NATURE STUDY READERS

V

HAROLD'S DIS-CUSSIONS

TROEGER

ISAAC NEWTON (1643–1727).

NATURE-STUDY READERS

By JOHN W. TROEGER

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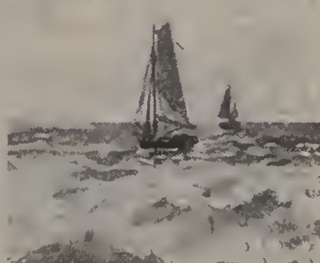
JOHN W. TROEGER, A. M., B. S.

AND

EDNA BEATRICE TROEGER



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AUTHOR'S PREFACE.

ANNUALLY a great army of children leave our schools before they reach grades in which they can have the opportunity to study elementary science. For such, in particular, this book has been written. If the young people who have read the proofs may be taken as a criterion, even those who have graduated from secondary schools will read the book with delight and profit. It also furnishes the general reader with the facts of science that will enable him to enjoy the learned scientific articles in our periodicals. These are becoming more numerous from year to year.

This volume presents the scientific subjects which are of highest interest to man, and which bear upon life at every hand. They are from the oldest records accessible to man. He may misinterpret them, but they can never be false; they are as true as nature itself.

The first ten chapters present a brief sketch of the life that has existed in the geological ages of the past. The forces acting on life and the earth, recording their history, have been considered in the foregoing volume. The next five chapters discuss subjects pertaining to the outer envelope of our earth, namely, the atmosphere, that plays so important a part in the evolution of life. Considerable attention is given to the movements of the air and their causes, and to the methods of observation by which we gain our knowledge. These chapters are the result of successful work done by the sixth grade.

In the next six chapters we look out upon the earth's surroundings—the sun, moon, planets, stars, and nebulæ, that contribute so greatly to our welfare and awaken in us feelings of wonder.

Chapters XXII to XXX treat of the unity and variation of plant and animal life to be observed all about us. As far as these lines of discussion have been presented to seventh and eighth grades, they have proved acceptable and profitable to them. They seem to give them the foundation to read the more pretentious works.

For information and suggestions I am indebted to many scholars, some of whom are mentioned in the appropriate place in order that readers may become familiar with their names. I may add here Prof. Joseph LeConte, James Dwight Dana, R. S. Tarr, A. P. Brigham, C. Flammarion, Simon Newcomb, John Ferrell, Pres. D. S. Jordan, and Marshall, Romanes, Huxley, Darwin, and Wallace. Also to E. Hazel Troeger, who has given me valuable assistance in the preparation of the book and the reading of the proofs.

The Plan and Scope of the Series.

The general plan of the series has been steadily kept in view, namely:

1. To provide a graded course of reading on elementary science, or what is called Nature Study topics. It seems desirable to have the reading as helpful as possible to the regular work of the school, and particularly geography and literature, for the former depends largely upon nature's phenomena, and the latter abounds in references to birds and flowers, beasts and plants, and to the phases of the skies, winds, and water; both become more interesting and intelligent to him who has read such a course; and

2. To present the information, as far as that can be done, in a way that may induce the reader to go beyond the book and see nature for himself. The child unaided will see but little in his environment, as is evidenced by the native races who live all their lives in the midst of nature without discovering any of her laws. The mind, excepting that of a genius, does not know how to begin to question nature. It needs assistance. The best help is that of an intelligent observer, who can go into the fields and forests with the child to question him and elicit from him such facts as will arouse his mentality. As that can not be done to any great extent, a book, the next best aid, must be put into his hand.

If the book gives the information in full and detail, the reader will content himself to take it second-hand. He will fail to improve his powers of observation and judgment, and thus defeat the chief purpose of science study. Many have not had their interest in nature aroused; they see no flowers, hear no birds, look at no insects, and think of no law of the ever-unfolding life that revels at their feet. Yet all of them have lessons of profit and beauty for the asking.

The field of nature is boundless, and her phenomena so multitudinous that a thousand volumes could not exhaust her. Every locality has its own studies of peculiar interest. A series like this can select only a small part for consideration. What shall guide us in choosing? It is evident it must be that which is of general distribution and can be used in a typical way. Accordingly the first three books treat of the flowers, birds, trees, fruits, plants, animals, and the phenomena of air and water, which are most easily accessible both in their environment and to the children in the schoolroom.

The fourth and fifth volumes, which are to be read by children of greater experience, naturally draw more heavily on the imagination and present facts from other lands and zones, but such as the reader will appreciate, and such as will enable him to obtain a fair conception of the realm of life as it exists in various climates and conditions. The interesting life of the sea, the tropical life of the earth, and the frozen north, as well as the evidences of nature's forces now operating, which have given us the geological history of the globe, receive attention in the fourth book.

Nature study is old. It is the universal book written for all, and in a language that all can understand. The ancient Greeks made considerable progress in correct observations. Aristotle was the foremost. He gave us the results of their study in ponderous books. Then followed an age when nature was discounted and man was turned to dogmas. He was soon plunged into the thousand years of the Dark Ages. When nature study revived, intelligence and personal liberty began at once to increase, and, with the study, have steadily moved forward.

In this age when life is so complex and loaded with so much that is false, the child should not be deprived of its birthright, but should be led to the simplicity of nature, and drink deeply of her fountains of unadulterated truth. It would make his life better and truer.

J. W. Troeger.

La Grange, Ill.

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CHAPTER I.

INTRODUCTION.

"Modern Science may be regarded as one vast miracle, whether we view it in relation to the Almighty Being, by whom its objects and laws were formed, or to the feeble intellect of man, by which its depths have been sounded and its mysteries explored."—Brewster.

Some years ago a lad just entering his teens was taken by his father to see the Leaning Tower of Pisa. As he beheld it, his first thought prompted the question, "Why doesn't it tip over?" He learned that the tower is one hundred and eighty-three feet high, its walls fifteen feet thick at the bottom and twelve at the top, and that it is one of the noblest remaining specimens of the Romanesque style of architecture. He looked upon its fine columns, and wondered at the bells in the upper story which is smaller than the others. All this interested him, but nothing made so profitable an impression upon him as the unanswered question. He was told that it stands because its heavy base keeps it in an upright position. Still, he could not comprehend the cause; the fact that the top of the tower extends nearly fourteen feet beyond the line of its base continued to stimulate his mind.

The word science means that which is known; it is classified or systematized knowledge. The human mind is not content to dwell in the realms of the

Fig. 1.—The Leaning Tower and Cathedral of Pisa, Italy.

known. As in the case of the boy looking at the Leaning Tower, it is ever attracted by that which is unknown to it. It is this spirit of investigation that makes science possible.

Sir Isaac Newton saw the apple fall while he was lying beneath the tree that bore it. Many others had seen the same phenomenon. But he asked himself why the apple should move toward the earth—why it did not fall in some other direction. That question immortalized Newton; it led to the discovery of the laws of gravitation. He gave his thoughts to the world. Others read them and began to think about the forces manifested in the universe. Astronomers gained new light and formulated new theories; mathematicians were able to present new demonstrations of those theories. All these in a certain sense were the result of Newton's attention to the falling apple. Much that we call science to-day originated in a similar way and passed through a similar confirmation—a thought, discussion, proof.

Questions, suppositions, and hypotheses are not science, but they are aids to it. To prove or disprove them facts are brought into line, and probable evidences are discussed, proofs are gathered up and laid at the pure shrine of Science.

"He most lives who thinks most, feels the noblest, and acts the best."—Bailey.

CHAPTER II.

THE EARTH-BOOK.

In the preceding volume I have considered the river valley and how the water made it; how the contraction of the earth's crust on account of the radiation of heat has produced elevations and corresponding depressions; how heat by liquefying the subterranean materials has thrown up volcanoes; how water percolating through rock strata, forming springs and underground rivers, has carved out caverns, carried the *débris* together with that eroded on the surface to the sea, and there deposited it; how plants and animal forms were buried in these deposits and preserved as fossils to become the key in retracing the history of the world; how animal and plant life contributed their share in making the great layers of limestone and coal; and how wind and sea, and heat and life, are still carrying forward earth's faithful record.

Let us now together turn over the great leaves of the earth-book and see if we can decipher some of its significant hieroglyphics. I am sure they reveal a wonderful story of life and death, of struggle for existence and "survival of the fittest."

As we have already studied the alphabet which the present can furnish us, we shall begin with the latest chapter lying on top where it was written, and quickly turn forward chapter after chapter until the earliest is reached.

The earth-book has no cover, for the last chapter is not yet written. Present deposits will preserve the story of present life just as former deposits have preserved earlier life. Growing plants and living animals will here and there fall into preserving mud, where they will remain till in some future time they reveal the present manner of life even if all man's proud monuments of stone and paper shall have perished.

The last leaf, the last chapter written, lies on top, but not everywhere. Water was the writing fluid; and consequently where the earth was out of water there no deposits could be had and no record made. The latest records, therefore, are about the shores of present lakes and seas. In past ages the land rose more and more out of the water; the sea is the mother of the land. The more recent layers are resting on the earlier.

To discover the different chapters we might go from one end of the country to the other, as did Dr. William Smith, "the father of geology" in England, but fortunately that has been done for us. The geologist examines the surface-rocks, collects all the specimens of fossil life he can find in that region, describes them with pen and pencil, and makes a list of them. The same is done in adjoining regions until the whole country has been mapped.

The rock formations of one chapter—that is, those of one age—are distinguished from those formed in another age, not so much by the character of the rocks as by the fossils of the life that existed during that period.

A comparison will show that the fossils of certain belts are much alike, and quite different from those in an adjacent belt. The conclusion that these unlike groups of animals lived in two unlike periods of time is evident, and the strata that lie lowest are, of course, the oldest.

Great periods of time are distinguished by great differences in their fossils, and short periods by correspondingly small differences. The division is sometimes based on only one or two forms whose remains make up a certain percentage of all the fossils found.

Let us examine the rocks exposed to view near Marquette, Wis. At the lake is a slight deposit of sand which the water has left. Going west and a little north, we come upon a kind of limestone which the expert at once recognizes as Galena lime-

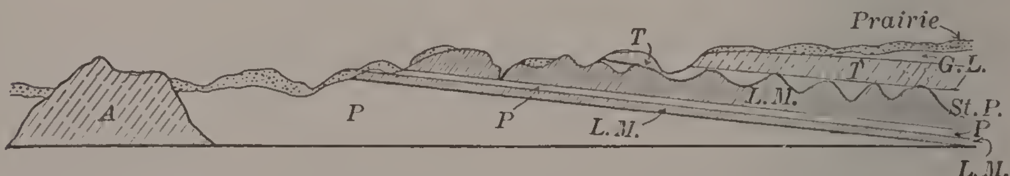


Fig. 2.—The south end of a cross-section of surface-rock of the State of Wisconsin, from Ashland south by east to Lake Michigan.

stone. This layer, as may be seen from Fig. 2, extends beneath the recent sand deposits, and of course it had been formed before the sand could be deposited on it. Farther west we find a different kind of limestone known as the Trenton, extending beneath the Galena, and hence it must be older than the Galena strata. Continuing our examination westward across a small valley we come upon a layer of St. Peter

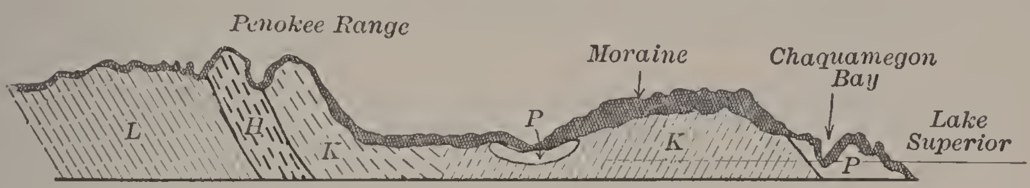


FIG. 3.—The north end of the cross-section mentioned under Fig. 2. Strata much disturbed from their horizontal positions. *L*, Laurentian (granite group); *H*, Huronian (granite group); *K*, Keweenawen (copper-bearing group); *P*, Potsdam sandstone. The surface-rock of the cross-section between Figs. 2 and 3 is Laurentian granite.

sandstone. On a ridge west of this is an outcrop of Lower Magnesian limestone, then a Potsdam layer, and so on. If we trace any of these layers, we find that they do not lie horizontally, but incline and extend under a layer which must be younger. If a well should be bored anywhere in the Galena outcrop, it would pass through these various strata and in the same order in which we found them while walking westward. The youngest rock found here, then, is the Galena limestone. If, however, we examine the rock strata elsewhere, we shall find that the Galena is not a recent formation, as many different strata lie above it in other parts of this and other countries.

Let us now go to the Gulf coast and begin in Louisiana. Here is a strata that forms the surface-rock in the greater part of the State, extending in an irregular strip up through Arkansas (Fig. 6). These rock layers in no place extend beneath other layers.

Fig. 4.—Cross-section from Lake Michigan west. *H.M.*, Hamilton rock; *N*, Niagara limestone; *H. R.*, Hudson River (Cincinnati) shale; *G*, Galena limestone; *T*, Trenton limestone; *St.P.*, St. Peter sandstone; *L.M.*, Lower Magnesian limestone.

We therefore conclude that they are the most recent chapter of the earth-book. For convenience, and not to introduce too many names here, I will call this formation Number 7.

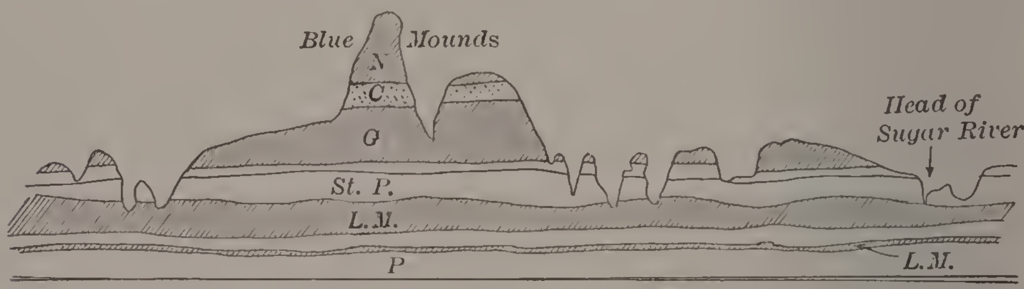


Fig. 5.—Cross-section from Lake Michigan west, south of Milwaukee. *P*, Potsdam sandstone; *L.M.*, Lower Magnesian limestone; *St.P.*, St. Peter sandstone; *G*, Galena limestone; *C*, Cincinnati shale; *N*, Niagara limestone. The formations above St. Peter sandstone have all been carried away by erosion, except at Blue Mounds and a few other high places.

As we go northward we come upon Number 6, a slightly different rock formation. It crops out in the State of Mississippi and north as far as southern

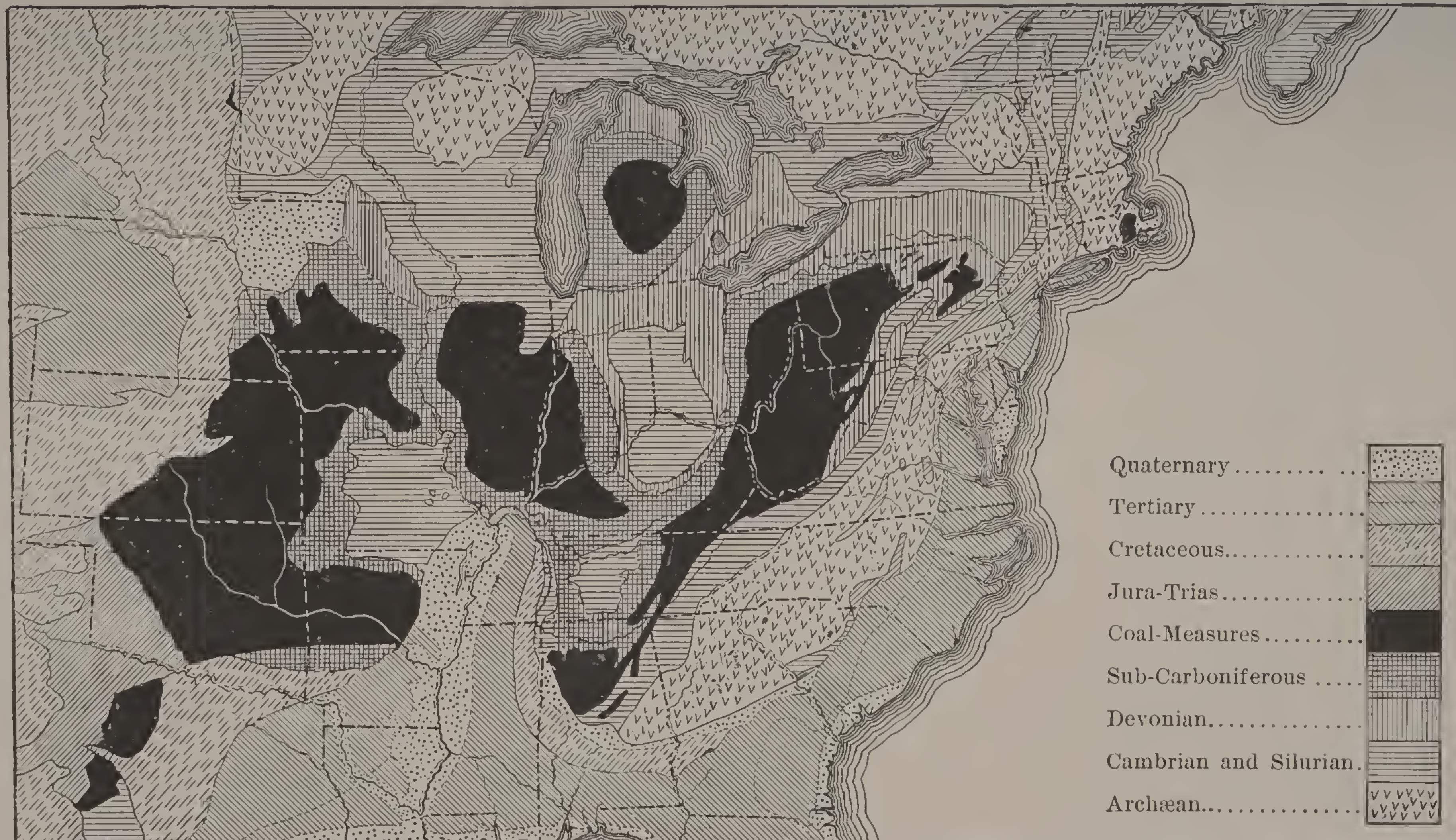


FIG. 6.—Map of the United States east of the Rocky Mountain highlands.

Illinois—in fact, all around the edge of Number 7. Southward these strata dip beneath the more recent, and therefore they are themselves the older. The fossils found in them also show that the rocks belong to an earlier age, as they clearly indicate a warmer climate. The Gulf must have extended over all this region during this age, and there must have been also an inland fresh-water sea in western Nebraska, with arms spreading north perhaps as far as Oregon and west to California. Near the Atlantic from New Jersey south extends a strip of Number 6 a hundred miles wide. As the rock is comparatively soft, water erodes it easily, and the rivers flowing east from the mountains contain cascades which afford natural facilities for cities; hence there are Richmond, Raleigh, Columbia, Macon, and Milledgeville in this "Fall line" belt.

Still farther north than Number 6 we find in eastern Kansas, Nebraska, and part of Dakota, a chalky rock formation which, from its position and fossils, we know is still older than Number 6. This we call Number 5. The region must have been under water during this age. About the boundary of formation Number 5 and extending beneath it, another formation crops out on the surface in Iowa, Illinois, Michigan, Tennessee, and neighboring States. This (Number 4) contains large and important beds of soft coal, and in its formation extended through a long period of warm, moist climate. Beneath the coal strata and cropping out around them is another stratum, Number 3, found in Illinois and Iowa. It abounds in curious fossil fishes, and lies upon a series of formations (Number 2) which comes to the surface in northern Illinois, southern Wisconsin, and along the mountain belts. It is full of old, quaint forms of life, and contains much of the valuable metals. In the northern part of Wisconsin and in Canada we find as surface rocks a formation of rocks mostly granite continuing beneath Number 2. They seem to be the oldest; for thus far we have found no other strata on the surface anywhere that extend beneath them. It must be Number 1, the first chapter that wind and water have written.

We see, then, that the earth-book has seven chapters. Each is full of interest, and has engaged the attention of great intellects in different parts of the world for a lifetime. Thus far I have traced only summarily their relative positions in order to give you an idea how the ages and periods are determined. I will now take up, as space will permit, the different chapters of the earth's evolution.

> "What cause
> Moved the Creator, in his holy rest
> Through all eternity, so late to build
> In Chaos: and, the work begun, how soon
> Absolvéd."
>
> MILTON.

CHAPTER III.

THE ARCHÆAN AGE.

The first, the oldest, rocks are at the surface over the greater part of Labrador, extending to the Great Lakes, and thence in a broad strip northwest between the Hudson Bay and Mackenzie River, covering a great V-shaped area. They also come to the surface on the south side of Lake Superior in Wisconsin and Minnesota, and in the greater part of the New England States; also on some of the highest mountain ridges of the Appalachians and at a few points in the Rockies. We find them, too, on the northeast coast of Scotland, in Bohemia, and in the highlands of Sweden. In all these locations they can be traced beneath other rock formations, and therefore they must be the oldest rock on the globe.

It is necessary to give a little attention to the character of these rocks. In some places they lie almost horizontal, in others they are tilted or much contorted. Gorges and defiles are numerous in them, and outcroppings occur in many places, so that they can be studied at many points (Fig. 7). This has been done in Canada by a number of geologists; prominent among them is Sir William Logan.

Great beds of iron ore are found in these rocks, sometimes more than a hundred feet thick. To this formation belong the iron mines in northern Wisconsin and Michigan, Missouri, New Jersey, and Sweden. It might be called the Age of Iron. In Canada these rocks also contain beds of graphite, some of it almost pure.

The rocks consist chiefly of granite, and are much used as paving-blocks. Besides, they furnish excellent building-stone and material for columns and monuments, as they can be highly polished.

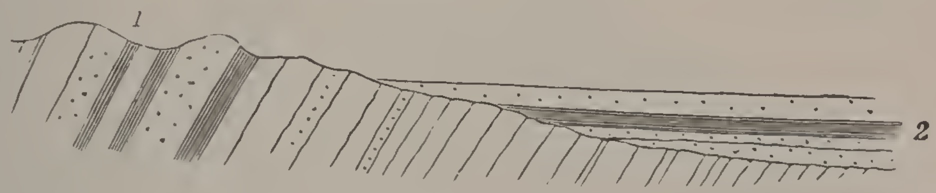


FIG. 7.—*1*, Old strata distorted by disturbances of the earth's crust. *2*, Newer strata deposited upon them.

The boulders, so common in the Northern States, are excellent examples of the Archæan rocks. They are within easy reach of most readers, and should be carefully examined.

All rocks which are stratified—that is, lying in layers upon each other, like courses of masonry—are called sedimentary (Latin, *sedere*, to settle). They have been laid by water. The rock material settled to the bottom, and hence such rocks were formed in a horizontal position, or nearly so.

Besides sedimentary rocks we find others which have once been in a liquid form; they are known as volcanic rocks. We frequently find them forced up through fissures in other rocks, or poured out of volcanoes and spread over the adjacent surface.

Furthermore, rocks are constantly undergoing change. Scarcely are they formed when forces begin to alter them. These forces are heat, water, and pressure. Sedimentary rocks are often so changed by these forces that all signs of stratification are obliterated, and the character of the rocks becomes more or less volcanic. Such rocks are known as metamorphic (*meta*, after, and *morphe*, form); we say that they have been metamorphosed. The changes

Fig. 8.—Specimen of crumpled gneiss. Photograph by G. H. Williams.

which thus take place are numerous and often complex, depending upon the relative amount of heat, water, and pressure present. Only a few of the more evident changes can here be mentioned.

Clay rock, which is fine-grained, can easily be detected by moistening a little and breathing upon it, for it then has a peculiar clay odor. If a stratum of this rock be pressed into a layered condition, it becomes shale; if metamorphosed, it becomes slate. It can then be split in only one direction. This is due to what is called the slaty cleavage. If we examine slate with a microscope, we shall find small micaceous flakes arranged parallel to the lines of cleavage. If the metamorphism be continued, this rock becomes a schist; if there is much mica, it is a mica schist; if it contains considerable hornblende, or chlorid, or talc, it becomes a hornblende, chlorid, or talcose schist. If the minerals are arranged in bands, it may become gneiss.

Sandstone is made up chiefly of fine, small quartz grains, so hard that it will easily scratch glass. It is often colored by iron or other minerals; in the presence of water the grains of quartz may become the centers of beautiful crystals. If other minerals are present to add color, the crystals may become agate, onyx, chalcedony, carnelian, amethysts, topaz, emeralds, or other valuable gems. The crystals under other conditions may become augite, a very hard and usually dark stone.

Limestone, under metamorphic agencies, becomes crystalline, and we call it marble; or if mixed with magnesium, it becomes dolomite, a coarse marble. Sometimes serpentine rock is mixed with it, and produces the beautiful, dark-green, veined marble. Sometimes iron gives it a cloudy brownish effect, as in Mexican onyx.

Rocks are frequently made up of fragments or pebbles bound together by one of Nature's cements, usually mixed with sand. Such rocks are conglomerates. The fragments may be of different sizes and shapes, and may consist of limestone, or shells, or pebbles. Oolite is a conglomerate composed of small, rounded pebbles of limestone, which look like fish eggs, hence the name, which means egg stone.

The coal series is an interesting one, ranging from peat and the various grades of hard and soft coal to the pure graphite in our drawing pencils.

Iron is seldom found in its pure metallic form in nature; it readily combines with oxygen, and forms several oxids, of which rust is the most common illustration. In this form it occurs in the rocks of all ages, as the red and brown colors evidence. It has been estimated that iron forms five per cent of all the rocks. It is frequently found with manganese, which gives the rocks a black or purplish color.

Water containing carbon dioxid coming in contact with iron oxid dissolves it and leaches it out of the rocks. When this is washed down into a peat bog it forms a light-colored mineral called siderite. If the siderite be subjected to heat it changes to limonite; under more heat the brown limonite changes to red hematite; if the heat continues it forms magnetite. The iron taken out of the mines in northern Wisconsin is mostly in the form of hematite and magnetite.

NOTE.—The Huronian and Laurentian rocks, found chiefly around Lakes Huron and Superior, though much distorted, show considerable evidence of stratification. For this reason Professor Dana considered them as a later division of the Archæan era, but recent geologists have placed them in an era by themselves, to which they have given the name Algonkian.

CHAPTER IV.

THE PRE-ARCHÆAN WORLD.

Although in most of the rocks of the Archæan period the traces of stratification are completely obliterated, there is no doubt that they were laid in strata, and, of course, by water. The Archæan areas must, then, have been under the sea; and in some region, not known now, there must have been areas of land above the sea from which materials to make the rocks could have been taken. Where was this pre-Archæan continent? Was it about the North Pole? It is reasonable to suppose so, as the first rocks are found in the northern end of the continent about the pole; besides, North America, as well as the British Isles and Europe, were formed from the north toward the south.

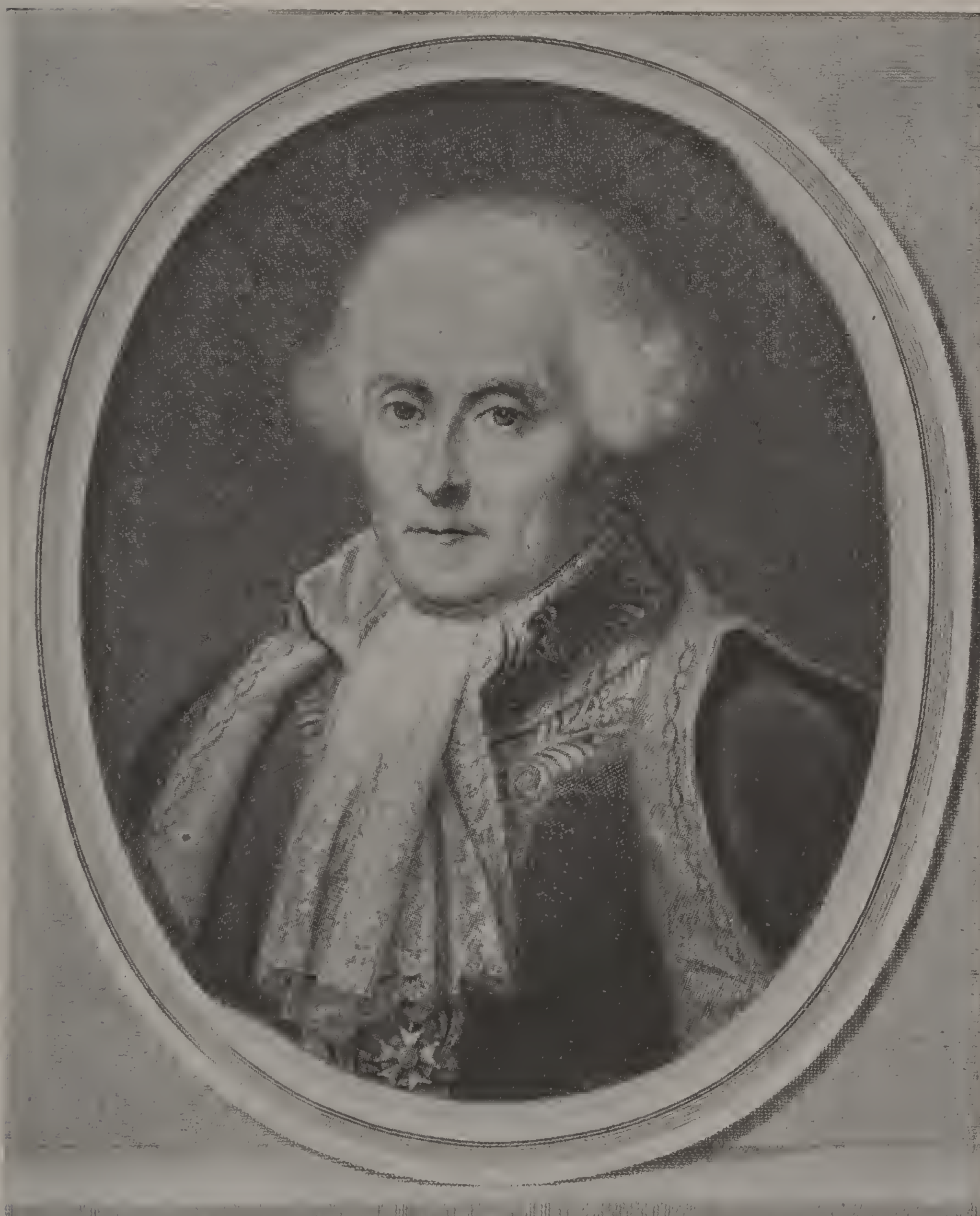
But what was there before the Archæan period? In what condition was the earth? Geology can take us no farther back; we must ask the astronomer and the physicist. They are not slow to inform us that the cold world was once a red-hot molten globe; that all the rocks flowed like molten iron; that the water now in our seas, rocks, rivers, and in our plants and animal bodies was a dense envelope of steam and mist about the earth; that the globe gradually cooled, so that a crust began to form on its surface like cakes of ice on a half-frozen river. Imagine the scene. A little water poured on a red-hot stove shoots up with a hissing noise as a cloud of hot vapor. In the cold outside boundary of the world's envelope the mist condensed into rain, which, in falling, came in contact with the hot steam below, and was again quickly hurled out with hissing screams. These violent changes produced untold quantities of electricity, which must have shot hither and thither in forked lightnings, accompanied by deafening peals of rolling thunder. How weary it makes us to think of this as continuing for days and weeks, but it must have lasted through centuries. Finally the crust hardened, and so far cooled that most of the water was allowed to find a resting-place on this much-ridged globe.

"A shoreless ocean tumbling round the globe."

Mr. Mathew Williams has well told us what takes place in the open furnace of a pig-iron refinery. It is a very instructive experiment. A mixture of iron, sulfur, carbon, and silicon is melted in the open air. The carbon unites with oxygen and rises as carbon dioxid. The silicon takes on oxygen, and, being lighter, floats on the iron, combines with the aluminum or calcium that is found to a greater or less extent in the pig-iron, and forms substances resembling the predominant material of the earth's crust. When the melting process has been carried far enough, the mixture is poured out into a box usually ten feet long and three feet wide. Here it settles and cools. The silicates, the rock materials, separate from the iron and form a thin crust on top. As the cooling progresses this becomes thicker, and begins to wrinkle, forming mountains much greater in proportion than those of the earth. Soon signs of volcanic action may be seen. Rifts are formed, and these are filled with molten matter from below, which forms dikes. Sometimes one side of the rift slips down slightly, thus forming what in geology is called a "fault." Then the material that wells up forms conical heaps on the crust, diminutive volcanoes. If water were present, these changes would no doubt be considerably modified, and would still more resemble what has occurred on the earth.

Likewise, in the case of the earth, after a mere shell of crust had formed, the inside, cooling, became too small for the outer envelope. As this was comparatively thin, and large areas were affected, it could not withstand the pressure of its own weight and that of the superincumbent atmosphere; it yielded and began to sink at some places, and this pushed it up at others. The low places became hollows for the oceans, and the ridges were the beginnings of mountain ranges. It is probable that at points the crust broke, and the liquid mass from below was forced up through the rifts and formed active volcanoes. I imagine that the little continents just born out of the universal ocean sent up curling smoke from more than a hundred little cones—the world's first furnaces.

The water was still hot, and contained much acid. Dense clouds obscured the orb of day—it was continuous night. The waters above and in the seas determined that no continents should live, and vigorously attacked the uncovered lands, rubbing and biting away until a large part of them had been brought low and spread over the adjacent sea floor. It is these first deposits that must have become the Archæan rocks.



PIERRE SIMON LAPLACE (1749-1827).

CHAPTER V.

WHAT BEFORE THE MOLTEN GLOBE?

> "Earth took her shining station as a star
> In heaven's dark hall, high up the crowd of worlds."—BAILEY.

IF the earth was once a red-hot sphere—and no one acquainted with the facts can now doubt it—how did it get so hot? Was it once a self-luminous star?

These are difficult questions to answer satisfactorily. We may make statements, but it is impossible to prove them successfully. There is, however, some evidence, and after going over it in order, most people feel that it must be true. Our space will not permit full discussion of all the evidence, as that would require a large volume alone. Only a few of the leading arguments can be stated here. The interested reader can find plenty of books on the subject. Prof. Alexander Winchell quite satisfactorily discusses these and other questions of cosmogony in his World Life, or Comparative Geology.

No one has ever observed the growth of an oak through all of its stages, and yet all of us are quite certain we know how it came about. We have seen the seed, an acorn, begin to sprout in the damp soil; we have followed the little shoot year by year; we have noticed it put forth tender buds, then unfold the leaves in the springtime, and during the cold winter again discard them; in short, we know how the monarch of two thousand years obtained his growth by observing the growth of oaks of different ages. These observations give us a clear idea of the evolution of the tree. Similarly the astronomer observes worlds in different stages of evolution, from the distant nebula to the airless, waterless, decayed moon.

Many explanations have been attempted to account for the birth of the earth. About a century ago Pierre Simon Laplace, French mathematician and astronomer, put forth his explanation, which has since become famous as the "nebular hypothesis." Before stating his theory, let us see of what the solar system consists.

In the center is the sun, a glowing globe nearly a million miles in diameter. The moon revolves about the earth at a distance equal to thirty times the earth's diameter. Imagine the earth sunk into the center of the sun with its revolving moon around it. There would then be nearly as broad a belt of sun outside of the moon's orbit as inside of it. Around this central sun revolve about four hundred planets, great and small, at various distances. The earth's average distance from the sun is nearly ninety-three million miles. Revolving around the sun, inside of the earth's orbit, are two of the eight major planets, Mercury and Venus. Outside of our planet's orbit, in the order of their distance from the sun are Mars, Jupiter, Saturn, Uranus, and Neptune. The last revolves about the sun in a path nearly thirty times as far from the sun as the earth is, and its year is more than one hundred and sixty-four times as long as the earth's.

The earth and all the planets outside its orbit have moons or satellites revolving about them as they them-

Fig. 9.—A spiral nebula in the constellation of the Great Bear. A mass of light, as it appears in the telescope.

selves revolve about the sun. The earth has one moon, Mars two, Jupiter, the largest planet of all, has five moons, and Saturn has eight moons and two wonderful rings. Uranus and Neptune are so far away that it is difficult, even with good telescopes, to see their satellites, but thus far it is agreed that Uranus has four small satellites and Neptune one. The latter satellite revolves about Neptune in five and three-quarter days.

Besides these eight major planets there are numerous other smaller bodies, called asteroids, or, rather

Fig. 10.—"Whirlpool" nebula, which shows rings as if they had been detached from the inner central core.

planetoids, in the solar system, revolving about the great luminary in obedience to the law of gravitation.

How did all these heavenly bodies with their satellites originate? Laplace claims that all the bodies of our solar system were once an immense globe of gaseous substance so large that it extended even far beyond the orbit of Neptune; that this substance began to cool, therefore to contract, and the contraction produced rotation and luminosity (Fig. 9). "And God said, Let there be light: and there was light." The heavier gases gravitated toward the center. In time an outer ring of cooler matter, but still gaseous, became separated from the greater inner core (Fig. 10), but continued to revolve, as probably Saturn's do to-day. Then parts of this ring became denser than others. The dense places attracted the rarer matter, and thus the whole ring rolled up into a gaseous or perhaps subgaseous globe, rotating on its own axis, and continuing its revolution around the central mass. Thus was born the first planet, the outermost and oldest and lightest—Neptune.

In course of time, as the cooling by radiation continued, another planet rolled off to shift for itself. In this way all the planets and planetoids became separated from the central mass. Mercury is the youngest of which we are certain. Some claim that they have seen another planet inside the orbit of Mercury, possibly two. If there are any they would be so near the sun that it would be difficult to see them. The sun is all that is left of the great nebulous sphere, and, according to the theory, it is still contracting.

The planets also continued the cooling and contracting process and themselves gave off rings, such as Saturn now has, and these likewise rolled up into a globe or possibly into several, which now appear as moons revolving about their progenitor. The planetoids were formed in the same way; being smaller, they may be only fragments of a ring.

This is a brief statement of the nebular hypothesis. From the nature of the case there can be no direct proof, nor can it be verified by mathematics. While not all the phenomena of the solar system can be explained by it, it serves to explain so many that astronomers generally favor it. If it is not the true one, then science has no explanation for the origin of the solar system.

EVIDENCES IN FAVOR OF THE NEBULAR HYPOTHESIS.

I can not pass on without giving a few of the twenty-eight reasons in favor of this famous hypothesis. For, no matter how young the reader is, his active mind must enjoy a statement of them.

1. All of the four hundred bodies of the solar system revolve about the sun in the same direction. 2. They revolve in nearly the same plane. 3. They rotate on their axes in the same direction as the central body which produced them. If we notice the lumps of mud flying off from a revolving wagon-wheel, where gravity does not interfere, we shall observe three things: the lumps move forward with the tire, they begin to rotate in the same direction, and they move in nearly the same plane. Uranus and Neptune are so far away that it is difficult to determine their rotation. 4. The evidences which we observe on the earth show that it was once a highly

heated if not a molten spheroid. Besides the condition of the lowest rocks, it has been found that everywhere as we descend into the crust the temperature rises about one degree on an average for every fifty-five feet. At that rate a temperature of three thousand degrees, sufficient to melt all known rocks, would be reached at a point thirty-two miles below the surface. 5. The nebulæ present different forms. If you look at the Milky Way on a clear night, you will see whitish spots like thin, airy clouds. These and many others have been examined by Sir William Herschel. He observed that some appear stationary, others are drawn out into a spiral shape, as if revolving about a given point, still others have the appearance of separating into two or more masses, etc. 6. Some of the distant stars, which are suns like ours, seem to have separated, forming double or even triple and quadruple stars. These appear to revolve around each other; sometimes both are seen, and then only one, as if one were moving behind the other. In 1845 Biela's comet divided and became twins; seven years later they reappeared and had separated 1,404,000 miles. 7. Mercury, it is claimed, is still enveloped by dense clouds, as if it were so hot that its water does not settle to form oceans. Jupiter, which is more than a thousand times as large as the earth, bears evidence that it is still very hot, if not glowing. It is possible that the sun may give off further rings and form other planets. Prof. George Darwin, in a study of the tides, established the birth of the moon by mathematical reasoning. He shows that the earth and the moon once formed one mass, that this mass rotated very rapidly, and that on account of the strong tides produced on it partly by the sun's attraction and partly by its own rotation, a part of the matter was separated from the earth and became the moon, which revolved about the earth very close to it and with the same velocity, as if the two were bound together by an invisible band; and that on account of the friction of the tides the velocity of rotation diminished. Professor Ball, of Dublin, in a lecture on Professor Darwin's demonstrations, published in Philosophical Transactions of 1879, says: "In those ancient times I see the sun rises and sets to give the succession of day and night, but the day and night together only amount to three hours instead of twenty-four." Nor is this all. The rotation will become slower and slower through ages until it shall cease altogether. The moon gradually withdrew from the earth until it is now more than two hundred and forty thousand miles distant. 8. From data at hand it has been computed that the sun is growing slowly smaller —about four feet less in diameter in a century. If this can be proved, it will be a strong evidence in favor of the nebular hypothesis. When Chufu erected the Great Pyramid the sun's diameter was eighty miles greater than it is now, and when Adam left the garden of Eden it was two hundred and forty miles greater. Thus we can imagine the sun's diameter to have been once increased and its substance more and more attenuated until it filled the space within the orbit of Mercury; yes, and more still till it expanded and became a filmy cloud of "star dust"—the world stuff.

9. The spectroscope reveals the constitution of all the solar bodies to be the same as the earth's.

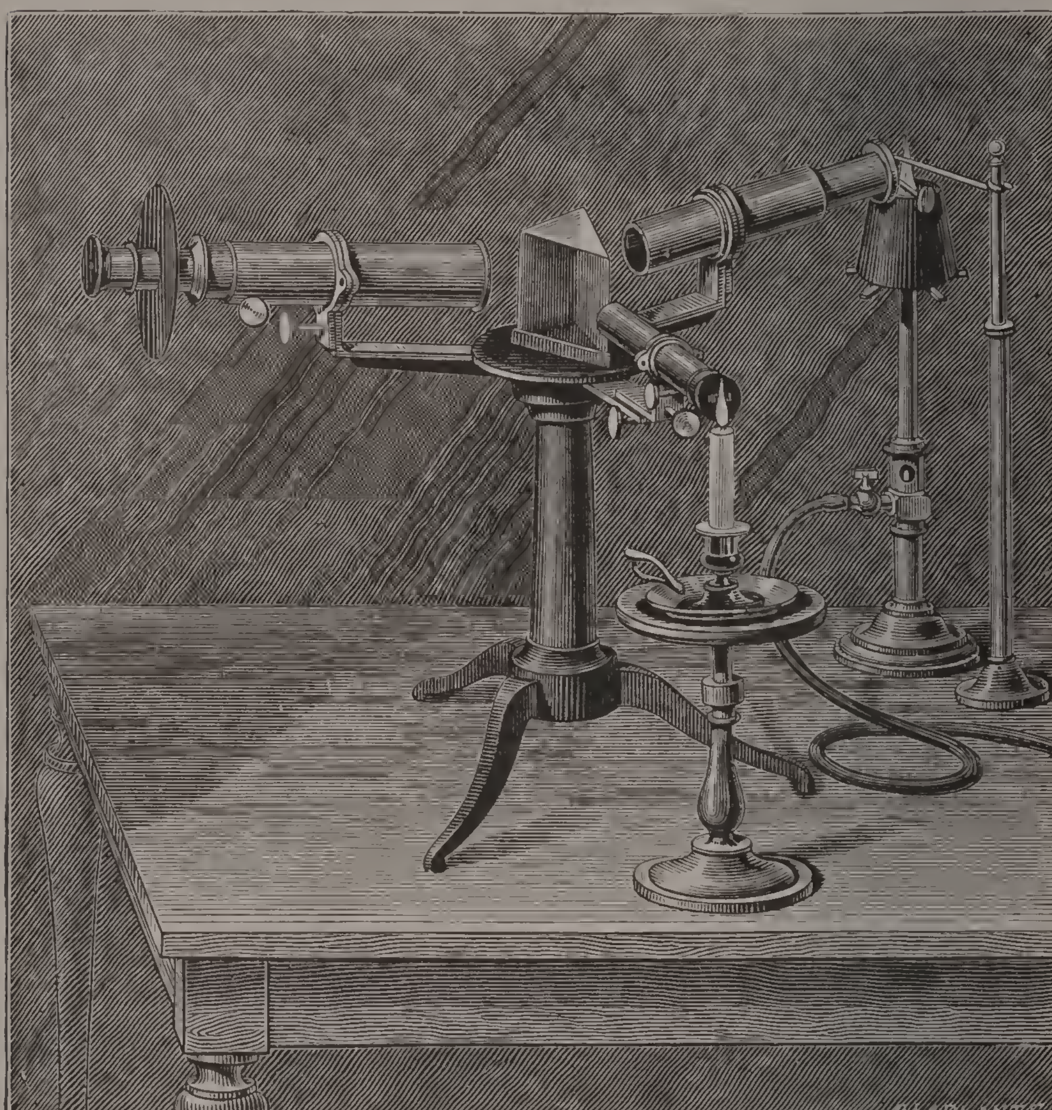
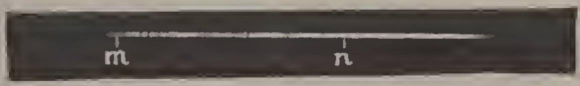


FIG. 11.—Spectroscope.

