stars are so extremely far off that this triangle, even with a base of only one foot, must have its sides many miles long. Indeed, astronomers will tell you that there is no more delicate or troublesome work in the whole of their science than that of discovering the distance of a star.

In all such measurements we take the distance from the earth to the sun as a conveniently long measuring-rod, whereby to express the results. The nearest stars are still hundreds of thousands of times as far off as the sun. Let us ponder for a little on the vastness of these distances. We shall first express them in miles. Taking the sun's distance to be ninety-three million miles, then the distance of the nearest fixed star is about twenty millions of millions of miles—that is to say, we express this by putting down a 2 first, and then writing thirteen ciphers after it. It is, no doubt, easy to speak of such figures, but it is a very different matter when we endeavor to imagine the awful magnitude which such a number indicates. I must try to give some illustrations which will enable you to form a notion of it. At first I was going to ask you to try and count this number, but when I found it would require at least three hundred thousand years, counting day and night without stopping, before the task was over, it became necessary to adopt some other method.

When on a visit in Lancashire I was once kindly permitted to visit a cotton mill, and I learned that the cotton yarn there produced in a single day would be long enough to wind round this earth twenty-seven times at the equator. It appears that the total production of cotton yarn each day in all the mills together would be on the average about one hundred and fifty-five million miles. In fact, if they would only spin about one-fifth more, we could assert that Great Britain produced enough cotton yarn every day to stretch from the earth to the sun and back again! It is not hard to find from these figures how long it would take for all the mills in Lancashire to produce a piece of yarn long enough to reach from our earth to the nearest of the stars. If the spinners worked as hard as ever they could for a year, and if all the pieces were then tied together, they would extend to only a small fraction of the distance; nor if they worked for ten years, or for twenty years, would the task be fully accomplished. Indeed, upwards of four hundred years would be necessary before enough cotton could be grown in America and spun in this country to stretch over a distance so enormous. All the spinning that has ever yet been done in the world has not formed a long enough thread!

There is another way in which we can form some notion of the immensity of these sidereal distances. You will recollect that, when we were speaking of Jupiter's moons, I told you of the beautiful discovery which their eclipses enabled astronomers to make. It was thus found that light travels at the enormous speed of about one hundred and

eighty-five thousand miles per second. It moves so quickly that within a single second a ray would flash two hundred times from London to Edinburgh and back again.

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We said that a meteor travels one hundred times as swiftly as a rifle-bullet; but even this great speed seems almost nothing when compared with the speed of light, which is ten thousand times as great. Suppose some brilliant outbreak of light were to take place in a distant star—an outbreak which would be of such intensity that the flash from it would extend far and wide throughout the universe. The light would start forth on its voyage with terrific speed. Any neighboring star which was at a distance of less than one hundred and eighty-five thousand miles would, of course, see the flash within a second after it had been produced. More distant bodies would receive the intimation after intervals of time proportioned to their distances. Thus, if a body were one million miles away, the light would reach it in from five to six seconds, while over a distance as great as that which separates the earth from the sun the news would be carried in about eight minutes. We can calculate how long a time must elapse ere the light shall travel over a distance so great as that between the star and our earth. You will find that from the nearest of the stars the time required for the journey will be over three years. Ponder on all that this involves. That outbreak in the star might be great enough to be visible here, but we could never become aware of it till three years after it had happened. When we are looking at such a star to-night we do not see it as it is at present, for the light that is at this moment entering our eyes has travelled so far that it has been three years on the way. Therefore, when we look at the star now we see it as it was three years previously. In fact, if the star were to go out altogether, we might still continue to see it twinkling for a period of three years longer, because a certain amount of light was on its way to us at the moment of extinction, and so long as that light keeps arriving here, so long shall we see the star showing as brightly as ever. When, therefore, you look at the thousands of stars in the sky to-night, there is not one that you see as it is now, but as it was years ago.

I have been speaking of the stars that are nearest to us, but there are others much farther off. It is true we cannot find the distances of these more remote objects with any degree of accuracy, but we can convince ourselves how great that distance is by the following reasoning. Look at one of the brightest stars. Try to conceive that the object was carried away further into the depths of space, until it was ten times as far from us as it is at present, it would still remain bright enough to be recognized in quite a small telescope; even if it were taken to one hundred times its original distance it would not have withdrawn from the view of a good telescope; while if it retreated one thousand times as far as it was at first it would still be a recognizable point in our mightiest instruments. Among the stars which we can see with our telescopes, we feel confident there must be many from which the light has expended hundreds of years, or even thousands of years, on the journey. When, therefore, we look at such objects, we see them, not as they are now, but as they were ages ago; in fact, a star might have ceased to exist for thousands of years, and still be seen by us every night as a twinkling point in our great telescopes.

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Remembering these facts, you will, I think, look at the heavens with a new interest. There is a bright star, Vega, or Alpha Lyrae, a beautiful gem, so far off that the light from it which now reaches our eyes started before many of my audience were born. Suppose that there are astronomers residing on worlds amid the stars, and that they have sufficiently powerful telescopes to view this globe, what do you think they would observe? They will not see our earth as it is at present; they will see it as it was years (and sometimes many years) ago. There are stars from which if England could now be seen, the whole of the country would be observed at this present moment to be in a great state of excitement at a very auspicious event. Distant astronomers might notice a great procession in London, and they could watch the coronation of a youthful queen amid the enthusiasm of a nation. There are other stars still further, from which, if the inhabitants had good enough telescopes, they would now see a mighty battle in progress not far from Brussels. One splendid army could be beheld hurling itself time after time against the immovable ranks of the other. They would not, indeed, be able to hear the ever-memorable "Up, Guards, and at them!" but there can be no doubt that there are stars so far away that the rays of light which started from the earth on the day of the battle of Waterloo are only just arriving there. Further off still, there are stars from which a bird's-eye view could be taken at this very moment of the signing of Magna Charta. There are even stars from which England, if it could be seen at all, would now appear, not as the great England we know, but as a country covered by dense forests, and inhabited by painted savages, who waged incessant war with wild beasts that roamed through the island. The geological problems that now puzzle us would be quickly solved could we only go far enough into space and had we only powerful enough telescopes. We should then be able to view our earth through the successive epochs of past geological time; we should be actually able to see those great animals whose fossil remains are treasured in our museums tramping about over the earth's surface, splashing across its swamps, or swimming with broad flippers through its oceans. Indeed, if we could view our own earth reflected from mirrors in the stars, we might still see Moses crossing the Red Sea, or Adam and Eve being expelled from Eden.

So important is the subject of star distance that I am tempted to give one more illustration in order to bring before you some conception of how vast such distances are. I shall take, as before, the nearest of the stars so far as known to us, and I hope to be forgiven for taking an illustration of a practical and a commercial kind instead of one more purely scientific. I shall suppose that a railway is about to be made from London to Alpha Centauri. The length of that railway, of course, we have already stated: it

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is twenty billions of miles. So I am now going to ask your attention to the simple question as to the fare which it would be reasonable to charge for the journey. We shall choose a very cheap scale on which to compute the price of a ticket. The parliamentary rate here is, I believe, a penny for every mile. We will make our interstellar railway fares much less even than this; we shall arrange to travel at the rate of one hundred miles for every penny. That, surely, is moderate enough. If the charges were so low that the journey from London to Edinburgh only cost fourpence, then even the most unreasonable passenger would be surely contented. On these terms how much do you think the fare from London to this star ought to be? I know of one way in which to make our answer intelligible. There is a National Debt with which your fathers are, unhappily, only too well acquainted; you will know quite enough about it yourselves in those days when you have to pay income tax. This debt is so vast that the interest upon it is about sixty thousand pounds a day, the whole amount of the National Debt being six hundred and thirty-eight millions of pounds.

If you went to the booking-office with the whole of this mighty sum in your pocket—but stop a moment; could you carry it in your pocket? Certainly not, if it were in sovereigns. You would find that after you had as many sovereigns as you could conveniently carry there would still be some left—so many, indeed, that it would be necessary to get a cart to help you on with the rest. When the cart had as great a load of sovereigns as the horse could draw there would be still some more, and you would have to get another cart; but ten carts, twenty carts, fifty carts, would not be enough. You would want five thousand of these before you would be able to move off towards the station with your money. When you did get there and asked for a ticket at the rate of one hundred miles for a penny, do you think you would get any change? No doubt some little time would be required to count the money, but when it was counted the clerk would tell you that there was not enough—that he must have nearly two hundred millions of pounds more.

That will give some notion of the distance of the nearest star, and we may multiply it by ten, by one hundred, and even by one thousand, and still not attain to the distance of some of the more remote stars that the telescope shows us.

On account of the immense distances of the stars we can only perceive them to be mere points of light. We can never see a star to be a globe with marks on it like the moon, or like one of the planets—in fact, the better the telescope the smaller does the star seem, though, of course, its brightness is increased with every addition to the light-grasping power of the instrument.

The Brightness and Color of Stars.

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Another point to be noticed is the arrangement of stars in classes, according to their lustre. The brightest stars, of which there are about twenty, are said to be of the first magnitude. Those just inferior to the first magnitude are ranked as the second; and those just lower than the second are estimated as the third; and so on. The smallest points that your unaided eyes will show you are of about the sixth magnitude. Then the telescope will reveal stars still fainter and fainter, down to what we term the seventeenth or eighteenth magnitudes, or even lower still. The number of stars of each magnitude increases very much in the classes of small ones.

Most of the stars are white, but many are of a somewhat ruddy hue. There are a few telescopic points which are intensely red, some exhibit beautiful golden tints, while others are blue or green.

There are some curious stars which regularly change their brilliancy. Let me try to illustrate the nature of these variables. Suppose that you were looking at a street gas-lamp from a very long distance, so that it seemed a little twinkling light; and suppose that some one was preparing to turn the gas-cock up and down. Or, better still, imagine a little machine which would act regularly so as to keep the light first of all at its full brightness for two days and a half, and then gradually turn it down until in three or four hours it declines to a feeble glimmer. In this low state the light remains for twenty minutes; then during three or four hours the gas is to be slowly turned on again until it is full. In this condition the light will remain for two days and a half, and then the same series of changes is to recommence. This would be a very odd form of gas-lamp. There would be periods of two days and a half during which it would remain at its full; these would be separated by intervals of about seven hours, when the gradual turning down and turning up again would be in progress.

The imaginary gas-lamp is exactly paralleled by a star Algol, in the constellation of Perseus (Fig. 3), which goes through the series of changes I have indicated. Ordinarily speaking, it is a bright star of the second magnitude, and, whatever be the cause, the star performs its variations with marvellous uniformity. In fact, Algol has always arrested the attention of those who observed the heavens, and in early times was looked on as the eye of a demon. There are many other stars which also change their brilliancy. Most of them require much longer periods than Algol, and sometimes a new star which nobody has ever seen before will suddenly kindle into brilliancy. It is now known that the bright star Algol is attended by a dark companion. This dark star sometimes comes between Algol and the observer and cuts off the light. Thus it is that the diminution of brightness is produced.

[Illustration: FIG. 3. PERSEUS AND ITS NEIGHBORING STARS INCLUDING ALGOL.]

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Double Stars.

Whenever you have a chance of looking at the heavens through a telescope, you should ask to be shown what is called a *double star*. There are many stars in the heavens which present no remarkable appearance to the unaided eye, but which a good telescope at once shows to be of quite a complex nature. These are what we call double stars, in which two quite distinct stars are placed so close together that the unaided eye is unable to separate them. Under the magnifying power of the telescope, however, they are seen to be distinct. In order to give some notion of what these objects are like, I shall briefly describe three of them. The first lies in that best known constellation, the Great Bear. If you look at his tail, which consists of three stars, you will see that near the middle one of the three a small star is situated; we call this little star Alcor, but it is the brighter one near Alcor to which I specially call your attention. The sharpest eye would never suspect that it was composed of two stars placed close together. Even a small telescope will, however, show this to be the case, and this is the easiest and the first observation that a young astronomer should make when beginning to turn a telescope to the heavens. Of course you will not imagine that I mean Alcor to be the second component of the double star; it is the bright star near Alcor which is the double. Here are two marbles, and these marbles are fastened an inch apart. You can see them, of course, to be separate; but if the pair were moved further and further away, then you would soon not be able to distinguish between them, though the actual distance between the marbles had not altered. Look at these two wax tapers which are now lighted; the little flames are an inch apart. You would have to view them from a station a third of a mile away if the distance between the two flames were to appear the same as that between the two components of this double star. Your eye would never be able to discriminate between two lights only an inch apart at so great a distance; a telescope would, however, enable you to do so, and this is the reason why we have to use telescopes to show us double stars.

