APPLETONS'
AMERICAN STANDARD GEOGRAPHIES
BASED ON THE PRINCIPLES OF THE SCIENCE OF EDUCATION

PHYSICAL GEOGRAPHY

PREPARED ON A NEW AND ORIGINAL PLAN

BY

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ILLUSTRATED WITH ENGRAVINGS, DIAGRAMS, AND MAPS IN COLOR—AND INCLUDING A SEPARATE CHAPTER ON THE GEOLOGICAL HISTORY AND THE PHYSICAL FEATURES OF THE UNITED STATES

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PREFACE.

As Physical Geography is a singularly comprehensive science, involving applications from a great variety of cognate sciences, it is presumable that no one author possesses the depth or variety of knowledge essential to the preparation of a successful text-book on the subject, especially in view of the important advances recently made in many diverse fields of inquiry through the researches of specialists. In this belief, and with the desire of presenting to the public a work thoroughly abreast of the times, the editor has enlisted the co-operation of a number of writers, recognized as authorities in their respective departments of science, and to each of these he has assigned a portion of the subject, governing his selection by the special qualifications of the author. The standing and reputation of the several contributors must secure for this work a value and importance possessed by few other school-texts.

The section on the general structure and geological history of the earth has been prepared by Dr. John S. Newberry, Professor of Geology and Palæontology in Columbia College ; that devoted to the geological history of the North American Continent, by Professor Charles H. Hitchcock, of Dartmouth College ; the portion relating to general physiography and the physical features of the United States, by Mr. Henry Gannett, Chief Geographer of the United States Geological Survey; the pages explaining terrestrial magnetism, with the chapters on volcanoes and earthquakes, coral islands, the earth's waters, and meteorology, by Dr. W. Le Conte Stevens, Professor of Physics in the Packer Collegiate Institute. Dr. N. L. Britton, Lecturer in Botany, Columbia College, furnished the chapter on plant-life; Dr. C. Hart Merriam, the Ornithologist of the Department of Agriculture, those relating to zoölogy and the animal life of the United States; Professor William H. Dall, of the Smithsonian Institution, that on ethnology; and Mr. George F. Kunz, gem expert and mineralogist with Messrs. Tiffany & Co., of New York, that on precious stones.

Many friends of the book have given it the benefit of their suggestions and criticisms. Special acknowledgment is due to Professor Egleston, of Columbia College, who carefully corrected the paragraphs on mineralogy ; to Commodore George E. Belknap, of the United States Navy, who examined the section on the ocean and its currents, besides extending many courtesies of a personal character ; to Professor Cleveland Abbe, of the Army Signal-Office, Washington, to Professors John and Joseph Le Conte, of the University of California, to Professor Loomis, of Yale College, and to Professor William Ferrel, for valuable criticisms and other assistance; to Lieutenant Schwatka, who generously placed at the editor's disposal his maps and photographs; and to Lieutenant Stoney, for an instructive page on his discoveries in Arctic Alaska, as well as for his aid in the construction of the map of that territory.

The attention of educators is invited to the following noteworthy features:

The book throughout is the product of painstaking and critical study on the part of those who have had practical experience in the lecture-room. The aim of the editor and his corps of authors has been to supply the useful elements in an inviting and assimilable form—to popularize the study of Physical Geography by furnishing a complete, attractive, carefully-condensed text-book, neither encumbered with wearisome details on the one hand, nor unentertaining by reason of paucity on the other. No effort has been spared to insure thoroughness, freshness, and perspicuity. The development of the subject is clear and logical ; the scope of the work, comprehensive. Great care has been exercised in the selection of material both for text-matter and illustration, to give prominence to the striking and unusual, without sacrificing the fundamental. Suggestive questions, not intended to supersede minute examination by the teacher, are scattered through the text; and an intimate acquaintance with the maps is secured by a variety of questions furnished with each, and requiring repeated reference on the part of the pupil.

The views of scientific students in regard to vulcanology and earthquakes are presented, together with several illustrations of these phenomena. The theory of ocean-currents is clearly unfolded in the light of modern discoveries. The subject of climate receives peculiarly full and interesting treatment, as also that of clouds and precipitation. The general motions of the atmosphere are made plain by the application of Ferrel's Law; while the theory and movements of cyclonic storms are thoroughly considered and explained. The chapters devoted to geology, botany, zoölogy, and ethnology, will be found as fascinating as they are instructive. The text is lively and readable throughout, and calculated to inspire the pupil with a taste, if not enthusiasm, for further pursuit of the study.

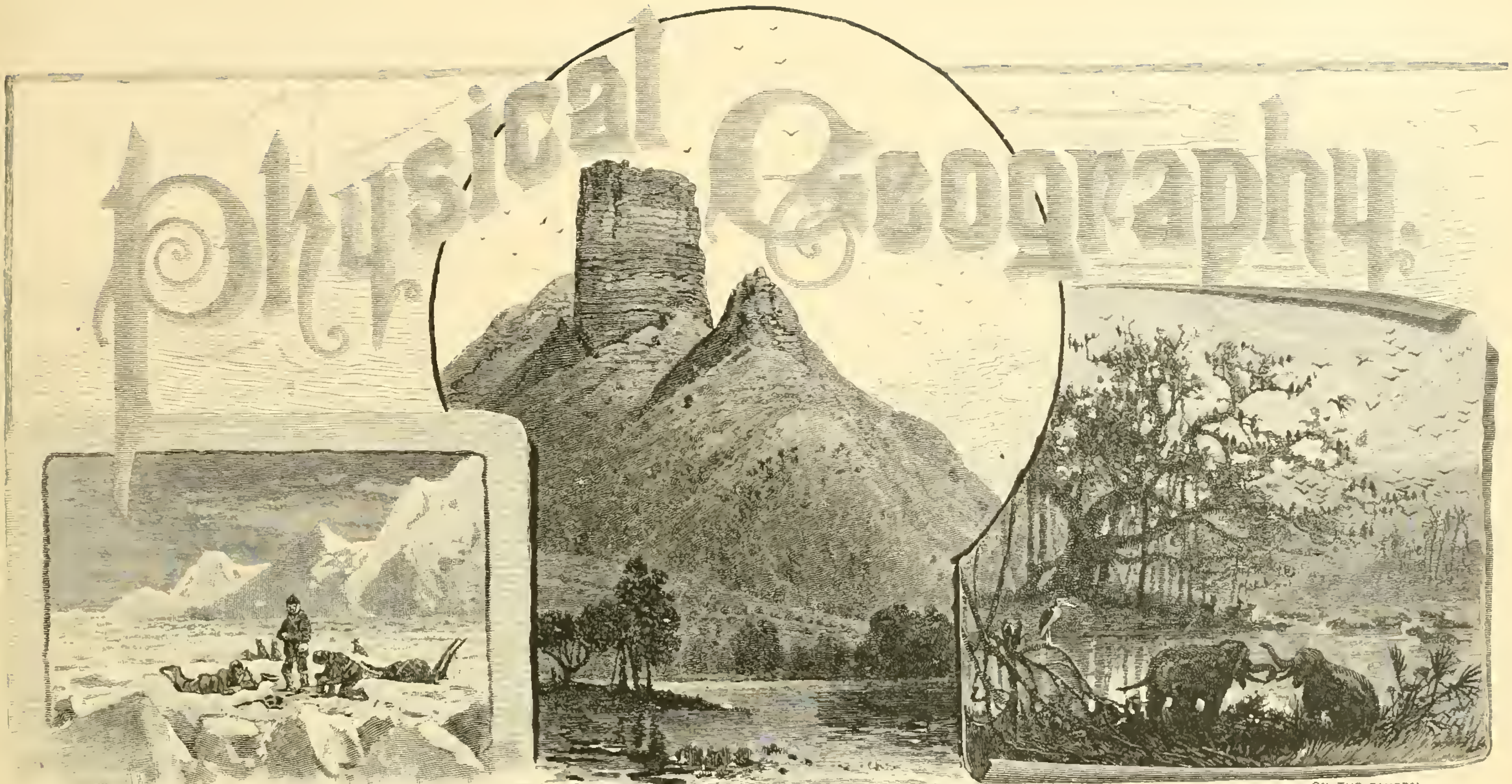
The value of the work is enhanced by the introduction of an ample bibliography of the subject. From their experience in the class-room, the authors have been led to anticipate the wants of both pupils and teachers, and have therefore incorporated in the text frequent references to standard monographs. These references are not made to supply omissions, but simply as guides for those readers who may desire fuller and more satisfying information.

The pictorial illustrations, introduced not as embellishments alone, but also as aids in imparting practical information, are based on original paintings, photographs and objects selected in actual travel, and sketches made both in this country and Europe by specially qualified designers. Woodward, J. C. Beard, Redwood, Fenn, Davidson, Cary, and Warren, furnished the originals, in accordance with the instructions of the several authors ; the botanical subjects were drawn from specimens in the Torrey Herbarium, Columbia College, by Arthur Hollick, Ph. B.

The maps, drawn by Mr. Jacob Wells, and engraved by Struthers, Servoss & Co., of New York, have been constructed under the supervision of the special authors, from the latest and most accurate information. The charts of the Gulf of Mexico and the Caribbean Sea were furnished by Commander Bartlett himself. In the map of Alaska are recognized the discoveries of Lieutenant Schwatka, Professor Libbey, and of later explorers, as well as those relating to the physiography and hydrography of the northern portion of the territory explored by Lieutenant Stoney. On the map of the Arctic Ocean and North Polar Regions will be seen the location of Dr. Nansen's farthest north. Particular attention is directed to the Relief Maps and profiles, which are unsurpassed by anything of the kind hitherto published.

The physical features of the United States receive especial consideration in the concluding chapter, which is embellished by a relief-map and a colored physical map of our country, reflecting the highest perfection of the engraver's art. The publishers trust that its unique and valuable features will recommend this work to the teachers of our grammar-schools, high-schools, and colleges, as a progressive text-book, on a level with the present state of science, and in full harmony with the requirements of the age.

LIST OF MAPS.



LOCKWOOD ISLAND.

GREEN RIVER BUTTES COLORADO.

ON THE ZAMBESI.

SUBJECTS OF GEOLOGICAL AND GEOGRAPHICAL SCIENCE.

Geography is a description of the earth on which we live. As a science, it relates chiefly to the present surface of the earth. It treats, also, of the earth as a whole, and of its relations to the sun; of the atmosphere that surrounds it; of the plants, animals, and minerals, distributed through its different parts; and of the divisions made by man, each having its industries, institutions, government, etc.

Geology is the ancient history of the earth. It is the science which determines the chronological succession of the great formations of the earth's crust, and investigates the causes of its present surface features; it further treats of the materials composing the earth's substance, and of the development of life upon our globe as recorded in its rocky framework.

These two sciences are so closely related that a thorough acquaintance with one implies at least some elementary knowledge of the other.

Geography is divided into three branches: Mathematical, Political, and Physical.

Mathematical Geography treats of the form and size of the earth, its motions and their results, the modes of determining position on its surface, and the methods of representing the earth in whole or in part.

Political Geography treats of the earth's surface as occupied by man, and divided by him into different countries; and of its inhabitants as regards their occupations, social condition, religion, and government.

Physical Geography, the subject of this volume, treats of the natural divisions of land and water without reference to political organization; of the atmosphere and climate of the earth, and the causes that are implied in present changes upon its surface; of its vegetable and animal life, and the distribution of such natural products as are of interest to man.

Physical geography is thus a comprehensive science that includes applications from astronomy, the science of bodies in space; from geology, the science of one of these bodies especially—the earth; from physics, the science of the laws and properties of matter; from botany, the science of vegetable life; from zoölogy, the science of animal life; from mineralogy, the science relating to a large class of natural objects that have not life.

In the following pages it will be assumed that the student has already some knowledge of mathematical and political geography. The subject of mathematical geography will be briefly reviewed for the purpose of applying its principles to physical geography. An outline of geology will also be given. For an explanation of the technical terms which follow, the pupil is referred to the introductory paragraphs in *Appletons' "Higher Geography."*

THE EARTH AS A PLANET.

The Stars.—The SUN is one of a multitude of STARS that are continually giving out their energy, manifested chiefly as light and heat, into space. It appears larger and brighter than the others only because it is much nearer to us than they.

Probably all the stars are in rapid motion, but as this is imperceptible on account of their great distance, they are called FIXED STARS. They appear grouped in CONSTELLATIONS.

THE DISTANCES OF THE FIXED STARS from the Earth are so great as to be inconceivable. The average distance of the Sun is nearly 93,000,000 miles. Light travels through space at the rate of 186,360 miles per second, and therefore consumes more than eight minutes in reaching us from the Sun. The time required for the passage of light from the nearest fixed star to the Earth is estimated to be four and a third years; and from the more distant stars that are visible through the telescope, many thousands of years.

The Stars are Self-luminous. If we assume them to be like our Sun, each must be a hot, dense body, surrounded by a less hot but still glowing atmosphere. Many are grouped in clusters amid clouds of burning matter. Such clouds are called NEBULÆ. Herschel discovered nebulæ whose light he estimated to have traveled three million years before reaching our world. (On the Stars and Nebulæ, *consult Lockyer's "Elements of Astronomy," p. 23.*)

The Solar System.—Many stars are attended by smaller bodies which revolve around them. The name SOLAR SYSTEM is applied to a group consisting of the Sun and a vast but unknown number of bodies revolving around it. The largest of these are called PLANETS (from a Greek word meaning *wanderer*).

The Primary Planets, in the order of their distance from the Sun, are: Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, and Neptune. Some of these are attended by smaller bodies, called SECONDARY PLANETS, or SATELLITES, which revolve around their primaries while these are revolving around the Sun. The Earth has one satellite, called the MOON; Mars has two; Jupiter, five; Saturn, eight; Uranus, four; and Neptune, one.

The path described by a body in its revolution around another is called its orbit. Between the orbits of Mars and Jupiter are many small bodies called PLANETOIDS, which revolve about the Sun. About 340 of these have thus far been discovered.

The planets with their satellites, and the planetoids, shine by light reflected from the Sun, and are therefore comparatively cold bodies. Jupiter, Saturn, Uranus, and Neptune, are probably feebly self-luminous, but far less hot than the Sun.

COMETS and METEORS also belong to the solar system.

Growth of the Solar System.—According to the Nebular Hypothesis, which was generally accepted by astronomers as probably true, the matter composing the solar system was once irregularly diffused in space as a great nebula, whose particles were mutually attractive. They tended, therefore, to collect at the center, and in so doing to give a whirling motion to the mass.

When the energy of motion is arrested, it is changed into that of heat and light, as is familiarly shown in heating a piece of iron by hammering. The dense but still nebulous mass, with its particles falling to the center, became hottest there, as the speed of rotation increased. This increase of speed in turn developed an increased tendency to fly off from the center, just as the mud is thrown from a rapidly-revolving wheel. The disk, therefore, became separated into a series of rings, with the greater part of the mass still rotating at the center, its temperature increasing until it was compressed nearly to the present size of our Sun.

Each ring continued to contract until its particles were aggregated into a hot sphere, rotating on its own axis and at the same time revolving around the central hot sphere. The heat due to contraction was continuously radiated into space, slowly from the larger masses and rapidly from the smaller ones. Thus were formed the Sun and its Planets.

Some of the planets in contracting threw off secondary rings, and these condensed into satellites like our Moon.

Whether or not the original form of matter was gaseous, recent researches seem to indicate that the heavenly bodies had their immediate origin in the gradual contraction of masses of meteorites. True Nebulæ are clouds of meteorites in collision and process of condensation. They will grow hotter and brighter as the collisions increase in frequency and violence, and it is believed will ultimately condense into suns.

Whichever hypothesis be accepted, our Earth is a cooling body that is still rotating on its axis and radiating forth the heat due to its condensation. It would naturally cool most rapidly at the surface, become most dense at the center, and continue to contract as long as it gives out heat. Its surface would become hard, and wrinkled into folds as it settled upon the contracting interior.

SIZE AND FORM OF THE EARTH.

The Earth is not quite spherical in form. The distance from North to South Pole is 7,899.17 miles. Its mean diameter at the Equator is 7,925.65 miles, or 26.48 miles in excess of the polar diameter. The form of the earth is very nearly that of an oblate spheroid.

There is reason to believe that the Equator is not an exact circle, and that no meridian is an exact ellipse. Nevertheless, the Earth is so nearly a sphere, that for most purposes it may be regarded as such. Its circumference at the Equator is 24,899 miles; its surface, not quite 197,000,000 square miles; and its volume, 260,000,000,000 cubic miles.

The Earth's deviation from perfect spherical form is trifling in comparison with its size; if a globe twelve inches in diameter were flattened in the same proportion, no eye could detect the change.

In speaking of the form of the Earth, the inequalities of its surface are not considered. The highest mountain has an elevation of only five and a half miles, and if proportionately represented on a twelve-inch globe, would be no larger than a grain of sand.

COMPARISON OF THE EARTH WITH OTHER MEMBERS OF THE SOLAR SYSTEM.

The Volume of the Sun (its cubical contents, or size) is over 1,300,000 times that of the Earth, while its mass (quantity of matter) is 330,000 times as great. Its surface is composed of exceedingly hot and brilliant clouds, which contain in a gaseous condition many of the substances that exist here in a solid state, such as iron, lead, nickel, and zinc. Its body is believed to be not solid, but gaseous; a ball of gas, probably one hundred times denser than any gas known upon the Earth. At a distance of 93,000,000 miles, it is now giving to us almost enough heat to balance that which the Earth is losing by radiation.

The cloudy envelope surrounding the Sun is subject to violent storms. Masses of hot gas are ejected to the height of many thousands of miles, and dark spots mark the areas of greatest disturbance. The solar surface is rarely free from spots. Their frequency increases or diminishes from year to year, periods of greatest frequency occurring once in ten or twelve years.

THE SUN.
(From Harvard College Observatory drawing.)

By the use of appropriate instruments, astronomers have ascertained the composition of the Sun's surface-clouds. About one-third of the elements known to compose the Earth's surface have been discovered in them. (On the Sun and Planets, *consult Peck's "Popular Astronomy," p. 135.*)

Jupiter and Saturn are hot bodies, whose surfaces are covered with thick masses of cloud that appear to be self-luminous as well as to reflect the light of the Sun. In form they are much more oblate than the Earth, and their density is less than that of the Sun. If we adopt the Earth's mass as a unit, that of Jupiter is 312, that of Saturn 93; but despite their great size, these planets rotate more than twice as fast as the Earth. Jupiter has five satellites. Saturn is inclosed within a series of rings, around which its eight satellites revolve. Like the Sun, these two planets appear to be masses of dense, hot fluid.

The surface of **Mars** is diversified with what are believed to be bodies of land and water. It has an atmosphere in which clouds float, and its polar regions are white with what appears to be snow. Its mass is about one-ninth of the Earth's; and its body is probably solid throughout.

MARS IN 1862.

The Moon's surface is greatly folded and cracked, and presents no evidence of having any gas or even water left upon it. It gives out little or no perceptible heat, aside from that which it receives from the Sun. The Moon is believed to be solid to its center, and to have radiated already nearly all the heat due to condensation. Its surface temperature is not known, but can be very little above that of surrounding space, which is estimated to be about 490° Fahr. below the freezing-point of water.

(On the Moon and Lunar Scenery, *consult Nasmyth and Carpenter's "The Moon, as a Planet, a World, and a Satellite."*)

Of surface conditions on **Uranus, Neptune, Venus, Mercury**, and the **Planetoids**, nothing definite is known. **Meteoric Bodies** which enter our atmosphere and fall upon the surface of the Earth are found to consist of well-known materials. The **Nebulæ**, and some of the **Stars**, are composed of elements like those in the atmosphere of the Earth and Sun.

The condition of the Earth is apparently intermediate between that of Jupiter and that of Mars. Its interior is still intensely hot, and although there is reason to believe much of it to be solid, or at least exceedingly dense, there are subterranean regions of softness, where the hot material, if not liquid, is viscous like tar. The surface is hard and much folded, and is still slowly contracting. No satisfactory estimate can be made of the millions of centuries that have elapsed since the Earth first assumed the liquid form, or of the time that has intervened since its crust became rigid, or since the temperature of the oceans that fill its surface depressions equaled the present temperature of boiling water. There is much reason to believe that its first living inhabitants made their home in hot water.

The Earth is thus seen to be only one of a multitude of bodies in various stages of planetary development, the rapidity of which is regulated by their size. It is now temporarily in a state adapted to the existence of such animal and vegetable life as we are familiar with. The Sun, Jupiter, and Saturn, have not yet reached this stage; Mars and the Moon appear already to have passed it.

THE EARTH'S MOTIONS.

The Earth has two motions—a daily and a yearly motion.

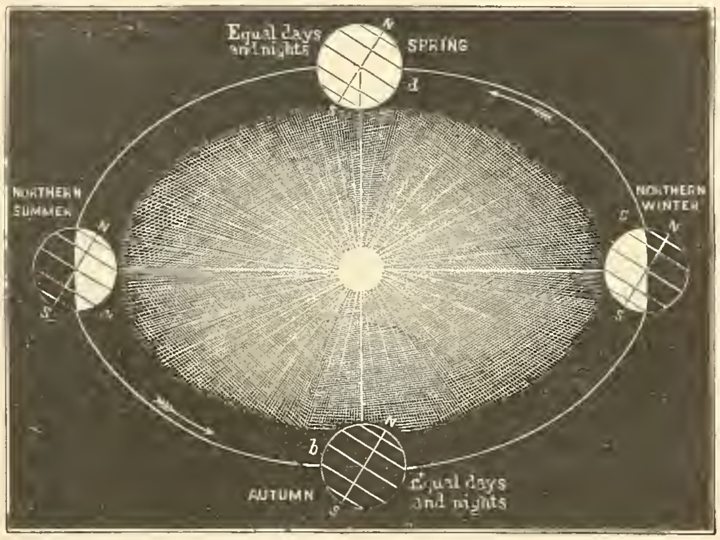
Daily (Diurnal) Motion.—The Earth, as we have seen, turns on its axis. One rotation is completed in a period which we call a day, and divide into twenty-four hours.

But the term day is used in another sense, as opposed to night. The Earth receiving its light from the Sun, it is day on that half of the Earth's surface which is presented to the Sun; the opposite half is in darkness or night. The Earth's rotation is constantly whirling new places into light (causing sunrise to them) and sweeping others into the shadow (causing sunset). It thus produces the **Succession of Day and Night.**

The great circle which separates the lighted side of the Earth from the dark side is called the **Circle of Illumination.** (Trace it on the spheres in the accompanying diagram.)

Yearly (Annual) Motion.—While the Earth is turning on its axis, it is also revolving in its orbit or path around the Sun. One revolution is completed in a period which we call a year, and which is equal to about 365¼ days.

The Earth's yearly revolution is performed with its axis *inclined to the plane of its orbit* and *always pointing in the same general direction;* to this fact is due the **Change of Seasons.** The direction in which the Sun's rays strike any part of the Earth's surface is continually changed, and with it the amount of heat received; for the more nearly perpendicular the rays are, the more heat they impart.



The above diagram shows the Earth at four points of its orbit. In each, the axis N S is inclined to the plane of the orbit (deviating from the perpendicular about 23½°), and points in the same direction. (The Earth's axis does vary in direction, but the change takes place so slowly as to be imperceptible, except with the most delicate instruments.)

At *a*, the Earth's position on June 21st, the North Pole is turned toward the Sun. The inclination of the axis being 23½°, the Sun's rays are now perpendicular at places on a line 23½° north of the Equator; the Sun at noon is here directly overhead. This line, from the fact of the Sun's appearing to turn south after reaching it, is called a Tropic (*turning-line*), and it is distinguished as the **Tropic of Cancer.** Summer now reigns in the north, winter in the south. The circle of illumination (*refer constantly to the diagram*) extends 23½° on the opposite side of the North Pole, and there fixes the position of what is called the Arctic Circle. Regions north of the Arctic Circle remain within the circle of illumination notwithstanding the rotation of the Earth, and hence have a day more than twenty-four hours long. Regions near the South Pole are not brought within the circle of illumination by the Earth's rotation, and hence have a night more than twenty-four hours long.

In three months the Earth reaches *b* (September 22d). The Sun's rays are now perpendicular to the Equator, and days and nights are everywhere equal; this is the period of the northern autumn and the southern spring.

Three months more bring the Earth to *c* (December 21st). The conditions of the position at *a* are now reversed. The South Pole is turned toward the Sun, whose rays are perpendicular to places on a line 23½° south of the Equator. The Sun appears to turn north after reaching this line, and this turning-line is distinguished as the **Tropic of Cap'ricorn.** The south has its summer, the north its winter. The circle of illumination extends 23½° on the opposite side of the South Pole, and fixes the position of what is known as the Antarctic Circle. South of the Antarctic Circle the day is more than twenty-four hours long, while north of the Arctic Circle the night is more than twenty-four hours long.

Still moving east, the Earth, on March 20th, reaches *d*, where the light once more spreads from pole to pole, and day and night are each everywhere twelve hours long. The solar rays are now again perpendicular to the Equator, and slant equally at the two tropics. Spring prevails in the north, autumn in the south. Observe that on the Equator the Sun is never far from the zenith, and we have perpetual summer.

Questions.—Into what inquiries connected with the Earth does geography enter? Geology? Explain the relation existing between these two sciences. What does physical geography teach, and how does it necessarily include applications from other departments of physical science?

What are Stars? Why does the Sun appear larger and brighter than the other Stars? To what is the brightness of the Stars due? Give an idea of their distance as measured by the velocity of light. Describe the various bodies composing the planetary system of which the Sun is the center. What important difference is there between the Planets and the Sun? Account for the formation of the Solar System according to the Nebular Hypothesis. What can you say of the Earth's past condition, and of its present state and form? Compare it with the Sun and its sister Planets in respect to size, density, and stage of development. State what is known of the Moon.

How many and what motions has the Earth? Explain the phenomena of day and night. Describe the Earth's yearly motion. What proof can you give of its annual revolution? To what extent are its movements felt by its inhabitants?

THE EARTH'S MAGNETISM.

Natural Magnets.—In various parts of the earth an ore of iron is found which has the property of attracting iron. It is called magnetite, or lodestone, and was known to the ancients, occurring near Magnesia, a city of Asia Minor. Any body which has this property is called a Magnet.

Artificial Magnets.—If a bar of steel be sufficiently rubbed against a natural magnet, it assumes a magnetic condition, and is called an artificial magnet. There are also other methods of producing artificial magnets.

Steel when once magnetized gives up this condition very slowly. A piece of ordinary soft iron receives and gives it up very quickly. The difference between permanent and temporary magnets is only one of degree. No artificial magnet retains its power permanently undiminished, or acquires it instantaneously.

Magnetic Polarity.—If a magnetized steel bar be buried in filings of soft iron and then withdrawn, these will cling to it thickly about the two ends, and usually not at all at the middle. Two points, one near each end of the magnet, are called its poles.


MAGNET DIPPED IN FILINGS.

(The teacher should give experimental illustration of the fundamental facts of magnetism.)

The Magnetic Meridian.—When a bar magnet is properly suspended, or balanced on a pivot, it assumes a definite direction called the magnetic meridian. This is nearly, or may be quite, north and south. The pole which points northward is called the north-seeking, or positive pole; the other is the south-seeking, or negative pole. They may be designated as the + pole and the − pole.

When the + pole of one magnet is brought near the + pole of another, they mutually repel; but if the + pole of one is brought near the − pole of the other, they mutually attract.

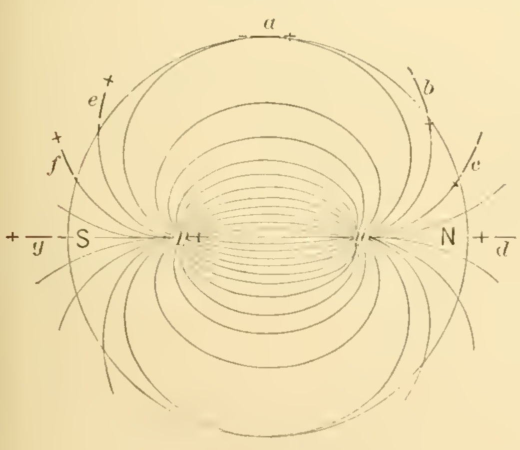
Magnetic Induction.—If either pole of a magnet be brought near to a piece of iron, the iron becomes for the time magnetic, with its + pole nearest the — pole of the first magnet; if free to move, the iron will be drawn toward the magnet. Magnetism thus excited is said to be *induced*. Induction is not prevented by intervening bodies which are not themselves magnetic.

Lines of Force.—If upon a horizontal bar-magnet a plate of glass be rested, and iron filings scattered over it, the filings, when the glass is gently tapped, become arranged by induction in peculiar curves, called lines of magnetic force. The space within which these lines may be thus produced is called the *magnetic field*. A magnetic body always tends to place itself along the line of force that passes through it. (*Consult A Lecture on Magnetism, in Professor Tyndall's "Fragments of Science."*)

The Earth a Great Magnet.—The fact that a magnetized needle places itself in the magnetic meridian shows that the earth acts as if it contained a great magnet, some of whose lines of force pass along the ground in certain places and penetrate it in others. A terrestrial — pole must be in the neighborhood of the geographical North Pole, in order to attract the + pole of the needle.

THE MAGNETIC SPECTRUM, SHOWING LINES OF FORCE.

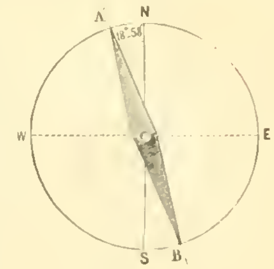
Thus, in the accompanying figure, if the great magnet be represented to have its + pole at *p* and its — pole at *n*, its lines of force will be represented by the curves. One of these passes along the earth's surface at *a*; others cut it at *b*, *c*, *d*, *e*, *f*, and *g*. The + poles of the needles at *a*, *b*, *c*, *d*, are all turned toward the geographical North Pole N; the needle at *a* is parallel to the earth's surface; those at *b* and *c* are inclined, with their + poles dipping toward the ground; that at *d* is vertical, with its + pole toward the ground. Those at *e* and *f* dip with their — poles toward the ground and pointing southward, while that at *g* is vertical, with its — pole toward the ground. Many of the lines of force are entirely within the earth. (*Refer to Deschanel's "Natural Philosophy," pp. 653–663.*)



LINES OF TERRESTRIAL MAGNETIC FORCE.

The diagram expresses an ideal case; the reality is not quite so simple.

Magnetic Elements.—The magnetic needle does not generally point exactly toward the true north. The angle between the magnetic meridian and the geographical meridian is called the angle of *declination*. If a needle be balanced so as to be horizontal when suspended by a thread, and then be magnetized, it will not only place itself in the vertical plane of the magnetic meridian, but will assume a particular direction in that plane, usually inclined at a considerable angle to the horizon. This angle is called the *dip*, or *inclination*. In the northern hemisphere, the north pole of the magnet dips; in the southern hemisphere, the south pole.

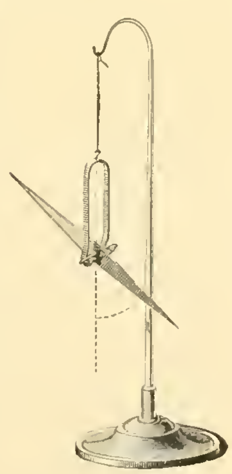


DECLINATION.

The force exerted by the earth-magnet upon the needle is not the same at all places. The measure of this force upon a unit magnet pole is called the *intensity*. Thus, in the figure opposite, the dip and intensity at *c* are greater than at *b*, because *c* is nearer to *n*. The declination, dip, and intensity, constitute the magnetic elements of a place.

The Mariner's Compass.—The tendency of the needle to seek a north-and-south line led to the practical application of magnetism by navigators. The Mariner's Compass consists of one or more magnetic needles attached to the lower face of a circular card, which is delicately pivoted and generally immersed in a liquid, so as to decrease the pressure upon the pivot. The circumference of the card is divided into degrees and also into thirty-two "points of the compass." It is supported in such a manner that the card may always be horizontal, notwithstanding the motion of the vessel. The needles remain in the magnetic meridian, with which a ship's course may readily be compared.

The Mariner's Compass was, according to some authorities, invented in China, and made known to Europeans through the instrumentality of the Mohammedan Arabs. The first mention of the use of the magnetic needle in Christian Europe occurs in a curious Provençal poem, written in 1190. Early accounts of the instrument describe it as a simple iron needle, magnetized and placed on a pivot, or floated on a cork in a vessel of water, in either case free to turn in any direction. It was observed that a needle thus treated came to rest in an approximately north-and-south line, early compasses presumably being very inaccurate. A cross-piece is thought, in some instances, to have been affixed to the needle, for the purpose of determining the cardinal points of east and west. This rude instrument served equally well to guide the traveler over the deserts of Central Asia and the Chinese sailor through the southern seas.

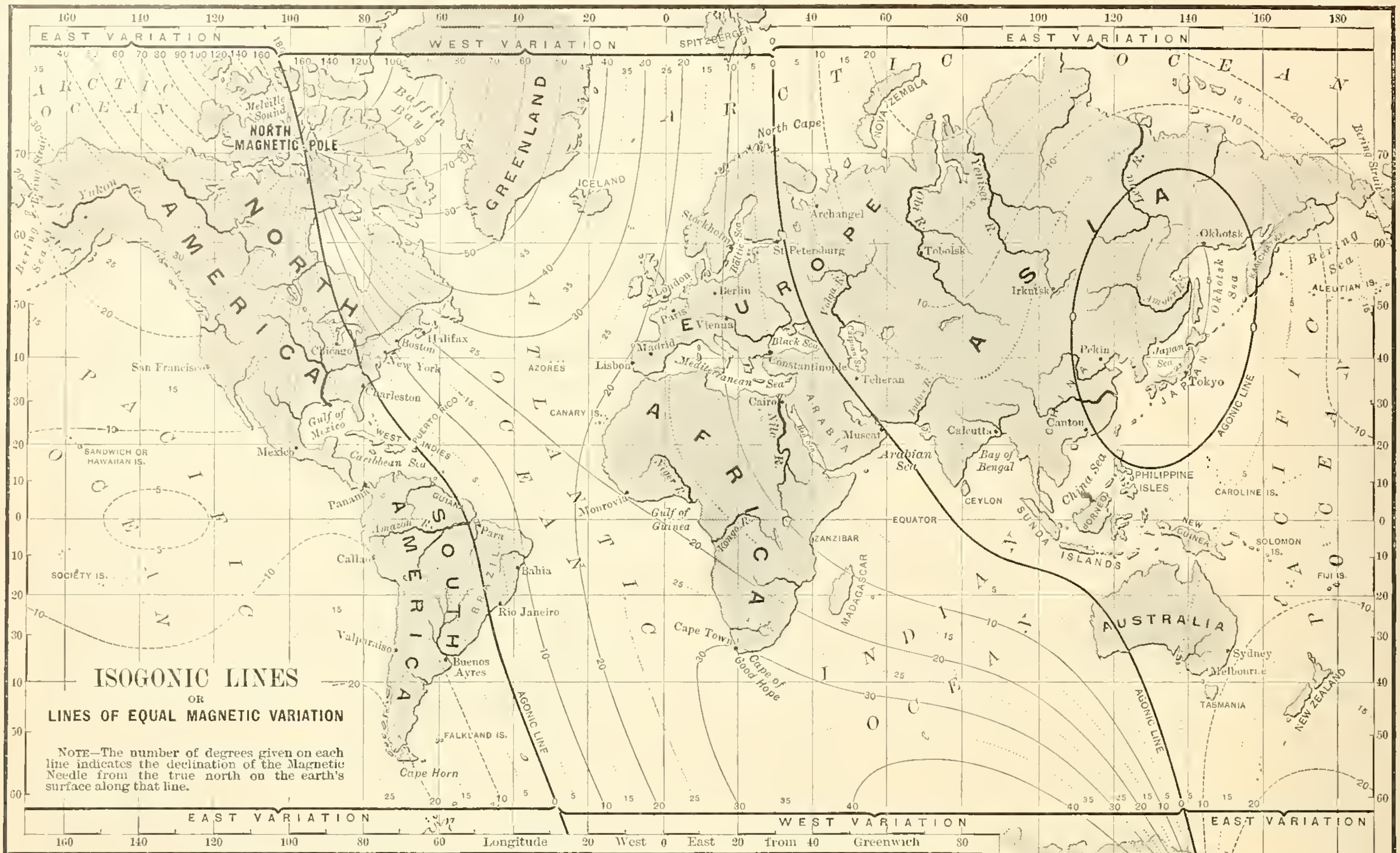


DIP OR INCLINATION.

A knowledge of magnetism, and of its practical application in the compass to determine directions, stimulated that thirst for maritime discovery which marked the transition from mediæval to modern times. It was not until the fifteenth century that voyages were confidently prosecuted by European navigators on a systematic plan, and Portugal and Spain laid the foundations of those vast colonial empires that were at once the admiration and envy of the world.

The declination of the compass-needle, known in Europe in the thirteenth century and independently discovered by Columbus in 1482, was noticed in an English publication of the sixteenth century, entitled "A discourse on the variation of the Cumpas or Magneticall Needle." The dip of the needle was discovered accidentally in 1576 by an English instrument-maker, who found the inclination at London to be 71° 50′.

Isogonic Lines.—The declination of the compass-needle at any place may be found by comparing its direction with that of the north point of the heavens, which is close to the polar star. Upon a chart of the world, lines may be drawn connecting places which have equal declination. These are called Isogonic Lines.



ISOGONIC LINES
OR
LINES OF EQUAL MAGNETIC VARIATION

NOTE—The number of degrees given on each line indicates the declination of the Magnetic Needle from the true north on the earth's surface along that line.

Refer to the Chart of Equal Declination above. It will be seen that on a line passing through Ohio, Kentucky, North Carolina, Guiana, and Brazil, the declination is 0°; hence, at any point of this line the compass-needle points to the true north. Such a line is called an *agonic line*. Immediately on the east of this line, the needle points west of north. This error increases as we go farther northeast, and then north and west. In Baffin Bay, the declination is 90° west, in Grinnell Land the + pole of the needle points to the southwest, and at a place in Melville Sound it points due south. As we pass toward Europe, the declination, though still westward, diminishes until it becomes 0° along a line passing through Russia, Persia, and Australia. Beyond this line, the declination becomes increasingly eastward until it is 20° east at the mouth of the Yenisei River. It then diminishes until it becomes 0° again along an oval line inclosing the Japan Islands, and parts of the Chinese Empire and Siberia. Within this oval the declination is westward. Beyond it, the declination becomes again increasingly eastward, reaching 90° east in the Arctic Ocean near Banks' Land. The + pole of the needle then points southeast until it reaches the place in Melville Sound where it points due south.

This behavior of the magnetic needle seems to indicate that, instead of a single focus of negative magnetic strength beneath the Arctic regions, there are two such foci, the stronger of the two being under North America, and another of the same kind under Siberia. Corresponding to them there should be a pair of positive magnetic foci beneath the Antarctic regions. The earth's magnetic system has long been believed to have four poles.

Isoclinal Lines.—The lines connecting places which have equal magnetic dip are called Isoclinal Lines. The line along which there is no dip is the Magnetic Equator.

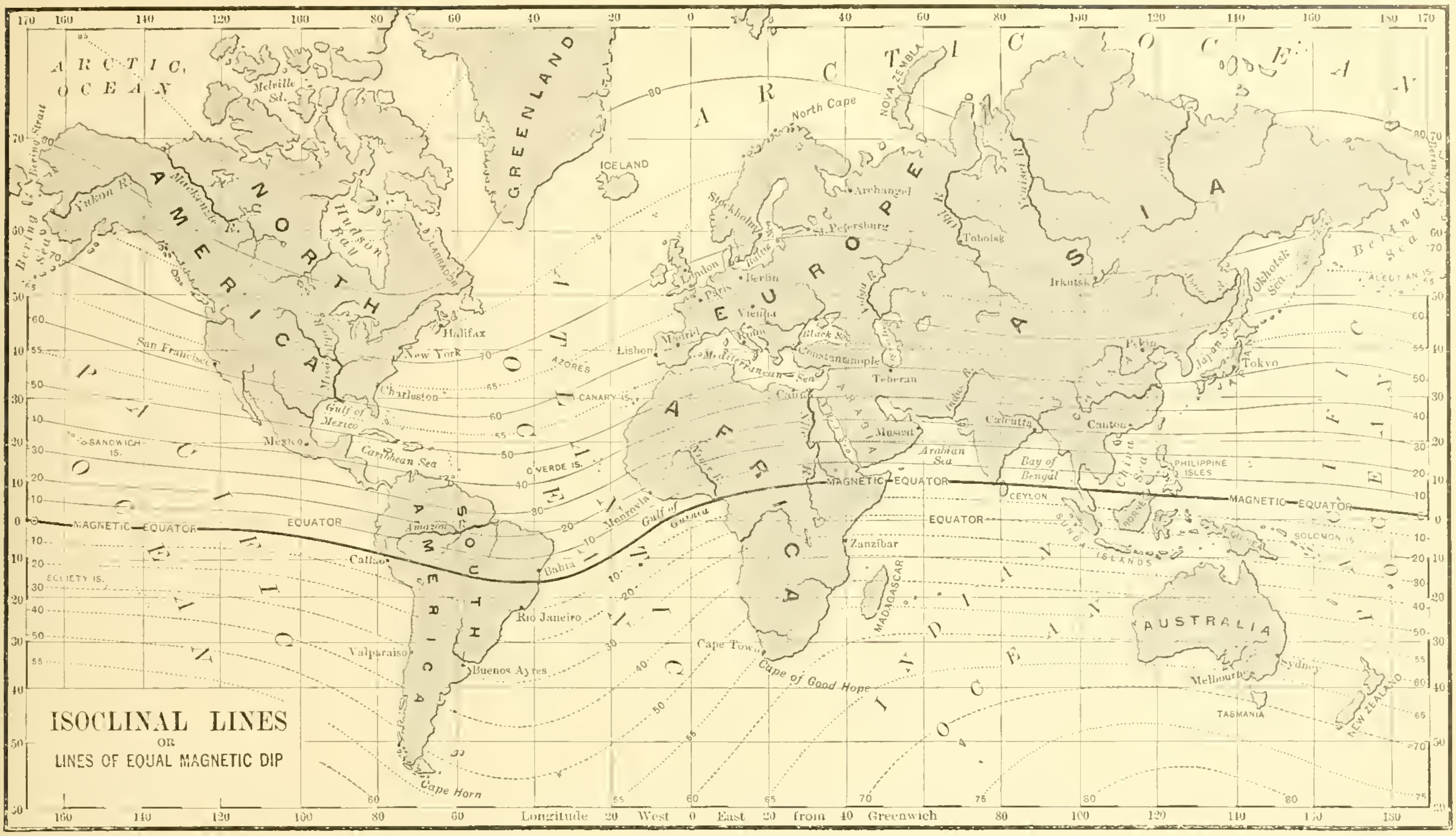
Refer to the Chart of Equal Dip, on page 9. It will be seen that the magnetic equator does not coincide with the geographical equator, but cuts it about longitude 6° west and 168° west, passes farthest south near the point where it crosses the American line of no declination, and farthest north near where it crosses the European line of no declination. The irregularity of the isoclinal curves is not so striking as that of the isogonic curves. As we pass northward from the magnetic equator, the dip increases until the + pole of the needle points vertically downward at a place in Boothia Peninsula whose position in 1884 was latitude 70° 30′ north, longitude 96° 40′ west. This is called the *pole of verticity*, or often simply the magnetic pole. The position of the southern pole of verticity is estimated to be about latitude 73° 30′ south, longitude 147° 30′ east. (*See Balfour Stewart's article on "Meteorology," Encyclopædia Britannica.*)

Magnetic Intensity.—The intensity of the earth's magnetic force is not the same for all places of equal dip.

The stronger, or American, focus of greatest intensity is estimated by Sir Frederick Evans to be in latitude 52° north, longitude 90° west, beneath the area between Lake Superior and Hudson Bay; and the weaker, or Siberian, focus at latitude 70° north, longitude 115° east, beneath the marshy region between the Yenisei and Lena Rivers. At the pole of verticity, therefore, which is between these two foci, the + pole of the needle is unequally attracted by both. The southern foci are supposed to be close together, between Australia and the Antarctic Continent.

Variation of the Magnetic Elements.—The magnetic elements are subject to slight daily and annual variations, and to variations extending through long periods of years.

The American line of no declination in 1790 passed through Norfolk, Virginia, where the declination is now (1886) more than 3° west. At New York the declination in 1686 was 9° west; in 1750, 6° 20′ west; in 1790, 4° 15′ west; in 1847, 6° 30′ west; in 1885, 8° west. This indicates that the American magnetic focus moved eastward from 1686 to 1790

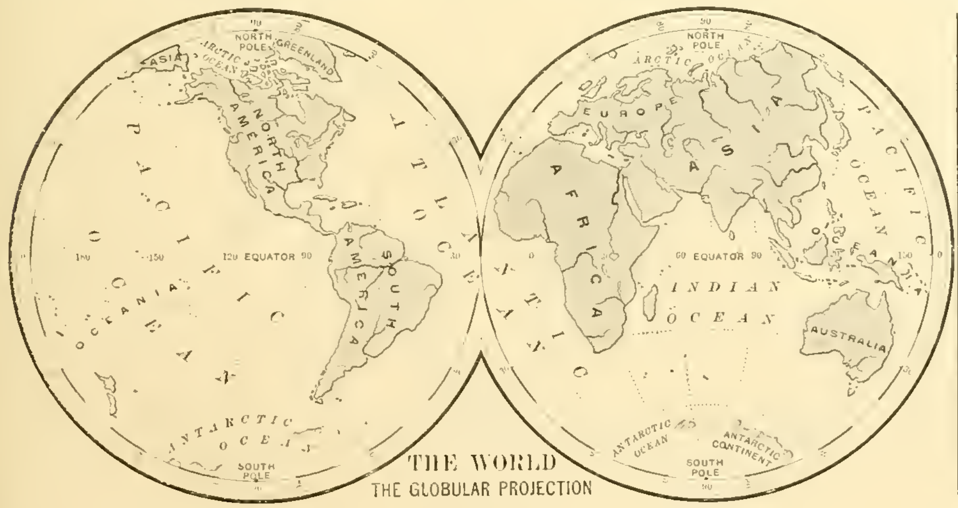


ISOCLINAL LINES OR LINES OF EQUAL MAGNETIC DIP

then became stationary, and has since been moving westward. Still greater variation has been recorded in London and Paris.

The Cause of the earth's magnetism, and of the variations noticed, is unknown. Violent and sudden variations, called *magnetic storms*, take place at times. They occur simultaneously with disturbances on the surface of the sun. The outbreak of a large sun-spot in 1882 was followed by a magnetic storm of such violence in the United States as to interfere seriously with telegraphic communication.

Questions.—What is a magnet? Explain magnetic polarity, and the law of magnetic behavior. What are the magnetic poles of the earth? Describe the mariner's compass. What is meant by the declination of the needle? The dip? Magnetic intensity? What are isogonic lines, and what is the position of the lines of no variation on the earth? Define isoclinal lines. What is the magnetic equator? Find the present declinatiou at New York; San Francisco; Tokyo; London. To what variations are the magnetic elements subject? Explain magnetic storms, and their effects.



THE WORLD
THE GLOBULAR PROJECTION

THE WORLD
MERCATOR'S PROJECTION

MODES OF REPRESENTING THE EARTH'S SURFACE.

Globes and Maps are used to represent the earth's surface. Globes represent the whole surface in its own spherical form; maps represent either the whole or part, and on a flat surface or plane.

Mercator's Projection.—The maps in this volume are principally on what is called "Merca tor's Projection." It represents the earth's surface expanded as it would have to be to coincide with the interior surface of a hollow cylinder enveloping the globe and touching it at every point of the equator.

The meridians are thus converted into parallel lines. The degrees of longitude, instead of diminishing as we leave the equator, remain of uniform length. The degrees of latitude, instead of remaining of uniform length as we leave the equator, are increased in the proper ratio. The consequence is, that the size of countries in high latitudes, north or south, is greatly exaggerated; as will be seen by comparing the northern part of North America, as shown in the Mercator map above, with the representation of the same in the map of the hemispheres on a globular projection. Yet the exact direction of one place from another is shown, and hence charts on Mercator's projection are used by navigators.

Geological Agencies.—The crust of the earth is that outward portion of it which has cooled, hardened, and subsequently become modified by various agencies. It is the province of geology to explain to us of what that crust is made, and how it has been formed. Among the agencies that have been most effective in causing changes upon the earth's surface are its envelopes, air and water. The friction of the air, which presses upon every square inch of the surface with a weight of 14.7 pounds, produces the waves of the sea, and sweeps sand from place to place on the land. The atmosphere also carries moisture, which is precipitated as rain and snow; rivers and masses of ice are formed, by the action of which highlands are worn down and valleys excavated (*see cuts, pp. 56, 83*). The material removed is transported to the sea-basins, where it is deposited in sediments, which become, by elevation, new land. (On erosion by rain, rivers, and ice, *consult Geikie's "Text-Book of Geology," pp. 343, 371, and 413.*)

The waves of the sea, the most potent of geological agents, dashing incessantly upon all shores, are constantly wearing away the land and spreading in the rear of their line of advance the materials which they grind up or take into solution.

Materials composing the Earth.—The materials composing the earth are called minerals. Water and air, with many other gases and liquids, are to be regarded as minerals, since they do not belong either to the animal or the vegetable kingdom.

Minerals, in their uncrystallized condition and generally mixed together, form Rocks. There are about twenty minerals which may be considered rock-makers. Of these, silica is the most abundant, since it constitutes about half of the minerals and rocks known. When pure it is called quartz (rock-crystal, agate, flint). Most gravel and sand is composed of quartz, which is so hard, tough, and insoluble, that it remains in lumps and grains after the minerals associated with it are ground up or dissolved away. Next to silica, the most abundant minerals are the feldspars, generally white or flesh-red in color, which when decomposed form clay.

Rocks may be divided into three classes—Igneous, Sedimentary, and Metamorphic.

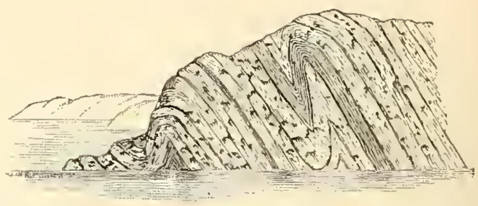
Igneous Rocks (from the Latin word *ignis*, meaning *fire*), generally characterized by a crystalline or glassy structure, are such as have been formed by fusion, or melting by heat. Some have been ejected from volcanoes (obsidian, or volcanic glass); others have cooled in great masses and solidified beneath the surface (sy'enite, sometimes called Scotch granite, quarried for monuments by the ancient Egyptians).

Sedimentary Rocks are those which have been deposited from water. Some, like sandstone, have been made of fragments transported from a distance, then deposited and consolidated; others, such as rock-salt and gypsum, have been deposited from solution; and others still (limestone, marl, and tripoli) are composed of the remains of animals and plants.

Metamorphic Rocks (from the Greek word *metamorphosis, change*) are made up of sediments that have been changed from their original condition by pressure, heat, or chemical action; they include the marbles.

Nearly all high, isolated mountains are the remains of projecting masses of igneous rock; continuous mountain-systems and great ranges are composed for the most part of metamorphic rock; while low plains consist of sedimentary deposits.

Strata.—Sedimentary material is found in layers, which are called Strata. When these are subjected to lateral compression due to the contraction of the earth's crust, they become folded, and even highly tilted and broken. Metamorphic rocks are always thus greatly folded.



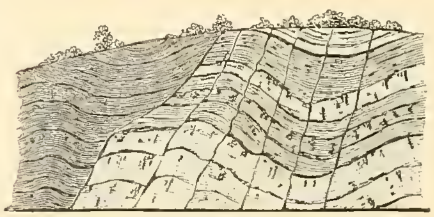
Disturbed Strata on the Berwickshire Coast.

The softer parts of strata, whether horizontal or folded, are washed away in time by the action of rain, leaving hills and valleys. The charm of bold mountain scenery is due to inequalities produced by erosion of this kind.

Erosion and stratification are continually modifying the earth's surface to-day as they have done in the past. The process of stratification is often noticeable on the sea-shore, where deposits are left by receding tides and hardened in the sun.

Fissures.—Faults.—Veins.—When strata break under pressure from the sides, the openings thus produced are called Fissures. Sometimes one wall of the fissure slides past the other, so that the strata on opposite sides are unlike. The result is called a Fault.

Such displacement in mountainous regions often amounts to thousands of feet. If the fissure becomes filled with rock material afterward, this is called a Vein. Most of the ores which yield valuable metals are found in veins. (On stratified rocks, faults, etc., *consult Le Conte's "Elements of Geology," p. 170.*)



Faulted Strata on Railway-Cutting near Tunbridge.

Soil.—All soil, except the trifling amount due to vegetable deposit, and such as is formed by the deposit of mineral particles from air-currents, results from the gradual decay of rock under the action of atmospheric agencies. The perfect gradation from soft surface-soil down to hard rock may often be seen in railway-cuttings, excavations, and quarries.

After the surface-rock has been broken up into soil, this is partly washed off by rain, and hence is often found far away from the place where it was produced. The harder detached masses left behind are roughly rounded by the surface decay, and are called bowlders of disintegration. The unchanged mass underlying the soil is distinguished as bed-rock.

Surface-rock is always traversed by multitudes of fissures, particularly in places where there are great extremes of temperature. Alternate expansion and contraction under the variation of heat causes it to crack, and through these openings moist air and rain-water gain access to great depths. The soluble material of the rock is thus separated from the silica with which it has been associated, and the solid mass crumbles into soil. Flinty rocks decay slowly on account of the insolubility of silica. Granite and limestone decay more rapidly.

In cold climates, frost is an important agent in disintegrating the rocks. Water expands with irresistible force in freezing, and that which percolates into the rock-fissures acts mechanically in splitting the rock into fragments when the weather is cold. At the base of many cliffs lies a pile of loose broken stones, produced by the falling of masses that have been gradually separated under the agency of air, water, and changes of temperature. (On the effects of weathering, *see Prestwich's "Geology, Chemical, Physical, and Stratigraphical," vol. i, p. 152.*)

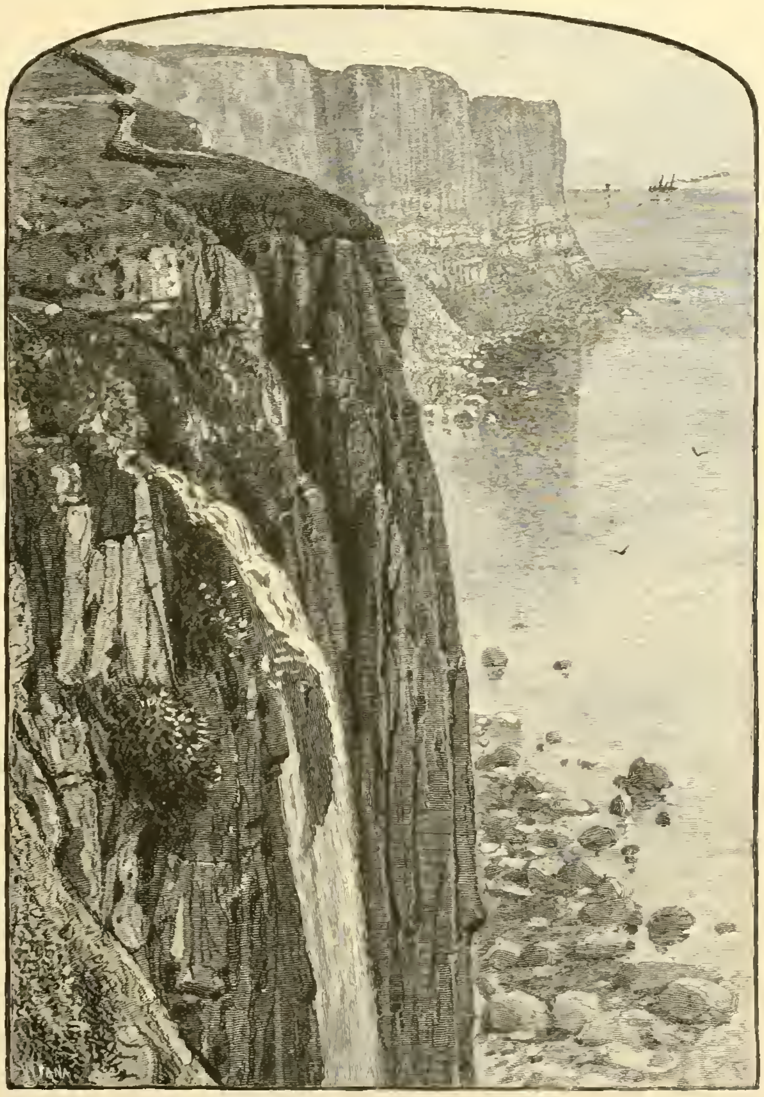
GEOLOGICAL AGES.

Fossils.—The buried remains of animal and vegetable life belonging to former ages are called Fossils (things *dug*). Fossils include not only petrifactions—representing the actual portions of organisms, like bones, wood, and bark—but also the traces of the existence of plants and animals as indicated by the casts of shells, the impressions of leaves, the footprints of various creatures, etc. Rocks rich in such organic remains are known as *fossiliferous.* The relative age of rocks, and often the conditions under which they were formed, are determined by the nature of their fossils.

The science which treats of the living beings that have inhabited the globe at past periods of its history, investigates their nature and distribution, and traces their relationship to existing species, is called Palæontology (*science of ancient life*). The principal fossils peculiar to the different geological formations are described in the following paragraphs and illustrated on the Geological Chart, pp. 12, 13. (For fuller information on this subject, the student is referred to *Nicholson's "Manual of Palæontology," and Binney's "Fossil Plants."*)

Succession in Time.—Careful study of the different layers composing the earth's crust, and of the fossils imbedded therein, has shown geologists that they are arranged in a chronological or time series, and form groups each of which is characterized by its own set of fossils. Special names have been given to the great divisions; thus, the oldest rocks known have been called the Archæan group (from a Greek word meaning *beginning*); the next is the Palæozoic (*ancient life*) group; the third, the Mesozoic (*middle life*) group; and the fourth, the Neozoic (*new life*) group. When used as divisions of time, these names designate Eras.

The subdivisions of these great groups are known as Systems, and the time-intervals during which they were deposited are the Geological Ages. The names of these have been derived from the localities where the corresponding strata are found, or from certain characteristics of the strata. For example, the Archæan rocks are divided into two systems, Laurentian and Huronian—the first taking its name from the St. Lawrence River, the second from Lake Huron.



THE KILT-ROCK, LOCH STAFFIN, SKYE; ITS FANCIED RESEMBLANCE TO THE HIGHLAND KILT DUE TO ALTERNATE STRATA OF TRAP-ROCK AND SANDSTONE.

The names of the groups of rocks and the systems of strata are presented in the following synopsis in tabular form:—

GROUPS OF ROCKS. ERAS OF TIME.	SYSTEMS OF STRATA. GEOLOGICAL AGES.
IV. Neozoic....	Quaternary, Tertiary.
III. Mesozoic....	Cretaceous, Jurassic, Triassic.
II. Palæozoic...	Carboniferous, Devonian, Upper Silurian, Lower Silurian, Cambrian.
I. Archæan....	Huronian, Laurentian.

Archæan Era.—There is no undisputed evidence of life during this era. The earth had cooled down to a temperature below the boiling-point of water, as shown by beds of stratified rocks, greatly folded and highly metamorphic, resting upon deeper material of which we know nothing.

The visible rocks of this group in North America for the most part form a V-shaped strip, extending from Labrador southwest to the Great Lakes, then northwest toward the Arctic Ocean. In Canada they are over seven miles thick. Small patches are also found in the other continents.

Palæozoic Era.—There was abundant life, both animal and vegetable, during this era. Metamorphism is found in many of the rocks; but this feature is far less frequently observed than in those of the previous group.

In the **Cambrian Age** the plants were all sea-weeds. The animals, so far as known, were invertebrate (*without a backbone*) and lived exclusively in the water. The most characteristic creature of this age was the Tri'lobite (*three lobes*, into which its body was divided), a crusta'cean allied to the modern king-crab.

NOTE.—The character and age of strata in such parts of the world as have been explored are now generally understood. Professor Jules Marcou has embodied all the available information on this subject in a geological map (reproduced on pp. 12, 13), showing the range of the chief groups in both hemispheres. It will be observed that the same order of strata is not to be expected in every locality; that owing to causes already explained, Archæan, or the lowest rocks, which if left undisturbed would be buried beyond our reach, may be surface features in one country; Mesozoic, in another; etc. A complete order of strata is never met with in any one place.

While occupied with the study of this map in connection with Professor Newberry's Geological Chart, the pupil will find it both interesting and profitable to visit the nearest geological museum for the purpose of inspecting rocks, ores, and fossils. He is further recommended to familiarize himself with the geological formations, minerals, and organic remains, which may characterize the locality in which he lives; and to verify by his own observation in field, quarry, mine, and cutting, the knowledge imparted in this chapter and gleaned from the books of reference. In cases where practical study of this nature is impossible, the teacher should, as far as circumstances permit, illustrate the subject with mineral specimens. Valuable aids in thus acquiring the true method of this science will be found in Canon Kingsley's "Town Geology," and Winchell's "Walks and Talks in the Geological Field." Read also "My First Geological Excursion," in Geikie's "Geological Sketches."


GEOLOGICAL MAP
OF THE WORLD
(AFTER MARCOU)
Longitude East 180 West from 150 Greenwich 120 90 30 Longitude
EXPLANATION OF COLORS.
Recent and Quaternary
Tertiary
Cretaceous and Jurassic
Trias and Permian
Trias and Dyas (Marcou)
Carboniferous
Devonian, Silurian and Cambrian
Crystalline
Volcanic
Water (Seas and Lakes)
ARCTIC OCEAN
PACIFIC OCEAN
ATLANTIC OCEAN
NORTH AMERICA
SOUTH AMERICA
SIBERIA
ASIA
ALASKA
GREENLAND
GRANT LAND
GRINNELL LAND
HALL LAND
WASHINGTON LAND
Kane Sea
Cape York
BAFFIN BAY
DISCO I.
Davis Strait
C. Farewell
ICEL
Mt. Hecla
PARRY ISLANDS
Melville Sound
Lancaster Sd.
Bering Strait
BERING SEA
Okhotsk Sea
ALEUTIAN ISLES
Yukon R.
Mackenzie R.
Gt. Bear L.
Gt. Slave L.
HUDSON BAY
LABRADOR
Str. of Belle Isle
NEWFOUNDLAND
G. of St. Lawrence
Quebec
Ottawa
Halifax
New York
Saskatchewan R.
L. Winnipeg
L. Superior
Chicago
Missouri R.
Mississippi R.
Ohio R.
ROCKY MTS.
VANCOUVER I.
Gt. Salt L.
San Francisco
Savannah
FLORIDA
BERMUDA IS.
AZORES
MADEIRA IS.
CANARY IS.
CAPE VERDE IS.
Gulf of Mexico
G. of California
MEXICO
Mexico
BAHAMA IS.
CUBA
WEST INDIES
Caribbean Sea
CENTRAL AMERICA
Panama
HAWAIIAN OR SANDWICH ISLANDS
EQUATOR
GALAPAGOS IS.
LLANOS
Orinoco R.
Amazon
SELVAS
C. St. Roque
Pernambuco (Recife)
Lima
L. Titicaca
ANDES
Parana R.
Rio Janeiro
PAMPAS
Valparaiso
Buenos Ayres
Montevideo
Rio de la Plata
Magellan Strait
FALKLAND IS.
SOUTH GEORGIA
MARQUESAS IS
SOLOMON IS.
NEW GUINEA
Torres Str.
SAMOA IS.
FIJI IS.
NEW HEBRIDES
NEW CALEDONIA
FRIENDLY IS.
SOCIETY IS.
PAUMOTU IS. or LOW ARCHIPELAGO
AUSTRALIA
Sydney
Melbourne
TASMANIA
NEW ZEALAND
Wellington
WILKES LAND
ANTARCTIC CONTINENT
VICTORIA LAND
Mt. Terror
Erebus Volcano
GEO
LAURENTIAN
HURONIAN
CAMBRIAN
L. SILURIAN
U. SILURIAN
DEVONIAN
ARCHÆAN
PALÆOZO

ICAL CHART by PROF. J. S. NEWBERRY, of Columbia College, N.Y. Illustrating the Development of Life on the Earth from the Archæan Era to the Age of Man.
CHARACTERISTIC FOSSILS ARE SHOWN IN CONNECTION WITH THE SEVERAL SYSTEMS. See p. 139.

Some of these trilobites were fully two feet in length. The perfection of the eye in many fossils is noticeable; the lenses, sometimes between three and four hundred in number, are arranged, as in the common butterfly, so as to command an extended field, and suggest conditions of water and atmosphere similar to those that now exist. From the abundance of this crustacean, the Cambrian has been called "the Age of Trilobites."

Silurian Ages.—The two Sīlu′rian Ages (so named from the ancient Sīlu′res who inhabited that portion of Wales and England where the rocks of these two systems abound) are alike in having mollusks (animals like the snail, with soft, fleshy bodies; *see p. 101*) as their most abundant and characteristic fossils. Together they form "the Age of Mollusks." Trilobites were still abundant, but not the reigning type of animal life.

The Lower Silurian plants were all sea-weeds. The most powerful animals were huge cuttle-fishes, one species of which was provided with a straight conical shell, partially divided into chambers. Some of these shells have been found a foot in diameter and twenty feet in length.

The Upper Silurian fossils are almost entirely distinct from those of the Lower Silurian system. Mollusks predominate, and trilobites are abundant but diminishing. Many Corals are found, but different from those of modern times. Quite numerous were the Crī′noids (*lily-forms*), animals which were rooted to the sea-bottom like plants, and presented a striking resemblance to lilies. Their fossil remains are often called Stone-lilies. Vertebrates (animals with jointed skeletons, *see p. 100*) make their appearance in the Upper Silurian Age, in the form of a few small fishes allied to the sturgeon and shark. Land-plants, such as ferns and club-mosses, are first found.

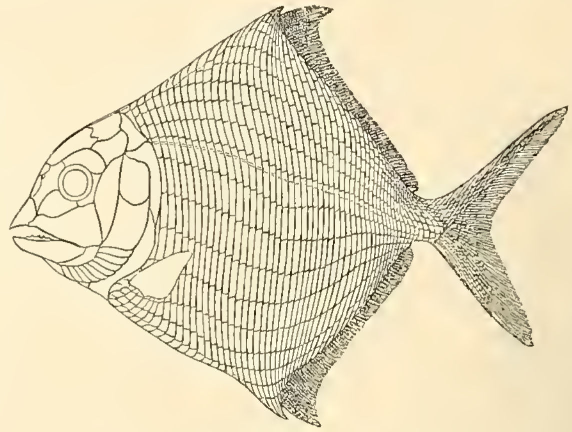
The life of the **Devo′nian Age** (named from *Devon*shire, England) is marked by the great abundance of fishes; but these are of a low type, with imperfect bones, and having bodies often covered with plate-like armor. It is called "the Age of Fishes." Land-plants were now numerous, and formed the first forests. Devonian rocks are the principal source of our mineral oil and gas.

Coal-Fern restored (after Dawson).

The Carboniferous Age is so called from the beds of coal which occur in the rocks then deposited in Europe and Eastern America. The "Coal-Measures" were beds of peat which accumulated in marshes, and this by pressure and partial decay gradually became bituminous coal. Where the Carboniferous rocks have been metamorphosed, or otherwise subjected to heat, the bituminous coal is converted into anthracite, or even into graphite (*plumbago*, or *black-lead*).

The trees during the Carboniferous Age were in many respects very different from those that are now most abundant. Tree-ferns were of great size. Cane-like rushes grew to a height of forty feet; club-mosses, which are now rarely more than a few inches high, constituted an important part of the dense forests of those times.

The animal life was similar to that of the preceding age, with the addition of some remarkable amphibians (*adapted for living on land or in water*), creatures intermediate between fishes and reptiles. A few true reptiles appeared during the last part of this period, and the fishes were still low in type and somewhat reptilian in their characteristics. Insects now for the first time occurred in considerable variety. (On coal-plants and animals of the coal-measures, *consult Professor Thorpe's "Coal, its History and Uses," pp. 73 and 110.*)



Fish of the Coal-Measures (after Traquair).

Mesozoic Era. — During this era reptiles were the representative animals, attaining great size and existing in large numbers. It was pre-eminently "the Era of Reptiles." Some were adapted for walking on the land, some for swimming in the water, and others for flying in the air. These last were, therefore, bird-like in their characteristics. Amphibians of great size formed the connecting links between them and the fishes.

The life of the **Triassic Age** (represented by *three* series of strata in the Old World) was marked by the prevalence of cone-bearing and fern-like plants, and of amphibians and reptiles. Multitudes of bird-like tracks, mostly three-toed, made by the latter, are found in the Triassic sandstone of the Connecticut Valley and New Jersey, varying from an inch to two feet in length. A few small mammals (*see p. 102*) of the lowest type existed toward the close of the Triassic Age.

The Jurassic System takes its name from the Jura Mountains, in Switzerland. In North America it is, for the most part, confined to the western portion of the continent, appearing in Colorado, Wyoming, Idaho, and Utah.

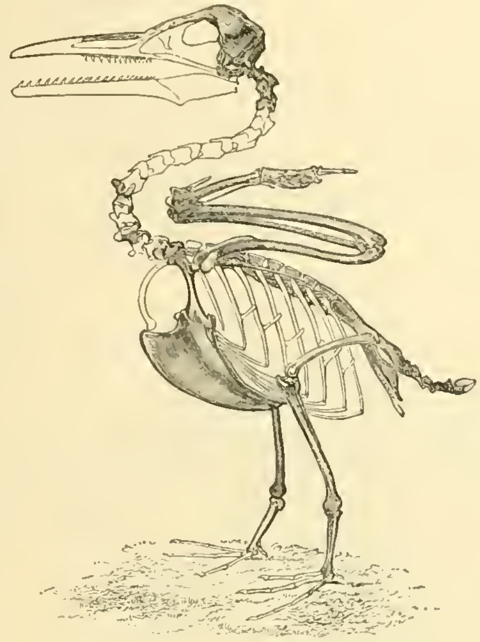
The Jurassic Age saw the culmination of the animal and vegetable life of the Mesozoic Era. Reptiles were the predominant type. Among them was the largest animal known, the plant-eating Atlanto-sau′rus, over one hundred feet in length, with a height of thirty feet. The Ich-thy-o-sau′rus (*fish-lizard*) and the Plē′si-o-sau′rus (*nearly a lizard*) were the rulers of the sea—the former, thirty or forty feet long, with short neck, immense jaws, and eyes a foot in diameter; the latter, with small head and almost swan-like neck. Both were provided with paddles instead of feet (*see Geological Chart*). Flying reptiles were also peculiar to this period. The best known of them, the Pter-o-dac′tyl (*winged finger*) had a distinctly reptilian head, jaws furnished with formidable teeth, a breast-bone like that of a bird, a bony tail, and a pair of bat-like wings attached to the elongated outer fingers of its hands.

The remains of the first bird are found in the Jurassic rocks; the seas swarmed with fishes.

The Cretaceous System takes its name from the Latin word *creta*, meaning *chalk*, a chalky limestone constituting one of its most important elements in England. This system covers more of the surface of North America than any other, including the clays and marls of New Jersey, as well as the sandstones, shales, and limestones, which extend from the Mississippi River to the Wasatch Mountains in Utah, and from southern Mexico to northern Canada.

The animals and plants were generally similar to those of the two previous ages. A peculiar cretaceous bird was the Ich-thy-or-nis, with a back-bone like that of a fish, a keel-like breast-bone, and no horny beak, but a pair of long, slender jaws, well furnished with socketed teeth. Its size was about that of a pigeon.

Neozoic Era.—At the close of the Cretaceous age, the life of the globe seems to have been revolutionized; the great ammonite family (allied to the nautilus), the most striking feature in Mesozoic molluscan life, and all the characteristic reptiles of the Reptilian ages, disappeared, while mammals multiplied and increased in size until they spread over and ruled the earth. Birds also in the later Cretaceous epochs gradually superseded the flying reptiles, and in the Tertiary wholly replaced them. The natural world then assumed its present aspects, and subsequent changes have been in degree, not in kind.



ICHTHYORNIS—*Fish-Bird* (AFTER MARSH).

In North America the **Tertiary Age** seems to have been the most interesting part of its geological history. The continent had then nearly its present form and dimensions; the sea covering only a narrow margin along the Atlantic and Pacific coasts, and reaching up the valley of the Mississippi as far as the mouth of the Ohio. The western portion of the continent was occupied by a series of great lakes, which in succession were filled or drained, changing their places or outlines at different epochs. The climate was mild to the Arctic Sea; the entire land-surface was covered with a luxuriant vegetation, and inhabited by a more abundant and varied fauna than now exists in any portion of the earth. The remains of this fauna and flora are found buried in the sediments by which the old lakes were filled.