The spectroscope is a most wonderful, though, when understood, simple instrument invented by two German professors, Bunsen and Kirchhoff. It has proved of the highest scientific and practical value.

It consists of three tubes—one a small telescope, another a tube with a slit for the light to enter to be examined, and a third containing a scale by means of which all the small lines of the spectrum can be definitely located and measured. These tubes are so arranged as to focus on a prism in the center. Here the light of any substance forming a spectrum can be examined.

In Book III a spectrum of sunlight is illustrated. It is continuous, and shows what is often spoken of as the seven rainbow colors. Besides these colors



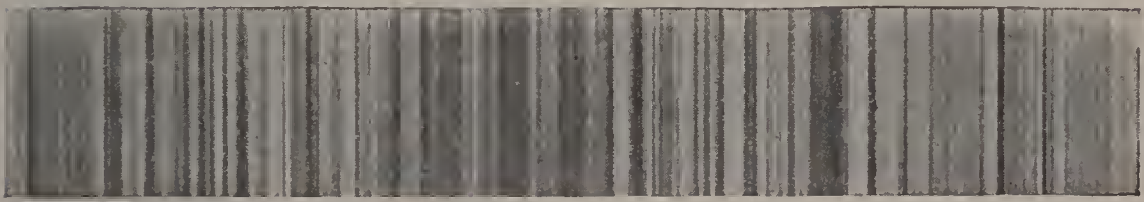


FIG. 12.—Spectrum of Pollux, one of the bright stars in the constellation of the Twins.

forming a continuous spectrum there are narrow, dark lines in it which can be seen only with a telescope. When we burn any substance in a flame its light produces a change in the lines of the spectrum. As, for instance, if sodium is held on the point of a platinum wire in a gas-flame, a bright yellow band appears in the spectrum. Hydrogen burned shows a broad, bright line in the orange and a narrow one in the blue. The mineral thallium (green twig) gives a single bright, green line, and so on. Each substance shows its own peculiar line or lines and no other, and no two substances give the same lines.

The spectroscope is very delicate in its tests. Cæsium was discovered in a mineral water that contained so little of it that forty-two tons of the water had to be boiled down to get a quarter of an ounce of the cæsium. The instrument shows the presence of even one-five-millionth part of sodium in a compound.

The sun's rays and the reflected light of the planets, and even of the moon, have been examined, and their spectra show that these bodies contain most, if not all, of the substances found on the earth. This looks as if they were a "slice of the same loaf."

Thus has science imprisoned wandering rays of light from even the most distant stars, which rays started hither long before Alexander marshaled his hosts to conquer the world, and has made them give up the secret of what substances their orb is composed.

CHAPTER VI.

THE ERA OF ANCIENT LIFE.

THE SILURIAN AND DEVONIAN AGES.

As I have said, there is some evidence that the Archæan rocks were chiefly sedimentary, but they have been metamorphosed by the agencies already mentioned. If they were sedimentary in origin, all the known lands of the earth must have been under the dominion of the sea. Then the first chapter of the earth-book must have closed with the elevation of Archæan areas.

Starting from Archæan areas, we may walk in almost any direction, particularly southward, and come upon a different formation. The character of the rocks in most places shows that they belong to another period. We also discover in it distinct forms of life, both animal and vegetable.

In some places this formation lies smoothly upon the Archæan strata, but in other places the older rocks were first very much eroded and irregularly grooved by water (Fig. 7). In other localities still they were tilted (Fig. 13) and considerably folded before the newer strata were deposited upon them. It is evident, then, that the newer strata would not conform in position with the older rocks, neither would they be of uniform thickness.

THE CAMBRIAN PERIOD.

The new strata have received the name Cambrian. They are exposed around Archæan areas both in America and Europe. They were first carefully

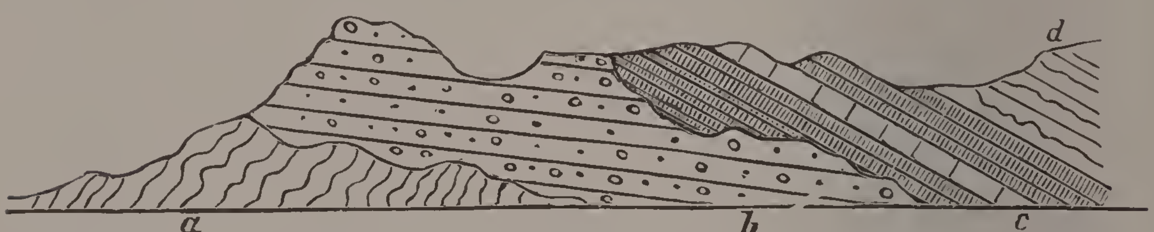


Fig. 13. — A cross-section of highland. *a*, Archæan; *b*, pre-Cambrian; *c*, Cambrian; *d*, Silurian.

studied in Wales, which was formerly known as Cambria, whence their name.

When the Cambrian age began, only a few small areas of rocky land stood above the almost universal dominion of the sea. Everywhere in this sea, especially near the shore-lines, sediments were being deposited. These were of three kinds: those obtained from the rapid erosion of the land surfaces, those resulting from chemical combinations in the water itself, and the remains of animal and plant forms.

The rocks of this period are very thick in some places, and consist mostly of limestone. This is natural, for the atmosphere must have been full of such acids as carbon dioxid, hydrochloric, and sulfurous, and the sea water must have contained large quantities of lime, magnesium, silicon, sodium, and aluminum. The silicon in the water, no doubt, took oxygen from the air and formed the quartz, not so much during this age as during the previous one. In the same manner the aluminum formed our clay, and the lime in the water united with the carbon dioxid from the air and formed the limestone. Magnesium formed the gypsum beds. The sodium of the water united with the chlorin in the hydrochloric acid and formed salt. The crinoids, and particularly the corals, must have taken large quantities of lime out of the sea water, and thus have purified it, while the salt was left, making it briny.

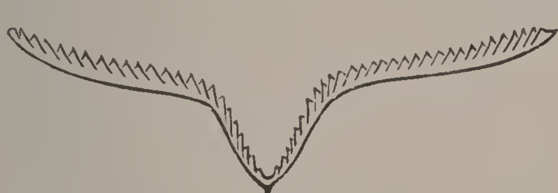
Fig. 14.—A trilobite of the Cambrian period.

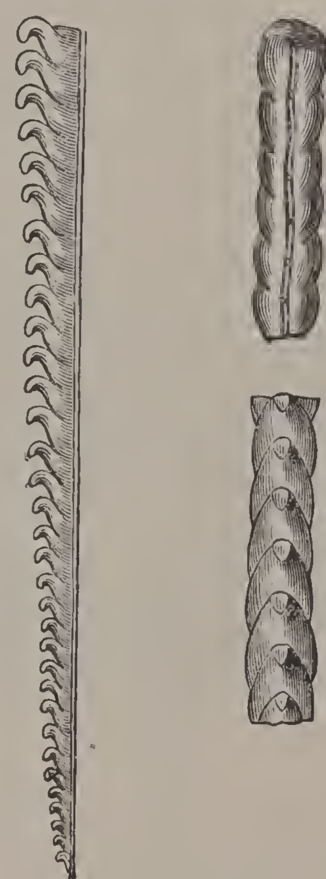
The best way to become acquainted with formations of rock is to go to some valley or cut where the different layers are visible; the typical forms of life, however, may be more easily studied and better understood by examining the fossils in a museum where they are arranged in the order of the ages to which they belong.

There is very little evidence that either plant or animal life existed on the earth during the Archæan age. Some geologists have found what appear to be remains of plants; indeed, they are quite sure that these are fossils of plants which existed during that period. But when we examine the rocks immediately on top of these Archæan strata, we soon find fossils of both plants and animals.

Fig. 15.—Lingula, showing stem by which it attached itself to rocks.

The first fossil to attract our attention is a crab-like animal called the trilobite. As you may see from Fig. 14, it is divided into three lobes by two divisions along the back. It has a roundish head and rather prominent eyes. There are many kinds, varying in size from a pea to several feet in length. Then, too, a little bivalve called the lingula seems to have been abundant, as the rocks are full of their fossils. Although the trilobite is the most striking form of life we meet, it is by no means the earliest, nor was the lingula, for long before either of these two animals made its appearance, the waters evidently abounded in smaller protozoan forms. There were also animals in the sea water that looked somewhat like our sponges. Almost everywhere in these rocks are found coral fossils. I noticed three leading kinds, named, from their shape, cup, honeycomb, and chain corals. As corals can not live in cold water, so far as we know, and these coral fossils are found even in what are now arctic regions, the seas must have been more or less tropical all over the world. Other fossil remains of animals look like beaded picture-molding; they are known by the name of graptolites. I have often found in these rocks animals that look like lily-buds, called crinoids. In their manner of life they did not differ much from our sea-urchins and starfishes that also existed in that age, as we may see from the fossils discovered. The stone lilies, however, are fixed by a stem to some object





Figs. 16 and 17.—Graptolites.

in the sea, while the sea-urchins and starfishes can move about.

Thus we see that life made a beginning in all its types below the vertebrates. There were protozoans, echinoderms, cœlenterates, mollusks, and crustaceans.

Plant life, too, made its appearance in the lowest forms, such as the fucoids, a species of seaweed which later became so abundant, and the little wheel-shaped rhizopods whose silicious skeletons make up the greater part of the rock in some places, not only in this time but in later periods. As vegetation is necessary to animal life, the sea doubtless contained myriads of minute plant forms which furnished food for the primitive animals already beginning to multiply. On the other hand, the land areas were still barren of vegetation except where the lowest forms of land plants covered the rocks in dark spots, as we now often see them on old stones.

Fig. 18.—A modern crinoid animal, which, like a plant, lives attached to the bottom of the ocean.

THE SILURIAN STRATA PROPER.

Continuing our walk southward, we come upon other strata, not so different from the Cambrian as the Cambrian is from the Archæan, and yet in some places so distinct as to be easily distinguishable.

At the close of the Cambrian age another change in the level of the crust must have occurred. The land areas were enlarged, and the sea bottom about the existing shores was raised. How much time intervened is not known. In Wales the interval is more marked than in this country, and it was in Siluria, Wales, that Professor Murchison first studied this new formation. To distinguish it from the Cambrian, which he called the Lower Silurian, he gave it the name Upper Silurian. These two rock systems have been described in Chapter II as formation Number 2.

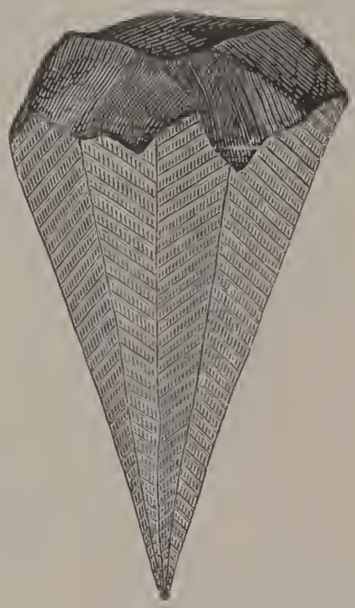


Fig. 19. — Conularia, a mollusk having a pyramidal shell.

During this age thick strata of limestone were deposited. Cup, chain, and honeycomb corals abounded, forming great reefs everywhere. As ripple and other shallow water-marks are frequently met in the strata, the sea must have been comparatively shallow.

Most of the forms of life introduced in the foregoing age continued, while many new and distinct species were added. More than ten thousand species belonging to this age alone have been described. Among the new forms we find two striking cephalopods (*cephal*, head + *pod*, foot). One was a long, straight-chambered sea-monster in the shape of a baseball bat, often more than fifteen feet in length. This has a special name, orthoceratite (straight hook). The fossils separate easily at the articulations. A narrow tube or cord seems to pass through the body from head to tail. These animals were not only large but numerous, and may easily have been the monarchs of the seas. Another cephalopod was similar in form, except that its shell was coiled like that of the nautilus, whose beautiful "chambered cell" has been so well described by Oliver Wendell Holmes in his poem "The Nautilus."

Fig. 20.—Orthocerus, a cephalopod (restored). The shell in the upper part is cut away so as to show a vertical section. *T*, muscular tube ("funnel") by which water is expelled from the mantle chamber; *C*, air chambers; *S*, siphuncle. In the background is a Silurian cephalopod of the nautilus form, curved like a ram's horn.

In the latter part of the age small, quaint-looking fishes appeared. They foreshadowed what the next age was to be. The abundance of animal life indicates that the seas abounded in vegetable growth. There were algæ, and perhaps many other seaweeds, but as the early plants consisted mostly of soft tissues, they were not so well preserved as the animals. On the land a few ferns and club mosses began to form a brownish-green covering.

There was no rising sun. His light, no doubt, glimmered through the misty atmosphere, distinguishing night from day. But there were no waving

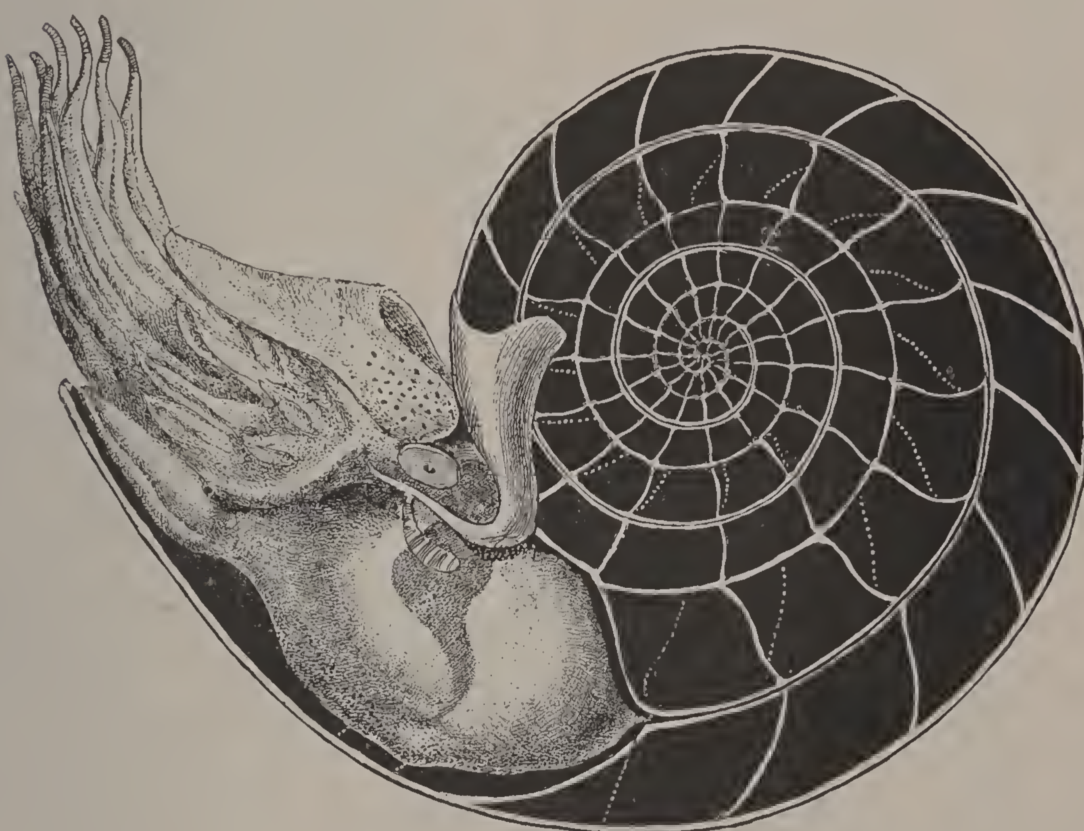


FIG. 21.—The nautilus. A cross-section, showing the chambers and the animal in the shell.

trees, no beautiful flowers, no croaking frogs, no singing birds, no climbing monkeys; and why should there have been? The world was silent as the deep except for earthquake rumblings. There was no eye for beauty, no ear for song, no taste for delicious fruits.

This was the age when invertebrates had everything their own way; it extended through a long period of time, perhaps millions of years, but the end came. The crust shifted; more land was wrested from the grasp of the sea, in broad belts about the existing islands, particularly at their southern limits. The sea settled down in smaller and perhaps deeper hollows to begin the problems of another age.

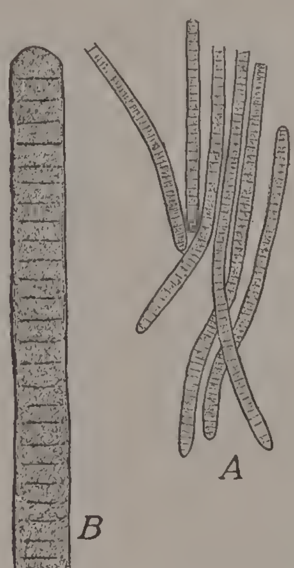


FIG. 22.—Green and brown algæ.

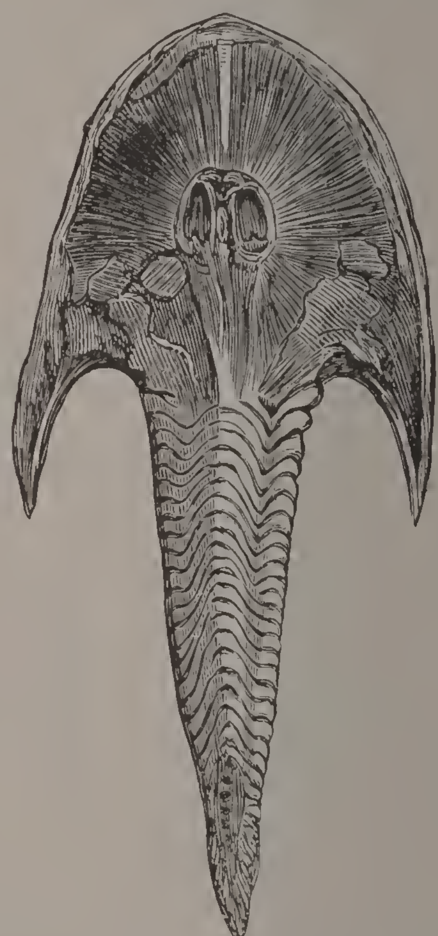


FIG. 23.—One of the earliest fishes, found in old red sandstone stratum.

THE DEVONIAN PERIOD.

On top of the Silurian rocks we find other strata which crop out in many places, and hence may be easily studied. The rocks differ very little from those in the Silurian age, and are not readily distinguishable from them; but in the fossils we notice a great difference.

In examining the fossils of this period, fishes at once attract our attention. There are so many, and some are so large, that the age period has been truthfully called the age of fishes. You would scarcely recognize them, for the fossil fishes do not look very much like those of this time. They were covered with thick, bony scales (and for this reason they are doubtless so well preserved); they had teeth two inches long; one has been found in Ohio whose head measured six feet across, and whose eyes must have been three inches in diameter. They looked

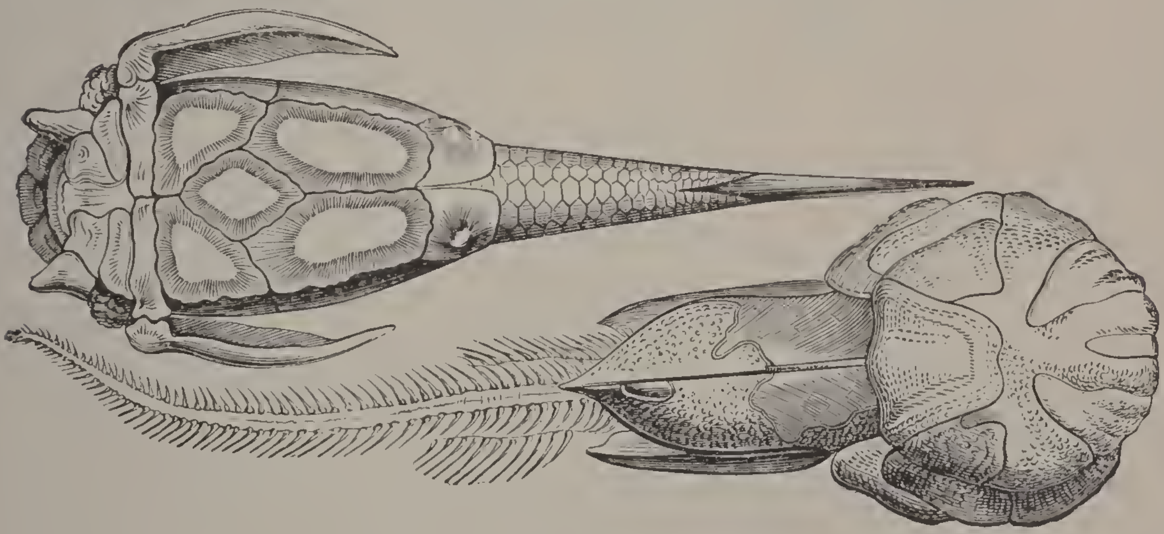


FIG. 24.—Ancient fishes.

lopsided, for one side of the tail was large and the other small, something like the thrasher sharks of the present day. The skeleton consisted entirely of soft bones. From the appearance and large teeth of the newcomers, we conclude that they must have been genuine fighters, and doubtless there were great battles fought in those waters.

It must not be supposed, however, that fishes were the only animals living during this age. Many of the invertebrate forms continued their existence. The brachiopods and cephalopods increased in size and number of species, but the trilobites diminished in both. A species of the ammonite cephalopods came in during the latter part of the period, and reached its highest development in the age of reptiles.

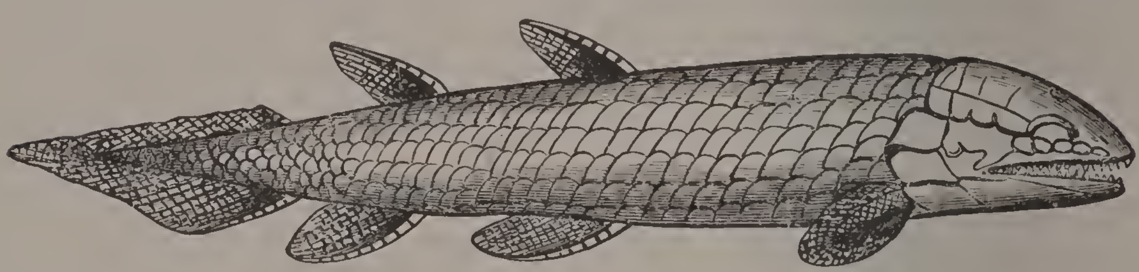


Fig. 25.—A type of Devonian fishes.

This cephalopod looked like a large sausage, larger at one end than at the other. It resembled the straight-chambered orthoceratite, except that it was rolled in a coil which was curiously divided on the inside into chambers. The shell had horny projections on top, but was smooth and pearly beneath. It was, in fact, a higher form of the Silurian nautiloids (see Fig. 21).

Fishes introduced another type of animal life—vertebrates—a class to which man himself belongs, namely, the back-boned animals.

The earth was, no doubt, clothed with verdure; flowering plants and deciduous trees were still absent, but there were ferns and cone-bearing trees which attained their highest perfection in the next age. We

FIG. 26.—Devonian forest (restored).

see that each age has some small specimens of the new type of life that is to become prominent in the following age—that is, one age foreshadows what is coming in the next.

Fossils of insects are rather common; some of them were of large size. The species which live on the nectar of flowering plants could not have existed then. Such insects and flowering plants seem to have developed side by side through the later ages.

Thus we see that in the third chapter of the earth-book, whose rocks we have called formation Number 3, the business of making limestone continued, and the battle of life was still confined to the seas. This age closed, as did the previous one, with the upheaval of considerable land, increasing the areas of the continents, and followed by a period of rest.

Table of Geological History.

LIFE.					ROCKS.	
PLANTS.	ANIMALS.	AGES.	ERAS.	AGES.	PERIODS.	KIND OF ROCK.
		Man.	Psychozoic.	Recent.	Present river, lake,	and sea deposits.
Modern plants, trees, and flowers.	Mastodon, cave-bear, tiger, lion, elk, rhinoceros, armadillo, butterflies.	Mammals.	Cenozoic.	Quaternary.	Post-Glacial: Terrace. Champlain.	Alluvial and lake deposits.
					Glacial: Third Glacial. Second Glacial. First Glacial.	Moraines, upper and lower till.
Magnolia, figs, cypress, palms	Primitive horses, whales, wolves, hoofed animals, monkeys, cats.			Tertiary.	Pliocene. Miocene. Eocene.	Atlantic, Gulf, and Pacific areas. Rocks, saline, siliceous, and lignite.
Sigillaria, lepidodendrons, calamites, equiseta, tree-ferns, and other coal-plants.	First mammals, dinosaurs, and other great lizards, archæopteryx, pterodactyl, crocodiles, sponges, turtles.	Reptiles.	Mesozoic.	Secondary.	Cretaceous. Jurassic. Triassic.	Limestone, chalk, conglomerates. Atlantic slope beds. Connecticut river beds.
	Amphibians, spiders, cockroaches, land shells, fusilina, new brachiopod.	Acrogens.	Paleozoic.	Carboniferous	Coal measures.	Shale, coal, conglomerate, limestone.
					Subcarboniferous.	Sandstone, Mauch Chunk limestone, Mississippi.
Ferns, sea-weeds.	Ganoid fishes, goniatites, lamellibranchs, blastoid crinoids, discina.	Invertebrates.		Devonian.	Shales. Sandstone. Limestone.	Chemung. Hamilton, Oriskany. Corniferous, Helderberg.
Few land-plants, lichens, algæ.	Insects, nautiloids, orthoceratites, spirifers, crustaceans, brachiopods, corals, sea-urchins.			Silurian.	Upper Silurian.	Limestone—Niagara, Clinton. Sandstone—Medina.
	Fishes, insects, (?) mollusks, crustaceans, crinoids, coral.				Lower Silurian.	Galena, Trenton, Chazy.
	Trilobite, lingula, brachiopod, graptolites.				Cambrian.	Potsdam, sandstones, shales, conglomerates.
Small marine plants. (?)		?	Azoic	Archæan.	Huronian—Algonkian. Laurentian.	Crystalline rocks, such as granites and iron beds.

CHAPTER VII.

THE ERA OF ANCIENT LIFE.—Continued.

THE CARBONIFEROUS AGE.

Investigation of formation Number 4, the rocks that lie exposed on top of those formed in the Devonian age, has brought to light fossils of quite a different character. Among the strata are layers of black rock. In central Illinois this rock is not nearly so hard as limestone, and seems to be quite unlike it in structure. We call this rock coal. Alternating with the coal layers are layers of shale and limestone. The period during which the coal was formed is known as the Carboniferous age; the lower layers are called the Subcarboniferous.

The number of layers or coal-seams, as they are called, varies in different places from a dozen to one hundred and seventeen, the latter being in Europe, where the total thickness amounts to two hundred and seventy-four feet. In Illinois the total thickness of the coal-seams is seventy feet. The layers vary from a few inches to forty feet in thickness, but in few places are they over seven or eight feet thick.

The coal-seams are by no means all the rock that was formed during this age; perhaps they are not over one-fiftieth part of it.

Coal is a great blessing to man. It furnishes him fire for warmth and for steam-power, and gas for lighting. Millions of tons are mined and consumed every year. In 1900 Great Britain mined two hundred and fifty-two million tons, and the United States two hundred and seventy million tons. All the coal mined in the world during that year amounted to

FIG. 27.—Vegetable structure in coal as seen with a microscope.

eight hundred and forty-five million tons. It is claimed that if coal-mining continues to increase as it has done during the past ten years, Great Britain will exhaust her mines in about a hundred years.

When we say that coal is a great blessing to man, we must not forget that there are few blessings without some drawbacks, and coal is no exception. There are thousands of people engaged in mining coal. Many of them scarcely ever see the daylight, being obliged to work below the surface of the earth. In many places wages are so low that the wives and children of miners are in poverty, which means neglect in education, and too often in cleanliness.

I once went to visit some coal-mines in central Illinois. The first mine I saw was one that was entered on a hillside, almost on a level. This coal-seam was rather near the surface of the earth, and the coal was of comparatively poor quality. The cars were run into the

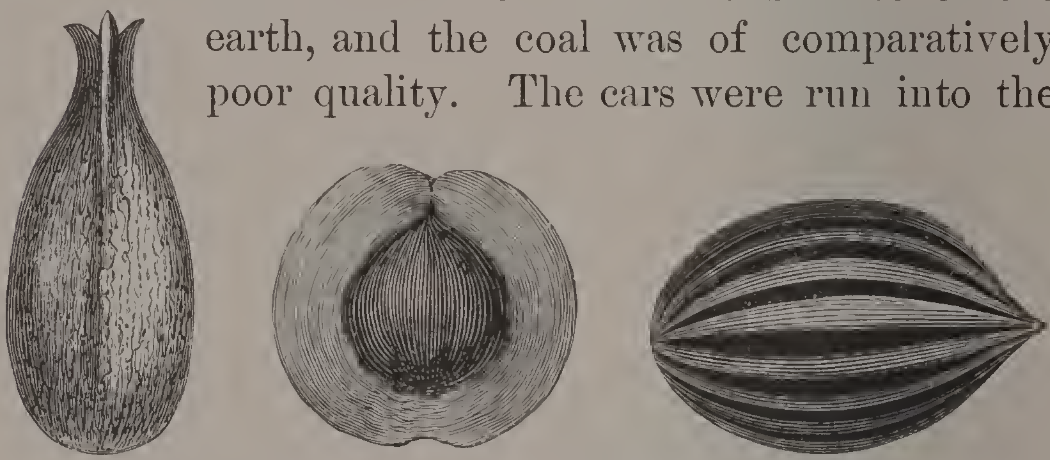


Fig. 28.—Fruits of the Carboniferous age.

hillside on a track, and the miners loosened the coal with a pickax and shoveled it into the car.

All the important mines in that region, however, are one hundred feet or more below the surface. First a hole is dug down to the coal, called the shaft, and its sides are "boxed," that is, boards are nailed in against the soil, so that it will not cave in. In this shaft the "cage" is lowered. The manager of the mine let us down in a cage lowered by means of a wire rope, much like an elevator in our city.

When we reached the floor of the mine we discovered, by light from the tiny lamps fastened to the miners' caps, that there were vacant halls and rooms where the coal had been taken out. In some places coal had been allowed to remain as pillars to keep the roof of the mine from falling down. Wooden posts had also been set up for the same purpose. In most parts of the mine the roof was so low that we could not stand upright.

At the foot of the shaft were tramways running off in several directions. On these were the cars. Each man had his own car to fill, for which he was paid at a uniform price. As each car was filled, the miners pushed it along the tramway to the cage, where it was raised in the shaft by a hoisting engine and the coal dumped into the freight car. In some of the old mines, where mining is done at long distances from the foot of the shaft, they have mules to draw the cars.

I noticed that the men worked with very little clothing on, and that each miner had a little lamp fastened to the forepart of his cap. This is a very interesting lamp invented by Sir Humphry Davy. It consists of a little cup containing oil, with a fine screen around the flame. The screen prevents the gas that may be in the mine from reaching the flame and thus causing explosions. Sometimes explosions do occur through carelessness when gas is accumulated in the mine. There is also danger to miners from fire-damp or choke-damp. Fire-damp is carbonic acid, which often collects in the mine; choke-damp is marsh gas, which seems to come from the coal-seams.

Fig. 29.—Coal-mine, showing miners in cage at the bottom of the shaft. Part of mine and tramways on which the small cars are pushed to the shaft.

I am told that other mines do not differ much from the one which I visited, except that in many parts of the world they are much farther below the surface. Now you will want to ask, "How is coal formed?"

HOW IS COAL FORMED?

If you will go to the coal-yards you can in a few minutes, no doubt, find a number of pieces on which are distinct impressions of leaves or stems of plants. In some mines there are found stumps and logs changed to coal.

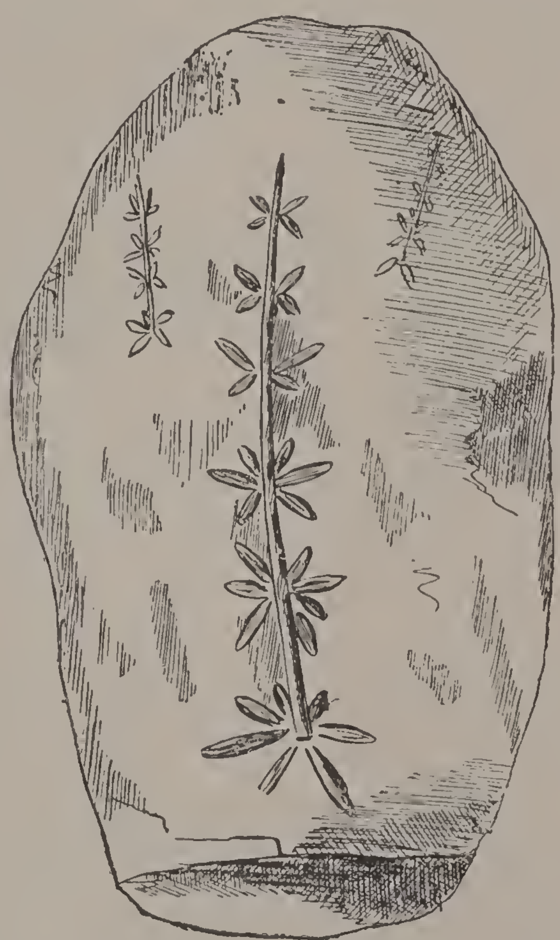


Fig. 30.—Stem of a calamite in carboniferous sandstone.

If we examine thin, prepared slices of coal with a microscope, we can discover vegetable cells and fibers; in pure specimens we can find even the blossoms and fruits of trees.

Lyell, a great English geologist, found in one place seventy-three tree stumps in an area of a quarter of an acre. Some of these were no less than two and a half feet in diameter, and one log was thirty feet and another fifteen feet in length.

The logs were so pressed together that they made a layer of coal only about an inch in thickness. He found that these tree-stumps had their roots embedded in a layer of shale, which was mud or clay during the growth of the tree, and had been changed to rock beneath the coal.

I have read other descriptions of the rocks of the Carboniferous age, and all agree that beneath the coal-seam there is always a layer of shale, and that in this shale are the roots of trees. Sometimes the seams have shifted from a horizontal position; in such cases

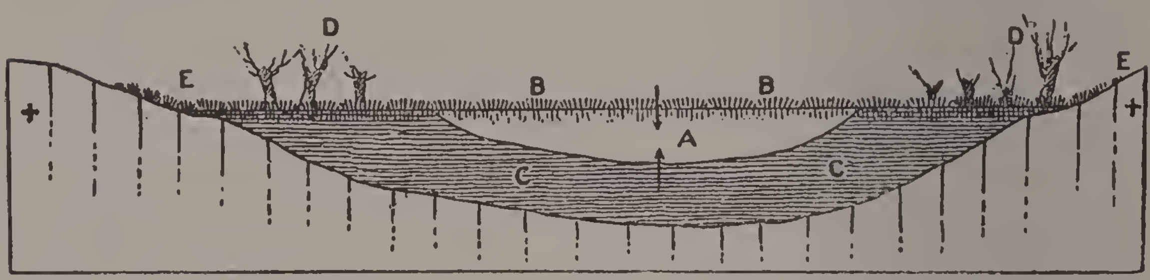


FIG. 31.—Section of peat-bog. *A*, remnant of pond; *B*, *B*, living sphagnum; *C*, *C*, peaty mass from disintegration of surface layer of plants; *D*, *D*, solid part of swamp with trees. (After Shaler.)

the stumps are no longer upright, but oblique, showing that the seam was tilted after the coal was formed.

All these facts will suggest to you that coal had something to do with vegetation, and is probably made from it, but how? At the present time, in the bottom of many peat-bogs, there are several feet of decayed vegetation, so well packed together that it forms a kind of poor grade of coal called peat. Beneath this is a layer of clay, in which are embedded the roots of plants and vines. In the Rocky Mountains we often find brown lignite, which is wood partially changed to coal. These facts lead us to believe that the coal has been formed in swamps and low places, and in the presence of water. Indeed, when we come to examine the location of our Pennsylvania coal-fields, we learn that they occupy what were once swampy basins near the ocean, surrounded on three sides by high ground, but open on the southeast toward the sea. In these swamps and along their borders flourished great ferns (Fig. 32) and trees in tropical abundance, for the climate of the age was warm and moist. As the vegetation decayed, it piled up in masses in the bottom of the marsh, and was preserved by the water and the acids produced by the decaying matter itself. On top of it sediments gradually formed, which helped to pack and preserve the vegetable matter beneath. After such a period the land, no doubt, subsided, allowing the ocean to overflow the marshy tracts. It must have remained under water for some time, as we now find layers of shale or limestone of varying thickness deposited on top of the coal-seams. Again the land rose, vegetation grew in the swamps and decayed and accumulated as before, until the land subsided once more. Thus the process was repeated as many times as there are seams of coal in that region.

Geologists used to think that coal had been formed only at the mouths of rivers where vegetation had been washed down by freshets and piled up in great masses. This may have been true to some extent, but

Fig. 32.—An ideal forest of the coal period. Lepidodendron on the right. Sigillaria on the left. Calamites and ferns in foreground.

the stumps which are found in coal-beds argue to the contrary, for trees evidently grew where the stumps are found. Then, too, only impure coal could have been thus formed, for at the mouths of rivers the vegetation must have been mixed with great quantities of mud brought down with the trees by the freshets. The quality of coal depends upon the amount of carbon it contains. The very best hard coal does not contain over ninety per cent of carbon; most of that which we use in our stoves and furnaces consists of scarcely more than half carbon.

Fig. 33.—Cast of lepidodendron bark in sandstone.

We may get some idea of the abundance of vegetation which flourished during this age from the number of fossils. They sum up eight thousand six hundred and sixty different kinds of plants. These plants consisted of cone-bearing trees something like our pines, great ferns (mostly tree-ferns); one kind, the lepidodendron, has the bark peculiarly marked in five-sided figures.

It will be interesting to gather some facts concerning the time it must have taken to form the coal-beds. Geologists have computed, from the decay going on in forests at the present time, that it would take one hundred years to form a layer one-eighth of an inch thick. To produce the aggregate depth of two hundred and fifty feet it would require at least a million years. Adding to that the time it would take to deposit the other strata between the coal-measures and above them and belonging to this age, we should get from two to three millions of years for the total period. The geologist is so accustomed to think of long periods of time that he scarcely takes notice of a thousand years, but always talks of millions.

It must, however, be remembered that on account of the climate and the kinds of plants, the growth of vegetation in that age was much more rapid, and decayed matter accumulated much faster than it does now; these facts would proportionately shorten the time required.

ANOTHER USEFUL CIVILIZING MINERAL.

Frequently in connection with coal we find beds of iron, varying in thickness from a fraction of an inch to many feet. This iron almost invariably rests upon a bed of clay. It is not ferric oxid like that in the Archæan rocks, but is found combined with carbonate of lime, forming what is known as ferrous carbonate. When clay is mixed with it, as is often the case, it is called clay ironstone.

Such iron beds are found in connection with all coal-beds, not only those of the Carboniferous age, but those of all other ages, for it must not be supposed that coal was formed only during the Carboniferous period.

As we always find iron in close proximity to coal, we conclude that plants must have had something to do with the formation of iron as they did with the production of coal. In boggy places I have often seen rusty sediment; sometimes this sediment had hardened into "bog-iron." In all geological ages there are rocks colored brown or red by the iron in them, but in the neighborhood of iron beds there are no such colored rocks. It would seem, then, that in some way, by means of water, plants leached the iron out of the rocks, and that water carried it down into low, swampy places, where it settled on clay beds and formed iron ore.

There is here a wise provision which looks forward to the time when man discovers the iron and makes it contribute to his civilization. The nearness of coal to iron enables man to smelt the ore at the lowest possible cost. The rapid industrial development of the western part of England is due to the coal and iron beds which are found there side by side.

PETROLEUM.

In many parts of the world spring-water has been found covered with a film of oil. Some springs contained a large proportion of oil. Such a spring was discovered near Titusville, Pa. Accordingly a company was organized, and a well sunk in 1859, which reached oil at a depth of thirty-five feet. Since then many other wells have been bored, not only in that State but in many other parts of the world; and the total output has increased to 155,000,000 barrels annually. From some of these wells the flow was very great. Some in Ohio yielded 5,000 barrels a day, and some in Asia, near the Caspian Sea, as many as 25,000 barrels a day.

The United States, in 1900, produced 63,362,704 barrels, valued at $75,752,691. This oil is known as petroleum—two Latin words which mean rock-oil. Petroleum was known even to people of ancient times. It has been discovered in all civilized parts of the world, not only in Paleozoic rocks, but in later for-

Fig. 34.—Oil-field in southern California.

mations as well. In Pennsylvania petroleum is found in sandstone strata of the Upper Devonian formation; in Ohio in porous limestone of the Cambrian; in California and in Europe in the Tertiary. Like water, it collects in porous rocks and seams, usually limestone or sandstone between two layers of shale. Generally gas is found in the upper part of the fissure, oil next, and water in the bottom. Salt beds are frequently found in connection with oil.

ORIGIN OF PETROLEUM.

What is the origin of the gas and the oil? We may take a piece of soft coal and heat it in a retort. We obtain gas, oil, and a black tarry substance called bitumen, besides a great many other products. It is often supposed that petroleum and natural gas have been produced in a similar way from the coal. The heat in the earth is thought to drive off the gas and the oil from the soft coal, leaving it anthracite. But this does not seem to be the case; oil is not always found near coal-seams, nor do oil-bearing rocks always give evidence of great heat. It is quite probable that gas and petroleum were produced independently of the coal; and since salt beds are usually found close to the oil, the theory is that it is formed at ordinary temperatures by organic matter. The coal was formed from land plants in the presence of fresh water; the oil from organic material in the sea in the presence of salt water.

It appears that marsh gas, CH_4, is constantly escaping from the petroleum. In this way the bitumen in the neighborhood of salt beds was probably formed. Professor Liebig suggests that the diamond itself is formed by crystallization from petroleum of greater or less density.

During the Carboniferous age the land areas were not much increased. There was comparatively little land. The mountains were low, so that there were no snow-capped peaks to chill the atmosphere and cause winds to any great extent. The climate, therefore, must have been warm over the entire globe. This is also suggested by the foliage, the fossils of which we find in coal-seams. At least three thousand kinds of tree-ferns have been described, and eighty per cent of these are found in what we now call the tropical regions. The tree-ferns of the present day are all in the warm climate. Some of the other vegetation must also have been tropical. We conclude, therefore, that Great Britain, the northern part of America, and even Siberia, must have had a tropical or semitropical climate.

The air must have contained a much larger proportion of carbon dioxid than it does now, for all the carbon in the coal must have been taken from the atmosphere by growing vegetation. The plants, which were very much alike, also suggest that the air contained a great deal of moisture. The carbon dioxid and water together in the air prevent the sun's heat from radiating, very much like glass. Glass lets the sunlight through, but keeps the heat in, as any of us may find out from going to a green-house, or even to our own windows. Experiment was made on Mount Whitney with an enclosure covered tightly by glass. The sun alone shining through the glass produced a temperature of 268° within, while the temperature in the shade outside was only 58°. Kept warm and moist by the protecting atmosphere, the earth was like a great hothouse where dense jungles of vegetation grew in luxuriance and stored up carbon, which ages after was destined to become so invaluable to modern civilization.

We have thus briefly mentioned the leading facts of the Cambrian, Silurian, Devonian, and Carboniferous periods. It was during these periods that most of the dry land was formed. At the close of the Archæan age there was a V-shaped continent about Hudson Bay, and small islands in the Appalachian ridge and in the Rocky Mountain region. Although the number of square miles of land was not large then, it was enough to fairly outline the great continent to be. At the close of the ancient-life era the American continent was practically complete. Only small strips of land have since been wrested from the sea along the ocean borders and in the Mississippi and Missouri valleys. The land was low and the seas wide and shallow; but a great change marks the close of the Carboniferous age. The Appalachian Mountains rose to splendid proportions, probably higher than the Rockies have ever been. It has been called the period of the Appalachian revolution.

In other parts of the world equally great changes must have taken place in land areas. From the irregular ridges in the floor of the Atlantic and Indian oceans, it has been supposed by some there was a great continent stretching eastward and uniting South America, Africa, and Australia with the Javan group of islands, if not with the Asiatic continent itself. It has been given the poetic name of Gondwana.

However this may have been, and whatever the elevations and subsidences, the close of this period is the starting-point of new conditions, and therefore of new life. The Cambrian strata, as we have seen, at once introduce us to primitive types and numerous species of life. Many of them gradually developed higher forms, and a new type, the vertebrates, is added at the close of the Silurian, when fishes appear. Plants of various species filled the sea and covered the low-lying continents. Indeed, some of them had reached perfection in the Carboniferous age and already began to decline. The trilobite and some of his fellow-paddlers passed away never again to appear. For a long time it had held sway. He was in his glory in the latter part of the Silurian age, but after that he slowly waned. The changes that time had brought upon him were such that his line has been classified into six families.

This was the era of ancient life known as the Paleozoic (paleo, ancient, and zoic, of life), or the era of invertebrates, for in the following eras these were subordinate to the vertebrates. The changes were so great and the life so different from the Paleozoic that time since then has been called the neozoic, new life.