You might look at that double star year after year throughout the course of a long life without finding any appreciable change in the relative positions of its components. But we know that there is no such thing as rest in the universe; even if you could balance a body so as to leave it for a moment at rest, it would not stay there, for the simple reason that all the bodies round it in every direction are pulling at it, and it is certain that the pull in one direction will preponderate, so that move it must. Especially is this true in the case of two suns like those forming a double star. Placed comparatively near each other they could not remain permanently in that position; they must gradually draw together and come into collision with an awful crash. There is only one way by which such a disaster could be averted. That is by making one of these stars revolve around the other just as the earth revolves around the sun, or the moon revolves around the earth. Some motion must, therefore, be going on in every genuine double star, whether we have been able to see that motion or not.

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Let us now look at another double star of a different kind. This time it is in the constellation of Gemini. The heavenly twins are called Castor and Pollux. Of these, Castor is a very beautiful double star, consisting of two bright points, a great deal closer together than were those in the Great Bear; consequently a better telescope is required for the purpose of showing them separately. Castor has been watched for many years, and it can be seen that one of these stars is slowly revolving around the other; but it takes a very long time, amounting to hundreds of years, for a complete circuit to be accomplished. This seems very astonishing, but when you remember how exceedingly far Castor is, you will perceive that that pair of stars which appear so close together that it requires a telescope to show them apart must indeed be separated by hundreds of millions of miles. Let us try to conceive our own system transformed into a double star. If we took our outermost planet—Neptune—and enlarged him a good deal, and then heated him sufficiently to make him glow like a sun, he would still continue to revolve round our sun at the same distance, and thus a double star would be produced. An inhabitant of Castor who turned his telescope towards us would be able to see the sun as a star. He would not, of course, be able to see the earth, but he might see Neptune like another small star close to the sun. If generations of astronomers in Castor continued their observations of our system, they would find a binary star, of which one component took a century and a half to go round the other. Need we then be surprised that when we look at Castor we observe movements that seem very slow?

There is often so much diffused light about the bright stars seen in a telescope, and so much twinkling in some states of the atmosphere, that stars appear to dance about in rather a puzzling fashion, especially to one who is not accustomed to astronomical observations. I remember hearing how a gentleman once came to visit an observatory. The astronomer showed him Castor through a powerful telescope as a fine specimen of a double star, and then, by way of improving his little lesson, the astronomer mentioned that one of these stars was revolving around the other. "Oh, yes," said the visitor, "I saw them going round and round in the telescope." He would, however, have had to wait for a few centuries with his eye to the instrument before he would have been entitled to make this assertion.

Double stars also frequently delight us by giving beautifully contrasted colors. I dare say you have often noticed the red and the green lights that are used on railways in the signal lamps. Imagine one of those red and one of those green lights away far up in the sky and placed close together, then you would have some idea of the appearance that a colored double star presents, though, perhaps, I should add that the hues in the heavenly bodies are not so

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vividly different as are those which our railway people find necessary. There is a particularly beautiful double star of this kind in the constellation of the Swan. You could make an imitation of it by boring two holes, with a red-hot needle, in a piece of card, and then covering one of these holes with a small bit of the topaz-colored gelatine with which Christmas crackers are made. The other star is to be similarly colored with blue gelatine. A slide made on this principle placed in the lantern gives a very good representation of these two stars on the screen. There are many other colored doubles besides this one; and, indeed, it is noteworthy that we hardly ever find a blue or a green star by itself in the sky; it is always as a member of one of these pairs.

How We Find What the Stars are Made of.

Here is a piece of stone. If I wanted to know what it was composed of, I should ask a chemist to tell me. He would take it into his laboratory, and first crush it into powder, and then, with his test tubes, and with the liquids which his bottles contain, and his weighing scales, and other apparatus, he would tell all about it; there is so much of this, and so much of that, and plenty of this, and none at all of that. But now, suppose you ask this chemist to tell you what the sun is made of, or one of the stars. Of course, you have not a sample of it to give him; how, then, can he possibly find out anything about it? Well, he can tell you something, and this is the wonderful discovery that I want to explain to you. We now put down the gas, and I kindle a brilliant red light. Perhaps some of those whom I see before me have occasionally ventured on the somewhat dangerous practice of making fire-works. If there is any boy here who has ever constructed sky-rockets, and put the little balls into the top which are to burn with such vivid colors when the explosion takes place, he will know that the substance which tinged that fire red must have been strontium. He will recognize it by the color; because strontium gives a red light which nothing else will give. Here are some of these lightning papers, as they are called; they are very pretty and very harmless; and these, too, give brilliant red flashes as I throw them. The red tint has, no doubt, been produced by strontium also. You see we recognized the substance simply by the color of the light it produced when burning.

Perhaps some of you have tried to make a ghost at Christmas by dressing up in a sheet, and bearing in your hand a ladle blazing with a mixture of common salt and spirits of wine, the effect produced being a most ghastly one. Some mammas will hardly thank me for this suggestion, unless I add that the ghost must walk about cautiously, for otherwise the blazing spirit would be very apt to produce conflagrations of a kind more extensive than those intended. However, by the kindness of Professor Dewar, I am enabled to show the phenomenon on a splendid scale,



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and also free from all danger. I kindle a vivid flame of an intensely yellow color, which I think the ladies will unanimously agree is not at all becoming to their complexions, while the pretty dresses have lost their variety of colors. Here is a nice bouquet, and yet you can hardly distinguish the green of the leaves from the brilliant colors of the flowers, except by trifling differences of shade. Expose to this light a number of pieces of variously colored ribbon, pink and red and green and blue, and their beauty is gone; and yet we are told that this yellow is a perfectly pure color; in fact, the purest color that can be produced. I think we have to be thankful that the light which our good sun sends us does not possess purity of that description. There is one substance which will produce that yellow light; it is a curious metal called sodium—a metal so soft that you can cut it with a knife, and so light that it will float on water; while, still more strange, it actually takes fire the moment it is dropped on the water. It is only in a chemical laboratory that you will be likely to meet with the actual metallic sodium, yet in other forms the substance is one of the most abundant in nature. Indeed, common salt is nothing but sodium closely united with a most poisonous gas, a few respirations of which would kill you. But this strange metal and this noxious gas, when united, become simply the salt for our eggs at breakfast. This pure yellow light, wherever it is seen, either in the flame of spirits of wine mixed with salt or in that great blaze at which we have been looking, is characteristic of sodium. Wherever you see that particular kind of light, you know that sodium must have been present in the body from which it came.

We have accordingly learned to recognize two substances, namely, strontium and sodium, by the different lights which they give out when burning. To these two metals we may add a third. Here is a strip of white metallic ribbon. It is called magnesium. It seems like a bit of tin at the first glance, but indeed it is a very different substance from tin; for, look, when I hold it in the spirit-lamp, the strip of metal immediately takes fire, and burns with a white light so dazzling that it pales the gas-flames to insignificance. There is no other substance which will, when kindled, give that particular kind of light which we see from magnesium. I can recommend this little experiment as quite suitable for trying at home; you can buy a bit of magnesium ribbon for a trifle at the opticians; it cannot explode or do any harm, nor will you get into any trouble with the authorities provided you hold it when burning over a tray or a newspaper, so as to prevent the white ashes from falling on the carpet.

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There are, in nature, a number of simple bodies called elements. Every one of these, when ignited under suitable conditions, emits a light which belongs to it alone, and by which it can be distinguished from every other substance. I do not say that we can try the experiments in the simple way I have here indicated. Many of the materials will yield light which will require to be studied by much more elaborate artifices than those which have sufficed for us. But you will see that the method affords a means of finding out the actual substances present in the sun or in the stars. There is a practical difficulty in the fact that each of the heavenly bodies contains a number of different elements; so that in the light it sends us the hues arising from distinct substances are blended into one beam. The first thing to be done is to get some way of splitting up a beam of light, so as to discover the components of which it is made. You might have a skein of silks of different hues tangled together, and this would be like the sunbeam as we receive it in its unsorted condition. How shall we untangle the light from the sun or a star? I will show you by a simple experiment. Here is a beam from the electric light; beautifully white and bright, is it not? It looks so pure and simple, but yet that beam is composed of all sorts of colors mingled together, in such proportions as to form white light. I take a wedge-shaped piece of glass called a prism, and when I introduce it into the course of the beam, you see the transformation that has taken place (Fig. 4). Instead of the white light you have now all the colors of the rainbow—red, orange, yellow, green, blue, indigo, violet, marked by their initial letters in the figure. These colors are very beautiful, but they are transient, for the moment we take away the prism they all unite again to form white light. You see what the prism has done; it has bent all the light in passing through it; but it is more effective in bending the blue than the red, and consequently the blue is carried away much further than the red. Such is the way in which we study the composition of a heavenly body. We take a beam of its light, we pass it through a prism, and immediately it is separated into its components; then we compare what we find with the lights given by the different elements, and thus we are enabled to discover the substances which exist in the distant object whose light we have examined. I do not mean to say that the method is a simple one; all I am endeavoring to show is a general outline of the way in which we have discovered the materials present in the stars. The instrument that is employed for this purpose is called the spectroscope. And perhaps you may remember that name by these lines, which I have heard from an astronomical friend:—

“Twinkle, twinkle, little star,
Now we find out what you are,
When unto the midnight sky,
We the spectroscope apply.”

[Illustration: FIG. 4. HOW A RAY OF LIGHT IS SPLIT UP.]

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I am sure it will interest everybody to know that the elements which the stars contain are not altogether different from those of which the earth is made. It is true there may be substances in the stars of which we know nothing here; but it is certain that many of the most common elements on the earth are present in the most distant bodies. I shall only mention one, the metal iron. That useful substance has been found in some of the stars which lie at almost incalculable distances from the earth.

The Nebulae.

In drawing towards the close of these lectures I must say a few words about some dim and mysterious objects to which we have not yet alluded. They are what are called nebulae, or little clouds; and in one sense they are justly called little, for each of them occupies but a very small spot in the sky as compared with that which would be filled by an ordinary cloud in our air. The nebulae are, however, objects of the most stupendous proportions. Were our earth and thousands of millions of bodies quite as big all put together, they would not be nearly so great as one of these nebulae. Astronomers reckon up the various nebulae by thousands, but I must add that most of them are apparently faint and uninteresting. A nebula is sometimes liable to be mistaken for a comet. The comet is, as I have already explained, at once distinguished by the fact that it is moving and changing its appearance from hour to hour, while scores of years elapse without changes in the aspect or position of a nebula. The most powerful telescopes are employed in observing these faint objects. I take this opportunity of showing a picture of an instrument suitable for such observations. It is the great reflector of the Paris Observatory (Fig. 5).

[Illustration: FIG. 5. A GREAT REFLECTING TELESCOPE.]

[Illustration: FIG. 6. THE RING NEBULA IN LYRA, UNDER DIFFERENT TELESCOPIC POWERS.]