Already many hundred species of land-animals and land-plants, with fresh water fishes and mollusks, have been obtained from these great cemeteries, and many more remain to reward future collectors.

From strata of the Tertiary Age in Greenland and Alaska, plant-remains have been obtained which show that our cypress, magnolias, tulip-tree, and sweet-gum, grew along the shores of the Arctic Ocean, and with these many colossal trees which have since disappeared. The giant trees of California, as also the finest elements in the Eastern forests, are relics of the luxuriant vegetation of the Tertiary Age.

The Tertiary is called the "Age of Mammals." All the mammalian types were represented, but the differences of species were not so marked as at present. The horse appears during this age, first as a little creature, the size of a fox, with three hoofed toes on each hind-foot and four hoofed toes on each fore-foot; later it attains the size of a sheep, and is provided with three toes on each foot; and still later, it develops into a single-hoofed animal, about the size of an ass, each foot provided with a pair of side-toes, not long enough to reach the ground.

Quaternary Age.—Age of Man.—After the Tertiary Age had continued long enough for the deposition of many thousand feet of strata, a great change took place in the climate of the northern hemisphere. That of the Arctic regions, which had been warm temperate, changed to what it is at present (in consequence, it is supposed, of a variation in the eccentricity of the earth's orbit). This change progressed until the climate now characteristic of Greenland and Alaska was brought down as far as New York, and all the more northern portions of the American Continent were buried under sheets of perpetual snow and ice. Animal and vegetable life was either totally destroyed or driven with many losses into southern lands. (On the work of the Glacial Time, and the effect of glaciation on the life of the earth, *consult Professors Shaler and Davis's "Glaciers," pp. 49 and 117.*)

This is called the Ice Period. The proof that glaciers covered all the highland of the northern half of this continent is found in the planed and worn condition of the surface-rocks, and the southward spread of great sheets of sand, gravel, and bowlders, from their places of origin —phenomena which only moving ice could produce. These glaciers after a time receded with the return of more moderate climatic conditions.

Similar traces of the Ice Period are found in Europe, Asia, Australia, New Zealand, and South America; but it is not probable that the cold periods occurred at the same time in the northern and southern hemispheres. (*See Croll's "Climate and Time in their Geological Relations."*)

Life during the Ice Period seems to have been much like that of the present day; but many animals similar to those that now dwell in torrid regions were then adapted to a cold climate. The Mammoth was an elephant, about twice the size of that now found in Asia, but distinguished from the latter by its dense under-coat of wool and long, coarse outer hair. Immense numbers of more or less entire mammoth-carcasses have been found in the frozen soil of northern Siberia; for centuries the fossil ivory furnished by their huge curved tusks has been an important article of Eastern commerce. The woolly rhinoceros, the mastodon, the great Irish elk, the cave-bear, the saber-toothed tiger—these and many other species probably preceded man, and have become extinct since the beginning of the human epoch. In New Zealand are found the remains of the gigantic Mo'as, wingless birds about twelve feet high.

The Advent of Man.—Up to the present time no remains of man have been found in deposits older than the Ice Period. In Europe, where the subject has been most thoroughly studied, it is thought that the first traces of man date from the time when the great glaciers began to disappear. Along with the hairy elephant and the woolly rhinoceros, the musk-ox and the reindeer, he followed the ice-fields and glaciers in their retreat to the far north. The prehistoric man of central Europe is believed to be now represented by the Finns and Lapps. He dwelt in caves, used the rudest stone implements, and contended with the other mammalia for the mastery of the earth. Of primitive man in Asia and Africa, nothing is definitely known. (On the antiquity of man, *consult Dawkins's "Early Man in Britain"; Wilson's "Prehistoric Man."*)

Questions.—Of what is the earth's crust composed? How are rocks classified? To what do the several varieties owe their origin? Explain stratification. Prepare a geological section illustrating varieties of stratification. Show, by a simple diagram, the nature of fissures, faults, and veins. Describe the appearance of rocks in a quarry or cutting, and tell what you understand by soil. By what agencies have changes in the earth's surface features been produced? Explain erosion; contraction by cooling of the earth's crust. How may we infer the future of our planet?

What are fossils? Explain their value to the geologist. What minerals are derived from fossil vegetation? Into what eras does geology divide the history of the globe? Name the systems of strata corresponding to each. Give an account of the animals and plants which characterized the several geological ages, and enumerate the changes that marked the beginning of the Neozoic Era. What climatic change, how explained, occurred at the close of the Tertiary Age? Give an account of life during and after the Ice Period. What is known of the advent of man? Explain the peculiarities of a geological map. Let the pupils prepare (in colors) an outline map, illustrating the geological structure of North America; also a geological map of their own state, if the necessary data can be obtained. (See specimens in Appletons' Geography of Virginia, of Pennsylvania, and of South Carolina.)

The Relief of the Earth.—The surface of our globe is crumpled or corrugated. Great masses of the crust have been raised, and extensive areas depressed. The largest elevated areas, which rise above the ocean, are known as continents; the great depressed areas, as oceanic valleys, being filled, up to a certain level, by the sea. These primary elevations and depressions are diversified by numerous secondary ones, producing the great plateaus and valleys, which give their general character to the continents; while these, in turn, are traversed by numerous smaller lines and groups of elevation, forming mountain- and hill-ranges, when they are abrupt and steep, and smaller plateaus, when the slopes are gradual.

All this *Relief*, as the alternation of elevation and depression of the earth's surface is called, is, as has been shown, the result of the opposing action of two agencies, that of strains or stresses in the solid crust of the earth, which produces elevation; and that of erosion, which cuts down and washes away. The science that treats of the relief of the earth, as well as of the system in the physical changes on the earth's surface, is known as *Physiog'raphy.*

Movements of the Earth's Crust.—The crust of the earth is not in a state of equilibrium. It is constantly subject to strains, and some portion of it is always in motion, either rising or sinking. Fossils found in the strata which compose certain mountain-ranges prove them once to have been sea-bottoms. Regions of elevation and depression are usually long in proportion to their breadth, as is seen in the form of the continents and in mountain-ranges.

Elevation takes place in one of two ways: First, beds of rock may be bent upward in the form of an arch, without breaking. The rise may be very slight in proportion to the breadth of the uplift, as is the case with the continents and great plateaus; or it may be great, as is to be seen in many mountain-ranges.

The second form of elevation is that in which the beds of rock are broken, and those on one or both sides of the break are bent upward. This form is seen in many mountain-ranges and smaller plateaus. The slope is generally much steeper on the broken side.

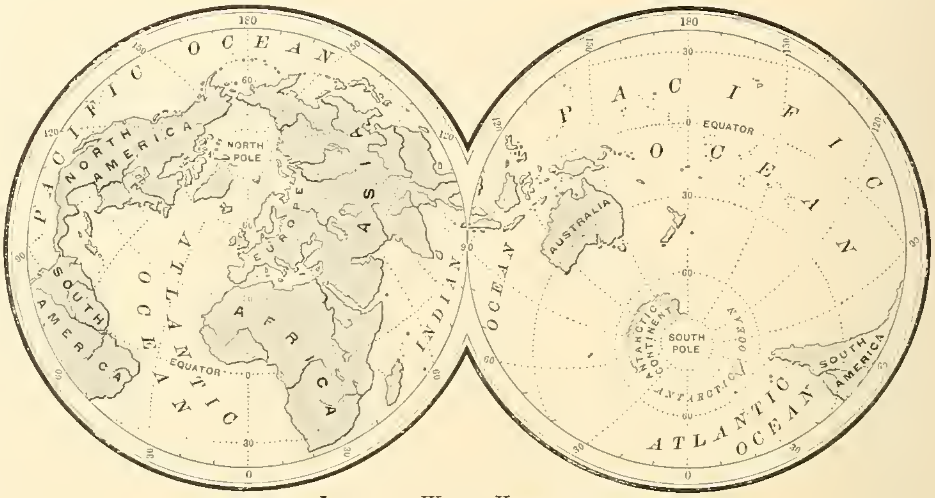
It is in this way that the land rises; but while rising, and indeed always, it is subjected to the attacks of an opposing agency, from which it will be freed only when it has been reduced to the level of the sea. (On the movements of the land, *see Huxley's "Physiography," p. 205.*)

Erosion.—No sooner does the land begin to rise, than the agencies of erosion, always at work, are brought into increased activity. Rain falls more abundantly and streams are swollen. The slope of the stream-beds also becomes greater; rivers flow more swiftly, and are capable not only of carrying off large amounts of sand and gravel, but cut away their banks and beds with greater speed. The temperature falls, and frosts disintegrate the rocks more rapidly into soil. The winds blow with increased force, and, carrying sharp sand, play a very efficient part in planing down the country.

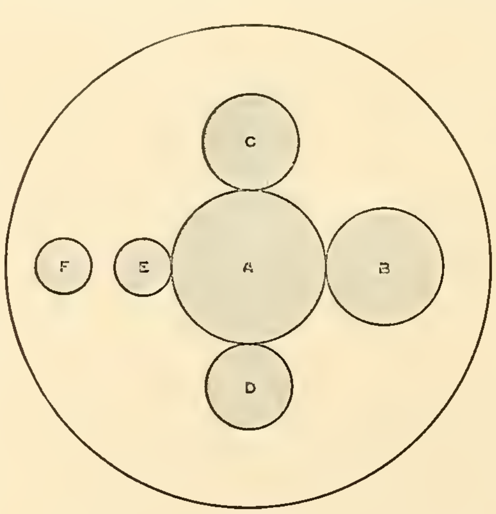
By means of these agencies, which are constantly at work leveling the land, a great part of the efforts of the forces of elevation have been brought to naught. Enormous masses of rock have been ground to powder, and carried down into the valleys or deposited upon the bed of the sea. From vast areas of land, strata of rock, thousands of feet thick, have been removed. Whole continents with their mountain-ranges and plateaus have thus been worn away, and the dry land upon which we live to-day has been built of their *débris.*

THE LAND.

The Whole Area of the earth's surface comprises about 197,000,000 square miles. Of this area, a little more than one-fourth (about 52,000,000) is land, while nearly three-fourths is covered by the sea. The deepest parts of the ocean are about $5\frac{1}{2}$ miles below the surface, while the highest mountain-peaks are almost as far above it. The distance from the depths of the sea to the summits of the highest mountains is therefore a little less than eleven miles, and this represents the total relief of the earth. Let us compare this with the earth's magnitude. The length of the earth's radius is not quite 4,000 miles; its relief is then but $\frac{1}{360}$ of its radius. If the earth were represented by a ball six feet in diameter, the tops of its highest mountains should be represented as but one-tenth of an inch above the deepest ocean bed.



LAND AND WATER HEMISPHERES.



COMPARATIVE AREAS OF LAND AND WATER.

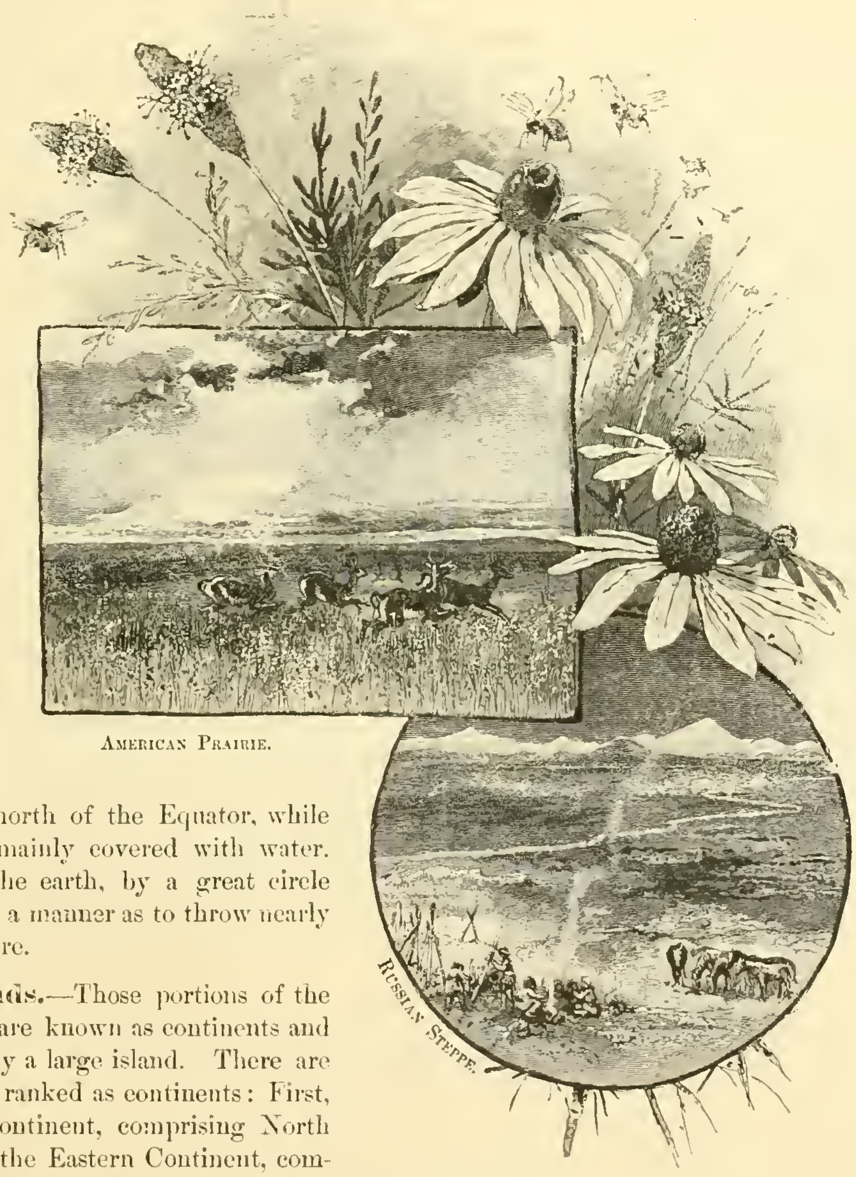
If the surface of the whole earth be represented by that of the largest circle, then the circle marked A will on the same scale represent the area of Europe and Asia; B, Africa; C, North America; D, South America; E, Australia; F, the sum of all the islands known. The rest of the space within the large circle represents the sum of all the oceans.

While the land covers fully a fourth of the earth's surface, and its greatest elevations nearly equal the lowest depths of the sea, its volume is very much less proportionally than that of the ocean. The great elevations of the land are mountain-peaks, while the great depressions of the sea consist of broad valleys. The average height of the land is estimated to be about 1,500 feet, and the average depth of the sea about 12,000 feet, or eight times as much as the height of the land. The volume of water composing the sea is therefore about twenty-four times as great as that of the land lying above sea-level. If the earth's surface were flat, the sea would cover it uniformly to a depth of about 8,500 feet, or more than a mile and a half.

The Oceanic Valleys.—The greatest valleys of the earth are occupied by the sea. The continents are vast plateaus separating the oceanic valleys. These continental plateaus are not always wholly above the sea; their outskirts are beneath the waves. There are other plateaus and mountain-peaks of less height, which, rising from the bed of the ocean and barely reaching the sea-surface, form islands; while yet others, still less elevated, are entirely submerged.

The Pacific Ocean occupies the largest and deepest valley on the globe. From its depths many mountain-peaks rise to the surface as islands; and it is separated from the Indian Ocean by a great plateau, extending southeastward from Asia, part of which is below and part above the surface of the water. Java, Sumatra, Borneo, Australia, and New Zealand, are included in this plateau.

In some places the bottom of the sea slopes off very gradually from the land for great distances seaward, as about the British Islands and Newfoundland; while in other places, the water deepens abruptly from the coast-line, as in the neighborhood of Japan and the Kurile (*Koo'ril*) Islands. (*See map, pp. 20 and 21.*)



American Prairie.

Russian Steppe.

Distribution of the Land.—The land is very unequally distributed over the surface of the earth. Not less than three-fourths of it lies north of the Equator, while the southern hemisphere is mainly covered with water.

It is possible to divide the earth, by a great circle oblique to the Equator, in such a manner as to throw nearly all the land into one hemisphere.

Continents and Islands.—Those portions of the land which rise above the sea are known as continents and islands. A continent is simply a large island. There are four bodies of land which are ranked as continents: First, the Western or American Continent, comprising North and South America; second, the Eastern Continent, comprising Eurasia (Europe and Asia) and Africa; third, Australia; and, fourth, the Antarctic Continent. Islands may be classed as continental and oceanic. The former lie near continents and properly form parts of them. They generally rise from comparatively shallow water, so that a slight depression in the ocean-level would lay bare a connecting isthmus. They are frequently long in proportion to their width, and parallel to the shore. In many instances they are the summits of submerged mountains, as in the case of the Aleutian Islands on the northwest coast of North America, and Tierra del Fuego at the southern extremity of South America.

Oceanic islands are those located far from large bodies of land. They are either volcanic in their origin, or the work of coral pol'yps (*see p. 30*). Volcanic islands are generally small in extent and mountainous.

The great bodies of land upon the globe show certain general peculiarities and resemblances. With hardly an exception they are broadest in the north. This peculiarity is strongly marked in North and South America and Africa, and may easily be traced in Eurasia. They taper to points southward, as is seen in the two parts of the American Continent and in Africa. This is true not only of most of the continents, but also generally of the great peninsulas jutting from them, such as Florida, in North America; Scandinavia, Spain, and Italy, in Europe; and Hindostan, Corea, and Kamchatka, in Asia. Eurasia is comparable to a huge hand "stretching with open fingers toward the south."

Plains and Mountains.—The infinite variety in the relief of the earth's surface may be classified into two general groups of features—Plains and Mountains. Mountains are high, abrupt elevations of land. All land that is not mountainous may be regarded as constituting plains, which occupy by far the greater part of the exposed surface of the earth.

A Plain may be level, or undulating, rolling, or even broken and hilly. Its surface may be horizontal, or inclined at low angles. Its elevation above the sea may be small or great. When high above sea-level, it is generally known as a Plateau or Table-Land. Its limits may be sharply defined by a line of ascending or descending cliffs, in which case it is also called a Plateau, or, if of small extent, a Mesa (*mĕs'a*). It may lie between two mountain-ranges or plateaus, and be the result either of erosion or of the fracture of upheaved rock-masses; in this case it is called a Valley. It may be low and wet, when it is known as a Swamp, Bog, or Marsh; and, if it be so near the North or South Pole as to be constantly frozen, at least in part, it becomes the Tundra of the Arctic regions. It may lie under an arid climate, when it is more or less completely a Desert. It may be covered with forests, as in the Silvas of the Amazon, of South America; or it may be mainly grass-grown, with occasional belts of trees, like the Prairies (in French, *meadows*) of North America, the Llanos (*lyah'noce;* in Spanish, *levels*) and Pampas (in Peruvian, *plains*) of South America, and the Steppes of Siberia. Barren, sandy levels, chiefly used for pasturing sheep, are known in England as Downs. Elevated lands, covered with a growth of small trees, but not timber, are called Barrens; they are not necessarily sterile.

It will thus be seen that the word *plain* is a very general term, not admitting of short or exact definition. Some of the varieties of plains defined above will now be described more in detail.

Plateaus.—In the southwestern part of the United States, there is a region of typical plateaus or table-lands. It is the area drained by the Colorado River and its tributaries. The surface of the plateaus is nearly flat; there is no rolling, undulating, or hilly country. Changes of level take place by gentle slopes; or by abrupt, precipitous cliffs, often of great height. The whole country is angular. There are no valleys; every stream is in a cañon (*kan-yŭn*), or gorge between steep banks, and flows hundreds, or it may be thousands, of feet below the level of the country. As this is an arid region, there are many cañons which are dry during most of the year.

Some of these cañons are of enormous depth, that of the Colorado River being, at the deepest place, nearly 7,000 feet below the surface of the plateau. The walls form a succession of steps, a veritable giants' staircase, with rises of 1,000 to 2,000 feet each.

In some regions, cañons are so numerous that they have left but a mere skeleton of the original plateau, which has the form of narrow, level ridges, separating the countless gorges of the streams. In other places the rains, streams, and winds, have worn away whole beds of rock from great areas, leaving only here and there a fragment of harder rock, which has successfully withstood the attacks of the elements. These fragments, which are usually flat-topped, with precipitous sides, are known as Buttes (*bŭtz*). (On the cañons of the Colorado and Major Powell's expedition, *see "Our Native Land," p. 4.*)

Swamps.—Swamps occur mainly in regions of heavy rainfall. They commonly occupy level country, where the slope is not great enough to carry off the water. In many places along the sea-shore are found areas which are so slightly elevated as to be flooded at high tide. These are known as salt-marshes. Swamps are usually covered with rank vegetation, and frequently with forests. The decay of this vegetation produces a rich soil, which makes the land valuable when reclaimed.

Tundras.—Along the shores of the Arctic Ocean (*see "Map of North Polar Regions," p. 54*), in both Asia and America, extending for hundreds of miles to the south, are vast level areas of what is called *Tundra*. In this cold region the soil is frozen constantly to a great depth. In the short, hot summer, the surface of the ground thaws, while below it remains solid. The surface quickly becomes covered with a luxuriant growth of heath and Arctic mosses, the latter affording food to the reindeer. This dense vegetation, together with the absence of slope, prevents the water from flowing off, and so the surface of the ground, covered with these mosses, is, like a wet sponge, constantly saturated with water. Travel in such a region in summer is almost impossible; but in winter, when all is frozen and covered with snow, the sledge, drawn by dogs or reindeer, affords a rapid and easy mode of locomotion. (For a description of a Siberian moss-steppe, *see Kennan's "Tent-Life in Siberia," p. 130.*)

Deserts owe their existence to the lack of rain. A typical desert is without vegetation or soil, its surface consisting of bare rock, or covered with shifting sands. A region, however, may still be a desert, though in less degree, if its surface is covered with soil, and even with sparse vegetation, such as the artemisias and cacti, of little value to man. Fertile spots in deserts are called O'ases.

Steppes, Llanos, Pampas, and Great Plains.—The steppes of Siberia, the llanos and pampas of South America, and the great plains of North America, resemble one another in general appearance. They differ mainly in temperature. The climate, as regards moisture, is semi-arid. There is not sufficient rain for the needs of trees, but generally enough for grasses. Such regions, therefore, occupy a position midway between deserts and forest-covered plains. Their surface is generally monotonous and undulating. The valleys of the few streams are but slight depressions, while the divides between the streams are not well defined. There are few landmarks, and the traveler over these great wastes is easily lost, if he leaves the beaten paths. (On Patagonian pampas, *see Muster's "At Home with the Patagonians," p. 15.*)

The Prairies of North America form a connecting link between the Great Plains and the forest-covered levels in the northern part of the Mississippi Valley. They everywhere occur along the line of junction of these two kinds of plains, but generally in narrow belts. They are better watered than the Great Plains, and hence are mainly covered with luxuriant grasses, interspersed with groups of trees, the latter becoming larger and more frequent as the forest-region is approached. Wild flowers of gay hue are in their season an attractive feature. The surface is usually level or gently rolling.

Where the seasons are distinguished as wet and dry, such grassy plains, which afford pasturage during the rainy season only, are called Savannas (in Spanish, *linen sheets*, from the appearance of the plains when covered with snow). Treeless regions of less extent are known in Europe as Heaths.

Forest-covered Plains.—Where the rainfall is sufficient for the needs of trees and the climate not too cold, the plains become covered with forests. The most magnificent forest-covered plain in the world is the region drained by the Amazon River. Here vegetable life, under the stimulus of a tropical sun and an enormous rainfall, attains extraordinary luxuriance. The soil produces a heavy growth of immense trees, among which are crowded herbaceous plants and climbing vines, making a mass of vegetation so dense that it can not be penetrated. The only avenues of travel through these Silvas of the Amazon, which cover a million square miles, are by the great river itself and its hundreds of branches.

Mountains are abrupt elevations of land. Hills have less height. Mountains occur most commonly in long ranges, having a definite direction or trend. They also appear in groups with little or no apparent system, and in isolated peaks; in the latter case they are usually of volcanic origin. Mountain-ranges are generally grouped in systems, the several chains having a common direction, and being separated by narrow valleys. Thus the Rocky Mountain system of North America, which crowns the great western plateau, consists of many ranges, all trending nearly north and south. The geographical axis of a continent is the main ridge, not necessarily continuous or the highest water-parting, from which the land slopes and the water flows in opposite directions.

Mountain-ranges differ greatly in length, breadth, height, and angle of slope. Some run for hundreds, and even thousands, of miles without a break, as the Andes, which traverse the South American Continent from north to south in an unbroken line. Some single ranges are fifty miles in breadth, rising upon either side in long slopes, cut into spurs or secondary ranges by torrents; while others, having steep, simple slopes or cliffs on the sides, are not more than two or three miles in breadth between the valleys at their bases. A mountain range or chain is sometimes known as a Cordil'lera (in Spanish, *little rope*); also as a Sierra (*saw*) when marked by a succession of pointed summits.

The Height of Mountains.—When we speak of the height of a mountain or of a range, it is generally its height *above mean sea-level* that is intended, as that is the most convenient level to which it can be referred. In very few cases, however, does this represent the height of the mountain above its base, which is generally very much less.

Thus, we speak of Mount Lincoln, in Colorado, as being 14,297 feet high—that is, above sea-level. This mountain stands, however, upon a plateau 10,000 feet above the level of the sea, so that its height above the country at its base is but little more than 4,000 feet. A mountain having an elevation of more than 10,000 or 12,000 feet above its base is rarely found upon the earth; while, commonly, the high mountains do not rise more than half that height. The most abrupt elevations are usually found in the case of volcanic peaks.

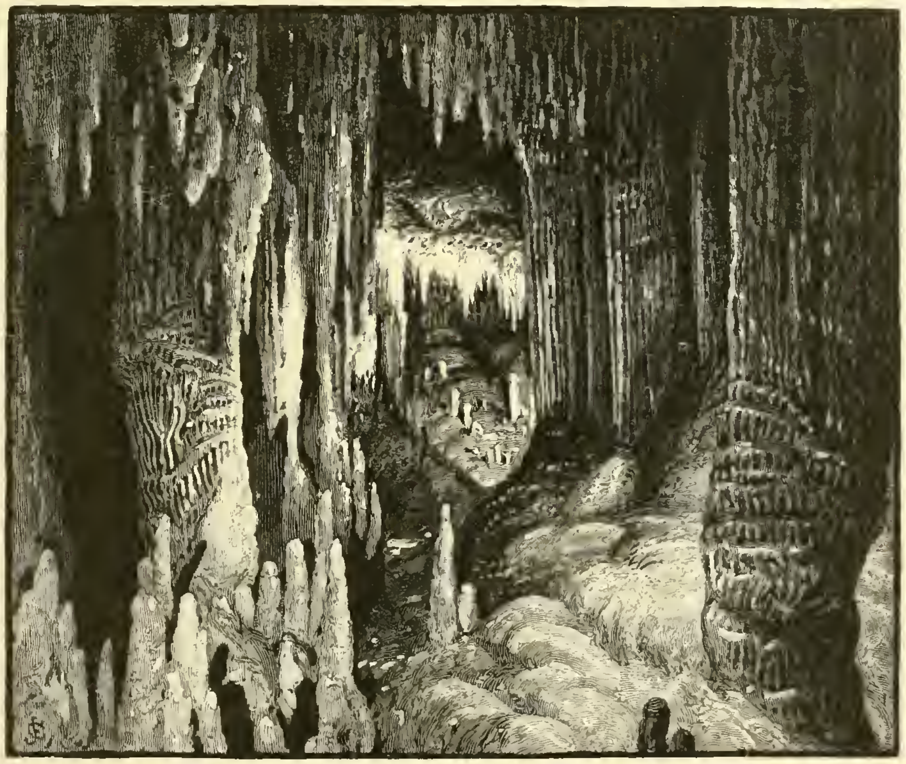
Erosion of Mountains.—Wherever erosion, from one cause or another, has produced but little effect, we find the mountain-ranges very nearly in the condition in which they were at the time of upheaval. Such ranges have smooth slopes and level tops, whether they be broad and plateau-like, or narrow and sharp.

But where rains, rivers, winds, and frosts, have had unrestricted play, the result is very different. The sides of the range are deeply scored by the beds of streams, producing gorges or cañons if they are narrow, and valleys if they are broad. Between them stand fragments of the original mountain, which are known as spurs. These spurs themselves may in turn be carved into a succession of secondary spurs and gorges. (On mountains and their origin, *consult Agassiz's "Geological Sketches," p. 94.*)

Mountain-streams have their origin far up in the heart of the range, and by them the crest-line itself is cut into a succession of high points and depressions. The former are known as Peaks, or locally as Domes, Balds, etc. The depressions, if practicable for travel, are called Passes or Gaps.

A mountain-range is sometimes divided into two parts by a depression through which a stream may flow from the valley on one side to that on the other. Such a depression is known as a Water-gap. The notch in the Blue Ridge, through which the Potomac flows, is an example of a water-gap.

The origin of water-gaps is interesting. In many cases, the river occupied its present course before the mountain was there. It had the right of way, and as the mountain slowly rose, the river, aided by the sharp sand and other eroded material which it was bearing to the sea, began to cut its way through the barrier which was forming across its path. In very few cases have rivers failed to maintain their courses through such obstacles. Mountains may rise and be eroded away; rivers not only flow on, but retain their ancient beds.



Campbell's Hall, Luray Cavern.

The Vegetation upon Mountains.—Mountains are generally covered, up to a certain height, with forests, unless these have been removed by the hand of man. Forests require a comparatively humid climate and heavy rainfall. The warm and moist air-currents which pass over the low country are, on reaching the mountains, forced upward into colder regions of the atmosphere. There they become chilled, and unable to hold as much moisture as before. Thus they are compelled to precipitate a portion upon the mountains, which are thereby well watered and clothed in forests, though the plains all around may be arid and barren. In some of the hottest, most arid regions, however, even the mountains fail to induce clouds to form and rain to descend; such mountains are not clothed with forests.

The Timber-Line.—At a certain height upon the mountains, where the average temperature for the year is below the freezing-point, the climate becomes too severe for trees to grow. This is called the timber-line. Above it there is little vegetation, except certain hardy grasses.

The timber-line varies greatly in height in different parts of the globe. It is highest near the Equator, where the temperature is greatest, and descends as the latitude increases. It is highest also where the country surrounding the mountains is high, and descends as the base of the mountains approaches sea-level. Most of the smaller mountains do not reach the timber-line, and are or may be covered with forests to their summits.

The Snow-Line.—At a still higher level upon the mountains, snow is always found, even in midsummer. The lower limit of perpetual snow is known as the snow-line. In the United States, snow lies throughout the year, in large bodies, only on the highest of the extinct volcanoes of the Cascade Range in Oregon and Washington, and upon the mountains of Alaska.

Caves and Grottoes.—In many regions, especially where limestones are abundant, caves are found, usually opening on the slopes of mountains and hills, or the abrupt sides of valleys and ravines. Limestone is very soluble in water which contains carbonic acid, and such water, percolating through the rocks, dissolves them and carries them away. In time, great quantities of rock are removed, leaving underground chambers and passages miles in extent. Thus have been excavated the Mammoth Cave of Kentucky, extending nine miles underground in a wonderful succession of avenues, abysses, domes, lakes, and rivers; the Luray Cavern of Virginia, with its "diamond chambers," rich in crystal beauty; and many others less notable in these states and in Tennessee. (*Consult Dr. Hovey's "Celebrated American Caverns."*)

PHYSIOGRAPHY

EXPLANATION OF COLORS.

HEIGHT OF LAND.	DEPTH OF WATER.
From Sea Level to 600 feet	*From Sea Level to 600 feet*
" " " " *1 mile*	" " " " *1 mile*
" " " " *2 miles*	" " " " *2 miles*
" " " " *3 miles*	" " " " *3 miles*
" " " " *4 miles*	" " " " *4 miles*
From Sea Level to over 4 miles	*From Sea Level to over 4 miles*

Land Surface below Sea Level

Questions on the Physiographic Map.—Elevations and depths, as shown on this map, are measured in geographical miles, each of which is a trifle more than six thousand feet.

If we give the general name, *lowland*, to regions whose elevation is less than six hundred feet, and *highland* to those exceeding six hundred feet, which contains the larger proportion of lowland, North America or Europe? If ocean-depths of less than six hundred feet be called *shallows*, where are the most extensive shallows found? What ocean contains the most extensive deeps? Name the largest of these. Trace out the most extensive plateau-region exceeding two miles in height. What similar region in the opposite hemisphere comes next to this in area? In what part of North America is the elevation between one and two miles? Is there any such region between

k and the Atlantic? Where is the Height of Land? Is its elevation less e, or more? Which of the great divisions contains the highest highland? t lowland? In what parts of America is the elevation between two and s? Where are similar regions found, if at all, in Europe? In Africa? In Are there any regions whose elevation is between three and four miles in In Europe? In Asia? In Africa? Find whether any areas of land are below n Africa; in Europe; in North America. Give the position of each of the asins. Where is Challenger Deep? Dolphin Rise? Norris Deep? Chal- e? The greatest measured depth? What is this depth in miles? Where is se? Belknap Deep? Connecting Rise? International Deep? Calculate epth in miles. Is the depth for the most part greater than six hundred feet, or less, in the North Sea? Mediterranean Sea? Bering Sea? China Sea? Baltic Sea? Caspian Sea? Arafura Sea? Gulf of Mexico? Gulf of Bothnia? Yellow Sea? Persian Gulf? Hudson Bay? Black Sea? Aral Sea? Caribbean Sea? From what ocean-depths, and where, do islands rise between two and three miles above sea-level? If the sea-level were depressed one-tenth of a mile, would it be possible to travel from New York to London by land? By what route? Could the trip be made wholly by water? If the sea-level were elevated one-tenth of a mile, where would be the head of the Gulf of Mexico? Of the Gulf of St. Lawrence? What long peninsula would extend northward from Eurasia? What American empire would become a large island? What cities of North America would be submerged? How near would the ocean come to the highest mountain in the world?

Some caves contain deposits of carbonate of lime hanging like icicles from the roof, or rising in the form of columns from the floor. Water charged with lime percolates through the roof of a cave, whence it falls drop by drop to the floor. Here it evaporates, and leaves the insoluble limestone behind, slowly building up a fantastic column. This is known as a *stalagmite.* In other cases it evaporates before falling, and so leaves the deposit hanging from the roof in the shape of a stony tassel or long incrustation called a *stalactite.* In some instances, the stalagmites and stalactites are extended until they meet. Stalagmites have been observed to grow at the rate of a little more than a quarter of an inch per annum.

A famous stalactite cavern is the Grotto of Adelsberg, in Carnio'la, Austria. Translucent sheets of spar hanging in the graceful folds of drapery, tinted formations counterfeiting cascades, natural galleries with balustrades and cornices of glittering stalactite—dazzle with their splendor when lighted by the explorer's torch.

Caverns are also hollowed out by the action of the waves, as in the case of Fingal's Cave on the island of Staffa, off the coast of Scotland, worn out of columnar basalt (*ba-sawlt'*), an igneous rock. In volcanic regions they may be formed by the passage of lava to the surface, by the expansion of steam, or by the upheaval of strata. Peculiar varieties of fish, sometimes blind, inhabit the waters of caves. (On cavern life, *see Shaler's "Aspects of the Earth," p. 98.*)

Caves have furnished important evidence as to the ancient history of man, and possess an interest from the fossil remains sometimes found beneath the incrustations of their floors. Cavern *débris* includes implements and weapons of bone and unpolished stone—awls, lance-heads, and hammers, of flint; bone needles, sculptured reindeer-antlers and mammoth tusks, ornaments, etc.—mingled with the organic remains of men and animals. These discoveries suggest that a race allied to the Esquimaux, dwelling in caverns and subsisting by hunting, were coexistent, in certain countries, with the mammoth, the woolly rhinoceros, and the cave-bear. (*See Dawkins's "Cave-Hunting."*)

Lost Rivers.—In some localities, particularly in the Appalachian Mountains of North America, rivers have dissolved passages for themselves through mountain-ranges, plunging into the range upon one side, and reappearing upon the other as huge springs. In other places, rivers sink abruptly into the earth, and, so far as known, do not reappear, but pursue their courses underground. These are known as Lost Rivers. Caves are sometimes the passages of subterranean streams. A river plunges into the mouth of the Adelsberg Grotto, and emerges on the opposite side of the mountain some eight miles distant.

Questions.—How have the irregularities of the earth's form been explained? What is relief? State the total relief of the earth in miles, and the proportion between that relief and the earth's radius. Describe the movements of the earth's crust, and the effects of erosion. State the area of the earth's surface, and the proportion covered by water. Account for the difference between the volume of the sea and that of the land above sea-level. Under what circumstances might there be no land? Show by diagram the hemispheres of greatest and least land. Illustrate the relation between Geology and Physical Geography by reference to the distribution of land, and the change of physical features.

What are oceanic valleys? Describe the bed of the sea. What are continents? Classify islands. Specify points of resemblance between the great bodies of land. Characterize the several varieties of plains. Describe a cañon; a tundra; a prairie-region; a desert; llanos, pampas, and selvas; steppes; swamps, and salt marshes. Present the geological characters of the different kinds of valleys. What are downs? barrens?

What are mountains? Describe a mountain-system. What can you say of the height and slope of mountains? What is the geographical axis of a continent? Explain the formation of a water-gap. Why are trees found on mountains? What is the timber-line? The snow-line? Would the earth be more valuable to man, or less so, if there were no mountains on its surface?

What are caves, and in what rock are they most common? Explain the principle of their excavation; the formation of stalactites and stalagmites. Describe a grotto. What remains are found in caverns?

THE AMERICAN CONTINENT.

The American Continent consists of two parts, North America and South America, connected only by a narrow neck of land, known as the Isthmus of Panama. Each of these parts is roughly pear-shaped, the broader portion being toward the north, while southward each tapers to a point.

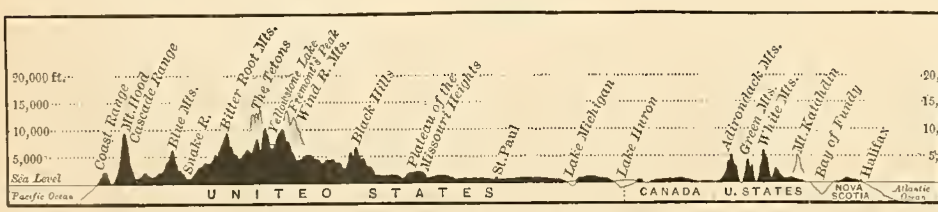
America has a total area of about 16,300,000 square miles, of which it is estimated that 9,400,000 belong to North America and 6,900,000 to South America.

The Atlantic Coast of North America is for the most part uneven, affording numerous excellent harbors. The extreme northern part is bold and rocky, distinguished by points projecting far into the sea, and fringed with islands. Its character changes in the neighborhood of Massachusetts Bay to a low, sandy, or marshy shore, with a line of outlying sand-shoals. Between the shore and these bars are coast swamps or open lagoons, which are becoming slowly filled with the deposits of the streams. This form of coast extends, with slight interruptions, nearly to the southern extremity of North America. (For a description of an ocean-beach, *see Thoreau's "Cape Cod," p. 51.*)

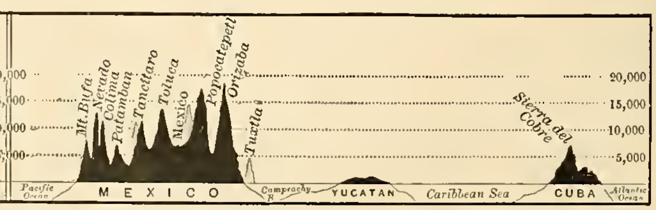
On the Pacific Side, the coast is quite simple, with very few harbors, as far north as the northern boundary of the United States. At this point, its character changes abruptly. The coast of British Columbia and Alaska is bold and rugged in the highest degree, with a network of fiord-like bays and inlets, separating mountainous islands and promontories. Through these narrow arms of the sea one may sail for hundreds of miles, amid mountains rising abruptly from the water's edge for thousands of feet.

The coast-line of the southern half of the continent presents little of the variety of the northern. On both sides it is broken by few indentations. Only at the southern end of South America, where the range of the Andes sinks into the sea, does the coast become broken and fiord-like.

In general outline, the relief of the two parts of the American Continent is strikingly similar. In each, the western portion consists of a long plateau, crowned by mountain-ranges, and extending northward and southward to the ends of the continent and westward nearly to the Pacific Ocean. In each, the central portion is a broad depression or valley, consisting of plains, prairies, lakes, and swamps, which is limited on the Atlantic side by a secondary system of mountains, shorter, less high, and less continuous, than that on the west.



SECTION OF NORTH AMERICA FROM WEST TO EAST, ABOUT PARALLEL 45°.



SECTION OF NORTH AMERICA, ABOUT PARALLEL 20°.

North America.—The Western Plateau.—In North America, the great western plateau, known as the Cordilleran or Rocky Mountain Plateau, is broadest and highest in the central part of the United States. Here it stretches from Colorado westward into California, having a breadth of over 800 miles, and ranges in height from 4,000 to 10,000 feet above the sea. Northward it gradually decreases in height as well as in breadth. The western border follows the Pacific coast, while the eastern inclines toward it. At the northern boundary of the United States, the plateau is not more than 4,000 feet above the sea; about the heads of Peace River, in British Columbia, it is a thousand feet less; and, as a well-defined geographical feature, it disappears a short distance farther north.

Southward also the plateau diminishes in height, but its breadth does not decrease until after the Mexican boundary is passed. In Mexico, hemmed in between the Gulf of Mexico and the Pacific, it narrows rapidly with the decreasing breadth of the continent, but at the same time it increases in elevation, as if what it lost in breadth it gained in height. In central Mexico, its altitude ranges from 7,000 to 8,000 feet. Interrupted by a break at the Isthmus of Tehuantepec, it passes eastward into the Central American states, its dimensions rapidly decreasing, until in Nicaragua the plateau disappears.

RELIEF MAP OF NORTH AMERICA.

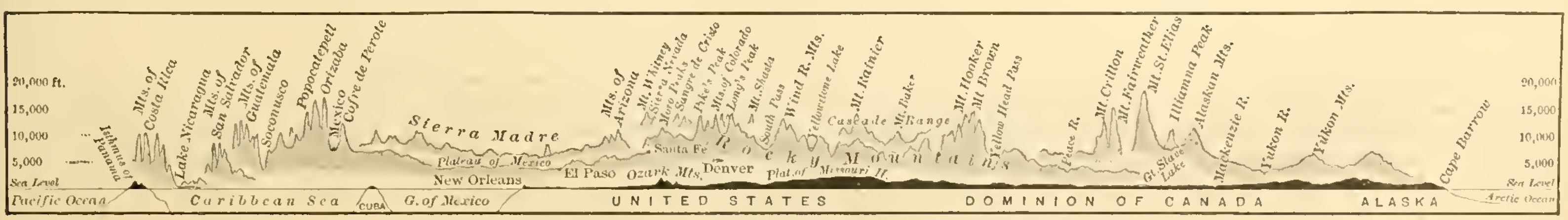
This great plateau supports many ranges of mountains, and contains numerous valleys. In some parts are extensive plains stretching for hundreds of miles, with a dull uniformity of surface.

The Climate of this Plateau, when considered as a whole, is arid. It is true that in the northern part of British Columbia there is ample rainfall for the needs of forests; but southward the rainfall decreases, and over nearly all that part of the plateau lying in the United States and Mexico, forests are found only on the mountains, while some of these even are bare. In certain regions the dryness is so great that the surface is a true desert, as in many parts of Utah, Nevada, Arizona, and northern Mexico; while over most of the country the vegetation consists mainly of sage-brush, cactus, grease-wood, and Spanish-bayonet, all of which are characteristic of arid regions. The soil is frequently white and glistening with alkaline efflorescences.

A large part of the summit of this plateau is drained neither to the Atlantic nor the Pacific Ocean. The streams which flow down from the mountains are either absorbed at once by the thirsty soil, or collect in lakes which have no outlet, and from which the surplus water is removed only by evaporation. This is known as the Great Basin.

The Mountain-Ranges of the Western Plateau.—Nearly all the mountain-ranges capping this plateau trend parallel to its general course—i. e., nearly north and south. The highest and most important of them crown its eastern and western edges. Thus, upon the western border, in the United States, are the Cascade Range, a line of extinct volcanoes, of which Mount Rainier (14,444 feet) and Mount Shasta (14,442 feet) are the highest peaks; and the Sierra Nevada, with Mount Whitney (14,898 feet). Upon its eastern border are the Wind River Mountains, with Fremont's Peak (13,790 feet); the Colorado Range, with Long's Peak (14,271 feet), and Pike's Peak (14,147 feet); and the Sangre de Cristo Mountains, with peaks exceeding 14,000 feet in height. In Mexico are the volcanoes of Orizaba (*o-re-zah'ba*) (18,314 feet) and Popocatepetl (*po-po-kah-tay-petl'*) (17,784 feet); at the other extreme, near the Alaskan border, in Canada, is Mount Logan (19,500 feet) and also Mount St. Elias (18,010 feet).

The highest peak in the United States (exclusive of Alaska) is Mount Whitney. A short distance southeast of it lies Death Valley, part of



SECTION THROUGH THE MIDDLE OF NORTH AMERICA, WITH COMPARATIVE HEIGHTS OF MOUNTAINS.

which is 100 feet below sea-level. This region presents the sharpest contrasts of elevation thus far known in North America. Near the mouth of the Colorado is a limited desert region, 300 feet below the sea.

The Great Valley of North America.—Eastward from the summit of the Rocky Mountain Plateau, the country slopes gently and almost imperceptibly downward. In the United States and the southern part of Canada, the slope is generally treeless and bears little vegetation except a sparse growth of grass, with a few other plants found only in arid regions. This slope is the Great Plains, "a monotonous, rolling, treeless expanse."

Farther northward and eastward, as the soil and atmosphere grow moister and the rainfall becomes greater, trees begin to appear, and the covering of the country gradually changes to a forest as the middle of the Great Valley of North America is reached.

This valley stretches from the Gulf of Mexico to the Polar Sea. Indeed, the Gulf itself may be considered as a part of it, which, lower than the rest, has filled with water. The southern portion is drained by the Mississippi. Farther northward the waters pass through the chain of the Great Lakes to the St. Lawrence, and still farther north the rivers flow into Hudson Bay and the Arctic Ocean.

The surface of this great valley is in the main level or slightly undulating. A few groups of hills occur, as in Missouri, Arkansas, and Michigan.

Relief Map of South America.

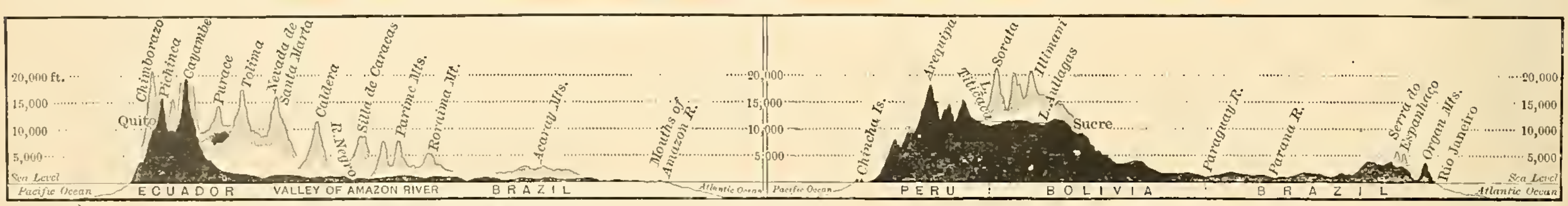
The Appalachian Mountain System.—Toward its eastern border, the surface of the Mississippi Valley becomes more broken, and soon rises into the mountains of the Appalachian System. This system commences in northern Alabama, and runs northeastward, terminating in Canada. It is by no means equal to that in the west, being narrower and less than half as high. Its loftiest peaks are Mount Washington, of the White Mountains (6,293 feet), and, in the southern part, Mount Mitchell, in North Carolina (6,707 feet).

From the Appalachian Mountains eastward the country slopes gradually to the sea, forming what is known as the Atlantic Plain.

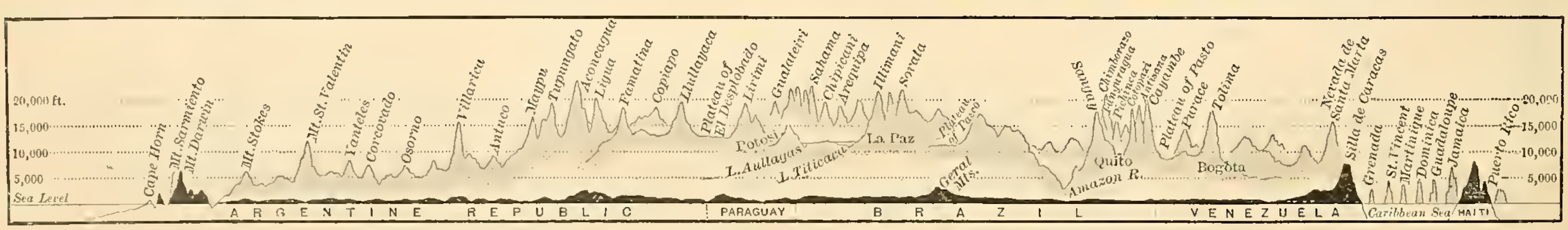
Continental Islands of North America.—In the northern part of North America, there is a group of large, desolate islands stretching northward beyond the Arctic Circle, such as Banks Land, Melville Island, the Parry Islands, and others. These form properly a part of the great interior plain or valley of North America, separated from the rest of the continent by shallow arms of the sea. Beyond them, east of Baffin Bay, lies the great island of Greenland.

Between North and South America, and stretching eastward into the Atlantic, is a group of islands, known as the West Indies. The principal members of this group are Cuba, Haiti, Jamaica, and Puerto Rico; the smallest are mere rocks rising from the sea.

South America.—The Andes.—In South America, the great western plateau, known as the Andean Plateau, is much narrower than the corresponding feature in North America, and borders the Pacific coast much more closely. The



Section of South America along the Equator. Section from the Chincha Islands to Rio Janeiro.



Section through the Middle of South America, with Comparative Heights of Mountains.

ranges which crown it are fewer in number, while the peaks reach much greater altitudes. Many of the highest of these are active volcanoes.

Near the southern end of South America, the mountains become partially submerged, producing, on the western side, a fiord-like coast. Through Chile, the Andean System gradually increases in altitude; while still farther north, in Peru, Ecuador, and Bolivia, it reaches its greatest breadth and height. Here it consists in the main of two parallel ranges, standing upon the opposite edges of a high plateau, from 100 to 250 miles in breadth, and from 10,000 to 13,000 feet in height. These are connected by occasional cross-ranges, and are flanked by numerous short branches, especially upon the eastern side. As we approach the Isthmus of Panama, the mountains become lower, and are divided into several ranges, one of which runs along the isthmus as a chain of low hills, but a few hundred feet above the ocean, while others extend northeastward to the shores of the Caribbean Sea.

The passes of the Andes are steep and dangerous; some of them, nearly three miles above sea-level, can be travelled only by mules and llamas.

The highest peak of the Andes, and also the highest summit in America, is Aconcagua (*ah-kon-kah'gwah*), in Chile (23,290 feet), formerly regarded as an extinct volcano. Farther north are the Nevada de Sorata (*so-rah'tah*) (21,286 feet), Illimani (*eel-ye-mah'ne*) (21,149 feet), and Chimborazo (*chim-bo-rah'zo*) (21,424 feet), besides scores of others of almost equal elevation. (On the geological history of South America, the rise of the Andes and the creation of the Amazon, *see Orton's "The Andes and the Amazon," p. 114.*)

While most authorities represent Mt. Aconcagua, in Chile, as the loftiest peak not only of the Andes but of America, recent surveys assign to peaks of the Bolivian mountains a somewhat greater height. An altitude of 24,812 feet is claimed for Mt. Illampu.

The Eastern Ranges of South America.—On the eastern side of South America, stretching across the United States of Brazil, is a system of mountains, consisting of several ranges running in a direction nearly parallel to the coast, and separated from one another by broad valleys. Neither in height nor in length are these mountains to be compared with the Andes. They contain some peaks exceeding 6,000 feet in altitude.

The Great Valley of South America consists, in its northern part, of the Valley of the Amazon. Unlike the corresponding feature in North America, the Andean Plateau has no long eastward slope, but descends steeply to the Amazon Valley, which is everywhere, even at the base of the mountains, but slightly elevated above the sea. This valley is a low plain, well watered and covered with dense, impassable Silvas already described.

Proceeding southward from the Valley of the Amazon, we pass over a plateau-like divide into a drier region. The forests become less dense, and gradually the country changes to prairie, and thence to arid plain—the Pampas of South America, where forests are unknown, and where agriculture is, for want of rain, impossible. Over these plains, covered with short grasses, range countless herds of cattle, the care of which forms the principal occupation of the civilized inhabitants.

Owing to the absence of rain, the narrow strip of country lying between the Andes and the Pacific Ocean is, except near its northern and southern extremities, nearly or quite a desert.

EURASIA.

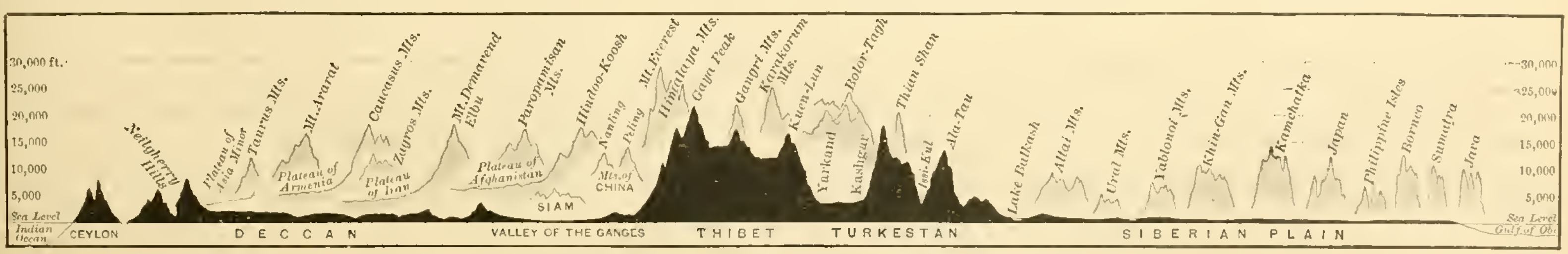
The Eastern Continent consists of two parts—Eurasia and Africa, connected only by the narrow Isthmus of Suez. Eurasia is frequently divided into Europe and Asia, but the line of division is an imaginary one, and there is no physical reason for so drawing it.

Eurasia has an area of 20,500,000 square miles, or about two-fifths of the total area of the land-surface of the globe. It extends over 200 degrees of longitude, and from the Equator nearly to 80 degrees north latitude. It has a very irregular shape, which can not be simply characterized, with numerous great peninsulas and capes projecting into the sea on all sides, such as Scandinavia, Spain, Italy, Arabia, India, Siam, Corea, and Kamchatka. Its shores are everywhere indented with bays and arms of the sea, and fringed with continental islands.

The Highlands of Asia.—In its relief, Eurasia presents no such simple picture as America; and its low plains, plateaus, and mountain-ranges, do not so readily fall into a system. Its apex is in its southern part, where stands the Plateau of Thibet (*tib'et*), 13,500 feet high, hemmed in by the Himalayas on the south, and by the range known as the Kuen-Lun (*kwen-loon'*) on the north. This is the highest extensive plateau on the globe. It is an arid region, almost barren, with a very severe climate. Its surface is diversified by mountain and valley, and contains numerous great lakes, many of which have no outlets. The mountains limiting it on the south are the highest on the globe. Among their peaks are Mount Everest, whose summit is the culminating point of the earth's surface, reaching an altitude of 29,002 feet; Dhawalaghiri (*da-wŏl-a-gher're*) (26,820 feet), and many others exceeding 20,000 feet. The Kuen-Lun is but second in height.

From this great center of elevation, there stretches northeastward toward Bering Strait and westward to the Persian Gulf and Arabia, a series of great plateaus, which diminish gradually in height as they recede from Thibet. They form a broad line of elevation near the southern and eastern borders of Asia. Toward the northwest there is a rapid descent to the level of low plains. These plateaus are crowned by numerous mountain-ranges, many of them of great altitude, here standing so close together as to divide the country into an alternation of mountain and valley, and there leaving broad expanses of plain or desert.

Desert of Gobi.—Examining this region of high plateaus in greater detail, we find that north and northeast of the Plateau of Thibet, and separated from it by the Kuen-Lun, is the Desert of Gobi (*go'be*), the great central desert of Asia. It lies at an altitude of from 2,000 to 6,000 feet above the sea, and is intersected by numerous mountain-chains, some of the peaks of which are known to reach altitudes of from 10,000 to 12,000 feet. Its eastern border bears the Khin-Gan (*kin-gahn'*) range, and on the north it is limited by the Yablonoi, Altai, and Thian-Shan (*tee-ahn'shan*) chains. The latter, which is sometimes known as that of the Celestial Mountains, is hardly inferior in height to the Kuen-Lun, some of the peaks being said to exceed 20,000 feet.



SECTION OF ASIA FROM SOUTH TO NORTH, WITH COMPARATIVE HEIGHTS OF MOUNTAINS.

Relief Map of Eurasia.

North of the Desert of Gobi lies a third plateau, which is limited on the north by the Altai Mountains; and beyond this, northeastward, extends a series of ranges, of gradually decreasing altitude, nearly to Bering Strait.

Northward and northwestward from the Altai Mountains, a vast plain stretches to the shores of the Arctic Ocean. This plain, low, level, or undulating, includes the steppes of Siberia, which pass into tundras in the north. It has an arid, arctic climate, with great extremes of heat and cold. Vegetation is scanty, consisting mainly of grasses and shrubs.

Plateau of Iran, etc.—Passing westward from the great Plateau of Thibet, we encounter a series of plateaus of less height, extending to the shores of the Mediterranean Sea. The southern limit of these plateaus follows the shore of the Arabian Sea and the Persian Gulf. They comprise Afghanistan, Baluchistan, Persia, Armenia, and Asia Minor, the northern limit being outlined by the south shores of the Black and Caspian Seas, and by a high range of mountains running east from the south shore of the Caspian, known in different places as the Hindoo-Koosh, Paropamisan (*pah-ro-pah-me-sahn'*), Elburz (*el-boorz'*), and Taurus ranges. These vary in height from 10,000 to 12,000 feet, and culminate in the lofty peaks of Demavend (18,800 feet) and Mount Ararat (over 17,000 feet).

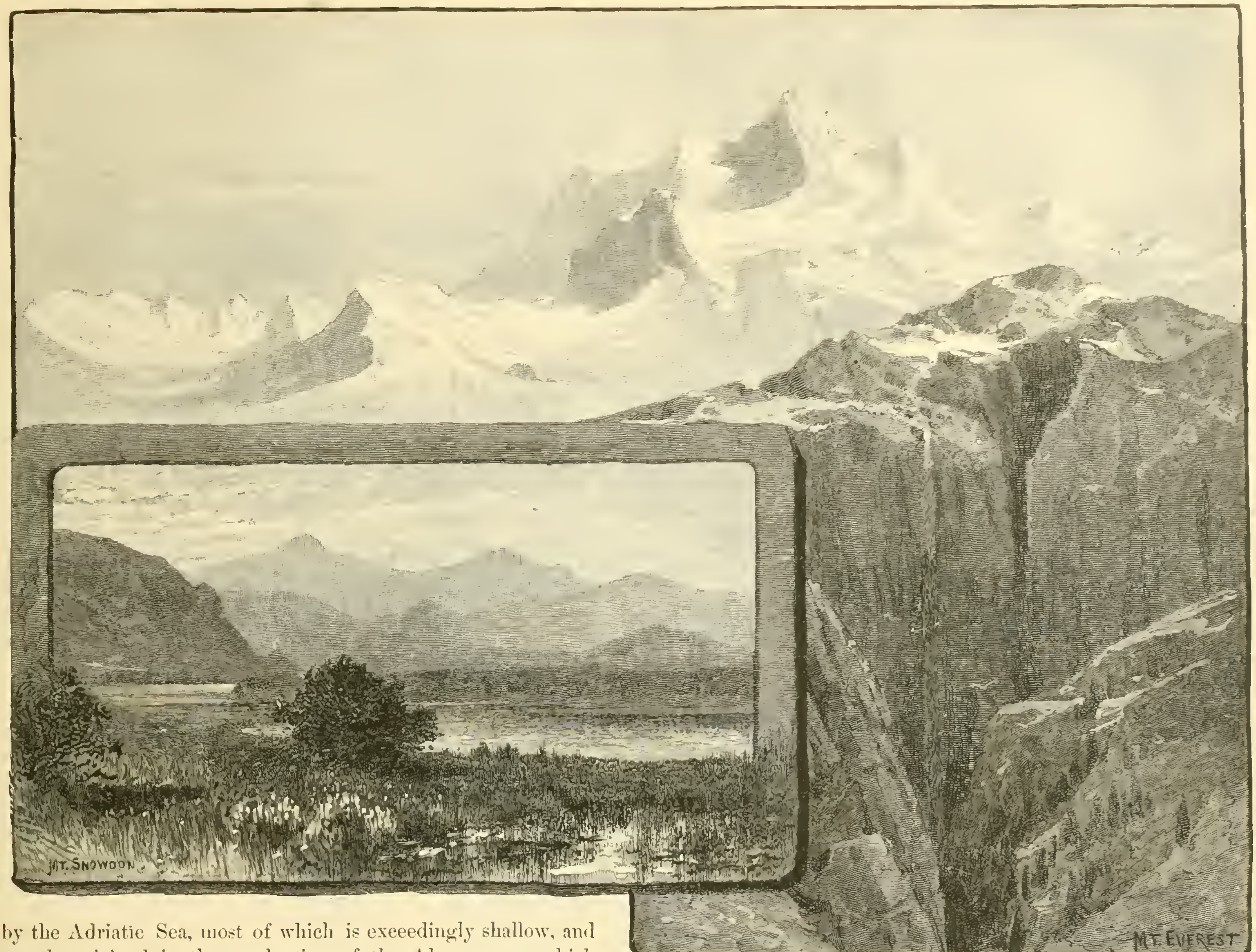
The elevations of these plateaus vary from 2,000 to 8,000 feet, being generally highest toward the east and lowest westward.

The eastern portion of this plateau region, comprising Afghanistan, Baluchistan, and Persia, is in part a desert. The climate is severe, with great extremes of heat and cold. Rainfall is slight, and at a distance from the mountains there is but little running water. In the western part, including the plateau of Armenia and Asia Minor, the climate is more humid and the soil less sterile.

Another plateau of considerable extent, though not of great elevation, is that of Arabia. It covers nearly all of the peninsula of that name, and is mainly a dry, hot desert, intersected by ranges of low mountains.

Between the Caspian and Black Seas stretches the short but rather lofty Caucasus Range, culminating in Mount Elburz, 18,570 feet.

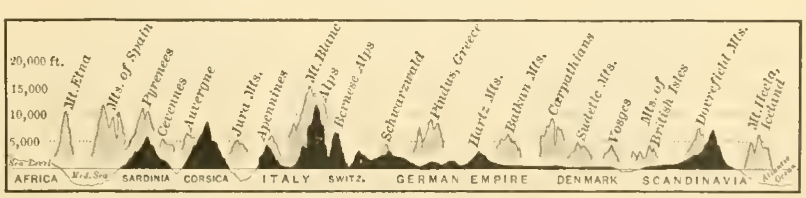
The Highlands of Europe.—The plateau of Armenia and Asia Minor, interrupted by the shallow Black Sea, continues westward and spreads over the southern part of Europe as far as the Atlantic Ocean. An offshoot to the south determines the position of Turkey and Greece, while another to the north is cut by the water-gap of the Danube and bends eastward and then northwestward in the Carpathian Range. Two parallel ranges are separated



by the Adriatic Sea, most of which is exceedingly shallow, and are then joined in the production of the Alps proper, which attain their greatest altitude in Mont Blanc, 15,784 feet in height. These include several ranges, trending nearly east and west. On account of their proximity to the densely populated and highly civilized regions of Europe, they are probably the best-known mountains in the world.

The Jura, consisting of parallel ridges inclosing narrow valleys, and the Cévennes (*say-vĕn*), with its extinct volcanoes, are lower ranges, the latter reaching almost to the Pyrenees. South of the Pyrenees, which are but little less lofty than the Alps, the plateau of Spain is traversed by a number of minor ranges, determining it as the most western part of the continent of Eurasia. (On Alpine sculpture, the conformation of the Alps, and an inquiry into the forces by which the Swiss mountains were elevated, *consult Professor Tyndall's "Hours of Exercise in the Alps," p. 221.*)

In the north of Europe are the Dovrefield (*fe-eld'*) Mountains, forming the axis of the Scandinavian Plateau from 3,000 to 6,000 feet in height. The surface of this is much broken, particularly on the west, where the coast-line is jagged and precipitous, being cut into a great number of fiords. The slope is more gentle toward the east.



Section of Europe from North to South, showing Comparative Heights of the Principal Mountain-Chains.

Great Britain, the largest island of Europe, is traversed by a mountain-range from south to north, which in northern Wales culminates in the beautiful peak of Snowdon (3,571 feet). There is a branch range running parallel to the east; while farther north, the Grampian Hills, intersecting Scotland, contain among their numerous picturesque summits Ben-Nev'is (4,368 feet), the highest mountain in the British Isles.

The Lowlands of Eurasia.—The Great Siberian Plain stretches from Bering Strait toward the southwest as far as the Caspian Sea. The insignificant Ural Range (whose highest summits are hardly 6,000 feet above the sea), trending northward to the Arctic Ocean, produces a slight interruption, beyond which the low plain extends westward to the Atlantic, being limited on the south by the Alpine Highlands and on the northwest by the Scandinavian Plateau. Over its western area it is partly covered by the shallow Baltic Sea.

With the exception of Scandinavia and the Mediterranean countries, Europe consists of plains but slightly elevated above the sea; and a small area along the coast of Holland is actually below sea-level. These plains are mainly well watered and fertile; and the climate is not severe except in the north.

In Asia, on the contrary, much the greater part is highland, capped by thousands of mountains that lift their heads into the region of eternal snow and inclose the loftiest plateaus in the world. Aside from the Siberian Plain the only lowland regions of noteworthy extent are the valleys of the Euphrates and Tigris, of the Indus and Ganges, and the Chinese Plain watered chiefly by the Hoang Ho and Yangtze Kiang.

Asia has two regions of remarkable depression. One is the basin of the Caspian Sea, where the Asiatic and European low plains unite south of the Ural Mountains. The level of the water is more than 80 feet below that of the Mediterranean. The other is the valley of the Jordan, which is about 3,000 feet below the surface of the country on its two sides. This shallow river flows at a depth much below sea-level, and enters the briny Dead Sea, the surface of which is nearly 1,300 feet below that of the Mediterranean.

Continental Islands of Eurasia.—As might be inferred from the very broken coast-line of Eurasia, the neighboring waters abound in continental islands, many of them of large size.

On the Atlantic side are found Great Britain, Ireland, and Iceland—the latter remarkable as the seat of great volcanic activity. Within the Mediterranean Sea are Sardinia, Corsica, Sicily, Cyprus, the Grecian Archipelago, and the Balearic Islands, which are all distinctly continental. On the Arctic side are Nova Zembla, Spitzbergen, New Siberia, and Wrangell Island. On the side of the Pacific is a line of islands extending southward from Kamchatka, showing the position of a submarine mountain-range parallel to the coast. These are the Kurile Islands, the Islands of Japan, the Liu Kiu (*le-oo' ke-oo*) and Philippine Islands, Celebes, Java, Sumatra, and Borneo. The last two are very large. A still larger island, New Guinea, should be included in the same group, but lies near the continent of Australia.

In the Indian Ocean, the island of Ceylon is separated by shallow water from the peninsula of Hindostan, of which it is geologically a continuation.

Relief Map of Africa.

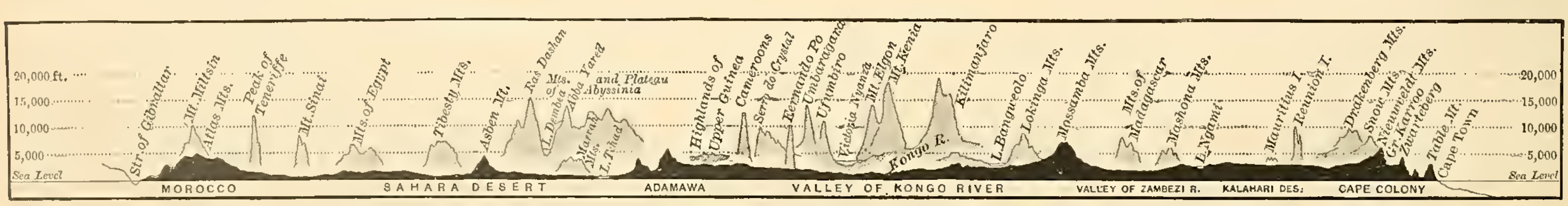
AFRICA.

Africa was, prior to the completion of the Suez Canal, a peninsula connected by the low, sandy Isthmus of Suez with Eurasia. It has been made artificially a distinct body of land. In form it is rudely pear-shaped, its narrower extremity, the stem end, being toward the south. Its area is estimated to be 11,600,000 square miles. The Equator divides Africa into two nearly equal parts; lying almost entirely within the tropics, this may fairly be called the equatorial continent.

The Coast-Line is extremely simple. Indeed, the good harbors may be counted on one's fingers. Its relief is varied by mountain, valley, and plain.

The Interior is almost entirely a plain, bordered on all sides near the coast by ranges of hills or mountains. In the northern part this plain is low, some of it being even below the sea-level. The climate is arid, especially in the region comprising the deserts of the Sahara, Egypt, and the Lower Soudan.

The surface of this region, while in the main level or undulating, is here and there broken by ranges of mountains, by plateaus



Section through Africa from North to South, with Comparative Heights of the Principal Mountains.

and hills. It is not entirely a desert. Although by far the greater part is devoid of vegetation and is covered with drifting sands and bare rocks, there are occasional oases, some of which are of great extent, where the soil is watered by springs; and in other places rivers fertilize narrow belts of country along their courses.

Farther south, as the Equator is approached, the elevation increases to a plateau, the mean temperature rises, and the rainfall is greater. In the equatorial region, the country is forest-clad. Here several of the great rivers of Africa take their origin, and here are numerous vast lakes and lake-like expansions of the rivers. The characteristics of climate and surface prevail southward across the equatorial belt; but, as the southern end of the continent is approached, the rainfall decreases.

The Mountains of Africa.—The ranges of mountains and hills that border the plateau follow the coast quite closely, leaving on the shoreward side a comparatively narrow strip of land. For the most part, they are not of great elevation. The loftiest of them are in Abyssinia, and southward on the eastern side of the continent. Almost under the Equator are the two highest African mountains thus far known, Mount Kilimanjaro (*kil-e-mahn-ja-ro'*), nearly 20,000 feet, and Mount Keni'a. The average height, however, of the mountains on the east wall of the plateau is not more than 7,000 or 8,000 feet; while those upon the west wall are even lower, ranging generally from 4,000 to 6,000 feet, the highest being the Cameroons and the highlands, near the Gulf of Guinea. The west border of the Sahara Desert is its lowest part, the mean elevation of this arid waste being about 1,500 feet.

At the northern and southern extremities of the continent also the surface is crumpled into rugged chains, the Atlas Mountains extending about 1,500 miles, and the Snow Mountains overlooking the Indian Ocean and terminating in the Cape of Good Hope.

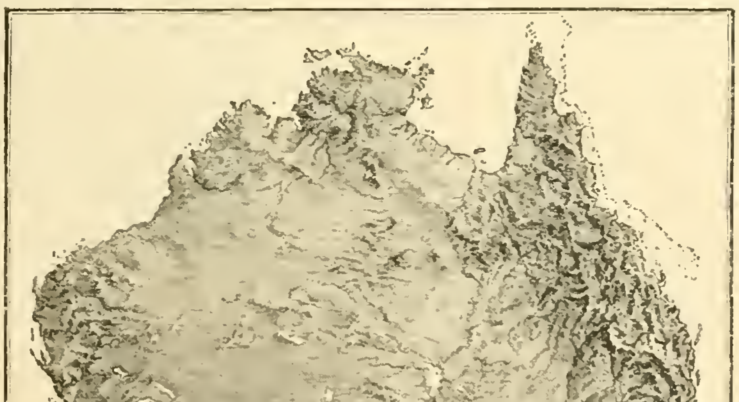
Madagascar is the only large island associated with Africa. It is separated from the mainland by a wide but shallow channel, and is very rugged, being occupied by two mountain-ranges which trend parallel to those of the eastern African coast.

AUSTRALIA.

Australia is the largest island, or the smallest continent, on the globe. It has an area of about 3,000,000 square miles, thus being about the size of the United States, exclusive of Alaska. Its coast-line, excepting on the north, where it is somewhat indented with bays and extended in capes and promontories, is simple.

Australia consists mainly of a low table-land, elevated but a few hundred feet above the sea. The surface is rolling, or broken by hills. Upon the east and west sides of the continent, this plain is outlined with ranges running near to the coast and parallel with it. The highest of these on the east are known as the Australian Alps.