Professor Le Conte sums up the closing Paleozoic life thus: "During the coal age there were extensive marshes overgrown with great trees of Sigillaria, Lepidodendron, and Calamites, whose dense underbrush of ferns was inhabited by insects and amphibians; no umbrageous trees, no fragrant flowers or luscious fruits, no birds, no mammals. These 'dim watery woodlands' are flowerless, fruitless, songless, voiceless, except the occasional chirp of the grasshopper. If the observer were a naturalist he would notice also the complete absence of modern types and animals—it would be like another world."

CHAPTER VIII.

THE AGE OF GREAT REPTILES.

Having considered the coal-bearing rocks, we naturally ask, What next? In many places the coal is covered with other rocks. Their story is a new chapter in the earth-book.

In olden times people did not use any capital letters or any marks of punctuation, and often no headlines. It is therefore no easy matter to tell where one chapter or one sentence leaves off and another begins. The last of the coal-bearing strata are not clearly distinguishable from the first layers of the next age, particularly in some places where the new strata conform quite closely to the old. But in other localities there was not only upheaval, but time enough for the waters to cut out hills and valleys, so that when the rock strata were laid there was a lack of conformity (see page 47).

The rocks of the new age we have located as formation Number 5. The best known among them are found in the Connecticut valley. The stones here exposed are mostly reddish brown, and are often known by the name "new red sandstone," to distinguish them from the old sandstone of the Silurian period. They are extensively quarried and used for building-stone. Many of the brownstone fronts of Staten Island, in New York, were taken from these beds. These "Connecticut River beds" have become famous for the many curious marks found on them. In the London Museum is a slab taken from these beds, six by eight feet, on which may be seen more than seventy tracks. Most of the tracks are from ten to twelve inches in length ; the largest is fifteen inches long.

In Wyoming and Colorado Professors Marsh and Cope found some striking fossils belonging to this

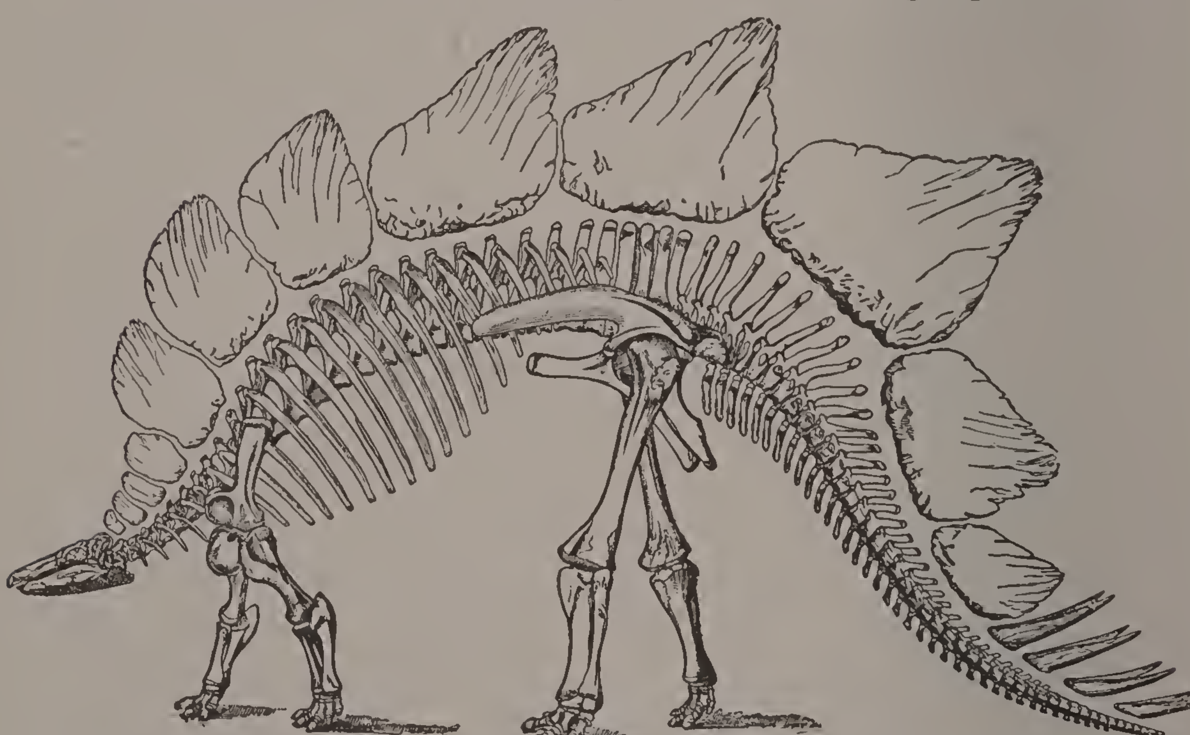


Fig. 35.—Stegosaur, a land reptile of Jurassic age. Small head and brains, combined with large body, protected by huge bony plates.

period. The skeleton of one of these fossils is now in Yale College. Its thigh-bones are over six feet long, with the other parts of the body in proportion, except the front legs, which are small. The animal, we should think from its structure, walked half-erect on its hind limbs like a kangaroo of the present day. It had a long alligator tail and large jaws full of teeth an inch and a half in length. The name given to this animal is dinosaur, which means a terrible lizard. These creatures ranged in size from a small rabbit to the largest beast ever known — perhaps eighty feet in length.

FIG. 36.—Track of reptile on Triassic rock.

In the Delaware valley has been found the green lizard, or megasaur. It seemed to be fish, crocodile, and beast combined. A dozen or more "saurs" have been found and described, but I will not trouble you with their long names. If you should see their skeletons in a museum you would know from the last syllable of the name that they belong to this age. Duplicates of the originals have been cast and are now in all the important museums.

Another curious-looking creature of this age is one which has a large, birdlike head full of sharp teeth, and broad-webbed front feet which are long and wing-shaped. It is difficult to see whether it is reptile or bird. It looks as if a reptile were in the

Fig. 37.—Pterodactyl.

process of changing into a bird and had not got over half-way through it. It is named pterodactyl, which is wing-finger in English.

Another animal existed in those days that seems to have been a greater success as a bird: the archæopteryx (first bird); at least it had feathers, as may be seen from the fossil found in Germany. Neither of these creatures can be considered as perfect birds; far from it. The archæopteryx was probably able to fly in the air clumsily, as our bats do, but the pterodactyl could fly only in a downward direction like the flying squirrels.

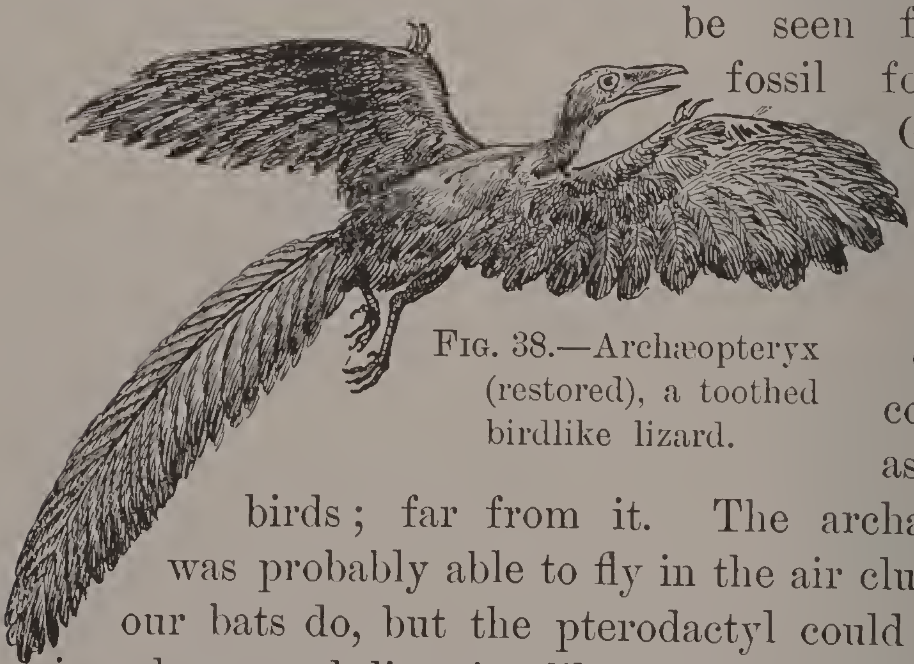


Fig. 38.—Archæopteryx (restored), a toothed birdlike lizard.

Through the surging waters of this age glided a long animal of graceful shape. Its round body was furnished with four short legs with flapped feet, by means of which it pushed its way through the waves, holding its snaky head and long, swanlike neck high above the water. This great lizard attained a length of not less than seventy feet. The student of fossils calls it the Plesiosaur, a Greek word meaning nearly a lizard.

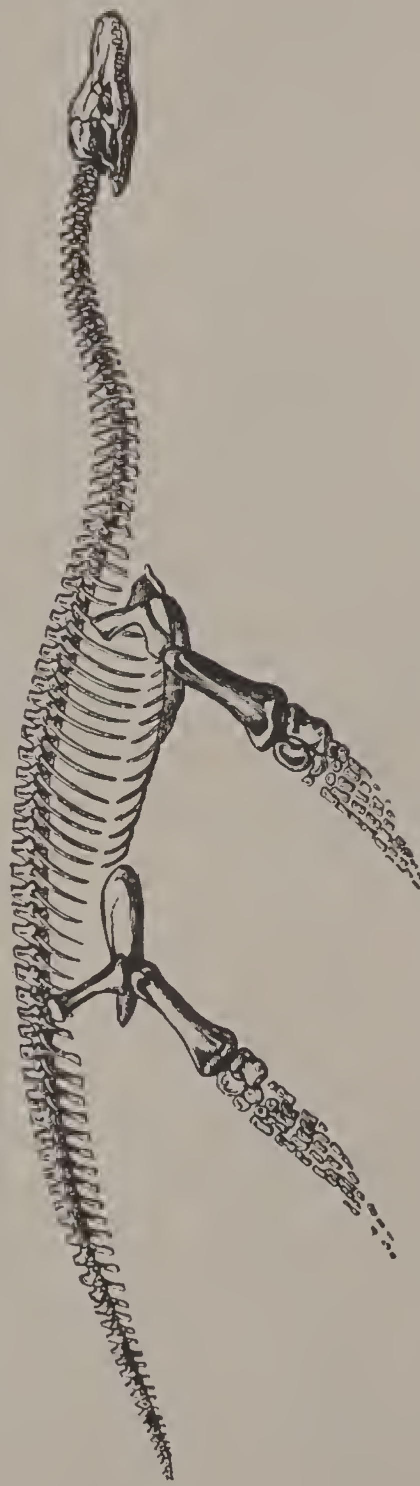


Fig. 39.—Skeleton of Plesiosaur, found in the Lias strata of England.

There were, then, three kinds of reptiles: one adapted to the water, another to air, and a third to both air and water. Most of them, and those, too, the largest ones, lived on vegetation, as their teeth show. The tracks they left in the soft mud are handlike. Their vertebræ, like those of fishes, were concave on both sides.

In this age insects began to multiply. According to good fossils found, beetles, a dragon-fly, and other insects enjoyed existence in the extensive though still songless forests. Among the shell animals in the sea the ammonites seem to have held sway.

A number of years ago some bones were discovered which were said to be the fossil bones of a man, and caused much sensation among scientists, but it proved to be a mistake. The world was not yet ready for man. Other and higher forms of animal life were to come into existence and pass out before the highest of creation could take his place on our planet.

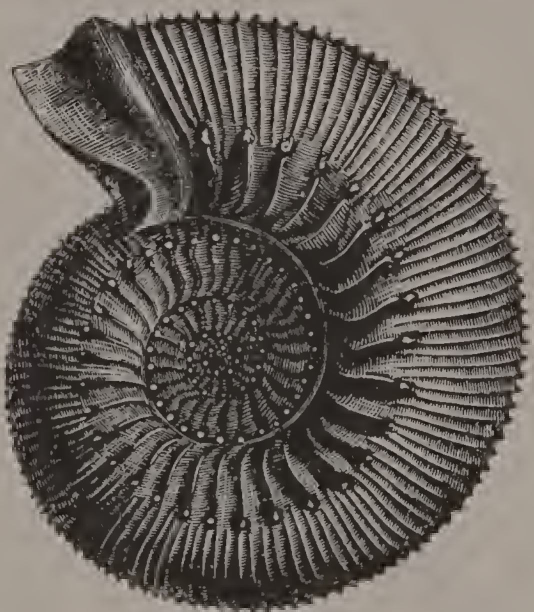


Fig. 40.—An ammonite of the reptilian age.

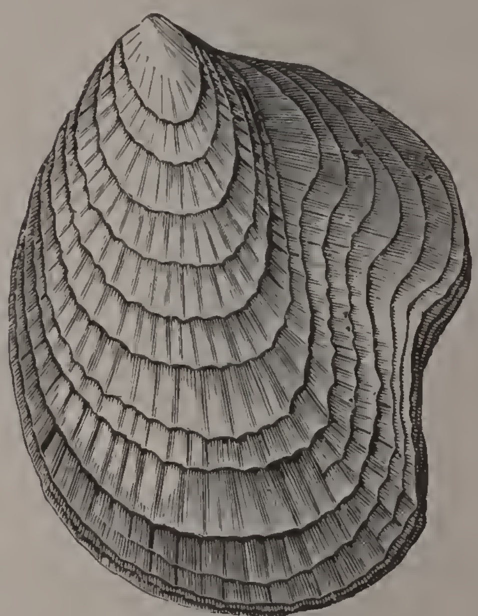


Fig. 41.—A Tertiary oyster.

The earth was growing old fast. Her great wrinkles in both the Appalachian and Rocky Mountain regions became more prominent, and the floor of the adjoining oceans probably sank lower, while the great Midland gulf that cut this continent in two from north to south was itself divided by a rise of land across the northern boundary of the United States. The slopes were getting themselves out of the sea to prepare for the green covering of seed-bearing herbs. There were no beautiful flowers, and, of course, Nature would never make the mistake to create butter-

Fig. 42.—Kangaroo of Australia carrying immature young in a pouch.

flies until there were nectar-producing blossoms to sustain them. The air was not enlivened by the song of birds; perhaps the finest music to be heard was a caw, a croak, or a chirp along the marshy inlets.

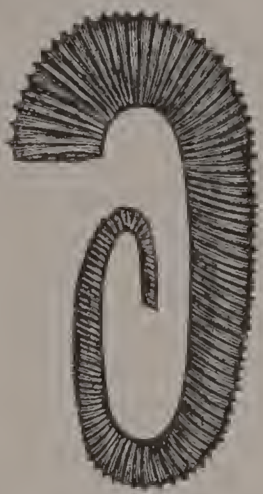


Fig. 43.—Cephaloid with coil of peculiar shape.

A few animals with a pouch in which they carried their young, the first to feed their young on milk, came into being about the middle of this period, but it was only a prophecy of what the succeeding age would bring forth. Another vibration of the crust was the signal for the introduction of a new order of life. The curtain was raised for the enactment of the next chapter.

CHAPTER IX.

THE AGE OF GREAT MAMMALS.

WHAT may we expect now? We have seen the reign of fire and water. Then life, at first rather low in structure and simple in wants, began its struggle for existence in the seas. Next the great fishes came to usurp authority in the waters. They were back-boned animals requiring higher conditions for a living and better equipment for defense. During the coal-forming period interest is transferred to the land. Great trees and broad-leaved plants take up every foot of the moist soil. Then life makes another leap toward higher conditions when large lizards come forth from the waters, taking on powers suited to terrestrial existence. Air, land, and water have gradually become fitted for lung-breathing creatures. May we not expect man, the head of creation? Let us examine the fossil pages of this chapter.

The waters continued their work of denudation, cutting narrow gulches in some places and broader depressions at others, so that when parts of the crust again became sea-bottom, the newly formed rocks filled the cuts, thus showing clearly the break in the rock system.

Geologists tell us that this break is very evident in Europe. In the British Isles everywhere the new rocks rest upon chalk strata, making it very easy to distinguish the new from the old. But in America there is so little evidence of erosion that it is almost impossible to know the new rocks from the chalk formations that preceded them.

The break in the life forms, however, is marked in both continents. The old types of life were called upon to make way for their successors, and in most instances these were higher forms of life. Many of them were so well adapted to the new conditions that they still exist as types, though somewhat reduced in size. For this reason it is called the period of Recent Life, or by its Greek equivalent, the Cenozoic.

On account of the fossils, particularly the shells, the lower part of the beds of the period is divided into three groups, known as the Tertiary (three-layered) strata. These consist of the Eocene (dawn-life), Miocene (middle-life), and Pliocene (more recent) layers, which together constitute what has been described as formation Number 6 (see page 47).

Wherever the sea covered the land at the close of the Tertiary period, deposits, of course, continued. Some of these areas were elevated later, and became the dry land described as Number 7, belonging to what geologists call the Quaternary (one of a set of four), or post-Tertiary, or Pleistocene.

In different parts of Wyoming, rocks bearing quite different fossils are found lying upon those of the previous age. Bones of a number of animals have been found that must have had all the appearance of an elephant, except the head, which suggests a rhinoceros; instead of one horn they had four on the nose and the frontal bone. It is called dinoceras, which means terrible horn. Another much like it is the dinothere (terrible beast), which had a short trunk and tusks that curved downward. The paleothere (ancient beast) had the characteristics of a horse and a tapir. Another beast was a mixture of a cow and bear, with teeth like a beaver.

In these beds is found a very curious fossil. It is an animal that resembles our horse; indeed, it was the ancestor of the horse, but it had four toes on its front foot and three on the hind foot. It is named

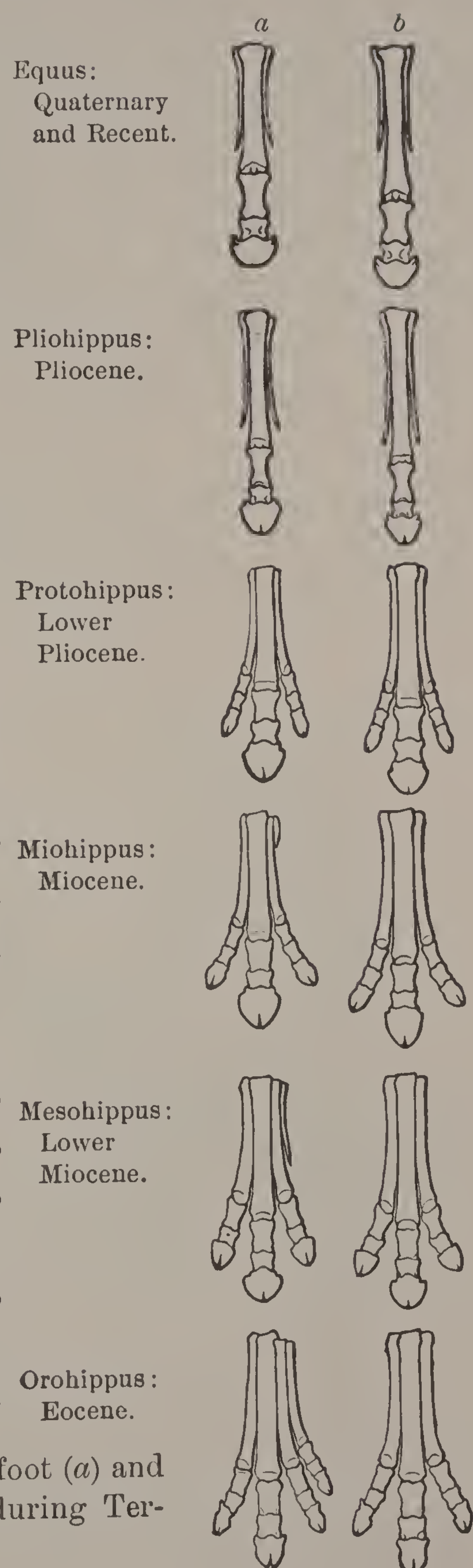


FIG. 44.—Development of fore foot (*a*) and hind foot (*b*) of the horse during Tertiary times.

the orohippus (first horse). A little later we find the same animal with one of the toes on the front foot elevated on the leg above the foot, much reduced and useless; then another with the useless toe entirely gone. This animal is about as large as a sheep. Still later beds contain one that has only three toes on each foot, and the middle one larger and longer than the two side ones. There were also changes in the head and neck. More recent fossil skeletons show further modifications; the side toes become mere splints on the side of the leg, and the remaining naillike toe is a hoof like that of the present horse. The camel has been traced through a similar line of ancestors.

FIG. 45.—Ancestor of the modern rhinoceros.

In the latter part of this period are found the ox, sheep, tiger, and other animals, now flesh - eating, but then only partly so, as their teeth show. Near the lower part of the Seine River the country is rich in fossil remains of the age. It seems to have been a large bay, in whose muddy banks the skeletons were safely buried for our discovery. The river regions of South America also abound in the fossils of the age—the camel, horse, rhinoceros. The question arises, Did these animals originate in the Western continent?

The anoplothere was a link between the tapir and the ox. It had two toes like the cow, the graceful body of the dog, and the head of a tapir, without the snout. Of all the fossils of animals found, about four-fifths were tapirs.

As large and terrible as these animals seemed to be, there were others of still greater size. Perhaps the greatest was the megathere (great beast). It walked like a bear on four broad fat feet. Its skull was rather small, and its brain not half so large as the elephant's. The megathere ranged over South America and as far north as North Carolina.

I must take space to mention one more, and that is the mastodon, the father of elephants. It is possible that he made himself at home in all the continents, as his remains have been found in the Americas, Europe, and Asia. In California a perfectly preserved mastodon's tooth was found; it is a foot and a third long, and four by eight inches on the top. A mastodon was discovered at Newburg, New York, thirteen feet high and twenty-five feet long. The position of the Newburg skeleton suggests that the great beast was mired in the mud, and perished with such food as leaves and twigs still in his mouth.

In Alabama forty skeletons of a huge whale have been discovered. In the mammals generally we see a change from water animals to those that lived on the land, but the whale is an instance of an animal returning to the water. Immense turtles, like the

Fig. 46.—Megathere, eighteen feet long, from the Pleistocene beds of South America.

glyptodon, lived in Central and South America after the manner of their race. This creature had a shell eight feet wide and seven feet high; its whole length was nearly twenty feet, and it must have weighed over a thousand pounds. In the seas swarmed great sharks whose jaws were set with four or five rows of cutting teeth that leaned backward. The waters also abounded in shell animals, crocodiles, and snakes, and many of them were like those of the species living to-day.

The birdlike forms which we saw in the last age have given way to better specimens. Swallows, grouse, owls, woodpeckers, and eagles, but probably no song-birds, added variety to animal forms. In the Paris bed was found a bird as large as an ostrich which waded along the boggy shores. Another in the same place, perhaps, had thigh-bones as strong as those of the horse; a third, resembling the emu of Australia in size and general appearance, laid exceedingly large eggs. The fossil eggs measure thirteen inches in diameter and contain two gallons. A single egg would have furnished cold sliced egg for a whole picnic party.

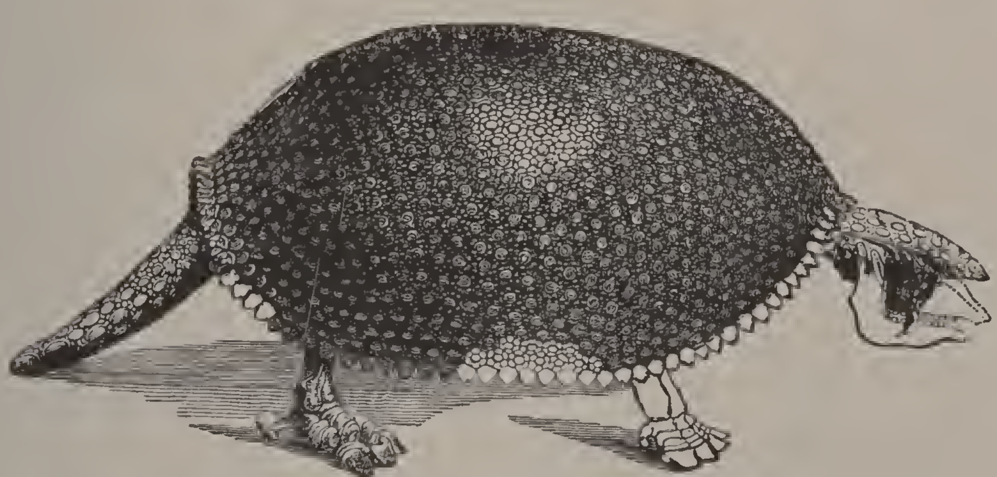


FIG. 47.—Extinct gigantic armadillo.

Similar birds exist to-day in Australia, but they are rapidly becoming extinct. The dodo, which resembled a duck, but which really belonged to the pigeon family, and weighed fifty pounds, was once found in Mauritius, but passed away less than two hundred years ago.

The patrefelis was doubtless the father of all cats. The sword-toothed tiger and the cave bear were representatives of the Carnivora. In one cave alone the skeletons of a thousand bears were found, besides those of elephants, tigers, lions, and rhinoceroses. The monkeys became the tree-dwellers of the latter part of the age; the bison began to roam over the prairies, and horses in large herds grazed on the green slopes undisturbed by man's presence.

The earth was prepared for nourishing cereals and luscious fruits. We may anticipate another change, a new being; nor are we disappointed, for the age of mind is about to begin.

GLACIAL EPOCH.

The age of mammals came to a close in an entirely new way. A great sheet of ice slowly advanced from the north, both in this country and in Europe. The evidences and effects of it have been described in Book IV. In New England it must have been a mile thick, and perhaps two miles in the Hudson Bay region. From that point it flowed outward, in obedience to the law of viscid bodies.

Some think the cause of this ice sheet was a change in position of the earth's axis, but this theory is not generally accepted. Others think it was due to land elevations, particularly in the north, which caused not only high altitudes but a change in the direction of the ocean currents. But so far no hypothesis advanced seems adequate to explain the origin of the ice sheet, and so only a few of the more important results of the Glacial period will be added here.

One effect was the destruction of some of the great animal monsters. The appearance of man at a later time must have caused the passing away of the rest, for man, with his inventive genius, doubtless proved more than a match for even the most ferocious of them.

Another result of the ice was the preparation of suitable rich farming areas for the use of man. The boulder till was spread over the best land, and it now produces the finest wheat and other cereals for man's subsistence.

A third effect was the formation of lakes and the changing of river basins. Before the ice came, many streams of this continent found outlet in the Arctic Ocean. As the sheet moved forward, pushing along the ground moraine, it dammed up these rivers and forced them to cut their way through the Alleghanies. The débris carried by the ice also enclosed bodies of water in Wisconsin and other Northern States; when the ice retreated by melting, the Great Lakes, which had thus far found outlet through the Wabash, Miami, and Mohawk valleys, turned eastward through the St. Lawrence. All along the shores of these lakes are evidences that the water in the lakes once stood much higher than it does at present.

There is proof that there were two Glacial periods, with a warmer epoch between when the continent was plunged into the sea.

When the continent was submerged during the warm period, the ice was melted or broken up into icebergs, as is now the case on the shores of Greenland. The sea extended as bays far up into the rivers in the Mississippi valley perhaps as far north as Iowa. The greatly shortened rivers deposited their débris into these quiet bays. When the land was again

Fig. 48.—Glacial flutings of bed-rock, near Burlington, Iowa.

raised, the rivers flowed in broad stream over this sediment, gradually wearing it down. As the land rose higher, the rivers narrowed and cut smaller and deeper channels. In this way the terraces along rivers have been formed.

On the high banks of Lake George, and on other bluffs, marine shells can be found. Some of these are as high as five hundred feet above the present sea level. In Wales they have been found at a height of one thousand three hundred and fifty feet. Being marine shells, how could they have come there unless the ocean once covered those bluffs and mountain sides?

The ice sheet withdrew only gradually; in fact, it still exists in Greenland and on the high peaks of Alaska and the west coast; in Europe it still lingers in Norway, on the Alps and the Pyrenees.

The change from the Glacial period to the present has been very gradual, as were most changes from one age to another through all geological time.

CHAPTER X.

WHEN DID MAN APPEAR?

This is the most interesting question that geology has to deal with. There is an abundance of evidence in geological deposits of the existence of man many years ago. But how many years is still very indefinite.

It has been claimed that man existed as far back as Miocene times. The Miocene evidences are these: scratches on bones and rude flints. The marks on the bones might have been made by the teeth of flesh-eating animals, and the flints could have been accidentally cracked off from larger rocks in that shape by sudden changes of temperature. It has also been claimed that human skeletons have been found in gold-bearing gravels in Miocene strata. But even if they were found in gravels belonging to that period, we have no right to conclude that they were buried in that period. Gravels can easily be disturbed, or the men may have fallen into a pit dug by some of the aborigines in these layers. There is, in fact, no proof of Miocene man that is satisfactory to scientists generally.

What is the next evidence? In Denmark have been unearthed three layers of tree deposits. In the lowest are remains of Scotch firs which have never existed in historic times. In the second layer were

Fig. 49.—A contemporary of man.

flint weapons, among the bones of the stag and primeval ox. In the third were bronze shields among oak trees. Chipped flints with bones of the horse and other mammals have been excavated from deposits in Kent, England, which are said to belong to the Champlain or later Ice period. A curious thick skull of low arch was found by Neanderthal, in Germany, that was at first supposed to belong to a being whose structure was between man and the apes, but it proved to be human. Later two more skeletons were unearthed having skulls like that found by Neanderthal. These men had bent knees. The Mentone skeleton found near Nice was tall and well-formed, and near his head lay twenty stag-teeth in a circle, each having a hole through it as if he had used them for a necklace. Rude implements were also found embedded with him in the stalagmitic deposits. Similar remains have been discovered in India, South America, Minnesota, Ohio, and New Jersey. From all these it has been argued that man first appeared about the middle of the Quaternary age, but there is much doubt as to the exact time.

It is quite probable, it would seem, that man came on the stage of action not until the ice sheet had retreated. How many years ago was that? Some geologists have computed from the erosion in gorges and at waterfalls that about ten thousand years have elapsed since that time; others make the time only seven thousand years.

Remains of human skeletons have been sought for very diligently, but few dating back much before early traditionary times have been found. At whatever time man appeared, the oldest relics are tools, which are crudely chopped. They would more easily be preserved than his bones. The period to which these rough implements belong is called the ancient or Rough Stone age. These tools consisted chiefly of weapons for defense, such as spear-heads and flints for cutting. His dwelling was probably a cave in the rocks. His food consisted of shell-fish, berries, and roots, to which occasionally was added flesh of such animals as he was able to surprise and to kill with his club or spear. When this age ended no one can tell. Possibly there are still savages in the world that belong to this age, as far as their state of culture is concerned. But man gradually improved, and later we find man's bones associated with implements that show better workmanship. He had learned to polish and to put a better edge on his tools, and the age became known as the Polished Stone age.

At Aurignac a laborer came upon a cave closed by a heavy stone. Inside were the bones of seventeen human skeletons, male and female. This had evidently been a family burying-place. Before the cave, in the ashes of the fires that cooked their simple meals, were found the bones of the mastodon and stag, with rude implements for fishing and agriculture. Similar finds have been reported in southern France. On the north coast of Europe large mounds of shells have been discovered in which were the remains of no extinct animals, but those of living species such as the reindeer and the dog. The implements of war, fishing, and farming also found here, show that these people lived in the new or Polished Stone age.

In many parts of Europe, in a later period, we find man associated with implements of still higher grade. He now has learned to make use of copper and iron in the manufacture of bronze tools and weapons. To this age also belong the remains of the lake-dwellers of Switzerland, etc. They lived in houses built on piles away from the shore and reached by a walk on piers. The inhabitants of the Bronze age cultivated several kinds of grains and fruits and made a coarsely plaited cloth. This age continued to historic times, and in secluded regions of the world some of its representatives are still found. The Bronze age was followed by the age of iron, which still continues, unless we may say it has become the age of steel.

CHAPTER XI.

THE OCEAN IN WHICH WE LIVE.

The foregoing chapters have treated briefly of the earth as a molten globe, its gradually forming crust of rock strata, and of the plants and animals that followed in successive ages. But that is not all there is of our globe. It is surrounded by an envelope of air which is called the atmosphere; an envelope practically not over fifty miles deep, although atmospheric gases in a rarefied form may float out from the earth for a distance of two hundred miles.

In pre-Archæan times the atmosphere was probably more than a thousand miles deep; but in the succeeding ages a great part of the vapors settled and formed oceans; the gases were absorbed until there is nothing left but oxygen and nitrogen. If the moon is to be taken as an example, not only the waters on the earth's surface but also the atmosphere will be gradually absorbed by the globe, so that at some time there will be no water and no air on this earth. Animal and vegetable life will have passed away and the earth will be dead indeed. But this will not happen, if it does at all, for at least millions of years hence, and there is no need to spend anxious moments over it.

We are in the habit of thinking of the earth without its atmosphere, but it is truly a part of our globe. It is quite as necessary to life on the earth as are the rock-sphere and the oceans of water. In a very important sense we do not live on the earth but in the earth—i. e., in the atmosphere. All terrestrial life would immediately perish if this gaseous envelope were removed.

Not only is life possible in this air-sphere, but its well-being depends greatly on the warmth, moisture, and movements of that sphere. Man's prosperity and happiness are so dependent upon the conditions of the atmosphere that where these are most favorable he attains his highest civilization.

Atmospheric conditions taken together for a period of time constitute climate. In the temperate zone climate consists of a mixture of wind and clouds, sun and frost, dew and snow, warm and cold. All these are continually changing and forming new combinations.

Although the atmosphere is so important to the life of the globe, it is the last scientific topic that has received studious attention. This is probably due to the idea that prevails so largely that we can not learn much about wind and storm; and this is partly true because of the extensive movements of the air, requiring observations at many and widely separated points.

In the year 1870, the United States Government first began to establish a system of such observations. Although much has been accomplished, still the science is yet in its infancy. If observations of value can be made, why should not young scientific students begin to make and record observations at their own homes? In this way alone can they get an intelligent comprehension of what might be accomplished if all the governments of the world would unite in making and publishing systematic reports of observations. Besides, it would be most excellent scientific training which every one may acquire. This thought led me to action, and I began a series of experiments and observations for myself.

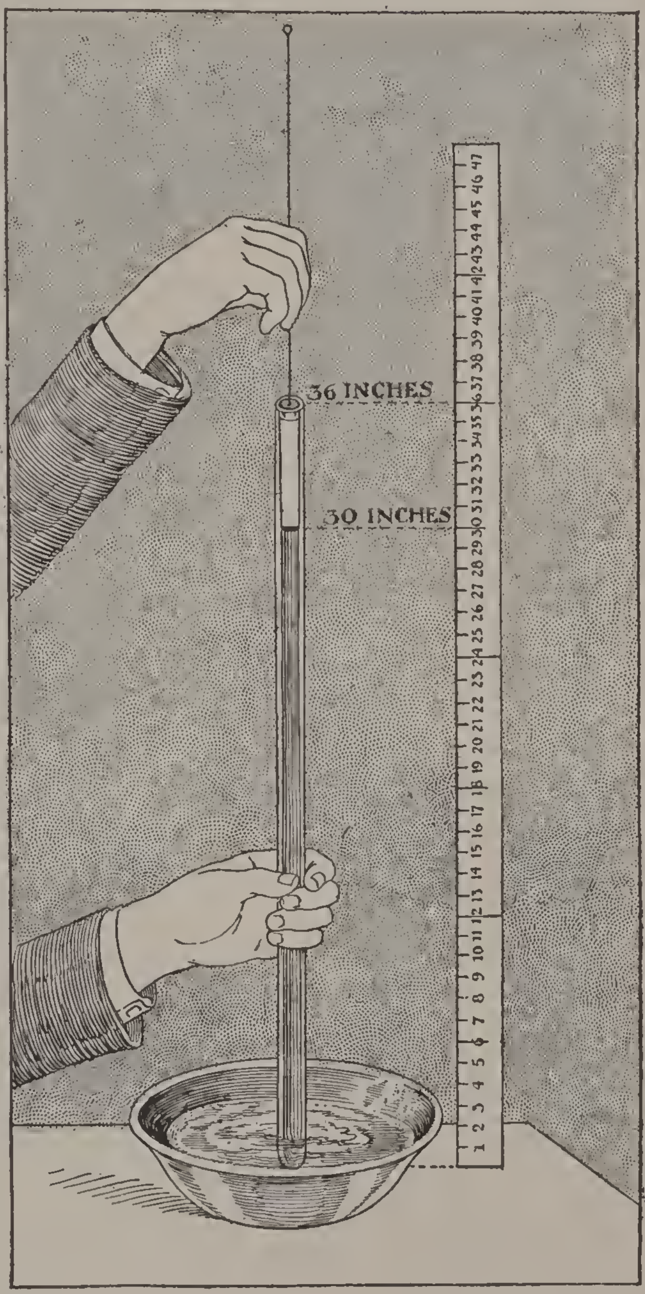


Fig. 50.—Tube showing height of mercury in vacuum, made by drawing a rubber cork up the tube.

First, I made a barometer, such as was described in Book III, Harold's Quests, and attached a graduated scale marked in inches and tenths of an inch, in order to read the height of the mercury in the tube at a glance. The greater the atmospheric pressure, the higher the mercury stands in the tube and the less there will be in the cup. Thus its level in the cup is constantly changing. The true height of the mercury column is the distance from the level of the mercury in the cup to the point at which it stands in the tube. Therefore, to get the correct height of the column, we must have a measuring wire so attached as to rest upon the surface of the mercury in the cup and move up and down with it. This I accomplished by attaching with little staples a fine wire about thirty-one inches long to the board beside the tube, so that it could move freely up and down. At the lower end of the wire I attached a piece of cork properly fitted into the cup so that the whole floated on the mercury in the cup. At the upper end I attached the scale-card, by which the standing of the mercury in the tube could be easily read. When the air had little pressure, the mercury in the tube dropped and increased the amount in the cup. As this increased, it raised the scale-card so that the thirty-inch mark, for instance, was always that distance above the surface of the mercury in the cup. When the air-pressure increases, the scale-card settles with the mercury in the cup.

A light board one foot square, suspended by wires, served to measure the force of the wind when blowing against it. By means of broom-wire the board was attached to a small spring balance fastened upon a horizontal rest. This indicated the pressure of the wind in pounds to the square foot.

The rate at which the air moves is its velocity, and is expressed in miles per hour. It is determined with an anemometer (wind-measure). By means of the table it was not difficult to learn the velocity from the pressure. Multiply the number of pounds of pressure by two hundred, and the square root of the product will equal the velocity. I found that the pressure was greater on high buildings or on a hill than in a valley. The wind is also stronger on the ocean or open prairie.

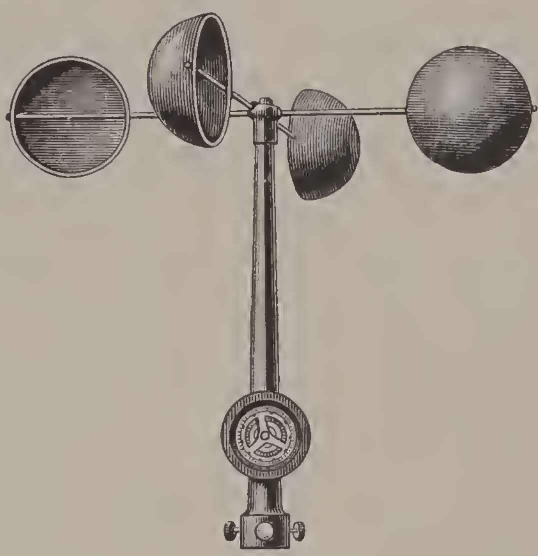


FIG. 51.—Anemometer. Wind blowing into the cups whirls them around. The velocity is indicated by the hand on the dial.

The air seldom moves at uniform rate, but in waves or gusts. It seems to come in great waves, with little waves upon them, as we often see upon the water.

Gentle breeze	4 oz.	7	miles per hour.
Light wind	1 lb.	14	" "
Stiff breeze..........	2 lbs.	20	" "
Gale.......	8 "	40	" "
Heavy storm.........	18 "	60	" "
Tornado.............	50 to 200 lbs.	100 to 200	" "

It is astonishing to find how much pressure there is against the side of a house if the wind strikes it squarely. A gale would exert a pressure of about 800 pounds on the side of a small house.

Next I secured a good thermometer and tested it, as explained in Book III. Then I ruled foolscap paper lengthwise so as to have ten half-inch columns, leaving the right margin for Remarks. This gave a column each for the Day of the Month, Temperature, Barometer, Wind, Sky, Precipitation, Dew or Frost, Fog, Moon's Phases, and Evening or Morning Star. Every evening at six o'clock I recorded my observations.

The thermometer was recorded in degrees, and the barometer in inches and tenths of an inch; the wind was indicated by an arrow flying in the direction of the wind, and as long as space would permit if the wind was very strong; frequently I added the force in pounds to the square foot. When the sky was fair I placed a circle in the column. When it was cloudy I shaded the circle, and when only partly cloudy I shaded a proper portion of it. The shading was in parallel lines if the clouds were of the cirrus type, in little squares if cumulus, and solid when the clouds were an unbroken mass. The phases of the moon were shown, when new by a circle, then by a narrow crescent, increasing the shading until the full moon filled the entire circle. The initial letters were used for the other items. Under Remarks were such as these: "The wind increased until three o'clock and then diminished"; "Drop of 35° from eleven to four"; "Clouds below moved toward the northwest, while a higher stratum moved toward the east."

After keeping a record for some time I began to study it. I noticed that usually when the thermometer rose the barometer fell. The conclusion was that the pressure of the atmosphere depends on the temperature, though not entirely, for several times the barometer fell very little though the thermometer rose considerably. There were also other deviations. Then I observed a connection between the barometer and the clouds; a cloudy sky with a rising thermometer, it seemed to me, always causes a corresponding fall in the barometer. Next I discovered that when there was much moisture in the air the barometer fell.

MOISTURE IN THE AIR.

To get some idea of the amount of vapor in the air, I fastened two good thermometers to a thin board, as shown in Fig. 52. This is a good home-made hygrometer. The bulb of one of the thermometers I wrapped with linen cloth, and tied with a thick cord, one end of which I inserted in a small vial fastened at the bottom of the board. When the vial was half-filled with water the string acted as a wick and kept the bulb moist. When the air contained as much water as it could hold, there was no evaporation from the cloth about the bulb, and the mercury stood at the same height in both thermometers. The drier the air the greater the evaporation.

We have learned that when liquids change to vapor they take up heat. The water from the cloth changing to vapor drew off heat from the bulb, or, in other words, it cooled the bulb. Consequently the mercury stood lower in the wrapped thermometer than it did in the other. The more rapid the evaporation the greater the difference in the two thermometers.

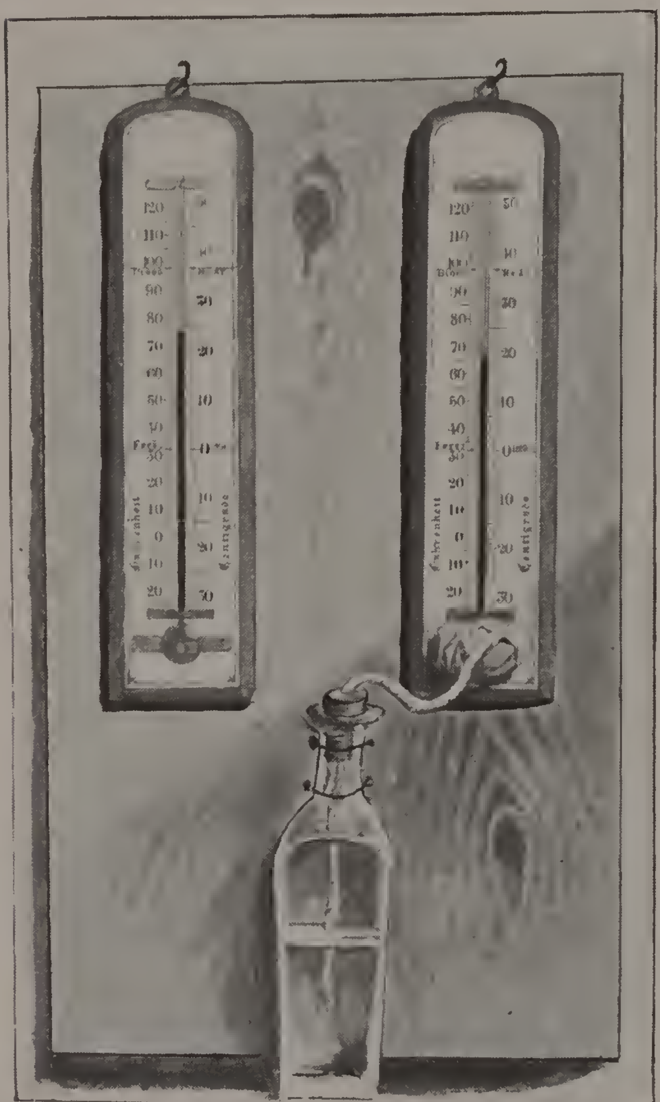


FIG. 52.—Simple hygrometer. Dry- and wet-bulb thermometers.

I soon discovered that cold air can hold but little moisture. Just as it is with a sponge: the drier it is the more moisture it will absorb, so with the air, the warmer it is the more vapor it will hold. When air contains all the water it will hold we say it is saturated; if it should grow cooler, its vapor would turn to rain, snow, dew, or frost. If the air above is cooled by a cold current, the vapor falls as rain; if the temperature is below freezing, it falls as snow or hail. When the saturated air is cooled by grass blades or by other objects that radiate their heat freely, the vapor condenses on them as dew; in freezing temperature, as frost.

Fig. 53.—Various forms of snow crystals.