There are such multitudes of nebulae that I can only show a few of the more remarkable kinds. In Fig. 6 will be seen pictures of a curious object in the constellation of Lyra seen under different telescopic powers. This is a gigantic ring of luminous gas. To judge of the size of this ring let us suppose that a railway were laid across it, and the train you entered at one side was not to stop until it reached the other side, how long do you think this journey would require? I recollect some time ago a picture in *Punch* which showed a train about to start from London to Brighton, and the guard walking up and down announcing to the passengers the alarming fact that "this train stops nowhere." An old gentleman was seen vainly gesticulating out of the window and imploring to be let out ere the frightful journey was commenced. In the nebular railway the passengers would almost require such a warning.

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Let the train start at a speed of a mile a minute, you would think, surely, that it must soon cross the ring. But the minutes pass, an hour has elapsed; so the distance must be sixty miles at all events. The hours creep on into days, the days advance into years, and still the train goes on. The years would lengthen out into centuries, and even when the train had been rushing on for a thousand years with an unabated speed of a mile a minute, the journey would certainly not have been completed. Nor do I venture to say what ages must elapse ere the terminus at the other side of the ring nebula would be reached.

A cluster of stars viewed in a small telescope will often seem like a nebula, for the rays of the stars become blended. A powerful telescope will, however, dispel the illusion and reveal the separate stars. It was, therefore, thought that all the nebulae might be merely clusters so exceedingly remote that our mightiest instruments failed to resolve them into stars. But this is now known not to be the case. Many of these objects are really masses of glowing gas; such are, for instance, the ring nebulae, of which I have just spoken, and the form of which I can simulate by a pretty experiment.

We take a large box with a round hole cut in one face, and a canvas back at the opposite side. I first fill this box with smoke, and there are different ways of doing so. Burning brown paper does not answer well, because the supply of smoke is too irregular and the paper itself is apt to blaze. A little bit of phosphorus set on fire yields copious smoke, but it would be apt to make people cough, and, besides, phosphorus is a dangerous thing to handle incautiously, and I do not want to suggest anything which might be productive of disaster if the experiment was repeated at home. A little wisp of hay, slightly damped and lighted, will safely yield a sufficient supply, and you need not have an elaborate box like this; any kind of old packing-case, or even a bandbox with a duster stretched across its open top and a round hole cut in the bottom, will answer capitally. While I have been speaking, my assistant has kindly filled this box with smoke, and in order to have a sufficient supply, and one which shall be as little disagreeable as possible, he has mixed together the fumes of hydrochloric acid and ammonia from two retorts shown in Fig. 7. A still simpler way of doing the same thing is to put a little common salt in a saucer and pour over it a little oil of vitriol; this is put into the box, and over the floor of the box common smelling-salts is to be scattered. You see there are dense volumes of white smoke escaping from every corner of the box. I uncover the opening and give a push to the canvas, and you see a beautiful ring flying across the room; another ring and another follows. If you were near enough to feel the ring, you would experience a little puff of wind; I can show this by blowing out a candle which is at

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the other end of the table. These rings are made by the air which goes into a sort of eddy as it passes through the hole. All the smoke does is to render the air visible. The smoke-ring is indeed quite elastic. If we send a second ring hurriedly after the first, we can produce a collision, and you see each of the two rings remains unbroken, though both are quivering from the effects of the blow. They are beautifully shown along the beam of the electric lamp, or, better still, along a sunbeam.

[Illustration: FIG. 7. HOW TO MAKE THE SMOKE RINGS.]

We can make many experiments with smoke-rings. Here, for instance, I take an empty box, so far as smoke is concerned, but air-rings can be driven forth from it, though you cannot see them, but you can feel them even at the other side of the room, and they will, as you see, blow out a candle. I can also shoot invisible air-rings at a column of smoke, and when the missile strikes the smoke it produces a little commotion and emerges on the other side, carrying with it enough of the smoke to render itself visible, while the solid black looking ring of air is seen in the interior. Still more striking is another way of producing these rings, for I charge this box with ammonia, and the rings from it you cannot see. There is a column of the vapor of hydrochloric acid, that also you cannot see; but when the visible ring enters the invisible column, then a sudden union takes place between the vapor of the ammonia and the vapor of the hydrochloric acid; the result is a solid white substance in extremely fine dust which renders the ring instantly visible.

What the Nebulae are made of.

There is a fundamental difference between the illumination of these little rings that I have shown you and the great rings in the heavens. I had to illuminate our smoke with the help of the electric light, for, unless I had done so, you would not have been able to see them. This white substance formed by the union of ammonia and hydrochloric acid has, of course, no more light of its own than a piece of chalk; it requires other light falling upon it to make it visible. Were the ring nebula in Lyra composed of this material, we could not see it. The sunlight which illuminates the planets might, of course, light up such an object as the ring, if it were comparatively near us; but Lyra is at such a stupendous distance that any light which the sun could send out there would be just as feeble as the light we receive from a fixed star. Should we be able to show our smoke-rings, for instance, if, instead of having the electric light, I merely cut a hole in the ceiling and allowed the feeble twinkle of a star in the Great Bear to shine through? In a similar way the sunbeams would be utterly powerless to effect any illumination of objects in these stellar distances. If the sun were to be extinguished altogether, the calamity would no doubt be a very dire one so far as we are concerned, but the effect

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on the other celestial bodies (moon and planets excepted) would be of the slightest possible description. All the stars of heaven would continue to shine as before. Not a point in one of the constellations would be altered, not a variation in the brightness, not a change in the hue of any star could be noticed. The thousands of nebulae and clusters would be absolutely unaltered; in fact, the total extinction of the sun would be hardly remarked in the newspapers published in the Pleiades or in Orion. There might possibly be a little line somewhere in an odd corner to the effect "Mr. So-and-So, our well-known astronomer, has noticed that a tiny star, inconspicuous to the eye, and absolutely of no importance whatever, has now become invisible."

If, therefore, it be not the sun which lights up this nebula, where else can be the source of its illumination? There can be no other star in the neighborhood adequate to the purpose, for, of course, such an object would be brilliant to us if it were large enough and bright enough to impart sufficient illumination to the nebula. It would be absurd to say that you could see a man's face by the light of a candle while the candle itself was too faint or too distant to be visible. The actual facts are, of course, the other way; the candle might be visible, when it was impossible to discern the face which it lighted.

Hence we learn that the ring nebula must shine by some light of its own, and now we have to consider how it can be possible for such material to be self-luminous. The light of a nebula does not seem to be like flame; it can, perhaps, be better represented by the pretty electrical experiment with Geissler's tubes. These are glass vessels of various shapes, and they are all very nearly empty, as you will understand when I tell you the way in which they have been prepared. A little gas was allowed into each tube, and then almost all the gas was taken out again, so that only a mere trace was left. I pass a current of electricity through these tubes, and now you see they are glowing with beautiful colors. The different gases give out lights of different hues, and the optician has exerted his skill so as to make the effect as beautiful as possible. The electricity, in passing through these tubes, heats the gas which they contain, and makes it glow; and just as this gas can, when heated sufficiently, give out light, so does the great nebula, which is a mass of gas poised in space, become visible in virtue of the heat which it contains.

We are not left quite in doubt as to the constitution of these gaseous nebulae, for we can submit their light to the prism in the way I explained when we were speaking of the stars. Distant though that ring in Lyra may be, it is interesting to learn that the ingredients from which it is made are not entirely different from substances we know on our earth. The water in this glass, and every drop of water, is formed by the union of two gases, of which one is

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hydrogen. This is an extremely light material, as you see by a little balloon which ascends so prettily when filled with it. Hydrogen also burns very readily, though the flame is almost invisible. When I blow a jet of oxygen through the hydrogen, I produce a little flame with a very intense heat. For instance, I hold a steel pen in the flame, and it glows and sputters, and falls down in white-hot drops. It is needless to say that, as a constituent of water, hydrogen is one of the most important elements on this earth. It is, therefore, of interest to learn that hydrogen in some form or other is a constituent of the most distant objects in space that the telescope has revealed.

Photographing the Nebulae.

[Illustration: FIG. 8. THE PLEIADES.]

Of late years we have learned a great deal about nebulae, by the help which photography has given to us. Look at this group of stars which constitutes that beautiful little configuration known as the Pleiades (Fig. 8). It looks like a miniature representation of the Great Bear; in fact, it would be far more appropriate to call the Pleiades the Little Bear than to apply that title to another quite different constellation, as has unfortunately been done. The Pleiades form a group containing six or seven stars visible to the ordinary eye, though persons endowed with exceptionally good vision can usually see a few more. In an opera-glass the Pleiades becomes a beautiful spectacle, though in a large telescope the stars appear too far apart to make a really effective cluster. When Mr. Roberts took a photograph of the Pleiades he placed a highly sensitive plate in his telescope, and on that plate the Pleiades engraved their picture with their own light. He left the plate exposed for hours, and on developing it not only were the stars seen, but there were also patches of faint light due to the presence of nebulae. It could not be said that the objects on the plate were fallacious, for another photograph was taken, when the same appearances were reproduced.

When we look at that pretty group of stars which has attracted admiration during all time, we are to think that some of those stars are merely the bright points in a vast nebula, invisible to our unaided eyes or even to our mighty telescopes, though capable of recording its trace on the photographic plate. Does not this give us a greatly increased notion of the extent of the universe, when we reflect that by photography we are enabled to see much which the mightiest of telescopes had previously failed to disclose?

Of all the nebulae, numbering some thousands, there is but a single one which can be seen without a telescope. It is in the constellation of Andromeda, and on a clear dark night can just be seen with the unaided eye as a faint stain of light on the sky. It has happened before now that persons noticing this nebula for the first time have thought

they had discovered a comet. I would like you to try and find out this object for yourselves.

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If you look at it with an opera-glass it appears to be distinctly elongated. You can see more of its structure when you view it in larger instruments, but its nature was never made clear until some beautiful photographs were taken by Mr. Roberts (Fig. 9). Unfortunately, the nebula in Andromeda has not been placed in the best position for its portrait from our point of view. It seems as if it were a rather flat-shaped object, turned nearly edgewise towards us. To look at the pattern on a plate, you would naturally hold the plate so as to be able to look at it squarely. The pattern would not be seen well if the plate were so tilted that its edge was turned towards you. That seems to be nearly the way in which we are forced to view the nebula in Andromeda. We can trace in the photograph some divisions extending entirely round the nebula, showing that it seems to be formed of a series of rings; and there are some outlying portions which form part of the same system. Truly this is a marvellous object. It is impossible for us to form any conception of the true dimensions of this gigantic nebula; it is so far off that we have never yet been able to determine its distance. Indeed, I may take this opportunity of remarking that no astronomer has yet succeeded in ascertaining the distance of any nebula. Everything, however, points to the conclusion that they are at least as far as the stars.

[Illustration: FIG. 9. THE GREAT NEBULA IN ANDROMEDA.]

It is almost impossible to apply the methods which we use in finding the distance of a star to the discovery of the distance of the nebulae. These flimsy bodies are usually too ill-defined to admit of being measured with the precision and delicacy required for the determination of distance. The measurements necessary for this purpose can only be made from one star-like point to another similar point. If we could choose a star in the nebula and determine its distance, then of course, we have the distance of the nebula itself; but the difficulty is that we have, in general, no means of knowing whether the star does actually lie in the object. It may, for anything we can tell, lie billions of miles nearer to us, or billions of miles further off, and by merely happening to lie in the line of sight, appear to glimmer in the nebula itself.