The rainfall on the eastern coast of Australia is ample for the needs of agriculture; but elsewhere on the coast and everywhere in the interior it is scanty, so that vegetation is sparse, except upon the mountain-sides. The great plain is mainly covered with grasses and shrubs, the "bush" of the Australian, while far in the interior are found extensive areas of desert.



RELIEF-MAP OF AUSTRALIA.

THE ANTARCTIC CONTINENT.

South Polar Regions.—The last continental mass of land is that surrounding the South Pole. Of this very little is known, as it is impossible to penetrate inland. Parts only of the shoreline have been explored; near the coast are high mountains, such as the active volcano Mount Erebus (12,366 feet), and Mount Terror (13,884 feet). (*See map, p. 55.*)

The whole land is covered with great glaciers, from which come the icebergs found in high southern latitudes. The climate of the region about the South Pole being colder than that of the North Pole, ice is encountered much farther away from it. Owing to this fact, and to the difficulties connected with land-travel in polar regions, a large area, nearly twice that of Europe, still remains unexplored.

Questions.—What two parts constitute the American Continent? Describe them and state their areas. Characterize the eastern coast of North America; the western coast; the coast of South America. Locate the geographical axis of the New World.

Give an account of the western plateau of North America; its surface, climate, and vegetation. What is the Great Basin? Describe the Great Plains; the Great Valley of North America; the Appalachian Mountain System. Name the loftiest summits of the North American chains. What continental islands belong to North America? Compare the eastern and western slopes of the Andes. Name the highest mountain in America; the highest volcano in the world. Describe the eastern ranges of South America; the Valley of the Amazon; the region between the Andes and the Pacific. Compare the physical characteristics of the two Americas.

Describe the contour of Eurasia; the coast-line. Mention the details of the Plateau of Thibet. Where is the great elevated region of Eurasia? Name the culminating peaks of the Himalaya chain; the loftiest known mountain on the earth. Describe the Desert of Gobi. By what ranges is it bordered? Describe the Siberian steppes; the plateaus west of Thibet; the low plains and highlands of Europe. At what elevation are the great passes across the Alps? across the Pyrenees? the passes from India to the Thibetan Plateau? Describe the Scandinavian Peninsula; the Southern highlands; the mountain-systems of Great Britain. Explain the mode in which hills are, in certain parts of Europe, formed near the sea. (Shifting hillocks called Dunes, sometimes a hundred feet or more in height, are formed of sand washed up by the sea or fresh-water lakes; human ingenuity has, in many instances, fixed the changing dunes, and converted them into substantial barriers against the encroachments of the ocean.) (On the origin of sand, sand-dunes, and sand-plains, *see Marsh's "Man and Nature," p. 451.*) Give an account of the continental islands of Eurasia.—What is the shape of Africa? its area? the character of its coast? Describe the deserts; the equatorial regions; the mountain-systems; the continental island. Give an account of the physical features of Australia. Present an outline of the position of the known lands in the Antarctic Ocean, and state their physical configuration so far as it is known.

OCEANIC ISLANDS.

Characteristics.—Oceanic islands generally occur at a distance from continents, either isolated or in groups. An examination of the sea-bottom, however, shows that many of these islands rise from submarine banks of great extent which are connected with continents or but slightly separated from them. By reference to the map, on p. 20, it will be seen that the banks from which they rise are more or less connected with the neighboring great continental islands, as if all of them were the remains of a continent, with its mountain-ranges and valleys, that has sunk below sea-level.

Oceanic islands present far less variety than continental islands. The material composing them is generally volcanic. They are often partly surrounded with limestone, and sometimes almost entirely composed of it.

As examples of volcanic oceanic islands may be mentioned, in the Atlantic, the Azores, Cape Verde, Madeira, St. Helena, and Ascension Islands; in the Indian Ocean, Kerguelen (*kerg'e-len*), St. Paul, and New Amsterdam; in the Pacific, the immense archipelago of Polynesia, over 3,000 miles in length.

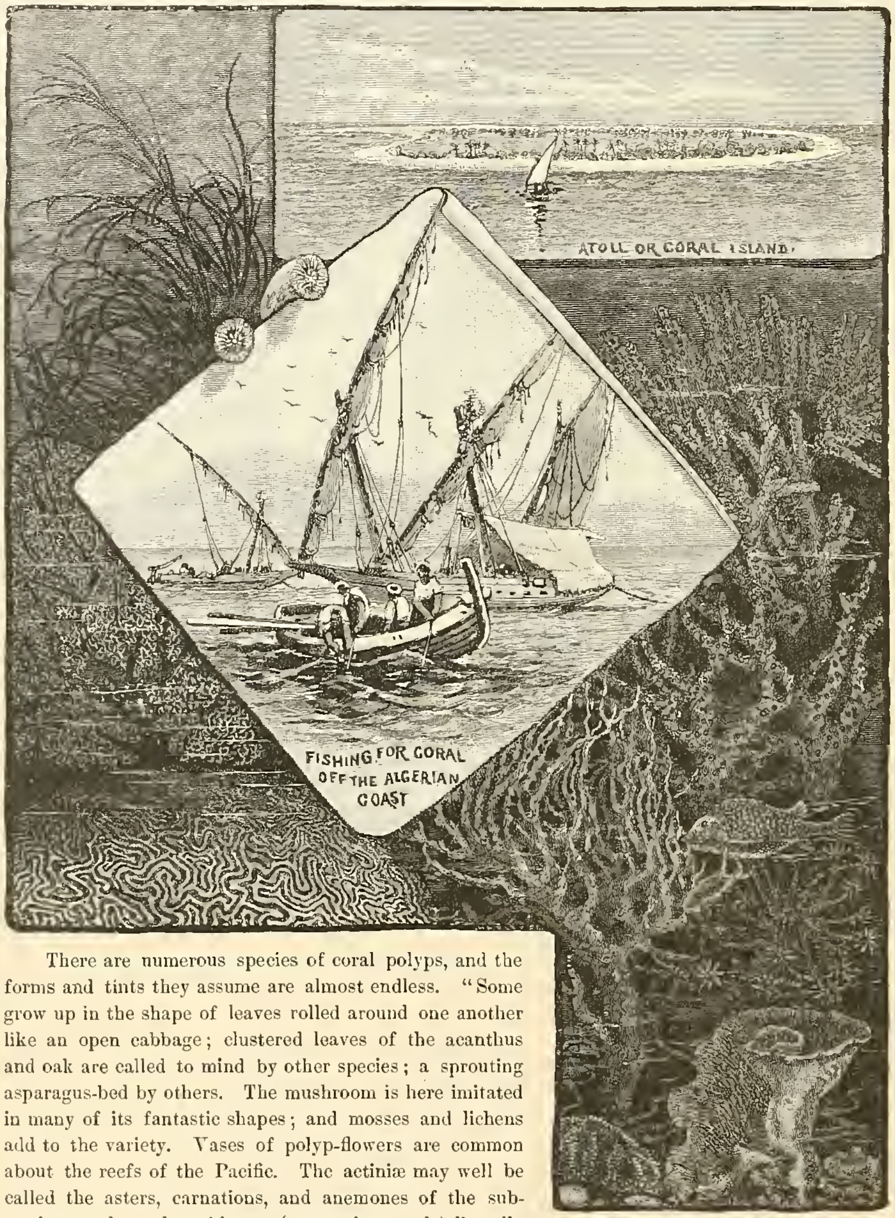
Coral Islands.—The most interesting of the oceanic islands are those which owe their existence wholly or partly to the agency of the coral pol'yp (*many-footed*), a minute marine animal that spends its life in secreting beautiful products, familiar to us under the name of coral (from two Greek words, meaning *maiden of the sea*).

Much of the coral used for ornamental purposes comes from the coast of Algeria, Sicily, and elsewhere in the Mediterranean, and from the Red Sea, the Persian Gulf, and the China Sea. There are many varieties; but that which is most highly prized for articles of jewelry is the red or rose pink coral of the Mediterranean, obtained by means of dredging. This "precious coral" was an important article of trade among the ancients. It was employed by both Gauls and Britons to decorate their armor, and Roman children wore charms made of it to protect them from the evil-eye.

The Coral Polyp may be regarded as a little sack of slimy flesh, usually cylindrical, the opening of the sack constituting its mouth. Around this are numerous delicate arms or tentacles, kept continually in motion for the purpose of producing minute currents of water which enter the creature's body and are rejected after yielding their mite toward its support. The coral polyp thus closely resembles a flower (*see p. 101*).

Sea-water contains lime carbonate in solution; this is extracted and deposited between the inner and outer surfaces of the little sack, forming a tube of limestone which thickens until the polyp dies. Meanwhile this has propagated its young, and a mass of limestone, perforated with fine holes, grows up gradually, sending forth tree-like branches in every direction. Coral-trees expand into groves and forests of limestone, many miles in extent, and alive with polyps whose brilliant tints, shining through the clear water, make the sea-bottom appear almost like a marine flower-garden. Naturalists have given to the coral polyp the name of zo'o-phyte (*animal which grows like a plant*).

A number of coral families have been recognized in a fossil condition, and the ruins of ancient coral architecture are scattered among the rocks of both continents.



There are numerous species of coral polyps, and the forms and tints they assume are almost endless. "Some grow up in the shape of leaves rolled around one another like an open cabbage; clustered leaves of the acanthus and oak are called to mind by other species; a sprouting asparagus-bed by others. The mushroom is here imitated in many of its fantastic shapes; and mosses and lichens add to the variety. Vases of polyp-flowers are common about the reefs of the Pacific. The actiniæ may well be called the asters, carnations, and anemones of the submarine garden; the tubipores (organ-pipe corals) literally form its pink-beds; and astræas embellish with green and purple blossoms which stud the surface like gems." In the engraving are shown the sea-fan, brain-stone, tree, rose, star, and cabbage coral.

Growth of Coral Reefs.—The first polyp having begun building its little monument on a shallow bank of mud or sand, the forest grows outward and upward until its branches reach the surface of the water. Here the waves are broken into foam by them, so that the line of reef is visible for miles as a white sheet. But the branches are themselves ground into fragments by wave-action; and the irregular mass becomes compacted into coral rock, on the outer margins of which the polyps continue to build.

The stronger waves break off large pieces and pile them up until they rise above the average level of the sea. The air continues the work of disintegration, and soil is formed. Dry coral sand is still further piled up by the wind, until an island is created, parts of which are beyond the reach of the waves. This becomes a resting-place for sea-birds, and upon it is stranded vegetable matter that has drifted from the nearest land. At last the seeds of the cocoa, date, and palm, the bread-fruit and the banana, find a place for growth, and the coral island becomes bright with verdure.

Reef-building corals inhabit only clear, warm, salt water, thriving best just below the surface. They cease to exist when the depth much exceeds a hundred feet. Mud or an intermixture of fresh water is injurious or fatal to them; hence, openings in coral reefs invariably occur opposite the mouths of rivers or streams.

Fringing Reefs.—Although the process just described is a general one, by far the greatest number of coral reefs grow out from the edges of volcanic islands or of continental masses. Where the proper conditions of warmth and clearness of water exist, every such island is more or less completely surrounded by a *fringing reef*, which extends out at least as far as the limit of a hundred and twenty feet in depth. Here the edge of the coral platform slopes off abruptly.

Barrier-Reefs.—In many cases a volcanic island is surrounded not only by a fringing reef, close to the shore, but also by an outer ring of coral from which it is separated by a lagoon of shallow water. Such an encircling coral formation is called a *barrier-reef*. Soundings taken close to the seaward margin of barrier-reefs indicate great depths of water immediately beyond them. Coral reefs act as walls or dikes to detain the wash of the hills and the fertilizing elements deposited by rivers, as well as to prevent marine erosion along the shores off which they lie.

Atolls.—Barrier-reefs are sometimes found with no visible volcanic island within. These are called *atolls* (from a Malayan word, meaning *order*). The slope of an ordinary island at the water's edge is usually very gentle, rarely exceeding 5° or 6°. The outer slope of an atoll is always steep, not unfrequently attaining 50° or 60°. Soundings upon these slopes indicate the presence of coral mud at depths of many thousands of feet, and at no great depth within the atoll.

Mode of Production of Atolls.—The explanation of the mode in which barrier-reefs and atolls are formed is due to the labors of Darwin, and has been confirmed by the observations of Dana and other geologists who have explored the islands of the Pacific.

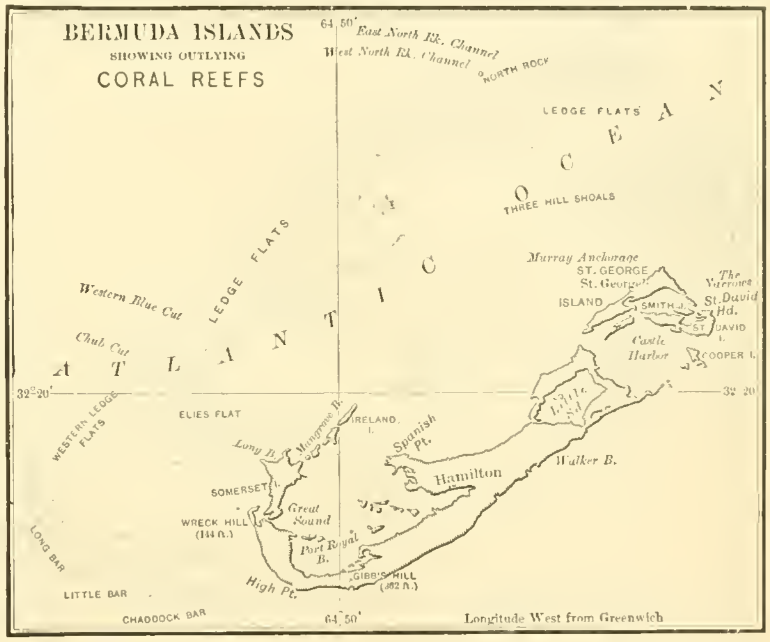
Fringing reefs are found wherever reef-building corals exist; atolls, principally in the Pacific, over an area that is skirted with regions where active volcanoes are seen, such as those of the Hawaiian Islands, New Zealand, and the East Indies. The ocean-bottom over this area gives evidence of being strewed with volcanic ashes, and seems to have been once active, but now to be studded with extinct volcanoes. The central portion has long been gradually sinking, so that volcanic peaks, once high above the surface of the sea, are deeply submerged. When exposed, coral reefs formed around them, as shown in the figure.

SECTION OF CORAL ISLAND, SHOWING LAGOON AND BARRIER-REEF.

As the ground slowly subsided, the corals continued to build upward, those next to the shore being less vigorous than those at the outer edges, on account of the muddiness of the water. A lagoon, therefore, was gradually left between the shore and outer part of the reef, while the sea-level encroached upon the sinking island.

A barrier-reef around a small volcanic island is thus produced. As the sinking continues and the coral on the outer part of the reef keeps up with the sea-level, the entire peak disappears, and a ring-shaped coral island is left, inclosing a shallow basin where the summit had previously been. Thus an atoll rests upon a submerged volcano. (On the structure and formation of coral reefs, *see Professor Dana's "Corals and Coral Islands," pp. 128, 222.*)

Barrier-reefs are most abundant near the edges of a great sinking area, and atolls near the middle. The northeast shores of Australia are thus still sinking, and a barrier-reef extends almost continuously along the coast for 1,200 miles, at an average distance of twenty to thirty miles from the present shore-line. The depth of the inner channel varies from ten to sixty fathoms; that of the outside sea sometimes exceeds 2,000 feet. West of the sinking area there are regions slowly rising, particularly in the neighborhood of active volcanoes; and the remains of the fringing reefs are found hundreds of feet above the present sea-level.



The Bermudas, a group of more than 100 islets formed upon a bed of coral, lie to the south of a bank or atoll, twenty-four miles in length, and are inclosed on three sides by formidable reefs, interesting as being farther from the Equator than any other living coral formations. The channels of approach are extremely intricate. The Bermudas are in a state of subsidence.

The coral reefs at the southern end of Florida are barrier-reefs, built up on the mud, fringing reefs being impossible immediately in contact with such a shore. Wherever found, such reefs are very dangerous to navigation. (*Consult Darwin's "On the Distribution of Coral Reefs."*)

Beautiful as they are beyond description with their enameled foliage and blue translucent seas, coral islands—in that their plants and animals are limited to a few species, in that they contain no metallic deposits, in that the commercial and agricultural advantages derived from mountain, river, and valley, are entirely wanting—have offered to their human inhabitants few opportunities of rising above the condition of savagery. (On this subject, *read Cooper's "Coral Lands."*)

Questions.—What are oceanic islands? Cite examples of volcanic islands in the Atlantic, Indian, and Pacific Oceans. Define coral. Describe the coral polyp, and coral reef-building. Is coral architecture confined to the Neozoic Age?

What are coral islands? Fringing reefs? Barrier-reefs? Describe the nature of an atoll. What is the theory of the circular formation of atolls? Explain the cause of breaches or openings into coral reefs. Describe the Bermudas; the Florida reefs. Account for the low condition of man on coral islands.

Changes of the Earth's Surface.—It has already been shown that in past geological eras the earth's surface underwent many changes due to its cooling from a molten condition, all of which tended to make it uneven. The earth has been continually diminishing in volume, though to what extent is unknown. Robert Mallet has calculated that its present diameter is 189 miles shorter than the diameter of the planet at the time solidification began; if so, the original crust must have been over 94 miles higher than the present crust.

Unless the material composing the earth was absolutely uniform in composition and original density, some portions of the surface must have cooled, and therefore sunk, faster than others. When the cooling had proceeded sufficiently far to condense the hot vapor of water, this must have gathered into the depressions and formed oceans; areas of slower cooling were left as continents. As the contraction still further progressed with loss of heat, the sea-bottoms must have increased in density and become rigid faster than the continents.

The earth as a whole is now about $5\frac{1}{2}$ times as dense as a globe of water of the same size. If we take the density of water as a unit of comparison, the average density of the materials composing the earth's exposed crust will be expressed by $2\frac{1}{2}$, and the density at the center by 16.

When an area is once covered with deep-sea water, the difference of temperature between it and the earth's interior is sensibly increased. Deep-sea soundings during the last few years have shown that the temperature at the bottom of the ocean is uniformly about 35° F. The average temperature of the land is about 62° F. The conclusion is that, not only in the past, but at the present day, the earth has been contracting less rapidly on continental surfaces than on oceanic beds.

The Effect of Continued Contraction is to make the external shell too large for the diminished interior, while at the same time it is settling in consequence of its weight. The result is, that the different parts of the crust press sidewise against each other with increasing force, until it yields and crumples at the places of least strength. As might be expected, this crumpling has always been greater on the less dense continental masses, particularly near their edges, than on the sea-bottom.

Deep-sea soundings have shown that although the ocean-bottom is diversified into "deeps" and "rises," there is nowhere such abrupt change of level as is found on continents. This is true even after making allowance for the fact that erosion on the continents tends to make inequalities in elevated regions and to reduce them in regions of depression.

While, therefore, continents are great areas left exposed in the process of the earth's contraction, mountain-chains are secondary products, made after the continents by the crushing of their weakest parts. The continual tendency is for the oceans to become deeper, and the continents to become higher in comparison with the ocean-level, not only because the continents are sinking less rapidly, but because they have been crumpling more rapidly. The effects of such crumpling are antagonized by erosion; but this does not interfere with the sinking of the central parts of the great ocean-bottoms.

Slow Oscillations.—We have the best evidence that there still exist great differences of temperature between the earth's surface and its interior. There is also evidence that the surface is rising in some places, and sinking in others, at least along the margins of the seas.

Regions of Elevation.—The western coast of South America was examined by Darwin through an extent of more than 2,000 miles. High up on the mountain-sides were found the evidences of former washings by the ocean, such as shells, old beach-lines, and corals. At Valparaiso, in Chile, the elevation has been at least 1,300 feet, of which 10 feet was raised between the years 1817 and 1834. At Chiloe the rate has reached one foot a year. Corals are found 3,000 feet above sea-level. A similar rise has been noticed over 1,180 miles of the eastern shore.

Observations on the shores of Norway have shown a steady rise of one foot in twenty years in the northern part, the average being one foot in forty years. Similar changes have occurred in Scotland, Iceland, Japan, the East and West Indies, and in volcanic regions generally. (*See map, pp. 38, 39.*)

Regions of Depression.—The sinking of the earth's surface in certain parts of the world is proved by the encroachment of the sea upon its shores. The Atlantic coast-line of the United States is steadily sinking. Along the coast of New Jersey, South Carolina, and Georgia, the stumps of trees have been found standing vertically under the water many hundreds of yards from the present beach.

Similar evidences are found in the deltas (*see p. 45*) of many great rivers, such as the Mississippi, Rhone, Ganges, Indus, and Nile.

The coast of Holland has been depressed to such an extent that much of it is now below the level of the sea, from which it is protected partly by natural sand-hills and partly by vast artificial dikes. The southern coast of Greenland is sinking so rapidly that ancient structures have become submerged, and the natives are careful not to build near the water's edge. The east coast of Australia is also settling, along with a large area of the Pacific Ocean, as shown by observation on coral islands. The whole Australian Continent is low.

Regions of Alternate Elevation and Depression.—On the Italian coast at Naples are some columns of an ancient Roman temple which was gradually submerged, probably after the twelfth century of the present era, to the depth of 21 feet, and has since been raised, along with the adjacent coast, to its former level. At other points along the coast of Italy are many evidences of alternate elevation and subsidence, all taking place so gradually as to be imperceptible from year to year, and ascertained only by measurement between long intervals of time. (On subsidence and elevation, *see Lyell's "Principles of Geology," vol. ii., p. 180.*)

Temperature below the Earth's Surface.—The earth's surface is subject to slight variations of temperature due to the alternation of day and night, summer and winter, the greatest of which do not extend to a depth of 200 feet. In the Mammoth Cave of Kentucky, 70 feet below the surface, the temperature throughout the year is 54° F.

The temperature of the earth's crust increases with increasing depth, even in the frozen soil of Siberia. The rate depends upon the nature of the ground, and has been found as rapid as 1° F. in 27 feet, as slow as 1° F. in 200 feet. The mean rate, determined by observations in deep mines and artesian bore-holes, is 1° F. in 55 feet, or about 100° a mile.

It seems highly improbable that such a rate should be uniform with increase of depth and therefore increase of pressure. If it were, and if the melting-point of known substances were not increased by pressure, the solid shell of the earth's crust could not exceed forty miles in thickness, one-hundredth of the distance to the center; beneath this limit, all would be fluid.

If the interior were gaseous or liquid, it would be subjected to tidal movements like the ocean. The pressure becomes inconceivably great as the earth's center is approached, and the temperature must also be inconceivably high. It will probably never be ascertained whether this temperature is sufficiently high to prevent the interior from becoming solid; and, if so, whether the rigidity of the crust is great enough to resist completely all tidal disturbances. The earth's interior is probably softened in some places, and quite near to the surface are reservoirs from which hot, pasty material is occasionally thrown; but we are compelled to content ourselves with knowledge only of phenomena at the surface. (On underground temperature and the condition of the interior of the earth, *see Fisher's "Physics of the Earth's Crust," pp. 1–28.*)

VOLCANOES.

A Volcano is a mountain built of material that has been forced up in a hot condition through one or more openings in the earth's crust. It is often to some extent isolated, and is usually roughly conical in shape. The openings, when the volcano is not active, are closed nearly to their edges, forming basins which are called Craters.

Volcanoes have existed during all periods of the earth's history, and many of those that have been active in the past are now *extinct.* Such are found in France, Germany, Asia Minor, and in great numbers in the western part of the United States.

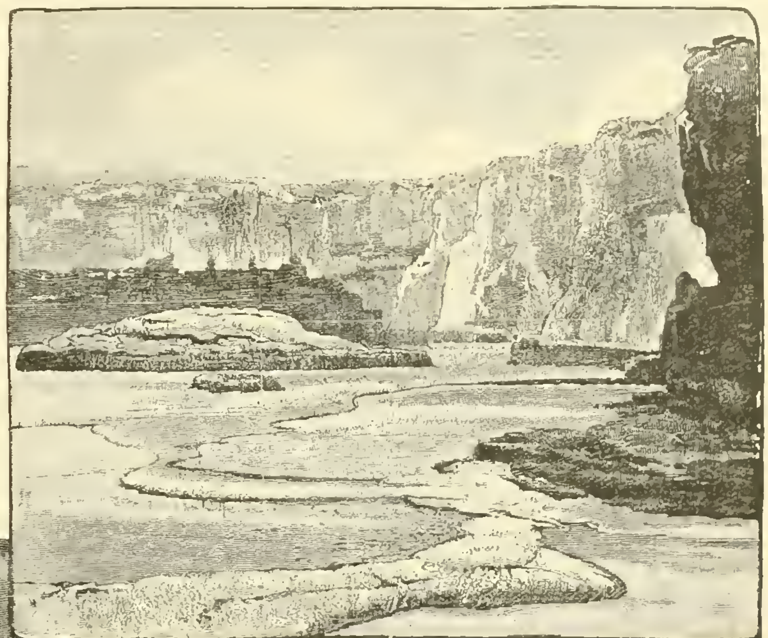
Of active volcanoes, the majority are *intermittent,* while some are *constant.* Vesuvius, Etna, and Hecla, are examples of the former; Strom'boli is the best-known instance of the latter.

Vesuvius was considered extinct until A. D. 79, when the terrible eruption occurred that resulted in the entombment of the cities of Herculaneum, Pompeii, and Stabiæ. Since that time it has been intermittent, and of late years nearly always active to a limited extent. Stromboli varies in the intensity of its activity, but has never been known to equal, in its eruptions, the violence of Vesuvius. Mount Etna, on the east coast of Sicily, the most famous volcano in the world, is remarkable for the number of minor cones scattered over its sides. A record of its eruptions has been kept since the seventh century B. C., the frightful lava-torrent of 1669, which overwhelmed the city of Catania, being among the most terrible convulsions known. Of late years, Etna has been comparatively quiescent.

CRATER OF VESUVIUS IN 1756.
(From a drawing made at the time.)

Phenomena of an Eruption.—Volcanic action is best understood by examining that of a constant, but not violent, volcano like Stromboli. This is one of the group of the Lip'ari Islands, lying north of Sicily and composed of volcanoes, most of which are now extinct.

Stromboli rises from the sea-bottom to the height of 3,000 feet above sea-level. On the side, 1,000 feet below the summit, is the present crater, which may be approached with safety. The bottom is traversed by interlacing cracks through which steam and various gases are continually rising. From larger fissures, molten material like tar overflows and slowly rolls down toward the sea, constantly sending forth steam in its course.



CRATER OF KILAUEA.
(From a photograph in 1885.)

From others, steam is emitted irregularly in sharp, explosive puffs. In the largest of the fissures, the stiff, hot, viscous mass is seen to heave sluggishly up and down. A large, thick bubble rises upon its surface and bursts with a loud explosion. The steam in its escape carries fragments of hardening scum high into the air. Part of this falls back into the crater, and part is scattered around, adding its mite to the pile that has thus grown up 6,000 feet above its submarine base during the course of untold centuries.

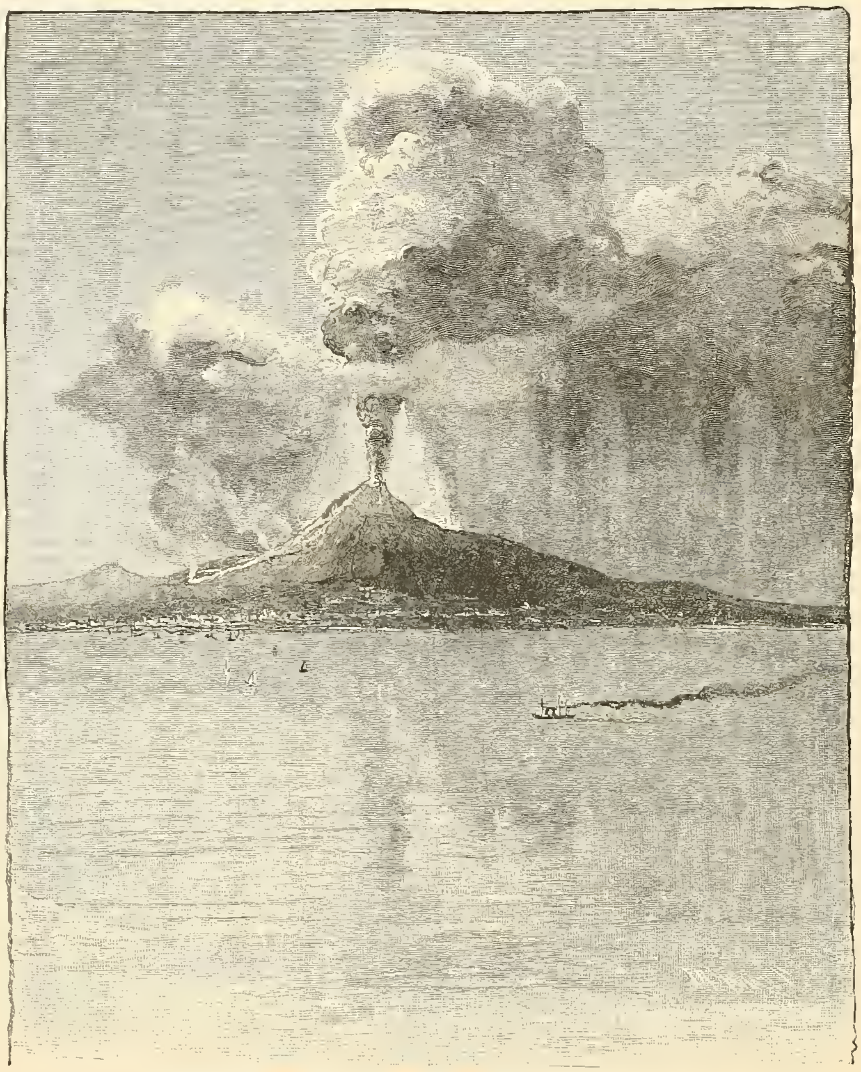
Stromboli is hence perpetually capped with a cloud of condensed steam. At night this is illuminated with the glare from the hot fissures below. Whenever a bubble bursts, this light suddenly increases, and gradually diminishes as the white-hot surface thus exposed cools down to redness. The effect is comparable to that of fog over an invisible and inconstant electric light, or around the revolving lamp of a light-house. (*Consult Professor Judd's "Volcanoes: What they are, and what they teach," p. 14.*)

A volcano has never been seen to emit a bright flame or any visible smoke as the result of combustion. It is in no sense a "burning mountain," nor has brimstone any agency in producing its heat, though sulphurous gases are often included among the products emitted. It is an immense terrestrial caldron, bubbling as it gives vent to overheated steam, which rises from underground reservoirs of intensely hot, viscous rock-matter.

If for any reason the communication with these reservoirs be interrupted, the steam gathers, as it does in a closed boiler. Finally, its elastic force becomes sufficient to blow up the entire floor of the crater in a single outburst or a series of outbursts, and this is followed by the overflow of great streams of lava. The sides of the mountain are split into fissures; and out of these, as often as from the crater, the hot streams flow.

Changes due to Eruption.—In the time of the Romans, the top of Vesuvius was a depressed plain, overgrown with wild vines, and surrounded by a rough and lofty rampart, a portion of which still remains and is called Monte Somma. It once served as a fortress for the besieged gladiator, Spartacus. A large part of this plain, together with the southern half of its rampart, was blown up in the violent eruption of 79 A. D., and a ragged pile of débris left in its place. This was perforated by subsequent eruptions, until in 1756 it presented the appearance of a series of ramparts within ramparts. These in turn were subsequently filled up, and at last destroyed in the great eruption of 1822, which left a huge cavity 1,000 feet deep and nearly a mile in diameter. Small cones were gradually piled up again, to be partly demolished by eruptions of greater violence like that of 1872. The present cone rises to the height of 1,000 feet within the half-inclosing ring of Monte Somma, and a railway now winds up to its summit.

Eruption of Vesuvius, 1872.—During 1871, Vesuvius was in a state of activity, which increased until, on April 24, 1872, a violent eruption began. From the crater, and from innumerable fissures, one of which extended from summit to base, liquid matter flowed. Three great lava-floods rolled down the mountain far beyond its base, destroying houses and villages. Their course could be distinguished by the thick volumes of steam given off and continuing to lift up miniature volcanoes on the hardened crust long after the surface became cool.



Vesuvius in Eruption, as seen from Naples, April 26, 1872.

(From a photograph.)

From the crater, vapors and rock - fragments were thrown to the height of nearly four miles, in a series of detonations like the heaviest of cannonading, that succeeded each other so rapidly as to produce a continuous roar when heard at Naples. Before and during the eruption, the ground, for miles in every direction, was in a constant state of tremor. The cloud of suspended vapor and dust was strongly electrified by the friction of the ejected materials. Bright flashes of lightning played around the column, and the rolling of thunder was added to the terrestrial cannonade. As the vapors condensed around the particles of volcanic dust, heavy showers of muddy rain fell, deluging the places that had not been reached by the hot streams of lava, or pelted with the hail of falling stones.

Eruption of Krakatoa, 1883.—One of the most gigantic eruptions recorded in history occurred on the 27th of August, 1883, in the Strait of Sunda, between Java and Sumatra. After eight months of variable activity, a series of violent detonations began on the afternoon of August 26th, continued throughout the night, and culminated on the morning of the 27th. The play of lightning about the whirling column of ascending dust and ashes was seen in Batavia, 94 miles away. Sunlight was excluded by the thick cloud, so that midnight darkness continued throughout the day over an area 400 miles across, and the air was gloomy to a distance of 1,000 miles. Trees seventy miles off were shattered by the weight of the falling mud, and Batavia was covered with it to a depth of three inches during the hours of darkness. To accomplish this, it is estimated that volcanic dust must have been projected not less than 10 or 15 miles up, even beyond most of the atmosphere. That it did reach this height is shown by the unexampled oscillations of the barometer in all parts of the world, indicating a series of air-waves that sped seven times round the globe at the rate of 700 miles an hour. The explosions were heard in India and elsewhere over a circle of 1,800 miles in radius, with Krakatoa as a center. The fall of dust was noted at points 915 miles northwest, 1,200 miles southwest, and 1,050 miles southeast.

By the two final outbursts, most of the small island of Krakatoa (*krah-kah-to'ah*), lying at the intersection of two fissures in the earth's crust, was hurled into the air; and the falling fragments formed two new islands about seven miles distant. The exposed parts had, in succession, been shot off till the remnant was reduced to the water's level. The sea then poured down into the chasm, and millions of tons of water mingled with white-hot lava in titan throes until the ocean gained the mastery. Over the shore 30 miles distant, waves 100 feet high rolled with resistless energy, sweeping away every tree, house, and living being. Coral blocks, from 20 to 50 tons in weight, were torn from their beds and stranded two miles inland. Upon the stifled crater, after the eruption, the depth of water was more than 1,000 feet, where previously there had been an elevation of 1,000 feet.

The finest dust from Krakatoa continued suspended in the upper atmosphere and was wafted over a vast area, causing a peculiar red glow at the time of sunrise and sunset that was noticeable for many months. (*Consult Report of the Krakatoa Committee of the Royal Society, 1888.*)

Among American Volcanoes must be remembered the Mexican Popocatepetl (*smoking mountain*), bearing upon its ice-crowned summit an enormous crater nearly a mile across and half a mile in depth; Jorullo (*ho-rool'yo*), forced up in a single night (1759) from broad plains covered with sugar and indigo plantations, to a height of nearly 1,700 feet; and the Andean Cotopaxi, most symmetrical of five active cones visible from the city of Quito, standing out in snowy splendor against the equatorial sky.

Most of the mountains of Iceland have been volcanic, Hecla being the best known of those that are now active. (*Consult Boehmer's "Observations of Volcanic Eruptions in Iceland."*)

Products of Volcanic Action.—Of the gases emitted from volcanoes, by far the most abundant is steam. Others in small quantity, chiefly acid in character, accompany it. The steam-blast, if violent, may carry off fragments of rock, as at Krakatoa. But of the denser material, most comes from greater depths and reaches the surface in a softened state. This is called Lava.

Composition and Characteristics of Lava.—Lava consists of silica, combined in various degrees with other substances known as *bases*, such as soda, alumina, iron, etc. If the latter predominate, the lava is usually dark, easily melted, and becomes glassy when cooled. If the silica predominates, the color is lighter, crystals are diffused through the mass, and it is stiff and viscous even when white hot.

Steam is often diffused through lava; hence, when the lava cools, it is full of bubbles. Pumice is glassy lava puffed with minute bubbles which give it a white look and cause it to float. Scoria is the name applied to crystalline lava, in which the bubbles are generally larger than in pumice, giving it a rough, cindery look. Fragments of it rubbing against each other produce volcanic dust. This, when soaked with water and compacted into a hard mass, is called Tufa.

Lava is a poor conductor of heat. The surface of a stream of it soon hardens into a rough crust, which protects that underneath from rapid loss of heat. Thus protected, it remains sensibly warm for many years. (On volcanic dust and lava-streams, *read Geikie's "Text-Book of Geology," p. 216.*)

Structure of Volcanic Cones.—The majority of volcanoes are built up of fragments of scoria and beds of tufa, piled around an aperture which becomes choked. If the eruption is violent, these fragments are spread far and wide, forming a broad base. The slope is steepest near the crater, and diminishes near the base.

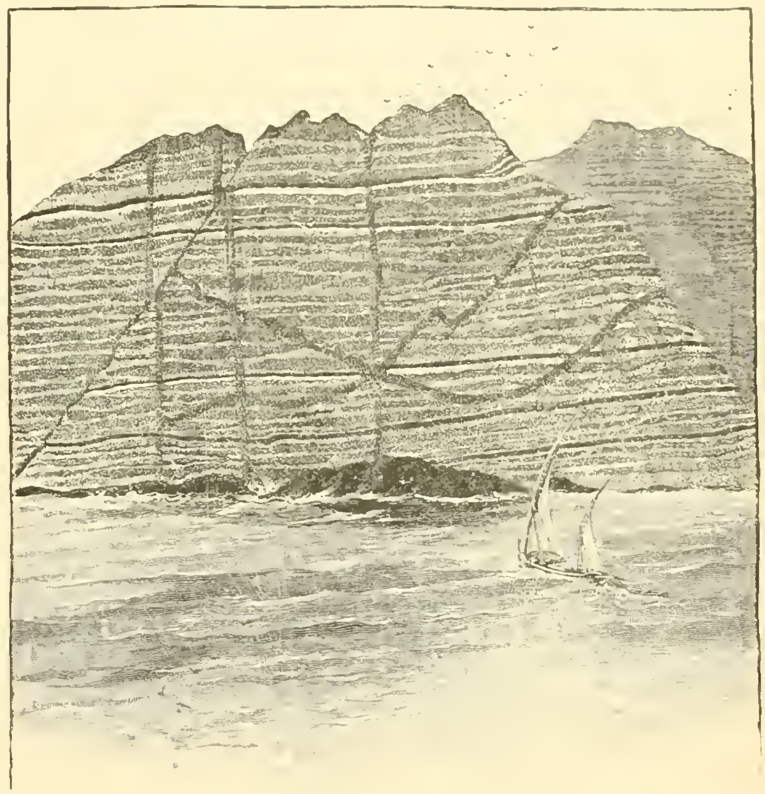
The layers of scoria and tufa are partly overlaid by streams of lava, which are covered with more scoria as the pile grows. After a period of rest the resistance of the solidified crater increases, until new eruptions cause the mountain to split. Lava is then forced up and hardens in the fissures, forming *dikes*, or it may overflow and spread in *sheets*. New craters are often started in this way.

In the island of Madeira a river has cut through the base of a volcano at one side, revealing the internal structure very beautifully.

Calderas is a name given to certain volcanoes which are made up entirely of lava cooled from a liquid state without being broken up into scoria and tufa. In these the ejections are but feebly explosive, and the activity is nearly constant. The lava contains much potash and iron, being very thin when hot and glassy when cold.

The best examples of this class are the volcanoes on the island of Hawaii (*hah-wi'e*), in the Pacific Ocean. This island is made up of a pile of lava. It is very gentle in slope, being 13,370 feet high at the top, from which the descent is at an average angle of only 6°. Near the summit of the flattened dome is the crater of Mauna Loa, a great pit over two miles wide, and from 700 to 1,000 feet deep. In this the lava is always hot; it overflows once every few years, but more frequently escapes by spouting up from fissures on the sides of the mountain, through which it is squeezed in great jets.

Another crater, known as Kilauea (*ke-low-ay'a*), exists about 10,000 feet lower on the side. Its greatest width is three miles, and its depth about 600 feet. Near the center is an inner pit 400 feet deep, in which the bottom crust is in almost perpetual movement, like the liquid in a caldron. Three areas in it are especially active, forming incandescent lakes where the lava is ever boiling and bubbling. At intervals small cones rise and burst, throwing the fiery spray from 50 to 100 feet into the air. Occasionally, as at Mauna Loa, the whole vast crater fills and overflows, or the lava bursts through the mountain-side, then sinks in the crater, sometimes out of sight. (*See "Science" for July 23, 1886.*)



Cliff-Section in the Island of Madeira, showing how a Composite Volcano is built up of Lava-Streams, Beds of Scoriæ, and Dikes.

On the 6th of March, 1886, Kilauea was unusually active. The following day the floor of the inner crater subsided, leaving an irregular cavity two-thirds of a mile long, wide enough to embrace the three lakes, and of unfathomed depth. Quiet and darkness reigned in the cavern until June. The crater has since become filled as formerly. (*See p. 33.*) (On Hawaiian volcanoes, *read Cumming's "Fire Fountains."*)

Fissure Eruptions.—Although the passage from the crater of an active volcano to the reservoir of lava below may be roughly tubular, it seems probable that every volcano starts over a fissure. If this be large enough, the lava is squeezed up through its entire length and floods the country. Such an overflow covers more than 100,000 square miles on the great western plateau of the United States, and is 3,000 feet thick where cut by the Columbia River.

If the fissure be small, lava is first forced through its widest parts; the rest becomes choked, and volcanoes are built over the first vents. The Lipari Islands are a group of volcanoes on three fissure-lines which radiate from a single point. Two of them, Stromboli and Vulcano (*vool-kah'no*), are still active. The crater of the latter has been shifted through six successive positions on the fissure, each new crater destroying the northern wall of the previous one.

Parasitic Cones.—When the volcano itself is split during an eruption, the smaller fissures serve as starting-points for minor cones, which grow upon the main cone, and hence are called parasitic.

Linear Arrangement of Volcanoes.—Most of the active volcanoes of the earth are situated upon zones where the crust seems to have been weaker than elsewhere, and along which fissures in all possible directions are specially numerous. One of these belts is continuous with the Andes, Cordillera, and Rocky Mountain systems; extends through the Aleutian, Kurile, Japan, and Philippine Islands, New Guinea, and New Zealand; and includes the volcanoes of the Antarctic Continent. Another reaches through the East Indian Islands, Southern Europe, the Azores, Canary and West Indian Islands, and Central America. The crossing points of these two zones in Central America and the East Indies are specially subject to the most violent outbursts.

Other less distinct zones may be traced, but these two include more than three-fourths of all the volcanoes known.

Of volcanoes not included in these zones, the Iceland group is the most celebrated. Near the middle of Asia three volcanoes occur in the Thian-Shan range, and another in the eastern part of Mongolia. The Hawaiian volcanoes form another isolated group. (*See Map, pp. 38, 39.*)

Proximity of Volcanoes to the Sea.—With the exception of the Asiatic group, all known volcanoes are within a few hundred miles of the sea. The Thian-Shan Mountains were once at the edge of a great inland ocean which in Tertiary times (*see p. 15*) covered the districts where its remnants may now be found in the Caspian and Aral Seas. This does not prove that the neighborhood of sea-water is necessary to volcanic activity; but since the greatest crumpling of the earth takes place along shore-lines, it might be expected that volcanoes would be most abundant in such regions. (On the geographical distribution of volcanoes, *consult Fisher's "Physics of the Earth's Crust," p. 259.*)

Number and Size of Volcanoes.—It is not known how many active volcanoes there are upon the globe. The number is variously estimated at from 225 to 600, the majority of which are on islands. The number of extinct volcanoes is far greater.

Volcanoes vary in size from mere hillocks to mountains four miles high. The depth of water in the neighborhood of Mauna Loa is 18,000 feet. The height of this pile of lava above the sea-bottom, therefore, exceeds that of the Himalaya Mountains above sea-level.

Cause of Volcanic Action.—All porous strata below a certain level are saturated with underground water, which is pressed by the overlying masses, and percolates even against great resistance through the rocks. It is believed that water may thus flow freely into volcanic vents, producing steam sufficient to account for the observed explosions.

Aside from this, many volcanoes are near enough to the sea to warrant the supposition that the percolation of sea-water may be added to that of fresh water, especially where any great lines of fissure are known to exist.

If water be sufficiently heated at great depths, it permeates the mass with which it is in contact, but is prevented by the great pressure from flashing into steam until a certain temperature is reached, at which its expansive force is sufficient to balance this pressure. The ground then yields at the weakest point; a crater is opened, and the consequent removal of pressure causes the water to change into steam throughout the whole mass of lava, which is blown out in a spongy condition.

But this explanation is not sufficient to account for the comparatively quiet forcing up of lava through fissures, as in the case of the Hawaiian volcanoes, where there is little explosive action. The primary cause of these eruptions is doubtless the shrinking of the earth's crust, which produces pressure upon any liquid, viscous, or plastic layer within it. Pressure is transmitted in all directions by a liquid, and hence the crust yields over such a reservoir, breaking into fissures which transmit the hot matter from below. Relief being thus gained, there is total or partial cessation of activity until further contraction causes a repetition of strain.

This general cause does not exclude the operation of other special causes, such as the local production of steam. Probably all may operate together, the outbursts of steam being most noticeable on cones of scoria and tufa.

In confirmation of this view, it may be observed that great eruptions are nearly always preceded by trembling of the ground and muffled subterranean sounds. When an outburst occurs, it is followed by the lava-flow, instead of being accompanied by it; which shows that steam alone is not sufficient cause for the upheaval of the lava. This flow in turn is coincident with the cessation of underground thundering.

Lava-Reservoirs.—The ejection of lava is no proof of connection between the surface of the earth and any general liquid interior. When Mauna Loa is active, there is no observable effect on Kilauea; and an eruption of Etna is not usually accompanied with special activity either of Stromboli or Vesuvius. The conclusion is, that each of these volcanoes has a separate reservoir. The earth's contraction does not produce equal strain on all parts of the surface; hence neighboring volcanoes may exhibit very unequal degrees of disturbance.

Relation of Volcanoes to Earth-Oscillations.—Wherever observations have been made in regions of volcanic activity, it has been found that the land is for the most part rising out of the sea, or becoming tilted. The east coast of New Zealand is rising, while its west coast is sinking. The coast of Naples was sinking for a time, and is now rising. In the great sinking region of atolls in the Pacific Ocean, volcanic activity seems to be quite extinct.

MINOR VOLCANIC PHENOMENA.

Mud-Volcanoes, Poisoned Caves, etc.—In regions where volcanic activity is nearly extinct, small fissure-eruptions occur, in which the ejected materials may be mud, water, or various gases. Among these last are included strong acid gases, which have a marked effect upon the surface rocks, forming compounds of much commercial value.

The last stages of dying activity are manifested in the emission of sulphureted hydrogen, the odor of which is peculiarly disagreeable, or carbonic acid, which, being a heavy gas, collects in fissures and craters, and mingles but slowly with the surrounding atmosphere. At the "Grotto del Cane" (*kah'ne*) near Naples, its presence is often shown by immersing a dog in the noxious gas. The animal soon falls, and is revived by the use of cold water before life is extinct.

The country about Rome has been the scene of volcanic action, and the springs are copiously charged with carbonic acid and sulphureted hydrogen. Lake Solfatara (*sol-fah-tah'rah*), between that city and Tivoli, receives a stream of tepid water saturated with carbonic acid, which escapes in such quantities as to cause the water to look as if it were boiling.

The stories of the Upas Valley of Java, strewed with the bones of dead animals and birds, are probably based on the presence of carbonic acid in old craters or fissures.

Geysers.—Water when hot dissolves many silicious substances, which are deposited when it cools. A fissure transmitting water thus charged becomes clogged with these deposits, until at last only an irregular tube is left. At the surface, the ground is covered over many acres with a silicious casing, and diversified with knolls and protuberances of fantastic form and dazzling whiteness.

If the subterranean temperature be above the boiling-point of water, much of this may remain temporarily underground in a superheated condition, ready to burst into steam with the slightest relief of pressure. The rest, reaching the surface, forms streams that gradually cool as they flow away.

The presence of steam beneath the surface causes these springs to emit their contents explosively like volcanoes. They may be regarded as miniature volcanoes in which lava is replaced by water. The explanation becomes therefore the same as that already given for volcanoes of the Vesuvian type. After an eruption, by which the tube is completely emptied, the water collects in it again and rises to the surface. Beneath it steam again gathers, raising the temperature of the water and becoming itself overheated, until the critical point is reached and a new explosion occurs. Since the supply of heat and the size of the tubes remain nearly constant, the eruptions follow each other periodically. The name Geyser (*gi'ser*) (an Icelandic word meaning *gusher* or *rager*) has been applied to springs which thus emit their contents explosively and at regular intervals.

The geysers of Iceland are perhaps the most celebrated, because they were the first studied and have been the longest known. They number about one hundred spouting springs, and lie near Hecla, within a circuit of two miles. The Great Geyser periodically sends up a column of boiling water 100 feet high and nearly 10 feet in thickness. Deposits of silica have produced a basin-like mound around the mouth of the tube, so that just before an eruption a bowl of hot water 56 feet in diameter is ready for discharge. (On the geysers of Iceland, *see Lyell's "Principles of Geology," vol. ii., p. 216.*)

In the volcanic North Island of New Zealand are geysers surpassing those of Iceland. But the finest geyser region in the world is that of the Firehole River in the Yellowstone Park, Wyoming, where may be seen abundant evidences of volcanic activity in the past, besides mud-volcanoes and holes now emitting steam and other gases continually. The total number of vents of all kinds in this region is estimated at 10,000.

Questions.—What are the changes produced by contraction of the heated interior of the earth, and where are there illustrations of slowly progressing change? Compare the density of the earth at its center and surface with the density of water. Explain the relation between density and contraction. What do deep-sea soundings show to be the condition of the ocean's bottom? What can you say of subsidence and elevation? Of underground temperature, and the general condition of the earth's interior?

Describe the appearance of a volcano. What is a crater, and how is it formed? How are volcanoes classified? Describe the succession of events in an ordinary eruption; the changes due to eruption. Give an account of the eruption of Vesuvius in 1872; of Krakatoa in 1883; of Etna; of Popocatepetl and Cotopaxi; of the volcanoes of Iceland. State the composition of lava. At what period of an eruption is it discharged? What is pumice? Scoria? Describe the crater of Kilauea, and Hawaiian volcanoes generally. What is known of the geographical distribution of volcanoes, and inferred therefrom? Present a theory of the cause of volcanic action. Are adjacent volcanoes generally active at the same time? Explain the relation between volcanoes and earth-oscillations.

Describe and account for the phenomena of mud-volcanoes, poisoned caves, and geysers. What is indicated by the issue of carbonic acid from fissures in volcanic rock? Where are the great geyser regions of the world?

EARTHQUAKES.

An Earthquake is a commotion transmitted in all directions through the earth's crust in waves of elastic compression. It originates in some center of disturbance, outcrops upon the surface, and is manifested in perceptible motion of the ground.

Earthquakes vary in intensity from gentle tremblings, requiring delicate instruments for their detection, to convulsions of terrific violence, capable of destroying the most substantial products of human labor.

During the last few years the study of earthquakes has been developed into a special branch of science, to which the name Seismology (from two Greek words meaning *science of earthquakes*) is given. Instruments called seismometers have been devised for measuring the shocks due to seismic energy. (On seismometers and experiments in observational seismology, *see "Transactions of the Seismological Society of Japan," vol. iii., pp. 1–12; vol. iv., p. 87.*)

Regions affected.—Earthquakes occur in all parts of the world, but are most frequent in mountainous regions, especially amid mountains that are geologically young, and in regions of volcanic activity. In some cases the shocks are directly the consequence of volcanic eruption, but they occur also in places and under circumstances that indicate no connection with volcanoes.

The Andes region of South America and the southern part of Italy include some of the most frequently and disastrously shaken districts in the world, as well as some of the most active volcanoes. But earthquakes often occur without the exhibition of any unusual activity in these volcanoes. The Himalayas and table-lands of Central Asia are subject to violent earthquakes, but almost free from volcanoes. The Alps and the Pyrenees are often shaken, but include no volcanoes that are not extinct. The same is true of the American Coast Range south of the Columbia River. Earthquakes occur also, though less frequently, in certain non-volcanic basins, such as the valley of the Mississippi and the basin of the Baltic Sea. They are most rare in Russia.

Past and Present Frequency of Earthquakes.—Robert Mallet collected a catalogue of more than six thousand earthquakes occurring between 1606 B. C. and 1850 A. D. Since 1850, the number of earthquakes recorded has greatly increased, though there is no reason to believe that there has been any increase in actual frequency. By the use of appropriate instruments in Italy, Japan, and elsewhere, it has been proved that in such regions as these hardly a day passes without a noticeable earth-tremor. Probably not a moment elapses without an earthquake in some part of the world.

Cause of Earthquakes.—No one cause can fully account for all earthquakes. By far the most general explanation is to be found in the breaking of the earth's crust under the same contraction that squeezes out lava from volcanoes, and folds the regions of weakness into mountain-ranges—the shrinking of the crust on the cooling interior. The strata bend very gradually, and the rock is put into a condition of strain, until it suddenly yields with a violent concussion. One wall of the resulting fissure may slide past the other, producing a fault (*see p. 10*), and giving a strong impulse to the adjacent rock. All rock is more or less elastic, and hence the impulse is propagated in every direction as an earth-wave. Most earthquakes are now believed to be the result of such faulting, due to strain gradually developed in the slow contraction of the earth's crust.

The theory that earthquakes are due to subterranean explosions of steam is perhaps applicable to some of the shocks that accompany volcanic eruptions; but such shakings are usually only local, and there is no evidence sufficient to establish this as a cause for the great tremors that have at times been felt over millions of square miles of the earth's surface. (*Consult a lecture by Professor J. S. Newberry, "School of Mines Quarterly," October, 1886.*)

Questions on the Map of Volcanoes and Seismic Areas.—Trace the longest line of active volcanoes you can find on this map. Where are they most numerous in the neighborhood of the Atlantic Ocean? Where do you find active volcanoes in Europe? Do you find extinct volcanoes in Europe? Where? Name all the islands of the mid-Pacific Ocean upon which you find active volcanoes. What remarkable series borders the Indian Ocean? Point out Krakatoa; Vesuvius; Stromboli; and Etna. Is the coast-line rising or sinking in the neighborhood of these volcanoes? Where is sinking land to be found in the neighborhood of volcanoes? At what places in the United States are the coasts sinking? Where in South America? Where in North America are the coasts rising? In South America? What do you observe about Greenland? Where is the most extensive sinking area in the world? Estimate the length of this in degrees of longitude. Translate these into miles. Give its width in degrees of latitude. Translate into miles. What sinking tract do you find next in area? What is the most characteristic feature of these tracts? Are there any coral regions in the immediate neighborhood of the United States? Where? Point out the most northern coral-reefs in the Atlantic. About what is their latitude and longitude? Do you find any coral-reefs equally remote from the Equator on the south side?

Longitude
from
Greenwich
East
West
BAFFIN BAY
GREENLAND
Lancaster Sound
DAVIS STRAIT
HUDSON BAY
LABRADOR
NEWFOUNDLAND
ARCTIC OCEAN
JAN MAYEN I.
ICELAND
ARCTIC CIRCLE
BRITISH ISLES
GERMANY
NORWAY
SWEDEN
Supposed Limit of Vibration in the Earthquake of Lisbon, 1755
Limit of Shock Earthquake 1755
Limit of Simultaneous Shock
AZORES
Lisbon
Stromboli
Etna
CANARY IS.
Teyde
MOROCCO
ALGERIA
TUNIS
AFRICA
TROPIC OF CANCER
CAPE VERDE IS.
Fogo
Cameroons
EQUATOR
Submarine Volc.
ASCENSION I.
ST HELENA I.
TRINIDAD I.
TROPIC OF CAPRICORN
TRISTAN D'ACUNHA
ATLANTIC OCEAN
NORTH AMERICA
UNITED STATES
ALASKA
C. Barrow
Bering Strait
Yukon R.
Mackenzie R.
Mt. St. Elias
Mt. Fairweather
Mt. Edgecumbe
ALEUTIAN IS.
BERING SEA
Mt. Baker
Mt. Rainier
Mt. St. Helens
Columbia
Mt. Hood
Mt. Shasta
Nat. Park
Geysers
New Madrid
Hot Springs
Mammoth Cave
Charleston
BERMUDA IS.
in the Earthquake of New Madrid, 1811
V. de las Virgines
Gulf of Mexico
BAHAMA IS.
WEST INDIES
Caribbean Sea
Grenada
TRINIDAD
Caracas
Orinoco R.
HAWAIIAN OR SANDWICH IS.
Mauna Kea
Mauna Loa
Kilauea
PACIFIC OCEAN
EQUATOR
PHOENIX IS.
UNION IS.
SAMOA IS.
FIJI IS.
FRIENDLY IS.
SOCIETY IS.
MARQUESAS IS.
Hiwaoa
PAUMOTU IS. OR LOW ARCHIPELAGO
TROPIC OF CAPRICORN
Easter I.
KERMADEC IS.
CHATHAM I.
Narborough
GALAPAGOS IS.
SOUTH AMERICA
Tolima
Cotopaxi
Amazon R.
Bahia
Callao
Lima
Arequipa
Valparaiso
Rio de la Plata
CHILOE I.
Fitzroy
TIERRA DEL FUEGO
Sarmiento
Deception I.
COMPARATIVE HEIGHTS OF VOLCANOES
VOLCANOES OF THE CENTRAL ZONE
WEST INDIES
ICELAND
ITALY
CENTRAL ASIA
AFRICA
SUMATRA
JAVA
PACIFIC OCEAN
VOLCANOES ON THE WEST SIDE OF THE PACIFIC OCEAN
KAMCHATKA
KURILE IS.
JAPAN ISLANDS
PHILIPPINE IS.
MOLUCCAS IS.
NEW HEBRIDES
NEW ZEALAND
ANTARCTIC CONTINENT
VOLCANOES ON THE EAST SIDE OF THE PACIFIC OCEAN
ALEUTIAN IS.
ALASKA
UNITED STATES
MEXICO
CEN. AMERICA
U.S.COL.
ECUADOR
PERU
CHILE
20,000 ft.
10,000
Sea Level
Snow Line
Line of perpetual Snow

The Violence of an Observed Earthquake-Shock may depend upon the following conditions:

1. The degree of strain preceding the concussion.
2. The extent of rock that yields.
3. The nature of the rock transmitting the impulse.
4. The distance of the observer from the starting-point.

The production of earthquakes just before a volcanic eruption, or during its continuance, is due probably to the repeated fissuring of the earth below the crater, the concussions resulting from sudden expansion of steam, and the collapse of cavities emptied by the eruption. They often cease after the outflow of lava begins, but as frequently continue for a long time, the equilibrium underground being not established at once.

Duration of an Earthquake-Shock.—Although the production of an underground fissure may be sudden, it is never instantaneous. A slight tremor is first felt; this quickly rises to a maximum, and then dies out more slowly, the entire shock lasting from fifteen seconds to two minutes or more. By the aid of seismometers, the duration is found to exceed considerably what is noticeable by the unaided senses.

Earthquake-Periods.—An earthquake is usually not limited to a single shock; several shocks occur in succession. At first these are separated only by a few minutes or hours, the earliest being most violent; their intensity then diminishes as the intervals become greater, until after a few months the ground is no longer sensibly disturbed.

During the twenty-four hours following the destruction of Lima, in October, 1746, 200 shocks were counted; and within the next four months, 250 more were felt.

At the island of St. Thomas, one of the Lesser Antilles, an earthquake occurred in 1868, in which 283 shocks were counted in a little over nine hours.

In some cases a series of violent shocks occurs, each attended with its retinue of minor ones, forming collectively one great seismic convulsion that may last for weeks. Such catastrophes are most frequent in volcanic districts.

In the Central American state of Salvador, near Lake Ilopango, more than 600 earthquake-shocks were felt during the last ten days of 1879. The water of the lake was thrown into commotion, the ground was broken into a network of cracks, and in January, 1880, a new volcano rose in the center of the lake. These earthquakes were obviously products of volcanic energy.

After the earthquake that shook New Zealand in 1848, the shocks continued for nearly five weeks, and during much of this time at the rate of at least 1,000 shocks a day.

The city of Messina in Sicily was destroyed in 1783, and the agitation of the ground continued with but little intermission for about ten years.

Nature of Earthquake-Waves.—The nature of these waves is best understood by assuming a single point as the *focus* of disturbance. From this a wave proceeds out spherically, each particle traversed by it receiving a forward and then backward motion. If a body be immediately over the focus, it is thrown vertically upward. Elsewhere the motion is both upward and sideward, the upward component becoming less in comparison with the other as the horizontal distance is increased.

If the focus be a long fissure instead of a point, the motion becomes rather more complex. In some cases a whirling effect is produced, as in the Calabrian earthquake of 1783, in which blocks of stone forming square columns were twisted at various angles. (*See Professor Milne's "Earthquakes and other Earth Movements," p. 41.*)

Illustration of Intensity of Shock.—In 1797 an earthquake occurred in the Andes, its focus being almost under the town of Riobamba, in Ecuador. The ground was shattered in some places; the bodies of men were thrown upward one hundred feet into the air and found afterward on a hill across a river. Graves are said to have been rent open, and corpses hurled out of them.

Despite such violence, the extent of swing imposed upon the ground by an earth-wave is seldom more than a few inches. By the use of seismometers, the vertical component has been found rarely to exceed one-fiftieth of an inch; and, when the horizontal component exceeds a fourth of an inch, buildings are shattered.

Determination of an Earthquake-Focus.—The earthquake of 1857 near Naples was carefully studied by Mallet. By examination of the cracks produced in buildings, and of the direction in which bodies were thrown, he estimated the focus to be a fissure nine miles long, the point of greatest commotion being near one end of it and not more than ten miles below the surface. With the aid of seismometers, the direction of motion and the angle of emergence may be registered at many different places around the same focus. By comparing these and noting the time at which the shock occurred at the station-point of each seismometer, the position of the focus and the rate of transit through the ground may be computed. The depth is rarely more than twenty miles.

Velocity of Transmission.—Japan is continually shaken by earthquakes, most of which are faint, and seismometers are kept always in readiness to register the motion. The following results have been deduced from many observations, those of special importance being in connection with the earthquake of October 25, 1881:

1. Different earthquakes across the same country may travel with different velocities, varying from a few hundred feet to two miles or more a second.
2. The same earthquake travels more rapidly near its focus than across distant regions.
3. The greater the intensity of the shock, the greater is the velocity of transmission.

Earthquakes have been artificially produced by the explosion of gunpowder or dynamite underground. The rate of transit for shocks produced by gunpowder was observed by Mallet to be 825 feet a second in sand, and 1,665 feet in granite. Dynamite explosions are more sudden and violent than those of gunpowder. An explosion of about 50,000 pounds of dynamite was effected at Hallett's Point, near New York, in 1876. Through the neighboring country the rate of transit varied from 5,000 to 8,000 feet a second. About 300,000 pounds of dynamite were exploded at Flood Rock in October, 1885. The rate through the same country varied from 5,000 to 20,000 feet a second, being fastest where the ground is of hard rock and slowest where it is sandy. (*See "Science," January 8, 1886.*)

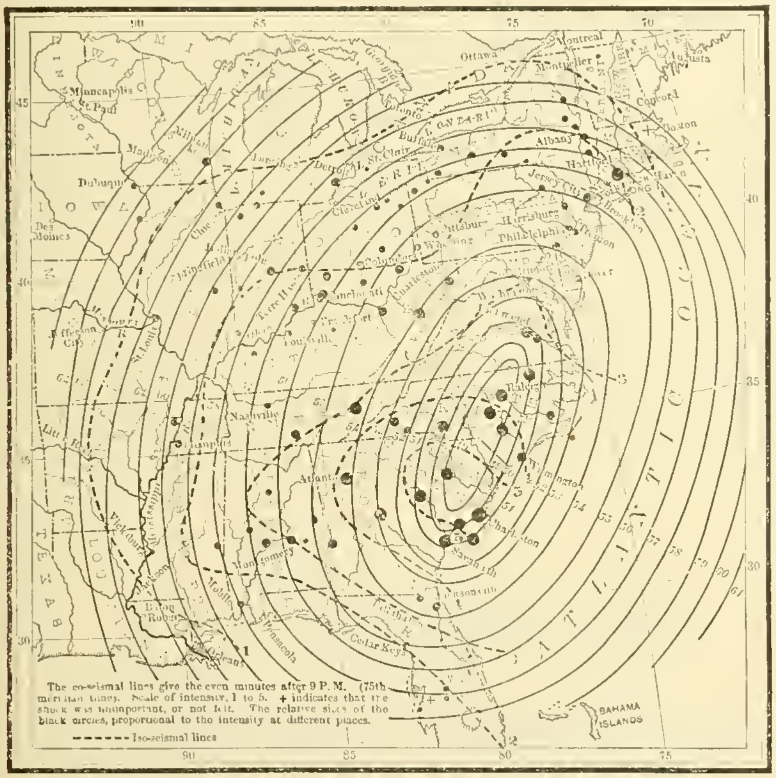
Effects of Earthquakes on Land.—The effect of an earthquake-shock is usually far more destructive on beds of sand or clay than on solid rock. In 1755, the most disastrous earthquake on record passed under Lisbon. The lower part of the city, built on clay, was utterly destroyed. All of the buildings in the upper part, resting on a foundation of basaltic rock and hard limestone, escaped entirely.

In soft ground, a violent earthquake nearly always produces cracks, which often close just after the passage of the wave, but sometimes are left as open chasms.

At the Calabrian earthquake, in 1783, a few such chasms were formed that exceeded 100 feet in width and 200 feet in depth, varying from half a mile to a mile in length. In the Port Royal earthquake, 1692, people were swallowed up by fissures or trapped about the middle. At the time of the Mississippi earthquake, 1811, water mixed with sand and mud was thrown out of the fissures in jets that dashed over the tallest trees.

Other effects produced by the passage of earthquakes have been disturbances in the level of lakes and rivers, the drying of springs and formation of new ones, the alteration of the temperature of water, the depression or elevation of large tracts, and even horizontal movements causing changes in the position of fences and walls.

The Ischian Earthquake.—The island of Ischia, in the Bay of Naples, was the scene of a destructive earthquake, July 28, 1883, which was presaged not only by premonitory shocks, but by abnormal variations in the temperature of the thermal springs for which the island is noted. A number of towns were destroyed or seriously damaged; and nearly 2,000 persons lost their lives. This earthquake is believed to have had its origin in a rupture along an old volcanic fissure. *(Consult "The American Journal of Science," vol. xxvi., December, 1883.)*



CO-SEISMAL AND ISO-SEISMAL LINES OF THE CHARLESTON EARTHQUAKE.

The Charleston Earthquake.—From 50 to 100 earthquakes occur annually in the United States, but most of them are mere tremors of the ground and hardly noticeable. The most violent of the present century took place on the 31st of August, 1886, causing great destruction at Charleston, S. C. It was followed by slight shocks occurring at irregular intervals through many weeks. The focus was a line of fracture, from which the disturbance extended over most of the country east of the Mississippi River. The position of this line and the rate of progress of the earthquake, as determined by the United States Geological Survey, are shown in the accompanying map, in which the elliptic Co-seismal Lines connect those places that were shaken at the same instant—while the dotted Iso-seismal Lines indicate the sections where the intensity of the shock was equal. *(See Rockwood's "Notes on American Earthquakes;" and Prof. Shaler's "Aspects of the Earth," pp. 36–45.)*

The Riviera Earthquake.—On the 23d of February, 1887, the northern part of Italy was shaken by an earthquake, involving the loss of about 800 lives in the many towns that suffered. The greatest damage was done at the fashionable winter resort of Riviera *(re-re-ā'rah)*. About seven hours after the first shock was felt in Italy, this earthquake was detected at Washington by means of a seismometer. The earth-wave therefore crossed the intervening area, 4,000 miles, at the rate of nearly 600 miles an hour, or 840 feet a second.

Effect of Earthquakes at Sea.—Many great earthquakes have begun under the sea, near coast-lines. The effects of these are worst of all, because of the great waves which follow.

The immediate cause of such a disturbance may be a submarine volcanic explosion, or probably more often the faulting of the sea-bottom, the focus being close under the water. The sudden uplift of one wall through hundreds of feet would be a sufficient cause for the production of a wave higher than any produced by the most violent storm. The water, once disturbed, moves up and down many times, each wave spreading out and extending thousands of miles. The destructive effect of such waves on a neighboring shore may even exceed that of the earth-wave. The sea at first recedes, and then sweeps over the exposed ground and far upon the land. The recession has been estimated as much as two or three miles. Ships thus caught are first stranded on the mud, and then dashed to pieces or borne inland.

At Lisbon, in 1755, 30,000 persons were killed by the earth-shock and falling houses. The first sea-wave, 60 feet high, came an hour afterward, flooded the wreck made by the earthquake, and 30,000 more perished before the series of great waves had spent their energy.

The velocity of transmission of the sea-wave is much less than that of the earth-wave, and depends upon the depth of water. Those which followed the Lisbon earthquake were distinctly perceptible on the American shores. After the wave has traveled a long distance, the motion is comparatively gentle, like that of a tide, recurring at intervals ranging from ten minutes to half an hour.

Relation of Earthquakes to other Phenomena.—By comparison of records covering long periods, it has been found that earthquakes are slightly more frequent in winter than in summer, and at times when the relative position of the sun and moon is such as to produce high tides. The earth's crust at certain places may be in a condition of strain, almost at the critical point of rupture. A change in the temperature or pressure of the air may possibly increase the surface strain. The attraction of the moon may have a similar effect. But such agencies are far from being alone sufficient causes for the production of earthquakes.

Prediction of Earthquakes.—In volcanic regions, the escape of soluble gases through minute fissures has occasionally served as an indication of underground disturbance by altering the taste of mineral springs; rumblings in the ground are often heard at the same time. But such signs are very untrustworthy. Accounts, also, of peculiar conditions of the air, or of the human system, or of the temper displayed by animals, as premonitors of earthquakes, have no better basis than superstition.

Questions.—Define seismology. What is meant by an earthquake? Where are earthquakes most frequent? Where rare? Discuss the accepted modern theory of earthquakes. Can they always be traced to volcanic action? On what does violence of earthquake-shock depend? Describe an earthquake as regards duration, periods, dynamic effect, nature and velocity of wave-transmission, and in explanation of the different movements imparted to the earth's surface. Explain co-seismal and iso-seismal lines; earthquake-foci.

Under what circumstances have earthquakes proved fatal to human life on a large scale? Describe earthquake-effects, especially in connection with the Lisbon, Ischian, and Charleston calamities. Can you discern the utility of volcanic vents, and suggest how volcanoes may possibly act as great safety-valves for the prevention of more frequent and more disastrous convulsions than those we are familiar with? How valuable are indications of approaching earthquakes?

THE WATERS OF THE EARTH.

Water is the principal agent that wears down the continents, and fills up the ocean basins with the fragments of such disintegration. In this process of leveling, it leaves the harder ridges exposed, and carves out the picturesque scenery of mountain-regions. Water is also the most important highway of communication on the globe, the source of power on which civilization is most dependent; it is, moreover, indispensable to all terrestrial life.

The science whose object is the measurement and description of the seas, lakes, rivers, and other waters of the earth, is called Hydrog'raphy (from two Greek words, meaning *water-description*).

Composition and Properties of Water.—Water is a chemical combination of two gases, oxygen and hydrogen. It exists ordinarily as a liquid, but may be readily transformed into a solid or a vapor by the withdrawal or application of heat. In its liquid state it fills the oceanic valleys and the beds of streams; it forms ponds and lakes in the depressions of the land, and collects in the cavities of rocks to produce springs. As a solid, it appears in the glacier and iceberg, and constitutes the frozen covering of the earth's crust toward either pole. In the form of vapor it is universally present in the atmosphere we breathe, and under certain conditions becomes visible as cloud and mist.

Water, when absolutely still, is an almost perfect non-conductor of heat. The temperature of a mass of it can be changed, therefore, only by the internal motion of currents. In cooling, it contracts until the temperature 39·2° F. is reached, when it begins slowly to expand. Its density, therefore, is greatest at this temperature, and the liquid thus cooled at the surface sinks to the bottom, to be replaced by the warmer portions from below. When the surface-water is cooled to 32° F., it crystallizes into ice, expanding at the same time about one-tenth. Ice, therefore, always floats, and because of its poor conductive power it protects the water beneath from further reduction of temperature. A shallow body of water in continued extreme weather may become frozen to the bottom, but this is not known to have ever occurred where the depth exceeded a few feet.