To compute how much vapor there is in a cubic foot of air requires properly constructed tables, which the interested reader can obtain in any good work on Meteorology. My hygrometer gives very interesting results without showing the number of grains of water in a cubic foot of air.

CHAPTER XII.

THE CLOUDS ABOVE US.

There never was a time when man did not find pleasure in watching the ever-changing clouds. I can not imagine them absent from the Garden of Eden, for the sun would be robbed of half his glory if his face were never hid by them, or if there were no cloudscape upon which to spread his beautiful colors.

A friend of mine moved to California at the beginning of the dry season. After weeks of cloudless sunshine the children grew homesick for these airy visitors. Indeed, we can scarcely imagine the influence of their presence upon the human mind. Even the city dweller, shut within the narrow limits of twenty-five feet of annual sameness, has above him a range of beautiful scenery which he may call all his own. He may see mountain ranges stretching across the heavens and sloping down to lofty plateaus full of beauty and interest. The open country, with its more extended horizon, nourishes the imagination not merely of fancy but one that brings much beauty into the very practical things of life. Thrice happy is that boy or girl who may have the privilege of running often to the hilltop, to widen his view not only of the landscape but of the outstretched heavens. Who can tell to what extent the heavens inspired the mind of David, when as a shepherd lad he lay on his back viewing the changing clouds above him, and when later he said:

> "The heavens declare the glory of God; and the firmament showeth his handiwork."
>
> "Thy mercy, O Lord, is in the heavens; and thy faithfulness reacheth unto the clouds."
>
> "O Lord my God, thou art very great; . . . who stretchest out the heavens like a curtain: . . . who maketh the clouds his chariot: who walketh upon the wings of the wind."

CLOUD-MAKING.

Have you ever been in a cloud? I am sure you have, for a fog is nothing but a cloud that has settled to the earth. We can feel the tiny water balloons as we walk through the fog. All at once the wind comes along and picks up the cloud and carries it far above. You will then see that clouds are mists floating in the air.

Where does all this mist come from to make the clouds, which are often thousands of feet in thickness, miles in extent, and sometimes pour down torrents of water?

Last summer I set a tub of water in the sun, and saw that on warm days the water was lowered more than an inch. What had become of it? The sunbeams had tossed the tiny water particles into the wind's embrace to be carried to cloudland.

Thus from sea and lake, river and pond, field and forest, water is constantly rising into the air as invisible vapor. Not only in the warm summer days, but even in the cold weather of winter, is this true. A few years ago I placed blocks of ice out-of-doors during a spell of weather so cold that not even the noonday sun could produce any thawing, but the ice-blocks grew gradually smaller. I believe the water evaporated from them without visible thawing. We do not often stop to think how much water is lifted skyward day by day the year through. Men who have studied the subject a great deal have estimated that not less than fifty million tons of water are evaporated on the surface of the earth every second.

The warm currents of air carry all this water from one to eight miles into the atmosphere. There it collects into clouds of various shapes and sizes in accordance with the temperature and currents of the higher air.

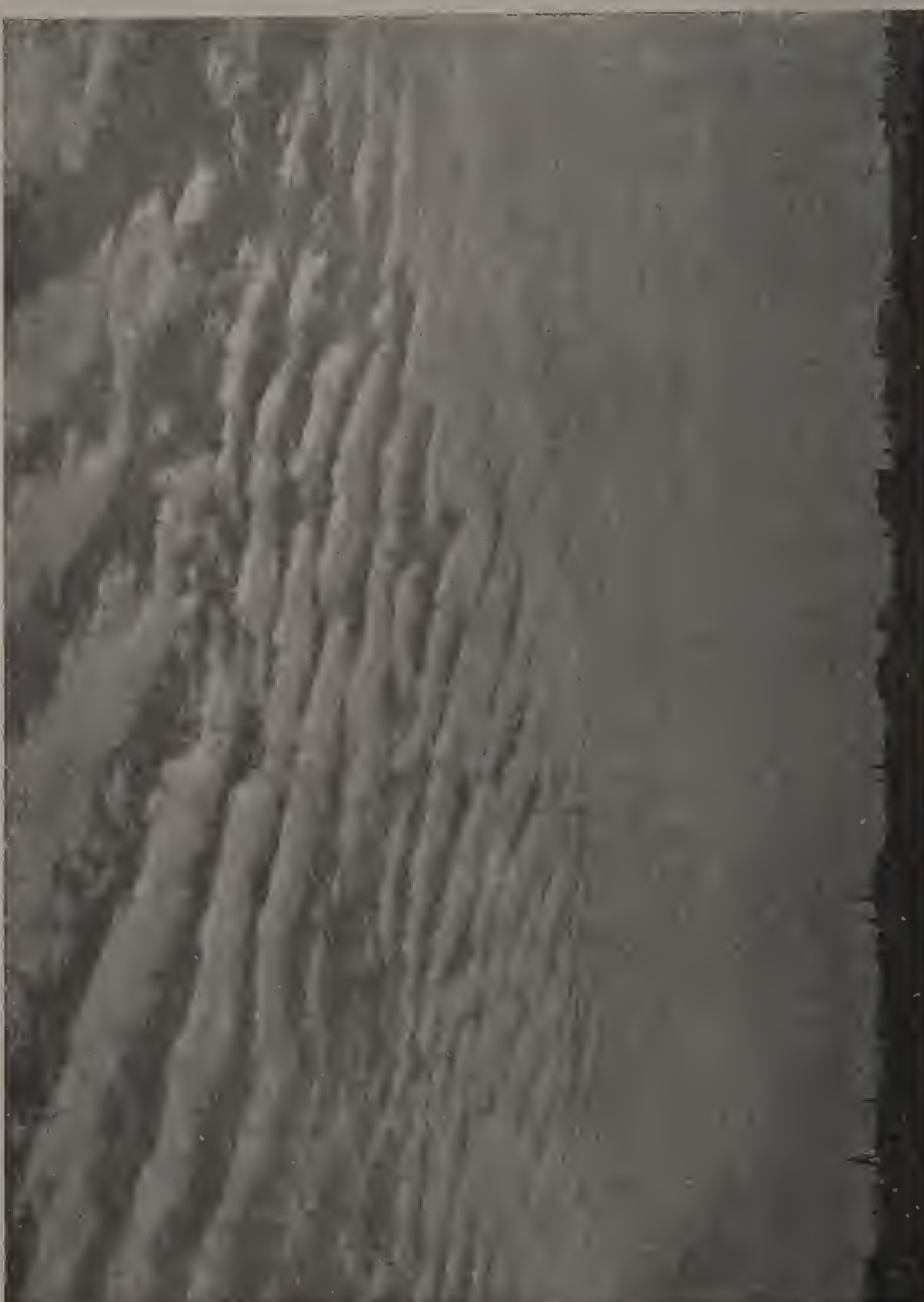
SHAPE OF CLOUDS.

At first we are inclined to think that there are so many different kinds of clouds that it is almost useless to attempt to classify them. While I must admit that one kind often shades into another, careful observation has enabled me to discover three fundamental forms which differ generally according to the altitude at which they ride the winds.

Scientists have given them names which are descriptive of their appearance. 1. The cirrus (curl) dwells in the upper air from eight to ten miles above the earth. As its name suggests, it is a filmy cloud curling into various shapes. 2. The cumulus (heap) is about two miles above the surface of the earth. It

Fig. 54.—Cirrus high-floating cloud. (From Harrington's About the Weather.)

resembles great masses of wool and is sometimes called wool heaps. 3. The nimbus (rain cloud) is a gray cloud lower than the cumulus, usually stretched out



From a photograph by A. J Henry.

FIG. 55.—Cumulo-stratus (wave cloud). (From Harrington's About the Weather.)

in thin sheets with ragged edges and peninsular points. Sometimes it scuds along in the wind in front of other clouds.

In the cold atmosphere far above the earth's smoke and dust, the vapor of the cirrus is frozen into fine spicules of ice that reflect brilliantly the unadulterated sunshine. It is so thin that it casts no shadow and is seldom visible in the midday sun. Its altitude enables it to catch the first ray of the morning. My observations lead me to believe that it usually takes an east and west position in this part of the country.

Sometimes the cirrus settles down somewhat and takes on a stratified appearance, stringy, and stretching out like a great net. Still it is too thin to cast shadows, but in its filmy mists the light is displayed, as the beautiful halos of the moon and the mock suns or sun-dogs, as they are commonly called. When it settles still lower it takes on a patchy appearance, reminding one of cumulus fragments, sometimes resembling floes of ice, and at other times the spots on a mackerel, and hence called the "mackerel sky."

We have therefore three kinds of this cloud: the cirrus, cirro-stratus, and the cirro-cumulus. Although they appear to be almost stationary, they fly along at the rate of eighty to ninety miles an hour.

The cumulus are the Himalayas of the heavens. Their broad bases are not much over a mile above the surface of the earth, although the tops sometimes reach up to a height of seven or eight miles, where the cold air touches them into frosty whiteness. The light-colored patches of cloud which career across the sky on a summer day are parts of the cumulus. I suppose the Greeks had these cumulus clouds in mind

From a photograph by A. J. Henry.

Fig. 56.—Typical large cumulus. (From Harrington's About the Weather.)

when they spoke of Apollo's cows. It is the cumulus, too, that shows us the silver lining.

When these clouds are at some distance and we look at them edgewise, they appear to be in layers, or at other times they rise into the higher air and spread out into smoky bands; when they take on this form we call them cumulo-stratus.

The cumulus, it seems to me, is the most wonderful of all clouds. Moving as slowly as it does, about twenty-five miles an hour, the vapors are constantly settling; as they drop down into the lower and warmer air they as constantly evaporate again and rise to the top of the cloud, ever changing its crest from one form to another. They are the playground of the sheet lightning on warm summer nights. In their folds the evening sunbeams seem to revel. "We often see the pink Alpine glow," Van Dyke says, "suffusing the white castellated tops; and the shadows caused by sharp breaks of form often show blue, lilac, and even pale green in hue."

The nimbus is the earth cloud, for it catches the smoke and dust, which give it a dark-gray appearance, but it is never black, according to the same excellent authority on color quoted above. "The heavy storm-cloud may border on purple," he continues, "and sometimes preceding cyclones it is sea-green, but it is never black."

Though the nimbus is the homeliest of all clouds, it is the most beneficent, for it is this cloud that brings us the refreshing showers and the steady rains. The nimbus often has a dark dust-cloud as an advance guard, carried along by a strong wind. Often during days of rainy weather this cloud stretches from horizon to horizon in a continuous gray sheet.

> "I bring fresh showers for the thirsting flowers
> From the seas and the streams;
> I bear light shade for the leaves when laid
> In their noonday dreams.
> From my wings are shaken the dews that waken
> The sweet birds every one,
> When rocked to rest on their mother's breast,
> As she dances about the sun.
> I wield the flail of the lashing hail,
> And whiten the green plains under,
> And then again I dissolve in rain,
> And laugh as I pass in thunder."

The Cloud, SHELLEY.

CHAPTER XIII.

WINDS.

After making observations for some time and comparing different items in my record, I discovered that the barometer rose or fell at times when, as far as I could see, there was no reason for it. I concluded from this that there must be other causes about which I, at present, knew nothing. I therefore began to study the wind.

In the first place, what is the wind? It is something I can not see, though I can feel its effects. I can see how it bends down the trees and carries along light objects like feathers and down. It must be the air in motion. Now the question comes, What makes it move?

I made a little paper windmill and attached a crank to it to which I fastened a paper man holding a saw across a log. When I held this mill over the hot stove it whirled around and made the man go through the motions of sawing wood. There was evidently an upward wind from the stove which set my machinery in motion. When there was little fire, the mill moved slowly. When I held it over the register, the hot air from the furnace also turned it around.

One day I held a candle near the top of the doorway between a hot and a cold room; the flame was bent toward the cold room. The more I lowered it the less it was bent, until the flame was perfectly erect about the middle of the doorway. Below that the flame was bent inward toward the warm room. This proved to me that the warm air moved outward at the top of the door and the cold air inward at the bottom of the door.

FIG. 57.—Bonfire, showing circulating air currents.

One day as I was watching a bonfire, I kicked into it some of the ashes of burnt paper that were about the edge. The heated air above the fire at once carried them up for some distance, and as there was no wind they gradually floated off to the side and down to the earth again. I perceived immediately that the heat of the fire warmed the air and expanded it, and that the colder air around it pushed the lighter air upward. This in turn became heated and was pushed up in like manner by other cold air. Just above the fire there was a vertical circulation caused by the horizontal inflow of the cold air near the ground. Other air near and above it slipped down and followed after it, producing a circulation as shown in Fig. 57.

I observed four things about the air in connection with the bonfire: there was an upward movement of the air just above the fire; an inward movement along the ground toward the fire (Fig. 57); an outward movement, some distance above the fire, of the air toward either side; and a settling of the air, which had now become cold, at some distance from the fire (Fig. 57). The bonfire suggested to me the philosophy of the winds: the air is heated in some places more than in others, and a current sets in from the colder toward the warmer areas. If the temperature were the same in all parts of the atmosphere there would be eternal calm.

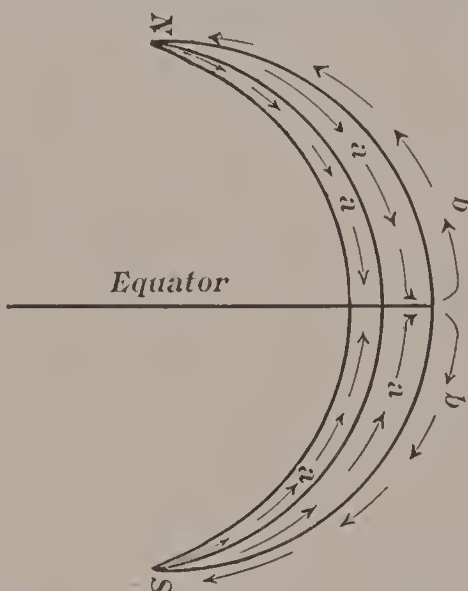


Fig. 58.—Air moving toward equatorial region and returning to the poles as upper air currents.

The sun, which shines more or less vertically in all regions of the equator, heats the earth there more than anywhere else, and the earth in turn heats the atmosphere. Therefore the colder air immediately to the north and to the south of the equator rushes in and pushes up the warmed air. As the colder air moves toward the equator it leaves a partial vacuum, into which the air back of it flows.

We would naturally think that the air would flow toward the equator all the way from the poles, and give us north winds in the northern hemisphere and south winds in the southern hemisphere. This would tend to draw the air away from the poles, producing low barometer, thus leaving a partial vacuum into which the higher air would drop, so that a current toward the poles would be started in the upper air. Then the circulation would be as follows: the warm air at the equator would rise and flow toward the poles, descend to the surface of the earth, and as a north or a south wind flow off toward the equator. Thus there would be polar winds all over the surface of the earth except at the equator, where it would be calm. Probably this would be the case if the earth were a globe of some uniform substance like glass, or were everywhere covered with water and did not rotate on its axis. But this ideal circulation exists only in part, and we must therefore look for influences which disturb the direction of the air currents.

HOW THE WINDS BLOW.

Observations covering a considerable period of time have been made in many parts of the world, and their results recorded. We can notice only a few of them, but enough to form some idea of the movements of the air, and to interest you, reader, in making some observation for yourself.

We will begin at the equator. Here, and on both sides of it, the records show that there is little wind, especially out at sea. It is the great region of calms, known as the doldrums (meaning dull, inactive); it is about 10° to 12° in width. Going north 5° or 6°, we observe a northeast wind, which increases in strength as we continue our course for a distance of 10° or 12°. This wind blows continuously day and night on the sea. On the land it is much interrupted during the night by contrary breezes.

Our course is still northward, and the northeast winds continue, but soon grow less in force, until they leave us in a calm at latitude 30°, or, if it is summer, 35°. The constancy of these winds greatly promoted commerce in the days when it was mostly carried on in sailing-vessels, and for this reason they have received the name Trade-winds.

In the southern hemisphere the trade-wind belt lies a few degrees nearer the equator. The winds blow from the southeast, and with even more regularity than in the northern hemisphere, as there is less land surface to interfere with them.

North of the trades is a belt of calms and slight variable winds, which has received the singular name Horse Latitudes. It includes the region of the Sargasso Sea, lying between Africa and the United States. The old skippers were often becalmed in this latitude. Might they have given it the name from the fact that the wind frequently "played horse" with them? The winds in this belt are largely controlled by storms.

North of the horse latitudes we encounter prevailing west or southwest winds. These are not so regular as the trade-winds, yet they are important. Although these are the prevailing winds, there are frequently winds from other points of the compass, sometimes from east, and often from north and west points. But the mass of air in a general way may be said to move spirally eastward toward the poles.

In this connection it is interesting to notice that there is considerable correspondence in the movements of the ocean currents and of the winds. On each side of the equator are two currents, for the most part parallel; the one south of the equator in the Atlantic deflects poleward along the Brazil coast, and the one in the Pacific Ocean deflects to the west of Australia. The one flowing along the north side of the equator in the Atlantic enters the Caribbean Sea and the Gulf of Mexico, and then, passing between Cuba and Florida, flows northeast across the Atlantic, as the Gulf Stream. That in the Pacific forms the Japan currents, which takes a northeast direction toward Alaska. All these currents in the ocean near the arctic regions more or less deflect, and turn back upon themselves. Do the ocean currents carry the air that rests on the water along with them? Or do the winds direct the currents? I have seen the direction of the Gulf Stream changed to a considerable extent by strong winds in the Caribbean Sea and the Gulf.

But to return to winds. We have thus far mentioned two calm regions, the doldrums and the horse latitudes. The calms of the latter are not so pronounced as in the former, there being frequent light, variable winds. There is a third region of calm, called the polar, in close proximity to the poles.

CHAPTER XIV.

OBSERVATIONS ON HIGH CURRENTS.

As suggested by our bonfire, the air circulates. If this is true, there must be currents in the air far above the earth that correspond to surface winds, but flow in opposite directions. Can we learn anything about those? Indeed we can. The clouds and the volcanoes shall teach us.

Every one has the privilege of observing the clouds, and has noticed that often there are two sets, possibly three layers, one above the other, moving in different directions. The higher clouds, of course, are carried along by the upper air currents, which for the want of a better name we will call the upper air currents. If we will observe the high clouds and record our observations for some time, we can learn much about the upper currents.

Again, the ascending smoke of volcanic eruptions has furnished interesting facts. In 1812 a volcano on the Isle of St. Vincent forced its ashes up into the higher air. Below, the wind carried them off toward the west; in the upper regions they were borne toward the northeast, and settled down on vessels more than a hundred miles to the northeast of the volcano.

The ashes borne up into the higher air at the great eruption of Coseguina, Central America, were transported by the upper currents to the northeast, considerably to the east, and fell in noticeable quantities on Jamaica, eight hundred miles off. The lower current carried them west to the Pacific.

In 1883, Krakatoa, which is situated in the Strait of Sunda, threw large quantities of material high up into the air, and the finer particles were carried east by the higher currents, as was shown by the showers of dust that fell upon the decks of vessels twelve hundred miles to the east.

The peak of Teneriffe, on the Cape Verde Islands, stands isolated in the ocean, and is constantly fanned by winds from two different directions. When Alexander von Humboldt, the great German naturalist and physicist, visited those islands he ascended the peak. At the foot, and for some distance up the mountainside he found a northeast trade blowing, but at the summit a southwest wind almost blew him into the crater as he was examining it. Prof. Piazzi Smyth spent some time in the observatory located on that peak at an elevation of ten thousand feet. His records show that there was an almost constant southwest, and sometimes an almost west wind blowing, while the northeast trades continued as regularly at the base of the volcano.

Observations on high mountains in North America, Europe, and Asia show that the upper air to the north of the horse latitudes also moves in an easterly direction.

Similar observations have been made in the southern hemisphere, and with like results, except that the higher air moves to the east and the southeast.

These observations tell us that the surface winds do not blow from the poles, nor the upper currents toward the poles, as we had supposed. The trade-winds, instead of being polar winds, bend westward near the equator—that is, they are northeast north of the equator and southeast south of it. Now the question arises, What gives them this westward tendency near the equator?

The earth, with its envelope of air, revolves on its axis once every twenty-four hours. This rotation whirls the surface at the equator through space at the rate of more than a thousand miles per hour, or over seventeen miles per minute. North and south of the equator this motion is less and less, until it becomes nil at the poles. Now, if water is poured on a revolving grindstone it flows in from the edges toward the middle of the stone, heaps up there, and lags behind. As the air is mobile, it is easy to see that in the equatorial region it might lag behind and thus turn the polar winds westward, and that seems to me the chief cause for the deflection of the trade-winds. This was Professor Hadley's explanation as far back as 1735.

From extensive observations it has been learned that the envelope of air surrounding the globe revolves with it, just as the water in the oceans revolves with the land. But if this were true, there could be no zone of calms at the equator, since there the rotation is most rapid.

Investigation has proved that winds are changed from their direction by another force, due to the spherical shape of the earth combined with its rotation. A French mathematician in 1837 computed that a freely moving body on the surface of a rotating sphere will, or ought to, move toward the right of its course and describe a circle, and that the faster it moves the greater will be the circle it describes.

The eminent French experimenter, Foucault, in 1851, suspended a long, heavy pendulum so that it could oscillate freely in any direction. He found that if the pendulum was started in a certain plane, it gradually oscillated more and more toward the right, north of the equator, until it completed the circle. The same experiment proved that it would move toward the left in the southern hemisphere. This can be tested by almost any one. The pendulum should be at least twenty-five feet long in order to make the movement evident.

Five years after Foucault's demonstration Mr. Ferrel applied this idea to the air currents and worked out his theory of the winds, which is now generally accepted.

This principle may be restated thus: If the observer stands with his back to the wind, the currents will gradually curve to the right, in the northern hemisphere, no matter which way the wind blows. Thus a north wind would not remain north, but would gradually veer toward the west, becoming first a northeast wind, then east, then southeast, and so on, completing the circle. A south wind would not continue as such for any great distance, but would by and by veer so as to become a southwest wind, west, and so around the circle. In the southern hemisphere the wind currents would, of course, veer toward the left.

This principle may also be observed in ocean currents. Those in the northern hemisphere curve toward the right, those in the southern toward the left. Rivers are said to illustrate the same rotary principle. In the northern hemisphere long rivers through level country, such as the Obi, gradually wear away the right bank, as we look down the stream.

Let us apply this principle to the trade-winds. They start at about latitude 30°, and as they move toward the equator this rotary influence would turn them more and more to the right of their course, until they would return perhaps in a circle to their starting-point; the west winds of latitude 40° and farther north would also take a circular path, turning east, then south, and finally west.

In obedience to the force of the rotating sphere, the winds would move in circular paths all over the surface of the earth. But although the currents turn to the right of a north and south course, they do not take a circular path. Are the Frenchman's mathematics wrong? It is said that figures do not lie. Or is there another force that we must take into account?

As the wind crowds toward the right, the atmosphere piles up like water before the moving oar.

This increases its density on that side and diminishes it toward the left. Fig. 59 will make this plain. Let us suppose that there is a low barometer at *T* and a high at *S*. On account of the difference of pressure, then, the currents would move from *S* to *T*, but on account of the rotation of the earth they would take the curved path, *S G R*. Now the crowding effect on the right would prevent the current from taking this path. Its course therefore would lie somewhere between *S T* and the curve *S R*, as, for instance, *S C*.

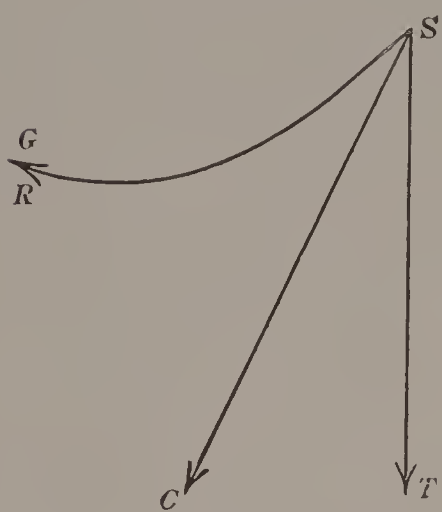


FIG. 59.

Thus the combined effect of the rotary principle and of the crowding gives the trades in the northern hemisphere a southwest motion, instead of either a southern or a circular direction, while the prevailing winds north of the horse latitudes continue in an easterly or northeasterly direction—that is, they are all generally west or southwest winds.

THE UPPER CURRENTS.

Now we come to consider the upper currents. As shown by the clouds and the smoke from volcanoes, the air that rises at the equator does not flow off directly toward the poles, but turns eastward, so that its course is even more oblique than the trade-winds below, as shown in Fig. 60. When these upper currents—the return trades, or antitrades, as they are often called—reach the horse latitudes the greater part of the air settles down to the earth and thus becomes the feeder of the trade-winds. The rest of it continues east, slightly northeast, spirally around the earth toward the poles. This circular motion around the poles creates a valley or rare area there. This idea may be illustrated by suspending a pail of water from the ceiling and twisting the rope. When the pail is left free to whirl, the water heaps up at the edge of the pail, leaving a depression in the center.

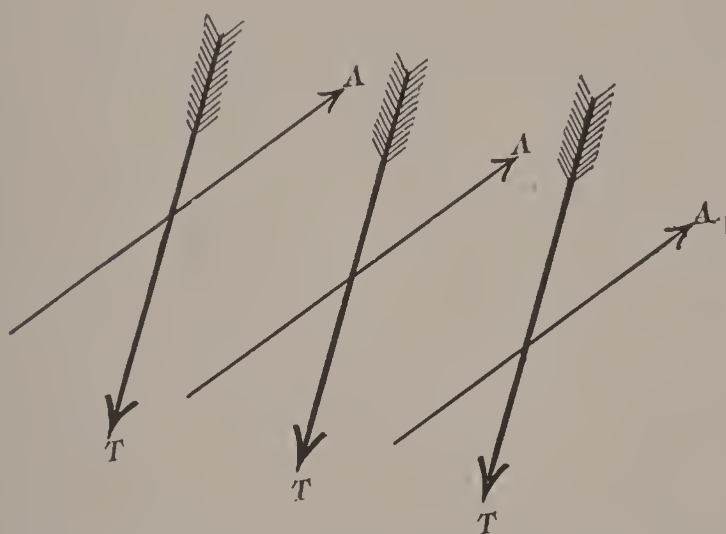


FIG. 60.—*T*, *T*, *T*, direction of northeast trade-winds; *A*, *A*, *A*, direction of anti or return trade-winds.

The air moving toward the poles would, of course, soon pile up there if it did not in some way flow back to the equator. Where and how it does that is not so well defined. Some of it gets back as a surface wind, and part of it as upper currents; sometimes it seems to glide south between the upper and lower currents of the earth. All of us have experienced cold winds suddenly dropping down upon us from the northern points of the compass.

BELTS OF HIGH PRESSURE.

Another interesting thing must be mentioned. The average annual barometer is 29.8 at the equator, in the horse latitudes it is 30.2, and in the high latitudes, 30 inches. Thus we see that there is a belt of high pressure in the horse latitudes the year round, and particularly over the Atlantic Ocean. There seems to be a hill of atmosphere over the Sargasso Sea, from which the air flows out in all directions.

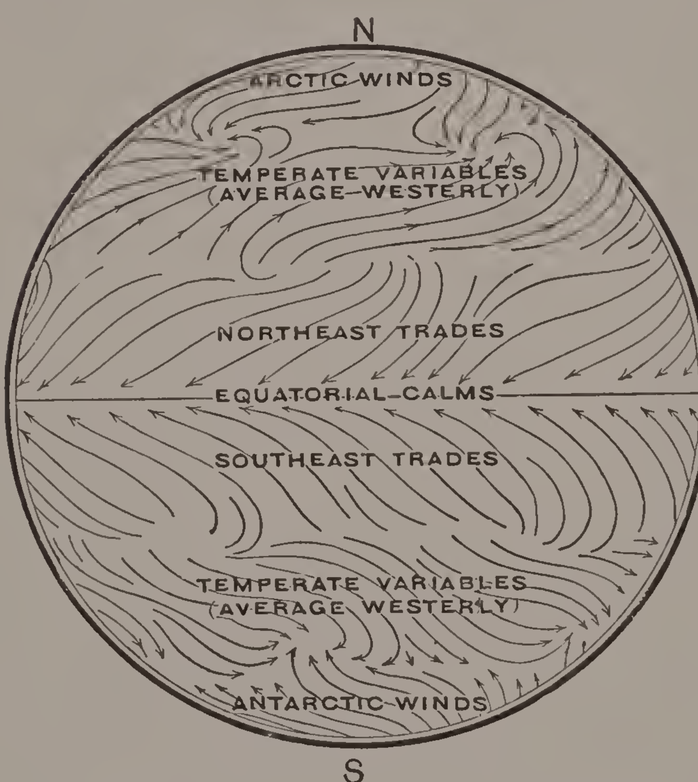


Fig. 61.—Wind belts or zones, and polar caps.

What can the cause of this be? It seems to me it is this: the air moving north is crowded together the farther it moves poleward. The meridians are nearly seventy miles apart at the equator, but at the poles they meet. At latitude 30° the distance between the meridians is only 60 miles; at latitude 40° it is about 53 miles. Thus it will be seen that air spread out over a distance of 70 miles at the equator, moving poleward, is crowded into a space of only 53 miles in width at latitude 40°. This would naturally heap it up in the horse latitudes, and thus, as the barometer shows, increase its density.

PERIODICAL WINDS.

Thus far I have considered the general circulation of the atmosphere. There are many things, however, which interfere with it. Just as the irregularities of the pebbles and boulders in the river-bed produce side currents and eddies in the onward flow of the stream, so there are various causes that disturb the general direction of the winds.

I set a pan of sand and one of water in the hot sun. The temperature of the sand rose sooner and higher than that of the water, but when the sun went down the sand cooled faster. Why?

One time I camped six weeks on the shore of the Caribbean Sea. Scarcely a breeze could be felt at eight o'clock in the morning, but a half-hour later a gentle wind came off the sea, which steadily increased in force until about two o'clock, then it slowly diminished, and died out a little after sunset. This evening calm was soon after disturbed by the wind blowing seaward off the land, and thus continued until the morning calm.

The cause of these winds is that the land becomes warmer than the water during the day. The cooler air from the sea forces the lighter air which is over the land upward, thus starting a current from the sea

FIG. 62.—Texan norther advancing with head of clouds.

toward the land. During the night the sea is warmer than the land, because it cools more slowly, and hence the wind is reversed. The wind blowing off the sea is known as a sea breeze, and that off the land as a land breeze. For the same reason currents of air may exchange between a forest or grass-covered plain and an arid region.

The "sirocco" of Algiers and Italy and the "solano" of Spain are hot, tiresome winds which have blown off the deserts of North Africa across the Mediterranean to the Alps. They have such a wearing effect on both man and beast that the Spaniards have a proverb, "Ask no favor during the solano." These winds usually come in the van of cyclones.

There are many other disturbances of this character in different parts of the world. They have received local names; some of them are interesting, as the United States "blizzard," the Texan "norther" (Fig. 62), the "southerly bursters" of Australia, the "pampero" of Mexico and the Argentine Republic, and the "mistral" of southeast France. These usually come in as the tail of the cyclone. The monsoons are nothing but exaggerated sea breezes which blow off the Indian Ocean across southern Asia during the season when the land is much heated by a torrid sun. The monsoons are so strong that they interrupt the trade-wind on the Indian Ocean. Mountains and valleys, forests, plains, lakes, each has a disturbing influence on the regular flow of the air currents.

CHAPTER XV.

CYCLONES AND ANTICYCLONES.

Some days the wind seems to be changing from one direction to another, and even to a third and fourth; my record shows that such changes usually accompany storms. I could not understand why this occurred until I studied the weather map issued by the United States Government. On my application to the Weather Bureau at Washington this was readily sent to me every day.

There were many lines on this map that at first puzzled me. The most prominent, I discovered, were those that connected places which had the same barometric pressure. They varied in direction from almost circular or elliptical curves to slightly winding lines. For instance, the line marked thirty connected all the places where the barometer stood at thirty inches that day. The curve marked 30.2 connected all places where the barometer stood at that height, and so on.

Where the barometer was highest the map was marked "high," and where it was lowest it was marked "low." I soon noticed that the high and low points were continually changing, and, what surprised me most, that they moved from the west toward the east quite regularly. The "low" would appear in the neighborhood of British Columbia and move southwest to Illinois, then northeast toward the mouth of the St. Lawrence River, and finally pass over the Atlantic. Sometimes a "low" would come up into Lower California and move eastward along the Gulf to the coast. Another "low" would appear from the southeast in Georgia and pass up the coast toward Chesapeake Bay. Storms almost always accompanied these "low" centers.

Now I wanted to find out about the forward movement of the storm center. For this purpose I studied the weather maps. November 1, 1899, there is marked on the weather map a "low" in the region of Chesapeake Bay. The same day there was a "high" near Winnipeg. The map for the next day shows that the "low" near Chesapeake Bay had moved northeast up the coast to the mouth of the St. Lawrence, and another "low" had appeared in southern Alabama. The "high" seemed to be developing two centers, one moving to the north of Lake Superior, and the other into Nebraska.

By means of the scale on the map I measured the distance traveled by the "low," and found it to be five hundred miles in twenty-four hours, or 20.8 miles per hour. Measuring these changes for a month, I found that the average distance per hour they traveled during the month of November was 23 miles. Mr. Ferrel gives 24.4 miles as the average velocity per hour for July, and for January, 30.8 miles per hour.

The map of November 1st shows that the wind throughout the Mississippi valley was northwest and north. This would indicate that there is a low barometer somewhere in the Gulf. The conclusion proved correct, for the next day the "low" from the Gulf moved into Alabama.

On November 1st the barometer was 30.2 in Manitoba and 29.9 at Chesapeake Bay, a difference of 0.3 inches in the pressure of the atmosphere. We would naturally expect the air to flow from the former to the latter region; but instead, it flowed from Manitoba toward Alabama, although the barometer on the Gulf coast was thirty inches, or one-tenth higher than at Chesapeake Bay. The deviation of the air currents from an easterly to a southerly direction, it seems to me, was caused by the Appalachian Mountains, the Mississippi valley becoming, as it were, a trough for the air to flow in.

Let us now look at the direction of winds about a "low." In Alabama, on the 2d of November, the wind blew toward the center of low pressure from the north, northwest, west, and northeast. This is fairly illustrative of the direction of the wind about a "low" (Fig. 63).

After examining maps for a number of days, I was convinced that the atmosphere moves spirally around the center of low pressure, and in the direction contrary to the movement of the hands of a watch if laid down face upward. These regions have therefore received the name of cyclonic centers; "highs" are known as anticyclonic centers.

Sometimes the cyclone has a diameter of more than a thousand miles. The atmosphere moves

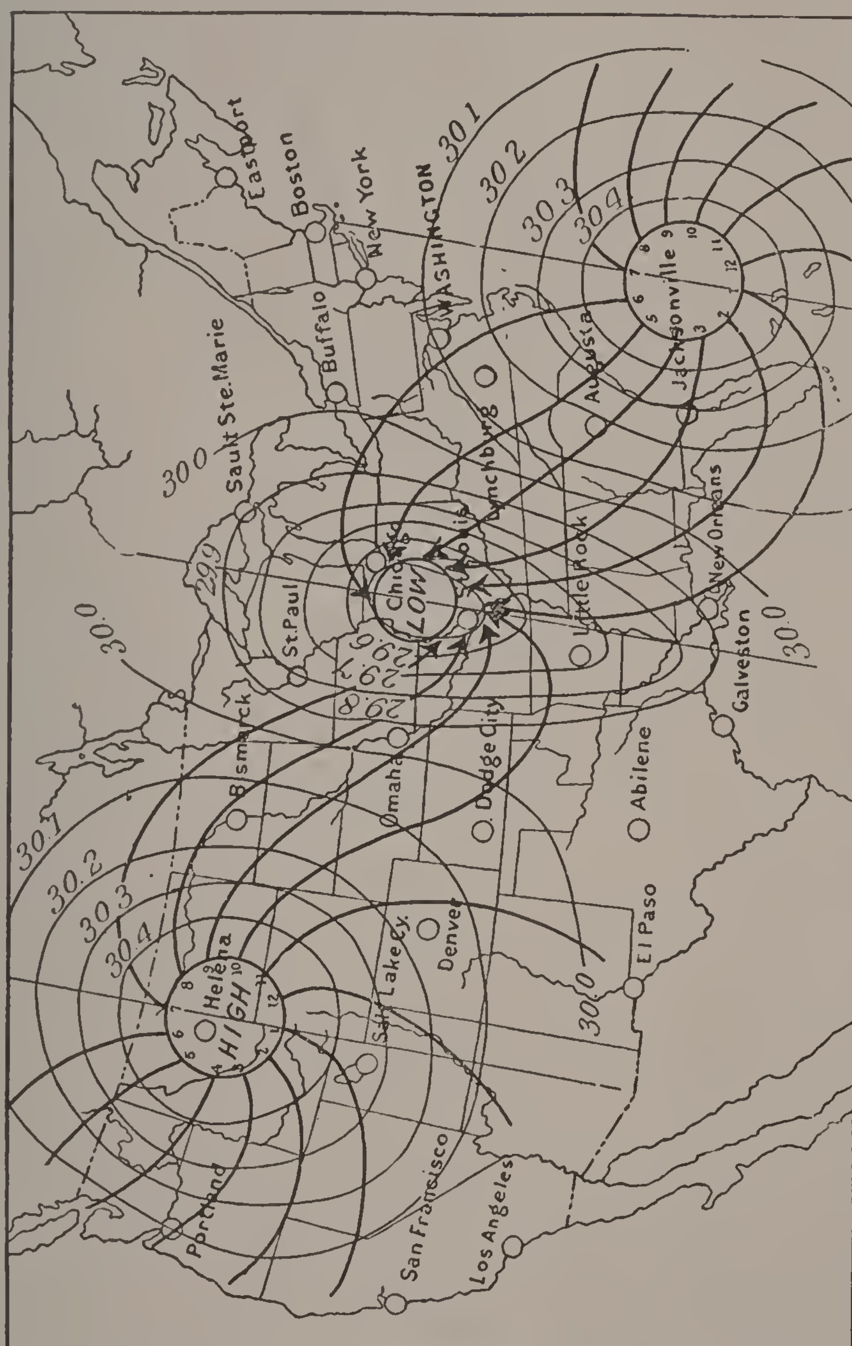


Fig. 63.—Winds flowing in toward the "low" or cyclonic center with a "high" or anticyclonic region at the left. (From the Popular Science Monthly for July, 1898.)

around a central point, in the shape of an immense spiral growing wider toward the top. It is, in fact, a great eddy in the stream of the atmosphere, which may be compared to water flowing out of a tub or basin through a hole in the bottom. I filled a large stationary wash-bowl with water, and after the liquid had become perfectly quiet I pulled the cork out very carefully. Soon the water began to move in a spiral direction just above the hole, and quickly developed a funnel-shaped opening. This experiment was performed thirty-eight times. Thirty-three times the water moved in a spiral direction contrary to the hands of a watch, and but five times in the opposite direction. I could easily see why it should move spirally, but why it should choose one direction rather than the other I was not able to tell.

As the plug is pulled out, the water begins to drop through the hole, and the liquid rushes in from all sides to take its place. As it does so, the opposing currents collide with and pass each other, producing a rotary motion.

A cyclone is very much like this, except that where the water flows downward through the opening, the atmosphere flows upward and outward in the center of the cyclone, as the rotary motion tends to produce a vacuum.

Why should the rotary motion be contrary to the hands of a watch? As the air particles flow toward the storm center, often from a great distance, in obedience to the suction, they are turned to the right of a direct course (Fig. 64) by the rotating influence of the earth. Its path to the center would therefore be a portion of a narrowing spiral (Fig. 64). Air particles from other points would take a like path, so that the atmosphere would flow about the storm center from right to left. No doubt it is partly due to another influence: the low-pressure area is several hundred miles in diameter, and the southern side would therefore be perceptibly warmer than the northern side. As the warmer air flows toward the center from the southern side it meets cooler currents. This results in the condensation of its moisture, and tends to diminish the pressure, while on the north side the cooler meets the warmer air, resulting in "clearing up." As the air in the southern part of the region would yield more readily to the eastward current than that on the north side, rotation in the direction stated is started. Rotation once started is kept up by its own inertia.

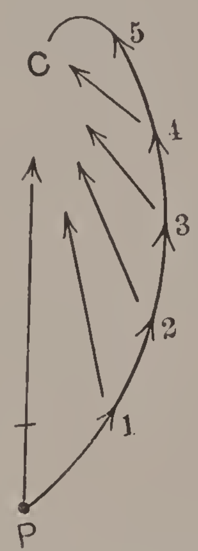


Fig. 64.—*C* is the storm center; *P* a particle of air moving toward it, but by rotating influence is carried into the curved path *1 2 3 4 5 C*. (From About the Weather.)

As the atmosphere north of the horse latitudes has the general eastward motion, it carries these storm centers with it. In the United States they come off the Pacific and enter the continent in the neighborhood of British Columbia, and after reaching the interior they bend slightly to the northeast, entering the Atlantic through the valley of the St. Lawrence. Sometimes, it is true, they are broken up or deflected somewhat from this course.

Now we shall be able to see how it is that an observer, who knows barometric pressure and the condition of the sky at a great many points, can figure out the location of a storm, and if he knows how rapidly a storm is moving, he can predict the time it will take to reach certain localities. The greater the number of stations where observations are taken the more certain may the predictions be made. Many things must be taken into consideration, and it is not strange that predictions should sometimes fail to come true. But as our experience and information increase, we may become more and more confident. Even now, the Weather Bureau by predicting storms is doing a work of inestimable value for shippers and ship-owners, and is, besides, saving many lives.

> "I am Storm—the King!
> My troops are the wind, and the hail, and the rain;
> My foes are the woods and the feathery grain,
> The mail-clad oak that gnarls his front to my charge
> and stroke."

THE PATH OF THE STORM CENTER.

In our region I noticed that during storms there are three series of changes (Fig. 66) in the direction of the wind. During five storms out of twenty the wind was from the south, or nearly so, just before the rain, and as it passed the wind changed to the north. In connection with six, the wind changed from the southeast to the east, and then to the northeast. In nine storms the wind changed from the southwest to the west, and then to the northwest.

Now these three series of changes show us the path of the storm in each case. As the wind blows around the storm center, contrary to the hands of a watch, it will be plain that when the storm passes through our locality it will blow from the south, or nearly so, at the beginning. When the center reaches us there will be no wind, and when it passes us we shall have a north wind. The second series shows that the storm center passes south, and the third series shows that the storm passes north of us. Fig. 66 will make this plain.

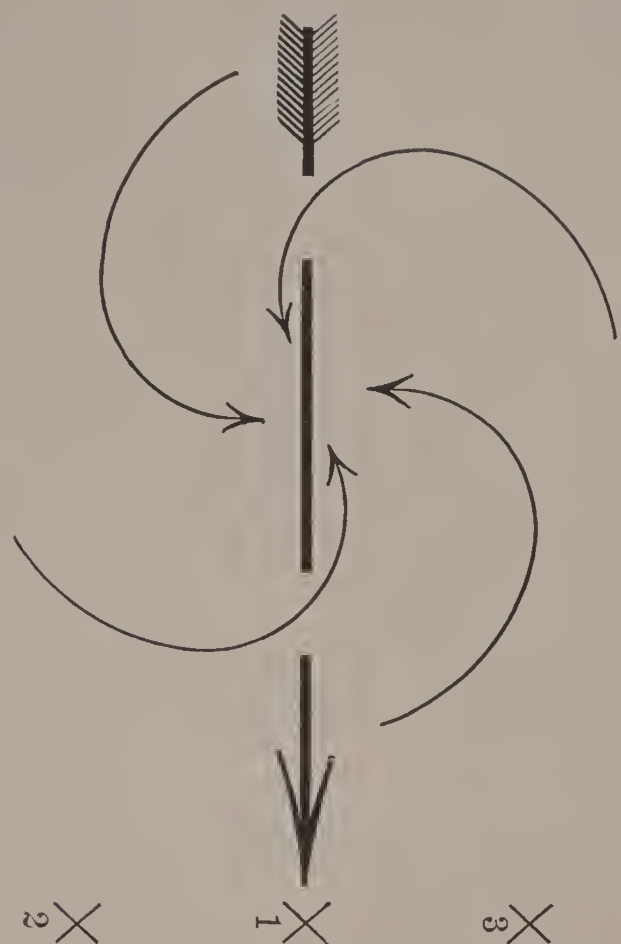


Fig. 66.—Changes of wind in general storms. If we are at *1*, the wind reverses; if south of it at *2*, it veers toward the northwest; if north of it, to the northeast.

TORNADOES.

In popular language all rotating storms are called cyclones, but it is better to confine the term cyclone to rotating storms whose diameter is more than a mile at least, and use the word tornado for smaller and more destructive storms. This distinction is generally made by scientific writers.

"Tornado" comes from the Spanish word meaning to turn, and it has the same signification as the Greek word cyclone. I have often watched "dust-whirls" skip across fields or down the street. I remember seeing a dozen or more at one time crossing a forty-acre field. The wind whirled about a central point, carrying with it straws and other light objects, whirling them round and bearing them ever higher and farther out, until their momentum carried them beyond the influence of the whirl.

Fig. 67.—A dust-whirl moving contrary to the hands of a watch.