If we have any assurance that the star is surrounded by a mass of this glowing vapor, then it may be possible to measure that nebula's distance. It will occasionally happen that grounds can be found for believing that a star which appears to be in the glowing gas does veritably lie therein, and is not merely seen in the same direction. There are hundreds of stars visible in a good drawing or a good photograph of the famous object in Andromeda, and doubtless large numbers of these are merely stars which happen to lie in the same line of sight. The peculiar circumstances attending the history of one star seem, however, to warrant us in making the assumption that it was certainly

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in the nebula. The history of this star is a remarkable one. It suddenly kindled from invisibility into brilliancy. How is a change so rapid in the lustre of a star to be accounted for? In a few days its brightness had undergone an extraordinary increase. Of course, this does not tell us for certain that the star lay in the glowing gas; but the most rational explanation that I have heard offered of this occurrence is that due, I believe, to my friend Mr. Monck. He has suggested that the sudden outbreak in brilliancy might be accounted for on the same principles as those by which we explain the ignition of meteors in our atmosphere. If a dark star, moving along with terrific speed through space, were suddenly to plunge into a dense region of the nebula, heat and light must be evolved in sufficient abundance to transform the star into a brilliant object. If, therefore, we knew the distance of this star at the time it was in Andromeda, we should, of course, learn the distance of that interesting object. This has been attempted, and it has thus been proved that the Great Nebula must be very much further from us than is that star of whose distance I attempted some time ago to give you a notion.

We thus realize the enormous size of the Great Nebula. It appears that if, on a map of this object, we were to lay down, accurately to scale, a map of the solar system, putting the sun in the centre and all the planets around their true proportions out to the boundary traced by Neptune, this area, vast though it is, would be a mere speck on the drawing of the object. Our system would have to be enormously bigger before it sufficed to cover anything like the area of the sky included in one of these great objects. Here is a sketch of a nebula, Fig. 10, and near I have marked a dot, which is to indicate our solar system. We may feel confident that the Great Nebula is at the very least as mighty as this proportion would indicate.

[Illustration: FIG. 10. THE SOLAR SYSTEM AS COMPARED WITH A GREAT NEBULA.]

RAIN AND SNOW

(FROM THE FORMS OF WATER.)

BY JOHN TYNDALL.

Oceanic Distillation.

[Illustration: SNOW CRYSTALS.]

At the equator, and within certain limits north and south of it, the sun at certain periods of the year is directly overhead at noon. These limits are called the Tropics of Cancer



and of Capricorn. Upon the belt comprised between these two circles the sun's rays fall with their mightiest power; for here they shoot directly downwards, and heat both earth and sea more than when they strike slantingly.

When the vertical sunbeams strike the land they heat it, and the air in contact with the hot soil becomes heated in turn. But when heated the air expands, and when it expands it becomes lighter. This lighter air rises, like wood plunged into water, through the heavier air overhead.

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When the sunbeams fall upon the sea the water is warmed, though not so much as the land. The warmed water expands, becomes thereby lighter, and therefore continues to float upon the top. This upper layer of water warms to some extent the air in contact with it, but it also sends up a quantity of aqueous vapor, which being far lighter than air, helps the latter to rise. Thus both from the land and from the sea we have ascending currents established by the action of the sun.

When they reach a certain elevation in the atmosphere, these currents divide and flow, part towards the north and part towards the south; while from the north and the south a flow of heavier and colder air sets in to supply the place of the ascending warm air.

Incessant circulation is thus established in the atmosphere. The equatorial air and vapor flow above towards the north and south poles, while the polar air flows below towards the equator. The two currents of air thus established are called the upper and the lower trade winds.

But before the air returns from the poles great changes have occurred. For the air as it quitted the equatorial regions was laden with aqueous vapor, which could not subsist in the cold polar regions. It is there precipitated, falling sometimes as rain, or more commonly as snow. The land near the pole is covered with this snow, which gives birth to vast glaciers.

It is necessary that you should have a perfectly clear view of this process, for great mistakes have been made regarding the manner in which glaciers are related to the heat of the sun.

It was supposed that if the sun's heat were diminished, greater glaciers than those now existing would be produced. But the lessening of the sun's heat would infallibly diminish the quantity of aqueous vapor, and thus cut off the glaciers at their source. A brief illustration will complete your knowledge here.

In the process of ordinary distillation, the liquid to be distilled is heated and converted into vapor in one vessel, and chilled and reconverted into liquid in another. What has just been stated renders it plain that the earth and its atmosphere constitute a vast distilling apparatus in which the equatorial ocean plays the part of the boiler, and the chill regions of the poles the part of the condenser. In this process of distillation *heat* plays quite as necessary a part as *cold*, and before Bishop Heber could speak of "Greenland's icy mountains," the equatorial ocean had to be warmed by the sun. We shall have more to say upon this question afterwards.

The heating of the tropical air by the sun is *indirect*. The solar beams have scarcely any power to heat the air through which they pass; but they heat the land and ocean, and these communicate their heat to the air in contact with them. The air and vapor start upwards charged with the heat thus communicated.

Tropical Rains.

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But long before the air and vapor from the equator reach the poles, precipitation occurs. Wherever a humid warm wind mixes with a cold dry one, rain falls. Indeed the heaviest rains occur at those places where the sun is vertically overhead. We must enquire a little more closely into their origin.

Fill a bladder about two-thirds full of air at the sea level, and take it to the summit of Mount Blanc. As you ascend, the bladder becomes more and more distended; at the top of the mountain it is fully distended, and has evidently to bear a pressure from within. Returning to the sea level you find that the tightness disappears, the bladder finally appearing as flaccid as at first.

The reason is plain. At the sea level the air within the bladder has to bear the pressure of the whole atmosphere, being thereby squeezed into a comparatively small volume. In ascending the mountain, you leave more and more of the atmosphere behind; the pressure becomes less and less, and by its expansive force the air within the bladder swells as the outside pressure is diminished. At the top of the mountain the expansion is quite sufficient to render the bladder tight, the pressure within being then actually greater than the pressure without. By means of an air-pump we can show the expansion of a balloon partly filled with air, when the external pressure has been in part removed.

But why do I dwell upon this? Simply to make plain to you that the *unconfined air*, heated at the earth's surface, and ascending by its lightness, must expand more and more the higher it rises in the atmosphere.

And now I have to introduce to you a new fact, towards the statement of which I have been working for some time. It is this: *The ascending air is chilled by its expansion*. Indeed this chilling is one source of the coldness of the higher atmospheric regions. And now fix your eye upon those mixed currents of air and aqueous vapor which rise from the warm tropical ocean. They start with plenty of heat to preserve the vapor as vapor; but as they rise they come into regions already chilled, and they are still further chilled by their own expansion. The consequence might be foreseen. The load of vapor is in great part precipitated, dense clouds are formed, their particles coalesce to rain-drops, which descend daily in gushes so profuse that the word "torrential" is used to express the copiousness of the rainfall. I could show you this chilling by expansion, and also the consequent precipitation of clouds.

Thus long before the air from the equator reaches the poles its vapor is in great part removed from it, having redescended to the earth as rain. Still a good quantity of the vapor is carried forward, which yields hail, rain, and snow in northern and southern lands.

Mountain Condensers.

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To complete our view of the process of atmospheric precipitation we must take into account the action of mountains. Imagine a south-west wind blowing across the Atlantic towards Ireland. In its passage it charges itself with aqueous vapor. In the south of Ireland it encounters the mountains of Kerry: the highest of these is Magillicuddy's Reeks, near Killarney. Now the lowest stratum of this Atlantic wind is that which is most fully charged with vapor. When it encounters the base of the Kerry Mountains it is tilted up and flows bodily over them. Its load of vapor is therefore carried to a height, it expands on reaching the height, it is chilled in consequence of the expansion, and comes down in copious showers of rain. From this, in fact, arises the luxuriant vegetation of Killarney; to this, indeed, the lakes owe their water supply. The cold crests of the mountains also aid in the work of condensation.

Note the consequence. There is a town called Cahirciveen to the south-west of Magillicuddy's Reeks, at which observations of the rainfall have been made, and a good distance farther to the north-east, right in the course of the south-west wind there is another town, called Portarlinton, at which observations of rainfall have also been made. But before the wind reaches the latter station it has passed over the mountains of Kerry and left a great portion of its moisture behind it. What is the result? At Cahirciveen, as shown by Dr. Lloyd, the rainfall amounts to fifty-nine inches in a year, while at Portarlinton it is only twenty-one inches.

Again, you may sometimes descend from the Alps when the fall of rain and snow is heavy and incessant, into Italy, and find the sky over the plains of Lombardy blue and cloudless, the wind at the same time *blowing over the plain towards the Alps*. Below the wind is hot enough to keep its vapor in a perfectly transparent state; but it meets the mountains, is tilted up, expanded, and chilled. The cold of the higher summits also helps the chill. The consequence is that the vapor is precipitated as rain or snow, thus producing bad weather upon the heights, while the plains below, flooded with the same air, enjoy the aspect of the unclouded summer sun. Clouds blowing *from* the Alps are also sometimes dissolved over the plains of Lombardy.

In connection with the formation of clouds by mountains, one particularly instructive effect may be here noticed. You frequently see a streamer of cloud many hundred yards in length drawn out from an Alpine peak. Its steadiness appears perfect, though a strong wind may be blowing at the same time over the mountain head. Why is the cloud not blown away? It *is* blown away; its permanence is only apparent. At one end it is incessantly dissolved; at the other end it is incessantly renewed: supply and consumption being thus equalized, the cloud appears as changeless as the mountain to which it seems to cling. When the red sun of the evening shines upon these cloud-streamers they resemble vast torches with their flames blown through the air.

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Architecture of Snow.

We now resemble persons who have climbed a difficult peak, and thereby earned the enjoyment of a wide prospect. Having made ourselves masters of the conditions necessary to the production of mountain snow, we are able to take a comprehensive and intelligent view of the phenomena of glaciers.

[Illustration: SNOW CRYSTALS.]

A few words are still necessary as to the formation of snow. The molecules and atoms of all substances, when allowed free play, build themselves into definite and, for the most part, beautiful forms called crystals. Iron, copper, gold, silver, lead, sulphur, when melted and permitted to cool gradually, all show this crystallizing power. The metal bismuth shows it in a particularly striking manner, and when properly fused and solidified, self-built crystals of great size and beauty are formed of this metal.

[Illustration: SNOW-STAR.]

[Illustration: SNOW-STAR.]

If you dissolve salt-petre in water, and allow the solution to evaporate slowly, you may obtain large crystals, for no portion of the salt is converted into vapor. The water of our atmosphere is fresh though it is derived from the salt sea. Sugar dissolved in water, and permitted to evaporate, yields crystals of sugar-candy. Alum readily crystallizes in the same way. Flints dissolved, as they sometimes are in nature, and permitted to crystallize, yield the prisms and pyramids of rock crystal. Chalk dissolved and crystallized yields Iceland spar. The diamond is crystallized carbon. All our precious stones, the ruby, sapphire, beryl, topaz, emerald, are all examples of this crystallizing power.

[Illustration: SNOW-STAR.]

You have heard of the force of gravitation, and you know that it consists of an attraction of every particle of matter for every other particle. You know that planets and moons are held in their orbits by this attraction. But gravitation is a very simple affair compared to the force, or rather forces, of crystallization. For here the ultimate particles of matter, inconceivably small as they are, show themselves possessed of attractive and repellent poles, by the mutual action of which the shape and structure of the crystal are determined. In the solid condition the attracting poles are rigidly locked together; but if sufficient heat be applied the bond of union is dissolved, and in the state of fusion the poles are pushed so far asunder as to be practically out of each other's range. The natural tendency of the molecules to build themselves together is thus neutralized.

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This is the case with water, which as a liquid is to all appearance formless. When sufficiently cooled the molecules are brought within the play of the crystallizing force, and they then arrange themselves in forms of indescribable beauty. When snow is produced in calm air, the icy particles build themselves into beautiful stellar shapes, each star possessing six rays. There is no deviation from this type, though in other respects the appearances of the snow-stars are infinitely various. In the polar regions these exquisite forms were observed by Dr. Scoresby, who gave numerous drawings of them. I have observed them in mid-winter filling the air, and loading the slopes of the Alps. But in England they are also to be seen, and no words of mine could convey so vivid an impression of their beauty as the annexed drawings of a few of them, executed at Greenwich by Mr. Glaisher.

[Illustration: SNOW-STAR.]

It is worth pausing to think what wonderful work is going on in the atmosphere during the formation and descent of every snow-shower; what building power is brought into play! and how imperfect seem the productions of human minds and hands when compared with those formed by the blind forces of nature!