The expansion of water in cooling from 39·2° to 32° is supposed to be due to the beginning and progress of crystallization, which is completed with sudden increase of expansion at 32°.

By heating water under ordinary conditions, it expands slowly until a temperature of 212° F. is reached, when it begins to change into steam. Additional heat accelerates this change without raising the temperature.

Three Temperatures are thus important to remember: 32° F., the freezing-point of water, or melting-point of ice; 39·2° F., the point of maximum density for water; 212° F., the boiling-point of water, or condensing-point of steam.

The boiling-point of water is subject to variations dependent chiefly upon the pressure of the atmosphere. On high mountains, where the air is less dense than at sea-level, the boiling-point is lower.

An exposed body of water gives off vapor from its surface at all temperatures. The rate of loss by evaporation is fastest when the air is dry, warm, and kept in motion by the wind. The vapor, as it ascends, forms clouds (*see p. 78*).

To change the temperature of a pound of water through 1° F., requires more heat than to effect an equal change of temperature in any other common substance. Water is hence less rapidly warmed and cooled than land. Since the air takes its temperature from bodies with which it is in contact, the presence of a large mass of water tends to keep the air from becoming either very cold or very warm.

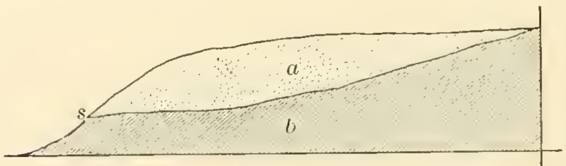
Water has the capacity for dissolving a greater variety of substances than any other one liquid. This property causes it to be an important agent in changing the character of all soil with which it comes in contact. (*Consult Professor Charles F. Chandler's lecture on water, delivered before the American Institute of the City of New York.*)

INLAND WATERS.

Disposal of Rainfall.—Of all the water that falls as rain or snow, it is estimated that about one-third sinks into the ground, another third flows off at the surface and is carried to the sea, and the remaining third is evaporated. This ratio is variable, depending to some extent on latitude, climate, and nature of ground. Ultimately nearly all finds its way to the sea, to be again evaporated and to take part ceaselessly in the great circulation of Nature.

Percolation of Water through the Ground.—Any piece of rock, apparently dry when taken from the ground, will lose in weight if exposed to heat. It contains water distributed through its mass in minute fissures and cavities. But independently of this, water passes through soils of all degrees of hardness, percolating fastest through sand, very slowly through clay, and almost wholly stopped by solid granite or limestone. Strata of sandy soil are therefore *permeable* (*admitting of being passed through*); those of clay and granite, comparatively *impermeable.*

Surface-Springs.—When a permeable stratum (*a*, see figure) rests upon one that is impermeable (*b*), the rain soaks through and the lower layers become saturated. Underground channels are formed by which the water reaches the surface, causing a Spring at the point (*s*) where the line between the two strata is exposed. Such springs are often found on hill-sides. If the area be large and the slope of the harder stratum slight, a spring thus formed may continue active from year to year without intermission, and serve as the unfailing source of a brook.



Formation of a Surface-Spring.

Artesian Wells.—If the permeable stratum rests between two impermeable strata, as in the figure on the following page, and is inclined so that an edge (*e*) is exposed, the region of saturation may extend to great depths. If a bore-hole (*h*) be drilled through the overlying strata (*c*) so as to tap the saturated region (*a*), the water reaches the surface, being forced up by the pressure below. The force depends on the elevation of the edge (*e*) where the water began to percolate, however distant it may be. An artificial spring thus made is called an Artesian Well.

Artesian wells derive their name from the French province of Artois (in Latin *artesium*), where the first European wells of this kind are believed to have been sunk. But the boring of artesian wells in the Desert of Sahara appears to have been an ancient practice; in all desert plains resting upon porous strata through which the surface-water percolates and is lost, their value is inestimable. Within the last quarter-century, numberless perforations have been made by French engineers in the Sahara, with the effect of supplying the needed water for irrigation, and thus converting much territory that was deemed irreclaimable into fertile and habitable country. Among the most noted artesian wells are those at Louisville, Ky. (2,086 feet), and Charleston, S. C. (1,250 feet); the latter discharges 1,200 gallons of water an hour.

In the western part of Pennsylvania mineral oil called petroleum is found in great quantities under the ground, and over 30,000,000 barrels are annually brought to the surface by means of artesian wells.

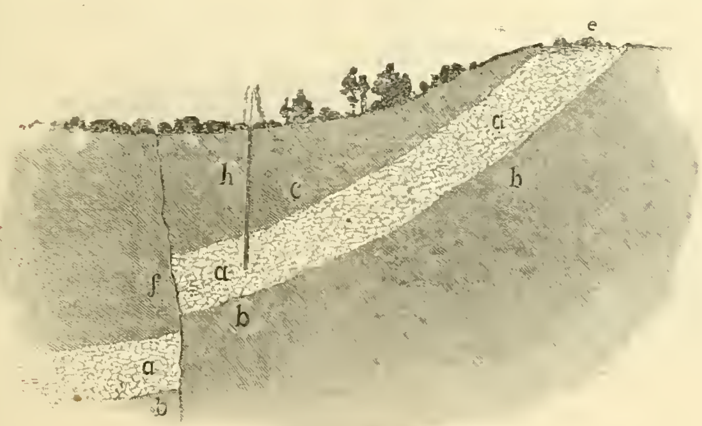
Mineral Springs.—If a porous stratum bearing water is interrupted by a "fault" (f), the effect is similar to that of a boring. The water is forced up through crevices, and appears at various points on the surface along the line of fissure. Having soaked through many miles, or even hundreds of miles, of earth in its underground passage, it often contains various salts and gases in solution. If the depth from which it issues be great, the water may be quite warm.

Among the most celebrated mineral springs in the United States are those of Saratoga, whose water is strongly charged with carbonic acid and salts. The springs are found along a line of fissure which passes through the village. They differ in their medicinal properties. (*Consult Dr. Walton's "Mineral Waters of the United States and Canada."*)

The hot springs of Arkansas are more than a hundred in number, and are similarly found along a line of fissure. The temperature varies from 135° F. to 160° F., and on account of the medicinal properties of the water these springs are sought for the treatment of disease. A cold spring is found within a few feet of one of these hot springs, the difference in temperature between the two being nearly 100° F. They issue from separate fissures, one of which is in connection with a subterranean area of heat, and the other is not.

Virginia is noted for its mineral springs, hot and cold, sulphurous and aluminous, chalybeate (*impregnated with iron*) and alkaline. Among those most widely resorted to are the Hot, Warm, and Healing Springs of Bath County. West Virginia also contains valuable sulphur springs.

Among the medicinal springs of Europe are especially to be noted those of Vichy in France, Baden-Baden in Germany, and Carlsbad in Bohemia, whose waters are regarded as specifics for certain forms of disease.



ARTESIAN WELL AND MINERAL SPRING.

Intermittent Springs.—Where the drainage area is small, or the strata are highly inclined, springs often appear after a shower of rain, and run dry within a short time. In some cases, especially where limestone abounds, underground cavities become reservoirs of water.

If a crevice from one of these happens to extend as shown in the figure, the exit being lower than the point (A) where the crevice communicates with the cavity, but another point (B) being higher, the water will rise to the level B L before beginning to flow. It continues to drain the cavity until the level is reduced to A L, when it stops. The crevice acts merely as an imperfect siphon. The cavity, then, through drainage from the surface, slowly fills again to the higher level, to be once more emptied. Such intermittent springs as these are rare in comparison with those whose periodic flow depends upon variation in rainfall.

AN INTERMITTENT SPRING, WITH SECTION OF THE SAME.

The rock beneath the surface, even when not of limestone, always contains cavities which serve as reservoirs of water. Below a certain level, which varies with the nature of the strata and the distance from the sea, the ground is in a permanent state of saturation. This level varies still further with the seasons, being higher after periods of rainfall. To obtain water in any place, it is necessary only to dig until this limit is passed. Water oozes into the cavity, and a Well is thus produced. (On the origin of springs, artesian wells, mineral and thermal waters, *consult Lyell's "Principles of Geology," vol. i., p. 386.*)

RIVERS.

Origin.—The brooks that trickle from springs down the slopes of mountains combine to form rivulets, which, swollen by tributaries, in turn unite, and a river results. The warmth of the sun causes perennial streams to flow from snow-fields and glaciers, and these, therefore, act like springs as the sources of rivers. Some rivers, like the St. Lawrence, are the outlets of lakes.

River-Drainage.—The region which is drained by a river is called its Basin. A water-shed is the ridge that separates two river-basins. The great water-sheds of a continent are its chief mountain-chains, which determine the position and size of its principal rivers. Their slopes becoming worn away by erosion, minor basins and water-sheds are produced.

Velocity.—The steeper the slope down which it flows, the greater is the velocity of a river. But water can not glide over the soil without being retarded; hence the velocity of a river is affected by the character of its bed, the nature of its course, whether winding or straight, the ratio of its width to its depth, and the volume of water carried.

A slope of three inches in a mile produces a current of between two and three miles an hour, about as fast as ordinary walking. A slope of three feet in a mile makes navigation laborious.

The size of a river depends upon the area drained and the annual rainfall. It varies with the seasons and the climate.

Transporting Power of Rivers.—Rivers, when moving slowly, wear away their banks, and carry along in a state of suspension the earthy particles thus dislodged from the soil. These remain suspended until the onward flow is slackened, when they are deposited in the shape of mud or fine earth called *silt*. Thus are formed shallows, sand-banks, and bars.

If the velocity of the current be increased, its carrying power is increased also, but in a higher ratio. A current flowing at the rate of a foot a second is capable of carrying particles of gravel; if this rate be doubled, it will transport fragments sixty-four times as large.

A mountain-stream flowing rapidly soon bears away all the soft material in its path, cutting for itself a deep and rocky bed. It deposits the coarser parts of its burden as soon as its velocity is checked; hence the upper portion of its bed is strewed with pebbles and even bowlders. Many such streams unite to form a river, which thus carries silt from the mountains to the sea.

The finest silt is deposited very slowly. The turbid waters of the Amazon discolor the ocean 300 miles from land.

A river's bed is continually deepened in its upper part by loss of material, and made broader and shallower in its lower part by successive deposits. The velocity of the water passing through it is greatest in the middle, and least at the margins; therefore, in overflowing its banks at times of freshet, a river also renders them higher by deposit.

Rapids and Waterfalls.—It has already been shown that rivers play an important part as agents of erosion, there being hardly any limit to their excavating power. Work of this kind in active progress is well illustrated in waterfalls. When the course of a river is across the outcropping edges of strata differing in hardness, the softer earth is worn away more rapidly until the harder ledge projects; over this, the river leaps as a Cataract. Unequal erosion may merely increase the slope of a river-bed, causing the stream to flow with heightened velocity over the inequalities of its channel; thus Rapids result.


THE SKJÆGGEDALFOS, NORWAY.

There is no cataract in the known world equal in grandeur to that of **Niagara**. The Niagara River above the Falls is divided by Goat Island into two channels, through which the water flows to the edge of a stratum of hard limestone underlaid by soft shale. The level of Lake Erie is 334 feet above that of Lake Ontario. The limestone plateau on which it rests outcrops as a very thin layer at Lewiston on the border of Lake Ontario, and thickens as Lake Erie is approached. This layer has been cut through and washed away, so that a deep gorge seven miles long remains as evidence of the water's work. As the shale is displaced, fragments of limestone are detached, so that since 1875 the edge over which the largest mass of water plunges to form the Horseshoe Fall has been receding at the rate of nearly 25 feet annually. The average rate of recession for all parts of the cataract, as it exists at the present time, is estimated to be 2.4 feet a year.

About two miles below the Falls, the slope is such as to cause the waters to rush tumultuously over fragments of rock left in former years, forming the famous Whirlpool Rapids. Shells, similar to those now found in Lake Erie, have been met with in the strata near the top of this gorge, on both sides, showing that the level of the water must have been at that height in geologically recent times. (*See "Picturesque America," vol. i., p. 432.*)

Among other picturesque **American Cataracts** may be mentioned the Falls of the Yosemite in California, produced by the plunge of the Merced River over several precipices in succession in a total descent of 2,600 feet, one of the falls being 1,600 feet high; the Falls of the Yellowstone in the National Park, and those of the Lewis River, one of the affluents of the Columbia; the Falls of St. Anthony, near the junction of the Minnesota and the Mississippi, which have cut a gorge eight miles long to Fort Snelling; Trenton Falls, a superb chasm near Utica, New York; and the Toccoa and Tallulah Falls in Georgia.

In Europe, **the Falls of the Rhine** at Schaffhausen, on the border between Germany and Switzerland, where the river plunges from a height of 80 feet, afford a grand illustration of the erosive power of water, especially in the cutting away of two pillar-shaped limestone rocks which stand in the current. The gorge of the Rhine, extending from Bingen to Rolandseck, a distance of sixty miles, is believed to have been cut by an ancient waterfall.

The Alps abound in cascades of no great volume but of considerable height, due to streams from the Alpine snow-fields. Among these may be mentioned the **Staubbach** (*stowb'bahk—dust-stream*), which leaps from a height of 900 feet into the Lauterbrunnen Valley (*low'ter-broon-nen—nothing but fountains*) near Interlaken, and is dispersed by the wind in the form of spray before reaching the bottom. A singularly beautiful sheet of watery particles hangs like a silver veil over the crags, oscillating in the wind, and varying in tint according to the position of the sun.

The famous Pyrenean Cascade of **Gavar'nie**, in southern France, 1,300 feet in height, presents a similar effect to the Staubbach fall. It is situated amid extremely romantic scenery, whose glaciers and waterfalls attract numbers of tourists.

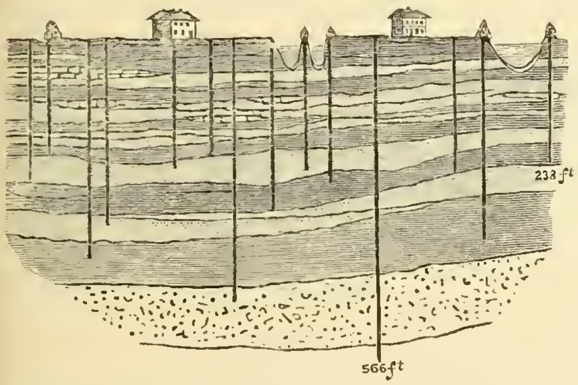
Norway abounds in cataracts remarkable for their height, volume of water, and great beauty. One of the finest of these, the **Skjæggedalfos** (*sheg-ge-dal'fos—fall in a bearded*, i. e., heavily wooded, *glen*), lies at the head of Hardanger Fjord, surrounded by the grandest of glaciers and water-courses. This magnificent fall, having a total descent of 1,400 feet, has been pronounced as worthy of a visit as Niagara itself.

The most imposing of South American cataracts, and among the grandest on the globe, is the **Fall of Tequendama** (*ta-ken-dah'mah*), near Bogotá, whose waters plunge through a gap but 36 feet wide, and are precipitated 650 feet in an unbroken mass amid the tropical vegetation and gorgeous scenery of the Andes.

In Asia and Africa are numerous waterfalls of considerable volume. **Victoria Falls**, in the Zambezi River, were discovered by Livingstone in 1855. The water leaps into a chasm 400 feet deep, bounded by perpendicular walls of basalt, breaking as it falls into a white mass resembling a sheet of driven snow, and sending up columns of vapor to a height of 800 feet above the brink of the cataract. The volume of water is second only to that of Niagara. (On earth-sculpture by waterfalls, *consult Phillips's "Manual of Geology," Part I., p. 154.*)

Deltas.—If a river empties into a large body of quiet water, deposits of silt and sand are ceaselessly accumulated at its mouth, tending to obstruct its free passage outward. Overflowing its banks, it in time makes many new mouths. The group of outlets with their intervening silt-banks is called a delta, because shaped like the Greek letter delta (Δ), with the apex pointing up the river and the base fronting the sea. A delta thus consists of successive layers of alluvial deposit, penetrated by constantly shifting channels. Deltas grow from year to year until they may extend many miles into the sea.

The Po has carried down deposits which thus extend for 21 miles, their progress during the last century having been at the rate of 300 feet a year. On the accumulations of this river, 566 feet in thickness, stands the modern city of Venice. Sections of artesian wells at this city display to advantage the structure of a delta and the range of its beds. The variability of the strata shown in the cut is explained by the irregularity of seasons and the action of floods and currents. The city of Ravenna, originally situated like Venice in a lagoon, is now four miles from the sea. (*See Prestwich's "Geology," vol. i., p. 85.*)



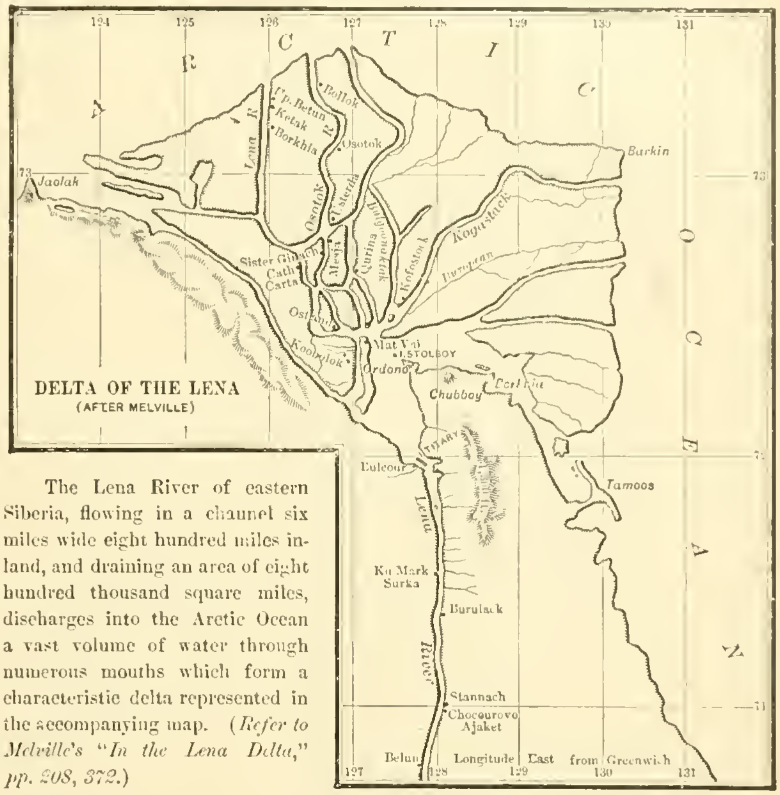
Section of the Delta Deposits of Venice, with overflowing Artesian Wells (after Laurent).

In the delta of the Nile stands a statue of Rameses II., the base of whose pedestal is at present 9½ feet below the surface. It was erected about 3,200 years ago. Borings have been made in the middle of the delta to the depth of 75 feet without penetrating through the alluvial soil. Egypt is elevating by such deposits at the rate of six inches in a century.

Many European rivers furnish instructive examples of delta-growth. The Tiber is advancing its coast-line at the rate of about 12 feet per annum, so that Rome's ancient harbor, Ostia, is now 3 miles inland. Along the shores of the North Sea, the wide plain of the Netherlands has been formed by the delta-deposits of the Rhine, Meuse, Scheldt, and other rivers. The Rhone delta is rapidly advancing in the Mediterranean, and that of the Danube in the Black Sea.

The deltas of the Ganges and Brahmaputra Rivers together form a mass of mud that covers about 15,000 square miles, an area larger than that of the whole of Massachusetts, Rhode Island, and Connecticut. Its front is 200 miles broad, and its starting-point is now 220 miles inland. An artesian well at Calcutta was bored to the depth of 480 feet without reaching the bottom of this delta deposit.

The Mississippi delta is advancing into the Gulf of Mexico at the rate of 338 feet annually. The area covered by it is about 12,300 square miles, and at New Orleans it is known to be more than 630 feet thick. The present river winds through its own deposits from its junction with the Ohio to the Gulf. In the lower part, its bed has become so raised that lev'ees (*elevated* banks or causeways) are necessary to protect the neighboring country from inundation. The annual discharge of sediment by the Mississippi is estimated at nearly seven and one-half billion cubic feet.



DELTA OF THE LENA (AFTER MELVILLE)

The Lena River of eastern Siberia, flowing in a channel six miles wide eight hundred miles inland, and draining an area of eight hundred thousand square miles, discharges into the Arctic Ocean a vast volume of water through numerous mouths which form a characteristic delta represented in the accompanying map. (*Refer to Melville's "In the Lena Delta," pp. 208, 372.*)

Bars.—When a river flows into an ocean whose shores are swept by tides, the formation of a delta is checked by the alternate reversals of the current each day. The tide rises and falls, causing the water to flow inward and then outward. The lower part of the river is widened by successive erosion in opposite directions. When the outflowing water meets the sea, a deposit of mud is formed called a Bar. This is cut by one or more channels where the water forces its way through to the sea. Another bar is formed where the incoming tide is checked by water flowing down from the sources of the river. This is called the head of tide-water.

The Hudson affords an excellent example of the effect of tides. In its lower course, its width varies from one to three miles. A bar extends from Coney Island across to Sandy Hook, and is pierced by three channels, through which ships are piloted. The river is obstructed by shoals at the head of tide-water near Troy.

Questions.—What can you say of the properties and composition of water? Name the subjects of hydrography. Define springs, and show how they may be classified. Account for intermittent springs. Describe the nature and origin of artesian wells, illustrating by a diagram. What are thermal springs? Is there any relation between such and volcanoes? What minerals and gases occur in the water of springs? Describe some celebrated medicinal springs.

What is the origin and history of rivers? the basin, or drainage-area, of a river? a water-shed? On what does the amount of water in a river-basin depend? Explain by diagram the details of a river-course from source to mouth. How far do rivers cut their own channels?

Name the chief waterfalls of Europe. Describe the following cataracts, and give the depth of leap in each instance: Niagara, Victoria, Yosemite, Skjæggedalfos, and Falls of the Rhine. What is a river delta? How do deltas grow? Describe some noted deltas; the formation of bars. Can you state the importance of rivers in reference to the occupation of the earth's surface by man?

LAKES.

Origin of Lakes.—Bodies of water occupying depressions, or hollows, in the land are known as Lakes; when small, they are called Ponds. As a rule, the great lakes of the world owe their origin to the upheaval of the ocean-floor, and not, as in the case of excavated valleys and cañons, to the erosive action of running water. The Caspian Sea, still having a maximum depth of 3,600 feet, has thus been severed from the main ocean; and there is geological evidence that a great inland estuary, in past ages, separated Europe and Asia, and extended across the steppes to the Arctic itself. The elevation of the English Channel 300 feet would convert a large portion of its bed into dry land, and leave a number of small lakes occupying its deeper portions. (On the origin of lakes in upheaval, *consult Phillips's "Manual of Geology," Part I., p. 134.*)

Lakes also result from the accumulation of water in natural hollows produced by the folding of the rocks, being fed by springs, or streams that drain the neighboring country. They are sometimes virtually expansions of rivers.

The *head* of a lake is that portion which receives the main entering stream, or *inlet;* the *foot*, or lower end, that whence the overflow is discharged through the *outlet*.

Classification and Distribution.—Lakes may be classified as salt and fresh. Those that have outlets are generally reservoirs of fresh water; such as have no outlets are mostly salt. When the amount of water supplied by inlets or rainfall exactly balances that lost by evaporation and discharge through outlets, the level of the lake remains unchanged.

Lakes occur in great numbers in the northern parts of both hemispheres, and less frequently, though often of large size, toward the Equator. Salt lakes are met with in the great inland plains in the heart of continents, where there is no opportunity for their waters to escape. In volcanic regions, lakes not unfrequently occupy the sites of extinct craters; such lakes usually have neither inlets nor outlets.

Size and Depth.—The size and depth of a lake depend upon the surface conditions of the country in which it is formed. In mountainous regions, lakes often fill up the valleys to a certain height; they are narrow and deep, and but rarely of great length.

If the lake-basin be in a flat country, its depth is small in comparison with its length and breadth. Lake Erie covers 10,800 square miles of surface, while its depth rarely exceeds 120 feet.

Lakes as Reservoirs and Purifiers.—Lakes, especially amid mountains, serve not only as reservoirs for the multitude of rills that flow down the mountain-sides, but as regions of deposit for the sediment they bring with them. The swift and muddy streams have their velocity checked on emptying into a larger body of almost quiet water. Deltas are formed, and the water issues perfectly clear at the outlet, thence to continue its career of erosion and silt-making in its course to the sea. In proportion to their size, lakes change their level but slowly, and thus tend to give steadiness to the outflow of the regions drained into them.

The Lake of Geneva is an expansion of the river Rhône, which enters its east end as a turbid stream whose waters are heavily charged with sediment from the Alps. It has filled this end of the lake, making a delta nine miles long and from one to two miles wide, that has grown more than a mile since the time of the Romans. The clear blue tint as the water sweeps through Geneva at the outlet is in striking contrast to its gray color near the delta.

Professor Geikie defines the geological functions of lakes as follows: I. They arrest and equalize the drainage by regulating the outflow and lessening the destructive effects of floods. II. They filter river-water, and permit of the accumulation of new deposits. III. They furnish an abode for certain animal and vegetable forms, and entomb in the growing deposits the remains of plants and animals washed down from the surrounding country, thus preserving a record of the life of the period.

Salt Lakes sometimes owe their origin to the evaporation of fresh water received through their feeders. The soluble material taken from the surrounding country gradually collected in their basins, and their waters became charged with various salts, especially those of soda, magnesia, and lime. There being no outlets, and consequently no escape for the dissolved saline matters, these bodies of water, which were originally fresh, became gradually more and more salt.

The most remarkable example of this variety of lake is the Dead Sea in Palestine. Its depth is over 1,300 feet; its surface is 1,272 feet below the Mediterranean; hence its bottom is nearly 2,600 feet below sea-level. It is fed by the river Jordan, a fresh-water stream; but the water of the lake is charged with common salt, nearly ten times as strongly as ocean-water. It occupies the lowest part of a deep valley, where the sun's heat causes evaporation to be in excess of what the lake gains from its affluents. Along the shore at its south end is a miniature mountain-range of solid rock-salt, a ridge six miles long, more than half a mile wide, and over five hundred feet in height. Much of this is covered with earthy deposits of varying thickness. The shores are everywhere incrusted, and the water is much more briny than at the north end, where the Jordan enters. This salt mountain has been evidently deposited from the water of the lake. (*Consult article in "Scientific American" for September, 1886; and Lieutenant Lynch's "Narrative of the U. S. Expedition to the Jordan and the Dead Sea."*)

In the neighborhood of the Caspian Sea are several salt lakes, annually diminishing in size, some of which become quite dry in summer, leaving the ground white with salt. Among those is the basin of Lake Elton, from which 2,000,000 pounds of salt are said to be taken each year.

Lakes that were originally parts of the ocean are not necessarily salt. When, for any reason, more fresh water is received by such a lake than it loses through evaporation, its salt water is diluted and overflows, little by little the salt is removed, and a fresh-water lake in time results. A former connection with the sea is claimed for Lake Baikal (*bi'kahl*), a vast body of fresh water in Siberia, the volume of whose waters nearly equals that of Lake Superior. (*J. Y. Buchanan, "Encyclopædia Britannica," vol. xiv., p. 217.*)

Lakes of North America.—North America has the largest lakes in the world. In the Dominion of Canada are the Great Bear, Great Slave, and Athabasca Lakes, which are drained into the Arctic Ocean. The waters of Lakes Winnipeg and Manitoba find their way into Hudson Bay. Lakes Superior, Michigan, Huron, Erie, and Ontario, form a connected group whose outlet is the St. Lawrence River; their combined area, including the estuary of the St. Lawrence, is 150,000 square miles. Lake Superior is the largest sheet of fresh water known, its area being 32,000 square miles, and its average depth about 900 feet.

Near the Pacific coast there is a series of smaller lakes, scattered over California, Nevada, and Oregon. One of these is in the heart of the Cascade Range in Oregon, at an elevation of 6,000 feet above the sea. Occupying an extinct crater of the same kind as that of Kilauea, but larger, being over seven miles long and five wide, it is called Crater Lake. Around this oval body of intensely blue water, the walls rise in precipices from 900 to 2,200 feet high. A cinder-cone lifts its head 600 feet out of the water, and two other submerged cones have been found by sounding. Crater Lake is believed to be the deepest body of water in America, its greatest depth being 2,005 feet. (*Consult "Science," August 27, 1886.*)

Lake Tahoe, occupying an elevated valley of the Sierra Nevada Range, is environed by magnificent scenery, and famed for the exquisite azure tint of its water.

In Utah is the Great Salt Lake, about 200 miles in circumference and from 12 to 60 feet in depth, with no visible outlet. Its waters are heavily charged with salt; but, unlike the Dead Sea, not to such an extent as to be incompatible with animal life. Connected with Great Salt Lake by the Jordan River is Utah Lake, a sheet of pure fresh water abounding in fish. The waters of many smaller lakes in this basin-region are strongly impregnated with soda.

Lakes of South America.—There are but two large lakes in South America, viz., Lake Titicaca, situated in an Andean valley, more than two miles above the sea, on the boundary between Peru and Bolivia, covering an area of 4,000 square miles, interesting on account of its ruins and historical associations; and Lake Maracaybo, 137 miles in length, whose waters are fresh, although it is in communication with the sea.

Lakes of Europe.—In the northern part of Europe are a number of lakes tributary to the Baltic Sea, the largest of which are the great Russian lakes of Lad'oga and One'ga, prolongations of the Gulf of Finland, the remains of a channel rendered dry in part by change in level.

In the Alpine region are many lakes, some of small size but great depth. The Lake of Lucerne, or "the Lake of the Four Forest Cantons," 25 miles in length and cruciform in shape, situated at the junction of four deep valleys which are filled by the streams from the neighboring mountains to the level of the outlet, is universally admitted to be the grandest sheet of water in Switzerland. The city of Lucerne (*the Shining One*) stands 1,420 feet above the level of the sea, at the point where the emerald-green waters of the Reuss (*roice*) issue from the lake, with Mount Pila'tus towering behind it, and the Rigi (*re'gē*) in front across the "Forest Sea."

The charms of the Lake of Lucerne can not well be exaggerated. At every turn of the steamer which plies upon its waters in summer, a new scene unfolds itself to the tourist. On this side, the mountains descend in gentle slopes, covered with luxuriant verdure; on that, in precipitous and barren steeps, their summits crowned with perpetual snow. Now velvety fields approach the shore; anon, a broad bay sweeps between peaceful orchards and brilliant meadows to the base of distant hills — suddenly, the lake narrows till it seems, as if to advance, the steamer must enter some mysterious tunnel through the granite piles that shut her in. Fluffy clouds float half-way down the mountains, up whose sides black forests creep, growing less and less dense as they ascend till a few straggling firs alone battle successfully with the snows and reach the tops of the less elevated ridges. Here the Spanish chestnut, the fig, and the almond, flourish in the open air; there, sheer walls of rock refuse support to the tiniest shrub. In front, a romantic hamlet mirrors its picturesque châteaux and little church in the glassy waters; behind, a group of farm-houses clusters on an impending cliff, and daring hay-makers gather in their crop from dizzy slopes; while yonder, a ruin, perched on some frowning promontory, or half-concealed in the dark foliage, breathes its legend.

The Lake of Constance, traversed by the Rhine; and the crescent-shaped Lake of Geneva, or Lake Le'man, with its peculiar sapphire-blue waters—are justly celebrated for their pleasing scenery.

The lakes of northern Italy are among the most picturesque sheets on the globe, especially Co'mo with its delightful climate, and Maggiore (*mahd-jo'ray*) with its imposing forest-clad mountains. In Sweden and Finland beautiful lakes abound; while the Scottish lochs are world-renowned for their wild aspects and historical associations.

Lakes of Asia.—Probably the deepest body of fresh water in the world is Lake Baikal, the Holy Sea, situated just north of the Altai Mountains in Siberia. Its area is over 9,000 square miles; its depth, more than two miles, or six times that of Crater Lake in America. Thermal and mineral springs are found near its shores, and naphtha floats on its surface. Volcanic phenomena and earthquakes are not uncommon in the surrounding region.

Koko-Nor (*blue sea*), south of the Desert of Gobi, has an elevation of 10,500 feet. Its waters are salt, and it is without an outlet.

But Asia is remarkable more especially for its salt lakes, some of which are large enough to be ranked as inland seas. The Caspian covers more than four times as much area as Lake Superior. The surface of its salt water is 84 feet below sea-level. The Sea of Aral is a diminishing body of salt water, about as large as Lake Michigan, and at the same level as the Caspian. The Dead Sea has been already described. (On the Caspian Sea and the surrounding territory, *consult O'Donovan's "The Merv Oasis," p. 40.*)

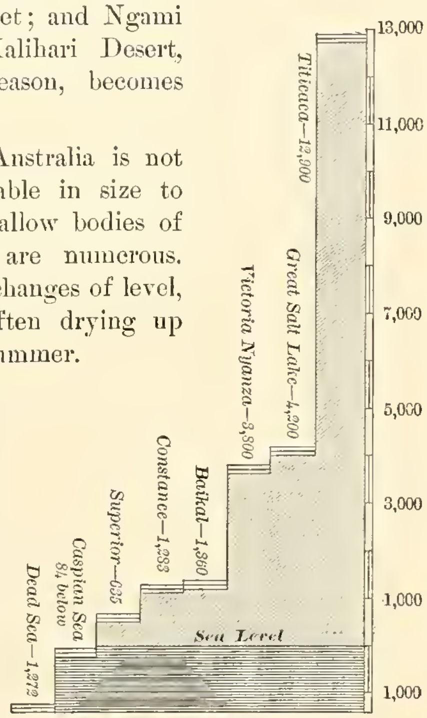
African Lakes.—Vast lakes form a prominent feature in the hydrog'raphy of Africa, the principal lake-region lying on, and immediately south of, the Equator. Here, at altitudes varying from 2,300 to 4,000 feet, are those expanses of fresh water which feed the great rivers Nile and Kongo. Lake Albert (2,300 feet above the sea) and Victoria Nyanza (3,800 feet), connected by a stream broken into rapids, form, together with Lake Albert Edward (3,200 feet), the source of the White Nile. Lake Tanganyika (*tahn-gahn-ye'ka*), over 300 miles in length, discharges its surplus waters through the Kongo

THE LAKE OF LUCERNE.

into the Atlantic; while Nyassa (*ne-ahs'sa*), 300 miles to the southeast, occupying 9,000 square miles of the basin of the Zambezi, drains into the Indian Ocean. (On Lake Tanganyika, *see Thomson's "To the Central African Lakes," vol. ii., p. 1.*)

The lakes that lie in the interior areas of continental drainage are frequently salt—though Tchad (*chahd*) in the Soudan is a large fresh-water sea, comparatively shallow and having ordinarily no outlet; and Ngami (*n'gah'me*), north of the Kalihari Desert, brackish during the dry season, becomes fresh in times of inundation.

Australian Lakes.—Australia is not supplied with lakes comparable in size to those already described. Shallow bodies of water, both salt and fresh, are numerous. These are subject to extreme changes of level, being high in winter and often drying up and disappearing entirely in summer.



The accompanying diagram shows the relative heights of some of the well-known lakes of the world. Lake Titicaca is the most elevated lake of considerable size, and the Dead Sea is the most depressed, the difference of level between the two being nearly three miles. In the table below will be found further interesting statistics.

TABLE OF SIZE, DEPTH, ELEVATION, AND TEMPERATURE OF LAKES.

NAME OF LAKE.	Length in miles.	Greatest breadth, in miles.	Greatest depth, in feet.	HEIGHT IN FEET ABOVE THE SEA. Surface.	Bottom.	Bottom temperature.
Superior	350	100	1,010	635	−375	38·8° F.
Michigan	320	80	864	578	−286	....
Huron	280	105	705	578	−127	....
Erie	220	48	324	565	+241	....
Ontario	190	55	738	231	−507	....
Tahoe	20	12	1,645	6,250	+4,605	39·2
Great Salt	90	35	60	4,200	+4,140	....
Titicaca	90	30	924	12,900	+11,976	54·6
Koko-Nor	91	42	...	10,500	......	....
Baikal	330	40	12,356	1,360	−10,996	....
Balkash	340	55	238	72	− 166	....
Caspian Sea	600	50	3,600	− 84	−3,684	44·6
Dead Sea	45	10	1,308	−1,272	−2,580	....
Tanganyika	330	40	1,000	2,700	+1,700	....
Como	48	2·5	1,926	670	−1,256	....
Geneva	45	8·7	1,017	1,218	+201	41·7 to 43·5
Constance	35	8	394	1,283	+889	39·6
Lomond	20	4	630	25	−605	41·4 to 42
Katrine	7	0·8	480	364	−116	41·4

Questions.—Define and classify lakes. How have they been formed? How are they supplied? Explain their connection with the water circulation, and their geological functions. Give examples of lakes formerly parts of the ocean. Why are such lakes not necessarily salt?

Where is the most extensive lake-region of the globe? What can you say of the great lakes of North America? Of South American lakes? Give an account of the lakes of Europe. Describe the Lake of Lucerne; the Caspian and Dead Seas; Lake Baikal; the lakes of the Nile Basin. Mention the peculiarities of Lake Tchad; of the Australian lakes.

CONTINENTAL DRAINAGE.

The direction and size of the rivers which drain a continent are determined by the position of its chief mountain-ranges. Most of the water finds its way at last to the ocean, but there are limited areas where the drainage is entirely into salt lakes.

Drainage of North America.—The chief water-sheds of North America are:

I. The Rocky Mountain Plateau, traversing the greatest length of the continent, and separating the tributaries of the Pacific Ocean from those of the Atlantic and Arctic Oceans.

II. The Appalachian Highlands, extending from the Gulf of St. Lawrence nearly to the Gulf of Mexico, and dividing the rivers of the Atlantic slope from those of the Mississippi Valley.

III. The Height of Land, stretching southwestward from Labrador to Minnesota, and separating the Mississippi Valley from the great Northern Low Plain.

From the Rocky Mountain Plateau, the drainage on the Pacific slope is less than on the side opposite, partly because of the smaller area, but also because, over much of it, the rainfall is slight and evaporation is rapid on account of the elevation of the surface and great dryness of the air. The only rivers of considerable size are the Yukon, flowing into Bering Sea, the Columbia, and the Colorado.

The Mississippi River is the chief outlet for the interior slopes of each of the three water-sheds. Its source, Itasca Lake in Minnesota (1,575 feet above the sea), is near the western extremity of the Height of Land, on its southern slope. From the great western water-shed it receives its largest tributary, the Missouri, besides many that are smaller, such as the Arkansas and Red Rivers. On the east, its main affluent is the Ohio, which drains most of the western Appalachian slope. The Rio Grande is the most important of the other rivers which drain the eastern slope of the Rocky Mountains.

South of the Height of Land, and partly surrounded by it, lie the Great Lakes, with the St. Lawrence River as their outlet.

East of the Appalachian Highlands, the Atlantic slope being narrow, the rivers are all comparatively small. The most important is the Hudson.

From the northwest slope of the Height of Land, and the northeast slope of the Rocky Mountain Plateau, a number of streams flow into Hudson Bay, the largest being the Nelson and the Albany River. Finally, the Mackenzie River carries the drainage of the more northern part of the continent into the Arctic Ocean.

Drainage of South America.—On account of the proximity of the Andes range to the Pacific, no large streams drain into that ocean. Three vast river-systems, however, are tributary to the Atlantic. The largest of these is the Amazon System, which drains a basin twice the size of the valley of the Mississippi, and equal to two-thirds of the area of all Europe (2,500,000 square miles), the most extensive and most abundantly watered in the world—with feeders, themselves rivers of the first magnitude, that reach into every country on the continent except Chile and Patagonia. The volume of water transported by this system is inconceivable. The delta is 200 miles wide, and the depth of the river in places exceeds 300 feet; with its source in the Andes only 60 miles from the Pacific, it gains in its long course of 4,000 miles an impetus which carries its fresh waters 200 miles unmixed into the sea.

North of the Silvas of the Amazon, between the plateau of Guiana and the northeastern spurs of the Andes, is a basin drained by the Orinoco, 370,000 square miles in area. On the table-land of the Parime (*pah-re'may*) Chain, which divides the drainage area of this river from that of the Amazon, occurs one of the most remarkable bifurcations in the world. While the main stream of the Orinoco flows on toward the northeast, a branch, the Cassiquiare (*kahs-se-ke-ah'ray*), turns southward, and after a rapid course of 180 miles unites with the Rio Negro, so that during the annual floods a portion of the waters of the Orinoco is discharged into the Atlantic through the Amazon system.

Between the Brazilian Plateau and the Andes lies the low plain drained by the Paraguay and Parana Rivers. The Uruguay unites with the Parana at its mouth, and the resulting great estuary is called the Rio de la Plata. The Parana rises in a swampy region that is connected with the head-waters of the Madeira. There is hence no complete separation between the Amazon and either of the other river-systems of South America.

Other rivers of minor importance in South America are the San Francisco, draining part of the Brazilian plateau; the Magdalena, between two spurs of the Andes; and the Colorado and Negro of the south, draining portions of the Argentine Republic.

Drainage of Eurasia.—The southern part of Eurasia is mostly highland, the great plateau widening in the east and extending northward as far as Bering Strait. Where it is broadest, there is little rainfall. The greatest rivers, therefore, are in the vast Siberian and Russian plains, and in the limited plains near the Indian and Pacific Oceans, where deficiency in area is more than counterbalanced by the conditions producing enormous rainfall.

From the northern slopes of the Alpine Highlands, the Loire, Seine, Rhine, Elbe, and Vistula, flow into Atlantic waters. The Scandinavian Peninsula is too narrow to produce any except insignificant streams. Southward, a few small rivers flow into the Mediterranean Sea, such as the Ebro, Rhône, and Po; and the Black Sea receives the Danube, the largest river that has its origin in the Alps.

Into the Arctic Ocean drain the Dwina and Petchora, the Obi, Yenisei, and Lena, with a few other rivers of smaller size; into the Pacific, the Amoor (*ah-moor'*), Hoang Ho, Yangtze Kiang, and Mekong.

To the immense rainfall on the southern slopes of the Himalayas are due the Indus, the Ganges, and the Brahmaputra, which are the chief rivers of southern Asia. The Indus, taking its rise 18,000 feet above the sea, breaks through the barriers of the Himalayas, receives the united streams of the Punjab (*five great waters*), and reaches its delta after a course of 2,000 miles. The Brahmaputra rises far up on the plateau of Thibet, and in part of its course over the highlands it is not far distant from the Yangtze Kiang, which drains a considerable part of the great Chinese plateau before reaching the low plains. The Euphrates and the Tigris are outlets for the least sterile part of western Asia between the plateaus of Arabia and Persia.

A considerable area within Eurasia is depressed so as to be deprived of connection by water with any of the oceans, the Caspian and Aral Seas serving as interior reservoirs. The former receives the Volga, the largest river in Europe, and the Ural, which is the arbitrary division-line between Europe and Asia. The Oxus and Syr Daria (*seer dar'yah*) drain the western slopes of the Altai Range into the Sea of Aral. Its eastern slopes feed the Tarim (*tah-reem'*) River which finds a small reservoir in the shallow, salt Lop Nor, a lake without outlet in the desert regions of Turkestan. Altogether, this is the largest region of interior drainage in the world.

The Drainage of Africa.—The seaward margin of the great African plateau is skirted with mountain-chains, which constitute the axes of the continent. Its great rivers, therefore, necessarily have their source in the interior, either in the lake-region, or on the inward slopes of these coast-ranges, through which they force a passage to the sea. By far the greater portion of the oceanic drainage is to the Atlantic, directly or through the Mediterranean Sea. The Nile, the Niger, the Kongo, and the Orange, are thus discharged. The Zambezi and the Limpopo enter the Indian Ocean.

The Nile rises in the equatorial lake-region; it is 3,700 miles long, and drains a basin of 1,600,000 square miles. Its delta occupies an area of 9,000 square miles, and is subject to an annual overflow which leaves behind a stratum of rich deposits.

Through upper Egypt, deep, broad valleys have been excavated in the rich soil by the tributaries of the Nile, swollen by the great rainfall among the mountains of Abyssinia. The former contents of these enormous cuttings have been distributed over the lowlands at times of inundation. The Atbara and the Blue Nile are the mud-carriers. The White Nile conveys, suspended in the finest particles, vegetable matters from the lakes whence it flows. (On the fertilizing rivers of Egypt, *consult Dr. Williams's "Life in the Soudan," p. 38.*)

The Kongo (length, 2,800 miles) rivals the Mississippi in magnitude, discharging, after the season of tropical rains, a volume of water nearly equal to that of the Amazon. It drains a basin 1,200,000 miles in extent, and abounds in lakes and water-courses. The river terminates in an estuary. The Niger ranks third in volume of water and area of basin. Its delta is more extensive than that of the Nile by 5,000 square miles, the marginal branches being 200 miles apart. The Zambezi enters the ocean by numerous mouths. Prodigious quantities of sand are annually carried down by its current into the sea; the finer particles are caught by the returning tides, and have been deposited, by successive ebbs and flows, with masses of decaying vegetable matter, through ages, until a delta extending a hundred miles inland has resulted.

The Drainage of Australia.—The peculiar positions and courses of the rivers of Australia render probable the supposition that at a comparatively recent geological period the interior of this continent was an ocean-bed, the ranges parallel to its eastern and western coasts being the highlands of former island groups. The Murray and its tributaries flow into the interior from the eastern mountains, and finally merge in a shallow lake with an outlet to the ocean on the south. Other rivers spend their waters in inland swamps and lakes, becoming reduced to insignificant streams during the dry season. (On the rise and fall of Australian rivers and the lakes of the desert-region, *consult Warburton's "Journey across the West Interior of Australia," pp. 205, 285.*)

The distribution of the earth's great river-systems, as described in the foregoing paragraphs, makes plain the relation of drainage to a continent's water-sheds. The total area drained to the Atlantic Ocean, directly or through its arms, the Gulf of Mexico, the Mediterranean and Baltic Seas, etc., nearly equals 10,000,000 square miles. The Pacific (including the Indian) and the Arctic Ocean receive, each, the drainage of over 5,000,000 square miles.

Questions.—What is a drainage-area? Explain the relation between continental axes and drainage; the connection of lakes with water circulation. Specify the principal water-sheds and river-systems of North America. Describe the Amazon System. Give an outline of the drainage-areas connected with the Mediterranean Sea; the Gulf of Mexico; the Sea of Aral. Describe the drainage-system of the Nile; state the nature and extent of the Nile delta, and the economic results of the annual overflow.

Trace the course and history of the following rivers, mentioning details of basin, tributaries, countries traversed, particulars concerning lakes, rapids, waterfalls, and bifurcations or connecting canals: St. Lawrence, Missouri, Mississippi, Yukon; Orinoco and Amazon; Ganges and Indus; Kongo and Zambezi; Volga and Lena; Murray.

Questions on the Map of Continental Drainage and Ocean-Currents.—What ocean receives the waters of the Great Slave Lake? the waters of Lake Superior? of Lake Baikal? of Lake Ladoga? of Lake Tanganyika? of Victoria Nyanza? Into what ocean does the Euphrates River flow? the Lena? the Colorado? the Mississippi? the Ganges? the Darling? Are there any large rivers in South America which flow into the Pacific? Why? (Consult Physiographic Map, pp. 20 and 21.) Are there any on the Mexican and Central American western coasts? Why?

What part of North America has no drainage-outlet? What is the largest body of water in this region? Where can regions without drainage-outlets be found in South America? in Africa? in Australia? in Eurasia? What is the largest reser of interior drainage in the world? Is its surface above or below sea-level? (See 20, 21, and 47.) What is the largest interior reservoir in South America? Wh its elevation? (See pp. 20, 21, and 48.) What other interior reservoirs are the Eurasia? Which is the loftiest of these? (See pp. 20 and 21.) Which the low What is the level of its surface? (See p. 46.) Making allowance for the projectio the Map (Mercator's, see p. 9), state which of the oceans drains the largest land-sur

What is the average direction of the Atlantic North Equatorial current? of South Equatorial? of the Guinea current? of the Equatorial counter-current of

? Trace the Gulf Stream and its branches. Trace the Japan current. Do you ny cold current near Labrador? What is its southern limit? Trace the southern of floating icebergs in the Atlantic. Can you account for its irregularity? Do nd such a limit in the North Pacific? Explain. (See p. 53.) Trace the north- nit of floating icebergs from Antarctic regions. Can you account for its irregu- ? (Compare with Map, pp. 20 and 21.) What peculiarity do you notice about the ar current? Explain. (See pp. 61 and 71.) Trace the Agulhas current. What it to turn near the Cape of Good Hope? Give the direction of the Humboldt t. The South Atlantic current. Are these currents warm or cold? Compare the direction of currents on the east and west coasts of Australia. By comparison with the Physiographic Map, can you offer any probable explanation of the remarkable course of the South Australian current? By comparison with the Isothermal Map (pp. 66 and 67), can you see any relation between the ocean-currents and the difference of climate between the east and west coasts of South America? of Africa? Are there any consider able currents connecting the Pacific and Indian Oceans? If any, where are they and in what direction? What is the prevailing direction of current along the coast of Guinea? How do you account for this? Do you find any current in the Gulf of Mexico? (Compare with p. 53.) Trace the direction of currents in the neighborhood of Cuba.

OCEAN-WATERS.

Area and Volume.—The ocean is a continuous body of salt water, covering nearly three-fourths of the earth's surface, and in volume twenty or thirty times as great as the sum of all the land-masses above its level.

For convenience, the ocean is arbitrarily divided into five parts, which are separately called the Atlantic, the Pacific, the Indian, the Arctic, and the Antarctic Ocean.

Color of the Ocean.—The color of the ocean, when viewed in mass, is so deeply blue that a special name, *ultramarine*, has been given to its characteristic tint. A glass of sea-water is clear and colorless, more so, indeed, than most spring-water. But it powerfully absorbs certain rays of light, so that what comes from beneath the surface at considerable depths appears tinted in consequence of loss by selective absorption and reflection.

White light is a mixture of many tints. If these be separated, as in passing rays through a prism, the most prominent are red, yellow, green, and blue. At the surface of the sea all the tints are reflected, but with increasing depth the red and yellow become absorbed, then the green, and finally all. The absorption is not noticeable for a thickness of a few inches; at five or six feet the loss of red causes the rest of the light to appear greenish; then this deepens into blue and violet. Six hundred feet down, all perceptible light is absorbed. For human eyes, therefore, all would be impenetrable darkness at this depth.

Composition of Sea-Water.—The sea may be regarded as an inexhaustible mineral spring. Sea-water has a disagreeable taste on account of the several salts which it holds in solution. Common salt (chloride of sodium) is the most abundant. Sulphate of magnesia (Epsom salt) gives it bitterness. Sulphate and carbonate of lime are always present, with small quantities of salts of potassium, iodine, and other elements. Thirty pounds of sea-water contain about one pound of salts.

The saltness of the ocean is not uniform. Near the Equator, the loss of pure water by evaporation causes the surface-water of the sea to be slightly more briny than in temperate zones. The same is true of certain landlocked seas, like the Mediterranean, Red Sea, and Persian Gulf. The Black Sea, the Baltic, and the polar oceans, are slightly freshened by the inflow of water from the land.

Variations in Appearance of the Sea.—The sea assumes a dark lead-color when the sky is overcast, because much light is absorbed by the clouds before reaching its surface. Where the water is shallow, the sediment reflects light of its own tint and modifies that of the water. The China Sea is colored yellow by mud diffused through it from the Hoang Ho. The dark-brown mud of the Amazon gives a deep coffee-color to the sea near its mouth. The Red Sea takes its name from the tint imparted to its waters by myriads of minute marine plants.

Phosphorescence.—Sea-water, especially in the tropics, teems with minute animals that shine like the glow-worm and firefly, particularly when they are momentarily brought into contact with the air. The property of phosphorescence belongs to many creatures, chiefly those of low type. From some of them, light is emitted not only during life, but after death. Very little is known as to the cause of this phosphorescence, or the manner in which it is utilized and controlled by its possessors.

It is on the crests of waves, or where the water is churned into foam in the wake of a ship, that these animalcules swarm, and at night the sea appears to glow with flying sparks. "Fantastic forms are seen, luminous circles, starry plumes, or lambent fringes; while a mass of these creatures resembles a globe of red-hot metal flinging off green festoons."

Density and Pressure of Sea-Water.—The density of sea-water exceeds that of fresh water in proportion to the amount of salt dissolved. If we suppose a given mass of pure water to weigh 1,000 grains, the same volume of average sea-water will weigh about 1,027 grains. The ratio of the second of these weights to the first, 1.027, is called *the specific gravity* of sea-water, and is a measure of its density. It varies with the saltness, the temperature, and the depth.

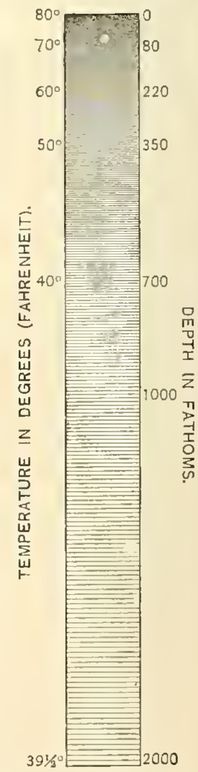
The greater density of sea-water increases its buoyant force and its pressure upon bodies immersed in it. Such bodies, if sunk to a depth of thirty-three feet, are pressed on all sides with an increase of fifteen pounds on each square inch. At a depth of three miles, the increase is about three and a half tons per square inch. This is sufficient to crush any ordinary hollow body, like a closed tube or bottle. No creature accustomed to life in the air, or at the surface of the water, could withstand such crushing force.

Life at the Bottom of the Sea.—Some animals are naturally adapted to conditions of life that would be fatal to others. Certain kinds of fish have been ascertained to live at a depth of 16,500 feet, a little over three miles. Deep-sea fishes are generally black or silvery in color. At great depths, blind fishes occur, possessing mere rudimentary eyes, and without special organs of touch.

The sea-bottom at great depths is covered over large areas with the shells of minute creatures, to which the name *foraminifera* has been given. (*See page 100.*)

It seems probable that life exists at all depths in the ocean, but the distribution of it is quite irregular. There are large tracts in the various zones where material dredged from the bottom has been found to be always devoid of living creatures. At slight depths, animal life is met with in almost unlimited variety, and sea-weed in some places covers the surface. (On deep-sea fauna, *consult Professor Wyville Thomson's "The Depths of the Sea," p. 407.*)

Effect of Cold on Sea-Water.—Sea-water grows denser when cooled; but, unlike fresh water, its point of maximum density is lower, not higher, than its freezing-point. For that of the Atlantic (of 1.027 specific gravity), the maximum density is at a temperature of 25.4°, its freezing-point at 27.4°. In the act of freezing, there is a tendency toward separation of the substances held in solution, so that sea-ice is far less salt than sea-water.



DECREASE OF TEMPERATURE WITH INCREASE OF DEPTH.
(Banda Sea, between Borneo and New Guinea.)

Temperature of the Sea.—At the Equator, the surface temperature of the open sea is about 80°. In confined bodies of sea-water like the Red Sea or Persian Gulf, where the direct effect of a tropical sun is heightened by warm air from the adjacent deserts, the surface temperature in summer may rise to 90° or more. It diminishes generally with increase of latitude, until in the Arctic regions in winter it is reduced as low as 28°.

It is only at the surface that such a wide range of temperature is encountered. By sinking a thermometer in the sea, the temperature in most latitudes is found to diminish rapidly, until 35° or 36° is reached. In equatorial regions this limit is generally at a depth of 10,000 or 12,000 feet; it rises nearer to the surface as the poles are approached. In Arctic regions the surface-water is colder than that below, so that the thermometer rises at increased depths. At all depths below the limit of 35°, the temperature is nearly constant; this, therefore, may be assumed as the average temperature of the ocean.

The rate of change of temperature with latitude and depth is well shown in the accompanying table, each of the four columns representing a separate set of soundings. It will be seen, from columns I. and II., that the lowering of temperature is greater in the first 2,000 feet than in the next 11,000 feet. By a comparison of columns III. and IV., it will be observed that with increasing depth there is cooling in the one case and warming in the other. (*Consult article on "The Properties and Constitution of Sea-Water," in "Popular Science Monthly," March, 1885.*)

Depth in feet.	I. 3½ degrees south of Equator.	II. 23 degrees north of Equator.	III. 55 degrees north of Equator.	IV. 78 degrees north of Equator.
0......	78°	73.4°	57.2°	32°
120....	....	....	53.6	....
270....	68	....	...	....
310....	....	....	....	33.5
1,500...	....	....	48.2	....
1,800...	....	51.8	....	....
1,920...	41	....	....	....
4,566...	....	....	....	33.5
4,650...	....	....	41	....
5,400...	....	39.2	39.2	....
8,400...	....	....	37.4	....
13,200..	33	....	....	....
15,760..	....	35.3	....	....

Configuration of the Sea-Bottom.—Since 1870 several cruises have been made for the purpose of studying the temperature, depths, and currents of the ocean. Great improvements have been achieved in the methods of deep-sea sounding, in dredging, and in the use of the thermometer. The sea-bottom is now known to be diversified with basins and plateaus. The slopes, however, are very gentle, so that, if the water were removed, all would appear to the eye like a flat plain, except in the immediate neighborhood of a continent or island, where a slope of as much as 5° is occasionally found.

The bottom is usually fine sediment of clay, sand, or chalky material; rarely pebbly or rocky. The mud, when examined with the microscope, is often found to contain multitudes of shells of foraminifera. Over large areas, the sea-bottom is thickly strewed with volcanic dust and small fragments of lava. (*Consult article entitled "Deep-Sea Sounding," by Captain George E. Belknap, U. S. N., in Hamersley's "Naval Encyclopædia."*)

The Atlantic Ocean.—The bed of the Atlantic consists for the most part of two winding valleys, of variable width and having an average depth of about three miles, separated by a rise whose mean distance below the surface is not quite two miles. This culminates in several oceanic islands, and extends to the Guiana coast, thus dividing the western valley into northern and southern basins.

The deepest part of the Atlantic, 27,366 feet, is near the island of St. Thomas, one of the West Indies. This depression has been called International Deep, independent soundings having been made here both by English and American officers.

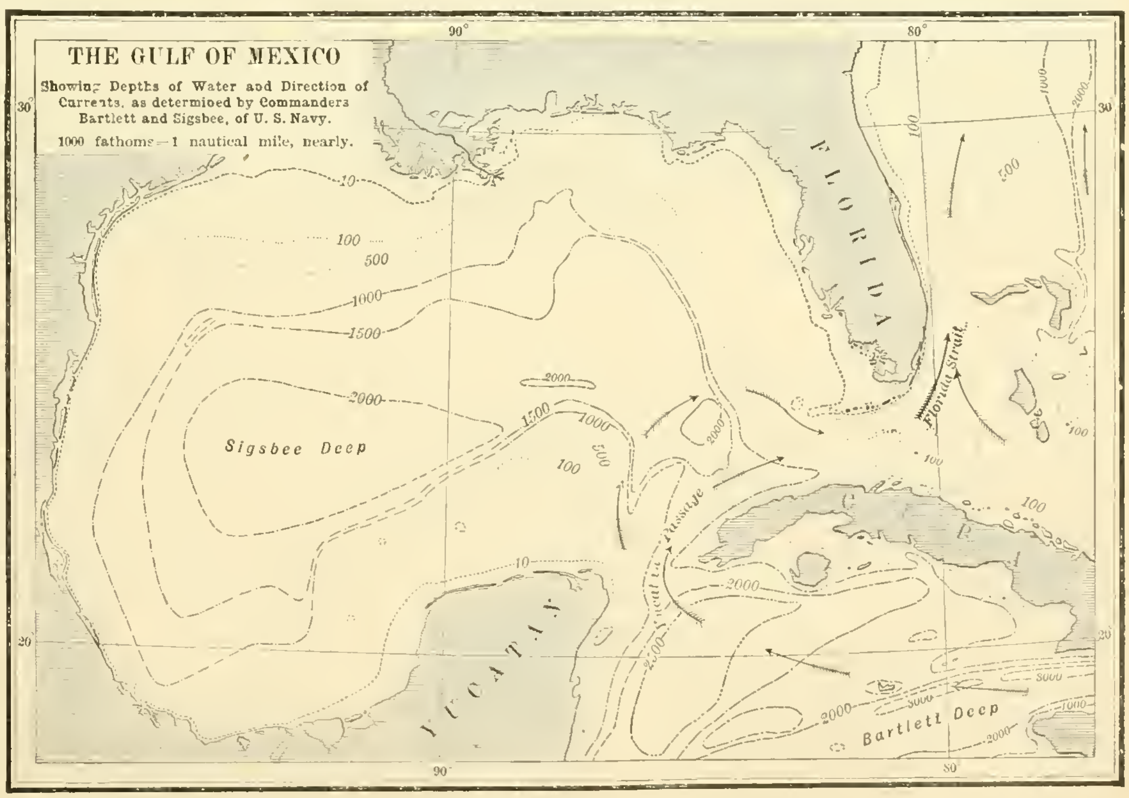
The three important branches of the Atlantic Ocean are the Mediterranean Sea, the Gulf of Mexico, and Hudson Bay.

The Mediterranean Sea has several basins, the deepest of which lies between Sicily and Greece. At its greatest depth, two and a half miles, its waters are warmer by 20° than those of the Atlantic at the same depth. At the bottom of the Strait of Gibraltar, one-fourth of a mile below the surface, both bodies have the same temperature, 55°. The cool strata at greater depths in the Atlantic can not rise above the barrier at Gibraltar, and therefore no water colder than 55° can enter the Mediterranean.

The Gulf of Mexico is a basin with three depressions more than two miles deep. Between Yucatan and Cuba, the depth is a little over a mile; and between Cuba and Florida, hardly more than half a mile. At its greatest depths, the water is warmer than in the ocean at the same distance below the surface. Indeed, this fact is always observable in the case of detached basins separated by submarine barriers from the deep sea.

The Caribbean Sea, although apparently not so distinct from the ocean, is really made up of two deep basins, nearly separated from the Atlantic by a volcanic mountain-range, whose exposed portions constitute the West Indian Islands. It attains a depth of three and a half miles south of Cuba. This part is called Bartlett Deep, and is divided from the main basin by an offshoot of the submarine mountains extending southwest from San Domingo. The West Indian Islands are separated from one another by valleys, no one of which much exceeds a mile in depth. (*Consult paper by Captain J. R. Bartlett, in "Journal of the American Geographical Society," vol. xiii., 1881.*)

The Pacific Ocean.—The Pacific is by far the largest of the oceans, its area being about twice that of the Atlantic. Its connection with the Arctic at Bering Strait is shallow. It rapidly widens toward the south, until between California and China the distance across is fully 8,000 miles. From the Indian Ocean, the Pacific is separated by an immense archipelago, between the islands of which its waters are shallow, or gathered into detached basins such as the Sulu, Celebes, and Banda Seas. The island-barriers are continued southward in New Guinea, Australia, and New Zealand, so that no deep current can pass from the Pacific to



Dotted contour lines connect points of equal depth. Arrows show the currents which unite to form the Gulf Stream.

EXPLANATION: *White, Snow and Ice; Blue, Open Water; Dark Green, Forest Land; Light Green, Bush and Grass Land; Buff, Tundra.*

THE ARCTIC OCEAN AND NORTH POLAR REGIONS.

the Indian Ocean except through a narrow, sinuous channel, which winds among the Spice Islands.

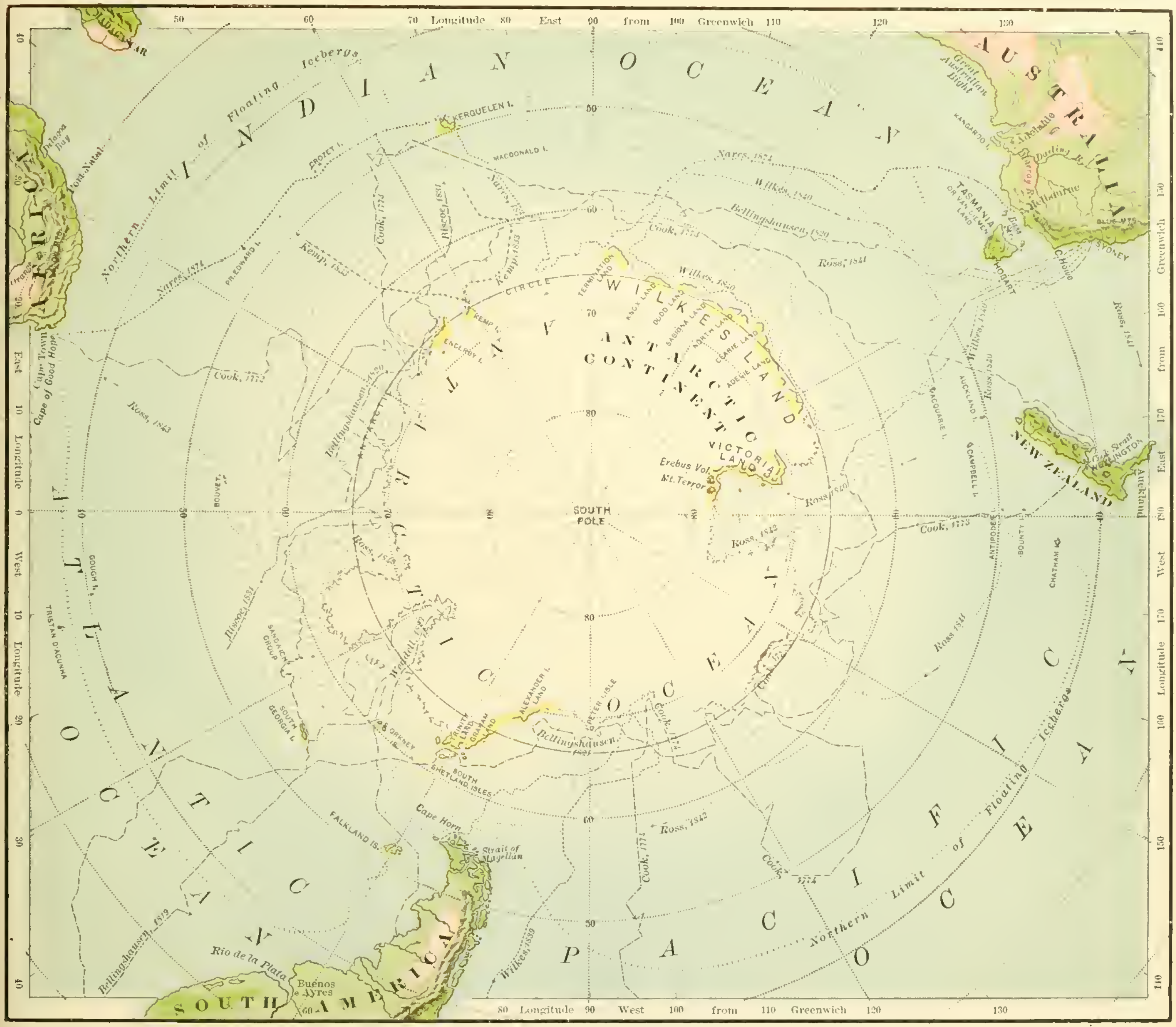
The Pacific is the deepest of the oceans as well as the most extensive in area. A large proportion of the North Pacific is as much as four miles deep. This area is called Tuscarora Deep. The greatest depth ever sounded in the ocean is 27,930 feet, more than 5¼ miles, nearly equal to the height of the Himalayas.

This sounding was made June 19, 1874, on board the United States ship Tuscarora, by Captain George E. Belknap, latitude 44°, 55′ north, longitude 152°, 26′ east, near the Kurile Islands. During the same year, a sounding of 27,450 feet was effected on board the British ship Challenger, near the Ladrone Islands. (*Consult Captain Belknap's "Deep-Sea Soundings in the North Pacific Ocean on the Steamship Tuscarora"; also Wild's "Thalassa."*)

The Indian Ocean is deepest over an area extending west of Australia and south of the Sunda Islands, becoming gradually shallower toward the Bay of Bengal. From Hindostan a plateau extends southward, from which the Laccadive, Maldive, and Cha′gos Islands rise to the surface. A similar plateau extends in a curve from Madagascar, including the Seychelles, Mauritius, and Réunion Islands. These two plateaus form in part a basin for the Arabian Sea.

The mean depth of this ocean is between two and three miles. Toward the south, it grows shallower and is interrupted by a few scattered mountain elevations, such as St. Paul's, New Amsterdam, Kerg′uelen, and Crozet (*kro-zay′*) Islands.

The Polar Oceans.—Little is known of the depth of the Polar Oceans. In the northern part of the Atlantic, the two basins unite and grow shallower, a plateau extending across from Greenland to Scotland, with Iceland as its culmination. Northeast of Iceland a basin is found, about three miles deep, which extends



EXPLANATION: *White, Snow and Ice; Blue, Open Water; Dark Green, Forest Land; Light Green, Bush and Grass Land; Red, Desert.*

THE ANTARCTIC OCEAN AND CONTINENT.

northward to an unknown distance. The Arctic Ocean north of Siberia is believed to be shallow. Soundings have not been made to such an extent as to give definite knowledge of the Antarctic depths. (*Consult Markham's "Great Frozen Sea."*)

The Polar Regions extend respectively from the Arctic and Antarctic Circles to the North and South Poles, the distance between the poles and the circles being 1,408 geographical miles. Three million square miles within the north polar circle, out of a total area of over eight million, remain unexplored, and of their physical geography nothing is positively known.

The avenues of approach to either pole are blocked with "floes," "ice-fields," and "pack-ice." Exploring vessels making for Lancaster Sound by way of Davis Strait, and whalers seeking the western cruising-grounds, have to cross the "middle ice," formed farther north during the winter and wedged in Baffin Bay in summer, and may choose one of three routes—the Southern, along the lower edge of the pack; the Middle, between latitudes 68° and 74°; and the Northern, to make which they must keep to the Greenland coast, brave the appalling dangers of Melville Bay, and if they escape these bear westward from Cape York. The middle passage is seldom practicable; Parry made it in 1819, but failed in a subsequent attempt in 1824. In the flourishing time of the whale-fishery, thirty sail would sometimes be waiting for days for a favorable opportunity to run the gantlet and escape the Devil's Nip.

The South Polar Regions differ from the northern in being almost covered by the ocean. The only extensive lands lie close to the pole.

A Slight Change of Sea-level would greatly modify the present boundaries of land on the earth's surface. If it were depressed 100 fathoms (about a forty-thousandth of the distance to the earth's center) Great Britain would form part of the continent of Europe; the beds of the North, Baltic, Black, and Adriatic Seas, would be dry; New York would lie a hundred miles from the coast; and the southern end of Newfoundland would be east of the inland city of Boston. If the sea-level were elevated 100 fathoms, London, Paris, New York, every large city in the world, would be submerged, along with nearly half of North America, three-fourths of Europe, a third of Asia, and half of South America and Australia.

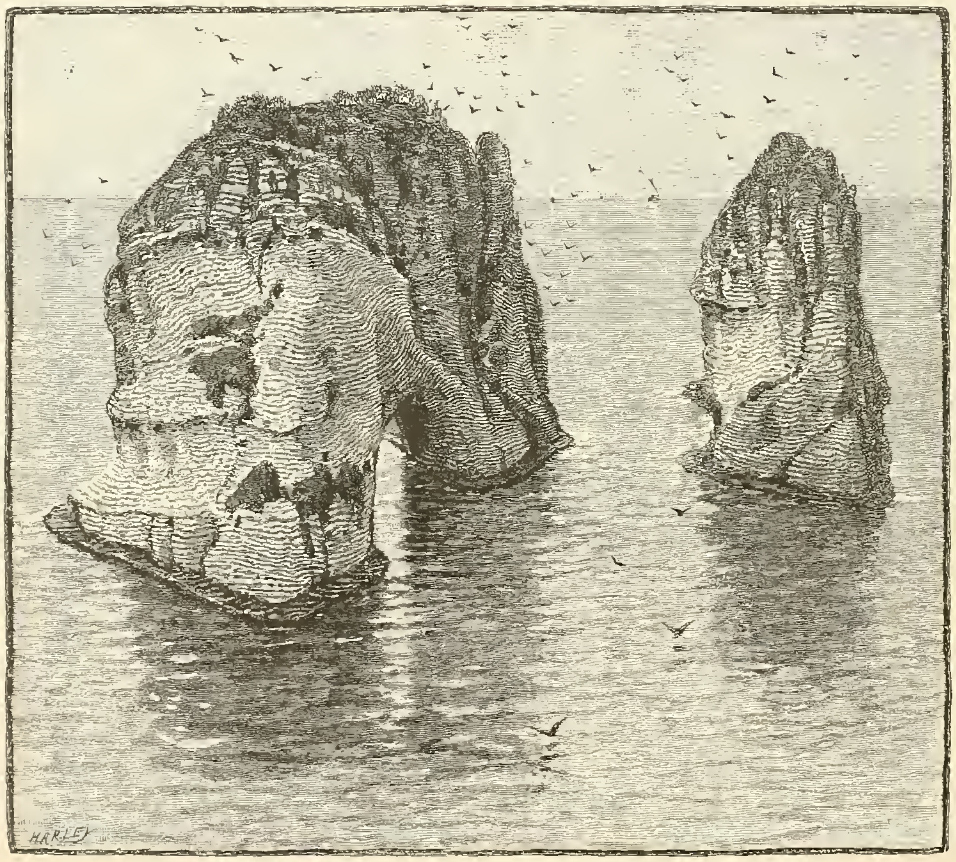
Questions.—What proportion of the earth's surface is covered with water? Name the divisions into which the ocean is usually separated. How are the great oceans connected? Compare the two main oceans as to their form, magnitude, depth, and floor. What would be the result if the surface of the ocean were elevated 100 fathoms? If depressed 100 fathoms? What can you say of the composition of sea-water? Of the salts it contains? Its color, phosphorescence, density, pressure, and freezing-point? State what is known of the depth of the ocean. Discuss its temperature; the configuration of its floor. How far has the sea-bottom been investigated? Give an account of the Atlantic Ocean; its bed, greatest depth, the inland seas that open into it. Of the Pacific. Of the Indian. How much is known of the Polar Oceans? If the water occupied the polar regions, leaving the equatorial for the land, would the earth better subserve the purposes of man?