The tornado is like the "dust-whirl," except that it is very much intensified. The air rushes up in the center with such force as to carry men, and even horses and other heavy objects, up to some distance above the ground. These, like straws, may be whirled about until they are carried out beyond the storm and sometimes set down unharmed.

A tornado passing near Storm Lake, Iowa, in 1893, picked up a six-months'-old child, and after carrying it

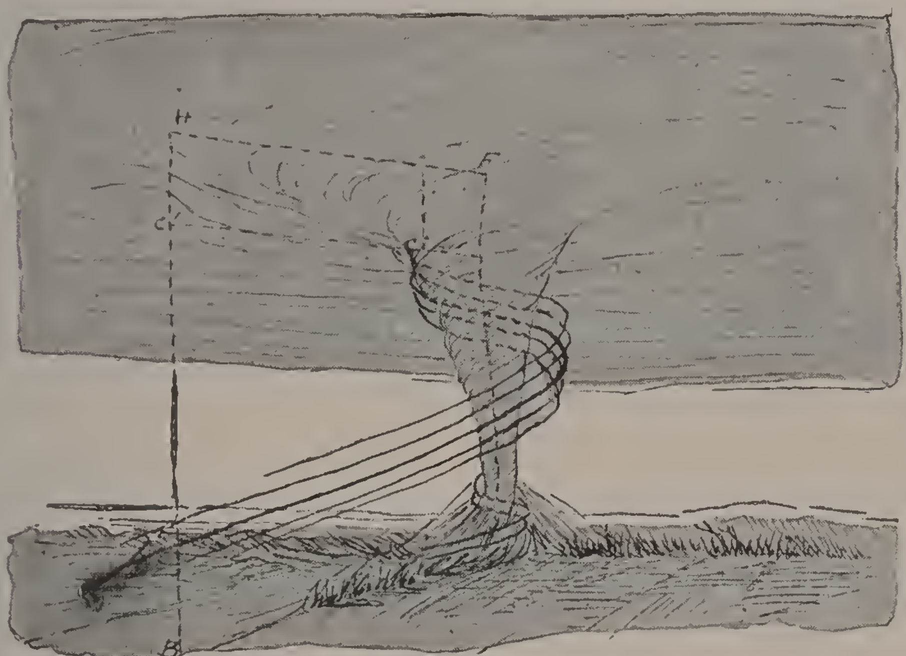


FIG. 68.—Tornado funnel cloud moving in a spiral around the vacuum center. Its vapor *C*, condensed by expansion and ascent, appears considerably below the ordinary cloud level *FH*. (From Story of the Atmosphere.)

through the air a distance of three-quarters of a mile, gently laid its sleeping burden down in a corn-field. The child did not seem to be at all discomfited by its airy flight, for it greeted its finders with a smile. Many other curious incidents accompanying tornadoes might be added.

The upward current of air is usually warm, and carries with it a large amount of moisture; this the cold air above condenses and pours down in brief torrents of rain, accompanied by lightning and other electrical phenomena.

A tornado is seldom over a quarter of a mile in width, sometimes not over twenty feet, and its length rarely exceeds twenty-five miles. At times the destructive cone of the tornado touches the earth for a short distance and then is lifted up so that it does no damage, and again is let down, to carry everything before it.

It is claimed that tornadoes form in the southern edge of a cyclone. As most of our storms in the United States are cyclones of greater or less extent, they afford frequent opportunity for tornadoes during the warm half of the year.

Waterspouts may be said to be nothing more than tornadoes on the sea. The water, which is generally believed to be drawn up from the ocean, is really the cone of water formed by the condensation of the moisture in the upward-flowing air. Sometimes the water seems to rise from the ocean, and it does doubtless heap up just beneath the waterspout; but the water in the funnel-shaped cloud is not salt, as it would be if it had been lifted up from the ocean; it is clear, fresh water. This has been proved by the testimony of seamen whose vessel-decks have been flooded by these terrors of the sea.

Hurricanes are the product of tropical seas. The word is Caribbean in origin, and it had a meaning akin to tornado, but is now often applied to any violent, destructive wind. The hurricanes of the West Indies are the children of the trade-winds. They approach as chilling storms from the northeast. As they near the equator they turn to the right, finally moving northwest to the United States and then along the eastern coast parallel to the Gulf Stream. As they turn northwest their force begins to diminish, though they often strand small craft as far north as New Jersey.

Hurricanes rotate about a central point, like the cyclone I have described, but in a contrary direction —that is, with the hands of a watch. As their diameter is smaller than that of the cyclone, their destructive power is correspondingly greater.

Hurricanes also occur in the southern part of the Pacific Ocean, but none have been seen in the southern Atlantic. Those which accompany the Japan current in the China Sea are called typhoons.

These storms are often very dangerous to life and property along the shores which they touch, not only on account of the force of the wind but because of the high ocean wave which they roll over the low-lying coast lands. Sometimes stanch ships caught in the path of a hurricane or a typhoon are destroyed. In 1885, on the Samoan Islands several war-vessels were wrecked by such a storm.

CHAPTER XVI.

LOOKING BEYOND THE WORLD.

We have looked into the crust of the earth and tried to read something of the story it has to tell, of its struggles, of its ever-changing and improving life. We have made some observations on the ocean of air that enwraps the globe, of its currents that surge to and fro, bringing health and breath to every living thing. We can not be content with this world. We look out through its blue envelope into the wide beyond. Man in all ages has done this. The child looks up, full of inquiry, feeling what the poet says:

"Twinkle, twinkle, little star,
How I wonder what you are,
Up above the world so high,
Like a diamond in the sky."

As he grows older he continues to wonder and enjoy.

Look up at the star above you so far away. Its light shoots through space faster than any bullet ever sped. If that star had been snuffed out when De Soto dropped into the Mississippi River, it would be years and years before the last of its rays would reach us.

But there is not the end of the heavens. Far beyond that star the telescope discovers other stars.

Fig. 69.—The Yerkes Observatory, Williams Bay, Wisconsin.

Are those at the end of the universe? No. Think far beyond that star, and you can not think the end is there. Well said Buffon, "The center of the universe is everywhere and its circumference nowhere."

All this space seems to be full of shining suns.

"Stars which stand as thick as dewdrops on the field of heaven."

"Silently, one by one, in the infinite meadows of heaven,
Blossomed the lovely stars, the forget-me-nots of the angels."
—LONGFELLOW.

How would it impress you if the stars were arranged in a row like the corn in our fields? Their irregular arrangement impresses us all the more with the idea of infinity. We can never properly estimate their influence on the world. Imagine these heavenly hearth-fires put out, never to be seen again, and the sky always as dark as it sometimes is when dense storm-clouds shut them out; that, night after night, year after year, there should be no stars; never again cheer, no more inspiration, in the dark hemisphere.

In all ages man has been touched with a feeling of interest in these celestial neighbors. He has ever dreamed that somehow they have something to do with his happiness and destiny. And so it happened that the first science we know anything about was astrology. At first this was a code to predict future events in the life of men and nations. Later it included the effect of stars and planets upon individuals, particularly at birth.

The primitive mind saw figures in the various star-clusters—figures of men and beasts—and gave them names. How far back it was we can not tell.

In Job, perhaps the oldest book in the world, we read: "Canst thou bind the cluster of the Pleiades, or loose the bands of Orion? Canst thou lead forth the Mazzaroth in their season? or canst thou guide the Bear with her train?"

FIG. 70.—From a photograph of the Pleiades.

In the second century B. C. Ptolemy gave a list of forty-eight of these clusters or constellations, to which nearly as many more have since that time been added. The only value they have is for convenience in locating comets and planets in their motion. For instance, the astronomer says a certain comet, planet, or nebula was seen in the constellation of Libra, or Leo, as the case may be.

All persons have an interest in the starry heavens, especially young people. After a beginning has been made, many an hour may be spent in profitable study and recreation as well as amusement.

To start with, it will be helpful to imagine the heavens to be a large hollow sphere with the earth in the center. The ancients believed that it was really so, and thought the stars were tacked on it on the inside. This conception is, of course, not a true one. Further, imagine the earth turning on its axis in the center of the supposed celestial sphere. As we turn about, the stars seem to move from east to west, as the sun does in the daytime.

Now let us become familiar with a few terms used in astronomy. Suppose you are standing on a hill, or, better, on the deck of a vessel out of sight of land. Directly above your head is the zenith, and in the opposite direction through the earth is the nadir. The circle all around you, where earth and sky seem to meet, is the horizon—that is, the sensible horizon. The true or celestial horizon is parallel to this and lies in the plane which passes through the center of the earth beneath our feet. It cuts the celestial sphere into two equal hemispheres. The sensible and the real horizon, however, are one and the same in the infinite distance of the sky.

When we speak of the meridian, we mean an imaginary great circle which passes from the north star through our zenith to the south pole. It divides the sky into two equal parts. The sun comes to this meridian at noon. As the earth turns, this meridian is constantly changing. The meridian of any place at any time is the one which passes exactly overhead. The celestial equator is the great circle that crosses the meridian circle at right angles half-way between the north and south poles. On the first day of spring the sun moves along the celestial equator in the heavens. If an observer stand on the earth's equator his meridian passes north and south directly overhead, and his celestial equator passes directly overhead east and west.

Right ascension is the longitude of the star, that is, the distance of the star west of the meridian passing through the constellation Aries. It is now usually reckoned in hours, not degrees. The declination of a star means its distance north or south of the celestial equator, expressed in degrees. Thus we may observe that a star is in R. A. 2 hrs. 45 min. 30 sec., and N. D. 30° 25′ 40″.

With this preparatory information, let us go forth some clear night and choose an eminence, if possible, from which to watch the motions of the stars. Standing with your face to the north, you may see the Dipper at your right, at about eight o'clock, if the month be January, or the Great Bear to the northwest and the Little Bear in front, looking toward your zenith. (See Book II of this series.) Also notice the position of other clusters and the several bright stars in view. Another view two hours later will show that all the stars have changed position, except the pole star. Further examinations will prove that the pole star is the only one that remains stationary, and that all those near it seem to revolve about it.

If the observer is in latitude 40° and his horizon is unobstructed, he will be able to see all the stars whose north declination is over 40° make a complete circle in the northern sky. He will also notice that the rest of the stars rise in the east and appear to pass across the heavens to the west, and that each star rises four minutes earlier every night.

Besides the stars about the north pole, which you can see every clear night the year round, and those that rise and set to our vision, there is another field of stars about the south pole which you can never see from your position. We can never see more than half the sky at a time, no matter where we stand on the earth. The farther north we go the greater the number of stars that never set. At the north pole we may see all the stars visible in the north half of the heavens, and none of them would set for us. If we take our position at the equator, we may see all the stars in the firmament in succession, and all of them would rise and set to our vision.

Now let us examine the stars that seem grouped into constellations. If we look at them we discover many outline figures. There are three bright stars arranged in a triangle; here is another triangle, and there is a square, and overhead is a trapezium. Then we notice some arranged so as to suggest a sickle or a crown or a coffin, and so on. Thus we might group most of the stars into constellations and give them names of our own. Some of these names would, naturally enough, be like those that have become historical.

Students of the stars speak of *Alpha Orionis* or *Gamma Ursæ Majoris*, which in plain English means the first or brightest star in the constellation Orion, or the third star in brilliance of Ursa Major (the Great Bear). Or the astronomer says, "The comet is now in Libra or in the right foot of Cancer." These and other like expressions can not be appreciated unless we are familiar with the leading constellations both by name and position.

First, then, the polar constellations may be familiarized. The two Bears are already known. It is convenient to have a measuring rod for the apparent distance between stars. For instance, the two stars that make the bottom of the Dipper are eight degrees apart; those forming the side opposite the handle, known as the pointers, have five degrees between them. The two end stars of the three that form Orion's belt are three degrees from each other.

CHAPTER XVII.

THE STARS ABOUT US.

Which is the brightest star in the sky? It is not difficult to find, for the star Sirius outshines them all easily enough. Venus often seems larger, but she is a planet and no star, and shines by the reflected light of the sun, as does the moon.

How many other bright stars can you find that might be put in the same class with Sirius? If you should group the visible stars, how many classes would you make? It will interest you to stop reading here and examine the stars, for the purpose of discovering an answer to the foregoing question, to find how nearly you agree with the astronomers.

Astronomers do a great deal of guesswork in classifying the stars as to their brilliancy. Professor Pickering, of Harvard, was the first to adopt a systematic plan for measuring the magnitude of the stars, He made a catalogue of nearly five thousand stars. varying from the first to the fifteenth magnitude.

All the brightest stars are said to be of the first magnitude. Of these there are twenty-one. I will add the names, as they are few and of sufficient interest. Later you may be able to locate them. The names in the order of rank are: 1. Sirius, in the Great Dog. 2. Canopus, in Argus. 3. *Alpha*, in the Centaur. 4. Arcturus, in Bootes. 5. Rigel, in Orion. 6. Capella, in Auriga. 7. Vega, in Lyra. 8. Procyon, in the Lesser Dog. 9. Betelguese, in Orion. 10. Achernar, in Eridanus. 11. Aldebaran, in the Bull. 12. *Beta*, in the Centaur. 13. *Alpha*, in the Cross. 14. Antares, in the Scorpion. 15. Altair, in the Eagle. 16. Spica, in the Virgin. 17. Fomalhaut, in the Southern Fish. 18. *Beta*, in the Cross. 19. Pollux, in the Twins. 20. Regulus, in the Lion. 21. Deneb, in the Swan.

The next group in brilliancy includes stars of the second magnitude, and so on. Few people can see stars smaller than the sixth magnitude.

Is the brightest star nearest to the earth? The distance of but few of the stars has yet been computed, as it is a difficult task. Their distance from the earth is so great that to state it in miles would be about as foolish as to measure the circumference of the earth in thumb-nail lengths. The measuring rod for stars is the distance light will travel in a year. Light travels 185,000 miles in a second; that will make our rod 5,839,031,680,000 miles in length. The nearest star, Alpha, in the Centaur, is four and a quarter "light units" distant; in other words, it would take light four and a quarter years to reach the earth from that star. Sirius is the fourth nearest star to the earth. We can hardly get an idea of the great distance of the stars from our earth. A star seen even through a large telescope does not appear increased in size. If we look at one in the northern part of our sky in winter it seems to be no brighter than in July, although we are then over three million miles nearer to it.

When God wished to impress Abraham with the greatness of his promise, he said, "Look now toward heaven, and tell the stars, if thou be able to number them." The stars visible to Abraham that night could not have exceeded three thousand in number. The whole sky, it is estimated, will not show more than six thousand to the unaided eye. Galileo's "baby" telescope added a long list, which was much increased by Lord Rosse's great reflector. Our famous modern glasses, and particularly photography, are steadily adding to the number. After considerable study, Sir John Herschel estimated the number of stars to be five and a half millions; a later astronomer made it twenty millions.

Numerous and interesting have been the answers through all ages to the question, What are the stars? The answers cover a great range of thought from the little child's idea that they were gimlet-holes in the sky to let the light in, to the most elaborate statement of the physicist.

The stars are, in short, suns like our own. Indeed, our sun removed to the distance of Sirius would probably become a star so small as to be unseen by the naked eye. Not only does the appearance of these luminaries suggest this answer, but students of the stars have actually examined a considerable number of them with the spectroscope, and found that their light is in composition the same as that of the sun. Men versed in star lore have the confidence, as Mr. Chambers suggests in his very readable Story of the Solar System, to say—

"Twinkle, twinkle, little star,
Now we've found out what you are,
When unto the midnight sky
We the spectroscope apply."

STAR-CLUSTERS AND GROUPS.

No one can long look at the sky on a clear night without observing the fact that the stars are in many parts grouped together in a cluster. These groups attracted the attention of the most ancient observers, for the oldest records mention them.

The one that is sure to be seen is a cluster of six visible stars in the shoulder of the constellation Taurus; they are called the Pleiades. The mythology connected with them is entertaining, and may be found in almost any encyclopedia. It is claimed that formerly seven stars were visible, and that one has since disappeared. Good eyes can see seven or eight; one lady claims to have seen twelve; a photograph reveals more than two hundred in the group.

Another cluster is known as the Hyades, meaning the raining. The ancient scientists connected them with the rainy season which began about the time of the year when the sun rose with the Hyades. This cluster is in the shape of a V, and forms the head of Taurus.

Many of the stars that appear to be single are really a cluster. Some are double, the smaller revolving about the larger; others are double-double, one two revolving about the other two.

Fig. 71.—α Herculis, double star in the telescope, appears single to the eye.

The Milky Way is a part of the sky where the stars seem to be crowded together, forming numerous clusters. These clusters are arranged in a belt that suggests a highway extending obliquely across the sky.

In places in this belt we may see with the naked eye hazy, luminous patches called nebulæ. They appear in many different forms. Herschel examined and made drawings of a large number of them, and others have since been described (Figs. 9 and 10). Some of them make a very beautiful field in the telescope. A curious one may be noticed in Orion just below the belt. It seems to be luminous pale-green matter. The spectroscope shows that it is burning hydrogen. It covers an area many times larger than our own solar system.

Other nebulæ are shown by spectrum analysis to be more condensed. One in the Great Bear has two central nuclei.

These nebulæ, together with others, could be arranged in the form of a series, from the simple gaseous matter apparently just beginning condensation, through various stages, until we reach the central nucleus, a star surrounded by more or less detached bands of luminous matter. Is it possible that interstellar space is filled with invisible star dust coming out of the abyss of nothing and gradually gravitating

FIG. 72.—ζ Herculis, a double star, as it appeared in 1865.

FIG. 73.—ζ Herculis, as it appeared in 1871.

here and there into nebulous clouds, just as the invisible vapor of our atmosphere piles up into clouds of various shapes and densities?

Are these nebulæ illustrations of the growth of solar systems? They certainly suggest this thought. If so, worlds are still forming. Indeed, these nebulæ are so far away from us that their nebulous light may long ago have been changed to pure sunlight. So immense are the distances that the swift messenger light could bring us only very tardy news. Yes, the news would not reach us until thousands of years after the transformation had occurred.

Fig. 74.—Herculis again, as it appeared in 1883.

There is one nebula in the Scorpion that has in the last century apparently changed into a star and then again become nebulous. Others have grown luminous at different periods and have again become invisible. Such are called variable nebulæ. Still others are double, and will probably in time become double stars.

Nebulæ are of different shapes and extent. The Cloud of Magellan is a nebulous field in the southern hemisphere containing 291 nebulæ, 46 clusters, and 582 stars. Other large nebulous tracts are found in different parts of the universe. Our minds grow weary thinking of the immensities of space which contain all these great and wonderful starry hosts.

CHAPTER XVIII.

THE CONSTELLATIONS.

The star-clusters known as the constellations are fanciful groupings of stars so arranged that the outline of an animal or other object can be imagined. In remote times, when man was wont to observe the heavens he thought he saw outlines of figures in the sky. He traced these outlines with much interest. Later they were mentioned in astrological writings, and poetry has in all times abounded in allusions to these star-clusters. Partly for information, but chiefly because they afford us opportunity for much observation in any part of the world, a brief description of the more important constellations is here given.

The prominent constellation generally known as the Great Dipper, or the Great Bear, is a good starting-point, and from this we may easily trace the others by means of illustrations (see Fig. 76).

As the stars follow the sun in their apparent westward course, it is evident that all the clusters will pass overhead in the course of a year, as far as they can be seen by us from our latitude. Every month one-twelfth of 360° passes into view, and as many pass out of view. Those about the north pole never go out of our view, while the others near the south pole never rise above our horizon.

First, then, let us make ourselves familiar with the polar constellations, and afterward with the clusters in the zodiac.

In the latitude of Chicago or New York the Great Bear may be seen on a clear night, when he is beneath the pole. In the month of October, about 9 or 10 o'clock, we may see him walking on the horizon eastward (six months later he will be overhead going westward). The Little Bear hangs from the north pole by his tail, his head pointing to the south toward the tail of his larger mate. Follow the "pointers" of the Dipper to the pole star, and just beyond and overhead is the cluster known as Cepheus, supposed King of Ethiopia. He was im-

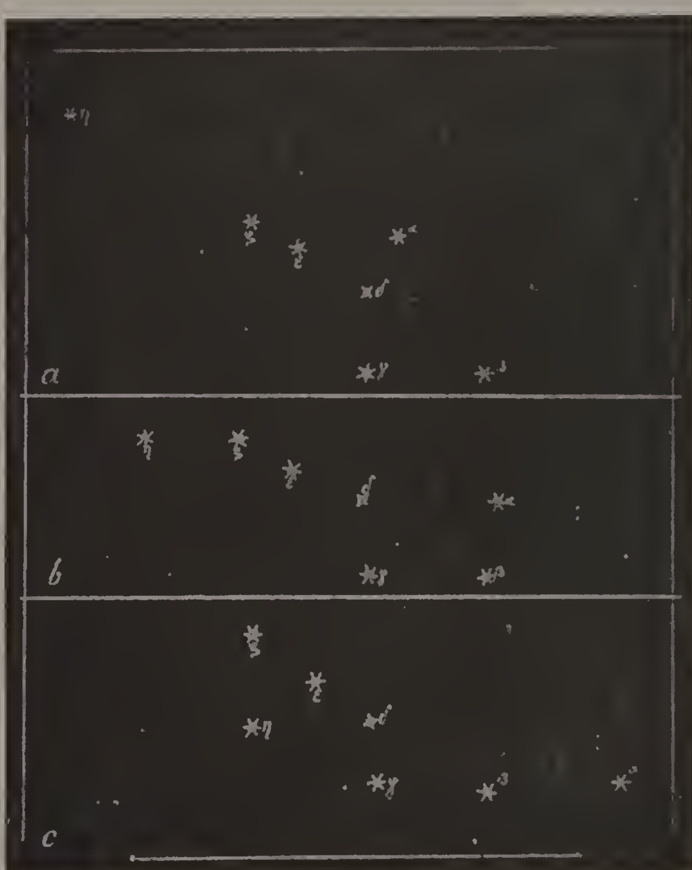


Fig. 75.—The Great Dipper. *a*, relation of the stars as they were several thousand years ago; *b*, as they are to-day; *c*, as they will be several years hence, as determined by observations.

mortalized in the heavens because he was one of the personages that accompanied Jason on his argonautic expedition in search of the golden fleece. The cluster includes thirty-five visible stars. He stands with his foot on the pole and his head touching the Milky Way. His crown can be found by three stars of the fourth magnitude in the form of an acute triangle. Some of those in the body suggest an outline of a capital K.

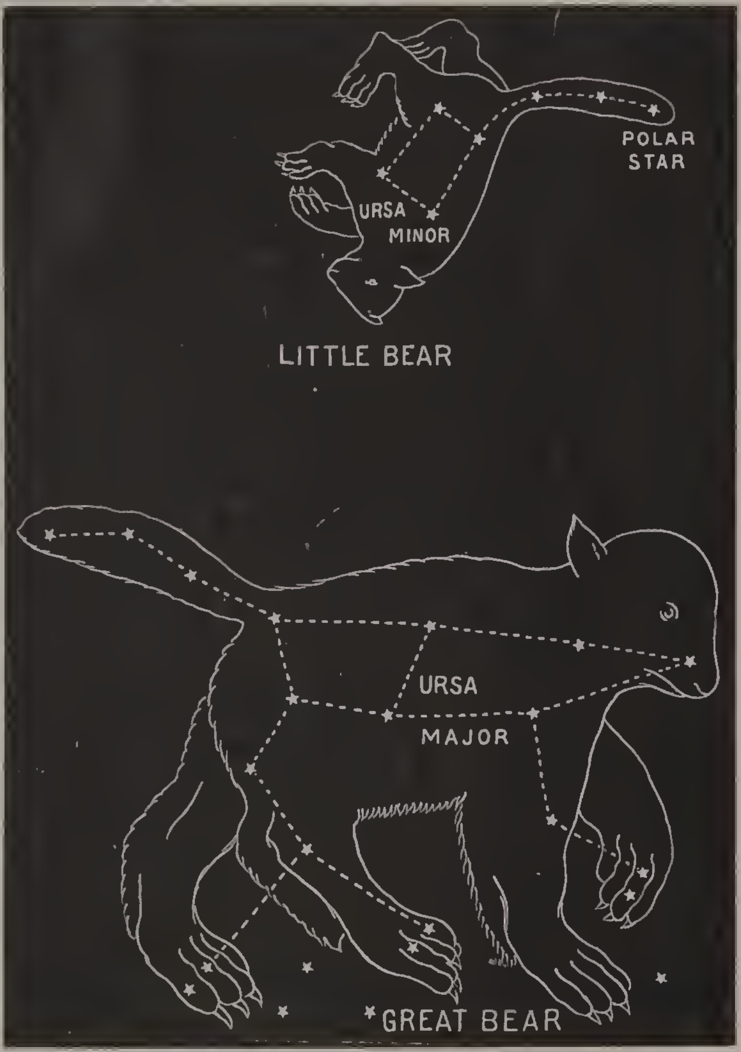


FIG. 76.—Constellations Great Bear and Little Bear.

Cassiopeia, his queen, is to the right of Cepheus and a little farther from the pole. Her chair, which is on the arctic circle, consists of four third magnitude stars and two smaller ones forming the back.

Andromeda, her daughter, is just above her. A star of the second magnitude locates her left foot;

one each of the second, third, and fourth magnitudes mark the girdle, and one of the third on the left breast; this and two smaller ones on either side of it form a small triangle. She is represented with her arm extended and chained to a rock. In her head is one of the four bright stars that form the "Square of Pegasus," the flying horse. The fable has her chained to a rock at the seashore by Neptune. Her mother had boasted that her daughter was more beautiful than the sea-nymphs. This enraged the sea-god so that he ordered her to be chained on the rock and sent a monster to devour her; or, as Milton says:

> "That starréd Ethiop queen that strove
> To set her beauty's praise above
> The sea-nymphs, and their powers offended."

But Perseus, passing by, was so impressed with her tears and beauty that he promised to slay the monster if her father would give her to him as his wife. The promise was given, and he slew the devourer. All the actors in this scene were honored with a seat in the heavens, but because of Cassiopeia's boasting they are obliged to pass half the time head downward. The constellation of Andromeda is between twenty and fifty degrees from the pole, and hence many of the stars dip below the horizon.

Perseus, her husband, is represented leaping at her feet with a sword in his right hand, and in his left the head of Medusa, by means of which he destroyed the devastating monster. The most important stars suggest the figure of a crutch; the crosspiece is an arc open toward the Great Bear.

Between Perseus and the Great Bear, but still farther from the pole, are the two constellations Auriga (charioteer) and the Lynx, the former being nearer to Perseus. He is represented as having a goat and kids in his left hand and a bridle-rein in his

FIG. 77.—North polar constellations.

right. The principal stars form an irregular five-sided figure—a "house-kite." A first magnitude star, Capella, is in the goat. Near by are the kids, shown by a small triangle.

The Lynx is near by and in front of the Great Bear. This contains forty-four minor stars, arranged in no definite outline. A third magnitude star in the mouth is the solstitial colure. The only two others of equal size are in the tail at the front feet of the Great Bear.

North of these two constellations is the Giraffe, stretching his long neck part of the way in between the two bears and near Polaris. It has no definite outline.

Bootes, the Bear-driver, is represented with a club in his right hand, and with his left holding the leash of his greyhounds, ever pursuing the bear in his course around the pole. His head is toward Cepheus. In his left knee is the beautiful reddish star of the first magnitude, Arcturus, of which mention is made in the ninth verse of the ninth chapter of the Book of Job. This star together with three smaller ones, two on the shoulders and the other in the head, form an elongated kite, with a double tail extending from Arcturus to his feet. It does not form a striking outline, as most of the stars are of the third and fourth magnitudes, but it can easily be found by following the direction of the tail of the Great Bear.

South of the Dipper handle, between Bootes' hounds and Virgo, is a star-cluster called Berenice's Hair.

Hercules follows Bootes around the pole. He is represented dressed in an African lion-skin, with his head away from the pole, holding the three-headed monster Cerberus in his left hand, in his right a club. His left foot is near the five stars that form the head of the Dragon, which extends in coils toward Cepheus, then back again, winding in between the Little Bear on the one side and Bootes and the Great Bear on the other. The principal star of Hercules, a

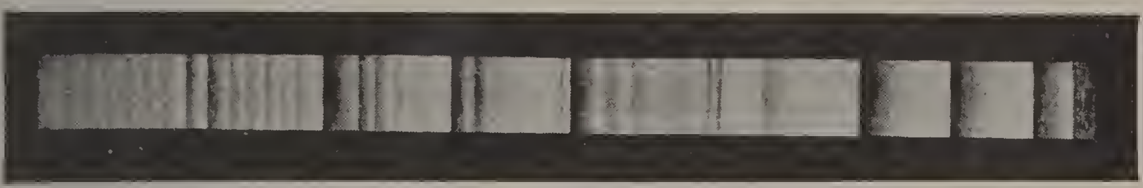


Fig. 78.—Spectrum of α Herculis, showing that in the atmosphere of the star numerous chemical compounds are burning.

notable double star, is in his forehead. This, with five others, forms a winding line extending toward the pole. The stars may also be grouped in the shape of two adjoining trapezoids.

The mythological history of Hercules is extensive and varied, but he is generally considered to be the son of Jupiter and Alcmena. Juno, being jealous of him, sent two serpents to destroy him while still in the cradle, but he succeeded in strangling them. Afterward, by her cunning, she induced Jupiter to put him under the command of her son, his half-brother, who imposed upon him severe tasks. These he successfully performed, and they have become known as the "Twelve Labors of Hercules."

His death is uncertain. It is believed that his wife, having dipped his white robe in the blood of the monster Nessus, gave it to him to wear. It clung to his body and frightfully irritated him. Being unable to tear it off, he finally threw himself on a funeral pile on Mount Œta. Hence Schiller says:

> "Till the god, the earthly part forsaken,
> From the man, in flames asunder taken,
> Drank the heavenly ether's breath.
> Joyous, in the new, unwonted lightness,
> Soared he upward to celestial brightness,
> Earth's dark, heavy burden lost in death."

Between Hercules and Bootes is Corona, composed of six stars arranged in semicircular form, suggesting a crown.

East of Hercules is Lyra, the harp, which consists of one brilliant white star, Vega, of the first magnitude, and four smaller ones near it in the shape of a parallelogram.

East of this, in the Milky Way, is an attractive constellation in the shape of a cross, called Cygnus, or the Swan. It contains the star nearest to the earth in the northern hemisphere, but it is so small that a sharp eye only is able to observe it.

South of Cygnus, near the edge of the Milky Way, is an attractive group of stars in the shape of a diamond, commonly called "Job's Coffin." This figure, together with minor stars, composes the Dolphin.

Between Cygnus and Andromeda is the constellation Pegasus, the flying horse. Three of its bright stars, with one in the head of Andromeda, form the "Square of Pegasus," which can easily be found; this, with three stars in the head and neck of Pegasus, form an outline similar to that of the Dipper, but much larger.

In Greek myth, Pegasus is represented as springing from the blood of the terrible Medusa, one of the Gorgons killed by Perseus not long before he delivered Andromeda. In ancient poetry the steed is considered as the horse of Jupiter fetching his thunder and lightning. He was also supposed to be the horse of Aurora, the dawn. Some authorities hold that the horse was sacred to Neptune and was sacrificed by drowning, and that Pegasus had the power of causing water to gush forth from the earth by striking it with his hoof. The Greek poet Pindar describes him as the "Winged Horse." These considerations, it would appear, have made him sacred to the Muses, and, indeed, modern poets allude to him only as the horse of the Muses. The constellations thus described lie about the north pole, and most of them do not dip below the horizon.

ZODIACAL CONSTELLATIONS.

These constellations lie in the path of the ecliptic, and consequently south of those already described. The first one, or, better, one that was first in ancient times, is Aries, or the Ram. It is now really the second, but it is a good starting-point for description. This constellation presents no striking group of stars. The brightest is Arietis, second magnitude, in the ram's head. The most remarkable thing about this star is that it was discovered as a double star, shining with bluish and white lights, by Mr. Hooke in 1664. Between Arietis and the foot of Andromeda, to the north, is a beautiful figure called the Triangles.

About the middle of October Aries may be seen at eight o'clock near the eastern horizon, almost below Andromeda. Two months later it comes to the meridian.

The Ram, like a number of constellations near it on the north, is connected with the most romantic

FIG. 79.—Equatorial constellations. (First group.)
For correct position, view these cuts held overhead, facing south.

maritime expedition of mythological times. The fable states that Phrixus and Helle, the two sons of Athamas, king of Thessaly, were so persecuted by their stepmother that they were obliged to flee for safety.

Mercury furnished them a ram with a golden fleece, but as soon as they had mounted, it vaulted to the heavens. In the flight, Helle became dizzy and fell into the sea, which bears his name—the Hellespont. His brother reached Colchis in safety, sacrificed the ram to Jupiter, and gave the golden fleece, in grati-

FIG. 80.—Equatorial constellations. (Second group.)

tude, to Ætes, who had protected him. According to the Greek story, the Argonautic expedition was organized for the purpose of recovering this fleece.

About two hours later than the Ram rises one of the most interesting constellations in the heavens, known by the name of Taurus, or the Bull. He is represented as plunging toward another beautiful cluster, Orion. In the head of Taurus is the attractive V-shaped cluster of five stars, called the Hyades

FIG. 81.—Equatorial constellations. (Third group.)

—"Rain-makers." The Pleiades, mentioned in Job xxxviii, 31, is a group of six or seven visible stars in the shoulder of Taurus. A bright star in one of the horns marks the foot of Auriga. Tennyson, in speaking of this star-cluster in Locksley Hall, says:

"Many a night I saw the Pleiads, rising through the mellow
shade,
Glitter like a swarm of fireflies tangled in a silver braid."

Orion, southwest of Taurus, though not in the zodiac, is so near it that a word may be added. Four

FIG. 82.—Equatorial constellations. (Fourth group.)

bright stars in the form of a parallelogram suggest his outline. Betelguese, a star of the first magnitude, is in the right shoulder, and another of the first magnitude is in the knee. "The Bands of Orion" show his girdle. They are so called because they are just three degrees long and are a convenient measure of distance in the sky. This constellation contains some of the most interesting telescopic nebulæ in the heavens. Orion, the mighty hunter, was pursuing the seven innocent, affectionate sisters, when Jupiter in pity transferred all of them to the heavens. South of Orion is a cluster of four stars called the Hare.

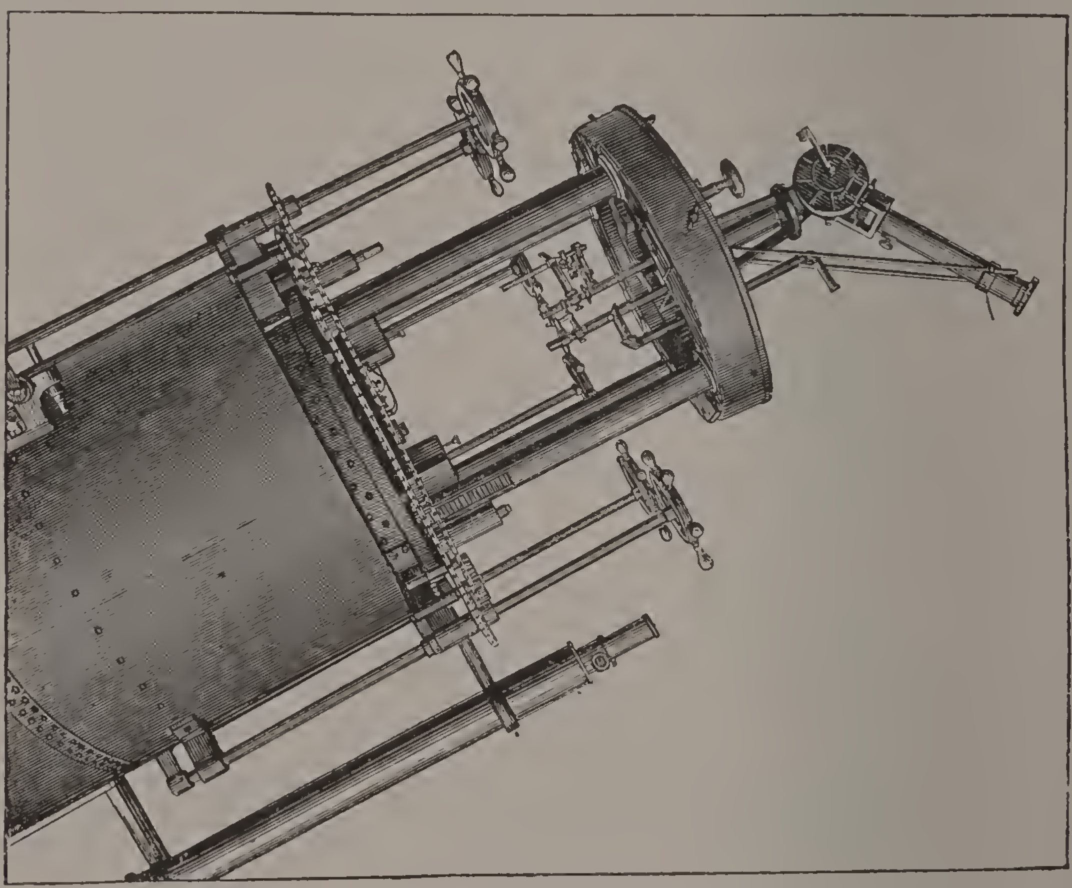


FIG. 83.—A spectroscope attached to the Yerkes telescope.

As the Ram approaches the meridian the "Twins," or Gemini, begin to rise. This cluster may be seen in the form of two nearly parallel lines. Two stars of the first and second magnitudes in the head are Castor and Pollux. Pollux is used as one of the stars from which longitude is reckoned by means of the Nautical Almanac, constantly used by sailors. Castor was celebrated for training horses, Pollux for boxing. They accompanied Jason on the argonautic expedition, and were supposed to exercise power, given them by Neptune, over wind and storm.

> "Safe comes the ship to haven,
> Through billows and through gales,
> If once the great Twin Brethren
> Sit shining on the sails."
>
> *Lays of Ancient Rome.*

South of Pollux is a very bright star, Procyon, in the body of the Little Dog. Southeast of the Little Dog is Canis Major, the Great Dog, which contains in the head the brightest star in the sky, Sirius. Other four stars farther south form a double triangle. Canis Major and Minor are supposed to be Orion's dogs in pursuit of the Hare.

Following the Twins comes Cancer, or the Crab. It is half-way between the Gemini and the Sickle, which is in the lion's neck. It has no definite outline, but in its center is a bright spot, which even a small glass shows up as separate stars.

Leo, the Lion, is next to rise. The principal stars are in the form of a sickle. Regulus, first magnitude, is in the handle, and seven stars form the curved blade. A second magnitude star, Denebola, is in the brush of the tail. According to the myth, Leo was a famous Nemean lion, slain by Hercules and placed in the sky by Jupiter. The Little Lion is between the head of Leo and the hind foot of the Great Bear.

Virgo, the Virgin, comes after Leo. She is represented with her head toward the east, with folded wings, and bears an ear of corn in her left hand. Spica, in the ear of corn, is a star of the first magnitude, southeast of Arcturus. Virgo is a long figure, extending 51 degrees east and west, south of Bootes and his dogs and the Great Dipper, and contains one hundred and one stars. She is on the meridian in June. Aratus thus speaks of her:

> "Once on earth
> She made abode, and deigned to dwell with mortals.
> In those old times, never of men or dames
> She shunned the converse; but sat with the rest,
> Immortal as she was. They called her Justice.
> Gathering the elders in the public forum,
> Or in the open highway, earnestly
> She chanted forth laws for the general weal."

But when the age became degenerate,

> "Justice then, hating that generation,
> Flew heavenward, and inhabited that spot
> Where now at night may still be seen the Virgin."

Libra, "the Scales of Virgo," is next in order. four principal stars form an irregular four-sided figure.

Between Scorpio and Hercules, but not in the zodiac, is the serpent-bearer, who holds a writhing serpent in his hands. The principal stars form a triangle.

Then comes Scorpio, whose chief stars may be imagined in the form of a J. Antares, a fiery red star of the first magnitude, marks the heart; the tail may be traced in a curve around the Milky Way. He is supposed to have stung Orion, and was placed in the opposite side of the heavens from him.

Sagittarius, the Archer, represented as a centaur, east of Scorpio, stands aiming an arrow at him. The stars do not delineate any striking figure; however, five in it suggest a dipper, and being in the Milky Way it has been called the "Milk Dipper." A small triangle indicates the head, and the rest of the stars may be seen in the form of a bow and arrow. Sagittarius was thought by the Greeks to be the centaur Cheiron, who had for his pupils the old Trojan warriors, Achilles, Diomed, and Peleus.

East of Sagittarius is Capricornus, the Goat. This constellation contains no conspicuous stars. Five can be seen in the shape of a right angle. Capricornus is the subject of several Greek fables of little consequence.

Then in order is Aquarius, the Waterman, near the head of Pegasus. He is pictured as pouring a stream of water out of an urn in his right hand. Three stars in the head of Pegasus, forming a small arc, mark the urn, and the stream can be traced by a number of small stars. Four stars of the third and fourth magnitudes, in the body, form a trapezium.

Pisces, the Fishes, formerly the twelfth in the zodiac but now the first, lies between Aquarius and the Ram. The eastern fish is south of Andromeda, and has no definite outline.

Near the tail of the western fish is a point in the heavens where the ecliptic crosses the equator, called the vernal equinox. The meridian passing through this point is called the zero meridian, from which, eastward, celestial longitude is reckoned, and expressed in hours, minutes, and seconds, right ascension. Thus the star Arietis, in the Ram, is 1 h., 47 min., 29 sec., right ascension (1890). Stars farther east are in greater right ascension.

The constellations of the zodiac are undoubtedly of Egyptian origin. The Bull represented the sacred Egyptian Apis; the Ram represented Jupiter Ammon; the Goat, the god Mendes, and so on. The Greeks adopted the figures and invented stories of their own.

CHAPTER XIX.

TWO GREAT LIGHTS.

The sun regulates not only our seasons but even our "sitting down and our rising up." Our homes move about him year after year, obedient to his call. His blessed light and warmth fail us not.

The sun appears as a luminous disk. When seen at or near the horizon it seems to be larger than in the zenith. This is an illusion. Things far away by themselves appear smaller than when there are objects intervening which serve as points of measurement for the eye.

How large does the sun appear to you? To some it looks like a good-sized dinner-plate, to others like a saucer, and to still others like a bicycle-wheel. In degrees the diameter of the disk measures ten and a half times the distance between the middle and end stars of Orion's belt, but the real diameter is about ten times that of the earth.

There are many things of interest to be said about the sun, but in this volume space can be given to only the most practical points in connection with such observations as any one may easily make.

First, we may observe the time and place of his rising and setting. On the first day of spring and of fall his apparent course across the sky is along the celestial equator. From March 21st the earth moves daily toward the southern end of its orbit, which makes the sun appear to move steadily north of the celestial equator. Thus his apparent path forms a spiral, passing through 23.5° in ninety days, when his vertical rays shine upon a circle which has been called the tropic of Cancer. On June 21st the earth enters its northward course, not exactly toward the pole star, but in a plane that makes an angle of 66.5° with the line from that star to the earth. Three months later, September 21st, it reaches that point in its orbit where the sun is again directly over the equator. On December 21st, when the earth reaches the north limit of its orbit, the sun's vertical rays fall upon the tropic of Capricorn, and he appears to us far south. These changes in the sun's course across the sky may easily be observed by anyone.

FIG. 84.—Total eclipse of the sun in 1860. The moon passed between the sun and the earth. (Feilitzsch.)

SUN-SPOTS.

The story of the dark spots that may often be seen on the surface of the sun might well fill an interesting book. When the sun is near the horizon the spots may sometimes be seen through a smoked glass.

They first appear at the eastern limb of the sun as a narrow dark streak. This gradually widens, until it becomes a more or less circular spot in the center of the disk. It continues westward, growing narrower again, to the very edge of the disk. About thirteen days after a spot disappears, it frequently reappears at the eastern limb, changed but little, if any. Occasionally the same spot may be observed even three times.

Fig. 85.—Ordinary sun-spot as observed June 22, 1885.

From the motions of the spots, it has been concluded that the sun rotates upon its axis once in twenty-five and one-third days. From these spots we are also able to determine the poles and equator of the sun.

Chinese observers noticed spots on the sun three centuries before the Christian era, long before any one in Europe thought of such a thing. They described them as being the size of eggs, dates, or plums.

The sun has ever been considered as the symbol of truth and purity. The ancients worshiped the sun, and even during the Middle Ages it was not safe for a man to suggest that the sun's face was covered with spots. Giordano Bruno suffered martyrdom for insisting upon it that he had seen such spots, and for believing that the earth was not the only world. For many years the official astronomers dared not make public what they saw in the sun. Thus it happened that the study of these phenomena was not scientifically undertaken until Sir William Herschel turned his improved telescope upon them. He made accurate observations and careful records of them. Since Herschel began, many others have given attention to the spots. However, much remains to be learned.

Fig. 86.—Sun-spots, August 17, 1894. (Goodsell Observatory.)

WHAT ARE THESE SPOTS?

This is an interesting question, and has been variously answered.

Are the spots planets revolving about the sun in small orbits? Some have thought this. But if so, they would make regular revolutions and retain the same shape. Neither is the case.

Are they more or less condensed fragments of gaseous rings that were once thrown off by the sun,

Fig. 87.—Sun-spot shown at western limb as a notch.

similar to those of Saturn at the present time, or are they gaseous clouds floating in the atmosphere of the sun? In either case the spots would show the lighter side toward us as they appear around the eastern limb of the sun, also when they disappear on the western limb. But the opposite is true.