But who ventures to call the forces of nature blind? In reality, when we speak thus we are describing our own condition. The blindness is ours; and what we really ought to say, and to confess, is that our powers are absolutely unable to comprehend either the origin or the end of the operations of nature.

But while we thus acknowledge our limits, there is also reason for wonder at the extent to which science has mastered the system of nature. From age to age, and from generation to generation, fact has been added to fact, and law to law, the true method and order of the Universe being thereby more and more revealed. In doing this science has encountered and overthrown various forms of superstition and deceit, of credulity and imposture. But the world continually produces weak persons and wicked persons; and as long as they continue to exist side by side, as they do in this our day, very debasing beliefs will also continue to infest the world.

Atomic Poles.

“What did I mean when, a few moments ago I spoke of attracting and repellent poles?” Let me try to answer this question. You know that astronomers and geographers speak of the earth’s poles, and you have also heard of magnetic poles, the poles of a magnet being the points at which the attraction and repulsion of the magnet are as it were concentrated.

Every magnet possesses two such poles; and if iron filings be scattered over a magnet, each particle becomes also endowed with two poles. Suppose such particles devoid of weight and floating in our atmosphere, what must occur when they come near each

other? Manifestly the repellent poles will retreat from each other, while the attractive poles will approach and finally lock themselves together. And supposing the particles, instead of a single pair, to possess several pairs of poles arranged at definite points over their surfaces; you can then picture them, in obedience to their mutual attractions and repulsions, building themselves together to form masses of definite shape and structure.

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Imagine the molecules of water in calm cold air to be gifted with poles of this description, which compel the particles to lay themselves together in a definite order, and you have before your mind's eye the unseen architecture which finally produces the visible and beautiful crystals of the snow. Thus our first notions and conceptions of poles are obtained from the sight of our eyes in looking at the effects of magnetism; and we then transfer these notions and conceptions to particles which no eye has ever seen. The power by which we thus picture to ourselves effects beyond the range of the senses is what philosophers call the Imagination, and in the effort of the mind to seize upon the unseen architecture of crystals, we have an example of the "scientific use" of this faculty. Without imagination we might have *critical* power, but not *creative* power in science.

Architecture of Lake Ice.

We have thus made ourselves acquainted with the beautiful snow-flowers self-constructed by the molecules of water in calm, cold air. Do the molecules show this architectural power when ordinary water is frozen? What, for example, is the structure of the ice over which we skate in winter? Quite as wonderful as the flowers of the snow. The observation is rare, if not new, but I have seen in water slowly freezing six-rayed ice-stars formed, and floating free on the surface. A six-rayed star, moreover, is typical of the construction of all our lake ice. It is built up of such forms wonderfully interlaced.

Take a slab of lake ice and place it in the path of a concentrated sunbeam. Watch the track of the beam through the ice. Part of the beam is stopped, part of it goes through; the former produces internal liquefaction, the latter has no effect whatever upon the ice. But the liquefaction is not uniformly diffused. From separate spots of the ice little shining points are seen to sparkle forth. Every one of those points is surrounded by a beautiful liquid flower with six petals.

Ice and water are so optically alike that unless the light fall properly upon these flowers you cannot see them. But what is the central spot? A vacuum. Ice swims on water because, bulk for bulk, it is lighter than water; so that when ice is melted it shrinks in size. Can the liquid flowers then occupy the whole space of the ice melted? Plainly no. A little empty space is formed with the flowers, and this space, or rather its surface, shines in the sun with the lustre of burnished silver.

In all cases the flowers are formed parallel to the surface of freezing. They are formed when the sun shines upon the ice of every lake; sometimes in myriads, and so small as to require a magnifying glass to see them. They are always attainable, but their beauty is often marred by internal defects of the ice. Every one portion of the same piece of ice may show them exquisitely, while a second portion shows them imperfectly.

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Annexed is a very imperfect sketch of these beautiful figures.

Here we have a reversal of the process of crystallization. The searching solar beam is delicate enough to take the molecules down without deranging the order of their architecture. Try the experiment for yourself with a pocket-lens on a sunny day. You will not find the flowers confused; they all lie parallel to the surface of freezing. In this exquisite way every bit of the ice over which our skaters glide in winter is put together.

I said that a portion of the sunbeam was stopped by the ice and liquefied it. What is this portion? The dark heat of the sun. The great body of the light waves and even a portion of the dark ones, pass through the ice without losing any of their heating power. When properly concentrated on combustible bodies, even after having passed through the ice, their burning power becomes manifest.

[Illustration: LIQUID FLOWERS IN LAKE ICE.]

And the ice itself may be employed to concentrate them. With an ice-lens in the polar regions Dr. Scoresby has often concentrated the sun's rays so as to make them burn wood, fire gunpowder, and melt lead; thus proving that the heating power is retained by the rays, even after they have passed through so cold a substance.

By rendering the rays of the electric lamp parallel, and then sending them through a lens of ice, we obtain all the effects which Dr. Scoresby obtained with the rays of the sun.

[Illustration]

THE ORGANIC WORLD

(FROM THE ELEMENTS OF SCIENCE.)

BY ST. GEORGE MIVART F.R.S.

The number of all the various kinds of living creatures is so enormous that it would be impossible to study them profitably, were they not classified in an orderly manner. Therefore the whole mass has been divided, in the first place, into two supreme groups, fancifully termed kingdoms—the “animal kingdom” and the “vegetal kingdom.” Each of these is subdivided into an orderly series of subordinate groups, successively contained one within the other, and named sub-kingdoms, classes, orders, families, genera and species. The lowest group but one is the “genus,” which contains one or more different kinds termed “species,” as *e.g.*, the species “wood anemone” and the species “blue titmouse.” The lowest group of all—a species—may be said to consist of individuals which differ from each other only by trifling characters, such as characters due to

difference of sex, while their peculiar organization is faithfully reproduced by generation as a whole, though small individual differences exist in all cases.

The vegetal, or vegetable, kingdom, consists of the great mass of flowering plants, many of which, however, have such inconspicuous flowers that they are mistakenly regarded as flowerless, as is often the case with the grasses, the pines, and the yews. Another mass, or sub-kingdom, of plants consists of the really flowerless plants, such as the ferns, horsetails (Fig. 1), lycopods, and mosses. Sea and fresh-water weeds (*algae*), and mushrooms, or “moulds,” of all kinds (*fungi*), amongst which are the now famous “bacteria,” constitute a third and lowest set of plants.

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[Illustration: FIG. 1. HORSE-TAIL (*Equisetum drummondii*).]

The animal kingdom consists, first, of a sub-kingdom of animals which possess a spinal column, or backbone, and which are known as vertebrate animals. Such are all beasts, birds, reptiles, and fishes. There are also a variety of remotely allied marine organisms known as tunicates, sea-squirts, or ascidians (Fig. 2). There is, further, an immense group of arthropods, consisting of all insects, crab-like creatures, hundred-legs and their allies, with spiders, scorpions, ticks and mites. We have also the sub-kingdom of shell-fish or molluscs, including cuttle-fishes, snails, whelks, limpets, the oyster, and a multitude of allied forms. A multitudinous sub-kingdom of worms also exists, as well as another of star-fishes and their congeners. There is yet another of zoophytes, or polyps, and another of sponges, and, finally, we have a sub-kingdom of minute creatures, or animalculae, of very varied forms, which may make up the sub-kingdom of *Protozoa*, consisting of animals which are mostly unicellular.

[Illustration: FIG. 2. A TUNICATE (*Ascidia*).]

Multitudinous and varied as are the creatures which compose this immense organic world, they nevertheless exhibit a very remarkable uniformity of composition in their essential structure. Every living creature from a man to a mushroom, or even to the smallest animalcule or unicellular plant is always partly fluid, but never entirely so. Every living creature also consists in part (and that part is the most active living part) of a soft, viscid, transparent, colorless substance, termed protoplasm, which can be resolved into the four elements, oxygen, hydrogen, nitrogen and carbon. Besides these four elements, living organisms commonly contain sulphur, phosphorus, chlorine, potassium, sodium, calcium, magnesium and iron.

In the fact that living creatures always consist of the four elements, oxygen, hydrogen, nitrogen and carbon, we have a fundamental character whereby the organic and inorganic (or non-living) worlds are to be distinguished, for as we have seen, inorganic bodies, instead of being thus uniformly constituted, may consist of the most diverse elements and sometimes of but two or even of only one.

Again, many minerals, such as crystals, are bounded by plain surfaces, and, with very few exceptions (spathic and hematite iron and dolomite are such exceptions) none are bounded by curved lines and surfaces, while living organisms are bounded by such lines and surfaces.

Yet, again, if a crystal be cut through, its internal structure will be seen to be similar throughout. But if the body of any living creature be divided, it will, at the very least, be seen to consist of a variety of minute distinct particles, called "granules," variously distributed throughout its interior.

All organisms consist either—as do the simplest, mostly microscopic, plants and animals—of a single minute mass of protoplasm, or of a few, or of many, or of an enormous aggregation of such before-mentioned particles, each of which is one of those bodies named a “cell” (Fig. 3). Cells may, or may not, be enclosed in an investing coat or “cell-wall.” Every cell generally contains within it a denser, normally spheroidal, body known as the nucleus.

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Now protoplasm is a very unstable substance—as we have seen many substances are whereof nitrogen is a component part—and it possesses active properties which are not present in the non-living, or inorganic world. In the latter, differences of temperature will produce motion in the shape of “currents,” as we have seen with respect to masses of air and water. But in a portion of protoplasm, an internal circulation of currents in definite lines will establish itself from other causes.

Inorganic bodies, as we have seen, will expand with heat, as they may also do from imbibing moisture; but living protoplasm has an apparently spontaneous power of contraction and expansion under certain external conditions which do not occasion such movements in inorganic matter.

[Illustration: FIG. 3. CELL FROM A SALAMANDER. *n*, nucleus; *n'*, nucleolus embedded in the network of chromatin threads; *k*, network of the cell external to the nucleus; *a*, attraction-sphere or archoplasm containing minute bodies called centrosomes; *cl*, membrane enclosing the cell externally, *nl*, membrane surrounding the nucleus; *c*, centrosomes.]

Under favoring conditions, protoplasm has a power of performing chemical changes, which result in producing heat far more gently and continuously than it is produced by the combustion of inorganic bodies. Thus it is that the heat is produced which makes its presence evident to us in what we call “warm-blooded animals,” the most warm-blooded of all being birds.

Protoplasm has also the wonderful power of transforming certain adjacent substances into material like itself—into its own substance—and so, in a sense, creating a new material. Thus it is that organisms have the power to nourish themselves and grow. An animal would vainly swallow the most nourishing food if the ultimate, protoplasmic particles of its body had not this power of “transforming” suitable substances brought near them in ways to be hereinafter noticed.

Without that, no organism could ever “grow.” The growth of organisms is utterly different from the increase in size of inorganic bodies. Crystals, as we have seen, grow merely by external increment; but organisms grow by an increment which takes place in the very innermost substance of the tissues which compose their bodies, and the innermost substance of the cells which compose such tissues; this peculiar form of growth is termed *intussusception*.

Protoplasm, after thus augmenting its mass, has a further power of spontaneous division, whereby the mass of the entire organism whereof such protoplasm forms a part, is augmented and so growth is brought about.

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The small particles of protoplasm which constitute “cells” are far indeed from being structureless. Besides the nucleus already mentioned there is a delicate network of threads of a substance called *chromatin* within it, and another network permeating the fluid of the cell substance, which invest the nucleus often with further complications. These networks generally perform (or undergo) a most complex series of changes every time a cell spontaneously divides. In certain cases, however, it appears that the nucleus divides into two in a more simple fashion, the rest of the cell contents subsequently dividing—each half enclosing one part of the previously divided nucleus. It is by a continued process of cell division that the complex structures of the most complex organisms is brought about.