MOVEMENTS OF THE SEA.—WAVES.

The sea is never at rest. The wind breaks its surface into Waves, the sun and moon change its level by producing Tides, and its waters are transferred from place to place by Currents.

Waves are ridges of water produced by the friction of the winds on the surface. They appear to move forward; but in deep water it is only the wave-form that advances, each particle in succession moving up and down in an ellipse. The dimensions of this ellipse determine the height of the wave, which does not often exceed ten or twelve feet. Only in the most violent storms have waves been observed whose height from crest to trough was 40 feet, and length from crest to crest 550 feet.

Force of Waves.—When a large wave meets a shelving beach, this retards the elliptic motion of the particles near the bottom, and the crest rolls forward, breaking into foam. Vertical motion is thus changed into horizontal motion. The force with which the water thus strikes against an obstacle depends upon the velocity of the wind and the time during which its energy has been accumulating. It has been estimated, in a violent storm, as high as forty pounds upon each square inch of surface exposed. Waves are therefore powerful agents in wearing away coasts, and thus increasing the inequalities of the outlines of the land.



Pigeon-Rocks, Beirut, Syria; illustrating the Results of Wave-Action.

Duration of Wave-Motion.—Even after the wind has lulled, the momentum acquired by the water is enough to keep it long in motion. When the air is perfectly quiet the ground-swell of the sea continues, and breakers roll on the beach. Only after a calm of many days does the sea become perfectly smooth at its surface.

Effect below the Surface.—The disturbance produced at the surface is imparted to the water below to a depth not exceeding the length of the wave. At depths of 50 feet, the water is ordinarily unaffected. The commotion may be communicated several hundred feet below the surface during the progress of a great cyclone, but below 700 feet the water is probably never disturbed except by currents.

Velocity of Transmission.—For great waves, whose length exceeds the depth of the water, the rate of progress depends on this depth as well as on freedom from obstructions. In open sea, therefore, a wave travels faster than in a narrow bay.

In 1877 an earthquake-wave, starting near Arica on the coast of Peru, crossed the Pacific Ocean, and reached Japan in twenty-four hours, with a mean velocity of nearly 600 feet a second, or ten times that of an express-train. The mean depth of the Pacific was thus calculated to be two miles. Such estimates are only approximate. In shallow water, the velocity of a wave's transit may be as little as fifteen or twenty feet a second.

TIDES.

Tides are the alternate swelling and sinking of the sea in great waves which reach the land at regular intervals.

The water rises, producing flood-tide; then sinks, producing ebb-tide a little over six hours afterward. This action is repeated continually, the interval between two flood-tides being nearly twelve hours and a half.

Tide-waves differ from ordinary waves in the following particulars:

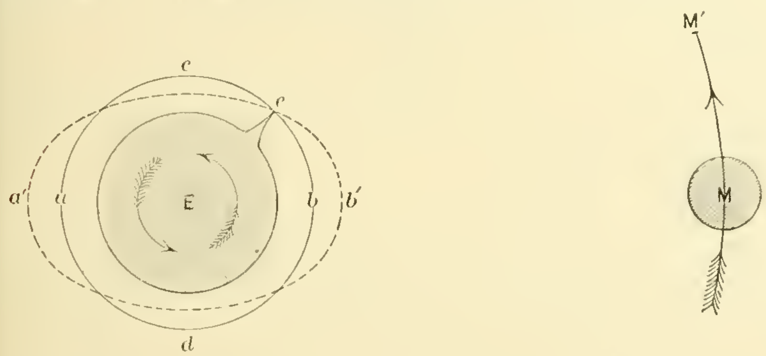
I. They are caused by the attraction of the moon and sun, and not by the friction of the wind. II. The disturbance affects the water as a mass, and is not confined to the surface.

Production of Tides.—To understand the production of tides, it is necessary to remember that, if a body is revolving around any center, its course is due to the combination of two influences. At every point it tends to continue on in a straight line, but the central attraction makes it fall continually toward the center. Its direction is thus perpetually changing, and it never reaches the center toward which it is falling.

Let the student whirl a ball which is secured to his hand by a string. The hand represents the earth, the ball is the moon, the pull of the string on it is like the earth's attraction. The ball is continually falling toward his hand without reaching it. If the ball is released, it flies off, at first in a straight line. Moreover, to keep it whirling, the hand revolves also in a small circle. The hand and ball move at different distances around the same center. The pull of the string on the hand is just equal to its pull on the ball.

The Lunar Tide.—Suppose two bodies like the earth and moon to be revolving around a common center. Then each is continually falling toward that center, both being pulled equally toward it, the earth by the moon and the moon by the earth.

To illustrate, let E in the diagram represent the earth's center, and M that of the moon. Imagine the earth to be a sphere completely covered with water of uniform depth. A particle of water at *a*, being more distant from M than E is, will be pulled less strongly; hence *a* and E must become separated in their fall, their distance apart becoming increased to E *a′*. The effect is the same as that of diminishing the earth's attraction on the water at *a*. The solid matter near *a* is affected likewise, but can not move from E.



In like manner a particle of water at *b*, being nearer to M than E is, will be pulled more strongly; hence *b* and E must become separated in their fall, their distance apart becoming increased to E *b′*. The water is thus drawn away from *c* and *d*, to become piled up at *a* and *b*. There is high tide at points aligned with the moon, and low tide at points distant from these a little over 6,000 miles. If the moon were covered with water, similar tides would be produced on it by the earth's attraction.

But the earth rotates daily. Suppose the top of a rock at *e* just to touch the surface of the water. Then, moving around with the earth, it will be exposed at *c*, submerged at *a*, exposed at *d*, and submerged at *b*. During the interval the moon has moved from M to M′, so that the high tides will now be aligned with M′; and fifty-four minutes more than a day are required for the rock to recover a position like that from which it started. The interval between high and low tide is hence about six hours and thirteen or fourteen minutes. If high tide occurs at noon, then on the next day the corresponding tide must take place nearly an hour after noon, an intermediate high tide having occurred shortly after midnight.

The Solar Tide.—The sun exerts also a tide-producing influence, but on account of its great distance its effect is much less than that of the moon. In New York Harbor, the difference between high and low water due to the moon is about four and a half feet; that due to the sun, only one foot. In mid-ocean, the sun's influence is about four-tenths of the moon's.

Spring and Neap Tides.—When sun and moon are in the same line with the earth, whether on the same or opposite sides, their effects are conjoined to produce tides higher than usual, called *spring-tides*. When their directions from the earth are crossed at right angles, the tide-producing influence of each conflicts with that of the other, so that the tides are lower than usual. Such tides are called *neap-tides*. There are two spring-tides during each lunar month, produced by the new moon and the full moon; and two neap-tides, produced by the moon at first and third quarters. The highest spring-tides occur when the earth is nearest the sun, and the moon at the same time nearest the earth. The opposite conditions produce the lowest neap-tides.

Tidal Motion of the Water.—Since the water is piled up in places of high tide at the expense of places of low tide, a tidal wave implies a transfer of water along with the advance and recession of the wave over any point. The rate of progress of the wave when once started depends on the depth of water and size of the ocean. The tide moves fastest in the deep sea, and is much retarded in approaching the shoals near the shore.

Height of the Tide.—In the middle of the Pacific Ocean, the height of the tide is calculated to be but little more than two feet. Where it approaches a shore, the retardation of the front of the wave causes a piling of the water from behind, so that the difference between high and low water is much increased. This becomes specially marked where the wave advances into a recess, or wedge-shaped bay.

On the east coast of the United States, there are three great recesses. One is between Cape Florida and Cape Hatteras, the inmost part being at the mouth of the Savannah River. At these two capes, the height of the tide does not exceed two feet, while at Savannah it is seven feet. The second recess is between Cape Hatteras and Nantucket, the highest tides being at New York. The third is between Nantucket and Nova Scotia, with several minor bays. At Boston, the height of spring-tide is eleven and a half feet, and in the Bay of Fundy it exceeds fifty feet. Wind and tide together may raise the water seventy feet above its lowest point at the head of this bay.

Bores.—When the front of a tidal wave is retarded, its slope is increased, so that the tide at a given point rises rapidly and falls slowly. In the Severn River, above Bristol, England, the whole rise of eighteen feet is completed in ninety minutes, while the fall occupies ten hours. At the time of spring-tide, the wave in ascending the river rushes violently like a billow eight or nine feet high. Such rolling tide-waves in estuaries are called Bores.

Bores are observed at the head of the Bay of Fundy; in the Dordogne River, where it empties into the Garonne, on the coast of France; and in the Hoogly and Brahmaputra Rivers, at their point of entrance into the Bay of Bengal. In the Chinese river Tsien-tang, the bores are thirty feet high and travel over twenty miles an hour. In the Amazon, at the time of highest tides, bores ascend the river to a distance of 200 miles, as many as six or seven of them appearing in succession during three days, like rolling terraces of water, twelve or fifteen feet in height.

Retardation of the Tidal Wave.—When the moon is most nearly overhead, its tide-producing influence is strongest. But the time of high tide does not actually occur until several days afterward. This is due to the fact that the momentum acquired by the water in rising causes the accumulation to continue at any place after the tide-producing influence has begun to diminish. Water can not move without friction, and this also greatly retards the production of the tide-wave. The velocity of the wave, moreover, being greatly affected by the varying depth of the ocean and the irregularities of coast-lines, can never approach that of a point on the earth in its rotation.

Even if formed just under the moon, the tide-wave can not keep such a position in regard to it. The eastward velocity of a point on the Equator is over 1,000 miles an hour. The westward velocity of a tide-wave rarely exceeds 500 miles an hour.

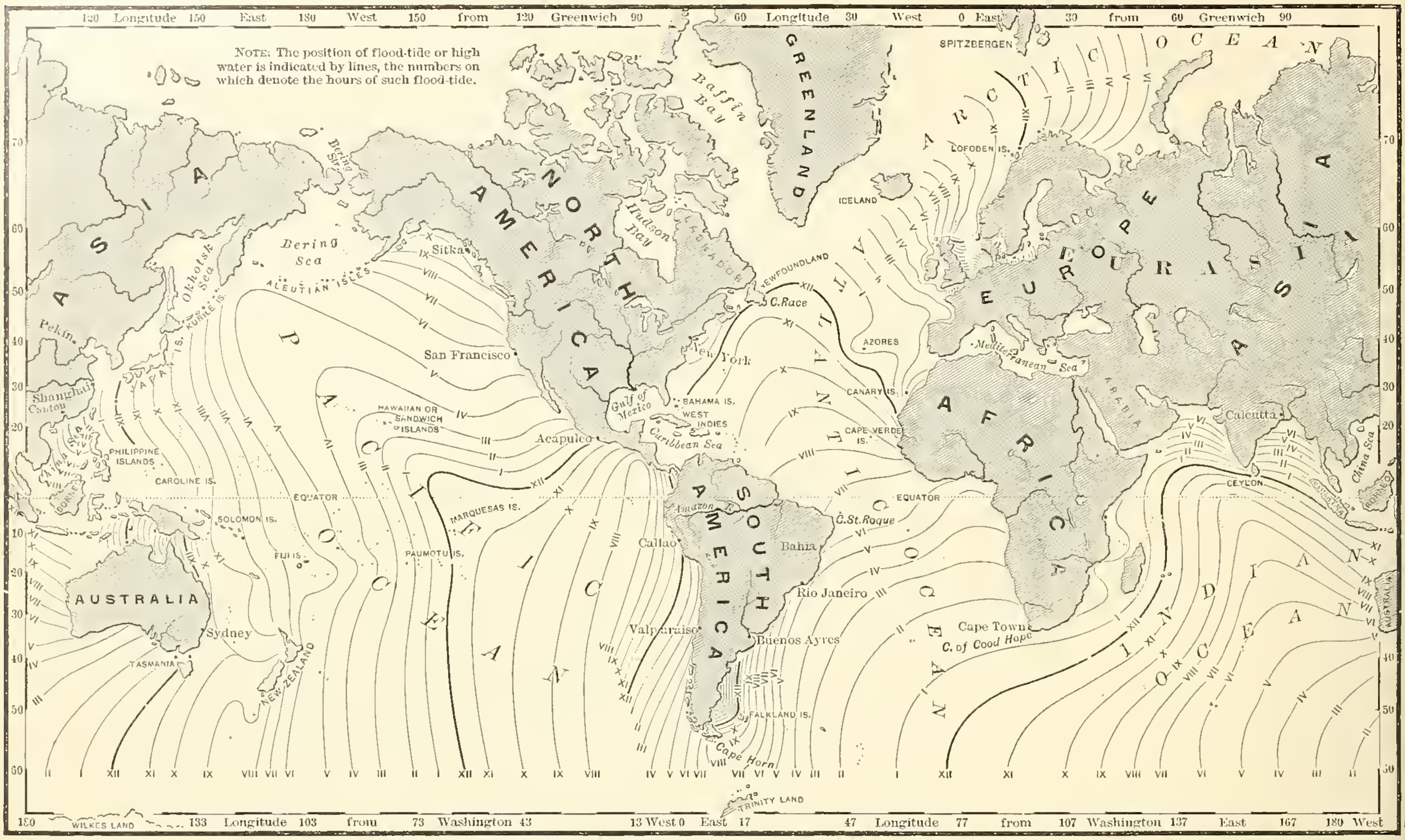


Chart of Co-tidal Lines, illustrating the Course of the Tidal Wave in the Four Great Oceans.

Co-tidal Lines.—If a tide-wave be assumed to start at a particular meridian, and its successive positions be represented by corresponding lines on a chart, these will not coincide with the successive meridians.

The South Pacific Ocean, being most nearly free from obstruction, is assumed as the starting-place of the tide-wave. As this advances, its rate becomes varied by obstructions. Lines connecting those places which have high water at the same moment, are called Co-tidal Lines.

By referring to the Chart of Co-tidal Lines, it will be seen that the high tide which occurs at noon in the middle of the South Pacific reaches New Zealand and Kamchatka about six hours afterward. The wave-front becomes greatly bent in the North Pacific, so as to approach Alaska from the south and California from the west. Traveling westward, it reaches the longitude of South Africa before noon on the following day, but has been much retarded in equatorial regions, so as to approach India from the south. By noon of the second day, a part of it has traversed the Atlantic in a northwestward direction and reached the North American coast; while about the same time, another part, much retarded on the eastern side, has arrived at the western coast of Africa, near the Sahara Desert. Advancing toward the northeast, it touches Iceland and Scotland six hours later; and at midnight it has passed Norway and nearly reached Spitzbergen.

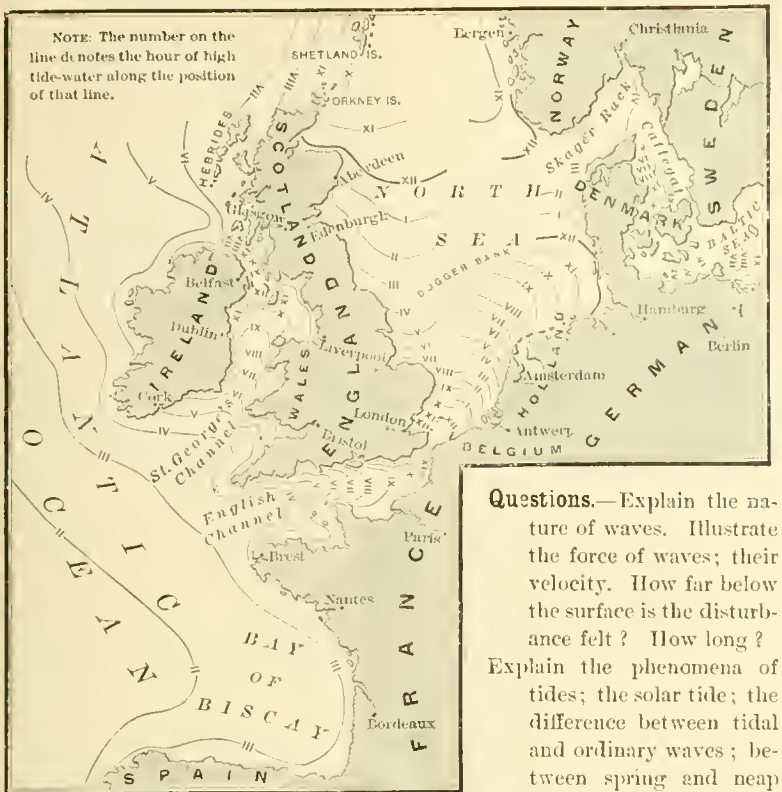
Opposition of Tide-Waves.—Owing to retardation in shallow water, the parts of a tide-wave in passing around a large island may meet on its farther side in different phases, so as to produce much disturbance and rapid local currents.

In New York Harbor at about seven and a half hours after the passage of the moon, high water enters between Sandy Hook and Coney Island with an elevation of four and a half feet. At the same time it passes the east end of Long Island with an elevation of two feet, and travels thence through the Sound toward New York. Meanwhile, the wave from Sandy Hook has slowly traversed New York Bay and ascended the East River. The meeting-place of these two tide-branches is at Hell Gate, the narrowest ship-passage between Long Island and New York. Differing in times and heights, they cause the surging currents that periodically sweep through the East River. If a partition-wall were built across the river at Hell Gate, the water would at times be five feet higher on one side than on the other, reversing the inequality with each change of tide. There is no actual opportunity for such an accumulation, but a difference of a foot in height within one hundred feet in distance is not uncommon.

Somewhat similar conditions exist in the British Channel, the tidal wave that passes through the Strait of Dover being met by another that has turned around Scotland and traveled southward through the North Sea. The roughness of the water in the Channel is well known.

Whirlpools.—Opposing currents, tides, and sometimes winds, produce the phenomena of eddies and whirlpools. Tidal currents round the Lofo'den Islands, off the Norwegian coast, cause the famous Maelstrom (*grinding stream*), a mile and a half in diameter. In certain states of the wind and tide, the Maelstrom is entirely unnavigable; vessels caught in the current are in danger of foundering, or of being dashed to pieces against the rocks. Ancient accounts represent this whirlpool as swallowing up ships and monsters of the deep; they are mere fables, for there is no reason to suppose that the violence of the Maelstrom has been modified in recent time by geological changes in the rocks about which it roars.

Near the island of Jura, off the west coast of Scotland, the whirlpool Corryvreck'an is produced by the opposition of a pyramidal rock to the tidal stream. Two whirlpools formidable to the ancients were Scylla and Charybdis, on opposite sides of the Strait of Messina. They still exist, but are no longer associated with danger to navigation.



CURVE OF THE TIDAL WAVE ABOUT THE BRITISH ISLES.

Questions.—Explain the nature of waves. Illustrate the force of waves; their velocity. How far below the surface is the disturbance felt? How long?

Explain the phenomena of tides; the solar tide; the difference between tidal and ordinary waves; between spring and neap tides. What are bores? Where are they observed? Briefly state the history and progress of the Atlantic tide-wave, mentioning its magnitude in open water, and the time it occupies in making the tour of the coast-line of the United States. Explain the retardation of the tidal wave. What are cotidal lines? Trace the course of the tide through the East River; around the British Isles. In what waters does the tide attain its greatest height? Suppose at new moon we should have high tide at mid-day, why would the opposite side of the earth have high tide at the same hour?

Discuss the causes of whirlpools. Describe the Maelstrom; the Corryvreckan. Where were the ancient Scylla and Charybdis?

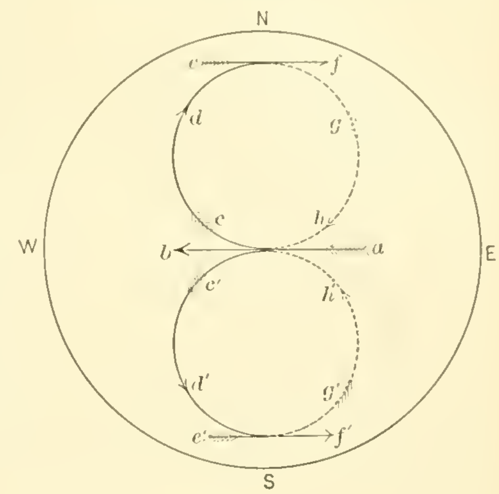
OCEAN-CURRENTS.

THE subject of ocean-currents is so intimately related to that of the great currents of the air that any discussion of the principles involved in one must apply at least partially to the other also.

Theory of Ocean-Currents.—Suppose the earth to be at rest and entirely covered with water of uniform depth. Let it be heated along the Equator and cooled at the poles to the bottom, so that equatorial waters are expanded and polar waters are made more dense. The level of the warm water is by expansion raised slightly above that of the cold water. A current always tends to flow from a higher to a lower level, therefore a surface-current must flow from the Equator toward each of the two poles. For the water thus removed, a supply of cooler water must come as an undercurrent from the polar regions. A constant circulation is thus established, tending to equalize the temperature of the earth's waters.

Let the earth now rotate on its axis. The surface velocity eastward is over 1,000 miles an hour at the Equator, diminishes to 500 miles near latitude 60°, and is reduced to zero at the poles. This motion belongs to all objects at the surface. The cold water, passing from slow-moving polar to fast-moving equatorial regions, can not instantly assume the increased rate eastward. The ocean-bed passes eastward under it, and therefore these currents gradually assume a westward direction in relation to the fast-moving ground, until they nearly reach the Equator. Here they rise to the surface as westward currents, and then overflow toward the poles after becoming warm.

These surface-currents now pass off toward the slow-moving polar regions, carrying with them the rapid eastward velocity acquired at the Equator. They therefore manifest this by sweeping eastward over the waters underneath, until they reach the polar regions. Here they sink and resume their journey beneath toward the Equator.



In the figure, the westward equatorial current is indicated by the arrow, *a b*; the overflowing warm currents, by *c d*, *c' d'*; the eastward currents in the neighborhood of the polar circles, by *e f*, *e' f'*; the undercurrents of cold water, by *g h*, *g' h'*, represented in dotted lines.

Ferrel's Law.—It has been proved mathematically by Professor Ferrel that "*in whatever direction a body moves on the surface of the earth, there is a force arising from the earth's rotation which deflects it to the right in the northern hemisphere but to the left in the southern.*"

This is known as Ferrel's Law. On it is based the theory of both oceanic and atmospheric currents. Each straight arrow in the figure touches a curve that bends to the right of the arrow-head in the northern hemisphere, to the left in the southern hemisphere. At the Equator the opposite forces are equal. (*Consult Ferrel's article on "The Motions of Fluids and Solids on the Earth's Surface," in "Professional Papers of the United States Signal Service," No. viii., pp. 30–51.*)

Modifying Influences.—The exact circulation just described is not realized in full, because the continents serve as obstructions, and also because the polar waters have a lower temperature at the surface than at the bottom. The comparatively warm water at the bottom tends to rise and displace the colder and heavier surface-water, making this flow outward before it can sink. Cold surface-currents from the poles, therefore, move for a short distance toward the Equator, becoming deflected to the west, and sinking under the warm currents that they meet. These in turn sink as they become cooled by mixture and by the cold air.

The wind, especially where it blows constantly in one direction, has a decided influence in determining the direction of the surface-currents of the ocean. Indeed, some authorities consider the wind the most important of all agencies in producing currents. But the depth of certain ocean-currents is too great to be accounted for by the action of the wind alone.

Atlantic Currents.—In the Atlantic Ocean, about equatorial regions, there is a general movement of the water westward. This fact was discovered by Columbus, and is most noticeable in those parts which are swept by the trade-winds.

The north equatorial current flows from the Cape Verde Islands to the West Indies. The south equatorial divides near Cape St. Roque, one part turning southward along the Brazilian coast as far as the latitude of the La Plata River. Here it gradually bends eastward and becomes lost by mingling with cold waters from the South Frigid Zone. The other and larger portion flows past the mouth of the Amazon and unites with the northern current, east of the Lesser Antilles.

Origin of the Gulf Stream.—Between the Lesser Antilles and the South American coast, an offshoot of the equatorial current enters the Caribbean Sea, in the deep basin of which it is partially checked by a shoal extending from Honduras nearly to Jamaica. The current is thus turned round so as to pass eastward along the south coast of San Domingo, and rejoin the main current near Puerto Rico. This washes the north shores of Puerto Rico and San Domingo, and is divided by Cuba into two streams, one of which flows on its north side to the Bahama Banks. The other passes through Bartlett Deep, then turns northward through Yucatan Passage, then eastward through the Florida Strait, where it unites again with the other stream. Here, at its narrowest part, its width is but little over forty miles, the depth does not exceed 3,000 feet, and the velocity at the middle is nearly five miles an hour.

This narrow stream is thus only a moderate part of the great body of warm water which flows from tropical to north temperate regions. Little, if any, of it circulates through the Gulf of Mexico. It is swelled in volume at and beyond the Bahama Banks by the rest of the great current, and to the whole, as it flows to the northeast, the name of Gulf Stream is applied. This name is the result of a misapprehension, as it was formerly thought that this body of water made the circuit of the Gulf of Mexico.

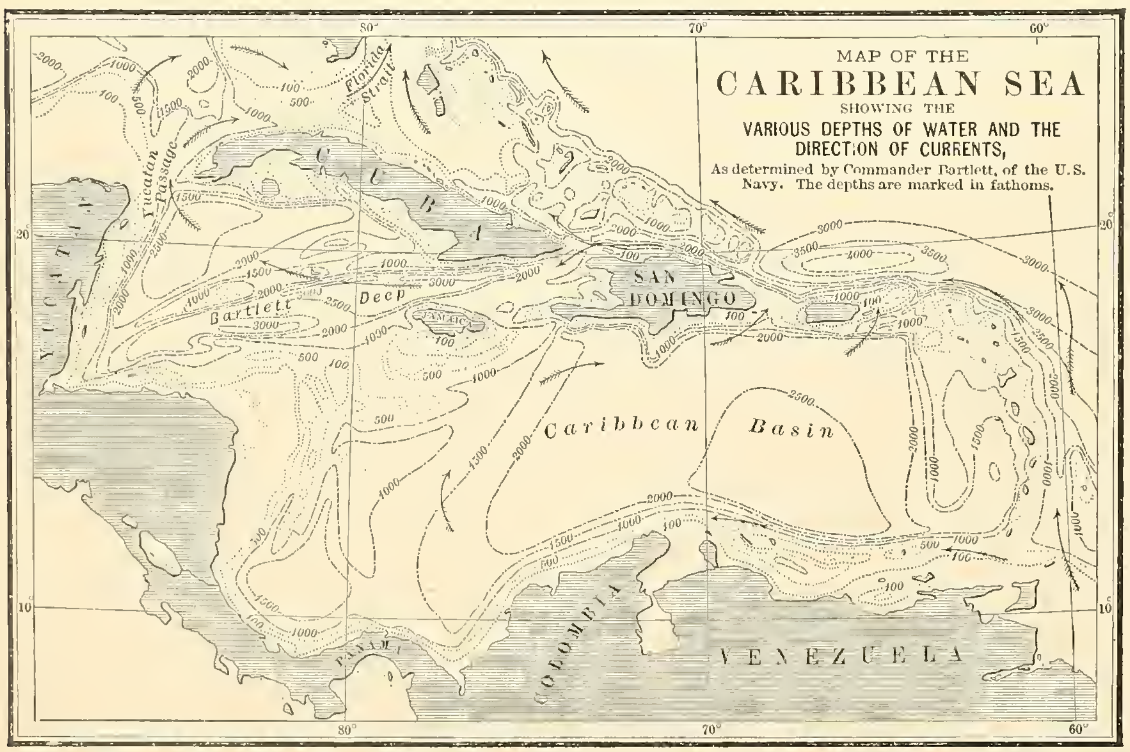
Temperature and Depth of the Gulf Stream.—The surface temperature of the water at the Lesser Antilles is usually 79° or 80°, and between Cuba and Florida it is 82°. This rapidly decreases with depth, until at 4,800 feet it is 39½°. The current sweeps the bottom from Cuba to South Carolina, and widens as it passes over a broad plateau whose general depth is 2,400 feet. It washes the ground bare, so that where the stream is fastest the only specimens obtained by sounding are pieces of hard coral rock.

North of latitude 33°, the current ceases to sweep its bed; for here a dark, greenish ooze, characteristic of the North Atlantic, begins to be found on the bottom indicating that at this point the heavier waters of the cold current from the Arctic regions are displacing those of the Gulf Stream. The warm water glides over its cooler liquid bed, until near Cape Hatteras the surface is alternately cold and warm. Here the Gulf Stream becomes divided into bands, as it gradually changes its direction toward the east and widens still more as its temperature falls. Near Newfoundland its width is 320 miles, and its velocity is reduced to a third of what it was off the Florida coast, while the quantity of water moving eastward is doubled on account of accessions from the streams that flowed past the Antilles without entering the Caribbean Sea. Off the west coast of Europe, the velocity hardly exceeds one hundred yards an hour. (*Consult Bartlett in "Journal of the American Geographical Society," vol. xiii., 1881.*)

Division of the Gulf Stream.—Crossing the Atlantic, part of this stream turns southward past the coast of Portugal and Africa, completing the circuit as it rejoins the north equatorial current. Another branch continues its northeast course past Great Britain, Iceland, and Norway, until it is mingled with the waters of the Arctic. A small current washes the southern part of Greenland, opposite Labrador.

Contrasts presented by the Gulf Stream.—The surface temperature of the Gulf Stream is such as to warm all the land near which it passes. It makes Norway habitable, and keeps the harbor of Hammerfest free from ice, although this town is within the Arctic Circle. At the same latitude in America, a severe Arctic climate prevails. In passing into the Gulf Stream near Halifax, a difference of 30° in temperature has been recorded during the same day, and of 8° or 10° in as many minutes.

The color of the Gulf Stream is the deepest azure, presenting a remarkable contrast to the greenish tint of the neighboring colder water. The difference between the water at the bow and that at the stern of a large ship, in tint as well as in temperature, is sometimes noticeable, especially in the seas near Newfoundland.



The dotted contour lines connect places of equal depth. The arrows show the currents which form part of the Gulf Stream, but without circulating through the Gulf of Mexico.

Where the slope of the sea-bottom is steep, the dotted contour lines are close together. The direction of slope is shown by the numbers. Thus, on the north side of Bartlett Deep, the depth diminishes from 3,000 to 1,000 fathoms; on the south side, from 3,000 to 500 fathoms.

1,000 fathoms = 1 nautical mile, nearly. Compare with map on p. 53.

Sargasso Sea. — The completed circuit of the equatorial current and Gulf Stream causes the inclosed mass of still water to become a receptacle for floating bodies gathered by the current. These include an immense quantity of sea-weed which covers thousands of square miles of surface. It grows without roots, and affords a home to multitudes of fish. Mingled with these marine grasses are occasional masses of drift-wood. The name Sargasso (*sea-weed*) Sea is applied to such areas, of which several have been found in the ocean. (*See p. 50.*) (*Consult Dr. Hartwig's "The Sea and its Living Wonders," p. 299.*)

Atlantic Polar Currents.—From the Arctic Ocean, a polar current sets southward. A narrow band of this current washes the east coast of Greenland; but the largest portion flows through Baffin Bay and extends southward until it meets the Gulf Stream. The earth's rotation causes this cold current to keep close to the western shores of the channel (Ferrel's Law). Labrador and

Newfoundland are therefore frozen wastes during much of the year, and the influence of its chilling presence is strongly felt on the coasts of Maine and Massachusetts. Where it meets the Gulf Stream, much sediment is deposited, thus forming the Banks of Newfoundland.

Another cold current flows southward past Spitzbergen, and is limited, like the Baffin Bay current, by the advancing Gulf Stream. The southern limit of floating icebergs is determined by the conflict of these cold and warm currents.

From the Antarctic Ocean, the cold water flows northward with little or no obstruction. The prevailing winds, which are constantly toward the southeast, give an eastward deflection to these currents at the surface over the whole southern ocean. Passing into the Atlantic, the Antarctic current washes the western coast of South Africa, making its cooling influence felt nearly to the Equator.

Pacific Equatorial Currents.—Across the 8,000 miles of the Pacific Ocean, a broad current sets westward with a speed estimated at from two to three miles an hour, being strongest in the trade-wind regions north and south of the Equator. About the middle of this strip there is a perceptible counter-current, setting east. This is due to the interruption opposed by the archipelago between Asia and Australia. Each of the two streams becomes banked up and tends to spread on both sides. The portion thus thrown off between them can only return between them.

Much the greater part of the northern current is deflected northward. Of the southern current, a very small part may penetrate through the Archipelago to the Indian Ocean, but most of it turns southward past Australia and New Zealand, and becomes mingled with the cold waters coming from the Antarctic Ocean.

The Japan Current, or Kuro-Siwa.—The north equatorial current for the most part turns northward in the neighborhood of the Philippine Islands, and then sets northeastward. It does not attain the velocity of the Gulf Stream, because its waters are nowhere pent up in a basin with narrow channels analogous to the Caribbean Sea.

The magnitude of the Japan Current is estimated to be about three times that of the Gulf Stream. Its name, Kuro-Siwa, means "Black Stream," and is applied on account of the dark-blue tint of its waters. East of Japan, it spreads out and divides into branches, the largest of which reaches the coast of Alaska, and imparts the remaining warmth brought from tropical regions, just as the Gulf Stream warms Norway. (*Read Antisell's article on "The Currents of the Pacific Ocean," in the Bulletin of the American Geographical Society, No. 2, 1883.*)

Arctic Current.—The only connection between the Arctic and Pacific Oceans is through Bering Strait, which is about forty-five miles wide and less than 170 feet deep (Dall, 1880). In the middle of the strait lie the Diomede Islands. It is impassable for icebergs, but field-ice is borne southward into Bering Sea, and a cold current of very small volume passes along its western half, disappearing at no great distance from the strait. Bering Sea is thus perceptibly colder than the ocean south of the Aleutian Islands.

The difference of temperature on the opposite sides of the projecting peninsula of Alaska is very marked. On the south side, humming-birds are found in summer; while the north side is visited at all times by walruses and thousands of seals.

Peruvian and Antarctic Currents.—The western coast of South America receives part of the Antarctic Current, after it has reached the Pacific Ocean, just as Africa receives that in the Atlantic. The shores of Patagonia and Cape Horn are therefore bleak and frozen. Part of the cold current sweeps past Chile and Peru, and then turning westward is lost in the south equatorial current.

In the neighborhood of Australia, the Antarctic Current sends a branch that washes the western coast of this continent, and is finally lost in the Indian Ocean. Another branch, flowing northward, is deflected west by Tasmania, and to the southern coast of Australia, returning upon itself. The part which flows toward the northeast between Tasmania and New Zealand mingles with the south equatorial current, and the two together attain a velocity as high as one hundred miles a day.

Currents of the Indian Ocean.—In the Indian Ocean north of the Equator, the currents are regulated entirely by the winds. South of it, there is a steady westward drift, the current dividing into two parts near Madagascar. One of these sweeps southward, east of this island, and joins the eastward Antarctic drift. The other and larger part flows between Madagascar and Africa to the extremity of the continent, where, under the name of the Agulhas (*ah-gool'yahs*) Current, it is turned sharply eastward by the Antarctic drift, and penetrates far southward.

General Considerations.—Where currents differing widely in temperature meet each other, the sea is often covered with fog, and is subject to sudden and violent storms. Among the best known of such regions are the Banks of Newfoundland, the vicinity of Cape Hatteras, of Cape Horn, and of the Cape of Good Hope.

Oceanic currents are the most important of all agencies in modifying climate and producing uniformity in the temperature of the ocean itself. Moreover, their constant circulation keeps the waters of the ocean pure by preventing stagnation. Seeds are transported by them to coral islands, and regions that would otherwise have remained deserts have, through their agency, been rendered fertile and habitable.

The great amount of evaporation in equatorial regions causes the water of the sea to become perceptibly more briny in low than in high latitudes.

Evaporation alone is capable of producing permanent currents. The Mediterranean Sea loses by evaporation more water than it receives from its shores. It is hence more salt than the Atlantic, and its surface at Marseilles is about three feet lower than the surface of the English Channel. A strong current continually pours in at the Strait of Gibraltar. For similar reasons there is a continual surface inflow from the Indian Ocean into the Red Sea and Persian Gulf. In the case of the Baltic Sea and Hudson Bay, evaporation is not sufficient to balance the accessions of fresh water from the surrounding basins. The water is deficient in saltness, its tint is greenish-blue, and currents flow continually out to the ocean.

Currents due to these local causes should not be identified with the great ocean-currents of the globe. Evaporation tends to lower the surface of the ocean in tropical regions and to make sea-water denser; the expansion due to heat at the same time tends to raise the surface and make sea-water less dense as long as it is warm. It may not be possible to decide which of these influences predominates. The direction of currents, due to either cause, is determined by the earth's rotation and the friction of the prevailing winds.

Questions.—Why are there currents in the ocean? Recite Ferrel's Law. What theories are based on it? By what influences is the natural circulation in the ocean modified? Describe the Atlantic currents. Account for the Gulf Stream. Why is the name Gulf Stream a misnomer? State the temperature, color, mean depth, width, and velocity of this current. Describe its course. What are Sargasso Seas?

Give an account of the Pacific, Peruvian, Arctic, and Antarctic currents; of the currents of the Indian Ocean; of the Black Stream of Japan. How do stream-currents differ from the tidal current? How far are the direction and force of currents influenced by the form of the land? Of what utility are the oceans in the economy of nature? Ocean-currents?

The Third Geographical Element—Air.—We have now considered the structure and physics of the earth's crust, its land and its water, and are prepared to investigate the more striking phenomena of that invisible elastic fluid which completely surrounds our globe—the Atmosphere. The atmosphere (from two Greek words, meaning *vapor-sphere*) is a vast gaseous ocean, the greater part of whose mass is comprised in a layer having nearly the same depth as the liquid ocean. Under the head of Atmosphere are to be studied the composition and general properties of air; its circulation in winds; its clouds and precipitations; storms, climate, and weather.

The science that describes and explains those phenomena of the atmosphere which may be conveniently grouped under the head of weather and climate, is known as Meteorology (literally, *description of things in the air*).

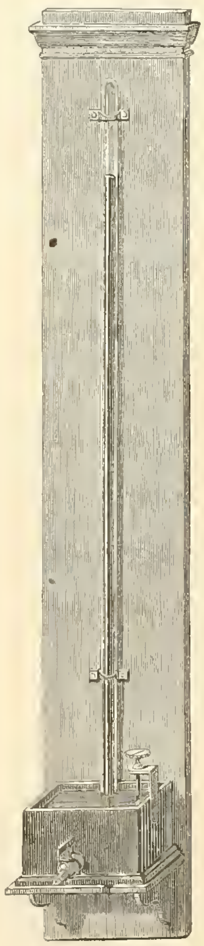
Air is a Mechanical Mixture, chiefly of two gases, oxygen and nitrogen; of these, the former, in a free state, is necessary to life. Although oxygen is a little denser than nitrogen, the two are uniformly mixed, in the proportion by bulk of twenty-one to seventy-nine, by weight of twenty-three to seventy-seven. There are minute quantities of other permanent gases, the most important of which is carbonic acid (*see p. 36*), normally present in the proportion of three pounds to 10,000. This ratio is often trebled in crowded rooms.

Invisible vapor of water is always present in variable quantity, and fine particles of dust float in the atmosphere, not only at the earth's surface but at great elevations. (On the constituents of the air we breathe, *consult Johnston's "Chemistry of Common Life," p. 13.*)

Weight and Pressure of the Air.—At the temperature of melting ice, 773 cubic feet of air weigh only as much as a single cubic foot of pure water, or nearly $62\frac{1}{2}$ pounds. One cubic foot, therefore, weighs about an ounce and a quarter.

Since air is a perfect fluid, its particles are freely movable among themselves. Each is subject to the weight of all those above it, and transmits this as pressure equally in all directions against those in contact with it.

The Barometer.—The pressure of the air is determined by means of the Barometer (*weight-measurer*). Of several forms of this instrument, the most familiar is that devised by an Italian physicist, Torricelli.

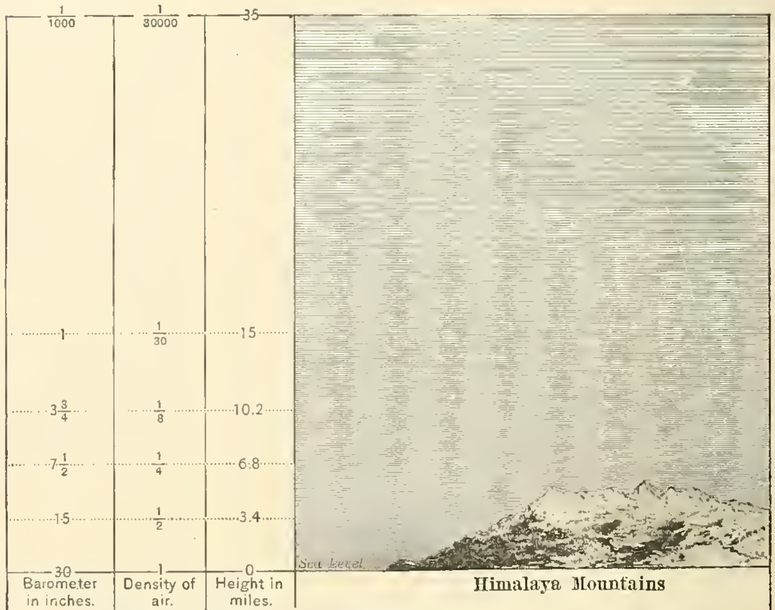


Barometer in its Simplest Form.

A glass tube, three feet long, and closed at one end, is filled with metallic mercury; it is then inverted with its open end in a cistern of the same liquid. The mercury in the tube falls until its level is about thirty inches above that in the cistern. Its weight is balanced by the pressure of the external air upon the exposed liquid.

A column of mercury thirty inches long therefore weighs the same as a column of air of the same diameter extending up to the extreme limit of the atmosphere. Such a column of mercury, if its cross-section be a square inch, weighs 14.7 pounds. At sea-level, therefore, the pressure of the air is in all directions 14.7 pounds on each square inch of surface.

Variation in Atmospheric Pressure.—As we ascend above the lower layers of the atmosphere, the pressure is diminished, the air becoming less dense because the overlying mass is smaller. At a height of 3.4 miles, half of the atmosphere is left below, and the barometer registers only fifteen inches. By calculation it is found that at an elevation of thirty-five miles there is only $\frac{1}{30000}$ of the atmosphere beyond, and the barometric column would be only $\frac{1}{1000}$ inch high. Beyond forty miles the amount remaining would be too small to affect the sun's rays perceptibly in any way, and for practical purposes two hundred miles may be assumed as an extreme limit. (On the pressure of the atmosphere, *see Scott's "Elementary Meteorology," p. 63.*)



DIMINUTION IN DENSITY AND PRESSURE OF AIR WITH INCREASE OF HEIGHT.

Mass of the Atmosphere.—The entire mass of the atmosphere is estimated to be about $\frac{1}{1000000}$ of that of the whole earth. The highest mountains penetrate through nearly three-fourths of this mass, and hence interfere largely with its motion over continents. If the atmosphere were of uniform density, the same as that at sea-level, instead of diminishing with elevation, its height would be about five miles, and the barometer would fall an inch for every 875 feet of ascent. The highest peaks of the Himalayas would pierce entirely through.

CLIMATE.

By Climate is meant the state of the atmosphere in regard to the conditions that make it favorable to human welfare. The most important of these are the temperature of the air, the amount of moisture it contains, and the character of the winds.

Temperature of the Air.—The air receives its temperature partly by direct radiation from the sun, and partly by return from the earth. Most of the heat it derives from the earth is what has been first transmitted through its own substance, absorbed by the soil, and then returned. The amount of heat conducted from the earth's hot interior, through its crust, to the air, is very limited.

Solar Radiation.—What the earth receives from the sun is called *solar energy*. This is radiated in waves so minute that of those which reach the sea-level the longest that have been measured are about $\frac{1}{1200}$ inch, and the shortest $\frac{1}{80000}$ inch in length. Between these limits of wave-length, all the rays of solar energy convey heat; they produce chemical changes, as in the growth of plants; and those whose wave-length is between $\frac{1}{60000}$ and $\frac{1}{40000}$ inch also affect the eye with the sensation of light. Those of longest and shortest wave-length are hence called dark rays.

Of rays which are manifested as light, those of greatest wave-length, besides conveying heat and chemical energy, produce the sensation of red. With decreasing wave-length, the corresponding sensations are orange, yellow, green, blue, and violet. The mixture of all these rays produces the sensation of white.

Absorption of Solar Energy.—No known substance transmits solar energy without absorbing some of it at the same time. Of solids, rock-salt transmits much of the heat as well as light; quartz, much of the chemical energy as well as light; common glass transmits each kind, but with great absorption of both heat and chemical energy. When the sun is in the zenith, the atmosphere absorbs more than one-third of the solar energy that would otherwise reach the sea-level, and far more than this proportion when the sun's rays are oblique. It absorbs the rays of short wave-length to a much greater extent than those of long wave-length.

If all the rays of solar energy were like those of violet light, with a wave-length of $\frac{1}{60000}$ inch, only about 40 per cent. would reach the soil. If all were of dark heat, with a wave-length of $\frac{1}{12000}$ inch, fully 90 per cent. would be transmitted. The quality of the atmosphere by which it seems to select certain rays for transmission and others for absorption is called its *power of selective absorption.*

As we ascend to great heights, not only does the air decrease in density, but, quite independently of this, its power of absorbing solar energy decreases also, and at a rate which varies with the wave-length. The light that enters the eye at the top of a lofty mountain is much richer in the short violet waves; hence the tint of the sky is a mixture of deep blue and violet, and the body of the sun looks bluish. But at sea-level the sky is pale blue, and the sunlight, which we call white, is yellowish. Our atmosphere thus transmits the long waves of solar energy at all elevations, but only at great heights does it transmit any large proportion of the short waves.

Minute particles of matter, floating as dust in the air, impede the rays of solar energy, reflecting and absorbing those of shortest wave-length, and transmitting a larger proportion of those of longer wave-length. The light that reaches the eye, being thus deprived of its usual amount of violet, appears reddish. To this fact is due the redness of the horizon in the direction of the morning or evening sun, especially when the air is charged with vapor. Dust floats in the air even above the highest mountain-tops, but by far most abundantly near the ground.

Effect of Elevation on Temperature.—Since the atmosphere absorbs heat more rapidly in its lower and denser parts, taking this not only directly from the sun but also from the surface on which it rests, it serves as the most important of all accumulators and distributors of heat over the land. At sea-level it absorbs so much heat as at times to check further effective radiation from below, and thus tends to produce uniformity of climate.

At great elevations the absorption is less, the air is cooled also by expansion, and the general temperature is thus lowered. Beyond certain limits of height, even in the torrid zone, the cold is such as to keep the ground perpetually covered with snow. Yet even on this snow, a good absorber, like the human body, when placed in direct sunshine, becomes temporarily heated, so that the rapid changes of temperature are very distressing. On the whole, the temperature of the earth's surface is due chiefly to selective absorption in our atmosphere, and in only small degree to direct solar radiation.

Temperature beyond the Atmosphere.—Our knowledge of the selective absorption of the atmosphere is due very largely to the labors of an American physicist, Professor S. P. Langley. As the result of a long series of experiments, conducted with the utmost skill and care, he estimates that, if the atmosphere were removed from the earth, the temperature of the soil in the tropics under a vertical sun would be reduced far below zero, probably down to −328° Fahr.

The temperature of space beyond our atmosphere is estimated to be −460° F. The average temperature of the earth's surface is about 60° F., or 388° higher than it would be without the selective absorption of the atmosphere. The difference between the warmest and coldest days in New York rarely exceeds 90°, which is hardly more than one-fourth of what the atmosphere secures by its absorption.

Terrestrial Energy Waves.—When the waves of solar energy are absorbed by the air or soil, they are radiated again as longer waves, far exceeding in length most of those received from the sun. From bodies thus but slightly warmed, Professor Langley has measured waves of nearly $\frac{1}{640}$ inch, or almost twice the greatest length of solar waves thus far measured. Air in contact with a portion of ground soon takes the temperature of that ground, through the agency of these terrestrial energy waves, transformed by absorption and subsequent radiation from the earth. An atmosphere thus serves to prevent such sudden and extreme changes of temperature as are continually occurring on the surface of the moon.

Glass readily transmits solar energy, and is nearly opaque to terrestrial energy. Advantage is taken of this in warming greenhouses, where tropical plants are thus made to grow under glass roofs.

The total energy that reaches the outer limit of our atmosphere from the sun is estimated to be sufficient to melt annually an ice-shell 180 feet thick over the entire surface of the earth. The absorptive power of the atmosphere is equivalent to that of more than one-third of this shell. Keeping the earth's surface warm, it is continually radiating the excess of heat back into space at all times, and thus preserving a nearly fixed balance.

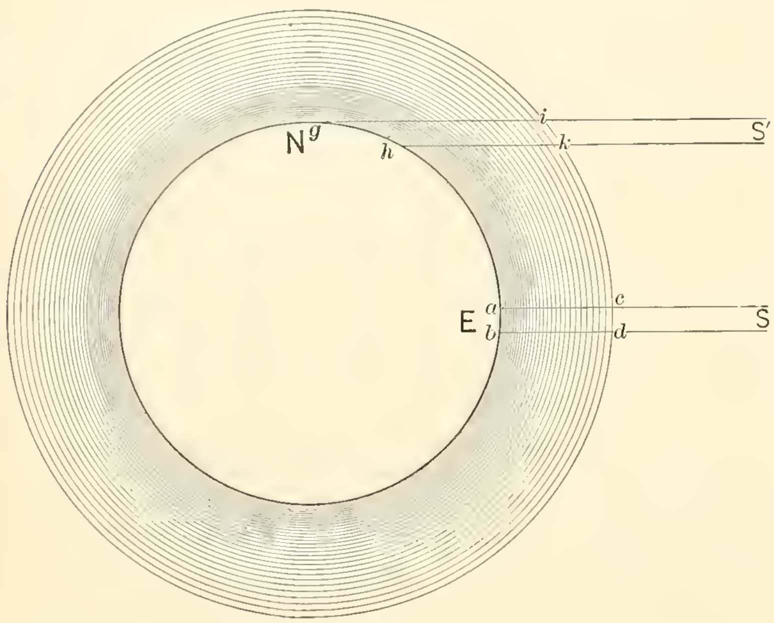
Effect of Aqueous Vapor on Radiation.—The atmosphere always contains a variable amount of vapor, even when no clouds are visible. This is a strong absorbent of solar radiation, of all wave-lengths, and still more of terrestrial radiation. The warmer the air is, the greater is its capacity for carrying invisible vapor, and the greater is its absorbent power for heat. A layer of air thus charged may serve as a screen, and make the atmosphere disagreeably warm. The effect is increased when clouds are present. But when the air is dry and clear, as at night, radiation goes on rapidly and the temperature falls.

Distribution of Aqueous Vapor according to Elevation.—With increase of elevation the air becomes colder, and its power of holding aqueous vapor diminishes. It has been calculated that one-half the quantity of vapor in the air is contained in the lowest 6,000 feet of the atmosphere; that above 20,000 feet the amount is only one-tenth of that at the surface, and that for the atmosphere as a whole the average quantity per cubic foot is only about one-fourth of what it is at sea level.

If the air were perfectly dry, the rate at which the temperature would fall with increase of elevation would be 1° F. for every 180 feet at the Equator, diminishing as we approach the poles, and also as we ascend. But owing to the moisture in the air, the rate is only about 1° F. for every 300 feet near sea-level. It gradually diminishes as we ascend, and approaches the ideal limit of perfect dryness. This fact has been ascertained by observation in balloons and in the ascent of lofty mountains.

In any given latitude, therefore, climate must vary with the influences that affect the absorbent power of the atmosphere for heat. The most important of these influences is elevation. Variation in latitude also produces variation in climate, so that in traveling a few thousand miles away from the equator there is as great lowering of temperature as in ascending vertically a few miles at the equator.

Influence of Latitude.—The warming effect of radiation from the sun upon the ground and the air in contact with it, is greatest in tropical and least in polar regions. This is due to several causes. To explain it, let the shaded ring in the figure represent the earth's atmosphere, densest next to the ground; and let S E and S′ N be equal bundles of rays from the sun, S E reaching the earth at the Equator and S′ N near the North Pole.



I. When the noonday sun is vertically overhead at E, the rays pass through the least thickness of air, *c a*. Nearly two-thirds of the solar energy is therefore transmitted to the surface at *a b*. When the rays fall obliquely, a much longer column of air, *g i*, has to be traversed, less energy can be transmitted to the surface, *g h*, and more is absorbed in the upper regions to be radiated back into space without warming the ground.

II. The effect of a wave of any kind is greatest when it strikes vertically. This is familiarly seen in the action of water-waves. The solar energy waves strike vertically after transmission at *a b*. Those which escape absorption at *g h* strike obliquely, and hence with greatly diminished effect.

III. The area crossed by the line *g h* is greater than that crossed by *a b* in proportion to the difference of latitude; if *g h* be three times *a b*, the corresponding area is three times as great. The same amount of solar energy can therefore have only one-third as much effect, even if there were no loss due to obliquity of direction and increased absorption in the upper layers.

Since the selective absorption is greatest for the short waves, the loss of light in the polar regions is perhaps as conspicuous as the loss of heat. During much of the year, there is nearly continuous twilight.

Variation of Temperature in the same Latitude.—Since the direction of the noonday sun is more nearly vertical in summer than in winter, all the causes just described tend to make summer the season of greatest light and heat. But, in addition, we have longer days and shorter nights in summer. The amount of solar energy received during the long days is in excess of what can be radiated back during the short nights. It becomes stored up in the air and in the ground, so that the second half of the day, as well as that of summer, is warmer than the first.

The warmest part of the day is usually between two and three o'clock in the afternoon, the coldest is in the morning before dawn. The warmest month of the year is July or August, though the sun is most nearly vertical at noon on the 21st of June.

Contrast of Low and High Latitudes.—At the Equator, the days and nights are of equal length throughout the year. Absorption and radiation are therefore nearly balanced. In June and December, the noonday sun is farthest from the zenith; in March and September, it is at or nearest the zenith. The climate is uniformly warm, with little difference in temperature between night and day. There are two summers, and two very mild winters, June and December being winter months. Generally, in low latitudes there is perpetual summer weather, with brief intervals of less fervid warmth.

As the latitude increases, the length of the longest day increases. At New Orleans it is fourteen hours; at New York, fifteen hours; at St. Petersburg, nearly nineteen hours; at Hammerfest, between two and three months. The continued effect of nineteen hours of sunshine, even though the rays are oblique, is to make the afternoons almost tropically warm during a few weeks of the year at St. Petersburg, the short nights affording little opportunity for loss of heat by radiation. But the greater part of the year is cold. Generally, in high latitudes, the extremes of temperature are great, the winters being long and severe, the summers short and uncomfortably warm.

Modifying Influences.—Important as latitude is in determining climate, there are many influences, both local and general, that cause wide climatic differences in the same latitude. Were it not for these, parallels of latitude on the earth's surface might also be called parallels of climate.

Isotherms.—A line connecting a series of places whose mean temperature is the same is called an Isotherm. If this mean temperature is for the whole year, it is called an annual isotherm; if for some particular month, it is named accordingly, such as the July or January isotherm.

The July isotherm of 70° is an irregular line, crossing North America, for the most part north of the United States. Taking then a direction slightly south of east, it arrives at Portugal and bends northeastward, reaching the neighborhood of Lake Baikal, in Siberia, where the mean annual temperature is only 30°. Deflected southward before reaching the Pacific, it passes over more than half of this ocean about the latitude of Japan, then bends down to the Tropic of Cancer before turning northward to cross America.

The January isotherm of 70° passes south of the United States, curves in crossing the Atlantic, traverses northern Africa and the southern part of Asia, and then crosses the Pacific in the neighborhood of the Tropic of Cancer.

An isothermal chart thus enables us to form a general idea of the climate of all regions embraced in it. By comparing the July and January isotherms, the annual range of temperature at each place is approximately learned.

Climatic Realms.—As the earth's surface is divided into geographical zones by definite parallels of latitude, so it may be separated into climatic realms by definite annual isotherms.

The torrid realm is that part on both sides of the Equator included between the annual isotherms of 70°. Its northern limit is almost wholly north of the Tropic of Cancer. Its southern limit crosses and recrosses the Tropic of Capricorn. There is no climatic equator, but within this realm are several areas of special warmth. Thus, over a large part of north Africa, the mean annual temperature is believed to exceed 85°.

The temperate realms are included between the annual isotherms of 70° and 30°, on each side of the Equator. In the northern hemisphere the isotherm of 30° is for the most part south of the Arctic Circle, but crosses this in Greenland and Lapland. In the southern hemisphere its course is entirely over the sea, and is supposed to coincide nearly with a parallel of latitude about 500 miles north of the Antarctic Circle. Within these two realms are the conditions best suited to human comfort and civilization.

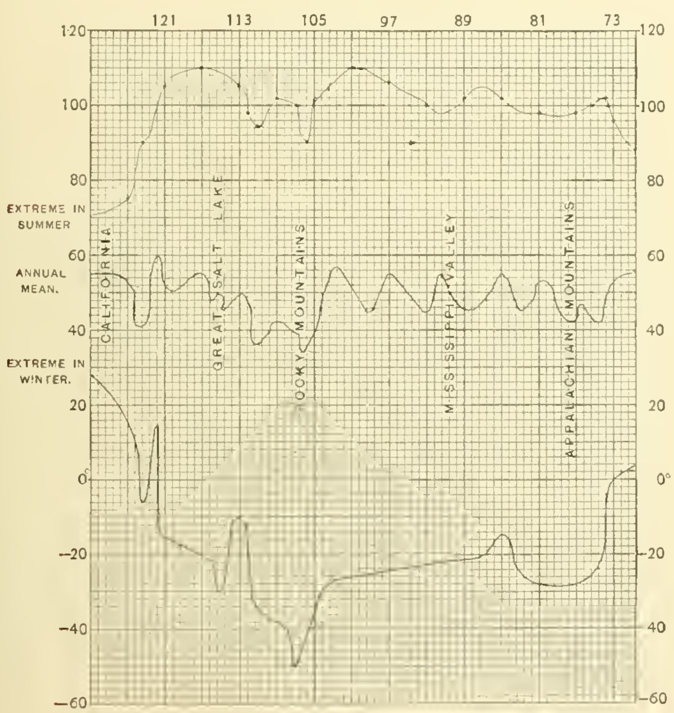
The Arctic realm includes all that northern area whose mean temperature is lower than 30°. The Antarctic realm includes the corresponding southern area.

Within the Arctic realm in Siberia lies Werchojansk, a place where the lowest temperature recorded has been −89°. Yet here the summer heat has several times reached +96°, making an extreme range of 185°. In the American Arctic regions there are places where the mean temperature is as low as −10°, and even in July rises hardly above the melting-point of ice.

The human body is thus shown to be capable of enduring seasonal changes of temperature about as great as the difference between the freezing and boiling points of water.

Influence of Land-Masses.—Since the warmth of the air depends chiefly on that of the surface upon which it rests, the annual range as well as the mean temperature is greatly affected by the nature of the surface medium that absorbs the solar rays. The effect of the sun in producing a high temperature is greatest on dry sand and least on water. To raise the temperature of a pound of sand through one degree requires only a fifth as much heat as to do the same for water. On the surface of such soil near the Cape of Good Hope, a temperature of 159° has been recorded by Herschel. Air in contact with it becomes rapidly heated and exceedingly dry.

Clay, particularly when moist, is warmed far less rapidly than sand; but any land-mass whatever becomes heated and cooled much faster than an equal body of water. Independently of elevation, therefore, the center of a continent becomes warmer during the day and colder at night than its shores. Its air is drier, its winter more severe, and its summer heat more intense.



TEMPERATURE-CURVES FOR THE FORTY-FIRST PARALLEL IN NORTH AMERICA.

These curves have been constructed from data afforded by the temperature maps prepared for the Tenth United States Census by Mr. Henry Gannett.

The influence of a large body of land in thus producing extremes of air-temperature is shown in the accompanying curves, which give the mean and extreme temperatures observed along the 41st parallel of latitude in the United States, extending from Long Island to the northern coast of California. The figures at the top give the longitude from Greenwich, those at the sides the temperature. By following these curves, it will be seen that at the California coast on the 41st parallel the mean temperature is 55°, and the extreme range is only from 71° in summer down to 28° in winter. On going eastward, there is at once a marked increase in range, so that at longitude 115°, passing through the lofty desert west of Great Salt Lake, the range is from 110° in summer down to −30° in winter. The additional effect of elevation is shown at longitude 106° in the Rocky Mountains, where the highest temperature is 90°, the lowest −50°, and the annual mean 34°.

The curve of mean temperature rises and sinks alternately until it reaches the Atlantic, where it marks about the same (55°) as on the Pacific coast.

Effect on Mean Temperature of the Whole Earth.—In the isothermal chart (pp. 66, 67) the heavy lines indicate isotherms due to actual observation; the dotted lines are continuations due to inference only, because of the lack of definite records. On this chart the following general features may be noticed:

1. The isotherms are more irregular in the northern than in the southern hemisphere.

2. The temperature of the earth's surface north of the Equator is apparently higher than it is south of the Equator.

Both of these peculiarities are due to the position of the great continental land-masses. The northern hemisphere includes much more land than the southern. Its mean temperature becomes higher in summer and lower in winter, and it comprises more than half of the torrid climatic realm. On this account the accumulation of heat on land causes the mean temperature of the globe to be about 62.5° in July and only 54.5° in January, although the total heat received from the sun on the two hemispheres is equal. In connection with this result it may be observed that the earth's orbit is not circular but elliptic, and that in January, which is the midsummer month for the southern hemisphere, the earth is 3,000,000 miles nearer to the sun than in July.

Influence of Ocean-Currents and Winds.—Ocean-currents have already been mentioned as the great distributors of temperature.

The Gulf Stream carries in its surface-waters the heat poured into it in tropical regions; it distributes this over the North Atlantic and far into the Arctic Ocean. The isotherms, in crossing the Atlantic, therefore bend toward the northeast. That of 30° passes near the mouth of the St. Lawrence, no farther north than London, and then extends over Greenland and the ocean to the north of Hammerfest, far within the Arctic Circle.

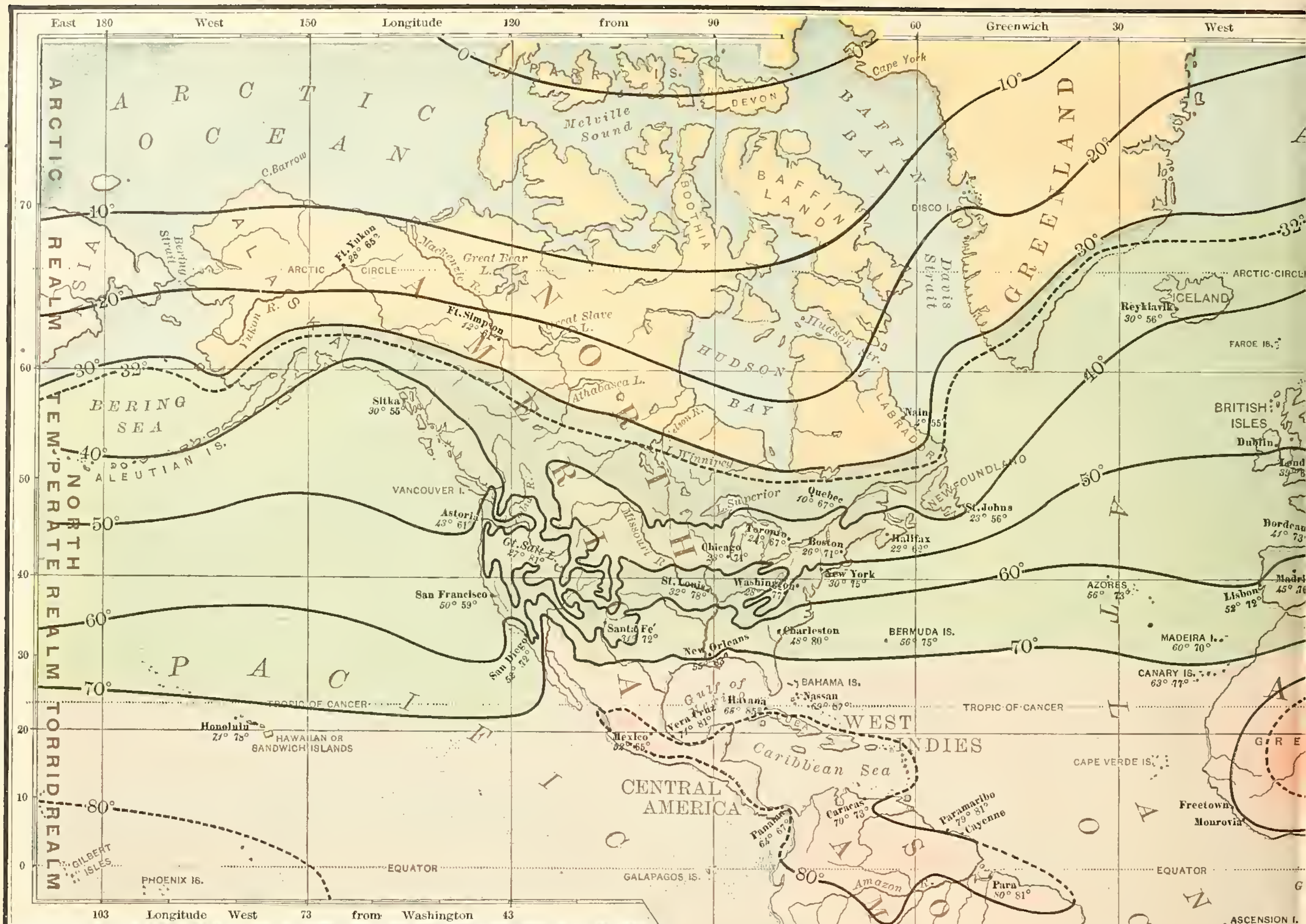
The Japan Current causes the isotherms in the Pacific Ocean to curve toward the north; but, having a much wider sweep than the Gulf Stream, its effects are not so marked. Its waters become moderately cool in the neighborhood of Bering Sea, and in completing their circuit they cause the isotherms to bend slightly southward near the western coast of North America. The temperature is still warm enough to give this coast a uniformly mild climate. It is densely wooded, and even bright with verdure.

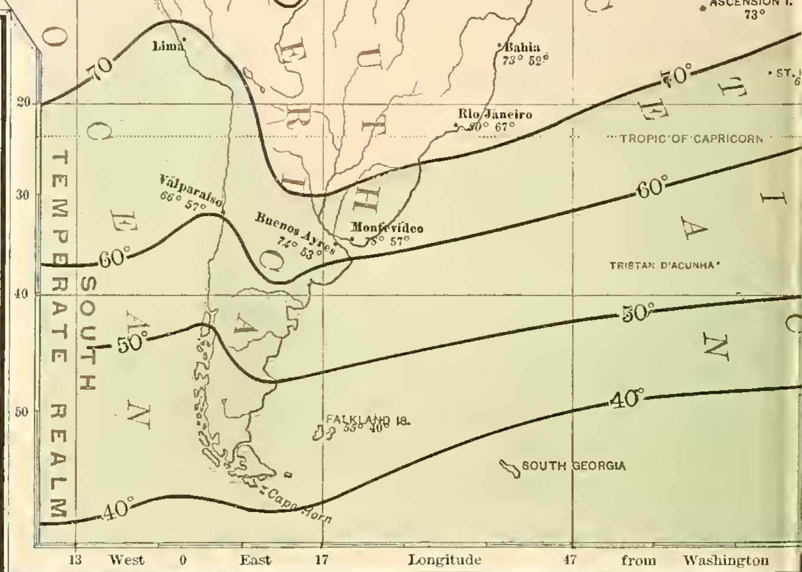
The Chief Conditions in determining the climate of a place may be briefly summed up as follows:

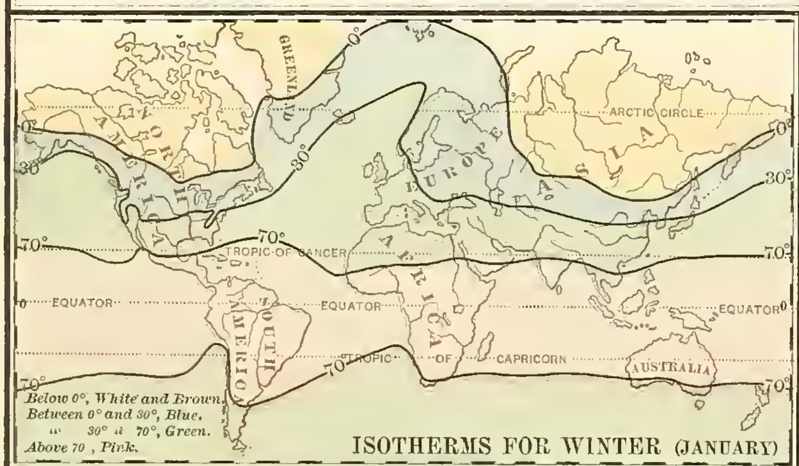
I. If close to the sea, its climate will be uniform, and warm or cool according to the temperature of the nearest ocean-currents and direction of the prevailing winds. This may be called *oceanic climate*. The Bermudas are perpetually warm, Chile is perpetually cool.

II. If far from the sea, its climate will be dry, and subject to extremes of heat and cold. This may be called *continental climate*. Moscow, in Russia, and Santa Fé, in New Mexico, possess such a climate.

III. High elevation above sea-level and great distance from the Equator alike tend to produce extremes of temperature, with preponderance of cold or warm weather according to the latitude of the place. The Sahara Desert, with a mean elevation of about 1,500 feet, is intensely dry and warm by day, and uncomfortably cold at night; as is also Werchojansk, in Siberia, with an annual range exceeding 150° F.





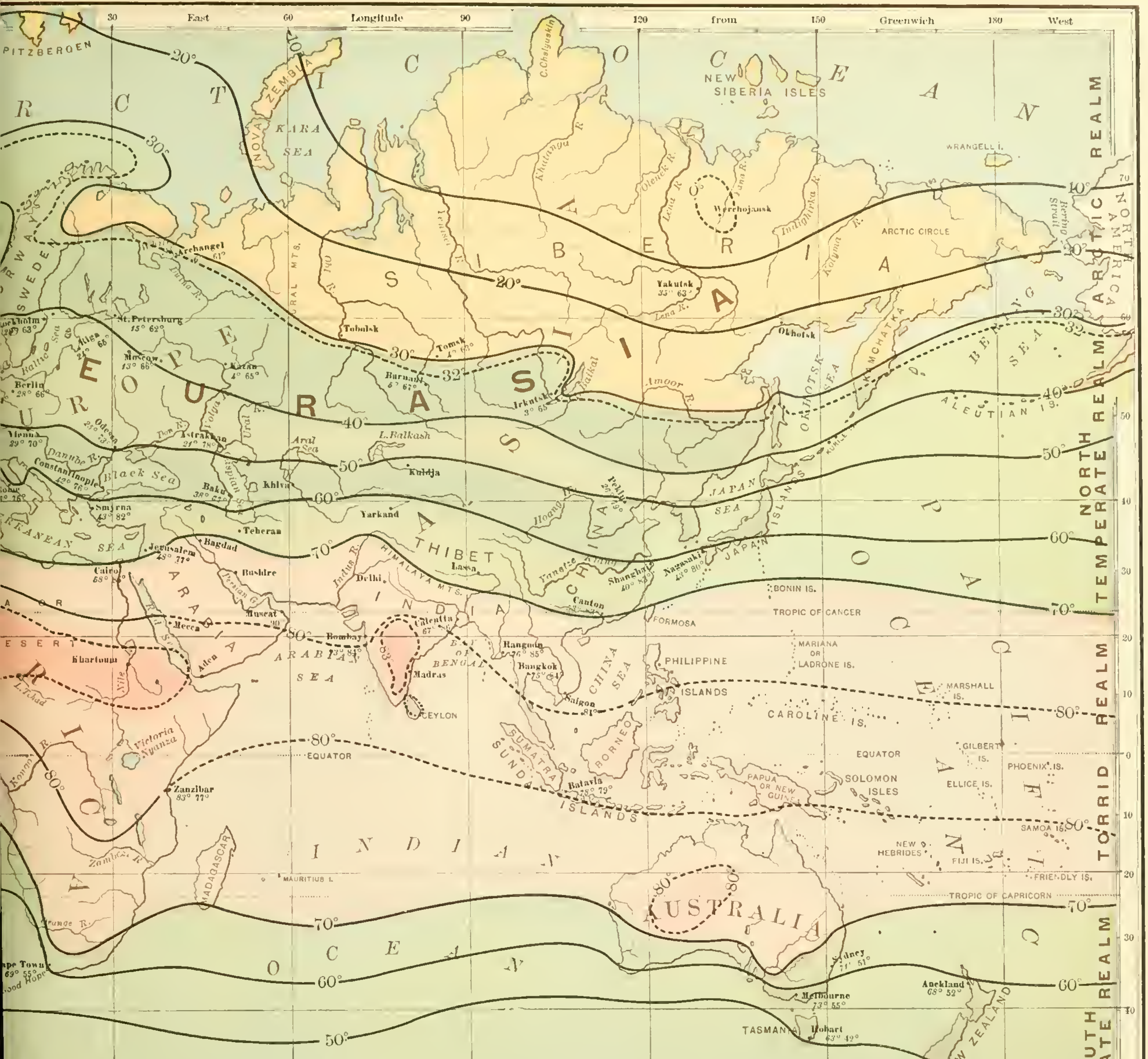


Below 0°, White and Brown.
Between 0° and 30°, Blue.
" 30° " 70°, Green.
Above 70, Pink.