Are the spots sheets of solid matter floating on a liquid surface of the sun? We would hardly expect

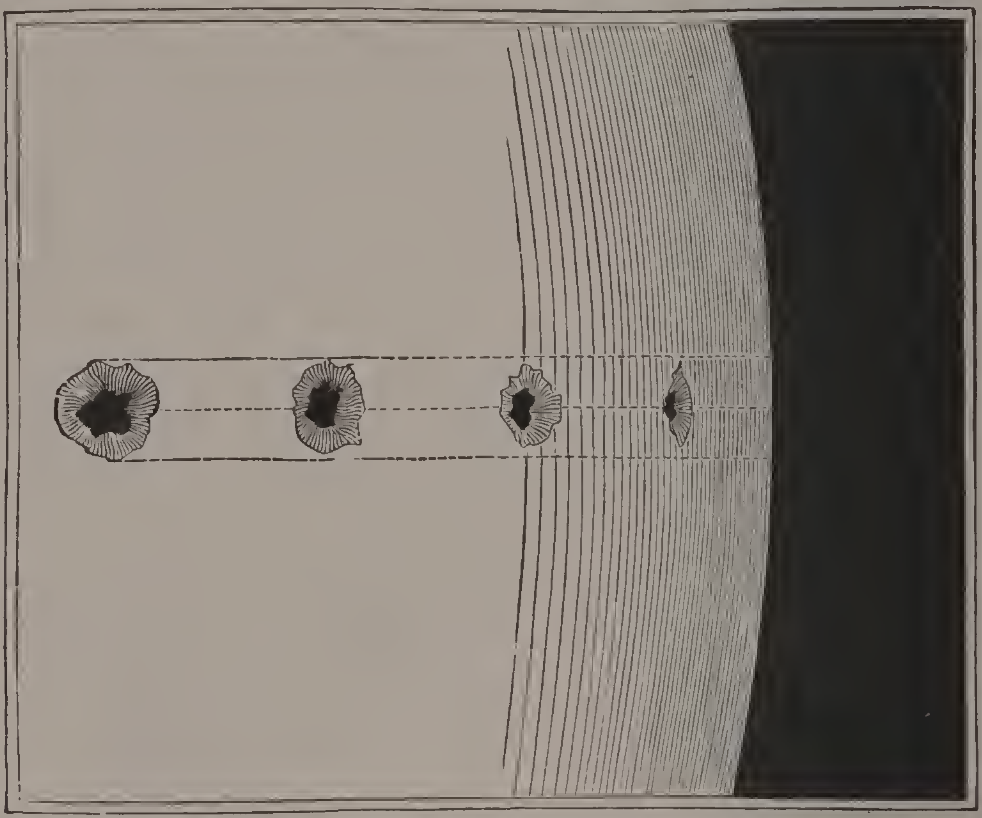


FIG. 88.—Spot as it appears at regular periods, while passing from the center to the western limb.

such fragments to take the same general path around the sun. The spots are seen on either side of the sun's equator in a zone about twenty degrees in width. Then, too, as in the case of clouds, the light part would be toward us when appearing and disappearing.

Are these spots cavities in the sun's surface? If this were true, we might expect to see notches in the sun's edge as the spots came on at the eastern limb, and again as they disappear on the western edge. This is just what has been observed. Again, the cavity would appear with its dark edge toward us, as the shadow would be on that side. This shadow would gradually disappear as the spot reaches the center of the sun's disk, where it would be uniform on all sides. The reverse would be true as it moves toward the western limb.

WHAT IS THE SUN?

The spectroscope tells us that it is composed of the same elements as the earth; that these elements are in a bright glowing or in a burning condition. But if the sun be a glowing solid, the spots could not be explained. They are not cavities in rigid matter, for they gradually, and sometimes quickly, change their shapes. Observers have noticed that occasionally several spots have run together into one continuous spot, having the long axis parallel to the equator. Furthermore, the spots seldom continue more than a month, and many for a less time.

When the spots are near the center of the sun they appear with a dark center. Between this dark spot and the rest of the surface is a band that seems to be half dark. The dark part is called the umbra, and the partially dark the penumbra. The penumbra varies in width, as would be the case if we viewed the cavity from different positions.

If the sun were a glowing solid, would cavities in the surface appear as dark spots?

The cavity theory, then, has led to the idea that the sun is a dark, possibly solid, sphere surrounded by a burning envelope of gaseous matter. The envelope is called the photo or light sphere. The spots are openings in the photosphere through which we can see the dark body of the sun.

This theory is further corroborated by other appearances on the surface. Careful observers, with fine glasses, have noticed that the surface of the sun is not smooth and of uniform color, as it appears to the eye. This appearance has been described by comparing it to "willow leaves" or "rice grains," arranged, more or less, in rows or bands. They appear somewhat more numerous and distinct near the center of the disk. They have been called faculi, which means torches, as they suggest flames leaping up into the sun's atmosphere.

Some have thought that the spots are storm centers in the photosphere. Occasionally, but not often, there has been noticed a spiral form, as if a cyclone prevailed. Though these spots sometimes move independently of the sun's surface, yet they appear too regular to regard them as cyclones in the photosphere. The fact that they occur in some zones, nearly corresponding to our trade-wind belts, seems to be in favor of the storm theory. In connection with eclipses, observers have often seen bright streams of light flash out as if flames of gas, chiefly hydrogen, shot out from the sun to a great distance. (See Fig. 84.)

The spots are often of immense size. In 1858, the largest one yet observed had a length of more than 140,000 miles. The great spot of 1883 was computed to be so large that if the earth could be dropped into it, it would lose itself like a marble in a teacup.

WHAT HAVE THE SUN-SPOTS TO DO WITH THE EARTH?

Perhaps this question concerns us more than any other about the sun. Do these spots affect our climate? The reliable records are altogether too incomplete to answer this question satisfactorily. Observations show that there are more sun-spots some years than in others, and that there are periods of maximum and minimum sun-spots. The maximum periods seem to occur about every eleven years. Again, the number of spots of the maximum periods is not the same, so that every five times eleven years we have the greatest number. This is not fully determined, for the records have not been kept long enough.

The records of general climate are still less complete and reliable. Few countries have made accurate observations of the weather, covering a large area, for more than thirty years. Conclusions are therefore largely based upon impressions, and all we can say is, that there seems to be a connection between the sun-spots and our climate.

The records of electrical conditions, kept for a short time only, and though still very incomplete, do nevertheless give us better results. There seems to be scarcely room for doubting that sun-spots disturb our electrical conditions. The earth with her life yields to the sun not only in gravitation and the matter of heat and light, but probably for electricity.

THE MOON.

The moon, being distant only about thirty times the earth's diameter, appears to us about the same size as the sun, but, in fact, its diameter is only two thousand one hundred and sixty miles, and it would take eighty-one moons to equal our earth.

When the moon is on the same side of our globe as the sun we can not see it, for the illuminated part is turned away from us. That is new moon. As the moon moves east, we see the illuminated part more and more, first as a narrow crescent in the west, gradually increasing until we see half of the illuminated part in the south, and then all of it as the full moon in the east. Passing through the "gibbous" last quarter and final crescent stages back to the new moon, it completes its course in twenty-nine days, twelve hours, forty-four minutes, three seconds. This is about two days more than is required for a revolution. As the earth moves forward in its orbit, the moon must make more than one revolution in order to get back to the same position in relation to the sun.

The face of the moon has attracted so much attention that the "man in the moon" has become famous. But is it a man? Observe the face, if possible, with an opera-glass. About the first quarter we can see bright spots, and near them corresponding dark ones, as if they were mountain peaks on which the sun is reflected and adjacent valleys in the shadow

Fig. 89.—Moon one day after first quarter.
(From a photograph made by the Paris Observatory.)

of the peaks. Good telescopes show most wonderful scenery; not only peaks, but ranges of mountains, large craters of extinct volcanoes, lava slopes, and old gorges, such as can not be found on this globe. But no seas or oceans and no clouds have been discovered. It is therefore thought that both the water and atmosphere of the moon have been absorbed by her rock strata.

The moon always presents the same side toward us, hence she does not rotate on her axis with her revolution.

The Hebrews, Chinese, and other ancient peoples counted time not as we do by the sun, but by the moon. Events are said to happen in such and such a moon of a certain year. The year contained twelve moons, and every third year (nearly) an extra moon was counted.

Not only in this respect were these nations governed by the moon. Even at this time some people believe that if potatoes are planted when the moon is waning they will produce only small ones; or if a beef be killed during that period the meat will shrink in the kettle.

Careful observations thus far have proved that our luna has no such influence, but it is beyond doubt that it does exert great influence upon bodies of water, particularly the oceans, causing the tides. Of course, it acts equally upon the solid crust, but the rigid form presents no visible effects.

CHAPTER XX.

CELESTIAL TRAVELERS.

The sun together with the planets that revolve around it constitute our solar system. It is probable that every star is the center of a solar system resembling our own, some of them, perhaps, much larger than ours.

The planets of our system are grouped as major and minor planets. The major or greater are eight in number. In the order of their distance from the sun they are Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, and Neptune. Our planet is the third. Venus and Mercury revolve about the sun, inside the earth, and hence are called the inferior planets; those whose orbits are outside the earth are superior planets.

The planets, as far as can be discovered, are very much alike in general appearance. Mercury is too near the sun, and Neptune and, indeed, Uranus are too far away from the earth to reveal their surface. Generally speaking, the planets have a dark, more or less variegated band on both sides of their equator, shading into a whitish surface about the poles. This suggests zones of climate resembling those of the earth. Their axes are also inclined, and at angles that differ little from the angle of the earth's axis.

The planets all revolve about the sun in elliptical orbits. The time required for one revolution varies as their distance from the central body. The earth requires one year—365 days, 5 hours, 48 minutes, 48 seconds, Mercury requires only 88 of our days, and Neptune about 164½ of our years, to make a revolution.

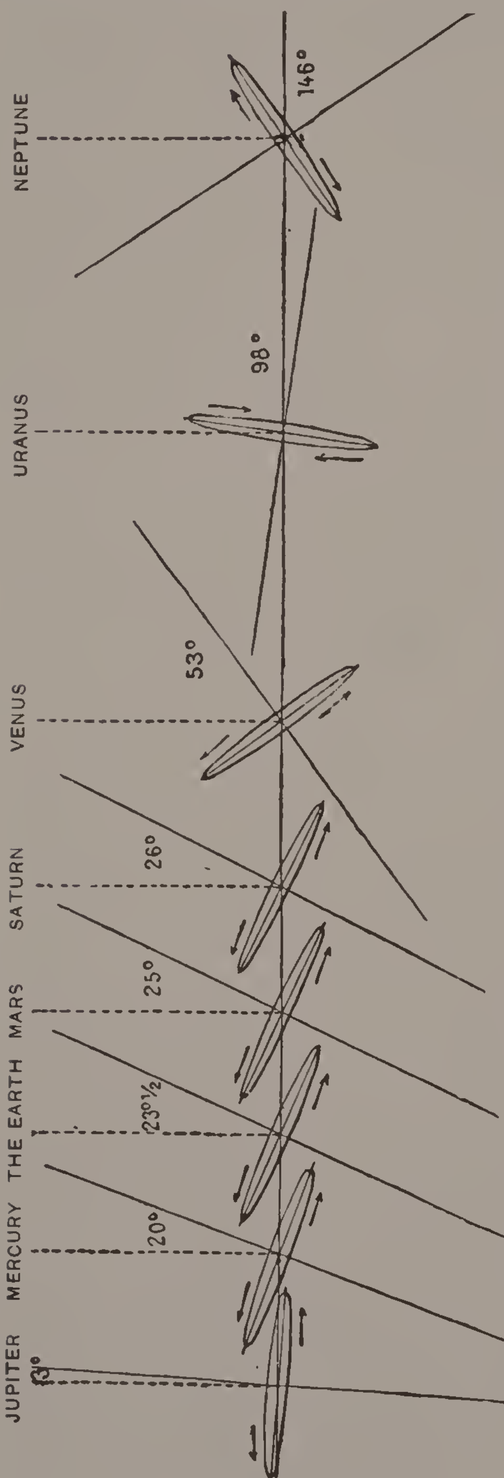


Fig. 90.—Inclination of the orbits of the planets to the equator.

The ecliptic is the plane that passes through the center of the sun and of the earth as it moves in its orbit.

Between Mars and Jupiter four small minor planets have been discovered. Their orbits are more eccentric and vary more from the plane of the ecliptic than do those of the major planets. It would seem that they are the fragments of a larger planet which formerly revolved about the sun between Mars and Jupiter.

Although there are many points of similarity among the planets, each differs from all the rest. They are, indeed, a wonderful family.

The baby Mercury skips around the sun in eighty-eight of our days, although its own day is longer than ours. Nevertheless, recent observations have led one astronomer to believe that its period of rotation coincides with its period of revolution; that it always turns the same side to the sun, as the moon does to the earth. Mercury is the most solid of all the planets.

The earth is five and a half times as heavy as if it were made entirely of water. A cubic foot of the earth at its average density weighs 344 pounds, and one of Mercury weighs 403 pounds.

Uranus is made of the lightest materials, only one-fifth as dense as the earth, which would be about the same as if it were made of water.

The most interesting of the group is Jupiter. It is the giant planet. Its axis is but little inclined to its orbit and so it has a very slight change of seasons. It revolves in nearly the same plane as the earth. But the most wonderful part of Jupiter is the scenery which it presents through the telescope. At the equator we see a white belt, on each side a dark red zone, then alternately white and gray, which merge into blue at the poles. These belts are not always the same. They change in width and position, and occasionally almost disappear. Sometimes one seems to grow narrower, flowing into the next one and making it wider. As we are looking, rifts form that look like dark streaks, white spots appear and lengthen out far across the disk. In 1877 an oval spot was discovered and has been visible since, although its color gradually changes from red to lighter tints.

All these cloudlike belts move from east to west, but they do not revolve around the planet as satellites; they are part of the planet, and yet they are not stationary, as continents and seas would be.

Now, what do you think the belts and patches are? You have the same privilege to reason about them that the astronomer has. Are the white and gray belts clouds? Are the reddish ones soil? Is the reddish oval with changing tints a new-forming continent?

Whatever our answer to this question, it is evident that there is great activity on this planet. If the light spots are clouds, evaporation must go on more rapidly than it does on this globe, and as the sun is only one-twenty-seventh as strong as on the earth, there must be great internal heat to produce such violent changes. Some think the reddish tints are the glow of the planet's own heat.

Is it probable that this immense orb is still in its pre-Archæan period when its crust is just beginning to form and its water (if it has any) is still flung off in clouds of steam? What other explanation can be given of its appearance?

In thought let us become inhabitants of Jupiter. We rise with the sun. Two hours later we finish breakfast, and before we can fairly get to the office for work the sun is in the meridian. Two hours and a half later it is setting. We have missed our luncheon and dinner as well. There are only five hours of day and as long a night, for the planet whirls around on its axis in less than ten hours. This rapid motion has bulged the equator out so that the orb is greatly flattened at the poles, like a tomato. A day's labor, therefore, could not exceed three hours, but the year would include 10,455 such days.

There are other surprises in store for us on this strange globe. A boy who weighed a hundred pounds on the earth now weighs two hundred and fifty, and finds himself so heavy that he becomes very tired after only a short walk. Instead of growing six feet tall, as he would on the earth, he would probably not exceed four and a half feet on Jupiter, but his width would be proportionately greater.

As we go star-gazing we behold not one moon only shedding her soft light from the heavens, but the sky seems full of them. We may count as many as five on a single night, the largest having a diameter nearly equal to half the earth, or five times larger than our moon. We see the moons in various parts of the heavens, moving at various rates of velocity. The nearest, the baby, one hundred miles in diameter, passes through all phases of our moon in eleven hours, while the most distant requires only sixteen and two-third days to complete its revolution.

Again, eclipses are numerous. These satellites not only eclipse the sun, but each other frequently, and in various situations.

The planet which offers the most striking spectacle through the telescope is Saturn. Its broad luminous rings are unique. We generally say there are two, but there are three, or even more. At least

FIG. 91.—Saturn as seen in various positions of its orbit. (From Chambers's Story of the Solar System.)

there are two bright ones separated by a darker one. They revolve about the planet like a satellite, and being flat we can sometimes see them as broad bands, and then again, when we look at them edgewise, as one narrow line. They are evidently not composed of solid material, as stars have been seen through them. Besides these rings Saturn is attended by eight satellites.

Neptune has the most interesting history of all. It was first discovered by mathematicians. They carefully calculated the amount of disturbance due to the gravitation of an unknown body in the path of our planets as they neared a certain part of the heavens. They found that there must be a planet of definite mass in that particular position in the heavens. This was done by two mathematicians, an Englishman and a Frenchman, working independently. The Englishman sent his figures to the royal astronomer, who put them into a pigeonhole without examination. About twenty years later the French astronomer sent his figures to the Berlin Observatory, requesting that examination of that part of the heavens be made with their telescope. The leading astronomer there took so little interest in the matter that he turned the papers over to some of his students, who directed the telescope to that part of the heavens described, and were rewarded by finding the disturber which has since been named Neptune.

OUR PLANET.

A few words about the earth must be added. It is, of course, the planet which concerns us most. The inhabitants of Venus viewing our earth and Mars see nearly the same scenery on both. They see the poles of both covered with ice-caps, points of which extend, here and there, farther toward the equator. They see land-masses and bodies of water, clouds and storms. Mars is, in fact, a miniature earth one-fourth as large.

Fig. 92.—The earth as it would appear if seen from the moon. (From Flammarion and Gore's Popular Astronomy.)

The earth revolves around the sun in 365 days, 5 hours, 48 minutes, and 48 seconds, in a slightly elliptical path. June 21st it is farthest from the sun, at aphelion it is called—that is, in round numbers, 94,350,000 miles, and December 21st it is nearest to the sun, at perihelion, or 91,240,000 miles. In winter it is 3,110,000 miles nearer to the sun than in summer.

Fig. 93.—Mars viewed from four different quarters. (By Barnard, from Comstock's Astronomy.)

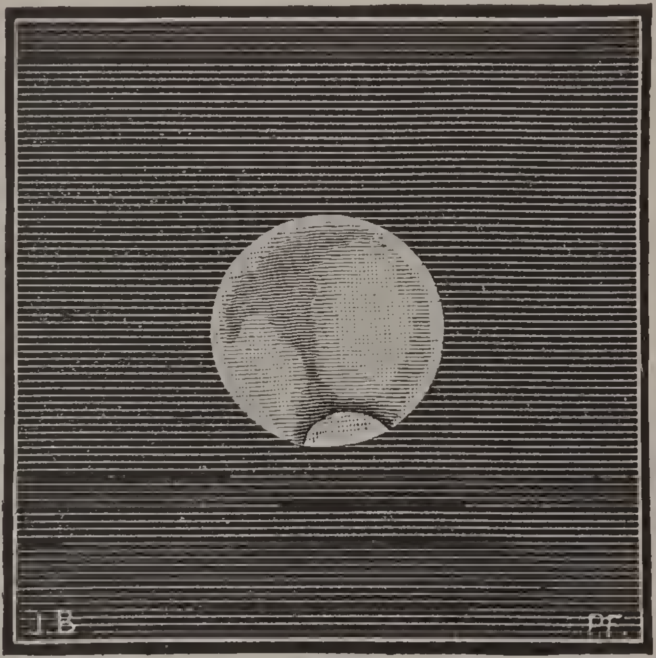


Fig. 94.—Mars, February 18, 1884.

Imagine the surface of the table the ecliptic, and in the center a half apple or orange representing the sun, with a half pea for the earth revolving about it. Stick a pin into the pea at the proper angle to represent the axis. Now move the pea around the orange in a direction contrary to the hands of a watch, keeping the axis toward the north star. When on the north side the pea should be twenty-three inches from the center of the orange—the earth's winter position. When on the south side of the orange it should be twenty-four inches distant—the earth's summer position. In March and September it should be between these two positions in the orbit, about twenty-three and a half inches distant from the center.

ARE THE PLANETS INHABITED?

No telescope thus far made is powerful enough to show any life on any of our sister planets. Years ago it was quite common to think them occupied by human beings. It was argued that the Creator would not swing such extensive orbs into space and then leave them uninhabited. The idea has, however, been generally abandoned by scientific men, as the conditions on most of them are very different from that one under which we know life to exist. Some of the planets, particularly Jupiter, seem to be in a process of evolution similar to that through which our earth passed at a time when there was no life on it. It must be admitted that these are cogent reasons, yet we ought to understand that the Creator who could speak into existence a universe so infinite in magnitude, in the number of spheres, and in varying conditions, could also create beings adapted to environments which we can not comprehend. This globe has life that can exist in a block of ice or earth, in air, in water of varying depth, in muscle, bone, or brain, and live through all temperatures from zero to 135°; life that breathes by lungs, by gills, by spiracles, or by none of these. There may be conscious intelligent beings who can live on entirely different food from that we need, or on no food at all; they may never need sleep, and have neither head nor feet. Infinite wisdom can plan where we can not imagine.

But suppose that the planets are not inhabited, could we say they are useless orbs? Suppose the other suns in the universe should have no attending planets, are they therefore created in vain? Are they not ornaments hung in the sky which call forth our admiration night after night? They are queries in the firmament to stir our thoughts and widen our mental horizon.

METEORS AND COMETS.

No one can be out under an open sky on a clear night without seeing bright objects shooting across the heavens in one direction or another. They look like red-hot balls moving through the air and leaving in their rear a trail of illuminated dust particles.

What are they, and whence do they come? Many have reached the earth, and their composition has been determined. They often look like a black lump of iron. Upon being broken in two, the smaller ones generally show a lamellated structure, as if they had grown by adding layers of matter. They are composed of many of the minerals found in the earth, chiefly iron.

On November 27, 1872, the earth passed through a swarm of meteors. It was a beautiful sight. We seemed to move toward a gigantic Roman candle shooting forth balls of fire in all directions about the earth. Whence came they? Astronomers expected Biela's comet to collide with the earth, but instead, this meteoric shower met it. Is it possible that the comet broke up into meteors? This comet was first seen in 1772, and every six and three-fourths years until 1845, when it had divided into two parts. These parts returned again in 1852, but eight times as far removed from each other. Since that time they have never been seen. It is probable that each of them separated into two or more parts and thus became invisible.

Fig. 95.—Meteor as seen in California, July 27, 1894.

Thus it is thought that meteors are broken pieces of former comets, and that when a comet breaks up the fragments remain more or less together and continue to move in the same orbit. Our earth is supposed to pass through one of these collections in

November once every thirty years, and in August we cross the path of another exploded comet.

Many of the meteors are not bright enough to be seen with the eye. From telescopic observations Arago estimated that in three hours over 243,000 meteors fell. It is thought 500,000 tons of meteoric dust falls annually upon the earth. The well-known astronomer Simon Newcomb estimated that 146,000,000,000 meteors reached the earth yearly. Thus we see that our globe is receiving material additions from interstellar space.

Fig. 96.—Famous comets.

Although so many meteors fall upon the earth, they very seldom do much harm. Instances, however, are on record where a man has been killed or a house set on fire.

As has been intimated, meteors are solid bodies and not gases. When they reach our atmosphere the friction makes them red-hot, so that they give off illuminated particles which mark their path. Some are of such structure that they are entirely consumed before they reach the earth. These are called shooting stars. Others, larger and more solid, are known as bolides, and often they explode with a dull thunder, and the remnants reach the earth. When the larger ones come to the earth they sometimes penetrate the soil for some distance, producing a quaking in the neighborhood.

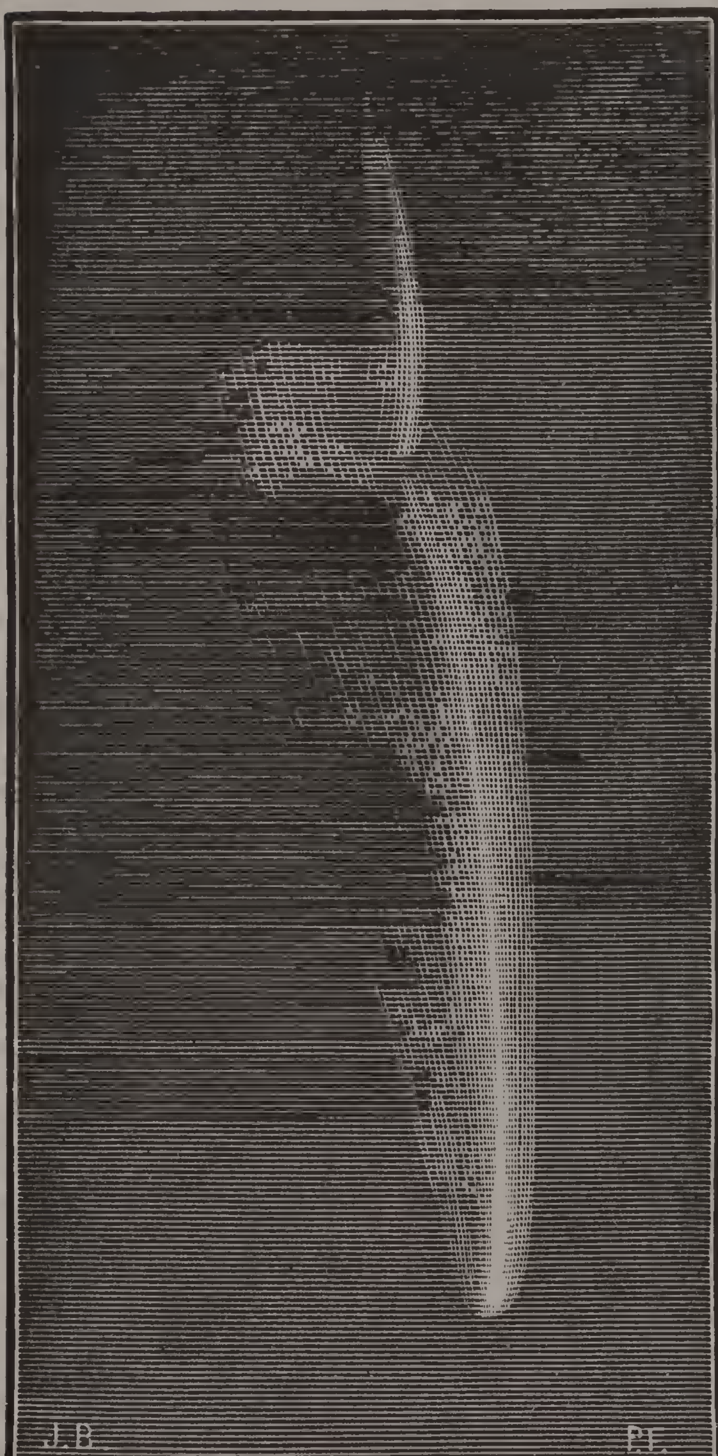


Fig. 97.—The Great Comet of 1882, on October 19th (Artus).

A class of celestial visitors which usually receive much attention is the comets. They consist of a nucleus with a streamer of more or less length, usually spoken of as the tail. This nucleus is probably solid, but the tail consists evidently of gaseous material, as stars have been seen through it.

Some comets move in regular elliptical orbits, but very eccentric ones, that have the sun as one focus, and extend far beyond Neptune's orbit. Others move in curves that never bring them back to this system. Still others that have revolved in an orbit for some time seem drawn away by some force so that they never return.

In times past comets have been an object of apprehension, being considered as precursors of war, pestilence, or famine.

To get a correct idea of our little solar system, we must imagine ourselves off at a distance and behold the planets and satellites in their various motions: some moving with the slowness of an hour-hand on the dial of a watch, others like the minute-hand, while some of the satellites circle about their primaries quite like the second-hand. Observations of the star-field indicate that our whole solar system is moving. And whither? No one knows, but it is aiming toward a point in the constellation Hercules at the rate of four or five million miles a year. Does the whole system, too, have an orbit to travel about some immense central sun, parent of all?

Fig. 98.—Comet III of 1862, on August 22d, showing jet of luminous matter. (Challis.)

Let us continue our journey on the wings of thought to the nearest star. As we recede, the smaller of our celestial group vanishes from sight, then the earth itself, and Jupiter; now nothing can be seen but the sun, which appears as a small star. On and on we fly, and still its light seems undiminished.

What a wonderful thing light is! How little it loses as it leaps across the densely dark chasm! The interstellar space is black darkness, no light but that of an occasional comet and that of the stars, now greatly diminished, for their twinkle is lost.

Is it not a beautiful thought that the starry heavens are a source of never-ending wonder to all ages and at all times? The mother and the child in her arms alike behold and wonder; the youth and maiden, the unlettered and the scientist grow gray in study and contemplation. All behold with admiration and curiosity.

You, in the twentieth century, may look upon the same stars which Abraham's faith counted, which Moses beheld from the plains of Midian, about which Homer sang, or Virgil wrote, or the Nibelungs chanted—the book of all people in all ages—the creation of the All in all, who "stretcheth out the heavens as a curtain."

CHAPTER XXI.

THE UNIVERSAL FORCE.

The force by which all objects are held to the surface of the earth as it whirls through space, is of such importance that a chapter must be given up to it. This force does not belong to the earth only, for, so far as we know, it holds all worlds in their appointed places.

In obedience to this force a stone falls to the earth; the waters seek the valleys and the sea. A balloon rises in the air because this force draws the air toward the earth more strongly than it does the balloon, bulk for bulk; that is, the air outside the balloon is heavier than the hot air or gas inside the balloon, and hence it crowds up the balloon.

This force acts upon us whether we wake or sleep. It draws the cannon-ball toward the earth's center as strongly when it flies through the air at the rate of a mile a minute as it does when the ball lies quietly in the gun. Such a universal force certainly requires some attention.

When we speak of this force as acting upon the earth, we call it gravity; when we speak of its action upon the spheres in the universe, we call it gravitation.

Newton was not the first to get the idea that bodies fall to the earth because a force draws them, but he continued to think about it as any one else might have done. It was he who discovered the laws according to which this force acts, and applied them to the entire universe. I will state some facts to help us understand these laws.

Every one has noticed that the larger the stone, the greater the lump of lead, or the more solid the block of wood, the more strongly it is drawn to the earth. On the earth we measure this force with scales and express the result in pounds. When we say that a horse weighs fifteen hundred pounds, we mean that it has matter enough in its body to be attracted by the earth to that extent.

If we lay a magnet on the table with a piece of magnetized steel a short distance from it, the two will attract each other; and if the steel be close enough so that the attraction can overcome the friction, it will be drawn to the magnet. If a pendulum be suspended in a plain near a mountain, it will be drawn slightly from a vertical position toward the mountain, and were it free to move to the mountain it would do so, just as the steel moved toward the magnet.

These illustrations are evidence of two forces which are quite different. Magnetism is active only in certain metals; gravity is active in all matter. There was the attraction of gravity between the magnet and the steel as well as that of magnetism. Magnetism is much less universal but much more intense than gravity.

If we lay two blocks of wood on the table, they undoubtedly attract each other, but the attraction is not strong enough to overcome the holding-back force of friction and move them toward each other.

Reasoning along this line, Newton concluded that every particle of matter in the universe attracts every other particle, and if they were not kept apart by other forces they would be drawn together. By mathematics Newton computed that a man standing on this planet is attracted three thousand six hundred times as much by the earth as he is by the moon, supposing the two spheres to be of like density. That is, the amount of gravitation is proportionate to the mass, and increases as the square of the distance between the bodies diminishes. The force exerted upon a stone on the earth's surface by the earth, is to the force exerted on that stone by the moon as the square of sixty is to the square of one, the distance of the moon from the earth's center being sixty times the distance from the earth's surface to its center. If the moon did not have a moving force of its own, which tends to carry it on in a straight line, it would quickly be drawn to the earth.

Newton's two laws, then, are: The attraction of gravitation between two bodies varies (1) directly according to their mass; (2) inversely as the square of the distance between them. No laws promulgated by science have been more positively proved by both astronomers and physicists than these two.

FALLING BODIES.

Several years ago a friend and myself made some experiments upon falling bodies which were not only interesting but profitable. First, we dropped some balls between the stairways in the corridors of the schoolhouse. The balls were of various sizes and substances—iron, wood, rubber, and marble. Then we tried coins and paper disks. We found that nearly all the heavier substances fell in about the same time, but the paper disks dropped much more slowly than the metal ones. If, however, we rolled the paper into little balls, so that the air could not offer so much resistance, they dropped more nearly in the same time as the heavier bodies. Galileo was the first to make similar experiments, using the famous Leaning Tower of Pisa from which to drop the bodies.

We also tried the "guinea-and-feather" experiment, first made in 1650. Into an inch-glass tube about four feet long we put a silver half-dime and a disk of paper of the same size. This we corked and hermetically sealed both ends, having first put a small glass tube through one of the corks. To this we attached the rubber tubing from an air-pump. We exhausted the air from the tube as completely as possible, and closed it by doubling the rubber tubing on itself and tying it. Then we turned the lower end of the tube up quickly in a vertical position. The silver and paper fell to the bottom with the same velocity. We tried the same experiment by allowing the air to reenter the tube; then the paper disk fell more slowly than the silver. What do these experiments show?

Is it not that all bodies fall with the same velocity in a vacuum, no matter how large they are or of what substance they are composed? In other words, "the earth exerts upon each particle of matter separately a force which is proportionate to the mass of the latter, independent of the material of which it is composed. On the moon, which has no atmosphere, a feather and a bullet would fall with the same velocity."

Our third experiment was also made in the corridors of the schoolhouse. First we made a pendulum with a lead ball and a string, that oscillated exactly once in a second. We did this because we could mark time better with the pendulum than we could with the watch. From the point of support to the center of the ball the pendulum was thirty-nine and one-eighth inches long.

Then we let a ball fall from different heights, until we discovered, if we held it sixteen feet above the floor, it struck the floor in one vibration of the pendulum—that is, in one second. The pendulum and the ball were started at the same time by tying them together with thread about a foot long and hanging them over the support so as to leave both in a proper position. They were then released by cutting the thread.

Next we wanted to find out how far a body would fall in two seconds. We discovered that if the ball were dropped from a height of sixty-four feet it struck the floor in exactly two seconds.

Now, what were the conclusions? The first second it fell sixteen feet; the second second it fell forty-eight feet—that is, thirty-two feet farther than the first second. Now, the force of gravity is constant, and it ought to fall by gravity no farther in the second second than in the first. Therefore the difference, or thirty-two feet, must have been due to the momentum gained in the first second. Later we had opportunity to make the same experiment by dropping a ball in a tower. There we found that in three seconds the ball fell a distance of one hundred and forty-four feet. Allowing sixteen feet a second for gravity, there would be left sixty-four feet due to momentum gained in the first and second seconds; in other words, the constant force of gravity draws falling objects toward the center of the earth through a distance of sixteen feet per second, and each second the body falls, its velocity is increased thirty-two feet. In the fifth second a body will fall one hundred and forty-four feet, or $16 + (4 \times 32)$ feet—that is, $16 + 32\,(t-1)$, t being the number of seconds. In five seconds a body will fall four hundred feet, or 25×16 feet (number of seconds squared by 16 feet).

We looked into a book on physics and found that our figures were practically correct. Mathematical calculations show that the distance a body falls the first second is least at the equator and most at the poles, varying from 16 to 16.25 feet. In latitude 45°

it is 16.08 feet. In accordance with Newton's second law, the attraction of gravity on falling bodies is greater at the poles; on account of the flattening of the earth at the poles a body is nearer the center of the whole mass of the earth.

Another experiment greatly surprised the class before whom we performed it. We laid a yardstick upon the table, one end projecting over the edge about four inches, the other end held down by several books. On the projecting end we laid a marble, and five inches from it another. Then with a heavy ruler one of us struck a horizontal blow, which sent the second marble and the stick off in a horizontal direction, allowing the first marble to fall to the floor. Both marbles left their position at the same instant. Although the second marble went through a horizontal space of fifteen feet, both struck the floor at the same instant.

The conclusion was that gravity acts just as well upon objects when they have been set in motion by some other force as when they are allowed to drop. Accordingly, a cannon-ball flying through the air with a great velocity will descend to the earth the same distance per second as a freely falling ball.

A ball thrown up into the air with a certain initial velocity will be as long in ascending as in descending, and will return with the same velocity with which it started, not taking into account, of course, the friction of the air.

What is gravitation? We say it is a force that belongs to all matter. All we know of it is that it is a force which acts in certain ways. Nobody knows what it is. In fact, we know nothing of any force except its manifestations in matter. Magnetism, electricity, chemical affinity, brain power, yes, life itself, are all known only to the extent to which they can manifest themselves in what we call matter. Quantity can be measured, quality can only be discovered.

PLANT AND ANIMAL LIFE.

CHAPTER XXII.

THE UNIVERSE OF LITTLE THINGS.

As soon as man discovered the principle of the refraction of light he opened new possibilities for himself. This principle he applied to the construction of the telescope and the spectroscope, instruments which have brought to him new visions and new knowledge from the immensities of space. Great spheres moving at great velocities in great orbits come within range of his scrutinizing gaze. But even while he was pondering upon the great and the far distant, there lay at his feet another world quite as wonderful, into which the microscope was soon to lead him.

Though the microscope was invented soon after the telescope, men were slow to see with it. It was not much over a quarter of a century ago that it was turned to practical uses. The discoveries made in this time, and particularly in the last ten years, have introduced man into a new universe—the universe of little things.

Let us get some idea of this world. We will begin by taking a little yeast from the sponge of mother's bread and place it on the slide of a good microscope.

As we look we see only small globules, and we are inclined to turn away without further interest.

But wait a few minutes: one of the oval bodies begins to swell; a protuberance develops on one side; it looks like a small potato grown to a large one. We look again and they are separated. That is not all: each of the two oval bodies begins to swell on one side and go through the same process that the first one did. There is one that has two buds at the same time, and another with three.

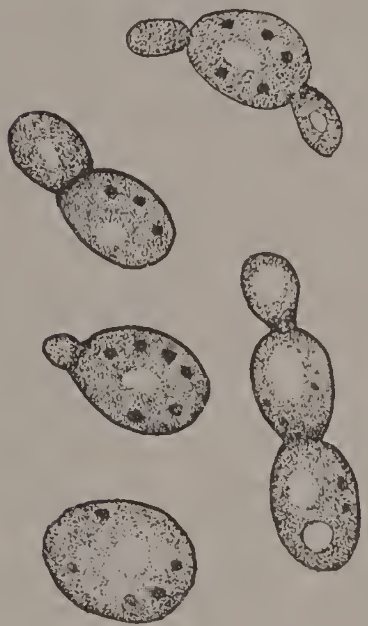


FIG. 99.—Yeast cells (magnified). (From Coulter's Plant Structures.)

The little oval bodies that grow out of the side of the mother-cell are called daughter-cells. This method of multiplication is gemmation, though it is commonly called fermentation.

The products of this process of multiplication are two: carbon dioxid and alcohol. In the bread sponge the carbon dioxid produces the bubbles, which usually break, allowing the gas to escape. In the dough they remain and make it porous, or "light." The alcohol is driven off by the heat in baking. Probably Chicago alone produces annually in this way no less than ten thousand barrels of alcohol.

The thing that surprises us about these "little things" is that there is growth, and where there is growth there is life. Is it plant or animal life? Its motions and method of gemmation would lead us to think that it is animal. But it has been found that the capsular covering of these oval bodies contains cellulose matter, which has been considered a characteristic of vegetables.*

The yeast germ is therefore regarded as a plant. It has no chlorophyll, and hence it can not make its own food out of carbon dioxid and mineral matter. It is compelled to live on more highly organized food prepared by higher plants. Organic matter is its food, and fermentation continues as long as there is food for the organism to feed upon.

Compressed yeast is a collection of yeast germs, which may be kept in a cool place for several days. Sometimes quantities of the germs are put into the form of a cake and dried. In this form they may be kept several months.

If we put a quantity of the germs where they can get but little or no nourishment, they begin to make out of their own substance small granular bodies which have about the same relation to the germ that a seed does to the plant. These are known as spores. They have much greater power of endurance, and under favorable conditions will produce the germs, as the seed produces the plant.

Occasionally the housewife finds that her bread does not turn out well, although, so far as she could

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* It has recently been discovered that the covering of the squid also contains cellulose.

see, she made it in the same way and kept it under the same conditions as she had at other times when it was good. She says she can not account for it. The scientist, however, has discovered that the conditions were not exactly identical; he has found other organisms besides yeast in the sponge. At times these are more numerous than at others, and then they produce evil effects.

FIG. 100. — Bacillus which makes milk sour.

The vintner sometimes finds his wine turning acid or bitter, becoming ropy, or acquiring a moldy taste. The same is true of beer. Investigations have proved that these undesirable effects, and others as well, are due to the presence of plant organisms very similar to the yeast germs. Other kinds are found in milk, and turn it sour; others cause meat to decay; still others produce sores where the skin is broken or cut, etc.

The air is full of these minute organisms; the water is alive with them, and the soil contains them in abundance to the depth of four feet. They far outnumber the plants to be seen with the eye.

Many of them are so small that twenty-five hundred can be placed side by side in the space of one inch. Since they are so tiny, it is no easy task to study their structure, and their species can not well be determined. They may be grouped into three classes by their general shape. Under the magnifier a large class of them resemble lead-pencils, some cut square at the ends, others sharpened or rounded.

Another class looks like marbles, and the third class has spiral forms. Each class appears to contain varieties innumerable, differing slightly in shape, but still having the general form. The rod-shaped forms were probably the first to be studied, for all these organisms have been named bacteria (bacterium is the Greek for stick).

Fig. 101.—General shapes of bacteria. *a*, spherical forms; *b*, rod-shaped forms; *c*, spiral forms. (From Conn's Germ Life.)

You may ask, How do we know that they are organisms? It would be an easy matter to convince you if you could see them through the microscope for half an hour. If we take a little fine dust from that which sticks to the window-pane and place it under a magnifier, we might watch it for hours, but it would always appear the same. On the other hand, if we take a drop of milk a day old, which has been freely exposed, and put it under the same magnifier, we should see some little things dancing up and down, others moving in a straight course or in a serpentine path, to and fro, in the milk.

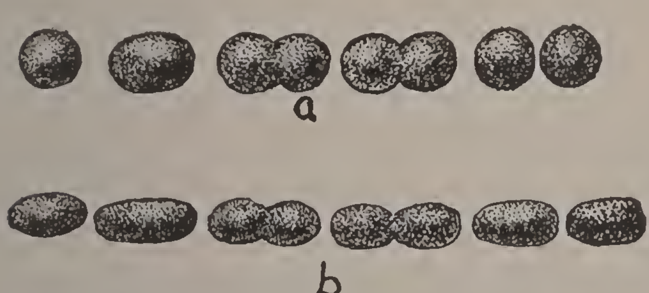

Fig. 102.—Method of multiplication of bacteria. *a* and *b*, bacteria dividing by fission.

Their motions would soon convince the most skeptical observer that they are alive.

Bacteria differ from yeast germs chiefly in this, that they multiply by fission. A bacterium begins to contract at the middle, or at several points, until it divides into two or more new organisms, each as perfect as the parent. Each grows and divides again, and generation follows generation with great rapidity.

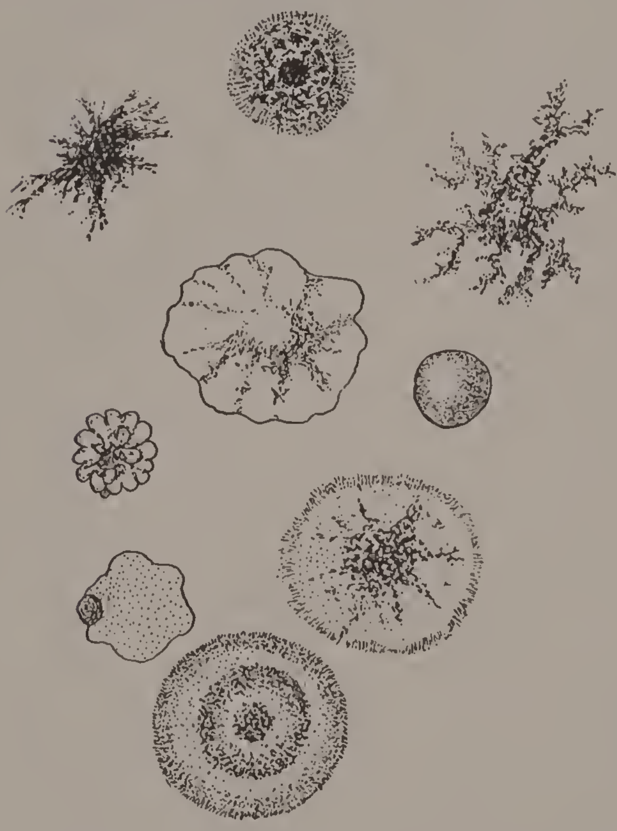

Fig. 103.—Various types of bacteria "colonies," cultivated in gelatin.

One species of bacteria divides into two, and each new one into two again, which again divide. In half an hour there will be three in the place of one, in an hour six, in two hours twenty-four, and so on. It has been computed that in three days there would be so many that we could not comprehend their number, and that in weight they would exceed seven thousand pounds. Not only are

Fig. 104.—Diptheria bacillus.

they great in numbers but in species. One investigator found not less than seventy kinds in cheese. There are perhaps more than a hundred in milk. It is possible that these are the same species which have developed somewhat different forms under different conditions. For this reason scientists are classifying them, not according to their structure, but according to the effects they produce in the various media in which they exist.

Tetanus or lockjaw bacillus.