The division of a cell, or particle of protoplasm, is indeed a necessary consequence of its complete nutrition.

For new material can only be absorbed by its surface. But as the cell grows, the proportion borne by its surface to its mass, continually decreases; therefore this surface must soon be too small to take in nourishment enough, and the particle, or cell, must therefore either die or divide. By dividing, its parts can continue the nutritive process till their surface, in turn, becomes insufficient, when they must divide again, and so on. Thus the term “feeding” has two senses. “To feed a horse,” ordinarily means to give it a certain quantity of hay, oats or what not; and such indeed is one kind of feeding. But obviously, if the nourishment so taken could not get from the stomach and intestines into the ultimate particles and cells of the horse’s body, the horse could not be nourished, and still less could it grow. It is this latter process, called assimilation, which is the real and essential process of feeding, to which the process ordinarily so called is but introductory.

Protoplasm has also the power of forming and ejecting from its own substance, other substances which it has made, but which are of a different nature to its own. This function, as before said, is termed secretion; and we know the liver secretes bile, and that the cow’s udder secretes milk.

Here again we have an external and an internal process. The milk is drawn forth from a receptacle, the udder, into which it finds its way, and so, in a superficial sense, it may be called an organ of secretion. Nevertheless the true internal secretion takes place in the innermost substance of the cells or particles of protoplasm, of the milk-land, which particles really form that liquid.

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But every living creature consists at first entirely of a particle of protoplasm. Therefore every other kind of substance which may be found in every kind of plant or animal, must have been formed through it, and be, in fact, a secretion from protoplasm. Such is the rosy cheek of an apple, or of a maiden, the luscious juice of the peach, the produce of the castor-oil plant, the baleen that lines the whale's enormous jaws, as well as that softest product, the fur of the chinchilla. Indeed, every particle of protoplasm requires, in order that it may live, a continuous process of exchange. It needs to be continuously first built up by food, and then broken down by discharging what is no longer needful for its healthy existence. Thus the life of every organism is a life of almost incessant change, not only in its being as a whole, but in that of all its protoplasmic particles also.

[Illustration: FIG. 4. AMOEBA SHOWN IN TWO OF THE MANY IRREGULAR SHAPES IT ASSUMES. (After Howes.)

The clear space within it is a contractile vesicle. The dark body is the nucleus. In the right-hand figure there is shown a particle of food, passing through the external surface.]

Prominent among such processes is that of an interchange of gases between the living being and its environment. This process consists in an absorption of oxygen and a giving-out of carbonic acid, which exchange is termed respiration.

Lastly, protoplasm has a power of motion when appropriately acted on. It will then contract or expand its shape by alternate protrusions and retractions of parts of its substance. These movements are termed amoebiform, because they quite resemble the movements of a small animalcule which is named amoeba. (See Fig. 4.)

Such is the ultimate structure, and such are the fundamental activities or functions of living organisms, as far as they can here be described, from the lowest animalcule and unicellular plant, up to the most complex organisms and the body of man himself.

[Illustration]

INHABITANTS OF MY POOL

(FROM MAGIC GLASSES.)

BY ARABELLA B. BUCKLEY.

The pool lies in a deep hollow among a group of rocks and boulders, close to the entrance of the cove, which can only be entered at low water; it does not measure more than two feet across, so that you can step over it, if you take care not to slip on the masses of green and brown seaweed growing over the rocks on its sides, as I have done many a time when collecting specimens for our salt-water aquarium. I find now the only way is to lie flat down on the rock, so that my hands and eyes are free to



observe and handle, and then, bringing my eye down to the edge of the pool, to lift the seaweeds and let the sunlight enter into the chinks and crannies. In this way I can catch sight of many a small being either on the seaweed or the rocky ledges, and even creatures transparent as glass become visible by the thin outline gleaming in the sunlight. Then I pluck a piece of seaweed, or chip off a fragment of rock with a sharp-edged collecting knife, bringing away the specimen uninjured upon it, and place it carefully in its own separate bottle to be carried home alive and well.

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Now though this little pool and I are old friends, I find new treasures in it almost every time I go, for it is almost as full of living things as the heavens are of stars, and the tide as it comes and goes brings many a mother there to find a safe home for her little ones, and many a waif and stray to seek shelter from the troublous life of the open ocean.

You will perhaps find it difficult to believe that in this rock-bound basin there can be millions of living creatures hidden away among the fine feathery weeds; yet so it is. Not that they are always the same. At one time it may be the home of myriads of infant crabs, not an eighth of an inch long, another of baby sea-urchins only visible to the naked eye as minute spots in the water, at another of young jelly-fish growing on their tiny stalks, and splitting off one by one as transparent bells to float away with the rising tide. Or it may be that the whelk has chosen this quiet nook to deposit her leathery eggs; or young barnacles, periwinkles, and limpets are growing up among the green and brown tangles, while the far-sailing velella and the stay-at-home sea-squirts, together with a variety of other sea-animals, find a nursery and shelter in their youth in this quiet harbor of rest.

And besides these casual visitors there are numberless creatures which have lived and multiplied there, ever since I first visited the pool. Tender red, olive-colored, and green seaweeds, stony corallines, and acorn-barnacles lining the floor, sea-anemones clinging to the sides, sponges tiny and many-colored hiding under the ledges, and limpets and mussels wedged in the cracks. These can be easily seen with the naked eye, but they are not the most numerous inhabitants; for these we must search with a magnifying glass, which will reveal to us wonderful fairy-forms, delicate crystal vases with tiny creatures in them whose transparent lashes make whirlpools in the water, living crystal bells so tiny that whole branches of them look only like a fringe of hair, jelly globes rising and falling in the water, patches of living jelly clinging to the rocky sides of the pool, and a hundred other forms, some so minute that you must examine the fine sand in which they lie under a powerful microscope before you can even guess that they are there.

[Illustration: FIG. 1. GROUP OF SEaweEDS.

(Natural size.)

1, *Ulva Linza*. 2, *Sphacelaria filicina*. 3, *Polysiphonia urceolata*. 4, *Corallina officinalis*.]

So it has proved a rich hunting-ground, where summer and winter, spring and autumn, I find some form to put under my magic glass. There I can watch it for weeks growing and multiplying under my care; moved only from the aquarium, where I keep it supplied with healthy sea-water, to the tiny transparent trough in which I place it for a few hours to see the changes it has undergone. I could tell you endless tales of transformations in these tiny lives, but I want to-day to show you a few of my friends, most of which I brought yesterday fresh from the pool, and have prepared for you to examine.

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[Illustration: FIG. 2. *Ulva lactuca*, A GREEN-SEAWEED, GREATLY MAGNIFIED TO SHOW STRUCTURE. (After Orested).]

s, Spores in the cells, ss, Spores swimming out. h, Holes through which spores have escaped.]

Let us begin with seaweeds. I have said that there are three leading colors in my pool—green, olive, and red—and these tints mark roughly three kinds of weed, though they occur in an endless variety of shapes. Here is a piece of the beautiful pale green seaweed, called the Laver or Sea-Lettuce, *Ulva Linza* (1, Fig. 1),[1] which grows in long ribbons in a sunny nook in the water. I have placed under the first microscope a piece of this weed which is just sending out young seaweeds in the shape of tiny cells, with lashes very like those we saw coming from the moss-flower, and I have pressed them in the position in which they would naturally leave the plant. You will also see on this side several cells in which these tiny spores are forming, ready to burst out and swim; for this green weed is merely a collection of cells, like the single-celled plants on land. Each cell can work as a separate plant; it feeds, grows, and can send out its own young spores.

[Footnote 1: The slice given in Fig. 2 is from a broader-leaved form, *U. lactuca*, because this species, being composed of only one layer of cells, is better seen. *Ulva Linza* is composed of two layers of cells.]

This deep olive-green feathery weed (2, Fig. 1), of which a piece is magnified under the next microscope (2, Fig. 3), is very different. It is a higher plant, and works harder for its living, using the darker rays of sunlight which penetrate into shady parts of the pool. So it comes to pass that its cells divide the work. Those of the feathery threads make the food, while others, growing on short stalks on the shafts of the feather, make and send out the young spores.

Lastly, the lovely red threadlike weeds, such as this *Polysiphonia urceolata* (3, Fig. 1), carry actual urns on their stems like those of mosses. In fact, the history of these urns (see 3, Fig. 3), is much the same in the two classes of plants, only that instead of the urn being pushed up on a thin stalk as in the moss, it remains on the seaweed close down to the stem, when it grows out of the plant-egg, and the tiny plant is shut in till the spores are ready to swim out.

[Illustration: FIG. 3. THREE SEAWEEDS OF FIG. 1 MUCH MAGNIFIED TO SHOW FRUITS. (Harvey.)]

2, *Sphacelaria filicina*. 3, *Polysiphonia urceolata*. 4, *Corallina officinalis*.]

The stony corallines (4, Figs. 1 and 3), which build so much carbonate of lime into their stems, are near relations of the red seaweeds. There are plenty of them in my pool.



Some of them, of a deep purple color, grow upright in stiff groups about three or four inches high; and others, which form crusts over the stones and weeds, are a pale rose color; but both kinds, when the plant dies, leaving the stony skeleton (1, Fig. 4), are a pure white, and used to be mistaken for corals. They belong to the same order of plants as the red weeds, which all live in shady nooks in the pools, and are the highest of their race.

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[Illustration: FIG. 4. CORALLINE AND SERTULARIA, TO SHOW LIKENESS BETWEEN THE ANIMAL SERTULARIA AND THE PLANT CORALLINE.

1, *Corallina officinalis*. 2, *Sertularia filicula*.]

My pool is full of different forms of these four weeds. The green ribbons float on the surface rooted to the sides of the pool, and, as the sun shines upon it, the glittering bubbles rising from them show that they are working up food out of the air in the water, and giving off oxygen. The brown weeds lie chiefly under the shelves of rocks, for they can manage with less sunlight, and use the darker rays which pass by the green weeds; and last of all, the red weeds and corallines, small and delicate in form, line the bottom of the pool in its darkest nooks.

And now if I hand round two specimens,—one a coralline, and the other something you do not yet know,—I am sure you will say at first sight that they belong to the same family, and, in fact, if you buy at the seaside a group of seaweeds gummed on paper, you will most likely get both these among them. Yet the truth is; that while the coralline (1, Fig. 4) is a plant, the other specimen (2), which is called *Sertularia filicula*, is an animal.

This special sertularian grows up right in my pool on stones or often on seaweeds, but I have here (Fig. 5) another and much smaller one which lives literally in millions hanging its cups downwards. I find it not only under the narrow ledges of the pool sheltered by the seaweed, but forming a fringe along all the rocks on each side of the cove near to low-water mark, and for a long time I passed it by thinking it was of no interest. But I have long since given up thinking this of anything, especially in my pool, for my magic glass has taught me that there is not even a living speck which does not open out into something marvellous and beautiful. So I chipped off a small piece of rock and brought the fringe home, and found, when I hung it up in clear sea-water as I have done over this glass trough (Fig. 5) and looked at it through the lens, that each thread of the dense fringe, in itself not a quarter of an inch deep, turns out to be a tiny sertularian with at least twenty mouths. You can see this with your pocket lens even as it hangs here, and when you have examined it you can by and by take off one thread and put it carefully in the trough. I promise you a sight of the most beautiful little beings which exist in nature.

[Illustration: FIG. 5. *Sertularia tenella*, HANGING FROM A SPLINT OF ROCK OVER A WATER TROUGH. ALSO PIECE ENLARGED TO SHOW THE ANIMAL PROTRUDING.]