ISOTHERMS FOR WINTER (JANUARY)

ISOTHERMS FOR SUMMER (JULY)

Questions on the Isothermal Map.—In what part of the worl the north-temperate realm widest? Why is this so? Where is it narrowest? W so? Trace the annual isotherm of 70° south around the world. What causes sharp curve about the western part of South America? Why should it bend southw over the same continent? Why should it bend northward near the African coa What can you assign as a cause for its irregularities about Australia? Compare annual isotherms of 40°, north and south, tracing each around the world. Why is t of 40° south so nearly regular? Does it cross any land? Can you discover wha the relation between the bending of the annual isotherm of 40° along the Nor coast and the nearest waters? The mountain-ranges? Do you note any connec with the prevailing winds? (*Consult Map of Wind-Zones, pp. 72, 73.*)



ISOTHERMAL LINES

HOWING THE MEAN ANNUAL TEMPERATURE OF THE AIR

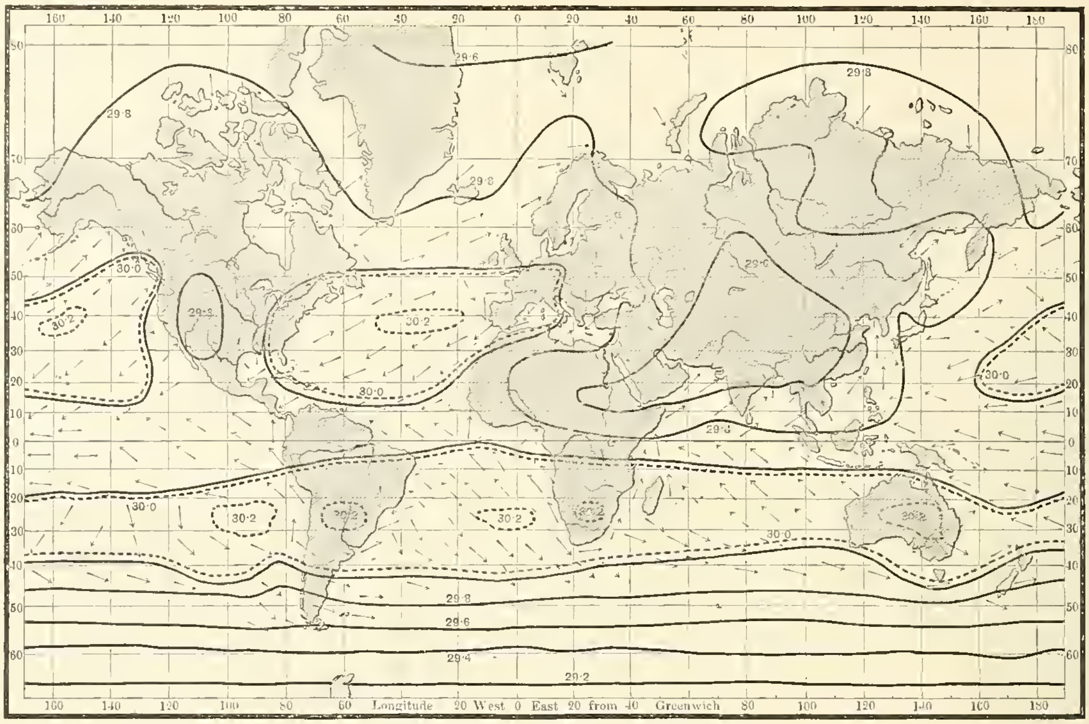
IN DEGREES OF FAHRENHEIT'S SCALE.

NOTE—*The heavy figures on the Lines indicate the degrees along the Lines. The number in Italic figures with name of a city gives its Mean Temperature for January; the number in Roman figures gives its Mean Tempera- for July.*

Vhat do you think can be the cause of the bend of the isotherm of 30° around nd? Compare the mean annual temperature of Lake Baikal with that of Dublin. are their latitudes. Trace the annual isotherm of 70° north around the world. are its most remarkable bends? Can you account for these? Trace the July rm of 70° north around the world. Why does it extend so much farther north d than over the sea? Trace the January isotherm of 70° north around the The same, for the January isotherm of 30° north. Where does this last pass that are overlapped in summer by that of 70°? What kind of climate must f these places have? Trace the July isotherm of 70° south around the world. same for the January isotherm of 70° south. In what month does this show lia to be warmest? Is any part of Australia thus shown to be perpetually torrid?

Name those parts of the Eastern Hemisphere whose mean annual temperature exceeds 85°; 83°; 80°. Mention the parts of America whose mean annual temperature exceeds 80°; those portions of the world whose January temperature is below 0°. What parts of these regions have a summer temperature exceeding 70°? What places have a mean annual temperature below 0°? Give the winter and summer temperatures of New Orleans, Santa Fé, New York, Chicago, San Francisco, Quebec, Reykiavik, Moscow, Para, Honolulu, St. Johns, Bergen. Why the difference between St. Johns and Reykiavik? Moscow and Bergen? Irkutsk and Berlin? Honolulu and Mexico? Yakutsk and Reykiavik? Which of the last two is farther north? In what climatic realm is New York? Boston? Charleston? Havana? London? Paris? Berlin? Rome? Calcutta? Melbourne? Rio Janeiro? Cape Town? Stockholm? Reykiavik? Khartoum?

IV. The range of temperature is less in the southern than in the northern hemisphere, which contains larger bodies of land extending into the polar regions. In the southern parts of South America, Africa, and Australia, the difference between the mean temperatures of July and January does not much exceed 20°. Over a large part of North America and Eurasia, it exceeds 60°.



JULY ISOBARS AND PREVAILING WINDS.

The dotted lines indicate pressures above 30 inches. The heavy lines indicate pressures below 30 inches.

THE WINDS.

Currents of the Atmospheric Ocean.—We have already seen (*p. 59*) that in any fluid surrounding the earth, currents are necessarily produced if the Equator be warmer than the poles. The air is a fluid much lighter than water and more easily set in motion. The currents in it are called Winds.

In the aqueous ocean we ordinarily perceive only those currents which flow at the top; in the atmospheric ocean, those which circulate at the bottom.

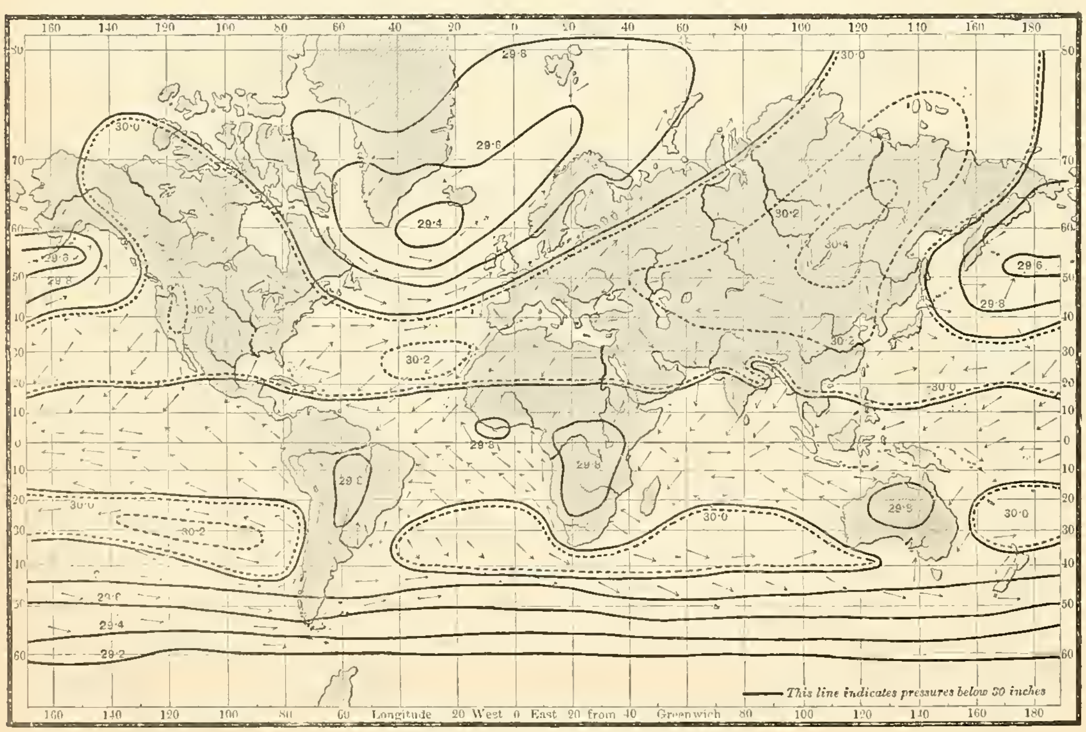
Winds are named according to the direction *from* which they come. An east or easterly wind blows from east to west.

Cause of Wind.—When air is heated by contact with warm earth or warm water, its density is decreased by expansion. The lower layers in expanding tend to lift up those which rest upon them, and produce an outflow in all directions at the top. Pressure being thus diminished, the lighter warm air is pushed upward by the inflow of the surrounding denser air at the surface.

The pressure of the air being measured by the height of the barometer (*compare p. 62*), it follows that, at the surface of the earth, *wind must generally blow from a region where the barometer is high toward a region where the barometer is low.*

Isobars.—Aside from local variation of pressure, the height of the barometer is influenced by variation of gravity, whose standard value is that at latitude 45°; by the temperature of the instrument; and by elevation above sea-level. Observations are therefore corrected so that all records may be compared according to a single standard. The results are called *reduced observations.*

Isobars are lines connecting places where the reduced height of the barometer is the same at the same time.



JANUARY ISOBARS AND PREVAILING WINDS.

The dotted lines indicate pressures above 30 inches. The heavy lines indicate pressures below 30 inches.

Thus, in the opposite map, the isobar of 30.4 inches is a closed curve over Asia, within which is an area of high pressure. Wind flows at the surface in all directions away *from* this. The isobar of 29.4 inches is a closed curve over the North Atlantic Ocean, within which is an area of low pressure. Wind flows at the surface in all directions *toward* this.

General Motions of the Atmosphere.—If the earth were entirely covered with water, uniformly heated at the Equator, and cooled at the poles, there would be a continual uprising of warm and moist air in the region of greatest heat, which would also become a region of low density. On both sides of this warm belt, there would be in the upper atmosphere an outflow toward the poles, and next the surface an inflow from the poles.

If the earth were not rotating, the direction of the upper and lower currents thus produced would be due north and south. Where the motion of the air is upward, no breeze would be felt.

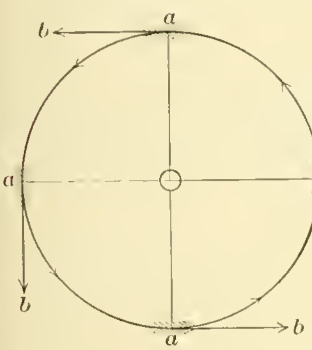
But since the earth rotates, air-currents as well as ocean-currents are turned away from their first direction (*see p. 59*). The eastward velocity of rotation at the Equator is over one thousand miles an hour, and diminishes with approach toward the poles. Currents of air, flowing over the surface from the slow-moving middle latitudes to the swift-moving equatorial zone can not at once assume the increased velocity of this region.

Over a belt north of the Equator, the wind must hence blow from the northeast; south of it, from the southeast; on both sides, becoming nearly east when close to the Equator.

In like manner, the outflowing upper currents, passing to the slow-moving middle latitudes, can not at once give up their eastward velocity. Cooled by their ascent, they gradually sink until they begin to sweep over the surface just beyond the tropics, as winds from the southwest in the northern hemisphere, and from the northwest in the southern.

Thus, *whatever be the latitude, a person traveling with the wind either from north or south would be gradually turning toward his right in the northern and toward his left in the southern hemisphere.*

Influence of Centrifugal Force on the Atmosphere.—Let a body, held by a string, *o a*, be swung around once a second on an axis, *o*. If released at *a*, it flies off in the direction *a b*. The tendency to fly off is called *centrifugal force*. If the string be lengthened while the body is still revolving once a second, the force is increased. If the body be swung faster, the force is additionally increased. Hence, on a rotating sphere, centrifugal force is greatest at the Equator. If the rate of rotation be decreased, a body on its surface tends to move *from* the Equator; if increased, *toward* the Equator.



Since the earth rotates rapidly *toward* the east while the direction of the wind near the Equator is *from* the east, the centrifugal force acting on the air is slightly checked. The air, therefore, tends to flow away *from* the Equator toward the middle latitudes where the distance from the earth's axis is *less*.

In like manner, since the earth rotates toward the east, and the direction of the wind in middle latitudes is also toward the northeast in the northern hemisphere and toward the southeast in the southern hemisphere, the centrifugal force acting on the air is slightly increased. The air, therefore, tends to flow away *from* the middle latitudes *toward* the Equator where the distance from the earth's axis is *greater*.

Thus, *whatever be the latitude, a person traveling with the wind either from east or west would be gradually turning toward his right in the northern and toward his left in the southern hemisphere.*

Ferrel's Law.—Taking all these motions into consideration, we may now state the law generally, that "*in whatever direction a body moves on the surface of the earth, there is a force arising from the earth's rotation which deflects it to the right in the northern hemisphere but toward the left in the southern.*"

This law was first applied to the atmosphere by Professor William Ferrel, and published by him in June, 1859. It applies to all bodies moving on the earth, whether solid or fluid.

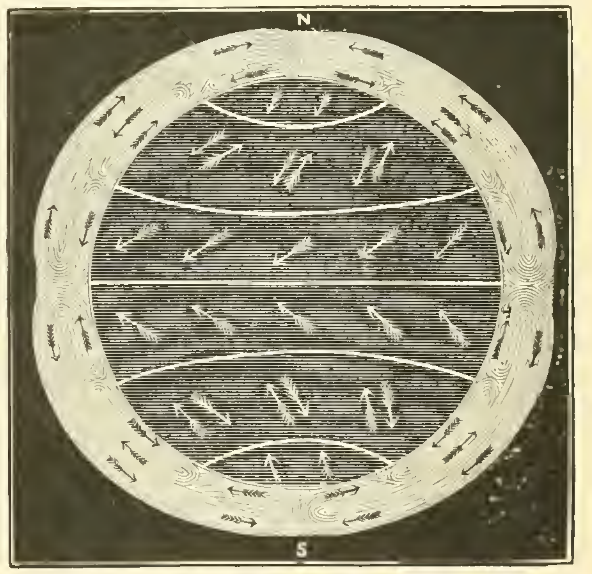
Exactly at the Equator, where the velocity of rotation is greatest, there can be no deflecting force. This begins to be manifested on either side of the Equator, and becomes greater as we move to higher latitudes.

Since by Ferrel's Law the air tends to move away from the Equator and also from the middle latitudes, there must be in each hemisphere a belt where it is piled up and thus made denser. This belt is where the eastward and westward tendencies due to the earth's rotation just balance each other. Referring to the isobars on page 68, we shall see that the mean pressure in January over the Atlantic Ocean is 29.8 inches near the Equator, 30.2 inches near the Tropic of Cancer, and 29.4 inches about latitude 60° north. Near the Tropic of Capricorn it is again over thirty inches, and it diminishes toward the Antarctic Ocean.

Again, since centrifugal force tends to make the air recede from the poles toward the tropics, the atmospheric ocean should be thinnest at the polar regions, and these should be regions of low pressure. This fact is shown by the isobars on page 68. A cold wind blows outward from the polar regions, due to centrifugal force, and not as elsewhere to excess of pressure. New supplies of air are furnished continually at the poles by upper currents from equatorial regions.

Illustration of Ferrel's Law.—All the chief constant motions of the atmosphere are shown in the figure below. Surface-currents flow from the tropics toward the Equator and then rise, leaving below an equatorial zone of calms and *low* pressure, *toward* which wind constantly blows obliquely. Of the outflowing upper current, part sinks to the surface near each tropic, and then divides, some going back to the Equator and some sweeping onward. Here, then, are the tropical zones of calms and *high* pressure, *from* which the wind blows toward both Equator and pole.

The rest of the upper current continues toward the pole, where it sinks and then flows outward as a cold surface-current. Here, therefore, are the polar zones of calms and *low* pressure, *from* which the wind blows outward in all directions. In the neighborhood of latitude 60° this cold current meets the warmer surface-current from the tropics, producing an area of variable winds, according as the one or the other predominates. Part of it is forced upward, and flows as an intermediate cold current toward the tropics. All these currents are deflected according to Ferrel's Law.



Illustrating Ferrel's Law.

Questions.—Of what does meteorology treat? State the composition of air. To what height does the air extend? What pressure does it exert? Explain the principle of the barometer; the diminution in the density and pressure of the air with increase of height.

Define climate. What are the principal elements of climate? Explain solar energy; the difference between heat-producing and light-producing rays of solar energy. What proportion of light-rays are absorbed by the atmosphere at different times of day? What can you say of the absorption of solar energy by different substances? Why is the sky blue? On what does the temperature of a place depend? How does elevation affect temperature? How, the air's power of holding moisture?

Discuss the influence of latitude on climate, and the variation of temperature in the same latitude. What is the warmest part of the day? the coldest? Why? What are isothermal lines? Into how many climatic realms may the earth's surface be divided by isothermal lines? Explain the influence of land-masses in modifying air-temperature; the general influence of ocean-currents and winds. In which hemisphere are the isothermal lines more irregular? Specify the conditions determining the climate of a place.

How are winds produced? Explain the circulation of the atmosphere. What are isobars? Explain the influence of centrifugal force on the atmosphere. State and illustrate Ferrel's Law.

CONSTANT AND PERIODICAL WINDS.

Wind-Zones.—The earth's atmosphere may be divided into wind-zones. Their limits are not fixed, for several reasons:

1. The heating of equatorial regions and the cooling of polar regions is not uniform, because of the great land-masses on which changes of temperature occur more rapidly than on the ocean.

2. Mountain-ranges interrupt the surface-winds and produce irregularities. It is only on the sea, where there is a free sweep, that constant winds are possible.

3. The belt of greatest heat changes its position with the seasons, moving farthest north in August and farthest south in February or March. The position of the wind-zones varies accordingly.

The Calms of the Equatorial Zone occur in a belt mostly north of the Equator. On the Pacific it covers the Equator in January, and is entirely north of it in July. (*Compare the maps on pp. 66, 72.*) The breadth varies from 1° to 6° in latitude, being greatest in the eastern part of each ocean, near the great continents which disturb the regularity of the winds.

In this zone the calms are not constant, nor do they occur in all parts of it, but only in isolated regions.

The Trade-Winds are constant winds on either side of the equatorial zone. Each belt occupies from 12° to 25° of latitude, beginning some distance west of the interrupting continent. The wind starts as a gentle breeze from the northeast or southeast, increasing in strength and becoming almost a due east wind along the equatorial margin of the belt. In the Indian Ocean, it is constant throughout the year only in the southern belt, being interrupted on the north by Asia.

The constancy of the trade-winds has been known since the time of Magellan. Their name was given on account of their importance in facilitating commerce across the oceans.

The Calm-Belts of the North and South Temperate Zones are narrow and not well defined. They are disturbed by storms and rapid alternations of wind, due to encroachment from the neighboring wind-zones.

The Anti-Trade Winds are limited by the tropical calm-belts and extend toward the poles into the region of Arctic and variable winds. The conflict of the polar winds causes variability over the greater part of this wind-zone, but the prevailing winds, especially over the oceans, are such as might be expected according to Ferrel's Law. In the southern portions of the Pacific and Indian Oceans, between latitudes 40° and 50°, they blow so steadily and strongly as to receive the name of "Roaring Forties." Encroaching upon the Antarctic Ocean drift, they cause this great current of water to flow permanently northeastward at the surface. (*See Jordan's "The Winds and their Story of the World," pp. 38, 48.*)

The Polar Winds.—Along the Arctic shores of North America and Asia, these winds blow quite constantly over the land, during most of the year, as dry and piercing cold blasts from the northeast. The Antarctic polar winds, so far as known, blow from the southeast.

It should be noted that, although the pole is a region of low pressure, this is not due to any special lack of density in the air at the surface, but to deficiency in the height of the atmosphere. The colder and drier the air is, the greater is its density. When the cold polar wind penetrates southward, it produces an immediate rise of the barometer by flowing under the lighter warm air, lifting this up, and adding its own weight to that of the elevated portion until the latter can flow away.

Wind-Zones on Land.—In certain parts of the torrid zone, where wide areas are but little interrupted by mountain-ranges, the trade-winds are perceptible on the land as well as on the sea. This is true of the valley of the Amazon, which is continually swept by moist winds from the east, bringing abundant rains that feed the great rivers of South America. Over the Sahara Desert in Africa, winds of withering dryness and warmth blow with much steadiness from the east and northeast.

Irregularities in Wind-Zones.—In the northern hemisphere, great modifications are produced by ocean-currents as well as land-masses. On the map of January isobars, it will be noticed that the region of low pressure on the Atlantic and Pacific Oceans extends down to latitude 40°, while that of high pressure in America and Asia reaches into the Arctic regions. The Gulf Stream and the Japan Current carry warmth into the zone of anti-trades, rarefying the atmosphere even more than would be due to the general circulation of air. The interior regions of North America and Asia become exceedingly cold by radiation in winter. The atmosphere has a greater density than would be due to general circulation. *In winter, therefore, the general tendency is for the wind to blow from the land to the sea.*

On the map of July isobars, the Atlantic and Pacific areas of low pressure are shown to have retreated northward, and the continental masses, being much heated, to have become covered with rarefied air. *In summer, therefore, the general tendency is for the wind to blow from the sea to the land.*

In the southern hemisphere the same truth prevails, but is not so strikingly shown, on account of the smaller size of the bodies of land.

The Variable Winds.—The alternation due to conflict between the anti-trades and polar winds is thus seen to be controlled largely by the seasons.

In the northern hemisphere, during the summer, the southwest anti-trades sweep over land and sea with moderate constancy almost to the Arctic regions. They bring warmth and moisture with them, but are modified locally by the relative position of masses of land and water. "Warm waves" in summer usually come from the southwest in this hemisphere.

In winter, the body of cold air in the Arctic regions grows larger, and the polar winds, increasing in strength, sweep farther south. In North America, they reach across the low plains around Hudson Bay, and are spread over the region of the Great Lakes. In the United States "cold waves" generally come from the northwest, and are followed by clear, dry weather. In Europe and Asia, they come from the northeast.

The transition from one prevailing wind to another in any place is usually accompanied with a rain-storm. When the center of such a storm in winter passes over the United States, cold air from the northwest is drawn in and cold weather follows, lasting often a number of days.

Periodical Winds.—In addition to the constant and variable winds already discussed, there are some which alternate with much regularity, reversing their direction each day or each year.

Land and Sea Breezes.—Ordinarily on the sea-shore, but especially in tropical countries during summer, whenever the weather is clear and bright, a morning breeze sets in toward the land, and subsides near sunset. This is called the sea-breeze. A little before midnight, an opposite breeze springs up and continues until sunrise. This is called the land-breeze. The interval between the two is often nearly or quite calm.

Water becomes changed in temperature very slowly *(see p. 42)*, while the surface of the ground is heated or cooled rapidly. On this account, and also in consequence of evaporation and the vertical circulation due to wind and waves, the surface of the sea is kept cooler by day than that of the land; but at night, the land by its rapid radiation becomes cooler than the sea. When the air in contact with the warm ground is heated, it expands and lifts the upper layers, so that these slide off toward the cooler sea, producing an increase of pressure at first some distance from the land. A breeze spreads along the surface; and at the same time, over the land, the removal of the upper layers causes a decrease of pressure. The sea-breeze starts in the offing, so as to be felt at sea before it reaches the land. Arriving during the forenoon, it is strongest about three o'clock P. M. *(See Blanford's "Indian Meteorologists' Vade Mecum," part ii., § 78.)*

During the night, the air in contact with the land is rapidly cooled and condensed. That from the upper layers over the sea flows in above, producing an excess of pressure, so that a breeze starts on the land and is forced out to sea. It is strongest during the latter part of the night. *(Consult Scott's "Elementary Meteorology," p. 286.)*

A similar explanation applies to the breeze that in warm countries flows from the valley or plain up the mountain-slope during the day, reaching its greatest strength in the afternoon, and reversing its direction during the night. The mountains grow warm by day and become cool at night faster than the valleys and low plains. Hence their relation to the plains is similar to that of a body of land to the sea. But the plain also becomes slowly warmed during the forenoon, causing the upper layers of air to flow off toward the cooler mountains, carrying moisture which is condensed into clouds. These are usually most abundant around mountain-tops during the latter part of the day. At night, the conditions are reversed, causing the peaks to be most free from clouds in the early morning.

The Monsoons.—In the tropical regions of the Eastern continent, where the sun's heat becomes accumulated on large land-masses, the sea-breeze prevails throughout the summer and the land-breeze throughout the winter, each blowing with much strength and constancy. They are called Monsoons (*seasons*), and are strong enough in the northern part of the Indian Ocean to modify the trade-winds, or even to overpower them. Over the area between India and Africa the summer monsoon blows from the southwest, the winter monsoon from the northeast.

The trade-wind belts, as has been already shown, vary in position with the season of the year. In the northern summer they reach farthest north, but require an open sea for their existence. The northeast trades, therefore, do not blow to any great extent in summer over the Asiatic and African Continents, but the southeast trade-belt extends even to the north of the Equator. The heating of Asia south of the Himalayas produces so continuous an upward current of warm air over the land that the southeast trades are deflected toward the north and east, causing an uninterrupted sea-breeze mainly from the southwest, which is laden with moisture and brings copious rains.

In the northern winter the trade-belts are shifted southward; the northeast trades set in, and are intensified along the coast of Africa by the heating of this continent. Crossing the Equator, they become deflected so as to produce the northwest monsoons on the coast of Australia.

The time of the "breaking up of the monsoons," just after the equinoxes, is marked by frightful tempests.

Monsoon regions occur also in tropical America, but the winds are not comparable to those of the Indian Ocean.

Local Winds.—Local names are given to winds that blow with more or less regularity at certain seasons of the year. Such are the Sirocco, from the Sahara to Sicily; the Khamsin and the Harmattan in Africa, all hot desert winds; the Mistral, the Bora, the Purga, cold winds. The "Northers" of Texas sweep in winter from the Rocky Mountain region sometimes entirely across the Gulf of Mexico. The general explanation already given applies to the local conditions that occasion these winds.

STORMS.

Definition.—Aside from the general circulation of the atmosphere, there are disturbances in which the air pursues a more or less spiral or whirling course for a limited time. Rain or snow usually falls, and when the commotion is violent it is accompanied with lightning and thunder. The general name of Cyclone is applied to all such whirling storms.

Classification of Storms.—Storms may be classified according to (1) their prominent *features*, as rain-, hail-, snow-, dust-, wind-, or thunder-storms; (2) the *direction* of the principal winds, as northeasters, southeasters, etc.; (3) the *strength* of the wind, as gales, hurricanes, tornadoes, etc.

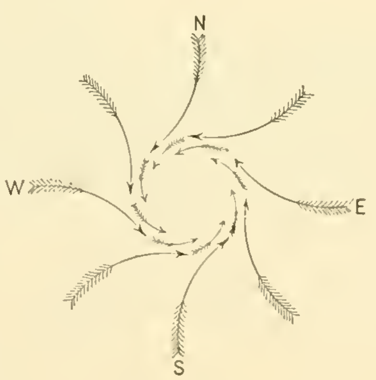
Local names are also applied, such as the tornado in the United States; the hurricane, an extensive whirlwind of the Atlantic Ocean; the typhoon of the Indian and Pacific Oceans.

The term cyclone should not be restricted to the tornado, as is too frequently done in the United States.

Cause of Storms.—We have seen how the influence of the summer sun on the land or water may cause the lower layer of air to expand and lift the upper layer like a great gaseous sheet. The tendency is for the lifted gas to spread uniformly outward in all directions, thus causing the heated area to become one of low pressure and the surrounding area to have its pressure increased.

If for any reason, such as the ascent of air from a limited area warmer than the rest, a local chimney can be forced through the upper stratum, an up-rush is established by which warm and moist air is raised and cooled by expansion. The vapor it contains becomes condensed, thus liberating as heat a large amount of energy which had previously become stored up in the process of evaporation. This in turn still further rarefies the ascending current, so that the draught is strengthened; warm vapor-laden air flows in from all sides at the bottom to supply the partial vacuum, and to increase it by adding new volumes of light vapor to be condensed into clouds. These spread outward in the upper regions, and the central area becomes quickly one of low pressure and rain. It is the starting-point of a storm.

Spiral Motion.—If the storm-center be in the northern hemisphere, the lower air-currents, flowing in at first gently from a distance on all sides, must be deviated toward the right according to Ferrel's Law. As they approach the center they increase in violence, and the storm area becomes better defined. In consequence of deviation, currents which would otherwise meet at the center tend to rush past one another, and a whirling motion is thus produced in a direction opposite to that of the hands of a watch. In the southern hemisphere, the deviation is toward the left, and the whirling motion is in the same direction as that of the hands of a watch.



As the circling currents are drawn still nearer to the center, the motion becomes spiral, as shown in the accompanying diagram, and that on p. 75, the deviation according to Ferrel's Law being now more than overcome by suction into the great vortex. Motion around any center develops centrifugal force, which tends to rarefy the central area still more. Within this area the barometer indicates very low pressure, and little or no wind is felt.

The central area of calm may be but a few yards in diameter, as in the tornado, or fifty miles or more, as in hurricanes and typhoons. The

In studying this map, or comparing it with the text, the student should bear in mind the following important considerations:—

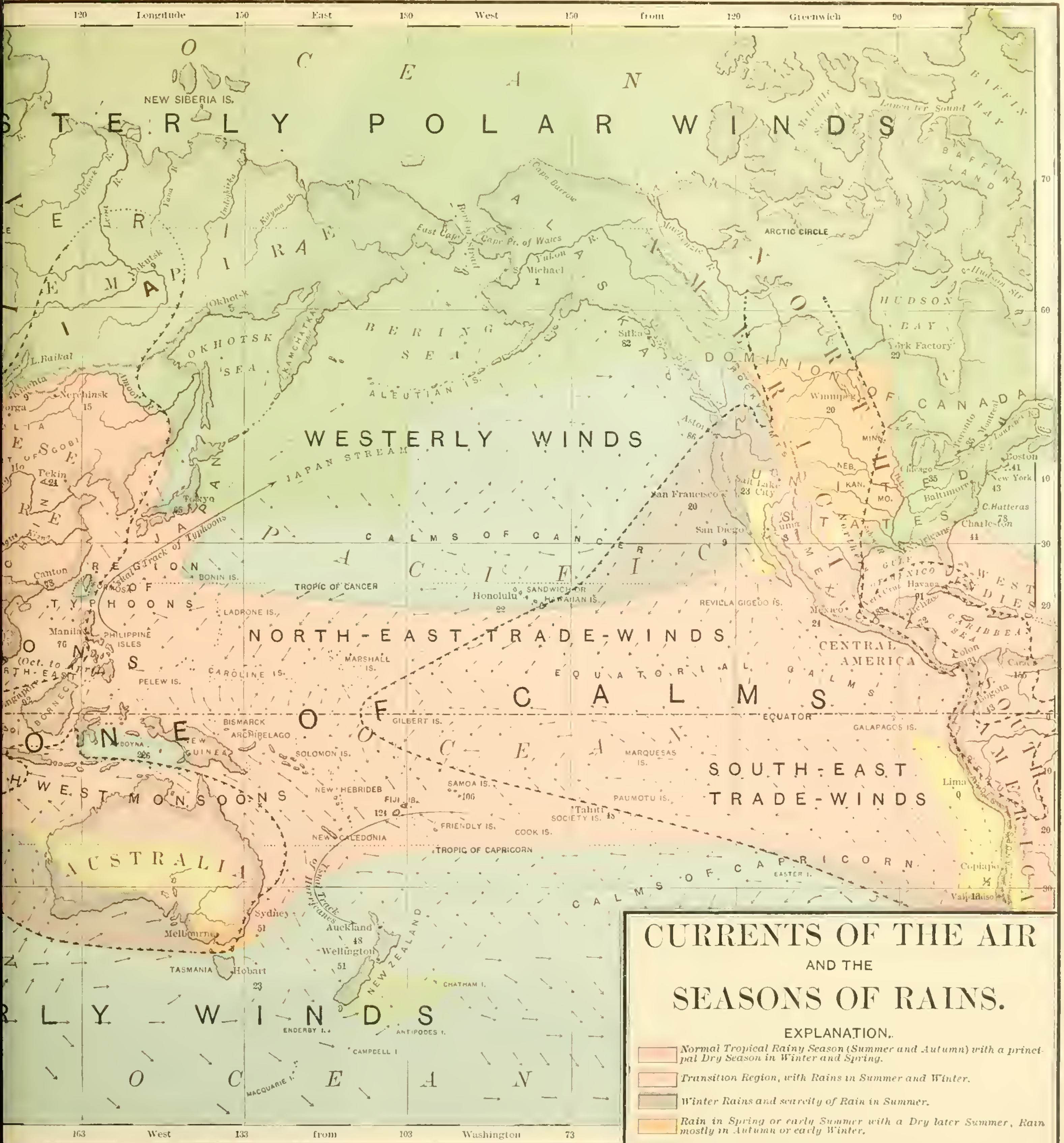
I. There are in reality no sharp lines of demarkation between rain areas like those between the different colors on the map. Each area grades insensibly into those which bound it.

II. The rain-zones mentioned in the text can not be properly represented on a map, because their position is variable according to the season of the year.

III. The arrows represent the prevailing direction of the winds, but these are also subject to much variation, due to local or temporary causes.

Questions on the Map of Wind and Rain Zones.—In what regions are prevailing westerly winds? Are these winds due west? When are they from the northwest? When from the southwest? When alternately from southwest and northeast? Trace the usual track of hurricanes over the North Atlantic Ocean. Over the Indian Ocean. Over the North Pacific. Over the South Pacific. Where do the following local winds occur, and what is the character of each: the Harmattan? the Khamsin? the Solano? the Föhn? the Mistral? the Bora? the Simoom? Where are the Horse Latitudes? The Doldrums? Where do you find calms indicated on the Atlantic Ocean? The Indian Ocean? The Pacific?

Where do you find the tumn, with the principal dr the regions of winter rains, you discover any connection places and the prevalence of the Atlantic from New Yo helped or obstructed by the returning from England to and winter? In what season perience most rain? What i to rain in Florida? Between



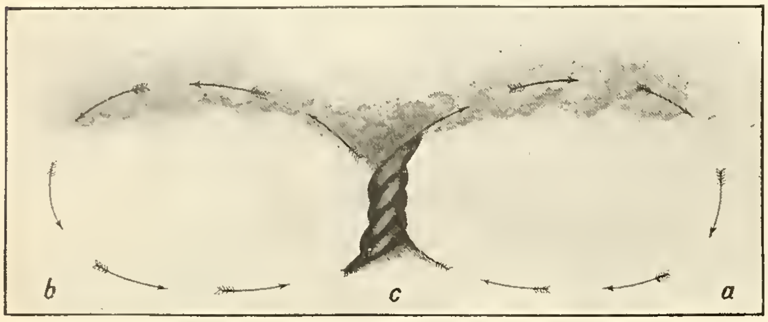
to be in summer and an- winter and spring? Trace of rain in summer. Can occurrence of rain at these trade winds? In crossing l, would a steamship be nds? How would it be in this true in both summer veler on such a voyage ex- r of the seasons in respect Cape Hatteras? Between

Cape Hatteras and Newfoundland? On the Great Plains west of the Mississippi River? In Mexico, Central America, and most of South America? Along the coast of Peru? The southern half of Chile? Why this contrast between Peru and Chile? What is the character of the seasons in respect to rain between Hudson Bay and Alaska? In most of Siberia? In most of Europe? In Canada and the northern part of the United States? Where are the Khasia Hills? What do you associate with them? Does this occur in summer or in winter? Where is the region of typhoons? What regions are nearly rainless? Are there any extensive rainless regions on the ocean? What is the mean annual rainfall at Pernambuco?

wind blows spirally around it, with the greatest violence at its edges. The ascending column, twisting around its upright axis, becomes spread out spirally in the upper regions, so that around the cyclone the pressure of the air is a little greater than average, while at the center it is far less than average.

On entering a cyclone area, therefore, the barometer first rises slightly at the outer margin (*a* and *b*, figure) and then falls rapidly, reaching its lowest limit at the middle of the central area (*c*) under the ascending vortex.

Motion of the kind just described is called *gyratory motion.*



GYRATORY MOTION.

This cut shows the upward and spiral course of the vapor-particles. In a great cyclone there is no such sharp outline or rope-like appearance; and probably no one particle makes a complete circuit, since the diameter of the column greatly exceeds its height.

In the hurricane of Guadeloupe, September 6, 1865, the barometer fell from 29.64 inches to 27.95 inches within seventy minutes. A fall of two inches during the course of a cyclone is not uncommon. (*See Buchan's "Handy Book," p. 266.*)

The wind blows at a rate too high to be measured, but certainly nearly or quite 100 miles an hour. It prostrates trees and houses, and raises waves on the sea that overwhelm the largest ships. At the center there is sometimes a warm area with clear sky, but around it the sky is covered with clouds so dense that day is almost turned into night. The rain falls in sheet-like torrents which are driven nearly horizontally by the wind and broken into blinding spray, so that large objects become invisible at a distance of 50 or 100 feet.

The effect of a cyclone is most disastrous when it passes from sea to land on a low, flat coast, at the period of high tide. Not only is the water driven on shore by the wind, but the height of the tide is increased by the partial withdrawal of atmospheric pressure at the storm-center. Thus, in October, 1886, a town in Texas at the mouth of the Sabine River was completely flooded and about one hundred lives were lost. This disaster was far surpassed in 1876 near the mouth of the Ganges. The sea swept over the land to the height of forty-five feet, destroying more than one hundred thousand human lives. (*Consult Blanford's "Vade Mecum," p. 257.*)

Starting-Places of Cyclones.—Since by Ferrel's Law the deflecting force due to the earth's rotation is greatest in high latitudes and vanishes at the Equator, there can not be a cyclone at the Equator. Thus far none have been observed between latitude 10° north and latitude 9° south.

But it is within tropical regions that the lower air becomes most heated and contains most moisture; hence, under favorable circumstances, an important class of cyclones start in these regions. Not only the starting, but the growth and movement of an extensive cyclone depend chiefly on such a combination of circumstances as may conspire to produce an abundant supply of ascending warm, moist air on the front, and descending cold, dry air in the rear.

A cyclone may be started by the penetration of a cool current under one that is strongly heated. This causes the beginning of an uprush. Cyclonic storms have been thus started in the neighborhood of Texas and Florida by north winds sweeping under the warm, moist air suspended over the Gulf and the neighboring ocean. Many originate on the Atlantic near the African coast, as well as near the Windward Islands.

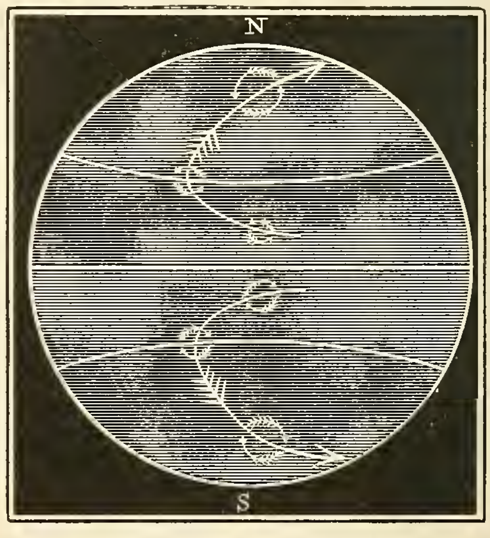
North of the Equator, these storms occur most frequently from August to October; south of it, from January to March. It is always during the season of the greatest heat, or at the limit of this season, that cool polar currents encroach upon heated areas.

Progressive Motion of Cyclones.—In the northern hemisphere, the wind blows toward the east on the southern side of a cyclone (*see figure, p. 71*). Hence, according to Ferrel's Law, the deflecting force toward the right causes a pressure toward the Equator. On the northern side, the wind blows toward the west, and the deflecting force causes a pressure toward the pole. But this force is greater as we recede from the Equator; hence the pressure toward the pole exceeds that toward the Equator, and a cyclone when once started must move northward. South of the tropical calms, it must also move westward in obedience to the same forces that cause the trade-winds; north of them, it must move with the anti-trade winds. The cyclones of the northern hemisphere, therefore, have a progressive movement that is continually deflected toward the right.

By similar reasoning, it may be shown that cyclones in the southern hemisphere must have a progressive movement with continual deflection toward the left.

The curve described by a cyclone in its path is very similar to that called the parabola (*see figure below*). In the North Atlantic Ocean, the southern extremity of the parabolic track is usually near the Windward Islands, or east of them. The northern branch passes over Newfoundland, or south of this island. The most abrupt part of the curve is between the meridians of 40° and 100° in west longitude, most frequently between those of 65° and 85°.

In this progressive motion, there is no actual transfer of the atmosphere from tropical to polar regions. The forces producing gyratory motion being greater on the polar side, new bodies of air are continually drawn in. On the equatorial side, where these forces are less, the various resistances that the cyclone has to encounter in its pathway are more effective, so that the storm-center is continually shifted into new regions of atmosphere successively farther away from the Equator.



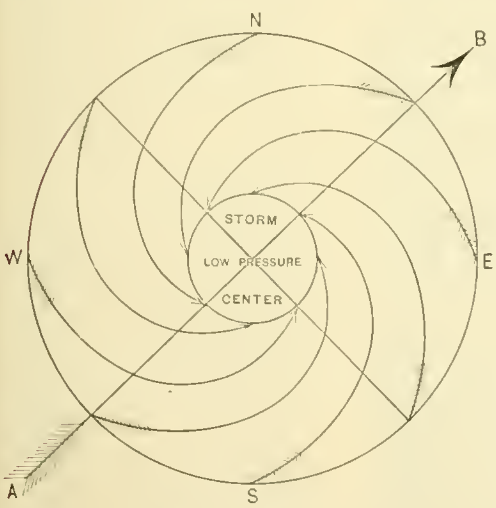
PROGRESSIVE MOTION OF CYCLONES.

On the advancing side of the cyclone, the rainfall is heavier, the temperature is higher, and the change of barometric pressure is more abrupt, than in the rear portions of the storm-area. As it approaches a place within the tropics, the atmosphere is often observed to become hazy and sultry; then the barometer, which may have been higher than usual, begins to fall; a breeze springs up, and the sky in the direction of the coming storm grows black with clouds which soon cover the heavens; wind and rain then exert their utmost fury. After the storm-center has passed, the temperature falls very decidedly, and the wind and rain gradually subside.

Duration and Rate of Progress.—The progress of a cyclone within the tropics is slow, being often as little as ten miles an hour. As the storm advances into cooler regions where the supply of moist air is less, its rate of progress increases and the area of disturbance widens. The central area of calm widens also, and the gyratory motion becomes gradually less violent.

Some cyclones become dissipated by the down-rush of air at the tropical zone of calms, and therefore last but a day or two. The more violent storms cross this zone and travel far into middle latitudes, lasting a week or more. They die out because the supply of vapor in colder regions is insufficient, while the energy of the cyclone is expended on a larger mass of air. The diameter of the storm-center grows to 80 or 100 miles, and that of the entire cyclone may finally exceed 1,000 miles.

Storm-Cards.—The general law of storms, as thus set forth, enables us to know the direction from which cyclones may be expected. In northern middle latitudes they come from the southwest, almost with the anti-trade winds. For any given place, therefore, a storm-card may be constructed, in which the straight arrow (A B, figure) marks the direction of progress, and the spiral arrows show the course of the wind around the storm-center. In the north temperate zone, the mariner, turning his back to the direction from which the wind comes, knows that the place of greatest danger is on his left in front, and hence steers to the right to avoid it. In the southern hemisphere, he would steer to the left.



STORM-CARD FOR NORTHERN MIDDLE LATITUDES.

Many of the West Indian cyclones, after crossing the tropical zone of calms, sweep on over the Gulf Stream and include the coast of the United States in the area covered. At Savannah, the storm begins with a wind from the east or northeast. It then veers to the north, and dies out while coming from the west, the path of the storm-center being over the ocean. On the next day, the same order of succession is observed at Washington, but with less violence, the central area having moved much farther eastward. Not infrequently the cyclone crosses the Atlantic, and is felt on the western shores of Europe. (On the hurricane season in the Windward Islands, *see Ober's "Camps in the Caribbees," p. 162.*)

If the storm reaches the Gulf of Mexico before crossing the belt of calms, its center may traverse the Mississippi Valley and even surmount the Appalachian Mountains, expending its last energy upon the Atlantic.

Irregular Cyclones.—Cyclones of less violence and regularity than those just described, are produced in temperate regions wherever the equilibrium of the atmosphere can be disturbed by heat. Such storms, imperfectly developed, occur in all parts of the United States. They often join or partially oppose one another, so that the oscillations of the barometer become irregular, and the shifting of the wind may at times seem unaccountable. Probably most of the changes of the barometer are due to cyclone-motion, however slight this may be.

In summer, the great plains of Kansas and Nebraska become warmer than either the wooded valley of the Mississippi or the Rocky Mountains on the west. Large areas of elongated or irregular shape are covered with rarefied air, and toward such "barometric troughs" wind blows from all sides. In accordance with Ferrel's Law, the motion soon becomes cyclonic, and the storm passes eastward to the Middle and Northern States.

The land on the Pacific slopes becomes heated, and moist air from the ocean is brought abundantly by the anti-trade winds to supply the areas of low barometer thus started. Cyclones are hence developed, many of which pass over the Rocky Mountains and traverse the entire continent. (For further information on this subject, *consult Professor Ferrel on "The Motions of Fluids and Solids on the Earth's Surface;" and Upton's "Investigation of Cyclonic Phenomena," in the "American Meteorological Journal," vol. iii., pp. 250, 316, 367.*)

Tornadoes may be defined as local cyclones of exceeding violence, in which the area covered is too small for the gyratory motion to be always determined by deflection due to the earth's rotation.

A tornado occurs only when the earth's surface is greatly heated and the air is calm and sultry. The upper layer of atmosphere rests in a state of unstable equilibrium over the rarefied layer next the ground. If from any slight cause whatever this equilibrium be disturbed, the upper layer is penetrated by an ascending current, which is followed by currents of various degrees of strength that meet below from all sides. Since these seldom balance one another exactly, gyratory motion in either direction is at once established.

To illustrate this, remove the plug very gently from the bottom of a basin full of still water. The water flows out quietly; but, if the least motion is imparted in any direction next to the opening, gyratory motion in the same direction is determined and rapidly increases in violence. The surface of the water becomes funnel-shaped, and air is sucked down with the outflow.

Comparison of Cyclones with Tornadoes.—The conditions that occasion a tornado may also give rise to a cyclone, if they prevail over an area of great extent. In this event, the influence of the earth's rotation in determining the direction of gyration exceeds all others, and being constant it tends to lengthen the life of the cyclone. A tornado quickly becomes extinct, seldom lasting more than a few hours, because of the resistance it encounters from the surrounding air and the earth. It may occur, moreover, within the equatorial zone of calms where cyclones are impossible.

At a distance from the Equator, the gyratory motion of tornadoes is usually like that of cyclones in the same hemisphere. Thus in the United States, it is opposite to the motion of the hands of a watch, and the direction of progress is generally northeastward. Tornadoes generally occur on summer afternoons, though occasionally during spring or autumn, and more frequently over arid plateaus than wooded low plains. The Western States are oftener visited by them than other sections of the Union. (*Consult Lieutenant Finley's "Characteristics of Tornadoes," and Ferrel's "Recent Advances in Meteorology," 1886, published by the United States Signal Service.*)

The path of a tornado is sometimes only a few rods in width. The centrifugal force developed in gyration so close to the axis is enormous, and the diminution of atmospheric pressure at the center is such as to create almost a vacuum. Hence, when a tornado passes over a building, the sudden expansion of the air within the structure bursts it into fragments. The whirling mass of air around the axis moves solid masses many tons in weight, and scatters lighter objects like chaff on either side of its track.

On the 14th of April, 1886, a tornado passed over a part of Minnesota, destroying about a hundred lives, and property valued at nearly half a million of dollars. Houses were wrecked, freight-cars lifted from the tracks, and in some places iron rails were wrenched from the cross-ties. Fragments of *débris* were hurled into the air, and carried more than twenty miles before falling. (*Consult "Scientific American" for May 1, 1886; and Professor Shaler's "Aspects of the Earth," p. 240.*)

The approach of a tornado is heralded by dark clouds which meet from opposite sides of the sky. Gyratory motion is established, and warm air is drawn up into the vortex from below. An ascending, twisting column of dust and condensing vapors spreads out spirally as it joins the cloud above, and causes this to assume the form of a dark, whirling funnel, with its smallest part below. As the motion increases in violence, the stem of the funnel descends, until it sweeps the ground, destroying whatever it touches.

The column has a progressive motion, that varies from fifteen to sixty miles an hour, often rising and descending at intervals. The rushing of the conflicting currents, frequently accompanied with flashes of lightning, produces a loud, roaring sound. After the work of progressive devastation has been continued a few minutes, or at most a few hours, the mass of cloud overhead breaks into torrents of rain and hail, and the tornado is soon extinct.

Water-Spouts and Sand-Pillars.—When a tornado occurs at sea, the funnel-shaped cloud descending to the surface of the water draws this up into the column of whirling, rarefied air, breaks it into spray, and thus connects the cloud with the surging waves below. Revolving columns of water and air thus created are called "Water-spouts."

Similarly, when a tornado sweeps over a desert of sand, clouds of dust are lifted up in the vortex. Such "Sand-Pillars" are greatly dreaded by travelers on the Sahara and Arabian Deserts.

Questions.—State the cause of the incessant motion which takes place in the atmosphere. What are wind-zones? Calm-belts? Can their limits be defined? Account for irregularities in wind-zones. What are trade-winds? Anti-trades? Why are these winds so called, and in what directions do they blow? Name the regions in which the winds are constant, periodic, or variable, stating the cause in each instance. Describe the polar winds and their effects. Explain land and sea breezes. What are monsoons, and how do they affect prevalent winds? Mention the most noted hot and cold winds, and state where each prevails.

Define a storm. Explain the cause of storms. Account for the spiral motion of cyclones. Describe the curve along which a cyclonic storm moves; the width and length of its path; its rate of progress and duration; the accompanying wind-pressure. In what direction do cyclones sweep over the United States, and why? What are storm-cards? Illustrate the production of a tornado. State the difference between a tornado and a cyclone. Describe the destructive effects of a tornado. What is a water-spout?

Why does a west wind bring fine weather to the Middle Atlantic States, while east and south winds are accompanied with storms? Where are easterly winds chiefly prevalent, and at what seasons? Of what value are winds in the economy of Nature?

WATER-SPOUT IN THE STRAIT OF MALACCA.

(From a sketch made in 1872.)

THE MOISTURE OF THE ATMOSPHERE.

Vapor.—The gases composing the atmosphere have been already mentioned. Their relative proportion remains very nearly constant, except in the case of watery vapor. Next to nitrogen and oxygen, this is the most abundant ingredient. In its relation to climate, it is the most important of all.

Source and Properties.—All the moisture in the air comes from the sea, either directly or indirectly. Vapor is continually rising from the surface of every exposed body of water. It is only three-fifths as heavy as air, and is therefore easily swept up by atmospheric currents and widely diffused.

What is popularly called *vapor* consists of small particles of liquid due to the condensation of an invisible gas. When vapor rises from sea-water, the salt is left below in solution. The saltness of sea-air is due to finely divided spray which is caught from the waves and wafted high up by the wind.

Saturation and Dryness.—A cubic foot of air at 30° Fahr. can hold only two grains of invisible vapor; but, if the temperature be raised to 100° F., the same volume will contain nearly twenty grains. When thus holding all that it can carry of perfect vapor, the atmosphere is said to be *saturated*. If a body of saturated air at 100° F. be cooled to 30° F., then nine-tenths of its vapor will be condensed into a visible cloud of minute drops of water. Air which contains but a small proportion of the vapor that it can hold at a given temperature is said to be to that extent *dry*. Thus, if saturated air at 30° F. be warmed up to 100° F., it becomes nearly dry, since it now carries only one-tenth of what it has the capacity of holding in the gaseous state at this temperature.

Dew-Point.—By many careful experiments the amount of vapor that a cubic foot of perfectly dry air can contain before becoming saturated has been ascertained for various temperatures. Thus, at sea-level, it is 6.15 grains for 62° F., which is estimated to be the mean surface temperature of the globe. If a body of unsaturated air at 100° has to be cooled down to 62° before any of its vapor begins to condense, this temperature, at which saturation is reached, is called its *dew-point*. The drier the air, the lower its dew-point.

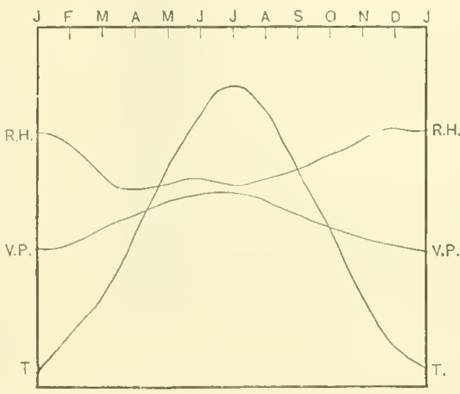
Absolute and Relative Humidity.—The quantity of vapor that a given volume of air actually contains at a certain temperature, is a measure of its *absolute* humidity. The ratio of this quantity to that which would saturate it at the same temperature, is its *relative* humidity.

Thus, if a cubic foot of air at 100° has to be cooled to 62° to become saturated, then 6.15 grains represent its absolute humidity. But at 100° it would require 19.8 grains for complete saturation. Hence its relative humidity is $\frac{6.15}{19.8}$, or about 31 per cent. The lower the percentage of relative humidity, the greater is the fall of temperature required to produce saturation or reach the dew-point.

Rate of Evaporation.—The lower its relative humidity also, the greater is the air's power of taking up vapor from water with which it is in contact. The process of evaporation hence goes on more rapidly in sunshine than in shade, on a warm day than on a cold one, with clear than with overcast skies.

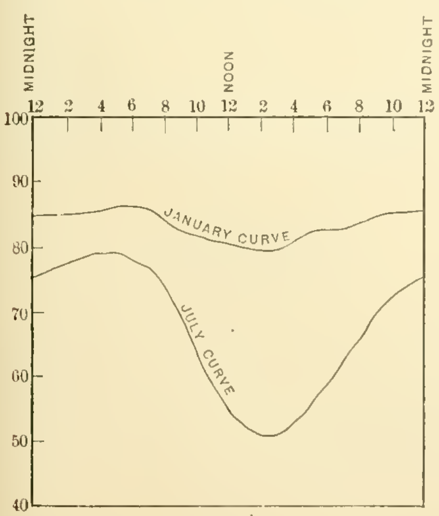
Assume a surface of water to be covered with still air; as soon as this becomes saturated, evaporation ceases. But, if swept by wind, the relative humidity of that which briefly touches it in passing can never be much raised, especially if the air be warm. Evaporation is hence more rapid in equatorial than in temperate regions, and most of all in the warm belts constantly swept by the trade-winds.

Evaporation also varies with the pressure of the atmosphere. If the air be dense, there is little room left for additional vapor of water. But, in proportion as it becomes more rarefied, evaporation is more rapid. If a liquid be exposed to a vacuum, the space over it becomes instantly saturated with vapor. Hence, when the barometer falls, evaporation becomes correspondingly more rapid.



Annual Changes of Temperature (T.), Vapor-Pressure (V. P.), and Relative Humidity (R. H.).

Vapor-Tension.—The vapor that saturates a space otherwise empty exerts a definite pressure, the measure of which is called the *vapor-tension*. Thus, if the pressure of the dry atmosphere at 62° F. be thirty inches, as measured on the barometer, that of water-vapor unmixed with air at the same temperature is a little more than half an inch, or about one-sixtieth as much. If mixed with air and not at the point of saturation, the vapor exerts less pressure. Vapor-tension is increased by heating and diminished by cooling. Its amount at any place is proportional to the absolute humidity of the air.



Change of Relative Humidity during a Single Day.

In the diagram above, where the names of the months are indicated by their initial letters at the top, it will be seen that the temperature-curve for the year (T) is low in January, high in July, and low in December. The vapor-tension, or vapor-pressure (V P), also rises in summer and falls in winter, though not in the same ratio. It is an index of the absolute humidity. The relative humidity (R H) is lowest in summer, though the increased heat during this season causes the absolute amount of vapor carried in the air to be far in excess of that in winter, often four or five times as much.

In like manner, during a single day, the relative humidity varies, being lowest during the warmest part of the day and highest just after dawn. The daily variation in summer, from 50 to 80 per cent., is also seen to be much greater than that in winter, from 80 to 86 per cent., on the days for which these curves were constructed.

Measurement of Evaporation.—By exposing a known area of water-surface and recording the daily decrease of depth, it is possible to estimate the total loss by evaporation during the year. Thus, at a reservoir in India, during the dry season of two hundred and forty days, the daily decrease of depth was over one-fifth of an inch, or in all more than four feet. For the whole year, it was about six feet.

The amount of rainfall may also be measured by catching the falling water in an appropriate instrument called a rain-gauge. By comparison of results, it has been found that for any single country the amount of water lost by evaporation is about equal to that gained by rainfall. There is hence no great amount of water transferred through the air from the torrid to the temperate zone by the upper trade-winds. (*Consult Haughton's "Six Lectures on Physical Geography," p. 165.*)

Distribution of Vapor according to Elevation.—Although vapor is lighter than air and hence tends to rise, it expands at a faster rate in ascending, so that the quantity actually held by the air rapidly diminishes with increase of height. It is estimated that fully half of all the vapor is within 6,500 feet of sea-level, and that not one-tenth of it remains after an elevation of four miles is reached. Hence the climate of lofty plateaus is usually very dry. Vapor, moreover, is a powerful absorber of terrestrial radiation; its partial absence contributes largely to the extremes of heat and cold that are felt at such heights.

Precipitation.—When the temperature of the air is reduced to the dew-point, the vapor it contains is precipitated, and the result may be dew, frost, fog, cloud, rain, snow, sleet, or hail, according to circumstances.

Dew and Frost.—When at night the earth radiates the heat which it has received during the day, the surface becomes colder than the ground beneath or the air above. Vapor rises from the moist soil below, to be condensed at the cooler surface. The adjacent layer of air above is also cooled to its point of saturation, and its vapor is deposited. This condensed moisture at the surface, whether from the soil or the air, is Dew. When the weather is cold, so that but little vapor can be carried in the air, the dew-point may be below 32° Fahr. In this event what is deposited is solid Frost.

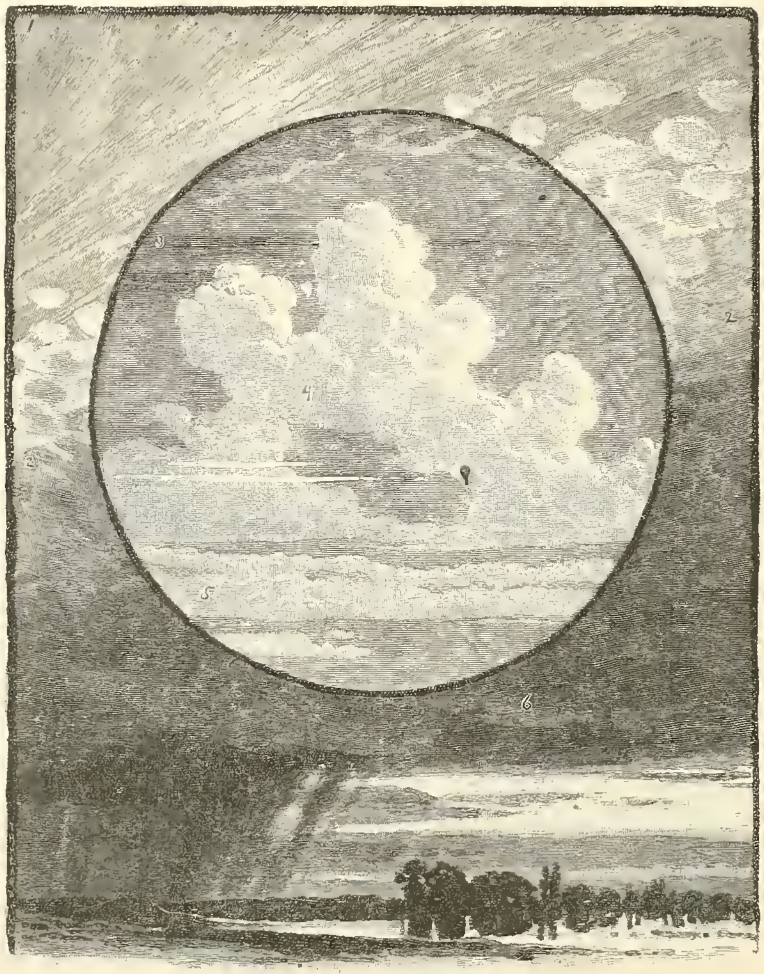
The difference of temperature between points four inches and four feet above the ground may be as great as 12° or 15°, so that frost may be deposited when the temperature of the vast body of overlying air is above 40°. The freezing often takes place before the deposit, and thus the ground may be spangled with minute ice-crystals. Dew does not fall, but is condensed on the best radiators, such as grass and trees. (*See Wells's "Essay on Dew."*)

In the dense forests of South America, Humboldt found that during the night there was apparently a shower of rain, while the sky overhead was cloudless. In the warm tropical atmosphere, radiation occurred chiefly from the trees, whose foliage was so dense as to screen the ground. The precipitation was sufficiently rapid to produce a gentle shower from the leaves. The same is observable to a less extent in the woods of Florida and other states bordering the Gulf of Mexico.

Dew and frost are much less abundant when the sky is clouded, or on a windy night. The clouds reflect the heat which would otherwise be radiated into space, and wind prevents the air from remaining long enough in contact with a single radiating surface to permit of any noticeable lowering of temperature.

It is estimated that the average annual deposit of dew on the earth's surface does not exceed 1.5 inches. This is greatly exceeded in the tropics, especially near large bodies of water that give abundant moisture to the air. In the rainless regions of Peru, dew is an important agent in sustaining vegetation. In Palestine, and on the plains of southern Texas, the deposit is phenomenally heavy; while in the Arctic regions there is little or no dew.

Sheet-Ice.—If the ground becomes very cold and is then swept by an atmospheric wave of warm and moist air, the deposition of ice may become such that all exposed objects are covered with a slippery sheet which grows in thickness until the ground is warmed above the freezing-point. This result is greatly intensified if a gentle rain falls at the same time. The limbs of trees become incased so thickly as to break under the load. A twig four inches long and weighing less than eight grains has been known to be covered with ice weighing over 920 grains. "Ice-storms" of this kind cause great destruction of property at times, and have interfered seriously with telegraphic communication. (*See Pike's article on Ice-Storms, "American Meteorological Journal," vol. iii., p. 32.*)



Varieties of Cloud-Forms.

Fog and Clouds.—If a body of moist air becomes cooled below its dew-point, by radiation or otherwise, its vapor is precipitated in minute droplets that float on account of their diminutive size. If this occur over the surface of the ground or of water, the result is called Fog; if at an elevation, it is termed Cloud. If the dew-point be low enough, as it is at great elevations, the cloud may be composed entirely of minute crystals of ice.

The formation of fog is much facilitated by the presence of dust or smoke in the air. Each floating particle serves as a nucleus around which the vapor condenses. A large manufacturing town is hence more liable to be visited with fog than the open country. Fog is frequently present in London when the atmosphere twenty miles distant is comparatively clear.

Since the temperature of a large mass of water is imparted to the air resting upon it, fogs are specially abundant in the neighborhood of Newfoundland where the Gulf Stream meets the cold Arctic current. In like manner an iceberg, after floating southward within the limits of the same mass of warm water, is attended with fog, which increases the danger of navigation in its neighborhood.

"Dry fog" is a name improperly applied to the haziness of the air due to suspended particles of dust or smoke. It is often produced by forest-fires in America. Rain falling through it may become slightly discolored. For nearly two months, in 1783, the whole of Europe was covered with an extraordinary dry fog.

Formation of Clouds.—Moist air, in ascending, becomes cooled by expansion. Its vapor, at first invisible, is condensed into visible clouds. The height at which condensation begins varies with the dew-point at the surface. In tropical regions, where the lower strata of air are warm, clouds seldom float nearer than a mile and a half above the ground, but often at heights exceeding four or five miles. In polar regions, on the contrary, the conditions are nearly always such as to permit their formation at or near the surface. According to circumstances, a cloud may be dissipated by the sun's heat above while receiving accessions from moist air below, or its lower part may be dissipated by descent into warmer and drier air while accessions are received from above.

Classification of Clouds.—Several modes of classifying clouds have been proposed, but that most generally in use at present is the oldest, and was adopted about the beginning of the present century by Luke Howard. He divides them into three primary types, from which other types are derived by combination, viz., Cirrus Clouds, Stratus Clouds, and Cumulus Clouds.

Cirrus Clouds (from a Latin word, meaning *tuft of hair*) appear at the loftiest heights as long, feathery streaks of delicate white spray (see upper left-hand corner of the engraving). From a balloon four miles high they have been seen still far beyond in the blue sky, where the temperature was necessarily much below the freezing-point of water. Cirrus clouds are composed of minute crystals of snow, grouped together in filaments that are stretched out by currents of air. They are supposed to indicate changeable weather; often to herald approaching wind and rain in summer, frost or snow in winter.

Stratus Clouds (see lower right-hand corner of plate) are arranged in horizontal *layers or strata*, particularly on the summer horizon at night and in the early morning, when the ground and lower atmosphere have become cool by radiation. They are due to the gradual falling of clouds that have been floating at greater heights, and sometimes settle in the valleys as fog to be dispersed by the morning sun. In winter they often cover the sky for days with a dull-gray mantle of no great thickness; but in summer they are the night-clouds, which disappear after sunrise.

Cumulus Clouds (literally, *heaps*) are those most frequently seen during the day in summer, forming white masses like balls of cotton, which rest on a thicker base that is sometimes almost horizontal (No. 4, in the circle). The half-globular masses are the descending bodies of condensed vapor, which thicken as they approach the lower limit, where they are dissolved by the warmer air below. They may be entirely dispelled by the sun, or condensed still further into rain by cool winds.

When cirrus clouds have gathered sufficiently, they may settle into layers, like stratus clouds, high up in the air. These are called *cirro-stratus* (No. 3, in the circle), and often form a network covering the whole sky. As they sink still lower, they become dark by increased condensation, and constitute an almost unfailing sign of rain or snow.

Cirrus clouds in descending sometimes break into patches like those of the cumulus cloud, but still at great height. Such clouds are called *cirro-cumulus* (upper right-hand corner of plate), and the sky studded with them is popularly termed a "mackerel sky."

Cumulus clouds increase in height as the day advances, and often become much denser and darker beneath. With this darkening, the upper masses may flatten out, producing a form approximating the stratus. They are then called *cumulo-stratus* (No. 5, bottom of circle).

Rain-Clouds.—Any of these forms of cloud may increase in density to such an extent that the minute floating drops unite to form full drops that fall. The dark *rain-cloud* which thus results is called Nimbus (lower left-hand corner of plate), and often begins to form perceptibly at the base of the cumulo-stratus clouds.

The size of the rain-drops depends upon the height and thickness of the rain-cloud, and the difference of temperature between the bodies of air whose mixture has caused precipitation. Each drop in falling meets with multitudes of minute droplets which compose the cloud, and are added to the descending nucleus of water. The growth which the drop attains is far greater in summer than in winter, not only because summer clouds are higher, but also because the absolute humidity of the rising warm currents is so much increased by the surface-heat radiated from the ground. This in turn causes the currents to ascend faster, and precipitation is thus more rapid. In the central area of a cyclone, where the dense cloud may be several miles in thickness, the big drops follow so closely that the rain seems to fall in unbroken sheets. Winter rains, on the contrary, are often little else than falling mist, particularly in high latitudes, where clouds are suspended but a few hundred feet above the ground.

Clouds as Protectors.—Clouds not only serve as the gatherers and distributors of rain over the greater part of the earth, as moderators by night of rapid evaporation from the soil warmed during the day by solar heat—but they also play an important part in torrid regions, as absorbers of the scorching rays of the sun, and thus afford protection to animal and vegetable life. As cloudless regions are always rainless regions, a desert is partly a cause and partly an effect of the absence of clouds.

Motion of Clouds.—At small elevations, clouds are wafted in the direction of the surface-wind, but at a much faster rate, because they move with air that is not retarded by friction against solid bodies. At great elevations, their direction is usually different from that of the lower clouds. Cirrus clouds thus serve to indicate the direction of upper currents that could not otherwise be traced.

Cloud-Tints.—The colors so often seen on clouds are due sometimes to reflection, sometimes to absorption of light. The fine particles of vapor, while absorbing all wave-lengths to some extent, transmit the long waves more easily than the short ones, and reflect the short ones in larger proportion. The light reflected from the front of a dense cloud is bluish. If the sun be directly behind it, the light transmitted through its edges is reddish or golden. (*Consult Professor Rood's "Modern Chromatics," pp. 55, 56.*)

RAIN.

The Chief Cause of Rain has been already indicated—the cooling of a current of damp air. In rising, such a current expands, and therefore becomes cooled until the dew-point is passed. We have seen that perfectly dry air would be cooled by expansion, 1° Fahr. for about 182 feet of ascent. If we assume the surface-temperature to be that of an oppressive summer day, 100° F., such air would be cooled to 40° below zero by rising five miles. But the air is never perfectly dry; hence precipitation must occur. This in turn implies the production of heat, so that the rate of cooling is variable, and not so rapid as it would be for dry air. Descending currents do not produce rain.

Other causes of rain are the cooling of damp air by passage over the land from the warm sea, and to a small extent the mixture of currents of air differing in temperature.

Warming Effect of Rain.—When the condensation of vapor into rain is copious, the heat evolved rapidly changes the temperature of the air. We have seen that this is a very important element in prolonging the life of a cyclone. A gallon of water weighs ten pounds, and if spread out so as to form a layer an inch thick it would cover about two square feet of space. To cover a square mile an inch in depth, 60,000 tons of rain are required, or twelve millions of gallons. In the condensation of the vapor needed to produce a single gallon, heat enough is given out to melt seventy five pounds of ice, or to make forty-five pounds of cast-iron white-hot. An inch of rainfall on each square mile hence implies the evolution of heat sufficient to melt a layer of ice spread over the ground eight inches thick, or to liquefy a globe of iron 130 feet in diameter, or a rod of it a foot in thickness and 260 miles in length.

Dr. Haughton estimates the heat given to the west coast of Ireland by rainfall to be equivalent to half of that derived from the sun. At certain stations in India the annual rainfall is four times as great as that on the west of Ireland. (*Consult Haughton's "Six Lectures on Physical Geography," p. 126.*)

Effect of Rain on Climate.—The climate can never be cold where the number of rainy days during the year is large. At Valencia, in the southwest of Ireland, rain falls usually on 235 days of the year, or about two days out of every three; and to the heat thus brought through the air from the Gulf Stream is chiefly due the rich verdure of the Emerald Isle. The entire western coast of Europe takes its equable climate thus largely from the ocean. Even when rain does not fall, the atmosphere, laden with vapor and clouds, checks radiation and keeps the surface warm.