Species can not be named here, but perhaps the genera should be given. The following have been generally recognized: Micrococcus, streptococcus, staphylococcus, sarcina, bacterium, bacillus, and spirillum.

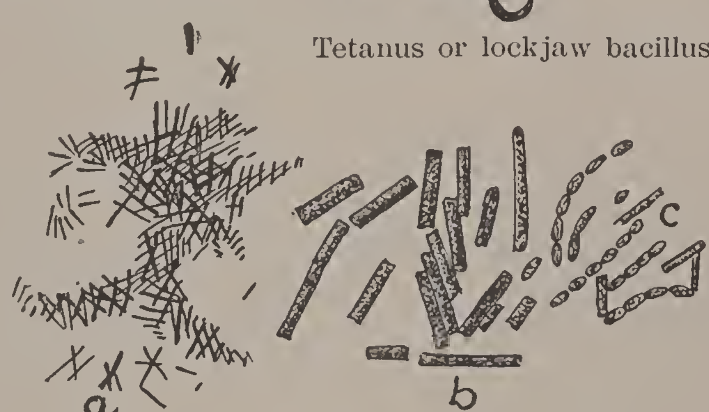

FIG. 105.—Tuberculosis bacillus. *a*, as seen in lung tissue; *b*, more magnified; *c*, as sometimes seen in sputum of consumptive patients. (From Conn's Germ Life.)

Are bacteria important? They are. They are an important factor on account of their wide distribution, for they are found almost everywhere, and on account of their rapid multiplication. They have the power, it seems, of breaking up complex molecules into simpler ones. Organic molecules are usually very complex. In this way they break up animal and plant tissues as soon as death sets in. They are diminutive scavengers, and assist insects and worms in clearing the earth of dead bodies. Others seem

Fig. 106.—Bacillus producing vinegar.

to possess the ability to produce chemical effects and thus to change the nature of a substance, as the souring of milk and beer or flavoring butter and cheese.

In their relation to man, bacteria may be classified as the beneficent, those which assist him in producing advantageous results, and the malignant, whose work is injurious to him.

We are just beginning to learn how to make the former serve us, and how to check the ravages of the latter. When we speak of bacteria, or germs, or bacilli, or microbes (the last is applied to any small life, animal or vegetable), we awaken prejudice at once. The truth is that the proportion of harmful species to the beneficent is no greater than that of poisonous plants to the useful ones.

Fig. 107.—Soil bacteria which prepare nitrogen for plants in soils where there is a lack of it.

Bacteria are useful agents in preparing the soil, in maintaining its fertility, in clearing away filth, in the preparation of foods and drinks; in short, they touch man in all his interests. Without bacteria butter could not have the flavor so much to our taste, and cheese would be but a poor diet.

Milk is a good medium for bacteria to thrive in. Some are usually in the pail; the cow has them on her hair and skin, and particularly in the filth that clings to her; they are in the dust of the hay; and thus before the milk reaches the house many kinds have made a good start in the warm liquid, which is rich in bacterium food and at a temperature favorable to their development. The milkman is often wrongfully accused of watering his milk when it has a bluish cast. This is due not to water, but to harmful bacteria living in the milk. The most harmful kind in milk is that which produces tuberculosis.

Fig. 108.—Dairy bacterium producing red milk.

The remedy is healthy cows, cleanliness in food and water, in the stable, in

Fig. 109.—Bacteria cultivated in scientific creameries for the purpose of ripening cream in order to give butter a pleasant flavor.

milking, in the utensils used. Heat is a great destroyer of germs. If milk is heated to 158° all bacteria in it are killed, but the spores require boiling for a minute or two; otherwise they have the power to produce new germs.

This much has here been given on the subject of milk because of its importance to health. Conn's Story of Germ Life (D. Appleton and Company) contains an interesting account of the uses and evils of bacteria.

MINUTE ANIMAL LIFE.

Starting with the yeast, I have given you a glimpse of the innumerable plants whose forms are revealed only by the compound microscope. Yeast is the most common of these, and its action is easily observed. Now we shall see what animal life the microscope reveals.

Let us dip a glass of water out of a stagnant pool. Possibly we have caught up a water-beetle or two, or a few wormlike creatures. These are all the life that is visible.

We will take the drop of water and put it on a glass slide. It seems to be quite clear and free from life; but what wonders the microscope brings into view! There are little swimmers moving quickly about in the drop.

A little jellylike speck attracts our attention. In appearance it does not differ from a bit of the white of an egg. But watch it, and you will find that it moves. It stretches out fingerlike points, and the rest flows on after them. It is now clear that it is a living thing. It has no permanent shape, but assumes first one form and then another. At one time it is round, then it puts forth a projection or two, sometimes a dozen at once. These projections are called pseudopods, which means sham feet.

But that is not all. The gelatin creature gets hold of a bacterium and quickly enwraps it by flowing around it. After some time it unrolls itself, and we see but little left of the bacterium.

The tiny animal has just enjoyed a breakfast. Since it has no stomach in which to put its food, it

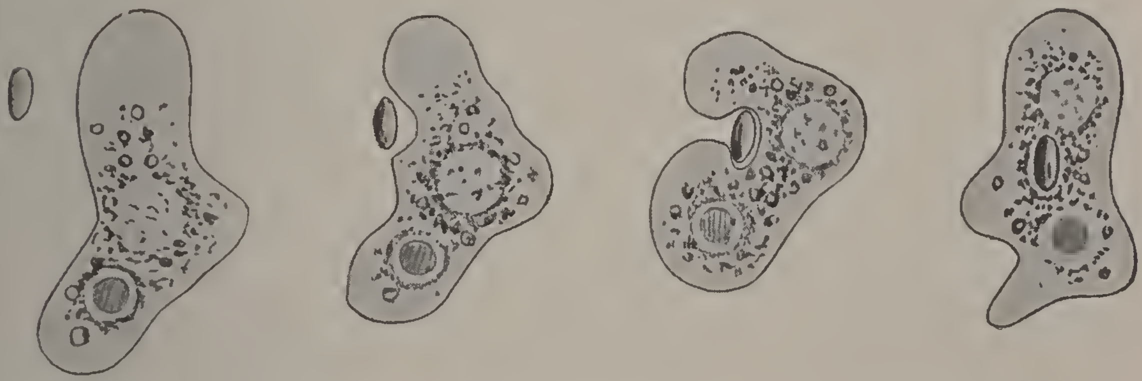

Fig. 110.—Ameba taking its breakfast, a one-celled plant. (Jordan and Kellogg's Animal Life.)

must wrap itself around the food and absorb it. Its food consists generally of vegetable matter, although it relishes bits of animal matter if it can get hold of them. Watch it again as it takes a nap after its meal. A minute bubble rises out of the center of the mass. The bubble is doubtless carbon dioxid, and it is proof that the little lump breathes. It takes in oxygen through the skin—no, the poor thing has not even skin—and gives out carbon dioxid.

The name of this jellylike being is ameba (change). As we have seen, it moves, breathes, and digests its food, and is one of the simplest of animals.

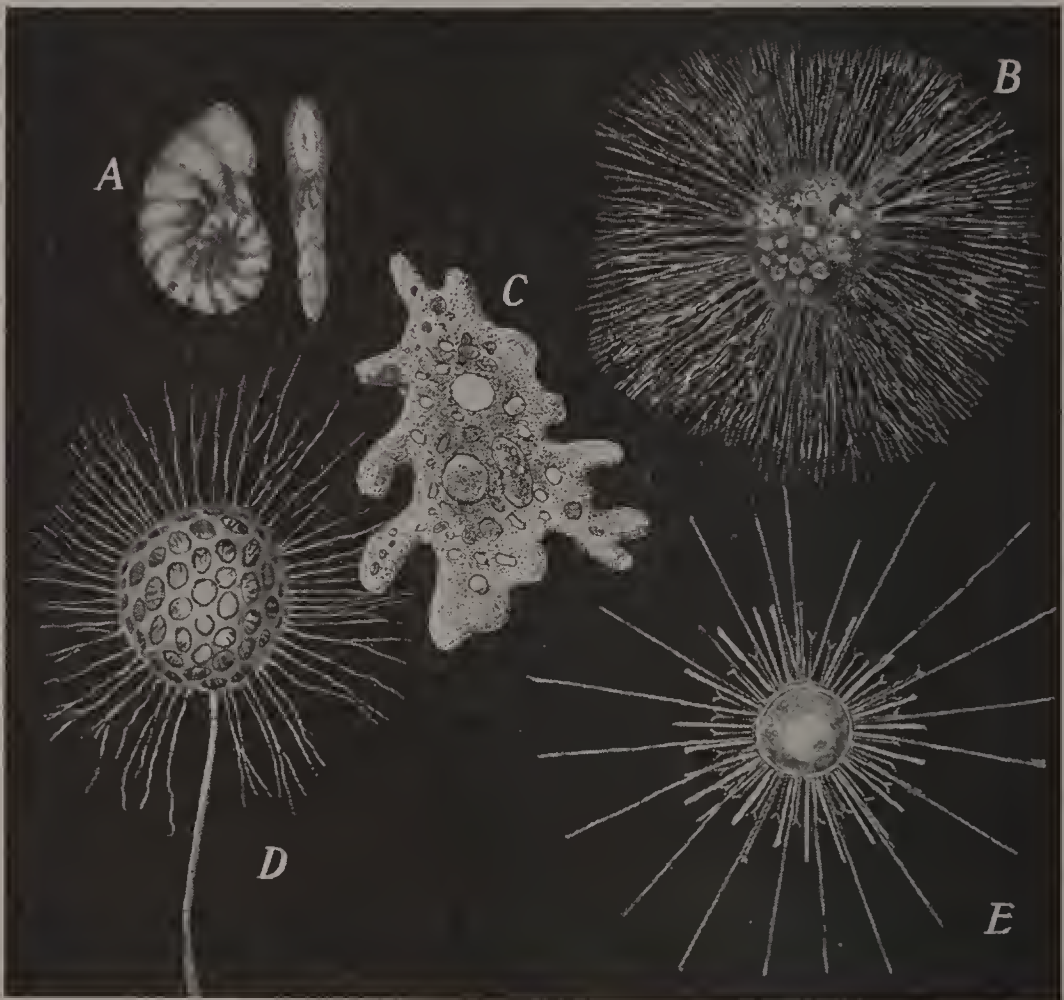

FIG. 111.—Rhizopod animals. *A*, a foraminifera, front and side view; *B*, Lobosa; *C*, ameba proteus; *D*, Clathulina elegans; *E*, sun-animalcule.

Its body is made up of one cell, but the cell is in itself not at all simple; it is composed of very complex matter.

A hen's egg is the best illustration of an enlarged cell. It has a covering which we call the shell. In this is the white, and within the white is the yolk, within the yolk the germ center, which is the basis of life. The yolk and the white are food stored up with the germ, upon which the undeveloped chick lives until the egg is hatched.

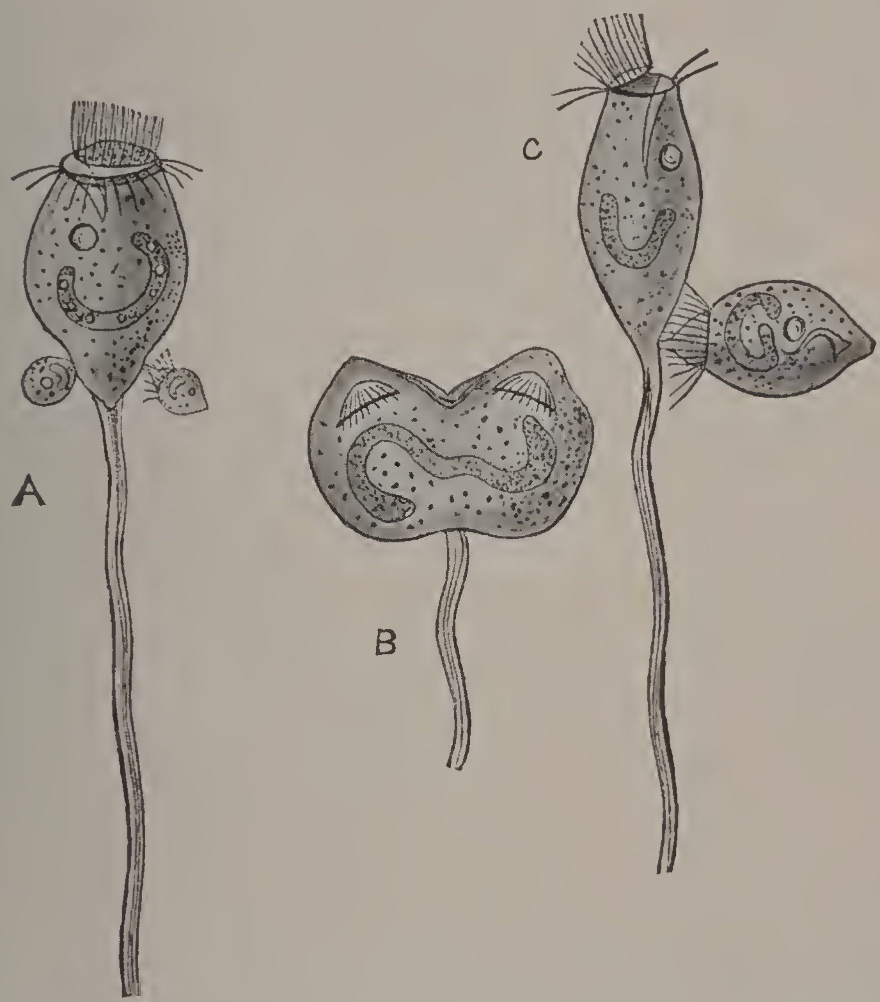

FIG. 112.—Vorticella magnified. *A*, small, free-swimming individuals conjugating with a large, stalked individual; *B*, a stalked individual dividing longitudinally; *C*, after division is completed, one part severs itself from the other, forms a ring of cilia, and swims away.

The ameba cell has no outer covering. Its outer part corresponds to the albumen or white of the egg;

in this is the nucleus or harder center, which contains the life germ.

If we continue to watch the ameba we shall see that after a while it begins to contract in the middle.

Fig. 113.—Rhizopods. Three kinds distinguishable by their caps.

The nucleus divides into two parts, and right before our eyes the little ameba becomes two amebas. Instead of the mother we see two daughters. These can

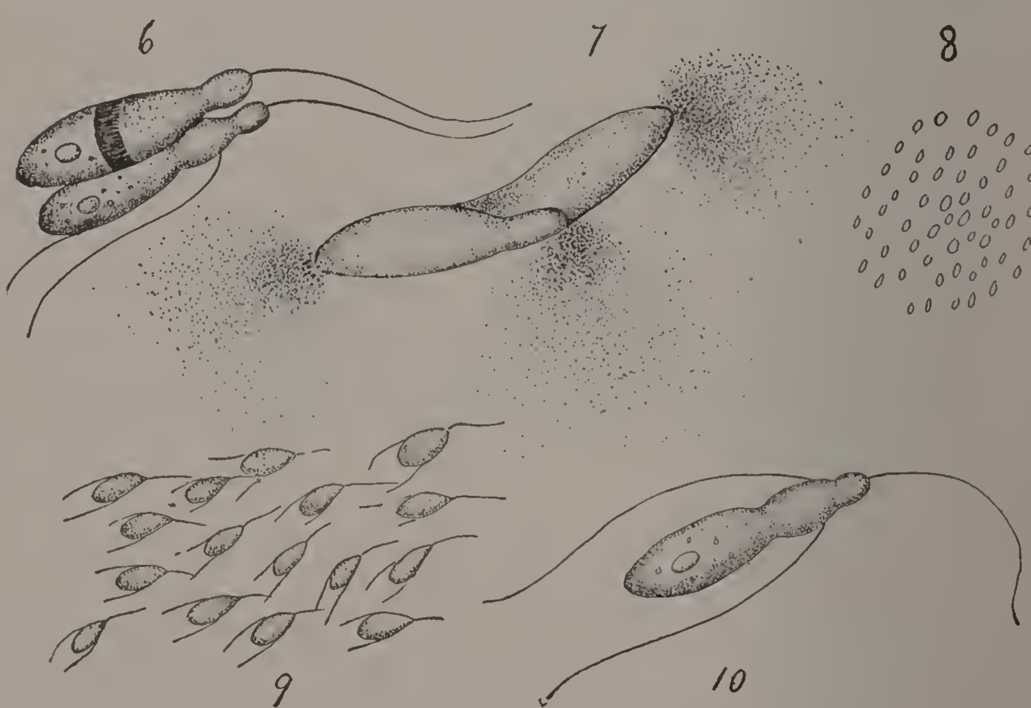

Fig. 114.—Dallingeria with her family.

do what the mother did. They, too, soon attain their growth, and each divides and becomes two amebas, as the mother did before it. You may say that the ameba can never grow old, for in the very vigor of life it becomes twins to start life over again.

In our glass of water we may also find little bell-shaped vorticellidæ attached by a stem. Many other microscopic creatures exist in this glass, but there is not room in this book to describe them. An enjoyable description of such life is given in Mrs. Bayliss's In Brook and Bayou.

I can not leave this subject, however, without referring to the Gregarina. These are minute organisms which live in the intestines of crayfish and of some insects. They attach themselves to the inner side of the alimentary canal, some by means of hooks, and live upon the liquid food in the intestines.

In time they become a cyst by enveloping themselves in a tough covering. The nucleus divides into numerous small elliptical bodies, which in various ways escape from the cyst as spores. These spores somewhat resemble the bacteria spores. Under suitable conditions they develop into Gregarina. Although the Gregarina is far more complex than the ameba, it is still a single-celled animal, and belongs to the simplest class of animals.

The water-beetle found in the same glass has legs, a head, and other distinctive parts of the body. Each has its particular use. The nervous ganglia, which form its brain, control the muscles and other parts. The beetle, therefore, is composed of organs, and the organs are composed of different cells. It is, then, a very complex creature compared with the Gregarina.

One-celled animals must perform the functions of life with the whole body, and they are poorly performed. However, the little creatures seem to enjoy life in their own demure way.

There are many kinds of these unicellular beings. Most of them live in water, either fresh or salt. Others live as parasites in the larger animals, and these in turn in still larger ones, so that in this world of little things, as throughout the animal kingdom, the truth holds good which is expressed, in reverse order, in the following lines:

"Great fleas have little fleas,
And these have less to bite 'em;
These fleas have smaller fleas,
So on *ad infinitum.*"

CHAPTER XXIII.

VARIETY AND TYPES IN NATURE.

HERE I am standing on the border of Passaconaway Glen. Points of oak forest extend into the prairie like peninsulas, and single monarchs stand out like islands in the sea. In the baylike recesses flourish tall grasses and weeds and colonies of wild flowers displaying their bright colors against green copses of hazel and hawthorn which fringe the taller trees. The sentinel oaks spread out their branches into a splendid crown, reveling in the abundance of sunshine. How different their kind crowded together in the dense forest—tall, slender trunks, with few ill-shapen branches and starved crowns!

Striking as these differences are, I am still more impressed by the various shapes and sizes of the leaves even on the same tree. The descriptions given in books on botany of the characteristics of different species seem to me to be applicable to the leaves on the same tree. One so-called species appears to grade into another. They are not distinct, as from my books I had supposed them to be.

When I examine the leaves of the poplar and the willow I find like differences. Those at the top vary

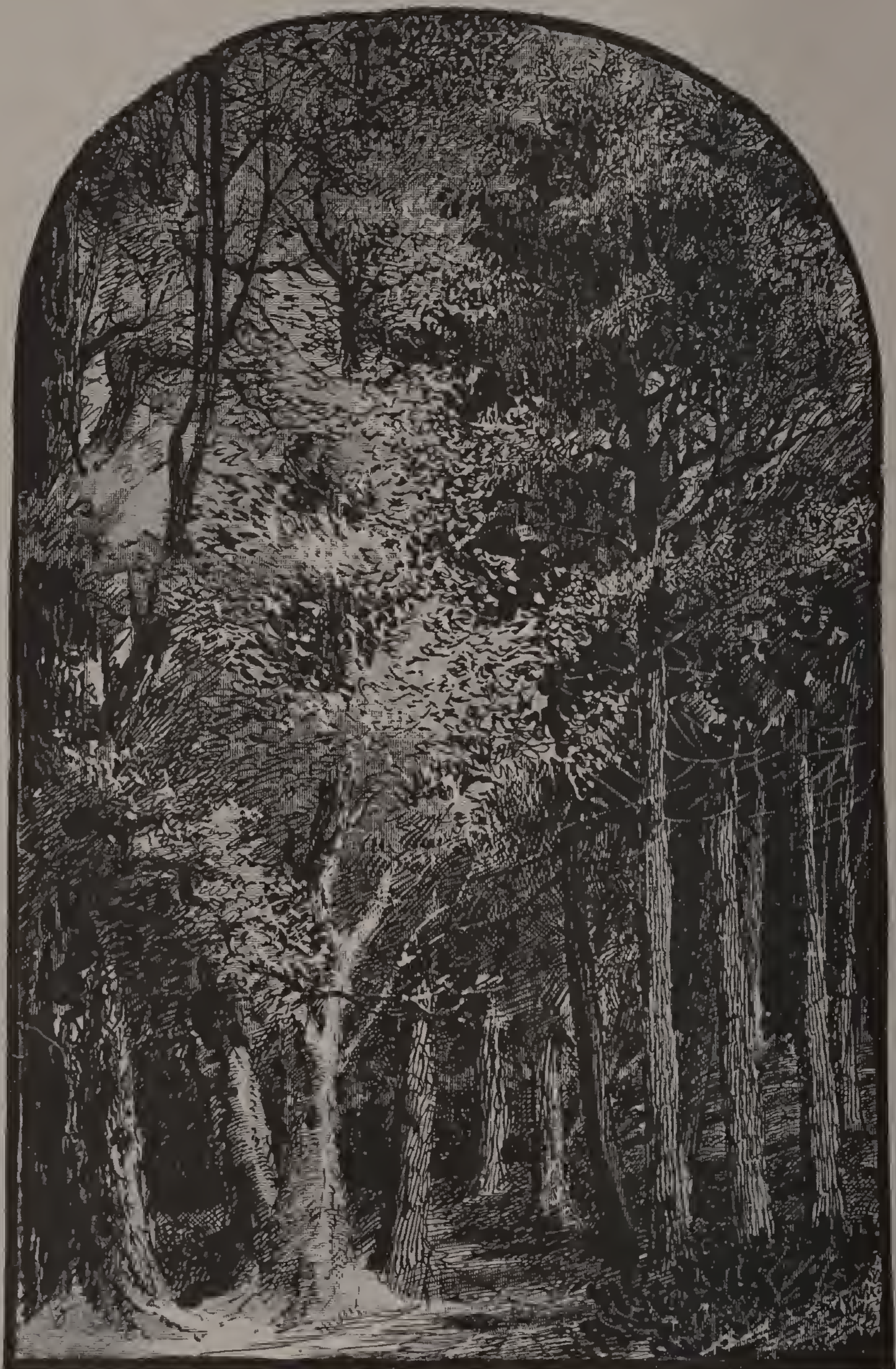

Fig. 115.—A dense forest of tall trees.

perceptibly from those borne on the lower branches and those on the north side of the tree often differ from the ones on the south side.

Professor K——, a Swiss naturalist, learned in college that there were at least fifteen species of oaks in the genus quercus. As most scholars did in the past, he studied from the specimens found in the herbarium. This is, of course, made up of only typical leaves and flowers. When he went out into the forest to study the trees themselves, he soon found on one tree two leaf types, on another three, and so on, till finally he discovered the entire number on a single tree. His fifteen species naturally enough dwindled down to one.

Equally great differences are quite as evident in flowers. The daisies, columbine, and honeysuckle seem to vie with each other in producing new shapes. Quite as puzzling are the asters. It is no easy matter to group them, and say this belongs to one species and that to another.

When Prof. Asa Gray first described the asters of North America he classified them into about thirty species. In his late years he gave it as his opinion that there was only one species, and that all the others were probably only varieties of that one.

The same thing has often been observed by other naturalists. There is everywhere a gradual shading of one variety into another, one species into another, and, to some extent, one genus into another. There are no distinct steps but a regular progression.

The differences are often so minute that the expert only can detect them. Two apples that look exactly alike are recognized as different varieties. Voorhelm, the Dutch gardener, cultivated twelve hundred varieties of tulips. He was able to distinguish the variety from the bulb alone.

Animals, too, vary greatly. I have heard that a shepherd is able to distinguish the sheep in his flock of several hundred, though the inexperienced can hardly discover any marks whereby he may know one from the other. Pigeons have been studied with much patience, and no two of them are exactly alike. The fancier can easily pick out any particular one. Twins often can be distinguished only by their mother. If our observations were sufficiently accurate, we should be able to discover many marks of recognition where now we think none exist.

Noticeable differences exist not only in the color and proportion of animals, but also in motion, habit, and odor. Mr. Thompson-Seton tells us the story of Wully, a "yaller dog," who was trained to herd sheep. One day his master sent him after a supposed missing sheep; the dog, not being able to find it, continued the hunt all day. Meanwhile the shepherd was obliged to go on and deliver the herd at a distant point, leaving the dog. When the animal returned he traced his master to a ferry and crossed in search of him. As the scent had long become "stale," he was unable to trace the man. For two years the dog crossed and recrossed, smelling every pair of legs that came over the ferry. It was computed that during this time the dog had smelled six million legs. One day there came over another shepherd, who wore a pair of mittens and a muffler which had once belonged to the dog's master, and Wully quickly detected them by their odor.

Probably no two individuals are exactly alike, else how would the mothers be able to recognize their young? Once I had two hens come off the nest in the same day each with a small brood. I concluded to give both broods to the same hen, and I did so the third day. Although the chicks were so nearly alike that I could not distinguish them, the hen knew her own, and at first pecked at the little strangers.

Does Nature revel in variety to such an extent that she is bound by no laws?

Notwithstanding these innumerable unlikenesses and ever-changing differences, there is as readily discoverable a line of likenesses, undeniable resemblances to parents, sufficiently definite for practical study. An eye trained by observation can readily distinguish the oaks from the maples or poplars, or true roses from the strawberry or apple, both of which have rose blossoms. The influence which holds to types and ancestral forms will be discussed in the next chapter.

CHAPTER XXIV.

HEREDITY.

AMONG the inhabitants of Mauritius was an engineer named Lislet-Geoffrey, the son of an intelligent white man and a stupid negress. The son had all the physical characteristics of his mother, but in mind he was like his father, and became so brilliant that, notwithstanding his objectionable color, he was received into the best and most aristocratic society of the island.

A famous illustration of inherited characteristics is the Bach family. It began in 1550 with Weit Bach, a baker, who spent his leisure hours in song and music. For three centuries his numerous descendants, scattered through the greater part of Central Europe, made themselves famous for more than ordinary musical ability, singing in church choirs and playing cathedral organs. Twenty-eight of them became celebrated as high-class musicians.

Our great preacher, Richard S. Storrs, was the fourth in the family succession possessing remarkable mental traits. The Adams family, too, gave us a succession of brainy men. Charles Darwin inherited not only the mental traits but even the very bent of his grandfather, Erasmus Darwin.

On the other hand, we often learn of great men whose ancestors were unknown. This does not disprove that mental traits are regularly inherited. If we knew all the facts, we should very likely find that the father or mother of Goethe or Shakespeare possessed keen poetical insight; that the ancestors of Gladstone, Newton, Laplace, Harvey, Parkman, were thinking men and women and possessed the particular trait which made their descendants famous, though for lack of opportunity it remained undeveloped.

Frequently it has been observed that the children of celebrated men do not appear to possess any of the father's ability. It is possible that in such cases the inheritance is present but has been suppressed by environment. This would seem to be true, inasmuch as the same trait asserts itself sometimes in the grandchildren.

Moral traits are no less inherited than mental. In his book entitled The Jukes, Mr. Dugdale traces the descendants of an unfortunate, vicious, and neglected girl. It is a line of immoral and criminal inheritances not only to the "third and fourth generations," but through six generations. Among the men there was nine times as much poverty as among ordinary men, and among the women seven times as much, while fifty-two per cent of the latter became outcasts. This is an extreme case, but instances of inherited immoral traits can be found in almost any community.

The inheritance of physical features is even more evident. A singular case is that of Andrian and his son Fedor, who were exhibited in Europe as the "dog men." The father was covered, face, hands, and all, with a thick growth of fine, dirty yellow hair. It was two to three inches long. Long tufts of hair grew out of his nostrils and ears and from the corners of his eyes, giving him the appearance of a Skye terrier. Fedor, like his father, was covered with hair, as was also a daughter, but another son was like ordinary men.

A certain Mr. Colburn had six fingers and toes, and this peculiarity was transmitted through four generations. A Scotch family carried this sex-digitism through three or four generations, when it disappeared, but in the place of the sixth finger there was still a slight deformity.

The Hebrews are now scattered into all lands and climes, but they carry with them everywhere the features peculiar to their race, by which they are easily recognized. The nose, it is claimed, is most persistent in holding hereditary traits, so that we speak of the Greek, the Roman, the Jewish, or the negro type of nose.

A long list of instances of the transmission of physical peculiarities might be mentioned, but these will illustrate the working of the law among the human race.

HEREDITY IN ANIMALS.

Near the close of the last century the farmers of Massachusetts were much annoyed by sheep jumping their fences, and often wished for a way to break them of this habit. In 1790 a lamb was born on Mr. Seth Wright's farm which had a long body and short bowed legs; doubtless it was a "sport." It was soon noticed that this lamb could not follow the others over the fences, and the owner thought it would be a good thing if all his sheep were like it. Accordingly he selected this one to breed from. Though some of its offspring were like ordinary sheep, a few of them inherited its peculiarities—a long body and short bowed legs. Thus originated the Ancon breed of sheep.

In the year 1770, in a herd of horned cattle in Paraguay was born a "sport" which developed into a hornless bull. He was used to breed from, and in this way was started a hornless breed of cattle.

By what principle are traits transmitted? Is there any law of heredity? If so, what is the law? These questions have engaged the attention of evolutionists for more than a quarter of a century. In fact, the law of heredity is the present-day problem. In order to get at it, we must consider the cell, which is the basis of all physical being. It is there that life ultimately resides.

We have already learned that the lowest living forms, both animal and vegetable, consist of a single living cell, and the most important part of that cell is its central portion, called the nucleus. Its structure is very complex, and thus far has defied all chemical analysis. The microscope reveals to us small threads in the nucleus. What have these threads to do with the transmission of parental characteristics?

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The ameba has been described in Chapter XXII. A study of this simple cell with a compound microscope reveals much that is suggestive. We may see it begin to divide. The mother cell separates into two equal cells. Each has its nucleus and threads. Evidently the mother-cell has divided the threads and given each daughter-cell half. They are therefore like their mother in every respect. Between them they have inherited their mother entire.

We may examine a vorticella in a drop of stagnant water, one of another class of simple one-celled animals. In shape it is like a bell (Fig. 112); at one end it has a short stem, by means of which it was attached to a dead leaf in the water. As I watch it with the microscope I notice that it divides like the ameba, but lengthwise. The two halves are upon the same stem. Soon one of them frees itself, and by means of a circle of very fine hairs called cilia, it paddles off in the drop of water. Here again the mother-cell has divided and become two daughter-cells.

Close by this is another verticel. Instead of dividing into two equal parts, it sends out a little bud on the side, which separates from the mother-cell as soon as it has developed its cilia, and then swims away.

This manner of reproduction, however, does not go on indefinitely. Exhaustion seems to take place in the course of two or three generations. Then two vorticellæ unite and each gives up a part of the contents of its nucleus to the other. The cells that unite are always unequal in size. We have here, then, a simple case of cell fertilization and a suggestion of sex.

Higher animals, as is well known, are composed of many cells united into one being. The cells also become differentiated—that is, each set has its own function to perform. There are muscle-cells, bone-cells, nerve-cells, reproductive-cells, and so on. They are divided into two groups: the reproductive or germ-cells, and the body-cells. The germ-cells alone have the so-called hereditary "threads." The off-spring gets both germ-cells and body-cells from the parent, and it is with the germ-cells that the hereditary threads are transmitted. These threads have the power of directing the growth of the body-cells, and thus construct a body which possesses the traits of the parent. What power in the cell accomplishes this work is not known, but we may sum it all up in the word life.

"A CHIP FROM MANY OLD BLOCKS."

Life everywhere presents two important facts. The one has already been explained under heredity; the other is variation. Heredity gives us types which may be recognized even in the midst of much modification. Variation gives us new species and new varieties.

There are many things which act upon life so as to produce variation. Earth, air, water, food, and exercise, each has its significant influence upon life.

Within certain limits variation is produced by heredity itself.

Living organisms reproduce in various ways—by division, by budding, by spores, and by conjugation. The first three are usually asexual. The more highly organized plants and animals reproduce by the union of germ-cells, male and female. In the reproduction of unicellular organisms there is but little chance for variation. The unicellular germ-cell embodies in itself a single line of hereditary influences, but in the higher organisms we have the union of two lines at least of hereditary influences, and the less closely they are related to each other the more diverse will be their characteristics.

The child often resembles the mother in some respects and the father in others; sometimes the characteristics are so combined that it is difficult to say which of the parents the child resembles. The eyes, the ears, the shape of the head, the nose, the chin, the form of the body and the carriage, the mental characteristics—all are subject to these laws. Sometimes the child resembles the grandparents or possibly still earlier ancestors. This tendency to go back is atavism.

It seems, then, that hereditary influences are treasured up from generation to generation, each marriage adding new characteristics to the life stream. We often hear it said that a certain person is "a chip from the old block," but it would be nearer the truth to say that he is "a chip from many old blocks."

It can not be denied that environment and natural selection are most potent in producing modifications and changing the character of species, yet it will thus appear the union of different sexes tends to produce variation in either of the two hereditary lines united. There is no better place than this to present an explanation of the meaning of species.

WHAT CONSTITUTES A SPECIES?

For convenience of reference and study, scientists have classified both animals and plants into species, genera, families, orders, and classes. Mr. Huxley says: "A species is the smallest group to which distinctive and invariable characteristics can be assigned."

Species are based upon form and structure, both external and internal. Animals of the same species must be able to produce beings like themselves, which shall again produce their kind. Animals of the same species are supposed to vary from each other only in color and proportions. Such variations would be called varieties of the species.

A genus includes one or more species. For instance, the foxes belong to the genus *Vulpes*. Wolves and dogs each belong to a different genus. In description two names are used: genus and species. The genus is written first, and usually begins with a capital letter. Thus the common fox of Europe is known as *Vulpes vulgaris*; the arctic fox is the *V. lagopus*; and our common red fox, *V. fulvus*, is really only a variety of the *V. vulgaris*, and may properly be called a subspecies. The cross and silver foxes again are color varieties of the red.

One species often grades into another; hence subspecies and subvarieties have been used to designate more definitely intermediate forms.

Families include one or more related genera. The dog family embraces the genera *Canis*, *Lupus*, and *Vulpes*. A number of families constitute an order, as the carnivora include all the flesh-eaters—dogs, cats, wolves, foxes. Suborders, tribes, and subfamilies are also employed to designate intergrading variations.

Recent studies have shown that there is no significant break that would divide animals or plants into definite groups, as the classifications might suggest, but the grouping is still retained because of its convenience.

CHAPTER XXV.

VARIATION BY FOOD.

EVERY one has observed that well-fed animals develop large and strong bodies. Poorly fed children, as well as animals, are often stunted in their growth. On the other hand, prize animals are forced to a great size and exquisite form by choice food. Vegetables grow much larger in rich soil than they do in that which is poor. Squashes, pumpkins, beets, and the like, are common examples.

The beehive contains males, neuters, and queens, as described in Book III. The so-called neuters are really undeveloped females. When a queen is needed, a grub is fed on a rich diet until she becomes a perfect female, much larger than those fed the ordinary diet.

Generally seven out of ten caterpillars are males, but if their diet be enriched there will be seven females out of ten. I have made several tests on chickens. If they were well fed the eggs hatched a much larger proportion of hens than when they were poorly fed.

The scientist Young made a test on tadpoles. Under ordinary conditions there are fifty-seven per cent females and forty-three per cent males. Young fed some on beef, and seventy-eight per cent developed into females; others he fed on fish, obtaining eighty per cent females; and of those that he fed on frogs, ninety-two per cent became females. He found that tadpoles pass through a stage when they are both male and female, and he claims that their food during this period has an effect on their sex.

A naturalist in 1870 took a number of pupæ of the Saturnia moth from Texas to Switzerland. These turned into moths like their ancestors, but their larvæ, feeding on the leaves of entirely new plants, metamorphosed into moths so unlike their grandparents that they are recognized as a different species.

In Ruatan I saw a parrot which was green all but a spot on the head. For some time it had access to salt pork, and ate some every day. Its feathers turned yellow, excepting the spot on the head, which remained red. I have also heard that a yellow canary fed on cayenne becomes orange-colored, and a bullfinch which is given hemp-seed will change its color to black.

Mr. John Hunter fed gull, which is a flesh-eating bird, on grain for a year, and he found that during that period the soft lining of the stomach had so changed and hardened that it resembled that of a chicken, a grain-eater. According to Edmonstone, this same operation is repeated in nature without man's help. He observed that another species of gull in the Shetland Islands changes its stomach to a great extent twice a year. Half the year its diet consists of fish, and then it has the carnivorous stomach; the other six months it feeds on grain, and develops granivorous lining. Similar experiments have been made on pigeons, with the result that the lining of the stomach became carnivorous when the bird was fed on flesh, and granivorous when fed on grain. These investigations prove that the stomach changes its character in accordance with the work it has to perform.

It is claimed that besides determining the structure of the stomach, the character of the food also has an effect on the length of the intestines. Men in training for physical strength know well what food is necessary to give them vigor and endurance. Alcoholic liquors weaken the constitution, change the color of the skin, and cause enlargement of the sebaceous glands, particularly on the nose.

It is evident, then, that the supply and character of food produce variation. The gardener and stock-raiser make good use of this fact, with the assistance of selection, in producing new varieties. Food changes not only the size but every part of the animal or vegetable structure. In plants and flowers the character of the tissues, the form of the leaves, the roots, and even the flavor, are affected by it. The mignonette, so odorous in rich ground, is destitute of fragrance when grown in a sandy soil. In animals the skin, the muscles, the secretive tissues, the bones, and the brain itself, are modified by food.

What determines the limits of the stature of animals and plants? Why does not the hen continue to grow until it attains the size of the ostrich, and why stop even there? Why not grow for a thousand years and outweigh the elephant?

It has been suggested that the ameba is limited in size only by the amount of food it can take in. According to a geometrical law, the surface of a body varies as the square of its dimensions, while the body varies as the cube of its dimensions. To illustrate: the area of a two-inch square is four times that of a one-inch square; the volume of a two-inch cube is eight times that of a one-inch cube. As the ameba absorbs through its surface the food necessary to build up its bulk, it seems evident that it can not keep up its growth and prevent death from starvation, so it starts over again by dividing and becoming two individuals.

If that thought is correct, all animals cease growing after they attain a certain size because they have not the necessary food; in other words, they get into a starving condition, which finally ends in death.

But this does not explain why the eagle is so much larger than the pewee, and the elephant than the mouse.

CHAPTER XXVI.

VARIATION BY ENVIRONMENT.

Environment is a term that embraces all things about us which affect our being. Light, air, earth, and water have their influence upon us. To put it categorically, Do climate and surface modify the bodies of animals and plants?

Many illustrations of the effect of environment have been noticed. Beginning with very common ones, I shall take the homely smartweed. This grew in abundance in a small valley near my home. During the spring and early summer there was considerable water in the ravine. The smartweed grew rank there; it had smooth stems and leaves. When the summer heat dried up the water, the stems developed tiny hairs. After several weeks of rainy weather these would again disappear.

Another species of the smartweed family has long stems bearing smooth obtuse leaves with stomata on the upper surface. When this plant grows out of water the stem is short, and is covered with downy, lanceolate leaves with stomata on both sides.

The terrestrial species of the buttercup develops a hairy scape and a felt-like surface on the upper side of the leaves, which are usually three-lobed. The aquatic species has the immersed leaves cleft by thread-like divisions, while the upper leaves, which grow out of the water, are lobed or rounded, much like those on the dry ground. Did not these two species have a common ancestor, and the one taking to the water become differentiated into a new species? We may conclude that the aquatic buttercup has taken to the water but recently, and is only partially adapted to aquatic life, for it is obliged to ripen its seed above the surface. On the other hand, the water-lily, in stem, leaves, and the manner of ripening its seeds, is perfectly adapted to aquatic existence.

Birches develop into goodly trees in the valley, but on mountains and in the far north they remain small bushes; still farther north, where growth must be completed in a few months, they are very short. The smallest variety, known as the "dog-ears," attains a height of less than one inch, and has but three leaves and a single catkin. It leaves in June, blossoms in July, and fruits in August. It is the Lap among trees.

It is well known that fruit-trees sometimes blossom a second time when the fall has been unusually warm for a few weeks. Vegetables, particularly potatoes, deteriorate in quality if the growing season be a wet one. In swampy ground we find plants with broad or round leaves. The prairies abound in thrifty, well-rooted grass, the western slopes have their buffalo-grass, and Arizona grows its singular cactus-trees and sage-brushes.

We often find three zones of plants in the same field if a part of it is swampy. In the lowest places broad-leaved plants thrive. Their leaves and stems are both adapted to a watery environment. On the dry ground we may find plants of an entirely different structure. Their stems are more slender and firmer in texture. The leaves are of a different shape, having most of the stomata on the under side. Both leaves and stems are often covered with down or bristles to protect them from injurious insects. Between this zone on high ground and the one on swampy ground is another in which the plants have an intermediate structure, so that they are adapted, as far as possible, to both wet and dry environment, for part of the year this zone is well supplied with water, but is rather dry during the rest of the year. We have here then three different plant societies which are the result of environment.

It is true that the plants of one zone grade more or less into those of another. If several dry seasons follow each other, the middle zone encroaches upon the aquatic, and the plants of the dry zone occupy some of the middle ground. Thus it is that climate to a large extent determines the character of vegetation.

How about animals?

Snails in England, Mr. Grant Allen tells us, that live near the water of the limestone region, have a calcareous shell of good proportions. On the contrary, those confined to localities where the surface is covered with mold have either no shell or only a very small plate covering the region of the heart. Between these two extremes range all sizes of shells, varying with the amount of lime available.

The snail was introduced into Lincoln County, Va., many years agô. Climate and food here were very different, so that the new environment, it is claimed, changed the structure to such an extent that sixty-seven new species were developed.

Near Black Lake are two lakes; the upper contained about 4 per cent of salt and the lower 25 per cent. The former is inhabited by the *Artemia Salina*, a small shrimp-like crustacean, half an inch long. Its tail consists of two pointed lobes, and is covered with bristles and hairs. In the lower lake may be found the *Artemia Milhausenii.* This species has rounded tail lobes, and is destitute of bristles and hairs. Some years ago the dam broke, allowing most of the water in the upper lake to flow into the lower. This diluted the water so that it was only 8 per cent salt. The fresh-water Salina was carried into the lower lake. The water gradually became more salty, and in three years regained its former 25 per cent of salt. And the Salina? Well, it lost its bristles, and its tail became rounded by degrees—in short, it was transformed into *Milhausenii.* The salt had changed it from one species into another. Later some of the Milhausen species were changed into that of the Salina by gradually freshening 25 per cent water to 4 per cent.

Small brown honey-bees were taken from high Burgundy to the neighboring province of Bresse.

They became larger, and changed their color to yellow in the second generation.

The horses of Normandy are large, while those of Brittany have always been small. Norman horses were sent to Brittany and at once began to degenerate, so that in the third generation they were like the native horses. Normandy is remarkable for its moist climate and lush vegetation.

On the smallest of the Madeira islands everything is diminutive—people, horses, cattle, and even the smaller animals. The *Vanessa* butterfly presents an interesting phase of life. There are two species, the levana and prorsa. The *levana* is hatched in the spring; it is red, with black and blue spots. It lays eggs which are hatched in the summer as the *prorsa*, which is deep black, with a yellow band on the wings. The prorsa lays eggs which again produce levana butterflies the next spring. Levana eggs have been put in a refrigerator in the summer. They came out butterflies, having the characteristics of both the levana and the prorsa. The warm weather has clearly the effect of changing the color of an insect to a great extent.

It is well known that the ringed snake lays its eggs in the sand and leaves them for the sun to hatch. When the snake is put into a box where there is no sand it brings forth its young alive.

The whale is an illustration of a singular change. From fossils it is clear that it lived mostly on land during the Mammalian age in a manner much like that of the beaver. Instead of developing and adapting its body to more perfect land existence, it chose the more aquatic life, and gradually became adapted to it. But its lung structure is still so far retained that it is obliged to come to the surface to breathe, and it is possible that it may yet, in future ages, become a thorough gill-breathing fish.

There are fish-like creatures of several species still found in Australia and in some of the rivers of Africa. They first appeared in the Triassic period. They have an eel-shaped body, and breathe by gills when in water. But the rivers in which they exist become dry during several months of the year. Then they lie in the mud and use the air-bladder as a lung.

In the United States lives another creature, the "mud-puppy," resembling a salamander, which has gills and also primitive lung spiracles for air-breathing. A third species is the amphiuma, which differs from the "mud-puppy" chiefly in that it has more perfect lungs and no gills, but still retains the gill sacs. These three species seem to be links in a chain of lung evolution. If this is a fact, the lungs are the product of environment—that is, of an attempt of the animal to adapt itself to the result of new conditions.