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Come and look at it. It is a horny-branched stem with a double row of tiny cups all along each side. Out of these cups there appear a row of tiny cups all along each side (see Fig. 5), Out of these cups there appear from time to time sixteen minute transparent tentacles as fine as spun glass, which wave about in the water. If you shake the glass a little, in an instant each crystal star vanishes into its cup, to come out again a few minutes later; so that now here, now there, the delicate animal-flowers spread out on each side of the stem, and the tree is covered with moving beings. These tentacles are feelers, which lash food into a mouth and stomach in each cup, where it is digested and passed, through a hole in the bottom, along a jelly thread which runs down the stem and joins all the mouths together. In this way the food is distributed all over the tree, which is, in fact, one animal with many feeding-cups. Some day I will show you one of these cups with the tentacles stretched out and mounted on a slide, so that you can examine a tentacle with a very strong magnifying power. You will then see that it is dotted over with cells, in which are coiled fine threads. The animal uses these threads to paralyze the creatures on which it feeds, for at the base of each thread there is a poison gland.

In the larger *Sertularia* the whole branched tree is connected by jelly threads, running through the stem, and all the thousands of mouths are spread out in the water. One large form called *Sertularia cupressina* grows sometimes three feet high and bears as many as a hundred thousand cups, with living mouths, on its branches.

The next of my minute friends I can only show to the class in a diagram, but you will see it under the fourth microscope by and by. I had great trouble in finding it yesterday, though I know its haunts upon the green weed, for it is so minute and transparent that even when the weed is in a trough a magnifying-glass will scarcely detect it. And I must warn you that if you want to know any of the minute creatures we are studying, you must visit one place constantly. You may in a casual way find many of them on seaweed, or in the damp ooze and mud, but it will be by chance only; to look for them with any certainty you must take trouble in making their acquaintance.

[Illustration: FIG. 6. *Thuricolla folliculata* and *Chilomonas amygdalum*. (Saville Kent.)

1, *Thuricolla* erect. 2, Retracted. 3, Dividing. 4, *Chilomonas amygdalum*. hc, Horny carapace, cv, Contractile vesicle. v Closing valves.]

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Turning then to the diagram (Fig. 6) I will describe it as I hope you will see it under the microscope—a curious, tiny, perfectly transparent open-mouthed vase standing upright on the weed, and having an equally transparent being rising up in it and waving its tiny lashes in the water. This is really all one animal, the vase *hc* being the horny covering or carapace of the body, which last stands up like a tube in the centre. If you watch carefully, you may even see the minute atoms of food twisting round inside the tube until they are digested, after they have been swept in at the wide open mouth by the whirling lashes. You will see this more clearly if you put a little rice-flour, very minutely powdered and colored by carmine, into the water; for you can trace these red atoms into some round spaces called *vacuoles* which are dotted over the body of the animal, and are really globules of watery fluid in which the food is probably partly digested.

You will notice, however, one round clear space (*cv*) into which they do not go, and after a time you will be able to observe that this round spot closes up or contracts very quickly, and then expands again very slowly. As it expands it fills with a clear fluid, and naturalists have not yet decided exactly what work it does. It may serve the animal either for breathing, or as a very simple heart, making the fluids circulate in the tube. The next interesting point about this little being is the way it retreats into its sheltering vase. Even while you are watching, it is quite likely it may all at once draw itself down to the bottom as in No. 2, and folding down the valves *w* of horny teeth which grow on each side, shut itself in from some fancied danger. Another very curious point is that, besides sending forth young ones, these creatures multiply by dividing in two (see No. 3, Fig. 6), each one closing its own part of the vase into a new home.

There are hundreds of these Infusoria, as they are called, in my pond, some with vases, some without, some fixed to weeds and stones, others swimming about freely. Even in the water-trough in which this *Thuricolla* stands, I saw several smaller forms, and the next microscope has a trough filled with the minutest form of all, called a *Monad*. These are so small that two thousand of them could lie side by side in an inch; that is, if you could make them lie at all, for they are the most restless little beings, darting hither and thither, scarcely even halting except to turn back. And yet though there are so many of them, and as far as we know they have no organs of sight, they never run up against each other, but glide past more cleverly than any clear-sighted fish. These creatures are mostly to be found among decaying seaweed, and though they are so tiny, you can still see distinctly the clear space contracting and expanding within them.

[Illustration: FIG. 7. LIVING DIATOMS.

a, Cocconema lanceolatum. b, Bacillaria paradoxa. c, Gomphonema marinum. d, Diatoma hyalina.]

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But if there are so many thousands of mouths to feed, on the tree-like Sertulariae as well as in all these Infusoria, where does the food come from? Partly from the numerous atoms of decaying life all around, and the minute eggs of animals and spores of plants; but besides these, the pool is full of minute living plants—small jelly masses with solid coats of flint which are moulded into most lovely shapes. Plants formed of jelly and flint! You will think I am joking, but I am not. These plants, called Diatoms, which live both in salt and fresh water, are single cells feeding and growing just like those we took from the water-butt, only that instead of a soft covering they build up a flinty skeleton. They are so small, that many of them must be magnified to fifty times their real size before you can even see them distinctly. Yet the skeletons of these almost invisible plants are carved and chiselled in the most delicate patterns. I showed you a group of these in our lecture on magic glasses, and now I have brought a few living ones that we may learn to know them. The diagram (Fig. 7) shows the chief forms you will see on the different slides.

The first one, *Sacillaria paradoxa* (*b*, Fig. 7), looks like a number of rods clinging one to another in a string, but each one of these is a single-celled plant with a jelly cell surrounding the flinty skeleton. You will see that they move to and fro over each other in the water.

The next two forms, *a* and *c*, look much more like plants, for the cells arrange themselves on a jelly stem, which by and by disappears, leaving only the separate flint skeletons. The last form, *d*, is something midway between the other forms, the separate cells hang on to each other and also on to a straight jelly stem.

[Illustration: FIG. 8. A DIATOM (*Diatoma vulgare*) GROWING.

a, b, Flint skeleton inside the jelly-cell. *a, c* and *d, b*, Two flint skeletons formed by new valves, *c* and *d*, forming within the first skeleton.]

Another species of Diatoma (Fig. 8) called *Diatoma vulgare*, is a very simple and common form, and will help to explain how these plants grow. The two flinty valves *a, b* inside the cell are not quite the same size; the older one *a* is larger than the younger one *b* and fits over it like the cover of a pill-box. As the plant grows, the cell enlarges and forms two more valves, one *c* fitting into the cover *a*, so as to make a complete box *ac*, and a second, *d*, back to back with *c*, fitting into the valve *b*, and making another complete *bd*. This goes on very rapidly, and in this plant each new cell separates as it is formed, and the free diatoms move about quite actively in the water.

If you consider for a moment, you will see that, as the new valves always fit into the old ones, each must be smaller than the last, and so there comes a time when the valves have become too small to go on increasing. Then the plant must begin afresh. So the two halves of the last cell open, and throwing out their flinty skeletons, cover themselves with a thin jelly layer, and form a new cell which grows larger than any of the old ones.

These, which are spore-cells, then form flinty valves inside, and the whole thing begins again.

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Now, though the plants themselves die, or become the food of minute animals, the flinty skeletons are not destroyed, but go on accumulating in the waters of the ponds, lakes, rivers, and seas, all over the world. Untold millions have no doubt crumbled to dust and gone back into the waters, but untold millions also have survived. The towns of Berlin in Europe and of Richmond in the United States are actually built upon ground called "infusorial earth," composed almost entirely of valves of these minute diatoms which have accumulated to a thickness of more than eighty feet! Those under Berlin are fresh-water forms, and must have lived in a lake, while those of Richmond belong to salt-water forms. Every inch of the ground under those cities represents thousands and thousands of living plants which flourished in ages long gone by, and were no larger than those you will see presently under the microscope.

These are a very few of the microscopic inhabitants of my pond, but, as you will confuse them if I show you too many, we will conclude with two rather larger specimens, and examine them carefully. The first, called the *Cydippe*, is a lovely, transparent living ball, which I want to explain to you because it is so wondrously beautiful. The second, the Sea-mat or *Flustra*, looks like a crumpled drab-colored seaweed, but is really composed of many thousands of grottos, the homes of tiny sea-animals.

[Illustration: FIG. 9. *Cydippe Pileus*.

1, Animal with tentacles t , bearing small tendrils t' . 2, Body of animal enlarged. m , Mouth. c , Digestive cavity. s , Sac into which the tentacles are withdrawn. p , Bands with comb-like plates. 3, Portion of a band enlarged to show the moving plates p .]

Let us take the *Cydippe* first (1, Fig. 9). I have six here, each in a separate tumbler, and could have brought many more, for when I dipped my net in the pool yesterday such numbers were caught in it that I believe the retreating tide must just have left a shoal behind. Put a tumbler on the desk in front of you, and if the light falls well upon it you will see a transparent ball about the size of a large pea marked with eight bright bands, which begin at the lower end of the ball and reach nearly to the top, dividing the outside into sections like the ribs of a melon. The creature is so perfectly transparent that you can count all the eight bands.

At the top of the ball is a slight bulge which is the mouth (m 2, Fig. 9), and from it, inside the ball hangs a long bag or stomach, which opens below into a cavity, from which two canals branch out, one on each side, and these divide again into four canals which go one into each of the tubes running down the bands. From this cavity the food, which is digested in the stomach, is carried by the canals all over the body. The smaller tubes which branch out of these canals cannot be seen clearly without a very strong lens, and the only other parts you can discern in this transparent ball are two long sacs on each side of the lower end. These are the tentacle sacs, in which are coiled up the tentacles, which we shall describe presently. Lastly you can notice that the bands outside the

globe are broader in the middle than at the ends, and are striped across by a number of ridges.

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In moving the tumblers the water has naturally been shaken, and the creature being alarmed will probably at first remain motionless. But very soon it will begin to play in the water, rising and falling, and swimming gracefully from side to side. Now you will notice a curious effect, for the bands will glitter and become tinged with prismatic colors, till, as it moves more and more rapidly these colors, reflected in the jelly, seem to tinge the whole ball with colors like those on a soap-bubble, while from the two sacs below come forth two long transparent threads like spun glass. At first these appear to be simple threads, but as they gradually open out to about four or five inches, smaller threads uncoil on each side of the line till there are about fifty on each line. These short tendrils are never still for long; as the main threads wave to and fro, some of the shorter ones coil up and hang like tiny beads, then these uncoil and others roll up, so that these graceful floating lines are never two seconds alike.

We do not really know their use. Sometimes the creature anchors itself by them, rising and falling as they stretch out or coil up; but more often they float idly behind it in the water. At first you would perhaps think that they served to drive the ball through the water, but this is done by a special apparatus. The cross ridges which we noticed on the bands are really flat comb-like plates (*p*, Fig. 9), of which there are about twenty or thirty on each band; and these vibrate very rapidly, so that two hundred or more paddles drive the tiny ball through the water. This is the cause of the prismatic colors; for iridescent tints are produced by the play of light upon the glittering plates, as they incessantly change their angle. Sometimes they move all at once, sometimes only a few at a time, and it is evident the creature controls them at will.

This lovely fairy-like globe, with its long floating tentacles and rainbow tints, was for a long time classed with the jelly-fish; but it really is most nearly related to the sea-anemones, as it has a true central cavity which acts as a stomach, and many other points in common with the *Actinozoa*. We cannot help wondering, as the little being glides hither and thither, whether it can see where it is going. It has nerves of a low kind which start from a little dark spot (*ng*) exactly at the south pole of the ball, and at that point a sense-organ of some kind exists, but what impression the creature gains from it of the world outside we cannot tell.

I am afraid you may think it dull to turn from such a beautiful being as this, to the gray leaf which looks only like a dead dry seaweed; yet you will be wrong, for a more wonderful history attaches to this crumpled dead-looking leaf than to the lovely jelly-globe.

[Illustration: FIG. 10. THE SEA-MAT OR FLUSTRA (*Flustra foliacea*).

1, Natural size. 2, Much magnified, s, Slit caused by drawing in of the animal a.]