Effect of Wind on Rainfall.—If the wind blows from cool to warm regions, however saturated the air may be at first, its relative humidity decreases with rise of temperature, and no clouds can be formed. Rainfall is thus impossible. The trade-wind regions on the ocean are hence almost rainless during a large part of the year, though the absolute humidity of the air is high.

If the wind blows from warm to cool regions, however dry the air may be at first, its relative humidity increases with fall of temperature, and clouds are formed. Rainfall thus becomes possible. The anti-trade-wind regions on the ocean are frequently visited with rain

The annual amount of rainfall at any place is hence largely determined by the direction of the prevailing winds. This is equally true of rainfall during particular seasons, and of individual rain-storms. A

MEAN ANNUAL RAINFALL FOR THE DIFFERENT COUNTRIES OF THE GLOBE. BY PROFESSOR LOOMIS, OF YALE COLLEGE.

l is sufficient to darken the sky and raise the temperature y within a few hours.

f Land-Masses on Rainfall.—Since heat is more ed and absorbed by land than by water, winter rains regions are often due largely to southwest winds blow- warm ocean to the cool land. This causes the "rainy e Pacific coast of the United States. But through- ne year, and especially in summer, the land becomes g the day, and vapor-laden winds on reaching it are upward and condensed into rain. This effect is in- land be mountainous. The wind forces its way up -sides and its vapor is rapidly condensed. Mountain- is the most important of all natural condensers. Any s over them is deprived of moisture and blows as a

f Vegetation on Rainfall.—Forests protect the the direct rays of the sun, and prevent the rapid evap- h moisture as the soil contains. The temperature of est is hence much lower, during the hours of sunshine, air over a desert. A body of saturated air, if wafted is apt to yield rain; but over a desert its relative hu- once depressed, and the clouds change into invisible *rown's "Effects of Forests on Humidity of Climate."*)

ons of Excessive Rainfall.—In India, during the sum- oon blows strongly and steadily, sweeping over the Bay thward up the valleys of the Ganges and Brahmaputra e surface, the average temperature exceeds 80° F. About h of the coast, the Khasia Hills rise abruptly from the n elevation of 4,125 feet stands the village of Cherrapoon- n two sides by precipices 2,000 feet in depth, which close in en southward to the plain. The warm and saturated wind l to ascend nearly a mile above sea-level before surmount- It is thus cooled below its dew-point, so that the greatest s at the level of Cherrapoonjee. Above this height the to contain much vapor.

The average annual rainfall at the village, as determined by the records of twenty years, is about 493 inches; and during special years it has exceeded 600 inches, the largest amount on record. If prevented from flowing away or evaporating, it would cover every inch of the plateau on which Cherrapoonjee stands to the depth of fifty feet. Of this vast amount of rain, 95 per cent. falls during the six months from April to September inclusive. In July alone, the rainfall is over 133 inches, which is at the rate of 4.3 inches each day, or as much in ten days as falls during the whole year at New York. Thirty inches have been known to fall in a single day. The January rainfall is less than an inch, the wind being then from the northwest. The annual rainfall thirty miles beyond Cherrapoonjee is only 100 inches, the air having become comparatively depleted by ascending beyond the limit at which the dew-point is reached.

The densely wooded plain of the Amazon, sloping gently toward the Atlantic under the burning sun of the torrid zone, is characterized by a heavy rainfall. The humid trade-winds, sweeping westward over a radiating continent, already moist with luxuriant vegetation, are depleted by a continuous precipitation which supports the magnificent river system of South America.

In the region of anti-trade winds on the western coast of America, the breeze blows from sea to land, and is quickly forced up the slopes of the great mountain-ranges that in places border on the water. At stations in Alaska, the State of Washington, and Chile, the annual rainfall varies from 100 to 125 inches, or nearly three times that at New York.

In the United States on the Atlantic side, the greatest annual rainfall is along the Gulf coast (about sixty inches); at Cape Hatteras, where the warm Gulf Stream and cool Arctic currents first meet (seventy-eight inches); and on mountain elevations like Mount Washington (seventy-seven inches). (*Consult Schott's "Tables of Rain and Snow Precipitation in the United States," second edition, Smithsonian Institution.*)

Illustrations of Deficient Rainfall.—The most extensive rainless tract in the world is that which includes the deserts of Sahara, Arabia, and Persia. Much of this is situated within the belt of dry northeast trade-winds, and consists of lofty plateaus bounded by mountain-ranges. Such moist winds as may at times blow from the ocean are depleted on the shoreward side of the mountains, and, on surmounting them, are reduced far below the dew-point. Even on the Mediterranean side, part of which is not fringed with mountains, clouds from the sea are vaporized on reaching the desert. Beneath a cloudless sky, absorption and radiation continually alternate, so that days of burning heat are followed by nights sufficiently cold to congeal the moisture in the air, which appears at dawn as frost on the ground.

The highlands of Turkestan and Mongolia are similarly bounded by lofty ranges which prevent the free access of surface-winds from surrounding countries. Together they include the great Desert of Gobi, which is separated from the Persian Desert by the ranges that culminate in the Karakorum Mountains. On the southern slopes of these, there are copious showers due to ocean-breezes that have swept over the Indian plain. But for this interruption, a continuous desert would extend from the eastern limit of Mongolia to the Atlantic, over 100° of longitude.

West of the Andes is a desert strip extending over the Peruvian and part of the Chilean coast. The prevailing winds are from the east, and hence are depleted by the lofty mountain-range. Evaporation from the neighboring ocean supplies the air with moisture enough to furnish abundant nightly dews, so that, though the region is rainless, most of it is not sterile. South of the Calms of Capricorn, the anti-trade winds, after producing very heavy rainfall on a continuation of the same coast, are depleted in passing over the mountains, and as the result of this most of Patagonia is an uninhabitable desert.

The character of the trade-wind is strikingly illustrated by comparing the rainfall at Pernambuco, Brazil, with that of Ascension, a small mountainous island in the Atlantic, midway between Africa and South America. The latitude of each is about 8° south. At the former the annual rainfall is 106 inches; at the latter, but little over three inches. At each the absolute humidity is high. The air ascends on reaching the Brazilian coast, but at Ascension there is no cause sufficient to produce upward motion. The island is, therefore, almost perpetually parched. (On mean annual rainfall in different parts of the globe, *consult Loomis's article in "American Journal of Science," vol. xxv., January, 1883.*)

General Laws of Rainfall.—Rainfall is so much determined by local conditions that no statement of general laws can be made without admitting many exceptional cases. The following laws may be accepted as roughly approximate:

I. In torrid regions the rains are more violent, and the total rainfall is greater, than in high latitudes.

This is abundantly shown by referring to the rainfall of the East and West Indies and comparing it with that of Arctic America and Asia. The mean annual rainfall at the Equator is estimated to be about one hundred inches; at latitude 40°, about forty inches; and within the Arctic Circle, less than ten inches.

II. Rainfall is generally most abundant on the coast, and becomes deficient in the interior of a continent.

An examination of the rain-map will make this law clear. It is true in regard both to the violence of rainfall and the annual number of rainy days.

III. The number of rainy days and the general cloudiness increase with increase of latitude.

The average ratio of cloudy and rainy days to clear days within the tropics is about one to three, in Great Britain about one to one, and in the Arctic regions three or four to one.

Rain-Zones.—Aside from the local influences that produce rain on land, the earth's surface has been divided into certain belts, each of which has its own peculiarities of rainfall. (*See Maps, pp. 80, and 72, 73.*) These may be named as follows:

I. The Equatorial Zone of Daily Rains.

This zone, like that of greatest heat, is north of the Equator, its mean position being between latitude 1° and latitude 10°. It is shifted northward and southward with the seasonal changes in direction of the sun. It nearly coincides with the zone of calms, and is due to the meeting and ascent of the north and south trade-winds. Throughout the forenoon, vapor is given off by the heated waters, and continues to rise with the ascending air-currents. By the middle of the afternoon, their height is such as to necessitate precipitation. A heavy shower falls, interfering with the air-currents. After two or three hours of rain, the upper atmosphere is so warmed with the heat evolved by condensation that further precipitation is checked. The clouds are dissipated, and the rain-storm is followed by a starlit night.

The equatorial zone, though best defined over the ocean, may be traced across the East Indies, Africa, and South America. The ascending air-currents retain their westward course, and their moisture is precipitated far inland. Since this belt crosses its mean position twice a year at intervals of six months, countries occupying this position have two annual rainy seasons, occurring in April and October.

II. The Rainless Zones of Trade-Winds.

These, for reasons already indicated, are nearly rainless only over the ocean. Their limits are variable, depending on the position of the sun; and the mean position of each is encroached upon by the equatorial zone of daily rains. The two rainy seasons, for countries included in them, are hence separated by less than six months, and indeed may in places become so closely connected as to be regarded only as one.

Ascension Island is just beyond the southern limit of encroachment by this equatorial zone, and hence has no rainy season. The rainless zones on the ocean extend to the neighborhood of latitude 25° south and latitude 30° north. Even on land there are regular seasons of comparative dryness prolonged several months.

III. The Sub-Tropical Zone of Rains.

This zone extends about 10° beyond the rainless zone. During summer, the trade-winds encroach upon it, and but little rain falls. In winter, variable winds occur, with correspondingly frequent rains.

On passing from the ocean to the land, this zone almost wholly disappears, the countries included being visited with rain at all seasons, determined by local conditions.

IV. The Rainy Zones of Anti-Trade Winds.

These extend from latitude 40° onward toward the poles. The prevailing wind is from the southwest, bringing abundant rain upon western coasts, and comparative dryness on eastern coasts.

V. The Polar Zones of Summer Rains.

In winter, the winds blow outward in all directions from the poles. They are cold and dry, hence the number of clear days is greatest at this season. As soon as warmer winds from temperate regions gain access, their moisture is condensed into clouds that rest on the ground or float at low heights. The cloudiness becomes greatest in summer, and often develops into drizzling rain. The annual precipitation is chiefly in the form of snow.

Measurement of Rainfall.—The annual rainfall at any place is measured by means of a rain-gauge—a graduated cylindrical cup, deep enough to hold all the water that can fall into its mouth during a single storm. It is usually provided with a funnel, which conveys the rain into a cylinder below. The area of the mouth of the funnel must be carefully measured. If sufficient rain falls to cover, to the depth of an inch, an area equal to that of the funnel's mouth, this amount of rain is taken as the unit of measurement. The sum of all the quantities thus registered during a year is the annual rainfall.

Great care is exercised in selecting a position for the exposure of a rain-gauge. It is generally placed in an open space, about a foot above the ground, where there can be no interference with wind or rainfall.

TABLE OF MEAN ANNUAL RAINFALL.

The following selections are made from a much larger table, published in the "American Journal of Science" for January, 1882, by Professor Loomis. The name of station, elevation in feet above sea-level, and annual rainfall in inches, are given:

STATION.	Height.	Rainfall.	STATION.	Height.	Rainfall.
Cherrapoonjee, India...	4,125	492.45	New York, N. Y.	....	43.44
Mahableshwur, India...	4,540	253.24	Washington, D. C...	110	37 96
Caracas, Venezuela.....	2,730	155.37	Charleston, S. C......	....	43.51
Pernambuco, Brazil....	....	106.07	Atlanta, Ga.........	1,050	58.43
Seathwaite, England....	1,334	152.24	Baton Rouge, La.....	41	60.16
London, England	....	24.57	Chicago, Ill.........	....	34.74
St. Petersburg, Russia..	10	17.67	Leh, Cashmere, Asia..	11,538	3.0
Yakutsk, Siberia.......	299	9.00	Ascension Island.....	....	3.3
Jerusalem, Palestine ...	2,500	18.83	Lima, Peru..........	530	0
Rome, Italy........ ...	....	30.91	Atacama, Bolivia.....	.	0
Paris, France..........	....	20.08	Cairo, Egypt.........	....	1.31
Fort Tongas, Alaska. ..	25	118.3	Thebes, Egypt	....	0
Blockhouse, Oregon....	....	96.29	Mourzouk, Sahara Desert...............	....	0
Valdivia, Chile........	42	115.49			
Boston, Mass..........	....	41.44			

Weather Observations.—The study of the weather is now reduced to a science. Observations of the temperature, the moisture and density of the air, the velocity and direction of the wind, etc., are simultaneously taken at different points in Europe and at over 500 stations of the "Signal Service" in our own country. From reports of these, telegraphed to Washington, charts are constructed, from which the "weather indications" for twenty-four hours to come are announced throughout the country in telegraphic bulletins. These bulletins are valuable to the farmer as guides in his operations; while the cautionary signals of approaching storms, displayed on the lakes and the Atlantic seaboard, are of still greater service to the sailor. Even on the coasts of Europe, vessels have been saved from disaster by telegraphic predictions from the United States. (On the principles of weather-forecasting and weather-charts, *see pamphlet by Abercromby, "Publications of British Meteorological Council," No. 60.*)

Questions.—Define vapor, and show how water is held in the air. What is the source of atmospheric vapor? Explain what is meant by the dew-point; by absolute and relative humidity; by vapor-tension. What determines the rate of evaporation? In what way is evaporation measured? How is the distribution of vapor affected by elevation?

Under what conditions, and in what forms, is the vapor of the air precipitated? Explain the phenomena of dew and frost; the effect of a cloudy atmosphere on the deposit of dew; of dense forests; of high winds. Illustrate the chilling effect of radiation. State the average annual deposit of dew. Show why ice sometimes forms during hot weather in calm, clear nights. Account for the formation of sheet-ice; of fog and clouds. Describe what are popularly known as "dry fogs." Classify clouds. Present the characteristics of cirrus clouds; stratus clouds; cumulus clouds; of other types derived by combination. What can you say of cloud-motion? of cloud-tints? How do clouds act as protectors? What determines the size of rain-drops?

Specify the chief agents in the production of rain. Explain the effect of rain on weather and climate; the effects of winds, mountains, and vegetation, on rainfall. Illustrate excessive and deficient rainfall. What is the heaviest rainfall recorded? State the general laws of rainfall. Into what rain-zones has the earth's surface been divided? What regions have constant, periodical, or variable rains? What becomes of the rain that falls on the earth? How do you account for the rainless region of Sahara? for the fertility of Egypt lying in the rainless region?

If the atmosphere remained in a state of equilibrium for one year, how would it affect the distribution of rain? State the essential difference between an insular and a continental climate. How does the climate of Alaska differ from that of New York? What part of South America receives the most rain? Of Asia? Of Africa? Compare New Guinea with Greenland in regard to rainfall; Ascension Island with Madagascar.

How far is weather periodical? Explain the nature and value of weather observations and prognostics.

SNOW, SLEET, AND HAIL.

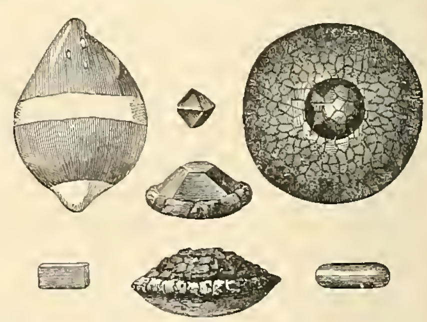
Snow.—When the temperature of the air within which precipitation occurs is lower than the freezing-point of water, the vapor is crystallized and falls in flakes of Snow. All snow-crystals are formed on the same type, that of a six-pointed star, but vary greatly in details of structure. A few of them are shown in the figure. Snow-storms are rarely accompanied with very violent wind, and seldom, if ever, with lightning and thunder. The ascent of the moist air from which snow is precipitated is hence gentle, and such storms are characteristic of winter alone.

Snow-Crystals observed by Captain Scoresby in the Arctic Regions.

When part of the vapor is frozen into snow and the rest condensed only into rain, the crystals in descending are washed together into ice-pellets, and the ground becomes covered with a slippery coating of Sleet. It is not uncommon for the fall of snow to change through that of sleet into a quiet rain-storm.

In certain regions the beautiful phenomenon of red snow is sometimes met with. Dr. Kane describes its color as deep, but not bright; a handful thawed in a tumbler looked like muddy claret. The coloring-matter he supposed to be either pollen or the bodies of animalcules. It is due to the presence of a microscopic plant.

Hail is also a result of the freezing of aqueous vapor, but under conditions that are comparatively exceptional. Hailstones are ice-pellets which vary from an eighth of an inch to two or three inches in diameter. They have been known to become massed into granulated bodies nearly a foot thick. The center of the hailstone is usually a collection of little grains of ice or snow imperfectly pressed together. Around this nucleus, successive shells of ice are formed, often arranged so as to present a radiated structure, with much air entangled within. Occasionally they form clear masses without the snowy nucleus, but containing each a small cavity full of compressed air. The exterior is irregular, often pear-shaped, or flattened and jagged. The force with which the largest hailstones fall is enough to kill animals and inflict much damage upon vegetation and even houses.



Forms of Hailstones.
(After various authorities.)

Hailstorms occur most frequently during the warm season of the year and the hottest part of the day; often in tropical or temperate, but never in Arctic, regions. The central line of the area covered is generally free from hailstones, while two or more belts parallel to one another are visited with an abundant fall. Lightning and thunder are almost invariable accompaniments. These phenomena imply the rapid ascent of saturated air, which is spread out, according to the law of cyclones, in the upper atmosphere, and cooled below the freezing-point at elevations much beyond that at which snow is commonly formed. A nucleus of snow in its descent grows by contact with more vapor, which freezes and imperfectly crystallizes into hail. Although the hailstone falls through warm air, yet its size prevents it from melting before it reaches the ground.

A memorable hailstorm took place on July 18, 1788, traversing France and Holland, over a belt five hundred miles in length. Upon a central band, ten or twelve miles wide, only heavy rain fell; this marked the vortex of the cyclone. On each side another band, from five to ten miles wide, was violently pelted with hail, which caused the destruction of property to the value of more than $5,000,000. Outside of these bands, a heavy fall of rain extended over many miles. The storm lasted nine hours.

Distribution of Snow.—What has been said in regard to the distribution of rain applies equally to snow, if the temperature be low. In the Arctic regions, drizzling rain falls through the short summer season, but during most of the year the precipitation is in the form of dry and powdery snow. In temperate regions, where the atmosphere has more capacity for moisture, snow-storms are heavier but less frequent. Nearer the Equator, no snow ever falls at sea-level. The intermediate limit separating snowless regions from those that are occasionally visited is not well defined; it is determined by the same conditions that fix the winter isothermal lines. The average number of days each year on which snow falls is, at St. Petersburg, 171; at New York, 17; at Charleston, 1.

The Snow-Line.—But the mean temperature falls with increase of elevation as well as of latitude, so that even under the Equator at the height of three miles the residue of vapor that reaches that elevation is precipitated as snow. With increase of latitude the snow-line descends irregularly, so that in the northern part of Greenland the region of perpetual snow is less than half a mile above sea-level, and at the poles it is still lower. Amid the Alps, its height is about 9,000 feet; in Lapland, 3,300; and at Bering Island, 600.

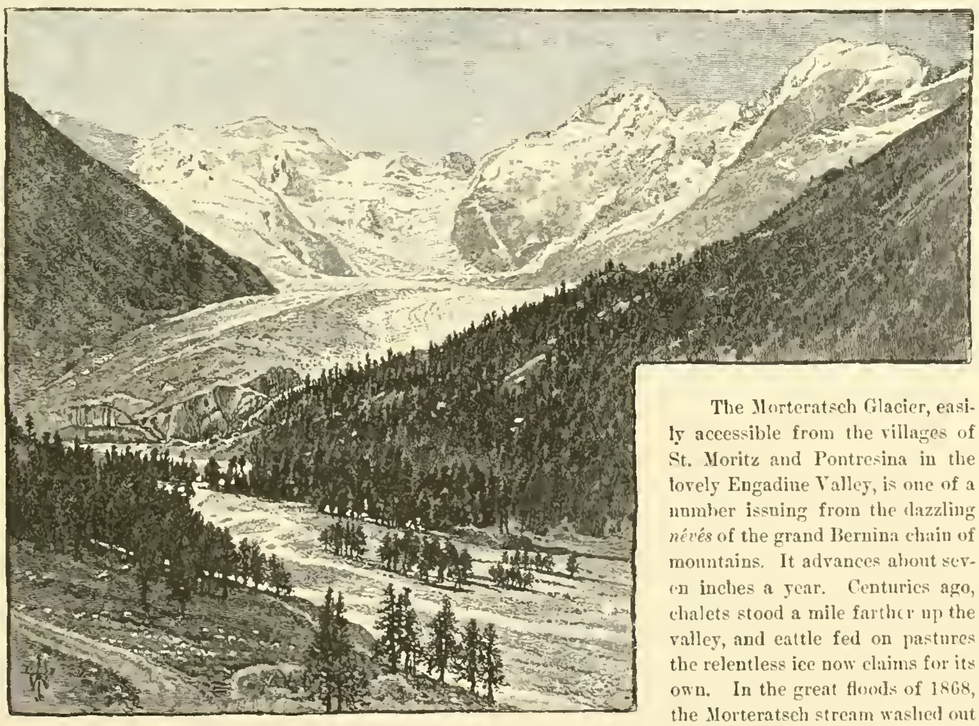
The position of the snow-line is dependent upon the mean temperature of summer rather than upon that of the whole year; upon the proximity to the coast, the exposure to moist winds, and the quantity of snow that can fall at a single place. On the south side of the Himalayas, exposed to the moist winds from the Indian Ocean, the height of this line is about 13,000 feet; on the north side, facing the dry and lofty plain of Thibet, it is 16,000 feet.

The total snow-fall at the summits of lofty mountains, such as the topmost of the Himalayas and Andes, is less than on their flanks, because the rarefied and cold air loses much of its capacity for aqueous vapor. The most abundant snow-fall is at heights of less than 12,000 feet. The wind blows the dry snow from the steep slopes into ravines and valleys, so that often the tallest peaks remain nearly bare.

GLACIERS AND ICEBERGS.

Glaciers.—Wherever large tracts of mountain-surface are exposed above the snow-line, and the annual precipitation exceeds what can be carried off by melting and evaporation, the excess of snow collects in the valleys and moves gradually far below its usual limit. Thus are formed rivers of solid water, called Glaciers.

Above the line where it falls even in summer, snow is soft and powdery, accumulating on the slopes, drifting before the wind, and covering the rocks with a sheet whose smooth surface reaches down to the nearest valley below the snow-line. The warmth of the summer sun melts the surface, so that the mass underneath becomes more or less charged with water, which freezes at night. Groups of feathery crystals are thus gradually compacted into granular masses, while the surface is furrowed by the rills that are daily produced by renewed melting. The water can not fill all the interstices, so that the sun-plowed snow-field only becomes more roughly granular below while new accessions of dry, white powder are received above, and press the compacted granules farther down. The term *névé* is applied to this mixture of clear ice and porous snow.



MORTERATSCH GLACIER, GRISONS ALPS.
(From a photograph.)

The Morteratsch Glacier, easily accessible from the villages of St. Moritz and Pontresina in the lovely Engadine Valley, is one of a number issuing from the dazzling *névés* of the grand Bernina chain of mountains. It advances about seven inches a year. Centuries ago, chalets stood a mile farther up the valley, and cattle fed on pastures the relentless ice now claims for its own. In the great floods of 1868, the Morteratsch stream washed out from beneath the ice fragments of these ancient dwellings.

With increase of pressure, the *névé* passes by insensible gradations into glacier-ice, which in mass appears of a deep greenish-blue tint, but at the surface is always granulated and white. At last the rigid stream reaches so far down that the loss by heat balances the gain from the snow-fields that feed it, and it ends in a rough wall of dirty ice, that arches over the surging waters of a turbid, milk-white stream. (On the formation of glaciers, *see Agassiz's "Geological Sketches," p. 208.*)

Dimensions of Glaciers.—In Switzerland 400 glaciers, varying in length from five to fourteen miles and in width from one half to one mile, are found amid the Alpine valleys. Their greatest thickness is unknown, but is estimated to exceed 1,000 feet.

The Alpine glaciers are insignificant in comparison with those of Alaska and Greenland. The Muir Glacier, discovered in Alaska in 1886, occupies an amphitheatre thirty or forty miles wide, from which nine main ice-streams and seventeen branches unite to form a grand trunk that abuts into the water of Glacier Bay in a wall 5,000 feet wide, and about 700 feet deep. (*See "American Journal of Science," January, 1887.*) The Agassiz and Guyot Glaciers, on the flanks of Mount St. Elias, are hardly, if at all, inferior to the Muir Glacier. In Greenland the glaciers are so numerous and extensive that it is difficult to determine the limits that separate them. The great Humboldt Glacier has a breadth of not less than 115 miles, and its thickness is estimated to exceed 2,000 feet. Nordenskiöld traveled 123 miles inland without discovering a limit to the great ice-field before him; the whole of the interior of Greenland is believed by Markham to be capped by an enormous glacier ever moving toward the coast. (On the existing glaciers of the earth, *consult Professors Shaler and Davis's "Glaciers," p. 8.*)

Motion of Glaciers.—The glacier creeps steadily down its valley at a rate depending upon the supply from its snow-fields, the slope of its bed, and the season of the year. The rate is much faster in summer than in winter, at the middle than at the sides, on top than beneath. Like a river of water, the glacier is retarded where the friction is greatest, adapts its course to its bed, but moves fastest along a line that is more crooked than the valley which guides it. Upon the well-known Mer de Glace in Switzerland, Tyndall found the greatest motion in summer to be twenty inches a day above Montanvert, and thirty-three inches a day where the slope was steeper a short distance farther down.

In August, 1886, the daily marginal motion of the Muir Glacier was ten feet, while that in the center was seventy feet. It was, therefore, thrusting about five million cubic yards of ice each day into the ocean. This rapid rate is due largely to the exceptional amount of precipitation in Alaska, where the annual rainfall is about one hundred inches, and the number of rainy days each year often exceeds two hundred. (On the annual motion of glaciers, *see Forbes's "Theory of Glaciers," p. 123.*)

Daily Loss of Glaciers.—At all times a glacier is losing material by evaporation at its surface. The loss in summer is further increased by melting. Rivulets are formed which cut their way through the blue ice, and pools of water collect in surface depressions and grow into miniature lakes. A lake was discovered in 1842 on the Aar Glacier 206 feet deep and ten acres in extent, with steep walls of ice over which rocks gradually tumbled as the edges melted away. It lasted twenty-four years and traveled 600 feet on the glacier before it disappeared. Many lakes still larger than this have been found on the glaciers of the Himalayas.

The variable ratio between gain and loss causes the lower end of the glacier to vary in position. During a series of winters of greater severity than usual, the gain is more than can be balanced by summer melting. The extremity of the Mer de Glace thus advanced 258 feet during one year, and 470 during another, into the valley of Chamouni. At present (1887) the summer melting is slightly in excess, so that most of the Swiss glaciers are retreating, and have been for twenty years.

Glacial Moraines.—On each side of a moving glacier, rocks and dirt are continually deposited from the mountain-slopes, and are carried on to its lower extremity. Such piles of *débris* are called lateral Moraines (*broken stones*). When two or more glacial branches unite, each moraine continues on its own course, so that long piles may be traced far out on the body of the main trunk. At the lower end they are all deposited in roughly semicircular heaps, varying in position with the advance or recession of the glacier. The terminal moraine is often thousands of feet below the snow-line, that of the Mer de Glace fully 5,000 feet. At the foot of the neighboring Glacier de Bosson are houses and cultivated fields.

Glacial Streams.—The stream of water issuing from beneath a glacier is derived partly from springs, partly from surface-melting, and partly from the melting due to friction at the bottom. It carries in suspension the fine sediment produced by continual grinding, so that the milky-white waters are recognizable after flowing scores of miles. The River Rhône is thus white or cream-colored until it empties into the Lake of Geneva.

Effects of Glacial Motion.—The slow, steady motion of millions of tons of solid ice over the rocky ground tends to grind off rough edges, and score out shallow channels wherever resistance is encountered. The difference in the rate of motion in different parts of the glacier causes the brittle mass to become split into thousands of cracks and crevasses extending down to inaccessible depths. Into these the surface-streams plunge and rocks fall. When firmly imbedded in the ice at the bottom, the rocky masses become the most powerful cutting engines known. There are instances of bowlders lodged in cavities where the water and ice have rolled them for ages against the walls, till all is rubbed smooth within the "pot-hole." On larger masses, systems of parallel lines are scratched; and, where a ledge abruptly ends, a pile of much-worn bowlders is found on its lower side. The traces of glacial action in ancient times are thus always easily recognizable.

At Lucerne, Switzerland, is a remarkable "Glacier Garden." It contains many marks of glacial action, including a number of pot-holes, one of which is thirty feet deep and twenty feet in diameter. Several subordinate cavities have been worn into the rock at the bottom, and in the largest of them rests the rounded bowlder, many tons in weight, that served as the glacial millstone.

Although the frozen surface of a pond or lake is nearly smooth, that of a glacier is very far from being so. Ice-pinnacles and moraines would alone be sufficient to make it rough. But this effect is greatly increased by the erosion of surface-streams, on the same principle by which the land is worn into valleys. In adapting itself to its rocky bed the glacier becomes much broken with fissures, producing ice-faults whose walls show displacements many feet in depth, tilting usually forward. Immense jagged blocks, separated by impassable chasms, jut out in wild confusion.

Theory of Glacier Motion.—Hard, brittle, and stiff as ice is, a horizontal bar of it, if supported at the ends, will slowly bend into an inverted arch when a moderate weight is rested on it for some time at the middle. Ice is, therefore, slightly viscous, like pitch; and a large mass of it, if strongly and gradually pressed, will slowly change in shape. (*Consult "American Journal of Science," vol. v., p. 305.*)

When water freezes, it crystallizes and hence expands. Whatever opposes this expansion tends to prevent freezing, or to promote melting if freezing has already occurred. When two masses of ice are strongly pressed together, even though the temperature be not sensibly raised, there is melting at the surfaces in contact. With relief of pressure the water thus formed immediately freezes again, and the two masses are thus cemented together. This process is called *regelation.*

Regelation may be illustrated by looping a piece of wire over a block of ice supported at the ends, and attaching a weight of ten or fifteen pounds. The wire cuts into the ice, which is melted under the pressure thus applied. The water immediately freezes over the wire, where the pressure is relieved. In this way the block is soon cut in two, but the parts are cemented together at the same time. The support has been severed without being weakened. (On regelation as a cause of glacier motion, *consult Croll's "Discussions in Climate and Cosmology," p. 248.*)

Like all other solids, ice changes in volume when its temperature is changed. Below 32° Fahr. it contracts by continued cooling, and at a rate that is faster than the rate of any known rock or metal, indeed nearly three times that of iron. Among the Alps, at an elevation of 11,000 feet, the extremes of air temperature in the month of August have been ascertained to be 59° F. during the day, and 14° F. during the night. The radiation at such heights is sufficient to reduce the temperature of the snow to 0° F. at times even in summer.

In consequence of these changes of temperature, ice contracts and expands to such an extent that a mass of it a mile in length would be made a foot longer by a rise of 10° F. The force of expansion is irresistible, and *pushes* the lower part of the glacier down the valley. But, if cooled 10° F., and thus made to contract, since gravity prevents any portion from moving up the slope, the upper part is *pulled* downward. Motion thus due to warming and cooling is confined to the surface of the glacier where radiation is free, and to the steep slopes where the *névé* is thin.

A Greenland Glacier, showing the Formation of Icebergs.

Floating Berg.

Aside from motion due to variation in temperature, every glacier is thrust steadily downward by the pressure of ice and snow at the top of the snow-field. Pressure causes melting, and this is followed by regelation of the water, some of which passes still farther down. Pressed over a projection in the valley, the mass splits from the top, and tilts forward. The portion behind it, thus losing its prop in front, soon yields to the pressure in its rear, topples over, and is cemented by regelation to that before it. The summer sun melts the surface-ice; streams of water wash through the crevices and widen them, and every part is continually settling obliquely downward, yielding always in the direction of least resistance, opening in cracks which are then closed by regelation, and thus creeping far below the snow-line.

The ice by gently bending, crushing and melting under pressure, snapping under tension, sliding and toppling over rocks, cementing by regelation, acts like a stiff viscous fluid. It spreads out where the valley is broad, and is squeezed through narrow gorges, changing its rate like a river, according to the width and slope of its bed. Wherever the pressure is strongest the granular mixture by melting and regelation loses much of the air that had been entangled in the snow, and becomes compacted into clear blue veins of nearly solid glacier-ice. These are pressed downward farthest in the middle, and are crossed by crevasses due to the stretching force exerted by the central parts upon the marginal portions. Thus the river of ice moves sluggishly on till it is arrested far down the valley. Here it gives birth to a river of water that loses itself at last in the ocean, is lifted up as vapor into the air, to be wafted back in clouds to the mountain-tops, there to be condensed as snow, and to renew its ceaseless round in the great circulation of Nature. (*Consult Professor Tyndall's "Glaciers of the Alps."*)

Icebergs.—In the polar regions, glaciers extend downward into the sea, and are pushed out until portions are undermined by the action of the waves and currents, and become detached. In some cases this is done gradually and quietly; in others the separation of gigantic masses of ice, toppling into the water, is accompanied with detonations like thunder. These masses are floated off as Icebergs into temperate regions, where they are melted in the warm waters of the great currents from the tropics.

Immense masses of field-ice accumulated along the shores, even where glaciers are absent, become detached in like manner and are floated away. The crew of a wrecked vessel was once drifted 1,300 miles on one of these great ice-floes.

Size and Appearance of Icebergs.—The majority of icebergs from the Arctic regions do not rise more than 50 or 100 feet above the surface of the water. Occasionally one is seen that exceeds five hundred feet in height. If thrown off by a glacier, its surface is rough and ragged, and sometimes scattered over with bowlders, the evidences of moraines. The white glacier-ice is melted by the sun, leaving minarets, towers, and grottoes, through which the light is broken into rainbow hues. A grand spectacle, but one full of danger to the mariner, is a fleet of bergs, with their picturesque cliffs and peaks, moving on slowly but with resistless momentum among floes and fields of ice.

Carrying-Power of Icebergs.—Pure water is densest at 39.2° F. Expanding as it freezes, pure ice is but little more than nine-tenths as dense. With salt in solution, the freezing-point is lowered and the density increased. A cubic foot of pure ice weighs fifty-seven and a half pounds; the same volume of sea-water weighs sixty-four pounds; both being measured at 32° F. Glacier-ice with its entangled air, is still lighter than pure ice, so that about *one-sixth or one-seventh of the whole mass is exposed and the rest submerged.* An iceberg a mile long, half a mile wide, and five hundred feet deep, would hence be capable of carrying over twenty million tons of rock. Large bowlders are thus transported many hundreds of miles and deposited on the bed of the ocean, as the ice gradually melts.

Antarctic Icebergs.—It is in the Antarctic regions that by far the largest icebergs have been seen. These rarely present the evidences of being broken from glaciers, but are for the most part flat-topped, with vertical sides, which on examination show a series of layers, made up alternately of blue ice and white compacted snow. Each layer is thought to represent the snow-fall of a year, so that these icebergs are the deposits of centuries. Some have been seen several miles in length, and as much as 900 or 1,000 feet high.

Making allowance for a submerged part six times as great, icebergs a mile in vertical thickness are not uncommon in these waters. Mr. Croll estimates the thickness of ice accumulated at the South Pole to be not less than seven miles. Exposed land is here a rarity. The Antarctic Continent and waters are alike covered with an ice-cap, from whose edges the supply of icebergs is exhaustless. (*Consult article on "The Antarctic Ocean," in "Popular Science Monthly" for September, 1886.*)

Questions.—Under what conditions does snow fall? Hail? Describe snow-crystals; hailstones. Explain the phenomenon of red snow. At what season of the year, and why, are hailstorms prevalent? What can you say of the annual snow-fall in different parts of the globe? Of the snow-line? Of the snow-fall on the summits and slopes of mountains? Why is the snow-line higher in the Peruvian Andes than at the Equator?

Trace the history of a glacier from the fall of snow on the mountain above to the melting of the ice in a valley or in the sea. Give some idea of the size of Alpine, Greenland, and Alaskan glaciers. Account for glacial motion. What effects are referable to glacial motion? Describe moraines; glacial streams. Explain regelation.

Describe icebergs, and illustrate their formation and their carrying-power. What can you say of the course of icebergs from Arctic waters? of Antarctic icebergs? What effect on our climate have floating bergs?

ATMOSPHERIC ELECTRICITY.

Sources.—Under certain conditions, electricity may be generated artificially by the expenditure of some kind of energy, such as friction, or the motion of magnets, or chemical energy. Its nature is not clearly defined, but many of its laws are well understood. It is continually manifested in the atmosphere; but the sources of atmospheric electricity are not known. The friction of moving masses of air is supposed to have some effect in electrifying the atmosphere. When an area of high atmospheric pressure encroaches upon one of low pressure, the air invariably shows higher electrification.

Definition of Terms.—A body is said to be electrified positively or negatively, according to the quality of its charge. If strongly charged positively, it is said to be at *high potential;* if negatively, at *low potential.* Bodies oppositely electrified attract each other, and if brought near enough each becomes discharged at the expense of the other. Discharge is usually accompanied with the appearance of heat and light, as when a spark is obtained from an electrical machine, or when lightning flashes in the sky. Under proper conditions it is often possible to secure discharge without these manifestations. If the opposite charges are equal, the bodies when discharged are brought to *zero potential.*

Measurement of Electricity.—Electricity, though not a fluid, may be measured like a fluid. Just as we express the height of a waterfall in feet, we may measure the height of electric potential in units called *volts.* Thus the fall of potential produced by the change of electrical energy into heat and light in an average electric arc-lamp is about forty-six volts. If a piece of zinc and a piece of copper be dipped together into a certain mixture of acid and water that acts chemically on the zinc, the difference of potential between the two plates is about one volt.

Electrical Condition of the Atmosphere.—In fair weather, the atmosphere is nearly always electrified positively; slightly at the ground, and much more strongly at great elevations. A fine stream of water-drops falling through the air becomes electrified like it, and, if caught by means of appropriate instruments, the potential of the air may be measured in volts. In this way it has been found that its electrical condition is always variable, but particularly so when a storm occurs. Just before a gentle rainstorm the potential usually falls, often becoming strongly negative. During a violent storm, it alternates from positive to negative with great rapidity and through a wide range.

Thunder-Storms.—Dry air is a poor conductor of electricity, but may be electrified uniformly throughout its mass. Water-vapor is a good conductor, but upon electrified masses of solid or liquid the charge is confined to the surface. Particles of vapor, becoming electrified like the air in which they float, are cooled on ascending; and many such particles become condensed together into a visible drop, whose surface is much less in proportion to its mass than when divided up as vapor. The potential of the drop is, therefore, much greater than before condensation. A dense cloud thus becomes strongly electrified, positively or negatively, according to the condition of the air from which its vapor came.

If two such clouds with opposite charges approach each other, discharge may take place through the intervening air as a stroke of lightning. The sudden heating of the air by this immense spark causes it to expand and immediately collapse. The impulse is transmitted from successive parts of the spark in a series of air-waves, producing the sound of thunder, which continues to roll, as if from many sources, because the sound is reflected many times from houses, hills, and mountains, from clouds, and from masses of air differing among themselves in density.

If a charged cloud approaches the ground instead of another cloud, discharge may take place between it and the earth. The lightning in transmission seeks the best conductor, and thus exposed objects, such as tall trees or houses, are apt to be included in its path, with disastrous effect.

The potential to which a cloud may be charged in summer, when the conditions are such as to produce exceedingly rapid condensation, is incomparably higher than any that can be attained by artificial means. The longest spark ever produced in a laboratory was less than four feet in length. Strokes of lightning several miles in length have been often seen. The potential needed to produce a spark one mile in length has been estimated to exceed a thousand millions of volts in dry air.

The explanation of thunder-storms just given is believed to be the most probable. No certain knowledge is possessed on this subject.

The Aurora is a luminous appearance believed to be of electrical origin. Because first seen only in the northern skies, the name Aurora Borealis, or Northern Lights, was formerly applied to the phenomenon; but its manifestation is quite as frequent and conspicuous in the Antarctic regions.

The sky becomes at first banded with faint, whitish light, which settles into an arch that spans the northern heavens. Beneath this is an unilluminated area that seems unusually dark by contrast. Beams and streamers, most of which are white, passing into yellow, red, and purple, radiate upward, as if from a center, under the arch, and appear to converge toward a point opposite, high in the southern heavens. A line drawn in space from this point to that from which they radiate below the horizon, has the direction of the magnetic line of force along which the dipping-needle is directed at the place of observation.

At the Equator, the aurora is unknown; it is probably never seen within the tropics, and up to latitude 40° north it is rare. The region of greatest frequency is a belt, roughly oval in shape, inclosing the polar regions. On the Continent of Europe and Asia, this belt is about three or four degrees wide, and embraces the most northern parts of Norway, Sweden, Russia, and Siberia. Crossing the Atlantic, it extends farther south, and on the American Continent it includes much of Labrador and Hudson Bay. Its course bears some general resemblance to that of the nearest line of equal magnetic dip. (*See Chart, p. 9.*)

Over its area, eighty or one hundred auroras are displayed annually, those seen from its inner or polar side appearing south of the observer. The center from which these displays appear to radiate seems thus to have some connection with the magnetic pole. But the belt is not constant in position; it swings with the seasons, reaching its most southern line at the time of each equinox, and traveling back farthest north in both summer and winter. In the United States, auroras are most frequent in April and September.

Electrical Character of the Aurora.—While the Aurora is not yet fully understood, all observations point to the conclusion that it may be referred to electrical discharge in the upper and thinner portions of the atmosphere. The height at which the glow begins to be visible has no fixed limit except such as may be determined by the density and humidity of the atmosphere. (On polar light, or the Aurora, *consult Nordenskiöld's "The Voyage of the Vega," p. 35.*)

If a series of electric sparks be passed through air that is gradually made thinner, the changes in appearance are very characteristic. In dry air of ordinary density, an electrified body retains its charge for a long time; but in a vacuum, the charge becomes rapidly lost. In like manner, a large body of air charged to high potential would quietly lose its charge by diffusion upward, if not discharged near the ground as in a thunder-storm. A spark that can not leap across more than half an inch of ordinary air passes easily through eight or ten feet of air whose density is diminished to one three-hundredth, and becomes then diffused, rosy, and stratified in bands. When the air is rarefied to the same degree that obtains at the height of fifteen miles, the electric discharge through it assumes the carmine tint so characteristic of the finest auroral displays.

We have seen that the average barometric pressure over the interior of a great continent is high in winter and low in summer, and that the change from one of these conditions to the other at the time of the equinoxes is accompanied with disturbances, such as storms, which are always preceded by a highly electrified condition of the atmosphere. When precipitation is rapid enough to produce dense clouds and rain, discharge occurs through the medium of lightning. This is the most common method within the tropics. But quiet discharge may also occur, between the earth and upper atmosphere, or between various portions of the atmosphere itself. There is reason to believe that the luminous bands are within ten miles of the earth. Lightning attends cumulus clouds; the aurora may attend cirrus or stratus clouds and haze.

The aurora is most frequent in high latitudes. Even more common than lightning or the aurora in middle latitudes is a phosphorescent appearance of the clouds, due to the silent discharge of electricity between their component particles. (*Consult Report of the Chief Signal-Officer for 1876, pp. 309, 310.*)

Auroral displays are nearly always accompanied with marked disturbances in the electrical condition of the ground as well as of the air. Earth-currents become strong enough to interfere seriously with the business of telegraph-lines. They cause the magnetic needle to sway from side to side, so that the direction of "magnetic north" becomes variable for hours together. To what extent the magnetism of the earth may be connected with the mean electrical condition of the atmosphere is yet unknown. (*Consult "Signal-Service Notes," No. XVIII., on "The Aurora in its Relations to Meteorology," by Alexander McAdie.*)

OPTICAL PHENOMENA.

Most of the **Optical Phenomena** of the atmosphere, aside from those already discussed incidentally, can be satisfactorily explained only with the use of mathematical symbols that would be inappropriate in the present volume.

Whenever light passes from one medium into another, some is absorbed and changed into energy of different wave-length, ceasing therefore to be manifested as light. The rest has its direction altered, part being reflected and part transmitted. If the second medium be denser than the first, the light is retarded, and hence bent toward the perpendicular erected at the point where it strikes.

Mirage near the Suez Canal.

Looming and Mirage.—In the Arctic regions, when the air is calm, the layer in contact with the cold ground or water may become cooler and denser than that at a moderate height. Rays of light from distant objects below the horizon are bent slightly downward, so that, like the morning or evening sun, such objects appear above their true positions. Often they seem distorted or roughly magnified on account of irregularities in the density of the lower air. This apparent elevation of distant objects is called Looming. Though best seen in the Arctic regions, it may be noticed at sea in all parts of the world when the air is calm and warmer than the water below, and it sometimes occurs on land.

Mirage (*mĭ-rahzh'*) is explained on the same general principle as looming. On the burning sands of the Sahara, the lowest layers of air are decidedly warmer and rarer than those a few feet above the ground. Rays coming obliquely down from tall objects near the horizon are hence bent slightly upward and totally reflected from the lower thin medium, as if from a mirror.

An educated surveyor once reported the existence of a large inland lake in the desert region of Australia. On examination, it proved to be only mirage.

(For the explanation of rainbows, of coronas and halos around the moon, and of "mock suns" and "mock moons," the student is referred to Lackland's "Meteors and Atmospheric Phenomena.")

Questions.—Mention the sources of atmospheric electricity. What is meant by high potential? Low potential? Describe the process of measuring electricity. What can you say of the general electrical condition of the atmosphere? Explain the phenomena of thunder-storms.

What is the Aurora Borealis? Where is it manifested, and how is it accounted for? Where is it unknown? Define the belt of greatest auroral frequency. Is this belt constant in position? By what disturbances are auroral displays accompanied? Explain looming and mirage.

PLANT-LIFE ON THE EARTH.

It is the Province of Physical Geography, not only to present a luminous picture of the earth's surface features, its ocean-waters and their movements, its rivers and lakes; to investigate the nature of the atmosphere with its system of circulation, of weather, and of climate—but also to inquire into the character and distribution of life on the globe, and to explain the relation between it and the inorganic world.

Another class of phenomena, therefore, now claims our attention—those connected with Organized Bodies—bodies which are endowed with vitality, and generally possess *organs* on the action of which their growth and development depend. The Organic World consists of plants and animals. Collectively these are often designated as the Vegetable and the Animal Kingdom.

The Organic World differs from the Inorganic in several important respects, other than its existence by virtue of life. These may be briefly summarized as follows:

Organized Bodies	Unorganized Bodies
consist mainly of the four chemical elements, carbon, hydrogen, oxygen, and nitrogen; grow by the assimilation of nutritious matter, and its digestion in their interior cavities; are of definite forms, bounded by curved lines and surfaces; as, for example, a shell.	may contain any of the sixty-five known chemical elements; can only increase in size by accretion of matter on their surfaces; are either of no definite form, or are crystalline; as, for example, salt.

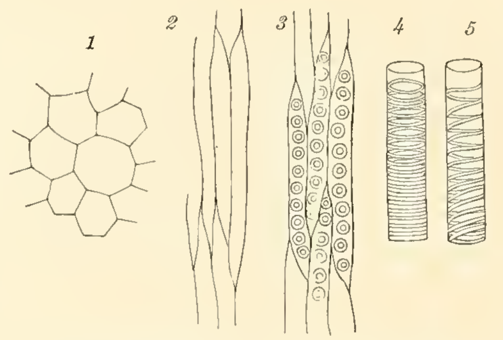
Plants, considered collectively, are less complex in organization than animals. They grow directly from inorganic matter which they assimilate, and transform into food for animals; thus they occupy an intermediate position in the economy of nature. While between the higher developments of the animal and vegetable kingdoms there are very manifest differences, the most simply organized plants so closely resemble the lowest forms of animal life that it is difficult to decide to which kingdom they more properly belong. There are, however, some nearly constant differences between the two, which may thus be briefly expressed:

Plants	Animals
in chemical composition contain more carbon; obtain their food from the mineral kingdom; inhale carbonic acid from the atmosphere, and exhale oxygen in sunlight.	in chemical composition contain more nitrogen; obtain their food directly or indirectly from the vegetable kingdom; inhale oxygen and exhale carbonic acid under all conditions.

STRUCTURAL ELEMENTS OF PLANTS.

Botany (from a Greek word meaning *herb*) is the science of plant-life in its broadest sense. While in the study of Physical Geography we have mainly to consider the geographical distribution of plants, we may also with propriety briefly discuss their structure, their classification, and the phenomena of their growth and multiplication.

Structure of Plants.—All that is known of the minute structure of plants has been learned with the aid of the microscope. This instrument shows that every portion of each vegetable organ consists of an immense number of minute and regularly formed cavities, called Cells. The walls of the cells vary greatly in thickness in different parts of the structure, and the cells themselves are of many different forms and dimensions. Cell-walls form the permanent parts of all plants, and the substance composing them is called *cellulose* in the softer tissues and *lignin* in the woody portions. (*Compare Goodale's "Physiological Botany," p. 25.*)



In the engraving, Fig. 1 represents cells from the pith of the sunflower; Fig. 2, wood-cells of the chestnut; Fig. 3, cedar-cells; Fig. 4, an annular, or ring-shaped, cell from the sunflower-stem; Fig. 5, a spirally marked cell from the same—all magnified one hundred times.

Cells are in general very small, and only in rare cases can they be seen with the unaided eye. The minute structure of the smaller and simpler plants may be studied directly under the microscope on slips of glass prepared for the purpose; but the denser tissues must be cut in very thin sections with a sharp knife before they can thus be examined. The study of plant-tissues is known as Histology. (*Consult Behrens's "The Microscope in Botany."*)

Classification of Plants.—More than 150,000 different species of plants have been described by botanists; new species are constantly being discovered. Those now known may be grouped in five subkingdoms, as follows:—

I. **Protophy̆'ta** (from two Greek words meaning *first plants*—the lowest order), the most simply organized and smallest plants, including bacte'ria (*staff-like forms*), and yeast or ferments. These are very minute, and consist either of a single cell or of loosely aggregated rows or groups of cells, which multiply mainly by splitting in two, or by a budding of new cells from the old.

The bacteria cause the putrefaction of organic matter, and are always characteristic of contagious maladies in man and other animals. It is believed that they are the active agents in the production of many diseases. Yeast causes the fermentation of sugary solutions with the production of alcohol and carbonic-acid, contrary to the action of most plants, which inhale this gas. (*See Grove's "Bacteria and Yeast Fungi."*)

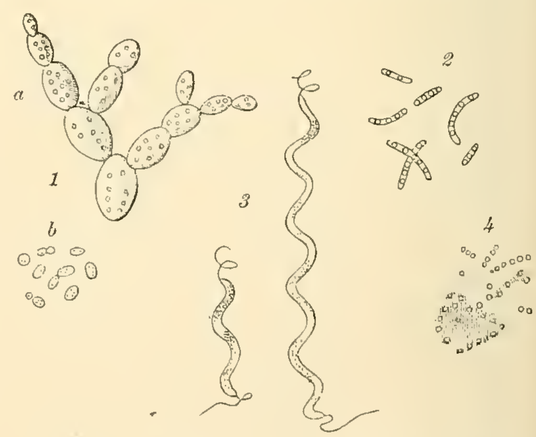
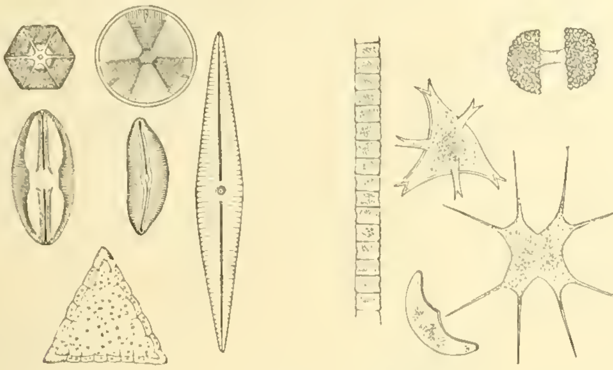


Fig. 1 is the yeast-plant; at *a* and *b* the process of budding, by which new cells are formed, is shown. Fig. 3 represents spiral bacteria; Fig. 2, the bacterium of the disease consumption, known as *Bacillus tuberculosis;* Fig. 4, a group of small globular bacteria, called *Micrococci* (*small kernels*)—all highly magnified.

II. **Thal'lophyta,** plants in which there is no well-marked distinction between stem and leaves, these being merged in a flattened or finely divided structure called a *thallus* (*young shoot*). Under this subkingdom are classed the sea-weeds or algæ (*al-jay*), the fungi (*fun'ji*), and the lichens (*li'kens*). These are mainly reproduced by *spores*, cells of small size which perform the office of seeds in the more highly organized plants. The simplest of the thallophytes are plants of single cells or rows of cells, whose walls are often beautifully marked, the cells themselves being of many curious shapes. These plants are larger than the protophytes, and differ from them also in other respects.

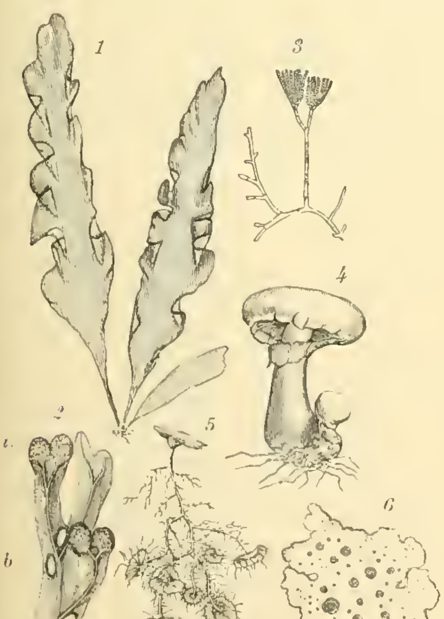
Among the minute algæ are the groups called *di'atoms* (*cut in two*) and *desmids* (*chain-forms*), characterized by their symmetry.



Diatoms and Desmids.

The figure illustrates some of these lowly thallophytes. On the left is a group of diatoms, showing circular, triangular, hexagonal, and elongated forms, with the wonderfully regular and beautiful markings on the cell-walls. The walls are in these plants largely composed of silica; they make up the material known as tripoli or electro-silicon, used as a polishing powder, as well as in the manufacture of the explosive, dynamite. In the figure to the right, is one of the jointed organisms called *oscillatoria*, from its wavy movement in the water. The rest are desmids.

The larger algæ are the common sea-weeds found on the ocean-beach at low tide. The fungi include mushrooms, toadstools, puff-balls, molds, etc.; a white fungus attacks certain species of fish, spreading over their bodies with fatal consequences. The lichens grow on dry rocks, on trunks and branches of trees, on fences, and on the ground. They are very long-lived.



Illustrations of Algæ, Lichens, and Fungi.

In the illustration, Fig. 1 is the common sea-lettuce; Fig. 2, a branch of the rock-weed, with the conceptacles which contain the spores shown at *a*, and the floats which support it in the water at *b*; Fig. 3 is a small fragment of a mold, with its rows of spores at the top, greatly magnified; Fig. 4, a mushroom, with the spores on the *gills*, under the *cap;* Fig. 5 represents a lichen, commonly found drooping from dead branches in the woods; Fig. 6, another lichen, which also grows on trees in flat patches of a gray color, the spores being found in the spots on its surface.

III. **Bry̆ophy'ta** (*moss-like plants*), comprising the bog-mosses, the true mosses, and the liverworts; mostly furnished with stems which bear distinct, small leaves. They are reproduced by spores, which are borne in conceptacles.

Most bryophyta grow on the ground in damp or wet places, or on trees and rocks; a few of the mosses thrive in fresh water, but no members of this family are marine.

IV. **Pter'idophy̆ta** (*fern-like plants*) include the true ferns and their allies, the club-mosses, and horse-tail rushes. These are among the most beautiful and interesting of all plants. They are also reproduced by spores, which in the ferns are generally borne on the under sur-

Illustrations of Mosses and Liverworts.

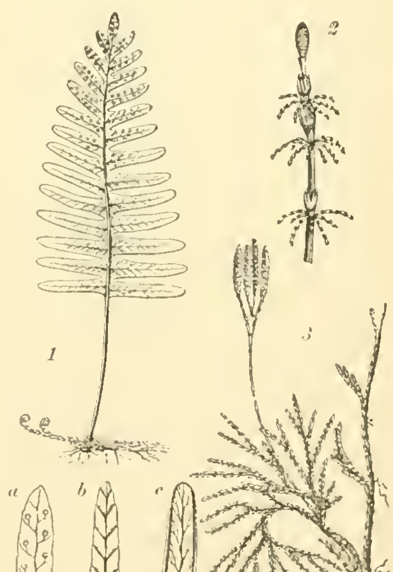
Fig. 1 is a common wood-moss; in Fig. 5, *b* shows the spore-bearing conceptacle, and *a* the same covered with its hood. Fig. 2 is a branch of a bog-moss; the round bodies at the top contain the spores, and one of these further enlarged is shown in Fig. 6, with its lid detached. Figs. 3 and 4 are liverworts, plants intermediate in aspect between the lichens and mosses.

faces of the leaves, and in the other groups on specially modified branches. Pteridophytes grow on the ground, as well as on rocks and trees.

V. **Phan'erogamia** (from two Greek words, implying, botanically, *with visible flowers*) include all the true flowering plants, such as roses, pines, and lilies. Their organs are of two kinds—*vegetative organs*, devoted to the growth and development of the plant itself, comprising the root, stem, and leaves; and *reproductive organs*, the flower, fruit, and seed.

Organs.—The Root, generally buried in the soil, is the organ which absorbs inorganic matter from the earth. It is fibrous in grasses, fleshy in the turnip and sweet-potato, and woody in all trees and shrubs.

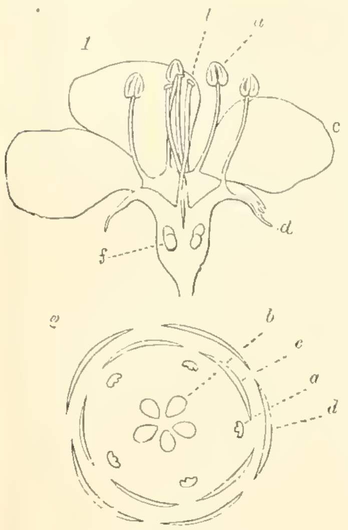
The Stem rises from the root and supports the leaves and reproductive organs. It is herbaceous when soft in texture and lasting only one or two years, and woody in trees and shrubs.



Rock-Fern, Equisetum, and Club-Moss.

In the engraving, Fig. 1 is the common rock-fern; at *a*, *b*, and *c*, are shown the positions of spores on the lower surfaces of various fern-leaves, *a*, in round spots, *b*, in elongated ones, and *c* along the edges. Fig. 2 is a piece of a horse-tail rush (*equisē'tum*), with the spores borne at the top; Fig. 3 is a club-moss, the common trailing Christmas green.

The Leaves are the organs which inhale most of the carbonic acid from the atmosphere, and transform it together with the sap into cellulose and other substances. The breathing-orifices (*stomata*) are mainly on the under sides of leaves, and open into air-chambers in the cellular tissue. They are minute and extremely numerous, 120,000 having been counted in a square inch of surface. Their function is to maintain a circulation between the cells of the interior of the leaf and the outer air.



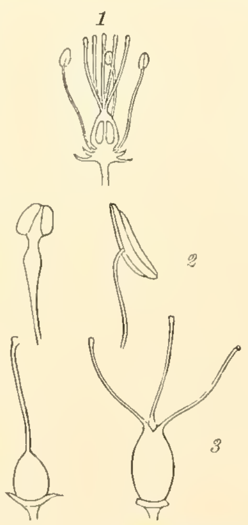
FLORAL ORGANS.

Fig. 1 represents a section through a flower; *d* is the calyx, *c* the corolla, *a* and *b* the essential organs. Fig. 2 is a plan of the same flower.

The Flower, when complete, consists of two external portions called *floral envelopes*, designed in part for protection; and an interior set of *essential organs*, directly concerned in seed-production.

The floral envelopes are the *calyx* (in Latin, *a cup*), consisting of distinct or coalescent *se'pals;* and the *corolla* (in Latin, *a little crown*), composed of leaves called pet'als, delicately or brilliantly tinted in many blossoms.

The essential organs are the *sta'mens* and *pistils.* In the accompanying figure *a* is a stamen, and *b* a pistil. The stamen consists of a stalk or *filament*, on which is borne a sac constituting the *anther*, filled with a dust-like substance known as *pollen*. The pistil is a straight shaft (*style*), dilated at its summit into a glutinous body called the *stigma* and expanded at its base into a cavity, the *ovary*, containing the *ovules* or bodies which are to become seeds (shown at *f*). The anthers, when mature, discharge granules of pollen; these are engaged by the stigma, descend through the tissues of the pistil, and fertilize the ovule, which develops, as the petals and essential organs wither, into the seed or embryo plant. (*See Professor Goodale's* "*The Wild Flowers of America*," *p. 6.*)



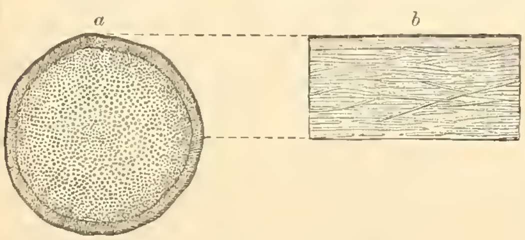
FORMS OF STAMENS AND PISTILS.

In Fig. 1, both are shown together; Fig. 2, stamens; Fig. 3, pistils—Figs. 2 and 3 magnified.

The process of plant-generation is materially aided by insects which, in their search for the nectar, become covered with pollen, and so convey the fructifying principles from blossom to blossom. In some species, fertilization could not be effected without aid of this nature. (On bees and flowers, *consult Buckley's* "*The Fairy-Land of Science*," *p. 212.*)

In certain parts of the world, humming-birds are useful auxiliaries in the transportation of pollen; while the hand of man not infrequently intervenes to practice artificial fecundation.

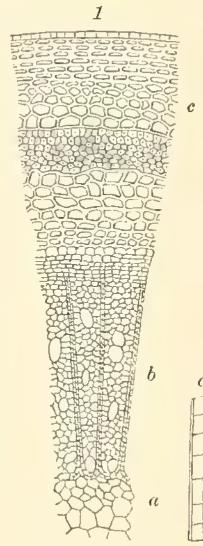
The Fruit is the ripened ovary. The Seeds are the ripened ovules; they contain germs, where the life of the plant is concentrated. (On fruits and seeds, *consult Figuier's* "*The Vegetable World*," *pp. 156–176.*)

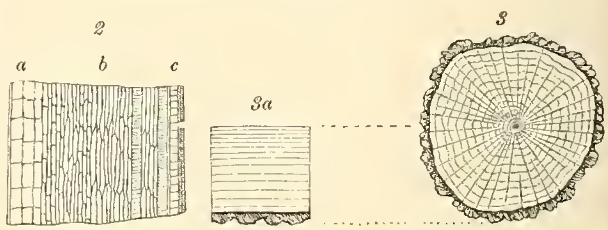


CROSS AND VERTICAL SECTIONS OF ENDOGENOUS STEM (PALM-WOOD).

The Phanerogamia are of two classes, viz., Angiosperms (*an'je-o-sperms*) (from two Greek words meaning *seed-vessels*), with closed ovaries; and Gym'nosperms (having *naked seeds*), with ovaries open, and ovules and seeds thus exposed to the air. To the latter class belong the pines, firs, and giant-trees of California.

The Angiosperms are further divided into two sub-classes, distinguished by the structure of the stem—Endogens, which increase the diameter of the stem by growth from within (the grasses, palms, orchids, lilies); and Exogens, which increase the diameter of the stem by adding layers of wood on those already formed, just beneath the bark (all trees of the temperate zone, as oaks, maples, and birches; gourds, cactuses, the rose family, the grape, buttercups, and many others).



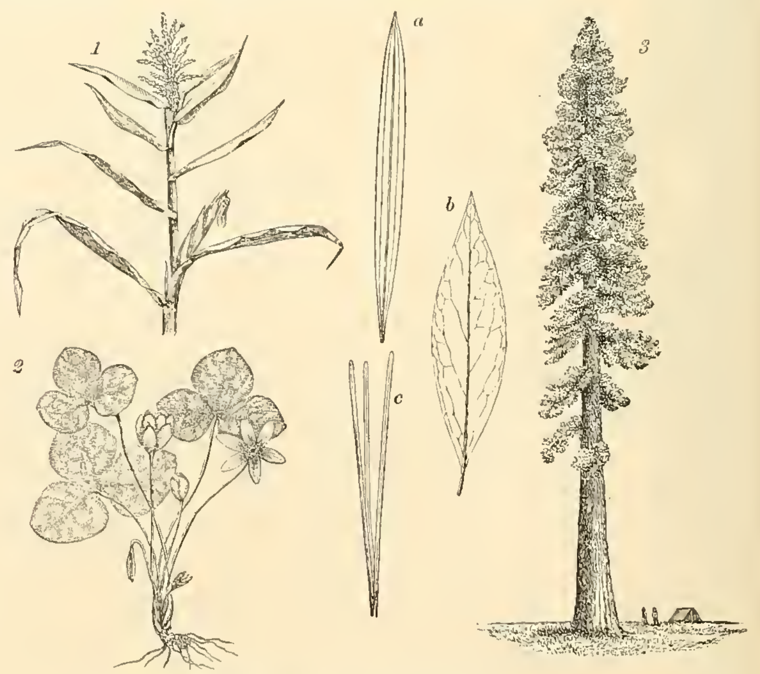


CROSS AND VERTICAL SECTIONS OF EXOGENOUS STEM.

In the cut, Fig. 1 is a segment of a cross-section of an exogen; the *pith* (*a*) occupies the center; then follow the *wood-zone* (*b*), and outside of this the *bark* (*c*). Fig. 2 is a longitudinal section of maple, less highly magnified. Fig. 3 represents a cross-section of the cork-oak, showing the rings of growth, the rays which connect the pith with the bark, and the cork, which is one of the bark-layers on the exterior.

In the temperate zone most exogens form every year a single layer of wood, which, in cross-section, appears as a ring; by counting these rings, the age of a tree can be approximately ascertained.

The cross-section of the palm-stem below (*a*) shows no concentric circles or distinct layers of wood, but a mass of pith through which bundles of woody fiber are distributed without apparent order. In the endogen, growth takes place *toward* the center, the newly-formed wood becoming indistinguishably blended with the other tissue (*b*).



ILLUSTRATIONS OF PHANEROGAMOUS PLANTS.

The engraving represents a group of Phanerogamia. Fig. 3 is the giant-tree of California, which reaches a height of over three hundred feet, and is the largest gymnosperm known; at *c* are needles or leaves of the pine. Fig. 1 is Indian corn, an endogen; endogens generally have parallel-veined leaves, as at *a*. Fig. 2 is the liver-leaf, one of our earliest spring flowers—an exogen; exogens have netted leaves, as at *b*.

PHYSIOLOGY OF PLANT-LIFE.

Processes of Vegetable Life.—In a growing plant, the following interesting processes are constantly going on: Absorption, Circulation, Metabolism, Transpiration, and Respiration.

Absorption.—The root-hairs are constantly absorbing the liquid in the soil. This liquid contains inorganic salts in solution; and, when brought into the plant, forms the crude *sap*. The roots have a remarkable power of selecting those chemical elements most needed by the plant. One species requires more lime, another more silica, a third more magnesia; these substances are supplied by the roots as long as the soil affords them, and, when the available supply of a needed element is exhausted, the plant does not thrive. The farmer thus finds it advantageous to sow different seeds year after year on a piece of ground, as repetitions of the same crop soon exhaust some vital element. Absorption by means of roots is extremely rapid. Some plants absorb more than twice their weight of material in a single season. (*See Johnson's "How Crops Grow."*)

Circulation.—Plants, as well as animals, have a system of circulation. The sap ascends through the woody parts of the stem and branches, under great pressure, in some cases as high as thirty pounds to the square inch. Rising into the leaves and other green portions of the plant, watery elements are largely evaporated, and the inorganic salts left behind.

Metabolism is the collective name for the chemical processes which take place within the plant, transforming the inorganic matters derived from the soil into cellulose, starch, sugar, and other nutritious products. These processes are governed by the *green* coloring-matter *chlo'rophўl*, which occurs as grains in the cells. The carbonic acid taken from the atmosphere is decomposed, and the carbon unites with other elements, which become ultimately new tissue; the oxygen is rejected. It is supposed that the energy exhibited in plant-growth is directly traceable to the chlorophyl, which, by absorbing rays of light, transforms molecular force (*residing in the molecules*, or ultimate invisible particles) into energy. Heat is also an important factor in this process.

Transpiration is the exhalation of water from leaves and green shoots. The amount of water transpired is greatest when the air is dry and warm.

The effects of transpiration may be illustrated by placing a growing plant beneath a glass jar; the under surface of the glass will rapidly become wet with the condensed water from the plant.

Respiration.—Plants, as well as animals, breathe. During the day, and most actively in bright sunlight, their leaves absorb carbonic acid and exhale oxygen through the minute orifices, or *stomata*. Thus they tend to purify the atmosphere, which is constantly vitiated by the impurities contained in the breath of animals, by the products of combustion, decomposition, and volcanic action. Hence the practical value of public parks and window-gardens. In darkness, however, plants absorb oxygen to a limited extent. (*Consult Goodale's "Physiological Botany," pp. 221–372.*)

Aquatic plants obtain their carbonic acid from its solution in water, as fish and other gill-bearing animals extract the oxygen mechanically entangled among the watery particles. Such plants liberate oxygen, which attacks and destroys poisonous organic matter, thus freeing water from its most dangerous impurities. The phenomenal spread of an aquatic weed in certain malarial sections of America is believed to have saved thousands of lives. (*See "A Lecture on Water," by Professor C. F. Chandler, p. 13.*)

GEOGRAPHICAL DISTRIBUTION OF PLANTS.

Floras—Conditions of Distribution.—The entire system of plants native to any region constitutes the Flora of that region. The floras of different districts differ widely, the character of the vegetation depending on differences in the amount of heat, light, and moisture received, on the character of the soil, and on present or former geographical peculiarities.

The Influence of Temperature is marked in the wide differences that prevail between the flora of equatorial and that of polar regions, between the plants that grow at the base of a mountain and those which approach its summit. The effect of an abundant supply of moisture is apparent in the luxurious vegetation of swampy districts or of those having a high annual rainfall, as compared with the meager one of arid regions in the same latitude. The difference is well exemplified in the abundant floras of the Mississippi Valley and the Pacific coast, as contrasted with the scanty vegetation of the plains of eastern Colorado. The influence of light may be inferred from the fact that many plants thrive only in the shade, others only in places exposed to the sun. The nature of the soil is a very important factor. Sandy soils support some species which will not grow at all elsewhere; the saline soils of the sea-beaches and salt-lakes sustain a peculiar type of vegetation; and some plants grow only upon rocks.

The Arrangement of Land and Water in former times has had a most powerful effect on the present distribution of plants. As an instance, we may consider the great similarity of the floras of northern Europe, northern North America, and northern Asia. These regions have a large number of species in common, while others are so nearly alike that they are plainly descended from a common parentage. As a single familiar example, the chestnut is found on all three continents, which in remote times were connected. Present geography limits as well the range of plants. The flora of Australia is strikingly different from that of any other part of the globe, and that of Madagascar appears to be almost as distinct.

Man, by bringing useful and ornamental plants under cultivation, and by unintentionally transporting seeds of weeds in the prosecution of commerce, has greatly altered the natural characters of floras. Thus, the cherry, originating in Asia Minor, the peach in Persia, the lemon and orange in tropical Asia, the potato and Indian corn in South and Central America, are now found cultivated in all parts of the earth where their growth is possible. Many of the weeds troublesome to American farmers, as the ox-eye daisy, the thistle, and the buttercup, are natives of the Old World.

Plant-Zones.—In connection with the prevalent forms of vegetation, the northern and southern hemispheres have been divided into eight Plant-Zones, separated, not by parallels of latitude, but by isothermal lines. They are as follows:—

1. The Equatorial Zone, between the isotherms of 78° north and south.
2. The Tropical Zone, between the isotherms of 78° and 69°.
3. The Sub-Tropical Zone, between the isotherms of 69° and 62°.
4. The Warm-Temperate Zone, between the isotherms of 62° and 53°
5. The Cold-Temperate Zone, between the isotherms of 53° and 42°.
6. The Sub-Arctic Zone, between the isotherms of 42° and 35°.
7. The Arctic Zone, between the isotherms of 35° and 28°.
8. The Polar Zone, from the isotherm of 28° to the pole.

(*See Map showing the distribution of plants and plant-zones, pp. 94, 95.*)

The Equatorial Zone includes the Eastern Archipelago, the two Indian peninsulas, southern Arabia, a large part of Africa, embracing Soudan and Sahara, the northern part of South America, and the southern part of the West Indies and Central America. Its vegetation is most luxuriant. The leaves of many plants attain

VARIETIES OF PALMS.