Environment has much to do with the distribution of animals. There are three reasons why particular species are not found in certain districts: (1) High mountains and large bodies of water are barriers that can not be crossed. For instance, the civet-cat is not found in this country, for the reason that it has never been able to migrate hither. (2) Others have come here or been brought by man; but they are not found here, because they were not able to maintain themselves. The English skylark is an illustration of this class. It was brought here, but perished because it could not maintain itself in the new environment. (3) Again, others having been introduced into a new environment, have been so changed by it that they

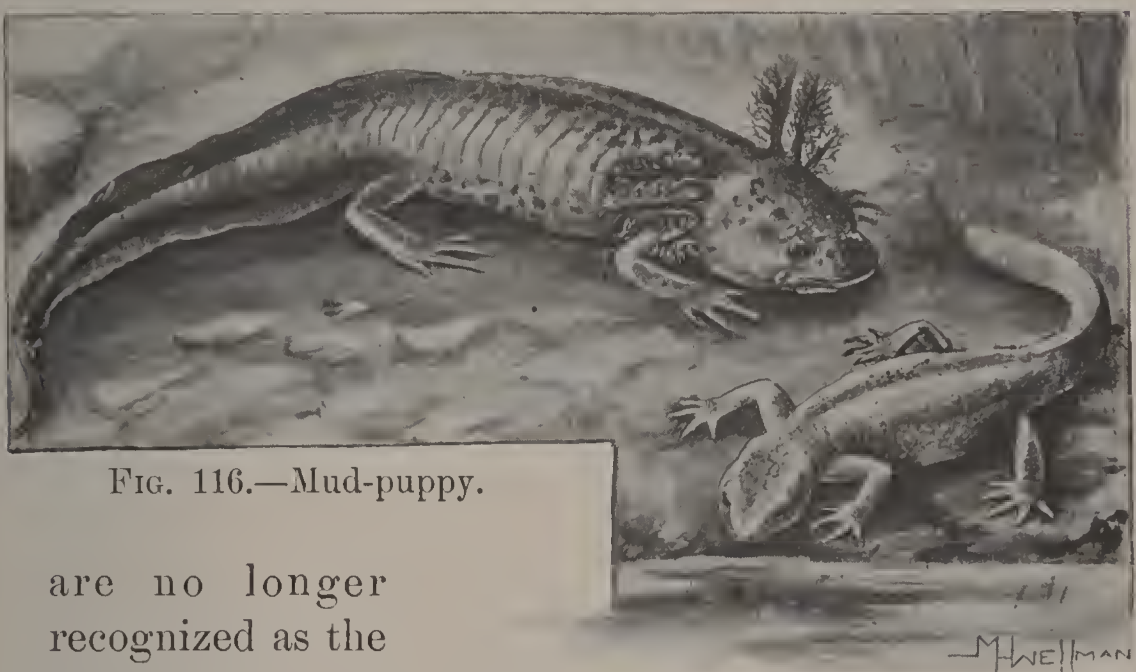

Fig. 116.—Mud-puppy.

are no longer recognized as the same species. For example, the European rabbit was taken to Porto Santo, one of the Madeira islands. It was able to maintain itself, but became so changed that it is now described as a new species.

Islands in an ocean cut off from all continental influences have given us both flora and fauna peculiar because of the still existing antiquated types. The insects of such isolated islands are particularly interesting.

The grasshoppers on the Cape Verde islands are said to be almost wingless, not being able to use their wings on account of the strong, continuous winds that blow upon the island. Mr. Wallace describes the peculiar insect life of some of the isolated tropical islands, which he so thoroughly explored. He mentions butterflies of striking color and habits, and other insects which seem to belong to former geological times. Each isolated island seems to have its own peculiar fauna.

Australia still contains both animal and plant life that belonged to former ages. Among these we may mention the tree-ferns, the "grass-tree"; and among animals, the kangaroo, the emu, and others. The dodo has become extinct in historic times.

The Galapagos islands lie about five hundred miles west of Ecuador. They are so far isolated from other countries that the land animals can have no communication with the animals of other regions. The sea-birds and the fish of these islands, being able to cross the intervening waters, are like those of the American coast. But while the land-birds, reptiles, insects, and animals closely resemble those of South America in color, habits, and tone of voice, yet they are so different in structure that scientists classify them as different species. These islands lie in a calm sea, have an equable climate, and abundance of food, so that the struggle for existence is reduced to a minimum. Its animal life, and plant life too, possesses less vigor, so that whenever they have been introduced into the new conditions of the continent they have not been able to maintain themselves against their better-schooled rivals.

Environment is slowly but constantly changing. As we have seen from the early chapter of this vol-

Fig. 117.—Animals of Galapagos islands.

ume, the geological ages differed greatly in environment. But these differences in general were brought about very gradually, and when they came about more or less suddenly, as was the case with the Glacial epoch, life did not have sufficient time to become adapted to the new conditions, and consequently, for the most part, perished.

We look about us and see no appreciable change. The forest appears the same year after year, the sea seems to roll upon the same shore, and the distant mountains cut an unchanging silhouette into the sky. Man's life is so brief that he can not see the motion of the centuries. In a flash of lightning all things seem stationary. "I believe the gardener is immortal," said the rose to the lily. "I have watched him ever since I opened, and he is just the same; and the tulip, who died yesterday, told me the same."

But the mountains have all come out of the sea, and the river valleys have been cut out, grain by grain, and the boundaries of the ocean are ever becoming narrower, as the mountains are carried down by the waters and deposited in their depths.

ACQUIRED CHARACTERISTICS.

Geology teaches us beyond a doubt that environment is ever changing. The change may be slight in a century, or even in a thousand years. But looking back over the eras of life, we can not doubt the fact of mutation. As we have seen, environment does change the characteristics of plants and animals, and, as we shall see in the chapter on Natural Selection, these characteristics reappear more or less intensified in at least some of the descendants. The question now arises, Do the descendants inherit acquired characteristics? This question is debated by scientists with much learning. Some claim they are, others insist that they are not inherited. If we suppose the latter to be the case, we naturally circumscribe the influences of environment and natural selection. Still, the tendency among scientists at the present time seems to be to deny that acquired characteristics can be transmitted by inheritance.

CHAPTER XXVII.

VARIATION BY USE AND DISUSE.

"In the sweat of thy face shalt thou eat bread." Nature owes no man a living: he must earn it.

> "God did anoint thee with his odorous oil,
> To wrestle, not to reign."

LOOK where we may, we see man at labor—in the field, in the factory, in the trench, and in the office. From morning till night, and from week to week, the merchant plans how to keep abreast of his competitors. The masses of our great cities repeat their tasks with every rolling sun, and they who have no tasks struggle to find one. Struggle brings exercise of body and mind, and with it come health and strength and thrift.

> "Labor is life! 'tis the still water faileth;
> Idleness ever despaireth, bewaileth;
> Keep the watch wound, or the dark rust assaileth."

At first it may not appear to us that plants and animals, like men, must struggle for a living. A little observation will soon convince us that this is a fact. Professor Bailey gives the results of his study of a cherry-tree which came up near his door. The first year it grew 19 inches and bore 27 buds, and a branch

8 inches long with 12 buds. In all it had 39 buds in the race for life. Each bud put forth its entire strength to get its share of food and light in order to fulfill its destiny and become a branch the next year. All but 19 of the buds failed to do that, and so they perished. The successful ones became branches, and put forth 370 buds. Only 8 of these succeeded in becoming branches the third year. Thus the struggle went on, and at the end of the fourth year the tree stood 8 feet high; but instead of having over 3,000 branches, as would have been the case if all the buds could have won, it had only 297, and these were mostly weak spurs 3 to 4 inches long, not more than a score of which could long persist. This is no exaggerated illustration of the battle that is taking place in every tree-top. Every bud is really a complete individual organism, as much so as the seed is. It will grow by itself and reproduce its kind, as the seed does. May we not look upon the tree, then, as a colony of plants? Every bud in the colony must struggle for food, light, and room, just as men in our large cities must struggle for a place in life.

It has been ascertained that in the forests of Denmark the beech-tree is crowding out all other trees. The birch can not long live in the shade of the beech; hence the young trees die, and the older ones carry their crowns high up into the sunlight, but in the end they, too, succumb.

The tree fossils of Denmark show that the region was once covered with aspens, then with the fir, the birch, the oak in succession, and lastly with the beech.

The oak is a slow and hardy grower, but in time the beech destroys it even on its most favorable soil.

In New Zealand a watercress grows so abundantly that the streams were kept open only at great expense. Recently willow-trees were planted on the banks; these have proved a successful competitor of the lusty cress, for they draw away its sustenance.

In the wild uncultivated parts the forest trees are steadily encroaching on the weaker plants of the prairies. Our native weeds have little show in the struggle with their more thrifty cousins introduced from Europe, and our useful cereals, if unaided by man, stand no show against either.

"Mr. Darwin," says Wallace, "observed on some extensive heaths of hundreds of acres, near Farnham, in Surrey, a few clumps of old Scotch firs, but no young trees. Some portions of the heath had, however, been enclosed a few years before, and these enclosures were crowded with young fir-trees, growing too close together for all to live; they were not sown or planted, nothing having been done to the ground beyond enclosing it so as to keep out cattle. On ascertaining this, Mr. Darwin was so much surprised that he searched among the heather in the unenclosed parts, and there he found multitudes of little trees and seedlings which had been perpetually browsed down by the cattle. In one square yard, at a point about a hundred yards from one of the old clumps of firs, he counted thirty-two little trees, and one of them had twenty-six rings of growth, showing that it had for many years tried to raise its head above the stems of the heather and had failed. Yet this heath was very extensive and very barren, and, as Mr. Darwin remarks, no one would ever have imagined that cattle would have so closely and so effectually searched it for food."

At two different times I have observed similar effects from the enclosure of prairie land. As soon as the cattle were kept out the grass grew taller, and seemed to be thicker, and many flowers never before seen on that prairie appeared and flourished. The birds also became more numerous.

Another interesting fact in connection with Mr. Darwin's investigations concerns several hundred acres of fir-trees on the virgin heath in Staffordshire. By the time the fir plantation was twenty-five years old significant changes had taken place. There were many more flowers on the plantation than on the open heath, among them twelve new species. The fact that six new species of insect-eating birds appeared in the forest shows an increased number of insects. These were some of the more easily observed changes, but there were many others. If such have been the modifications of life in so small a district and in so short a time, what may they not be in a geological age, and when a whole continent is affected?

Mr. Clark shows that the Pampas are destitute of forests, not because trees are unadapted to the climate, as Darwin believed, but because they are destroyed by animal life. The dry season in that region is so severe that thousands of cattle perish for want of food and water. They eat every green thing in sight, and the numerous rodents which infest the region dig the very roots out of the ground. Thus the young tree shoots come up during the wet season, but in the succeeding dry months they perish in the struggle with drought and animal life.

Animals furnish equally striking examples. Some years ago, in California, the cottony cushion-scale, brought in from Australia, became so numerous that it threatened to destroy the entire orange-crop of the State in a few years. An entomologist discovered that in Australia this insect had a natural enemy in a ladybird beetle. Some of these beetles were brought to California, and as they increased the insect rapidly diminished. When the natural food of the beetles was exhausted they almost died out. Now, in order to preserve the balance between beetles and insects in California, man steps in and assists the scale in the struggle by protecting some colonies from destruction. It is quite probable that the beetle in its native home had other food than the insect.

It has been computed that if no English sparrow perished except by a natural death, that species of bird would increase so rapidly that in twenty years, in the State of Indiana, there would be one sparrow to every square inch. Even a slow-breeding animal would, if allowed to live its natural life, in time cover the whole earth. But where one survives, a thousand perish in the struggle for existence. Mr. Thompson-Seton truthfully says that wild animals always come to a tragic end.

The struggle for existence is naturally more intense between individuals of the same species—as sparrow against sparrow, wolf against wolf, beetle against beetle. They require the same food, and

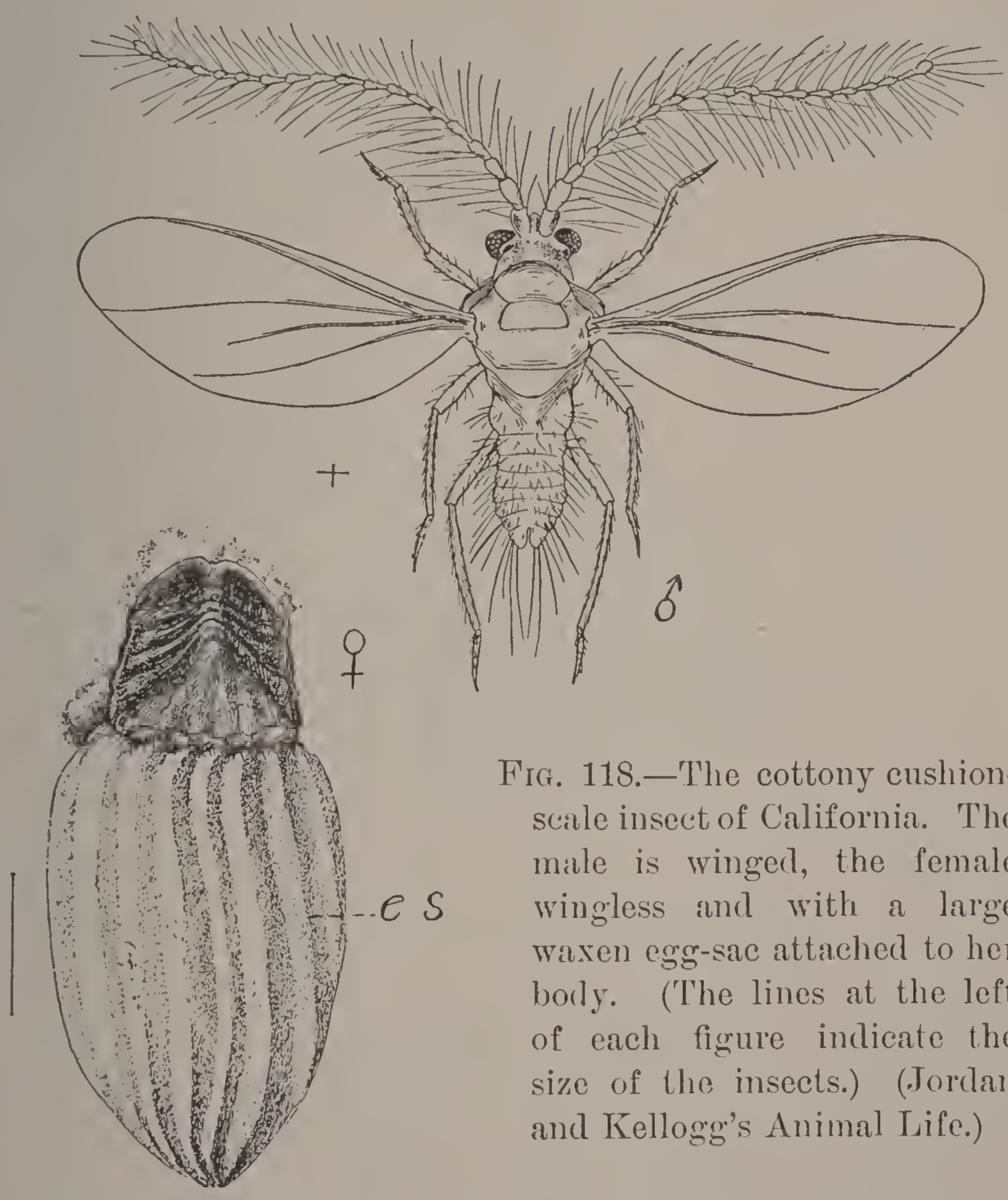

Fig. 118.—The cottony cushion-scale insect of California. The male is winged, the female wingless and with a large waxen egg-sac attached to her body. (The lines at the left of each figure indicate the size of the insects.) (Jordan and Kellogg's Animal Life.)

when the species is greatly increased, the food supply is insufficient, and the weaker ones are forced to the wall. Then there is a struggle between related species —as sparrow against robin, beech against birch. Species which live upon entirely different food do not come into competition, unless it be in a very indirect way. The butterfly has no fight with the rabbit for food, and yet the latter may greatly diminish the plants whose nectared blossoms feed the former. Thirdly, there is the struggle of all species against climate. Severe cold, chilly rains, and sudden extreme changes are very trying to animal and plant

Fig. 119.—Armadillo. Has covering of bony plates, in which he can roll himself for protection.

life. It is evident that those having even a little advantage in these struggles are likely to become the parents of future generations. This process Herbert Spencer calls the "survival of the fittest"—that is, not the fittest in the sense of being the best, but in the sense of possessing the characteristics that win in the struggle. The raw-boned long-horned Texas steer would survive where the well-formed, comely thoroughbred would perish.

Those individuals of a species which have distinct points of advantage are most likely to survive; among runners the swiftest, among fighters the stoutest, and so on. Hence Professor Bailey applies the expression, "survival of the unlike."

De Varigny gives an account of some experiments made upon common pond snails. Three young snails of the same brood were put into different vessels, containing five hundred, one hundred, and three hundred cubic centimeters of water respectively. Each snail was supplied with plenty of food. It was soon discovered that they were developing unequally; the one in the largest vessel surpassed the others in size, and the one in the middle-sized vessel was larger than the one in the smallest. The conclusion was that the amount of water had something to do with the growth of the snail.

De Varigny doubted this conclusion, and began to experiment for himself. He put equal quantities of water into two vessels, one broad and shallow and the other spherical. The snails in the shallow vessel grew larger than those in the spherical one. He then put unequal quantities of water into two broad, shallow vessels, so that each had about the same water surface. The snails placed in them appeared to develop at nearly the same rate. De Varigny observed that in the shallow vessels the snails spent much of the time swimming about at the surface of the water. He therefore concluded that the growth of the snail was due largely to the amount of exercise it took, and not to the volume of water in which it lived.

The struggle for maintenance brings into play certain organs of the animal more than others, and of course produces modifications of them. The blacksmith's arm is a familiar illustration of this fact.

Not only the enlargement of organs but even their origin has been accounted for on the principle of use. For instance, it is supposed that the antlers of the deer originated in the struggle for male supremacy. Bumping heads together first hardened the skin and developed protuberances; later came the antler with its tines.

Professor Dawkins has carefully examined the fossils of deer, and he finds that the earliest form which existed in the Middle Miocene had only clublike protuberances on the crown. The Upper Miocene deer showed enlargement of these protuberances. In the next age we find deer with antlers of the "Axis and Rusa" types, having three tines; and specimens of the Pleistocene period possess the complete modern antler.

This seems to corroborate the "use and disuse" theory of development. But how has it come about that deer lose their antlers every spring? Why is it that the horns of the moose are so broad and clumsy?

The theory of use and disuse was first stated by M. Lamarck. He was a Frenchman and the colleague of Cuvier, the great French scholar who laid the foundations of paleontology. Lamarck was the first to set forth a definite theory of the origin of species. He believed that when a new want arose the animal exerted itself to supply that want, and that this exertion in time produced a new organ or modified one. For instance, the giraffe, living upon the foliage of trees, developed its long neck and front legs by continually reaching for its food. The American bison, when the white man first came to this country, was a short-legged, thick-bodied animal. But when he was hunted persistently on horseback by both Indians and whites, he developed longer legs and a more slender body, thus becoming much more capable of escaping by flight.

Likewise, organs which were in the way or useless disappeared. The snake is supposed to have had limbs like the lizard, but living as it does in the underbrush and constantly forcing its way through between stems and roots, it found these limbs in the way, and by disuse gradually lost them, while the body grew to a disproportionate length.

The wild duck has not only thicker muscles on the breast-bone than the tame duck, but also a proportionately larger brain. It needs to be more on the alert for danger and so exercises its brain more. The domestic duck is less on the wing and uses its feet more; hence it has weaker wings and longer, stronger legs than the wild one.

The flying fish, as mentioned in Book IV, has the pectoral fins much enlarged by exercise. The mole and the fishes in Mammoth Cave have lost their eyes by disuse.

The kangaroo has long, strong hind legs and short, weak front limbs, for he uses the former constantly and the latter but seldom. The legs of the ostrich are well developed, but its wings, which are used for balancing only, have lost their power to carry the bird. It depends for safety no longer on flight, but seeks to escape by running away.

According to the Lamarckian theory the skin, the senses, and the brain itself are the result of activity

FIG. 120.—A kangaroo leaping.

induced by surrounding conditions. Some things act so as to be a benefit to an animal, others so as to be harmful. The former are courted and the latter are to be avoided. As soon as the lowest type of living matter begins to move, it needs means by which to become conscious of its surroundings so as to distinguish the harmful from the beneficial. Hence the need of touch. This sense the little ameba seems to possess, for it flows away from the pricking pin.

But to recognize the hurtful things only when they touch us would afford late protection. The faster we move the farther away we must detect the obstacles in our path in order to avoid them. If we could not do this we should run against objects, as we do in the dark.

It is therefore clear that we need sight. This may have been developed by our surroundings themselves. At first there may have come a little more

FIG. 121.—An ostrich running.

sensitiveness in one part of the body than in the others. This spot may have been put forward to feel the way, and thus grew more sensitive, until in time it changed its structure. These changes inherited and further intensified, finally resulted in a special organ, a primitive eye, which became ever more perfect, so that it recognized not only form in general but color, detecting the slightest differences in lights and shadows, until we have the artist's eye.

In like manner, hearing, smell, and taste were developed, according to the theory of Lamarck.

Our environment includes all things that influence or touch us. Of these the air is doubtless the most important. The fish must have water with air in it. It is evident that the first life was aquatic and breathed by gills; some of these creatures were driven out of the water either by their enemies or by the desire for food on the shore. A few had power to remain out of their native element a little longer than their fellows. This was an advantage to them. Practise augmented this power, and in the course of generations it accumulated so that something pointing toward lungs was evolved.

Lamarck further taught that the characteristics acquired by any individual were inherited by the offspring, and the slight gain that any individual might have made was further augmented by its descendants. In this manner Lamarck thought that the changes produced in the course of time become sufficiently great to make the animal a new species. Although this idea has been ridiculed, there is a growing inclination among American scholars to adopt it in a modified form as a part of the theory of natural selection.

CHAPTER XXVIII.

NATURAL SELECTION.

The principle of selection has long been applied by agriculturists for the purpose of improving their stock and their crops.

One of our neighbors, who thought that the small potatoes would do as well for seed as the large ones, sold the best and used for seed those too small to sell. It required only four years, however, to prove his mistake to his entire satisfaction. His potatoes had "run out," as he expressed it. Most of his crop were small, while his neighbors had fine tubers.

All the numerous varieties of potatoes have been produced from a single variety by selecting for seed those tubers which had the desirable qualities to the greatest extent. Food and environment aided in intensifying the variation.

It is quite probable that the varieties of corn—not only the field-corn, but pop-corn and sweet corn—came from a single kind. The same is true of most of the crops that man raises.

The tomato is perhaps the most remarkable of our garden vegetables. This berry, now so common, has had only one century of cultivation. In its original wild state the tomato was a small two-celled berry, so unlike its present form that should any one find it to-day it would scarcely remind him of a tomato.

Nature, assisted by soil, climate, cultivation, and selection, has produced the wonderful modern tomato. There are hundreds of varieties, differing not only in color and size, but very much in form, both externally and internally. The plant itself has been transformed into a great number of varieties, different in the character of the stem, the manner of branching, and in the form of the leaves and leaflets. Some of the varieties are so unlike others that if they were found in nature no one would hesitate to call them different species. These varieties, if we may not be permitted to call them species, are the result of careful selection by the gardener.

In their original wild state the roots of beets, radishes, and carrots were colorless, but by cultivation and selection man has produced the various colors now so highly prized in the market. Suppose we take the seed of a wild beet and plant it in good soil. This would result in some variation at least; a number of the roots would have a suggestion of red in spots. By using the seed of these for planting some of the roots would contain still more color. Let this process be repeated for a sufficient number of generations and a beet of definite color could be produced. If the selection be continued, a light-red or a blood-red variety would be the result. It would, however, happen that in some, if not all, of the plantings there would be roots with little color. In other words, there is a constant tendency to revert to the wild state. This is true of many vegetables and other plants, too.

Garden sweet peas have been made to bloom in great variety of color, but the seed hardly ever comes true. Perhaps the process has not been long enough continued. The pansies, which have yielded so much beauty and grown to so great a size, develop seed that is much more reliable. The fact that seeds revert shows the force of heredity and the truth that it persists through many generations.

At every fat-stock show we find examples of thorough breeding. The great variety in any one kind of stock is not only marvelous, but very suggestive. The horses are familiar examples. In one stall is exhibited the dwarf-like Shetland pony, so small that we could almost carry it off on our shoulders; in another stands the fleet race-horse with well-trimmed limbs and slender body; in another is the stately coach-horse; in another the strong-limbed, broad-footed Clydesdale; in still another the immense Norman, which crowds the scale far toward the ton mark. All these and many others are descended, without doubt, from the ancient primitive horse which, as we have already seen, was itself a descendant, through a series of evolutions, of the five-toed horse of the Miocene period.

Similar descent could be traced in cattle, sheep, hogs, and fowls, but space will permit but one more illustration, and that is pigeons. There are the slender, timid mourning-dove; the passenger, with broad wings and long pointed tail; the clever carrier, the beautiful fantail, the hooded jacobin; the pouter, with its ridiculously inflated crop; the tumbler, which has the peculiar habit of turning somersaults in the air as it flies, and so on. It seems that almost every part of the pigeon has been seized upon for special development, and that, too, with success.

All of these variations are the product of selection from the original blue rock-pigeon. Now and then reversions occur which prove this. It is well known that crossing has a tendency to produce reversion. Mr. Darwin succeeded in breeding pigeons back to the original stock, and that by a very short route. He paired a barb fantail with a barb spot, neither of which had any blue color on them, and produced a pigeon resembling in every way the original blue rock.

Thus far I have mentioned variations produced by man's agency in selection. This is sometimes called artificial selection. You will ask, "Does Nature also carry on this process?"

A little observation along this line would soon convince the most skeptical that Nature does. Mr. Darwin collected much material bearing on the subject, and so did Mr. Wallace. The former used the term Natural Selection. Now, how can Nature make selections?

Take the nettle, for instance. It has stinging bristles, evidently for its protection. It has been stated that all living forms are subject to a struggle, and that not all come off victorious. Once the nettle did not have the bristles. Now, suppose that ages ago one of the plants had some roughness in its stem which proved helpful in keeping off injurious insects. Such individuals would stand a better chance of developing their seed than the others. Some of the plants from that seed would develop individuals which possessed the means of protection to a still greater extent than the parent stem. Thus in time the poisonous bristles may have come into being.

The common strawberry may serve as an illustration of the same thing. This plant, it seems evident, once had dry, hard seeds like the buttercup. The plant which distributes its seeds most widely is the best equipped for the struggle. We have noticed how ripe red cherries attract robins. So the strawberry plants, whose red berries are most attractive to the birds, have the best chance of getting their seeds distributed. If one of them had a spot of color, it would have had the advantage; then if a juicy pulp were added, it was still better. Those plants would stand the best chance of being propagated, and in the course of ages our sweet wild berry was the result.

This all sounds very plausible; but, as Mr. Allen has remarked, the little potentilla seems to be still in its pristine condition. Why did it, too, not wake up to its privileges and produce the red berry? Indeed, it does not appear to need the coveted berry, as it has survived without it. Such questions are very awkward, to say the least. We can only plead that we probably do not know all the facts about it. Perhaps it is a much younger plant, and has not had the time required to perfect such fruit. This is clear: there are many facts which we do not know which would lead us to reason as we did about the strawberry and

Fig. 122.—Wild strawberry.

the nettle. Compared with the era of plant life on the earth, a man's time of observation is as a grain of sand upon the seashore.

There are some curious forms and devices which seem to have come about through artificial selection. The sage furnishes an interesting device for the dispersion of its pollen. The flower has two lips; the upper one is nearly straight, but the lower one forms a platform for the bee to rest on as she enters the flower for nectar. In young blossoms the single pistil is erect and under the upper lip. The stamens develop the pollen and then shrivel up. Then the pistil drops so that its double stigma just touches the back of the bee as she enters the corolla, and thus the pistil gets some of the pollen taken from a younger flower. The stamen is still more peculiar. The two developed anthers are supported on two pillars and stand erect. When the bee enters the flower, it pushes on the lower or rudimentary anthers, so that the upper ones drop down on her back and deposit their ripe pollen. This the bee carries to the next blossom, which takes it off as before described. Now, it is plain that the plants that have such a contrivance most perfectly developed secure the best fertilization for the species. Each flower works unselfishly for the good of its race.

Jack-in-the-pulpit is within the reach of every one. Upon studying it you will notice that it has a central pillar and is surrounded by a protective sheath. Near the bottom of the pillar are a number of stigmas; a little above are the anthers, and above these is a circle of hairs. Here the pistils mature first, while the pollen is unripe, and so the flower can not become self-fertilized. The only way this flower can become fertilized is by insects. Small flies enter it either for protection or for nectar. The hairs imprison them, and in their struggle they are thoroughly dusted with ripe pollen. Now the hairs wither and allow the flies to get out and enter a younger blossom. There they rub off the pollen on the stigma.

The Jack-in-the-pulpit is another illustration of how individuals contrive for the good of the race.

Fig. 123.—Jack-in-the-pulpit, leaf with blossom, and the fruit.

The unselfish acts of all plants as well as of men become a great blessing to the species.

These contrivances for producing vigorous seeds are found only among the flowers that depend on insects for the dispersion of their pollen. Those fertilized by the wind present few peculiarities.

COLOR ADAPTATIONS.

Color also is developed as a means of attracting insects. Flowers which need the visits of insects have the brightest blossoms. The blue gentian of the valley becomes white high up on the mountain-side. The flowers in the arctic regions, and on mountains where there are but few insects, are of brilliant colors. Those fertilized by moths flying about after dark are mostly white, as that color is best seen in the dark.

This fact is still more significant in animals. In the arctic belt the gray hare of our forests is as white as the snow. Are there two species, or has one become white by adaptation? The latter is probably the case. The gray hare in our own climate is more or less white on the under parts, and there is much variation as to the amount of white in different individuals.

In the winter, when the fox and other carnivorous animals find food scarce, it is of advantage to the hare to hide from its enemies. This it can easily do, if its color is white like the snow, which covers all things. Now, those individuals having the most white are the more likely to survive, and thus would

Fig. 124.—The whippoorwill, which is colored so as to harmonize with its usual surroundings when at rest.

become breeders. In some of the young the color so advantageous would be intensified, and these in turn would become progenitors. Thus, in the course of time, little by little, the white hare would be developed. Many other animals of the cold areas are much lighter in the winter season than in the summer. This, too, seems to be due to natural selection, and to be brought about in the same manner.

The power to imitate surroundings in the color of coverings appears to be for the purpose of protection, and it is very common, especially among insects and birds. The lion can easily hide in the long yellow grasses of his habitat; the tiger finds concealment in the checkered shade of the jungle; the lark and grouse sit safely on their nests in the dry grass; the tree-frog is hard to distinguish from the bark on which he sits; and beetles and bugs sink so completely in foliage and flower that motion only betrays their position.

This is an advantage in the struggle for life: those having the most perfect imitation find the best protection, and hence are fittest to survive. Thus they are selected to become parents of offspring, some of which are sure to intensify the protective quality.

In some creatures the color is a warning to enemies, as, for instance, the Heliconidæ family of butterflies, which is more fully described in Book IV. In others color is for the purpose of recognition. A good example is the cottontail rabbit. The young can easily follow Molly's white flag to a safe retreat.

The rear marks of the antelope may suggest the same explanation. Color for recognition is only

FIG. 125.—The upper butterfly is poisonous to birds, who do not molest it. The second one is not poisonous, but imitates in form and color the first, and thereby escapes seizure by birds.

found in animals of a timid nature who depend upon flight for safety.

A very interesting case of color adaptation for the advantage of the individual is that of the small lizard found in the desert parts of Central Asia. The lizard is sand-colored and has at each angle of the mouth a fold of red skin; when the mouth is open it bears a remarkable resemblance to a small desert flower, and is thus the means of attracting insects to their doom. Might not, perhaps, the beautifully colored patches about the neck and throat of some birds have a similar purpose?

It must be admitted that there are many instances of color for which no explanation suggests itself. Probably color has no significance in such cases. One color would serve as well as another, and so the color which may once have been useful has been retained by the species. Adaptation only takes place in qualities that are useful to the race.

Examples of natural selection in which the facts are apparent are quite as numerous as those of artificial selection. Mr. Darwin and Mr. Wallace, independently of each other, collected a multitude of facts with care and persistence that border on the marvelous. To-day these facts stand unchallenged, and have been used as a basis for various conclusions for which neither of these scientists would feel himself responsible. Every one may observe some of these facts for himself. When he does he will be unable to deny that food, exercise, and climate have a determining influence on both animal and plant forms and habits.

Only a few examples of variation are given under each of these heads, just enough to illustrate the idea. If space had permitted, a large number could have been cited, but the interested reader can find them readily accessible in more pretentious works.

Heredity is the unchangeable force which holds on to ancestral traits; environment is a variable influence which antagonizes heredity and in time conquers it. "It is easier to weigh an invisible planet than to measure the force of heredity in a grain of corn," says President Jordan, for the laws of planetary motion are known and have been reduced to mathematics. Frequently, as already stated, the victory seems complete, when suddenly the offspring reverts to some ancestral trait, showing that the heredity germ was not destroyed but lying latent, only waiting a weak link in the chain of environment to reassert itself.

These two forces must be reckoned with in the human family. Man has the ability to select his environment—intensify one line, and weaken or entirely remove the objectionable. Thus it may be said that with him environment is the most significant factor. Society, education, religion may become levers to lift him, to a very great extent, above his undesirable inheritances.

On this subject Mr. D. Kerfoot Shute says: "Every man is born into the world with a certain physical constitution, and therefore with a given temperament—with certain passions, with a power of judgment, with a certain strength of will. If the power of his will be not equal to the strength of his passions, the latter will surely predominate and will display him as the slave of heredity. If he has such an organization of his nervous system that his volition is superior to his passions, he will be none the less the servant of heredity, though a being now possessed of the power of free will. Happily, the average man with his present constitution has his perverse heritages so proportioned that we may repeat that his life and character (in customs, morals, and religion) are vastly more influenced by environment than by heredity."

CHAPTER XXIX.

BIOLOGICAL EVOLUTION.

From the foregoing chapters it will appear that there are two lines of forces in action upon every individual. One is the unchangeable force which holds on to ancestral traits; the other is a variable influence which is constantly operating to modify them. The one reproduces in the offspring the same forms of bone, the same fiber of muscle, the same digestive, circulatory, assimilative, and nervous systems, and the same tenor of brain and disposition, as belonged to the parent; the other slowly, but none the less certainly, affects each of these so as to cause significant variations. The one is the force of heredity; the other includes, as has been stated, changes in climate, soil, and food — indeed, everything that touches life from without. All of these may be embraced under the term environment, used in a somewhat technical sense. Heredity can not originate life; environment can not act upon life until it exists.

The word evolution signifies the act of unfolding. It presupposes something to unfold, and that something is life.

WHAT IT IS NOT.

There seems to be a prejudice in the minds of many people against the idea of evolution, as if it ruled God out of creation. Evolution in biology is not a system of speculations; it is the history of the unfolding of plant and animal life as observed by man. We can not think it possible that the facts of nature would rule out the Creator, but rather testify to his presence and power.

Evolution does not begin with inert matter and speculate how it may become life of its own accord. Indeed, it has nothing to do with the origin of life. It must be admitted that the word evolution is sometimes applied to a system of cosmogony which seeks to explain the origin of all things. Such explanations are mere speculations; they can not be called science. That life originated spontaneously is not a part of true evolution, and it is a fact that evolutionists have rejected that thought, for if life once originated of its own accord, it would again so originate. Of this no proof has ever been found.

WHAT IT IS.

Evolution begins with the germ, the cell life, and traces the development in its variations from generation to generation, from species to species. Under proper conditions the acorn begins to grow, sending out a little radicle and a tiny upward shoot. These extend and add branches, and continue for centuries until the majestic oak has come to the limit of its possibilities. The egg begins with the life germ, and adds to itself nourishment and a protective shell. The proper degree of warmth continues the evolution through the hatching process; and afterward, with the support of food and environment along the line of its own predetermined sphere, it reaches the form of a Plymouth Rock.

These are illustrations of individual evolution, or better, development. Evolution makes use of the facts that geology furnishes; those collected by the science of biology; those brought together by natural history; those supplied by embryology, physiology, anatomy—of all these it takes cognizance, brings them into relation, considers their meaning. It makes use of the facts that every one may observe, but it must add to them those observed by others in all ages, so far as they can be collected.

By means of these facts evolution has formulated laws. These laws apply to animals and plants alike; they apply to man in his physical, moral, and intellectual development; they apply to society and institutions. They are the most far-reaching laws known, and hence of very great interest to man. They teach him the unity of life; they broaden his views; make him humble; they ennoble his thought of the Creator, who holds the reins of life in his omnipotent but beneficent grasp.

CHAPTER XXX.

THE PROGRESSION OF LIFE.

The story of life, from its early dawn to the present day, is full of interest, if not surprises. Its beginning is humble, its structures the simplest, the numbers of individuals countless. The lowest and earliest geological forms are those of the rhizopods, whose remains are the chief constituents of miles of rock.

What are life's secrets before the rhizopods? (see Fig. 111.) How science would like to discover them! But it has no key to unlock the door of her abiding. As with one bound, life leaps into myriad forms of existence. Whence? She tells us not.

The jelly-like speck of matter called ameba is the lowest animal life man has been able to discover. But this is matter already highly organized. There is a wide chasm between such a speck and a crystal, which seems to be the next highest form of matter. The particles of the crystal have assumed definite shape in accordance with some determining law. But it can not move, only as it is made to do so by light or heat. The ameba, however, already possesses the power of locomotion, of respiration, of digestion and assimilation, and of reproduction, by light or heat, or some other external force.

Apparently at the same time with the rhizopods there came into being the types of invertebrate life, and they seem to have been perfectly adapted to their environment. Had they ancestors which constituted the connecting link between themselves and the unicellular rhizopods? If so, where were they? Did their bodies leave no molds in the mud to be infiltrated, no substance to become petrified? If so, why have they not been found? Did they chance to live only in those parts of strata that have not yet been unearthed? It may be, but it seems unlikely.

The abundant forms of life continued for millions of years, with very slight variations here and there. Suddenly there appears a fish, a new type and perfect in all its parts; a higher type, having a spinal cord extending from the brain in a bony channel along the back. Where are the intergrading forms? Again we inquire in vain. The few examples of a notochord afford us little satisfaction in our search.

Trees, as well adapted to their age as are the palms to the tropics, covered the low-lying areas; the seas begin to swarm with aquatic forms of immense size and great strength. Simultaneously with these there came in those that could live on the land as well as in the water. These were obviously higher in point of being and possessed wider adaptations.

Life was progressing; but it did not halt there. No sooner had some creatures become at home on the land than we observe a few taking to themselves wings; crude ones to be sure, but still a great advance upon the webbed foot. Then we find the primitive feather, wonderful in its adaptation to the air. The butterfly, gracefully floating upon the breeze, begins with the earliest flowers. Trees of exogenous growth suddenly spread over the land, and terrestrial animals in varied force follow each other upon the scene. Finally, man stands there in full stature.

EVOLUTION BY EXPLOSION.

As we have seen, life leaps into existence as it were with a bound. Many species and myriads of individuals seemed to originate in a comparatively short interval of time. Frequently thereafter, a new crop of species left forms in the preserving strata. Between these periods were long intervals of rest.

These rest intervals have caused much trouble to theorists. Environment is ever present and ever active, and ought to have a constant influence upon the life forms. There should be a steady progression of life, a more or less regularity in the variations. How shall the rest periods and the quickening intervals be explained?

Dr. Stanfuss has long experimented with butterflies, in order to discover the law of heredity. The results are considered important. He observed that sometimes an unusual richness in new varieties appeared, and has applied the expression "Transformation by Explosion" to such an outburst. It was this, probably, that led M. de Vriès to apply "Evolution by Explosion" to the periods in the life history of the globe that are especially rich in new species. It seems to these scientists that an old species explodes, as it were, some of the fragments disappearing and others becoming new species. They think that this would account for the sudden appearance of others, also for the interval of rest. It is assumed that groups of varieties, like individuals, have a time of birth, a period for maturing, followed by decline and death. These suggestions are attracting some attention, but to what extent they can be made helpful remains to be proved.

REVEALS AN INTELLIGENT PLAN.

As far as we can see, life began with the unicellular form of being, the lowest that man has been able to discover. Environment and selection have done much to change its forms; still, there are many facts about life unexplained. From time to time new features appear as suddenly as the beginning of life, and each seems to be a step in the direction of a higher goal, as if the whole were planned and directed by a supreme intelligence.

The evolution of man's inventions affords at least a suggestive parallel to the evolution of life. Take, for instance, our modern self-binder. The beginning was made when man used the sharp-edged stone for cutting. This led to the polished edge, then to a bronze knife, and finally the sickle and cradle. Here there was a long halt. Then suddenly the reaper loomed up, making use of all that had preceded it.

The crank took the place of the arm in giving the sickle motion, and the iron guards of the fingers that held the grain against the cutting-blades. Then the platform was added to collect the falling spears; next the self-rake, and lastly the self-binder or thresher.

The evolution of the means of transportation probably began with the dragging brush and the primitive "stone-boat." A great forward step was taken when the rolling wheel was invented. Thus the story went on until we had our modern limited express. Each stage of progress was suited to the environment of its time. There was a constant evolution from the simpler and lower to the higher and more complex. At every step man's intelligent handiwork is evident.

All through its history we find life marching on to a higher goal, becoming more and more specialized, while all the lower types continue. Each successive advance seems to be the outgrowth of that which went before, with the addition of something entirely new. Man embodies the greatest advance. He is a new order of being, with an entirely new and distinctive endowment.

Life has come down the ages in great leaps and bounds; at every bound she leaps over a mystery; at every leap she gathers up something new and strange. Every new feature appears as suddenly as the chick from the shell. Has environment worked it all out? It can work only by infinitesimally small changes. That would require thousands of intermediate forms between man and his ancestral animal.

Looking backward, we can see that all the animal creation was a prophecy of man; and, considering man's inspirations and endowments, we can not but feel that he himself is the prophecy of a higher life.

We can not get away from the idea that a power and intelligence has been constantly attending the evolution of life, and we feel that the old story still stands. If it is not true, science has no other solution.

"In the beginning God created the heaven and the earth." He it was who spoke light and life into existence, and created man in his own image.

"Let the earth bring forth grass, the herb yielding seed, and the fruit tree yielding fruit after his kind, whose seed is in itself, upon the earth."

"Let the earth bring forth the living creature after his kind, cattle, and creeping thing, and beast of the earth after his kind."

"So God created man in his own image, in the image of God created he him; male and female created he them."

CHAPTER XXXI.

THE BEGINNINGS.

Can knowledge earth's deep mysteries unfold,
And from events discern the primal law
When earth began? Can chemistry resolve
The elements to chaos, and restore
Again the substance with its living germs?
Where science lays the mystic question down,
Religion takes it up and holds our faith
In bondage to the things we can not prove.
When faith is strongest, reason holds her peace;
When faith is weak, then reason reigns alone,
Demands the evidence for knowledge claimed,
But hears not, cares not, what we may believe.

The most uncertain things we know are facts;
Old creeds, like moonbeams, shine with borrowed light,
But shine the brightest where the world is dark.
So circumscribed and earth-bound are the facts
Of sense, compared with faith in things beyond,
We grasp with childlike minds the miracles
Of life, greatest of which is life itself.

Sage parables exemplify the law,
And fiction sends a ray of friendly light,
To lead the restless soul's imaginings
Where finite joins the infinite in truth.

Who says the laws of nature came by chance,
Without an author and without design,
When all of human wisdom can not make
A worm, nor vest the simplest form with life?
Who says the mystery of life is solved
By autogenesis?

. . . .

Man, like all animated things, began
A pregnant atom made of dust, and doomed
To suffer and to die; but in that dust
A spirit dwells no other creature knows,
Sole image of a life-creating Power
Which conquers death, and rebegotten man
By death is born again to endless life.

. . . .

Each age improves the last
And strikes still higher planes upon the scale
Of human thought. All grosser forms cast off,
Man rises to conditions new and strange;
He finds himself endowed with attributes
Inspired by wisdom, and a longing soul
To know the source of that all-loving Power
Which gave the fruitful earth for man's domain,
Enriched her mountain chains with veins of gold,
And sprinkled deserts wild with precious gems.

Long ages ere primeval man was born,
Unnumbered species in the lower forms
Of animated life, had each its own
Beginning, ran its course and disappeared;
Yet nothing e'er began, without some cause

To give it motion. Self-existing Force
Without beginning, having power to make
From nothing something which can change its form
But can not be destroyed, is far beyond
The reach of finite minds to comprehend.

We read the perfect universal law
Which rounds the dewdrop, rules the distant stars,
And guides the earth unerringly through space,
Therein to find an attribute of God,
Appealing to our senses by the truth
That He who made the law, reveals Himself
Thereby to all mankind who read it well.
The never-broken link between First Cause
And the beginning of existing things,
Is constant as to all effects produced,
But silent when we look beyond
Or seek to know more than the law reveals.

. . . .

James Goodwin Batterson.

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NOTE.—The letters I, II, III, IV refer to the other volumes of the series. Figures not accompanied by roman numeral designate pages of this volume.

(1)

THE END.

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