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First of all I will pass round pieces of the dry leaf (1, Fig. 10), and while you are getting them I will tell you where I found the living ones. Great masses of the Flustra, as it is called, line the bottom and sides of my pool. They grow in tufts, standing upright on the rock, and looking exactly like hard gray seaweeds, while there is nothing to lead you to suspect that they are anything else. Yesterday I chipped off very carefully a piece of rock with a tuft upon it, and have kept it since in a glass globe by itself with sea-water, for the little creatures living in this marine city require a very good supply of healthy water and air. I have called it a "marine city," and now I will tell you why. Take the piece in your hand and run your finger gently up and down it; you will glide quite comfortably from the lower to the higher part of the leaf, but when you come back you will feel your finger catch slightly on a rough surface. Your pocket lens will show you why this is, for if you look through it at the surface of the leaf you will see it is not smooth, but composed of hundreds of tiny alcoves with arched tops; and on each side of these tops stand two short blunt spines, making four in all, pointing upwards, so as partly to cover the alcove above. As your finger went up it glided over the spines, but on coming back it met their points. This is all you can see in the dead specimen; I must show you the rest by diagrams, and by and by under the microscope.

First, then, in the living specimen which I have here, those alcoves are not open as in the dead piece, but covered over with a transparent skin, in which, near the top of the alcove just where the curve begins, is a slit (s 2, Fig. 10) Unfortunately, the membrane covering this alcove is too dense for you to distinguish the parts within. Presently, however, if you are watching a piece of this living leaf in a flat water-cell under the microscope, you will see the slit slowly open, and begin to turn as it were inside out, exactly like the finger of a glove, which has been pushed in at the tip, gradually rises up when you put your finger inside it. As this goes on, a bundle of threads appears, at first closed like a bud, but gradually opening out into a crown of tentacles, each one clothed with hairs. Then you will see that the slit was not exactly a slit after all, but the round edge where the sac was pushed in. Ah! you will say, you are now showing me a polyp like those on the sertularian tree. Not so fast, my friend; you have not studied what is still under the covering skin and hidden in the living animal. I have, however, prepared a slide with this membrane removed and there you can observe the different parts, and learn that each one of these alcoves contains a complete animal, and not merely one among many mouths, like the polyp on Sertularia.

[Illustration: FIG. 11. DIAGRAM OF THE ANIMAL IN THE FLUSTRA OR SEA-MAT.

1, Animal protruding. 2, Animal retracted in the sheath, *sh*, Covering sheath, *s*, Slit. *t*, Tentacles. *m*, Mouth. *th*, Throat, *st*, Stomach. *i*, Intestine, *r*, Retractor muscle, *e*, Egg-forming parts. *g*, Nerve-ganglion.]

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Each of these little beings (*a*, Fig. 10) living in its alcove has a mouth, throat, stomach, intestine, muscles, and nerves starting from the ganglion of nervous matter, besides all that is necessary for producing eggs and sending forth young ones. You can trace all these under the microscope (see 2, Fig. 11) as the creature lies curiously doubled up in its bed, with its body bent in a loop; the intestine *i*, out of which the refuse food passes, coming back close up to the slit. When it is at rest, the top of the sac in which it lies is pulled in by the retractor muscle *r*, and looks, as I have said, like the finger of a glove with the top pushed in. When it wishes to feed this top is drawn out by muscles running round the sac, and the tentacles open and wave in the water (1, Fig. 11).

Look now at the alcoves, the homes of these animals; see how tiny they are and how closely they fit together. Mr. Gosse, the naturalist, has reckoned that there are six thousand, seven hundred and twenty alcoves in a square inch; then if you turn the leaf over you will see that there is another set, fixed back to back with these, on the other side, making in all, thirteen thousand, four hundred and forty alcoves. Now a moderate-sized leaf of *flustra* measures about three square inches, taking all the rounded lobes into account, so you will see we get forty thousand, three hundred and twenty as a rough estimate of the number of beings on this one leaf. But if you look at this tuft I have brought, you will find it is composed of twelve such leaves, and this after all is a very small part of the mass growing round my pool. Was I wrong, then, when I said my miniature ocean contains as many millions of beings as there are stars in the heavens?

You will want to know how these leaves grew, and it is in this way. First a little free swimming animal, a mere living sac provided with lashes, settles down and grows into one little horny alcove, with its live creature inside, which in time sends off from it three to five buds, forming alcoves all round the top and sides of the first one, growing on to it. These again bud out, and you can thus easily understand that, in this way, in time a good-sized leaf is formed. Meanwhile the creatures also send forth new swimming cells, which settle down near to begin new leaves, and thus a tuft is formed; and long after the beings in earlier parts of the leaf have died and left their alcoves empty, those round the margin are still alive and spreading....

If you can trace the spore-cells and urns in the seaweeds, observe the polyps in the *Sertularia*, and count the number of mouths on a branch of my animal fringe (*Sertularia tenella*); if you make acquaintance with the *Thuricolla* in its vase, and are fortunate enough to see one divide in two; if you learn to know some of the beautiful forms of diatoms, and can picture to yourself the life of the tiny inhabitants of the *Flustra*; then you will have used your microscope with some effect, and be prepared for an expedition to my pool, where we will go together some day to seek new treasures.

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[Illustration]

NOTES

AGASSIZ, J.L.R., naturalist, born in Switzerland, 1807; died, Cambridge, Mass., 1873. In 1846 he came to America, after having gained a high reputation in Europe, to deliver a course of lectures in Boston "On the Plan of the Creation," and met with such success that he spent the rest of his days there, declining an invitation to return to his native country and to Paris. In 1848 he was elected to the chair of Natural History at Harvard. In 1850-51 he went on an expedition to the Florida Reefs. In 1858 he founded and organized the Museum of Comparative Zoology at Cambridge—and, later on, went on his important voyage to Brazil. In 1872 he founded and organized the summer school of Natural History at Buzzard's Bay. He wrote "The Fishes of Brazil," "A Study of Glaciers," "Natural History of the Fresh Water Fishes of Central Europe," "Contributions to the Natural History of the United States" (unfinished), and with his wife, "A Journey in Brazil."

BALL, PROF. SIR R.S., English astronomer, born in Dublin, 1840. Was appointed Lord Ross's astronomer in 1865. Professor of mathematics and mechanics at the Royal Irish College of Science in 1873, and is now astronomer royal for Ireland. He is the author of "The Story of the Heavens," "Starland," etc., and is well known as a successful lecturer on astronomical subjects in this country.

DARWIN, CHARLES R., English naturalist, born, 1809; died, 1882. He first formulated what is known as the principle of Natural Selection. In 1831 he went in the famous scientific voyage of the *Beagle* as naturalist, and afterwards published an account of it. He was one of the most thorough, careful, and painstaking scientific men of this or any age. He is the author of many famous books. "The Origin of Species," "The Descent of Man," "Insectivorous Plants," "The Power of Movement in Plants," "The Structure and Distribution of Coral Reefs," "Geological Observations on Volcanic Islands." "The Formation of Vegetable Mould" was his last published work.

FLAMMARION, C., famous French astronomer, born, 1842. He has written many popular works on astronomy, most of which have been translated into English. "The Stars," "The World Before the Creation," "Uranus," "Comets," "Popular Astronomy," are among his best known.

HOLDEN, PROF. E.S., American astronomer, born at St. Louis, 1846. Lieutenant engineers, U.S.A., 1870-73; professor mathematics, U.S.N., 1873-81; director Washburn Observatory, 1881-85; president University of California, 1883-88; director Lick Observatory, 1888-98. Is a member of several learned societies of Europe. Is the author of a "Life of William Herschel," "A Hand-book of the Lick Observatory," "Earth and

Sky," "Primer of Heraldry," "Elementary Astronomy," "Family of the Sun," "Essays in Astronomy," "Stories of the Great Astronomers," *etc.*

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HUXLEY, T.H., English biologist, born, 1825; died, 1895. Went on an exploring expedition on the *Rattlesnake*, and devoted himself to the study of marine life. For his scientific researches he received many honors. His lectures were models of clearness, and he could simplify the most difficult subjects. He strongly advocated Darwin's views and evolutionist doctrines. His writings are numerous and many of them technical. Among some of the most popular are "Man's Place in Nature," his "Lay Sermons," "Critiques and Addresses," "American Addresses," "Physiography," "Science and Culture," "Lessons in Elementary Physiology," etc.

KINGSLEY, C., English clergyman and author, born, 1819; died, 1875. Wrote "Westward, Ho!" which every boy should read, "Hypatia," "Alton Locke," "Hereward the Wake," etc., and a charming book of travel, entitled, "At Last." His "Water Babies" is exceedingly popular, and his "Heroes" is a book much appreciated by the boys and girls alike.

PROCTOR, R.A., English astronomer, born, 1834; died, 1888. He was a very popular writer, and lectured on astronomical subjects in this country, and in England and her colonies. A memorial teaching observatory is erected in his honor near San Diego, Cal. He was a man of untiring industry, an athlete, a musician, and a chess-player. His books are numerous. Among them are "Half Hours with the Telescope," "Other Worlds than Ours," "Light Science for Leisure Hours," "The Expanse of Heaven," "The Moon," "The Borderland of Science," "Our Place Among Infinites," "Myths and Marvels of Astronomy," "The Universe of Suns," "Other Suns than Ours," etc.

SHALER, N.S., professor of geology at Harvard. Born Newport, Ky., 1841. Served in the Union Army during the Civil War. Instructor zoology, geology, and paleontology, Lawrence Scientific School, till 1887. Since then at Harvard. Is the author of "Kentucky a Pioneer Commonwealth," "The Story of Our Continent," "The Interpretation of Nature," "Feature of Coasts and Oceans," "Domesticated Animals," "The Individual," "Study of Life and Death," etc.

THOMPSON, SIR C. WYVILLE, English zoologist, born, 1830; died, 1882. He conducted scientific dredging expeditions in the *Lightning* and *Porcupine*, 1868-69, and was the scientific head of the famous voyage of 68,900 miles in the *Challenger* for deep-sea explorations (1872-76). His books are "The Depths of the Sea," and "The Voyage of the Challenger."

TYNDALL, JOHN, English physicist, born, 1820. Began his original researches in 1847, when teacher of physics in Queenwood College. He and Professor Huxley visited the Alps together, and they wrote a work on the structure and nature of glaciers. It is impossible to detail the work he has done; but his inquiries and experiments in connection with light, heat, sound, and electricity have all had practical results. He is a popular lecturer, and devoted

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the proceeds of a lecturing tour in this country to founding scholarships at Harvard and Columbia Colleges, for students devoting themselves to original research. Among his books are "Glaciers of the Alps," "Mountaineering," "Heat as a Mode of Motion," "On Radiation," "Hours of Exercise in the Alps," "Fragments of Science," "The Floating Matter of the Air," and volumes on Light, Sound, Electricity, and the forms of water.

WALLACE, A.R., English naturalist and traveller, born 1822; was educated as land surveyor and architect, but afterwards devoted himself entirely to Natural History. He explored the Valley of the Amazon and Rio Negro, 1848-52, and travelled in the Malay Archipelago and Papua, 1854-62, publishing the results of his explorations later on. He also wrote "Contributions to the Theory of Natural Selection," "Miracles and Modern Spiritualism," "Geographical Distribution of Animals," "Tropical Nature," "Island Life," *etc.*

GIBERNE, AGNES, English author—living. Began to write at seven years old. Her first story for children was published when she was only seventeen. Her stories for children have not been so popular as her scientific writings, "Sun, Moon, and Stars," "The Starry Skies," "Among the Stars," "The Ocean of Air," "The World's Foundations," "Radiant Suns," *etc.*

WILSON, ANDREW, English physiologist and lecturer, born, 1852. Is the author of "Studies on Life and Sense," "Leisure Time Studies," "Science Stories," "Chapters on Evolution," "Wild Animals," "Brain and Nerve," *etc.*, and is a constant contributor on scientific subjects to the magazines and newspapers, contributing weekly "Science Jottings" to the "Illustrated London News"

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