In the engraving, Fig. 1 represents the date-palm, a native of northern Africa; the dates of commerce are the fruit, and grow in bunches at the summit. Fig. 2 is a graceful Central American palm; and Fig. 3, the cocoanut-palm, now found throughout the tropical regions of the earth.

an enormous size, while the flowers are large and brilliant. The trees grow closely together and to great dimensions. Huge climbing plants stretch from one to another, and the dense masses of vegetation are sometimes quite impassable without the use of the axe.

Palms are the most characteristic trees of the Equatorial Zone. Their general habit of growth consists in the production of an upright cylindrical trunk, often a hundred feet in height, without branches. This is surmounted by a tuft of magnificent leaves, ten or fifteen feet long and three or four feet wide, their divisions arranged *palmately* (as the *fingers* of one's hand), or *pinnately* (like the divisions of a *feather*).

Many species of palms are of the greatest use to mankind. The date-palm yields an important fruit, oil is produced from several kinds; a valuable wax is obtained from a Brazilian palm, and the nuts of another yield the vegetable ivory; the tender tissue of the stems of other varieties forms the sago of commerce, and wine is made from the juice of still different species.

The cocoa-palm is the most valuable of all. The natives of tropical regions obtain from this tree almost everything necessary to existence. The nuts, which grow in clusters at the top, furnish nutritious food, the milky contents supplying also a delightful drink; a great variety of utensils is made from the hard, internal shell. The sap contains much sugar, and when boiled with quick-lime forms a strong cement; fermented, it becomes wine, and, on further fermentation, vinegar; the wine, when distilled, yields the intoxicating liquor known as *arrack*. Oil is expressed from the fresh kernel, and used as a food as well as for illumination. The young tufts of leaves are palatable, and form a substitute for cabbage. The wood is put to a great variety of uses. The fibers of the leaves are woven into sails, cloth, matting, brooms, baskets, and hammocks. Those of the external husk are employed in calking boats, and are made into cables and cordage.

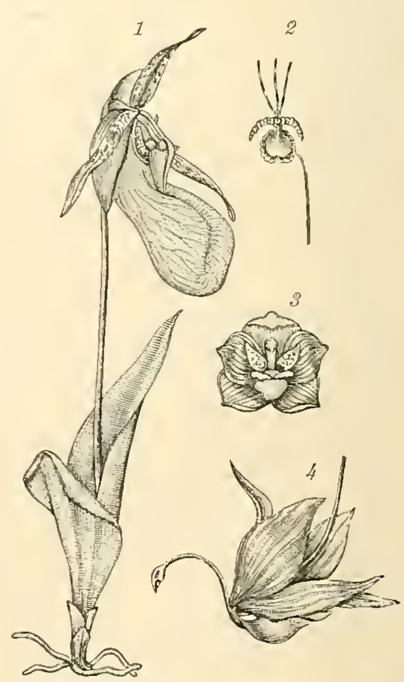
Among other important trees of this zone are the mahogany of South America; species of *bombax*, the silk-cotton tree of Brazil and equatorial Africa; the banyan or pagoda tree of India, from whose branches aërial roots descend, enter the ground, and become new trunks, so that a single tree covers a great surface. The baobab-tree, a native of Africa, attains the enormous circumference of eighty to one hundred feet.

Orchids (*or'kids*) abound in the damp forests of the Equatorial Zone in both hemispheres. They are often found resting on the trunks and branches of trees to which they are loosely attached by long, fleshy roots. They obtain no nutriment from the plants on which they grow. *Ep'iphy̆tes*, as plants which *grow upon* other plants are called, draw all their food from the atmosphere, differing in this respect from *parasitic* plants, like the mistletoe and fungi, which live on the juices of their neighbors.

Orchids are a particularly interesting order of plants by reason of their very irregular and remarkably shaped flowers, often richly colored and odorous, in many cases resembling birds and insects. Their fleshy roots and stems assume most grotesque forms. The flavoring extract vanilla is obtained from the fruit of orchids native to Brazil, the West Indies, and Central America. The nutritious substance called *salep'* is derived from the roots of certain European and Asiatic species.

While the orchids are most abundant and vigorous in the Equatorial Zone, they occur also in other regions. About 110 species are natives of North America, and many of these grow directly in the ground, though a few of the more southern are air-plants.

Enormous climbing plants of many different kinds; the important food-plants, the banana and the plantain; the giant water-lily of the Amazon, the *Victoria regia*, with its leaves six feet across and its showy flowers two feet in diameter; and the calla-like plants, called *a'rums*, which bear immense leaves — also characterizes this zone. Mention should further be made of the *u'pas* (*poison*) tree of Java, from whose sap the natives extract a deadly substance to tip their arrows. Animals wounded with one of these poisoned shafts die almost instantly; even handling the foliage is attended with evil consequences.



ORCHID FLOWERS.

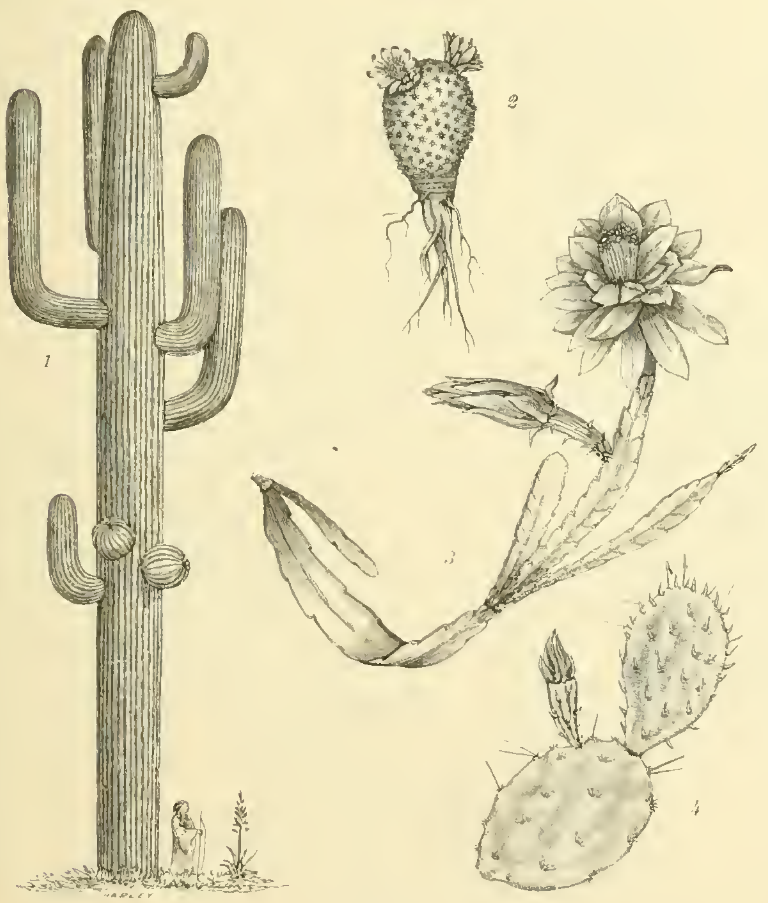
In the engraving, Fig. 1 represents a common North American orchid, known as the pink lady's-slipper; Fig. 2 is an orchid-flower resembling an insect; Fig. 3 suggests a dove with spread wings; and Fig. 4 is another bird-like orchid blossom.

Tree-ferns are a prominent feature. Their trunks are erect, straight, cylindrical columns, without branches, supporting tufts of leaves—which give them the appearance of palms. Their delicate, graceful foliage adds much to the beauty of tropical landscapes.

The Tropical Zones.—The north tropical zone includes a narrow belt of southern Asia and northern Africa, the West Indian Islands, and part of Mexico. To the south tropical zone belong the northern half of Australia, Madagascar, Africa from the Kongo basin to the latitude of the Orange River, and in South America most of Brazil, Bolivia, and Peru.

The vegetation of these countries resembles that of the equatorial zone. Palms, bananas, orchids, calla-like plants, and tree-ferns, abound. The pineapple, the fig, cotton, coffee, and sugar-cane, are widely distributed. The bread-fruit tree, a plant related to the fig, is native to many islands of the Pacific; it has been introduced into the West Indies. The papaw is also an important fruit, native to the West Indies and other parts of tropical America.

On the arid plains of southern Mexico, numerous species of cactus (*prickly plant*) are found. These plants are remarkable for their peculiar forms; some branch toward the top, others consist of thick, fleshy joints. The leaves are generally small, in most species reduced to mere spines. In the cactuses, the green stems and branches perform the ordinary functions of leaves.



Types of the Cactus Family.

In the engraving, Fig. 1 represents the giant cactus of Mexico and the southwestern part of the United States; Fig. 2, a small, very spiny species of the same region; Fig. 3, a red-flowered cactus from Brazil; and, Fig. 4, one of the common prickly pears.

One species of cactus forms a great ball, sometimes several feet in diameter, ribbed and covered with bristling spines. Another supports the cochineal insect, from which the brilliant, crimson dye is obtained. Other varieties, known as prickly pears, bear edible fruits. The night-blooming cereus, famous for its large, white, fragrant flowers, is a cactus, native to the West Indies and Central America.

The cactuses are not all confined to the warmer parts of the globe; a few of the prickly pears extend into the warm-temperate zones, and one species is found in the northeastern part of the United States.

The Sub-tropical Zones (including the southern extremities of Europe, the opposite shores of Africa, and the Gulf region of the United States), with their hot summers and short mild winters, form the transition between the tropical and temperate regions; their flora combines the characteristics of both. Much of the vegetation is green throughout the year. The laurel and myrtle, magnolia and fig, occupy a prominent place in the flora.

The remarkable *dragon's-blood* trees of the Canary Islands and the west coast of Africa, whence is obtained the resinous coloring-matter used for tingeing varnishes and staining marbles and plasters, are natives of the north sub-tropical zone. The celebrated tree of Teneriffe is stated to have been seventy feet high and forty-eight feet in circumference, and was worshiped by the aboriginal inhabitants. It was completely destroyed in 1867.

The evergreen cork-oak of southern Europe and northern Africa is also a characteristic tree of the north sub-tropical zone. The cork of commerce is the outer layer of the bark. The tree, which attains a height of about thirty feet, is not subjected to the operation of *barking* till it has reached the age of fifteen or twenty years; after which it is regularly stripped every eight or ten years, each time yielding a finer quality of cork. It continues to be productive, and to thrive under this treatment, for more than a century.

Roses are largely grown in this zone (especially in Turkey and Persia) for the purpose of manufacturing attar and rose-water. The flowers are gathered at sunrise and distilled the same day; but they contain the fragrant oil in such minute quantities that it requires more than a thousand roses to yield two grains of the costly attar. From the petals are made conserve and infusion of roses, agreeable medicinal preparations.

The bamboo, a tree-like grass growing to a height of fifty or sixty feet, has been called "one of Nature's most valuable gifts to uncivilized man." Its slender stem, from five to fifteen inches in thickness, is divided into joints, and develops so rapidly that it attains its full height in a few months; a growth of two and a half feet has been observed in a single day. A decoction of the leaves of the bamboo furnishes a valuable medicine; its seeds are a favorite food; and its tender shoots are eaten like asparagus, or made into pickles and confections. A great variety of utensils is manufactured from its stem, and paper is made from its pulp. Its joints serve as water-buckets and cooking-vessels; small ones, as bottles. Dwellings are constructed entirely out of this plant; and vessels are rigged from its various parts.

Bamboos are extensively imported for a variety of purposes, especially for basket- and wicker-work; carefully selected strips of a certain species are united to make the "hexagonal split-bamboo" rod of the modern angler. (On the bamboo and its economic importance, *consult* "*The Treasury of Botany*.")

The Warm-Temperate Zones.—In these zones many plants are still evergreen. A few palms are found, such as the palmetto of the southern United States, a small species in southern Europe, and others in Chile. The north warm-temperate zone is characterized by forests of deciduous trees (whose leaves *fall* in autumn), such as oaks, elms, etc., and by the fig, orange, pomegranate, peach, olive, and grape; in the south warm-temperate zone grow many large grasses, like the pampas-grass of the Argentine Republic.

The mammoth trees of California (*Sequoia*), the mulberry whose leaves supply the silk-worm with food, the camphor-tree, and the camellias of eastern Asia, are important elements of the flora.

The tea-plant is allied to the camellias. There are numerous varieties produced by cultivation, but all are now generally regarded as belonging to one species. They are both wild and cultivated in China and Japan; the area devoted to the cultivation of tea in China is 25,000,000 acres. The beverage was first introduced into England about 1610. Numerous substitutes have been tried for tea, but none have met with much favor. Attempts to cultivate it with profit in the United States have hitherto proved unsuccessful. (*See Money's "Tea-Cultivation."*)

PLANT ZONES

ILLUSTRATING THE DISTRIBUTION OF

PLANT LIFE ON THE EARTH.

Questions on the Map of Plant Zones.—Locate the eight plant zones on the map, and notice the isotherms by which they are bounded. Which of the plant zones has the most luxuriant vegetation? In what plant zone do you live? Why do the boundaries of the more northerly zones run so far north in the Eastern Continent? What are the climatic limits of the growth of maize? The ranges of the tree-fern and the fig? Point out the native country of the potato, yam, maize, millet, coffee, caoutchouc. Name any marine plants you may find noticed on the map. Enumerate the forest-trees that accompany pines in the temperate latitudes of the United States. What corresponding trees are found south of the Equator?

Mention the food-plants of the coldest portions of the globe; of the warmest. What plants are most widely distributed? How far does a knowledge of geology help to explain an apparently wide range in the distribution of certain plants? How far do islands exhibit the vegetation of adjacent continents? Point out the striking botanical features of the Amazon Valley; of the west coast of Africa; of the Mediterranean shores; of Mexico; of Siberia; of the Sandwich Islands. What are the peculiarities of Australian vegetation? Compare the vegetation of the Pacific coast of North America with that of the Atlantic shore. Enumerate the characteristic fruits of southern Asia; of tropical Africa; of southern California; of the islands of the Pacific Ocean.

What is the range of tobacco? of the banana? of indigo? of sugar-cane? Where is amber found? peat? bog-moss? myrrh? copal? the aloe? the mango? vanilla? sarsaparilla? In what part of the globe are the spices of commerce largely cultivated? Where does the castor-oil plant grow?

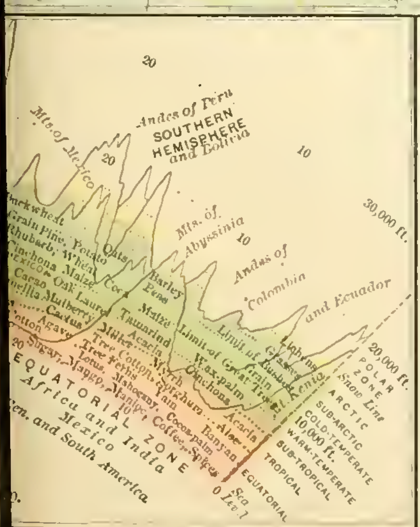
VERTICAL PLANT ZONES

IN THE NORTHERN HEMISPHERE,

From their Latitude at Sea-level to their Altitude at the E

NOTE.—*The Vertical scale is in proportion to the scale of Latit*

Longitude from Greenwich
East West
POLAR ZONE
ARCTIC ZONE
SUB-ARCTIC ZONE
COLD-TEMPERATE ZONE
WARM-TEMPERATE ZONE
SUB-TROPICAL ZONE
TROPICAL ZONE (NORTH)
EQUATORIAL ZONE
TROPICAL ZONE (SOUTH)
SUB-TROPICAL ZONE
WARM-TEMPERATE ZONE
COLD-TEMP. ZONE
SPITZBERGEN
NOVAIA ZEMBLA
NEW SIBERIA ISLES
WRANGEL
KARA SEA
TUNDRA
Bog moss and Peat
Lichens
Saxifrages, Mosses.
Shrubs, Dwarf Birch, Polar Willow,
Dwarf Willow and Birch, Stunted Pine,
Alder, Juniper Berries, and Bushes
ARCTIC CIRCLE
EXTENSIVE FORESTS OF LARCH,
WITH PINE, ASH, ASPEN & WILLOW INTERMINGLED
SIBERIA
Frozen Swamp
Buttercup
Hemp
Flax
Barley
Oats
Buckwheat
North Limit
EXTENSIVE FORESTS OF FIR, SPRUCE, ASH AND PINE
EUROPE
ASIA
Oak and Beech
Grass Steppes
Summer Desert
Trees without
Desert of Gobi
Scanty Vegetation except Summer Grass, Rushes, Prickly Shrubs
OKHOTSK SEA
BERING SEA
ALEUTIAN IS.
JAPAN SEA
Black Sea
THIBET
HIMALAYA
CHINA
INDIA
ARABIA
ARABIAN SEA
BAY OF BENGAL
CEYLON
CHINA SEA
PHILIPPINE ISLANDS
MARIANA OR LADRONE IS.
MARSHALL IS.
CAROLINE IS.
GILBERT IS.
PHOENIX IS.
ELLICE IS.
SOLOMON ISLES
NEW GUINEA
NEW HEBRIDES
FIJI IS.
SAMOA IS.
FRIENDLY IS.
NORFOLK I.
TROPIC OF CANCER
EQUATOR
TROPIC OF CAPRICORN
North Limit of Palms
Southern Limit of Palms
Cocoa-nut, Sago, and Cabbage Palm
Bread-fruit Tree, Sugar-cane, Plantain, Paper-mulberry
SUMATRA
JAVA
ISLANDS
MADAGASCAR
MAURITIUS I.
AUSTRALIA
Treeless Region of Rushes
Native Grass
TASMANIA
NEW ZEALAND
Kauri Pine
INDIAN OCEAN
Extensive Regions of Sea-weed, Algæ, etc.
Desert
Stunted Grass and Shrubs
Tea
Rice
Cotton
Coffee
Sugar-cane
Date-palm
Dates
Olive
Mulberry
Cocoa-nut Palm
Cinnamon
Cassia
Teak
Bamboo
Eucalyptus
Gum-tree
Acacia
Gigantic Ferns



SOUTHERN HEMISPHERE
Andes of Peru and Bolivia
Mts. of Mexico
Mts. of Abyssinia
Andes of Colombia and Ecuador
30,000 ft.
20,000 ft.
10,000 ft.
Sea
0 Feet
Snow Line
POLAR ZONE
ARCTIC
SUBARCTIC
COLD-TEMPERATE
WARM-TEMPERATE
SUB-TROPICAL
TROPICAL
EQUATORIAL
EQUATORIAL ZONE
Africa and India
Mexico
Cen. and South America

MAP TO ILLUSTRATE PLANTS HAVING IMPORTANT COMMERCIAL PRODUCTS.
Timber Trees
North Limit of the Growth of Cereals
TIMBER TREES
FORESTS
EQUATOR
Wheat
Potato
Grapes
Coffee
Cocoa-nut Palm
Sugar
Tobacco
Cotton
Rice
Tea

The Cold-Temperate Zone, in the northern hemisphere, includes the State of Washington and British Columbia on the Pacific, the northern parts of the United States, central Europe, and the more southerly regions of central Asia. In the southern hemisphere, Patagonia, the southern portion of New Zealand, and part of Tasmania, are the principal land-areas that belong to this zone.

Its flora is characterized by forests composed of conifers—as pines, firs, hemlocks, cedars, larches, the gigantic redwood of the Pacific coast of North America—with many deciduous trees. The conifers are the most marked feature. Most of our wheat is produced in this zone, the plant finding here favorable conditions for its growth.

The Sub-arctic Zone, represented in the southern hemisphere only by a few barren islands, includes in the northern the Pacific shores of Alaska, portions of Canada and the northern United States, Newfoundland, Iceland, most of Norway and Sweden, and a belt of land extending from central Russia to the Japan Sea. The low mean annual temperature of these regions would restrict vegetation still more than it does, were it not for the long summer days. In certain sections, the grains mature and even thrive. The birch, willow, fir, and hardier pines, are the representative trees. The swamps are generally filled with peat. Eatable kinds of sea-weed are collected on the coasts.

CHARACTERISTIC ARCTIC PLANTS.

Fig. 1 is an Arctic lichen; Fig. 2, a species of wintergreen from the Antarctic zone; Fig. 3, an Arctic willow; and Fig. 4, one of the Arctic grasses.

The Arctic Zone includes a narrow belt north of the sub-arctic. Vegetation generally is dwarfed and stunted. Wide regions on the northern boundary of this zone are covered with lichens, which furnish the reindeer its food. A few grasses are found. Bog-mosses are abundant.

The so-called "reindeer-moss" is really a lichen. It grows directly on the ground, and in immense quantities. As the reindeer is an all-important animal to the Laplanders and other high northern races, this little plant may be regarded as indirectly the source of their support.

The Polar Zones comprise, in the north, the northern extremities of Europe, Asia, and America; and in the south, the Antarctic Continent.

The vegetation is mainly composed of lichens, and of bog-mosses, which form the tundras. There are no trees, and the only woody plants are the dwarf polar willows, attaining a height of but a few inches; one might crush a forest with his foot. Rushes, several species of the buttercup family, and a few grasses are found in some places.

The climate of Spitzbergen, being tempered by the Gulf Stream, allows there a more abundant flora. (On Arctic vegetation, *consult Nares's "Narrative of a Voyage to the Polar Sea," p. 140.)*

Plant-Life at Different Heights.—As elevation above sea-level modifies heat, so it affects vegetation. If we ascended a tropical mountain to a height of 15,000 feet, we should have a succession of climates and plant-belts similar to those met with in going from the Equator to the Arctic regions.

Questions.—What is meant by the flora of a country? How do plants differ from animals? From inorganic matter? How many species of plants are supposed to exist? Name, define, and illustrate the five sub-kingdoms into which they have been divided. What are floral organs? Explain the functions of the root, the leaves, the flower; the difference between endogens and exogens; between evergreen and deciduous trees.

Name and explain the several processes of vegetable life. How is vegetation influenced by climate? Mention the eight plant-zones, and the characteristic species of each. Show that the distribution of plants varies with difference of level as with difference of latitude.

PLANT-PRODUCTS.

Man obtains from the Vegetable Kingdom many products necessary to his welfare; indeed, he can exist on these alone.

The plants most important to man may be included in the following groups: 1. Food-plants. 2. Plants yielding fibers. 3. Timber-trees. 4. Plants yielding sugar. 5. Medicinal plants. 6. Plants yielding beverages. 7. Dye-plants. 8. Spice-plants. 9. Plants yielding oils, gums, and resins. 10. Plants yielding narcotics.

Food-Plants comprise cereals, tuberous and bulbous plants, plants bearing edible fruits, and plants yielding succulent stems or leaves.

Cereals are the grain-producing grasses; the most important being wheat, rice, Indian corn or maize, oats, barley, and rye.

Wheat.—Of the cereals, wheat is the best adapted for the food of man, as it contains all the elements necessary to support life. At the present day, wheat is grown most extensively in the temperate zones. It has been cultivated from remote antiquity; but its native region is not definitely known. It will not grow in hot countries at sea-level, but thrives at elevations of from 8,000 to 10,000 feet.

Rice is second only to wheat as an important food-product. It is the chief support of the inhabitants of western and southern Asia, where it is probably indigenous, and is largely used in all warm countries. It has been cultivated from prehistoric times.

Millet (from the Latin *mille*, a *thousand*, in allusion to its fertility) comprises a number of important cereals, long cultivated in the eastern hemisphere. The grain is extremely nutritious. It is estimated that one-third of the inhabitants of the globe subsist on the millets.

Indian corn is a native of Central or South America, but exactly where it originated is as yet unknown. It was cultivated by all the American tribes, and at the time of Columbus was a staple article of food over the greater part of both the American Continents. It was soon exported to Europe.

Oats are considered by De Candolle as native to eastern temperate Europe. They are mainly cultivated in northern and western Europe, and the northern United States. With us, their principal use is as food for stock.

Barley has been under cultivation since early ages. It has never yet been certainly found in a wild state, and its native home is but a matter of conjecture. Barley matures in colder climates than the other cereals, and is the most important food-plant of Siberia and northern Europe. Rye, also, is most prolific in northern regions. It probably originated in eastern Europe, but is not now known in a wild state.

Buckwheat, though not a true cereal, should be noted in this connection. It has been found wild in Mantchooria, and its origin is undoubtedly Asiatic. It is extensively cultivated throughout the north temperate zones. (*Compare De Candolle's "Origin of Cultivated Plants."*)

Tuberous and Bulbous Plants.—The most important plants of this class are the potato, yam, and manioc.

The potato, a native of Chile, and perhaps of other portions of the Andes, is now cultivated in all parts of the civilized world. The tubers are thickened portions of subterranean branches of the plant, and not roots.

The sweet-potato probably originated in tropical America, and is of wide-spread cultivation. It bears true thickened roots.

Several species of yams are raised in the warmer regions of the globe. Their roots grow to great dimensions, sometimes weighing forty pounds or more.

The manioc is a shrub with large roots, native to tropical America, and cultivated there, in Africa, and in parts of Asia. The roots contain a poisonous juice, which is separated by grinding, washing, and baking. The residue is called *cas'sava*, or when further purified *tapioca*, and is a most important food-product.

Onions are true bulbs. The plant belongs to the lily family, and is stated by De Candolle to be wild in central or eastern Asia; it was cultivated by the ancients.

Plants bearing Edible Fruits.—Among herbaceous plants of this class, the beans are the most important; through cultivation, they have developed into a great many varieties. Peas, also, are here to be noted; and the numerous kinds of berries, including the grape. There are also many trees bearing edible fruits.

THE BANANA AND THE PINE-APPLE.

The apple is a native of Europe; the pear, of Europe and Persia; the plum, of Europe and western Asia; cherries, peaches, and apricots, are of Asiatic origin. Bananas are generally considered indigenous to southern Asia; they are more properly perennial herbs than trees, as their stems do not become very woody.

The mangosteen is a most delicious fruit, about the size of an apple, reddish-brown in color, with a thick, nutritious rind. It grows wild in the Sunda Islands and the Malay Peninsula, and is cultivated in Ceylon.

The mango is an important East Indian fruit. It has been introduced into tropical Africa and America.

The fig is regarded as a native of the Mediterranean region. The tree is allied to the mulberry, but the form of fruit is very peculiar, being a fleshy, hollow sac. It is extensively cultivated in all tropical countries. The dried figs of commerce come mainly from Turkey and the islands of the Mediterranean.

The pineapple is an important and familiar fruit, native to tropical America, and cultivated with some success in Florida.

The bread-fruit tree grows from thirty to forty feet in height, and has large, deeply-parted leaves. The so-called *fruit*, a foot or more in length, is of a spongy consistence, white, and nutritious. The true fruits are nuts, imbedded in this mass; but they are rarely produced by cultivated plants. The bark of the bread-fruit tree is composed of very strong fibers, from which a fine cloth is woven.

Plants bearing Succulent Stems or Leaves.—Among these are several of our common garden vegetables—cabbage, lettuce, celery, and spinach.

The cabbage is probably of European origin. It is found in a wild state on the coasts of Denmark and the British Isles, and on the northern shore of the Mediterranean Sea. Numerous varieties have been produced by cultivation, among them cauliflower and broc'coli. The many cultivated forms of lettuce are generally regarded by botanists as originating from the wild prickly lettuce, which grows in southern Europe, northern Africa, and western Asia. Celery is common as a wild plant from northern Europe to India.

Plants yielding Fibers furnish materials for thread, clothing, ropes, etc. The most important are the cotton-plant, hemp, flax, and jute.

Cotton is the long hairs attached to the seeds of the cotton-plant. These seeds are borne in a pod, which bursts when ripe, allowing them to be wafted through the air like thistle-down. The object of these hairs is to facilitate the natural distribution of the seed; but man has taken advantage of their structure, and from cotton many fabrics are woven, notably muslin and calico.

Botanists at present regard the cotton-plant as of three species—the Tree-Cotton, a native of tropical Africa; the Barba'dos Cotton, of a great number of varieties, most probably native to tropical America, and including the valuable Sea-Island Cotton, growing on islands along the coasts of South Carolina and Georgia; and the ordinary Herbaceous Cotton, of very ancient Asiatic cultivation, the commonest in Europe and the United States.

Hemp, a native of western Asia, where it is yet found wild, is extensively cultivated in the north temperate zone. A very strong fiber is obtained from it, and woven into cordage, ropes, etc. The greater part of the supply comes from Russia. In the mountainous districts of India, the plant is dried and smoked, or macerated in water, to form an intoxicating drink.

Flax is an important textile fiber obtained from the bark of an herbaceous plant, doubtless indigenous to the Old World, and in one form still found wild in northern Africa and western Asia. The woven fiber is called linen. The seeds form an article of commerce; and from them linseed-oil is expressed, of which large quantities are used in the manufacture of printers' ink. The residue from dressing the fiber is called tow.

Jute is a fiber obtained from the stems of a plant extensively cultivated in southern Asia. It is woven into mats, canvas, and other articles. Jute has been introduced into tropical Africa and America.

Timber-Trees.—Pines and other conifers are the most important timber-producers. There are about seventy species of pine known, thirty-five of which are natives of the United States. Of these, the most important are the white-pine, which forms the forests of the northern and northeastern parts of our country; the long-leaved pine and Georgia pine of the southern Atlantic States; and the western yellow-pine of the Rocky Mountain region. Among other coniferous trees are the spruces, firs, white and red cedars—the former extensively used for shingles and the latter for lead-pencil wood—the southern bald cypress and the redwood of the Pacific coast. The Scotch fir is the most important timber-tree of western Europe.

Of oaks, there are a great many species. The live-oak of the Southern States, and the white-oak, are the most valuable; in Europe, the English oak and the Turkey oak. The locust yields a very hard and durable wood; the chestnut is much used for railroad-ties. The maple, ash, and tulip tree, are extensively employed for indoor work.

Among familiar tropical woods are the rose-wood and mahogany. Brazil is wonderfully rich in beautiful wood products.

Forestry.—The care and cultivation of forests are subjects to which marked attention is paid in Europe, and which are beginning to assume great importance in America. The error involved in the indiscriminate cutting of trees is now apparent, through agitation and discussion by societies and newspapers. From all parts of our country where the forests have been cleared, comes the complaint of diminished water-supply. Rains are less frequent and heavy, springs and streams dry up; snow does not fall in sufficient quantities to protect the ground in winter, and all the evils of excessive drought are experienced in summer. (*See Dr. Brown's "Forests and Moisture," p. 165.*)

Forest-cover determines the water-supply of a region, which is invariably diminished or irregularly dispensed in countries that have been subjected to reckless denudation. By storing up the rainfall in the spongy soil about their roots, and mechanically keeping it back while protecting it by their leaves from evaporation, forest-trees tend to distribute it gradually and uniformly in the natural river-channels. In a denuded region, it runs rapidly into the valleys, and swells the streams to dangerous proportions.

In mountainous countries, forests act as barriers against avalanches; while their roots, extending deep into the soil, prevent its being easily loosened by melting snows. Many villages in Switzerland and northern Italy would be uninhabitable were it not for the wooded tracts above them. Forests also serve to retard the progress of storms and modify the violence of winds; thus they give important protection to cultivated districts, and tend to prevent sudden and extreme changes of weather. Their leaves, falling periodically, decay and enrich the neighboring land. (*Consult Professor Hough's "Elements of Forestry."*)

The encouragement of tree-planting has been begun in many states by the appointment of an "Arbor-Day." There are great portions of our country suitable only for forest cultivation, and the possible financial returns from tree-planting have been very generally overlooked. There is a growing demand that the Government shall obtain control of our standing timber by setting apart forest reservations, and shall adopt measures for planting extensively, not only in deforested regions, but in the treeless states and territories of the West.

Plants yielding Sugar.—This valuable product is obtained principally from the sugar-cane, the beet, sorghum, the sugar-maple, and from several palms.

Sugar-cane is a tall grass, somewhat resembling Indian corn, native to southern Asia, and grown in all warm regions of the globe. The ordinary process of extracting the sugar is to crush and press the stalks, and then boil the juice until the crystalline product is formed. Another method of recent introduction and liable to replace the above, is to chop the stalks into small pieces and extract the sugar by immersion in water —a process known as "diffusion"; the liquid is then concentrated, and the sugar remains. The uncrystallized residue in these processes is called molasses, or sirup.

Sorghum is another large grass, long cultivated in China, and now grown in the southern United States. It does not require so warm a climate as the sugar-cane, thriving as far north as Cape May, New Jersey.

Medicinal Plants.—A large number of plants yield products used in medicine. Some of the most important of these are quinine and its associated alkaloids, aconite, nux-vomica, and cocaine.

Quinine, cinchonine, cinchonidine, and other alkaloids acting as febrifuges, are obtained from the bark of trees called Cinchona, natives of the Andes of South America. Cinchona-trees are now also cultivated in India and the West Indies, and the price of these invaluable remedies, formerly so high, has been very much cheapened in consequence.

Cocaine is an anæsthetic of recent introduction. It is obtained from the leaves of the cuca or coca, a shrub which grows on the slopes of the Bolivian and Peruvian Andes. Its leaves were chewed by the Indians in the most ancient times, to remove drowsiness, enliven the spirits, and impart nervous energy to endure cold, wet, great bodily exertion, and even want of food. It is estimated that coca is still used as a nervous stimulant by 8,000,000 of the human race.

Plants yielding Beverages.—Wine is produced in great quantities by the fermentation of the juice of the grape. Numerous species of grapes grow wild on both continents, and from them the many varieties of cultivated grapes have been derived. Wine is also made from a number of other fruits. Rice-wine forms the principal and almost only alcoholic beverage of Japan.

Infusions called "teas" are made from the leaves of a number of plants, notably the Chinese tea (*ts'a*) shrub. Green and black teas are not from different species of plants, but are differently prepared. To produce the former, the leaves, as soon as plucked, are placed in iron pans and exposed to the action of heat for a few minutes only; then they are rubbed together, and a second time "fired" for two or three hours, being constantly stirred by persons in attendance, and in the case of fine tea "fanned," to preserve their green color. Small quantities of Prussian-blue are added to intensify the hue. In the case of black tea, the leaves are exposed to the air for some time before they are fired. Chinese ladies anoint their heads with tea-oil, extracted from the seeds.

MATÉ-PLANT, COFFEE, TEA-PLANT IN FRUIT.

Paraguay tea or maté (*mah'tay*) is prepared from the dried leaves of an evergreen-tree of the holly family. It has been in use among the Indians from time immemorial, and is now consumed by almost the whole population of South America.

Labrador tea is the dried leaf of a marsh Le'dum peculiar to the colder regions of North America. It possesses narcotic, soothing, and exhilarating properties.

Coffees are infusions of seeds. The low, branching coffee-tree is a native of Abyssinia, and is widely cultivated in all warm countries. Its fruit is red, and about the size and shape of a cherry, containing two seeds, with their flat sides contiguous. These seeds are the "coffee-beans." (*See Hewitt's "Coffee; its History, Cultivation, and Uses."*)

The cacao-tree, indigenous to tropical America, is cultivated in most warm countries. The fruit is pod-like and contains a great many seeds called chocolate-beans, from which chocolate is prepared.

Dye-Plants.—Indigo is obtained in greatest quantities from two plants of the bean family, one a native of India, the other of the West Indies. The blue coloring-matter is obtained by macerating the green plants in water and collecting the sediment. Logwood, a Central American tree, yields a deep-red dye. Madder is an important red dye, obtained from the roots of a European plant of that name. It is now nearly superseded by the introduction of aniline colors.

Spice-Plants include the nutmeg, the pimento-tree (yielding allspice), the cinnamon, cloves, and the peppers.

Nutmegs are the seeds of a small tree of the laurel family found in the Malay Archipelago. These seeds are enveloped by a net-like covering, the *mace* of commerce.

Cinnamon is the inner bark of another tree of the laurel family. It is both wild and cultivated in southern India and the Malay Archipelago. The bark of a related species furnishes cassia, which is much used to adulterate cinnamon.

Cloves are the dried flower-buds of a tree which formerly grew chiefly on the island of Amboyna, one of the Moluccas, but is now cultivated in India, Zanzibar, and elsewhere.

Pepper is the fruit of a climbing plant from India. Its berries resemble currants, and when dried and powdered constitute *black pepper;* when the skin is first removed by washing, they form *white pepper.*

Red or Cayenne pepper (capsicum) is obtained from the fruits of two South American plants, now generally cultivated in tropical and warm countries. These belong to the potato family.

Plants yielding Oils, Gums, and Resins.—Of these there are a great number. Linseed-oil is obtained from the seeds of flax; castor-oil from the seeds of the castor-oil plant, also known as Palma Christi. Oil is obtained from the seeds of many other plants, as cotton and rape. Cotton-seed oil is largely used as a food and in the arts.

Gums are soluble in water. Gum-arabic, the most important, is obtained from several acacias in Asia and Africa. Gum-tragacanth is yielded by a pea-like shrub of the mountainous regions of western Asia.

Resins are soluble in alcohol. Rosin, the most important, is obtained from the pines of the southern United States and elsewhere.

Several fossil gums are used in considerable quantities. While copal is yielded by trees now growing, most of it is obtained in the sand where trees once grew. Madagascar and Zanzibar produce the greatest quantities. Dammar is another fossil resin, the product of certain coniferous trees of Australasia. Amber is a fossil gum, found mainly in northern Europe. It is believed to occur in regular veins along the Baltic coast; large quantities, detached by the force of the waves, are thrown upon the shores during heavy storms. It is also met with inland, and mines are worked in certain localities. Insects belonging to extinct species are often found incased in amber.

Rubber, or caoutchouc (*koo'chook*), is the thickened and hardened milky juice of various trees, natives of South and Central America, southern Asia, and equatorial Africa. The sap of caoutchouc-bearing trees, when rubbed between the fingers, coagulates into an elastic fiber. Symmetrical balls made of this material were used in playing a certain game by the natives of Haiti at the time of the discovery of the island by Columbus. During the dry season, between August and February, the gum-trees are tapped in South America. The milk flowing from the incisions is collected in shallow cups of clay, the average yield of juice for a tree being two ounces a day. The juice yields about thirty per cent. of its weight in caoutchouc, which is prepared in flat, rounded cakes ("biscuits"). Mozambique rubber occurs in balls about the size of an orange. Many million pounds of gum are annually consumed in making various appliances used in the arts and manufactures.

Plants yielding Narcotics.—Of these, the most important are the tobacco and opium poppy.

Tobacco is an annual plant of the potato family, native to America, and was smoked by the Indians when the continent was first visited by Columbus. It was introduced into England by Raleigh in 1589, though earlier known to the Spanish and French. It is now cultivated throughout the tropical and temperate zones.

Opium is the dried juice of the seed-pods of a species of poppy. In parts of Asia, and by the Chinese of America, it is chewed and smoked to produce intoxication. Opium and its alkaloid morphine are largely used in medicine to induce sleep. The plant is believed to be native to the Mediterranean region.

Belladonna, or deadly nightshade, is a tall, bushy plant of the potato family, bearing a highly-poisonous but attractive-looking fruit. Preparations of belladonna and its alkaloid *atropine* are used in medicine as anodynes; they are of great service in the treatment of certain diseases of the eye, on account of their peculiar property of expanding the pupil. (*Consult Smith's "Dictionary of Economic Plants."*)

Belladonna and the Opium Poppy.

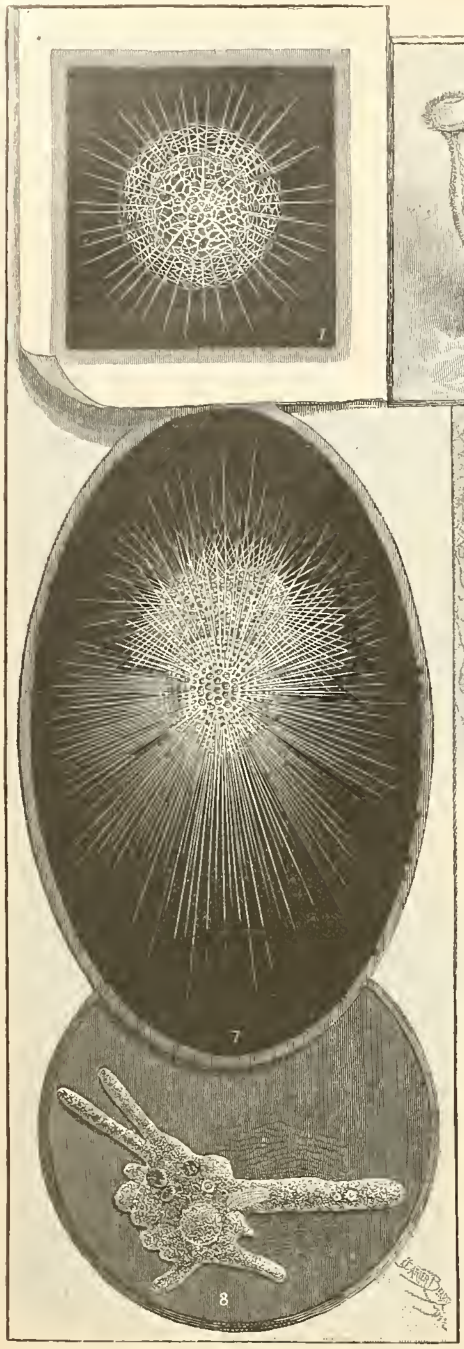
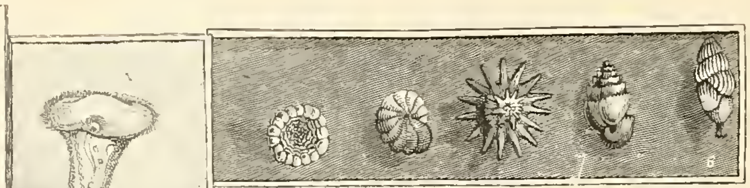
Questions.—Name the different classes of plants most important to man. What do food-plants comprise? Define cereals. Which is the most important and why? What can you say of wheat? Rice? Millet? Indian corn? Rye? Buckwheat? What is meant by tuberous plants? Give an account of the principal members of this group; of the chief fruit-bearing plants; of the plants bearing succulent stems and leaves.

For what are plants that yield fibers useful? Describe cotton. How many varieties of the cotton-plant are recognized by botanists? What is hemp, and for what is it used? Flax? Jute? State the habitats and uses of the principal timber-trees. Explain the economic value of forests.

What is sugar? Describe the process of its manufacture. Whence is quinine obtained? Where are cinchona-trees successfully cultivated? What are the medicinal properties of coca? What are teas, and from what plants are they made? Describe the coffee tree and bean. Name the principal dye-plants; the spice-plants; the plants that produce oils and gums; the most important narcotics.

Note.—The student who is interested in the subjects of plant-structure and plant-life should secure an inexpensive microscope, and prosecute his studies in the highways and fields. A multitude of beautiful and instructive forms will be found on every side—cells and cell-contents, pollen of different shapes and markings, desmids and algæ, spores on the leaves of ferns, mosses and molds growing on various bodies, plant-crystals, starch-granules, etc.—all evincing exquisite workmanship and wonderful design. Many of the illustrations in this chapter have been drawn directly from the microscopic field. (For fuller and most interesting information, *read Dr. Hogg's "The Microscope; its History, Construction, and Application," pp. 255–365;* and *Dr. Stokes's "Microscopy for Beginners, or Common Objects from the Ponds and Ditches," chap. iii.*)

ANIMAL LIFE ON THE EARTH.


Several varieties of protozoa are illustrated in the engraving. Fig. 1 belongs to the order Radiolaria; the framework of the body consists of radiating spines. Fig. 2 is a Stentor, or trumpet-animalcule, a common infusorian. Figs. 3 and 4 show adult colonies and single specimens of the flower-like Flagellata. Figs. 6 and 7 represent forms of Fo-ram-in-if'era, or Rhiz'opods whose bodies are protected by *perforated* limy shells. Fig. 8 is the Amœba, or Proteus animalcule, containing a nucleus whose functions are not known, a circulatory organ called "the contractile vesicle," and "food-spaces." (*See Professor Lankester's illustrated article on Protozoa, "Encyclopædia Britannica," vol. xix., p. 830.*)

PROTOZOA.

PRIMARY GROUPS.

I. Protozo'a (*first*, i. e., *lowest*, animals).
II. Porif'era (*pore-bearing* animals).
III. Cœlentera'ta (having *hollow intestines*).
IV. Echinoder'mata (animals with *spine-covered skins*).
V. Vermes (*worms*).
VI. Molluscoid'ea (*mollusk-like* animals).
VII. Mollusca (mollusks, *soft* animals).
VIII. Arthrop'oda (animals having *jointed bodies and appendages*).
IX. Tunica'ta (animals *clothed with a tunic* or *envelope*).
X. Leptocar'dii (*having no distinct heart*).
XI. Marsipobran'chii (*having gill-sacs*).
XII. Elas'mobranchii (*having gill-pouches*).
XIII. Pisces (*fishes*).
XIV. Dipnoi (*double-breathers*, i. e., having *gills and lungs*).
XV. Batra'chia (*frogs*).
XVI. Reptil'ia (*reptiles*).
XVII. A'ves (*birds*).
XVIII. Mammalia (*that suckle their young*).

Animals constitute the second great division, or "Kingdom," of organic nature.

The distinction between plants and animals is sufficiently clear in the higher groups; but, in the case of many of the lower forms, it is difficult and often impossible to determine to which of the two kingdoms an organism belongs (*see p. 88*).

Zoölogy.—The science that treats of animals, their structure, habits, and classification, is called Zoölogy (from the Greek *zoön*, an *animal*, and *logos*, a *discourse*).

Classification of Animals.—In order to study objects intelligently, they must be classified. In the animal kingdom, classification is necessarily arbitrary, because sharp distinctions between groups rarely exist, except where wide gaps have been left by the extinction of intermediate forms.

It was formerly the practice to class all animals under the four divisions—Radiates (having their organs arranged radially about the axes of their bodies; often star- or flower-shaped), Mollusks (with fleshy bodies, usually protected by shells), Articulates (composed of joints without internal skeletons), and Vertebrates (having an internal skeleton and spinal cord). But the rapid progress recently made in natural science has demonstrated the necessity for a different and more comprehensive system. Still, owing to the incompleteness of our knowledge of the life-histories of many animals, a perfectly satisfactory classification has not yet been attained. The following may be considered to represent the present state of knowledge on the subject, so far as the primary groups are concerned:—

The Protozoa comprise the lowest forms of animal life, many of them being single, isolated cells; they are all of small size. Among the groups into which the Protozoa have been divided are the Rhizopods (*riz'o-pŏds*, *root-footed* animals, from their power to protrude at will, from different parts of their bodies, extensions of their substance called "false feet"); and the Infuso'ria (so called because they are generated in *infusions* left exposed to the air).

The Rhizopods form vast deposits in many parts of the ocean, both at great depths and along the shores; some of the fossiliferous rocks consist almost wholly of the remains of graceful shell-bearing species. The Infusoria abound both in salt and in fresh water, and are interesting objects of study under the microscope. Some of them are so diminutive that 30,000 have been counted in a half-ounce of sand.

The Porifera comprise the sponges. Some of these are characterized by a deposit of lime in their bodies; others, including the sponges of commerce, by a fibrous or horny structure. Still others are remarkable for the silicious deposits they contain, and are hence called glass sponges. The beautiful "Venus's flower-basket" is a glass sponge.

Dry sponges are the skeletons of sponge-animals. "At the bottom of the warm seas on the Mediterranean coast or in the Gulf of Mexico, these sponge-animals live in wild profusion, sometimes hiding in submarine caverns, sometimes standing boldly on the top of a slab of rock, or often hanging under ledges. Some are round like cups, some branched like trees, some thin and spread out like a fan; while there is hardly a color, from a brilliant orange to a dull, dingy brown, which is not to be seen among them." Sponge-colonies are visited once in three years by trained divers, who tear the adult specimens from their rocky beds, and subject the skeletons to bleaching and purifying operations. (On sponges and how they live, *see Buckley's "Life and her Children," pp. 33–49.*)

The Cœlenterata comprise the jelly-fishes, sea-anemones, and coral polyps. Many of them are brilliantly colored, and are among the most beautiful objects to be found along our sea-shores.

One variety, the Portuguese man-of-war, is a common object in tropical waters. The sea-anemones (*a-nem'o-nes*) are fleshy polyps, which, from their supposed resemblance to flowers, were called zoöphytes, or plant-animals (*see p. 30*), by the older naturalists. (On the Cœlenterata, *consult Professor Dana's "Corals and Coral Islands."*)

The Echinodermata comprise the crinoids (represented by few living species, but enormously abundant in the past, as evidenced by their remains in some of the fossil-bearing rocks—*see p. 14*), the serpent-stars, the star-fishes, the sea-urchins, and the sea-cucumbers (*see p. 102*). The tough, leathery bodies of the latter, under the name of "trepang," are eaten by the Chinese. (*See Agassiz's "Sea-side Studies."*)

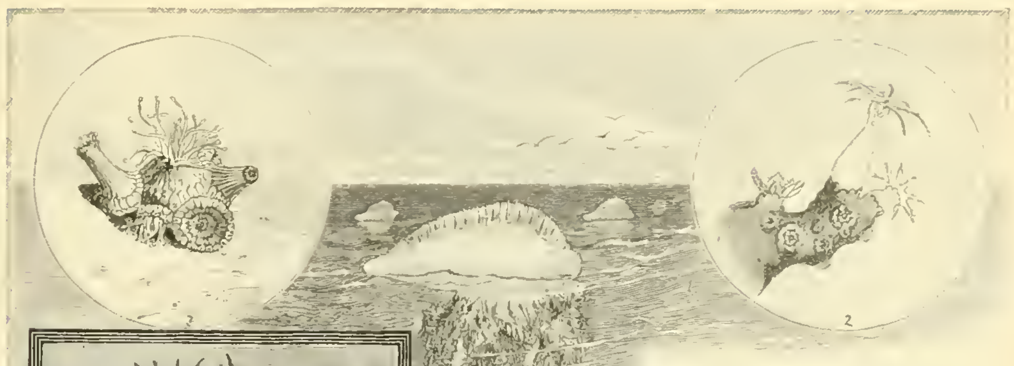
The Mollusca embrace the land and sea snails, bivalve-shells, slugs, cuttle-fishes, and the beautiful nautilus and argonaut (*see p. 102*). They are divided into three groups: the first includes mussels, clams, and oysters; the second, snails, slugs, limpets, periwinkles, and all spiral shells; the third, cuttle-fish, squids, and the nautilus, the only living representatives of the ammonite group that once filled the primeval ocean (*p. 15*). (On animals of this group, and shells, *consult Woodward's "Manual of the Mollusca."*)

Mollusks supply many articles of great commercial importance. Pearls and portions of certain shells are much prized as jewels and parlor ornaments; and oysters, clams, scallops, periwinkles, and other species, are largely used as food. The oyster industry alone is one of great magnitude. In the United States, in 1890, according to the official census, more than 50,000 persons and 4,000 vessels were employed in the oyster fishery; the annual yield sold for over $15,000,000.

The Arthropoda comprise invertebrate animals with jointed legs, such as crustaceans (barnacles, shrimps, crabs, and lobsters), centipeds, spiders and scorpions, and all insects; the **Tunicata,** animals which, though resembling some of the lower organisms in external appearance, are really highly organized, and are probably the immediate predecessors of vertebrates; the **Leptocardii,** but a single genus, the lancelet, which is the lowest known vertebrate. The lancelet is from one and a half to two inches in length, and has no distinct head or lateral appendages. It inhabits shallow portions of the sea where the bottom is sandy, and is found along our own coast from the mouth of Chesapeake Bay to Florida. (On these Primary Groups, *compare Dr. Packard's "Zoölogy."*)

The Marsipobranchii include the hag-fish, or borer, and the lamprey-eel; the former inhabiting muddy bottoms at considerable depths in the sea, the latter living both in fresh and in salt water. Both feed on other fish. The lamprey fastens on its victims, and sucks their blood at its convenience. The hag-fish buries itself in their flesh and abdominal cavities.

The Elasmobranchii comprise the sharks, skates, rays, torpedo, saw-fish, devil-fish, and chime'ra. They have been characterized as "engines of destruction, having been since their early appearance, in the Upper Silurian Age, the terror of the seas. Their structure is such as to enable them to seize, crush, and rapidly digest large invertebrates, and the smaller members of their own class."



1. Portuguese man-of-war.
2, 3. Coral polyps.
4 to 10. Sea-anemones.
11. Jelly-fish.

CŒLENTERATA.

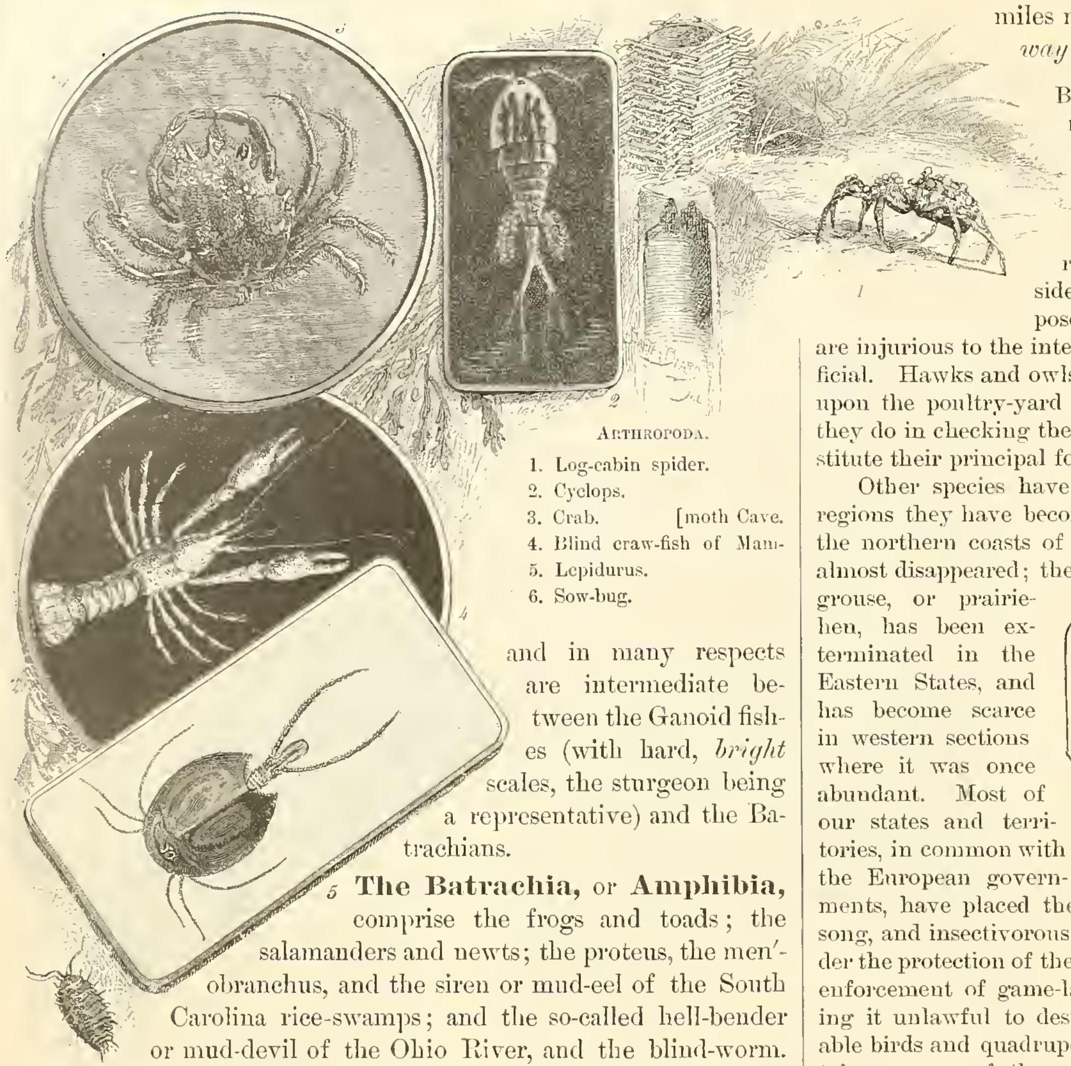
Sharks are most abundant in the seas between the tropics, but few kinds being found in Arctic waters. One formidable species is known to attain a length of 40 ft. Sharks' fins are a favorite article of food with the Chinese; they are also used in the manufacture of gelatine. At Kurrachee, India, there is a valuable shark-fishery; forty thousand fish are taken annually for their fins. (*Consult Dr. Günther's "An Introduction to the Study of Fishes," p. 316.*)

The torpedo, or electric ray, is a very remarkable fish. It possesses a pair of large electric organs, constructed on the principle of the voltaic pile. In the American species there are about eleven hundred cells in each battery—more than double the number present in the European. These batteries are under the control of the animal, so that at will the torpedo is capable of administering a powerful shock, either in self-defense, or for the purpose of disabling its prey.

The Pisces, or true fishes, comprise a vast variety of forms inhabiting the seas, rivers, lakes, and streams, of all parts of the world. They vary in size, from species only an inch in length to those weighing many hundreds of pounds, and supply a large and important part of the food of the human race. (*Read Goode's "The Fisheries and Fishery Industries of the United States."*)

The artificial propagation of fishes has become an important industry both in Europe and America. The possibility of successfully hatching ova and of stocking barren waters with valuable food-fishes has been demonstrated, so that most of our states and territories have appointed commissioners to protect and develop their fisheries. The government also has established a fish commission. (Standard authorities on fish-culture are *Green and Roosevelt's "Fish-Hatching and Fish-Catching," Livingston Stone's "Domesticated Trout,"* and *Maitland's "The History of Howietoun."*)

The Dipnoi are remarkable fish-like animals, possessing both gills and lungs. They are thus enabled to exist in pools which become dry in summer. The Dipnoi are a very ancient group,



ARTHROPODA.
1. Log-cabin spider.
2. Cyclops.
3. Crab.
4. Blind craw-fish of Mammoth Cave.
5. Lepidurus.
6. Sow-bug.

and in many respects are intermediate between the Ganoid fishes (with hard, *bright* scales, the sturgeon being a representative) and the Batrachians.

The Batrachia, or **Amphibia,** comprise the frogs and toads; the salamanders and newts; the proteus, the men′obranchus, and the siren or mud-eel of the South Carolina rice-swamps; and the so-called hell-bender or mud-devil of the Ohio River, and the blind-worm. The young of these animals undergo a transformation or metamorphosis before arriving at maturity. They live in water, and are provided with external gills; while, as a rule, the adults breathe by means of lungs, and live on land.

The Reptilia comprise the snakes, lizards, turtles, and crocodiles. Most of them dwell upon land, and all are air-breathing. They are most abundant in the tropics and warm-temperate regions. A vast number of fossil reptiles have been discovered, among which the great flying Pterodactyls (*see p. 14*) are among the most remarkable. Another fossil group is intermediate between reptiles and birds.

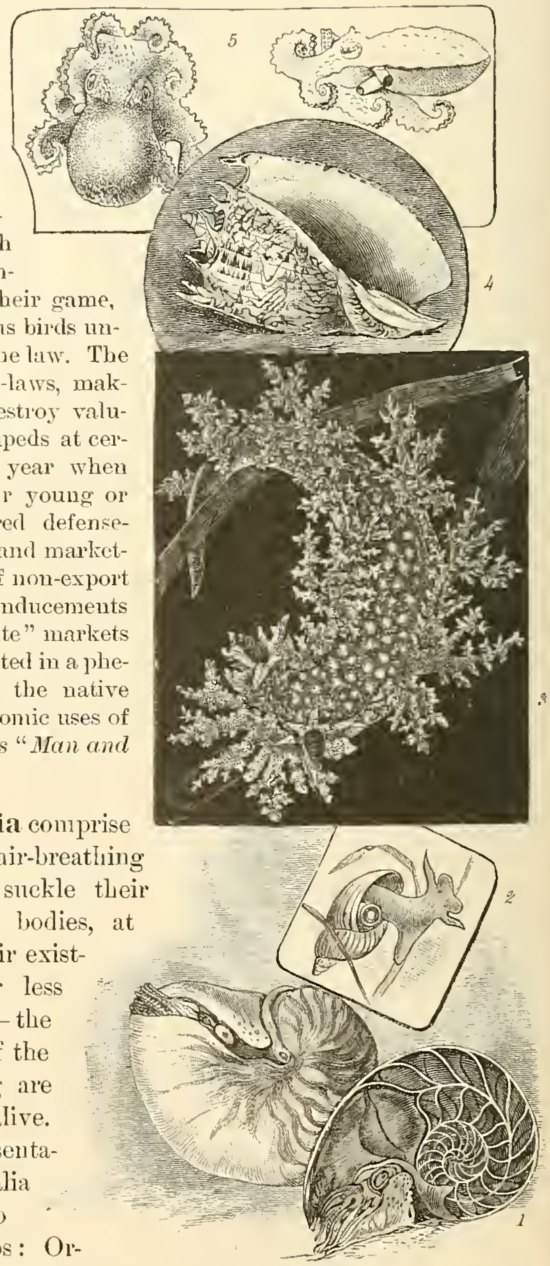
The Aves, or Birds, are highly specialized animals which bear feathers, and as a rule are adapted for locomotion in the air. They constitute a very distinct and at present a very circumscribed group, though fossil forms have been found which indicate close relationship to reptiles. A number of extinct birds with teeth have been discovered, and one, the *Archæop′teryx* (*ancient wing*), had a long bony tail with feathers on both sides (*see diagram, pp. 12 and 13*).

All existing birds may be subdivided into three principal groups: the first includes the ostriches, cassowaries, moas, and tin′amous of Guiana and Brazil; the second, the penguins; and the third, all other species, viz., grebes, auks, gulls, petrels, snipe, ducks, pelicans, grouse, pigeons, birds of prey, parrots, humming-birds, swallows, finches, thrushes, etc. Many birds are remarkable for performing extensive biannual flights or migrations, which enable them to spend the summer seasons in regions hundreds of miles north of their winter homes. (*Consult Ridgway's "Manual of North American Birds."*)

Birds are of very great economic importance to man, and yet their services are so little appreciated that many of them have been slaughtered by hundreds of thousands, chiefly for millinery purposes. Some species have been actually exterminated, and many have been made rare where formerly they were abundant. Besides the birds that are killed for decorative purposes, others are destroyed in the belief that they are injurious to the interests of mankind, while in reality they are beneficial. Hawks and owls are marked examples of this class. Their raids upon the poultry-yard are insignificant in comparison with the good they do in checking the increase of mice and noxious insects, which constitute their principal food.

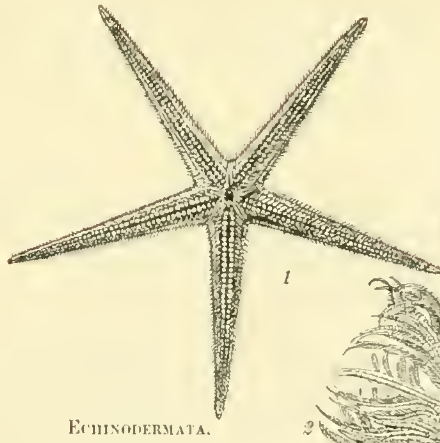
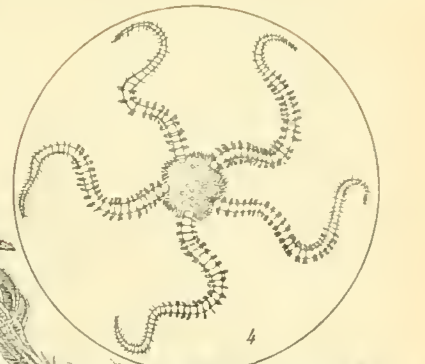
Other species have been hunted for the market, until in certain regions they have become extinct. The great auk, once abundant on the northern coasts of America, no longer exists; the wild pigeon has almost disappeared; the wild turkey is passing away; and the pinnated grouse, or prairie-hen, has been exterminated in the Eastern States, and has become scarce in western sections where it was once abundant. Most of our states and territories, in common with the European governments, have placed their game, song, and insectivorous birds under the protection of the law. The enforcement of game-laws, making it unlawful to destroy valuable birds and quadrupeds at certain seasons of the year when they are rearing their young or are otherwise rendered defenseless against poachers and market-hunters—as well as of non-export laws that remove the inducements to kill for "out-of-state" markets—has invariably resulted in a phenomenal increase of the native fauna. (On the economic uses of birds, *consult Marsh's "Man and Nature," p. 57.*)

The Mammalia comprise the warm-blooded, air-breathing vertebrates which suckle their young, and whose bodies, at some period of their existence, are more or less coated with hair — the normal covering of the group. The young are generally born alive. The living representatives of the mammalia fall naturally into three major groups: Ornithodelphia, Didelphia, and Monodelphia. The first of these consists of the

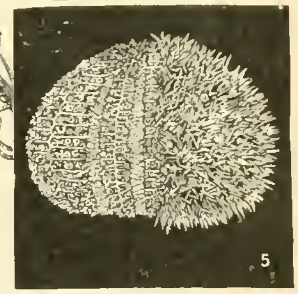


MOLLUSCA.
1. Nautilus. 2. Pond-snail. 3. Sea-slug. 4. Volu′ta. 5. Octopus.

duck-billed platypus, or ornithorhyn'chus, and the echidna (e-kid'na), or porcupine ant-eater, both of which are confined to the Australian region. They are the lowest of mammals, and in many respects are intermediate between mammals and reptiles, with which latter class they share many striking peculiarities. They differ from all other mammals in being *oviparous*, which means that they lay eggs. The echidna places her eggs in two little abdominal pouches, and carries them about with her till they hatch; while the ornithorhynchus sits upon her eggs after the manner of a hen.


ECHINODERMATA.
1. Star-fish. 2, 3. Crinoids. 4. Serpent-star. 5. Sea-urchin. 6. Sand-dollar. 7. Sea-cucumber.



The Didelphia, or Marsupials (from a Greek word meaning *bag* or *purse*), are distinguished by having, among other peculiarities, an abdominal pouch in which the young, born in a very rudimentary and helpless condition, are carried till able to care for themselves. Excepting the opossums, which are found in America, the Marsupials are confined to Australia, New Zealand, and New Guinea.

The Monodelphia occur in all parts of the world, and are modified for habits of life in the water, on land, in trees, and in the air. This group contains, among others, cattle and horses, sea-cows and whales, squirrels, bats, lions and tigers, seals, apes, men.

GEOGRAPHICAL DISTRIBUTION OF MAMMALIA.

Faunal Realms.—Animals, as well as plants, are influenced in their dispersion by climatic and physical conditions, among which may be mentioned temperature, humidity, elevation above sea-level, and character of soil. The result of these several influences, acting singly or in combination, is that the various species are not diffused equally in different directions, but are restricted to certain well-defined areas as thoroughly as if limited by impassable physical barriers. Hence it becomes possible to divide the surface of the earth, according to the distribution of its animal inhabitants, into a number of *faunal regions* or provinces.

Temperature, clearly, is the most potent factor in determining the boundaries of the principal divisions or realms. For this reason, life is distributed in zones whose boundaries are not coincident with the parallels of latitude, but generally with the isotherms.

The primary divisions or "Realms," according to Allen, are the following:—

I. Arctic, or North Circumpolar.
II. North Temperate.
III. American Tropical.
IV. South American Temperate.
V. Indo-African.
VI. Australian.
VII. Lemurian.
VIII. Antarctic, or South Circumpolar.

(On the Geographical Distribution of Mammalia, *see an important paper by J. A. Allen, in "Bulletin of the United States Geological and Geographical Survey," vol. iv., No. 2, 1878.*)

The Arctic, or North Circumpolar, Realm embraces the ice-clad and barren lands of America, Siberia, and Greenland, and extends southward to the northern limit of trees, or approximately to the isotherm of 32° Fahr. It is remarkable for the polar bear, musk-ox, Arctic fox, and lemmings (small animals resembling our meadow-mice); and in its seas dwell the walrus, narwhal, white whale, and many seals. Myriads of water-birds rear their young within its borders.

The North Temperate Realm extends from the southern boundary of the Arctic Realm to the isotherm of 68° or 70° F., thus embracing North America as far south as Mexico, Central Asia, Europe, and northern Africa. It is the home of the fur-bearing animals, such as the fur-seal, sea-otter, otter, sable, mink, fisher, beaver, and ermine; also of the lynxes, wolves, foxes, badgers, and bears; of the moose, elk, reindeer, bison, and pronghorn-antelope; of the moles and shrews; of flying and other squirrels; of the prairie-dogs and marmots.

The American Tropical Realm is included between the isotherms of 70° north and south. Its southern limit may be indicated by a somewhat irregular line passing northwestward from the southeastern corner of Brazil to northern Peru. Thus the American Tropical Realm comprises southern Florida, the West Indies, Mexico, Central America, and the northern half of South America. The characteristic mammals are—the spider- and howling-monkeys and marmosets; the coa'tis (closely related to the raccoon); the jaguar, ocelot, and civet-cat; the American tapir and the peccary; the manatee, or "sea-cow," hunted for its flesh, oil, and hide; the capy'bar'a, cavy, and agouti, varieties of rodents or gnawers; leaf-nosed bats; armadillos (armor-plated, burrowing animals), ant-eaters, sloths, and opossums.

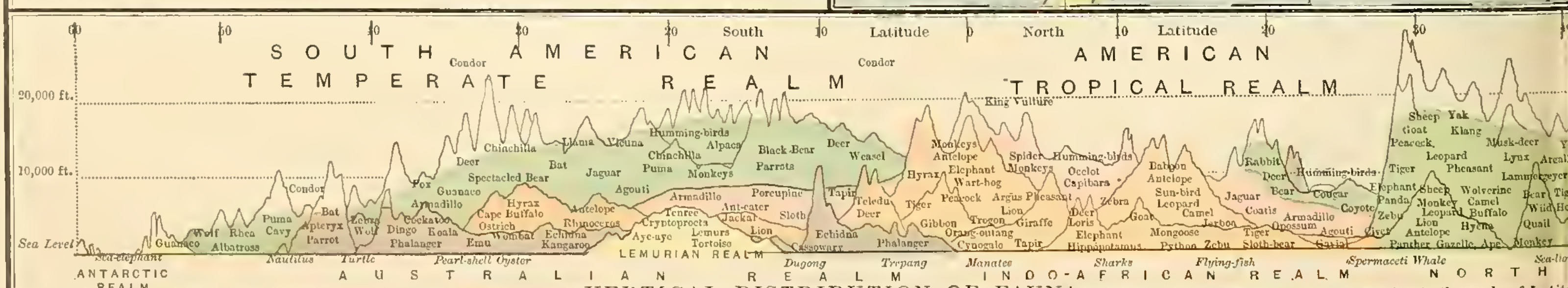
The South American Temperate Realm embraces the southern half of South America and the adjacent islands on the east and west. It is the home of the peculiar South American deer, of the llama, guanaco, chinchilla, and spectacled bear.

The Indo-African Realm covers tropical Asia, and Africa south of the central portion of the Great Sahara Desert.

The Indian Region includes the Malay Peninsula, Sumatra, Java, Borneo, Celebes, the Philippine and Sunda Islands, and Formosa. The most remarkable animals are the orangs, the gibbons or long-armed monkeys, the le'murs (animals with a fox-like muzzle resembling monkeys); certain bats; the Bengal tiger, the Indian elephant, and rhinoceros; wild cattle (from which the zebu was domesticated); the babyroussa or "hog-deer," and the axis deer.

Questions on the Map of Faunal Realms.—What advantages have animals over plants in distributing themselves? Note the limits of the great faunal regions, and name the characteristic mammals of each. To what parts of the world are the larger carnivora confined? Where do you meet with the monkey? In what respect does it differ from man in distribution? To what part of Africa is the gorilla limited? For what class of animals is South America chiefly remarkable? Australia? Madagascar? Where does the alligator abound? What great serpent infests the forests of Brazil? What African river is the home of the crocodile? Mention countries almost without reptiles.

Show that the distribution of land-animals in vertical space depends on certain laws of climate. Of the fishes noted in the map, which are used for human food? Where is the electric eel found? the cuttle-fish? the spermaceti whale? What waters are inhabited by the walrus? the seal? What fish are taken off the coast of Norway? in the river Volga and the Caspian Sea? off Newfoundland? in the Mediterranean? Where are sponges found? valuable mollusks? Mention an important group of birds peculiar to Africa. What birds are essentially American? Where are song-birds chiefly met with? eider-ducks abundant? What bird is peculiar to New Zealand? The apteryx (*wingless*), having partially developed wings. Illustrate the wide range of certain birds.



VERTICAL DISTRIBUTION OF FAUNA. NOTE. *The Vertical scale is in proportion to the scale of Latitude.*

UNAL REALMS
NG THE DISTRIBUTION OF
NIMAL LIFE
CIRCUMPOLAR REALM
ARCTIC REALM
NORTH TEMPERATE REALM
EURASIATIC REALM
INDO REALM
AUSTRALIAN REALM
LEMURIAN REALM
AFRICAN REALM
ARCTIC OCEAN
PACIFIC OCEAN
INDIAN OCEAN
SIBERIA
TIBET
ARABIAN SEA
BAY OF BENGAL
JAPAN
AUSTRALIA
NEW ZEALAND
TASMANIA
EQUATOR
TROPIC OF CANCER
TROPIC OF CAPRICORN
ARCTIC CIRCLE
from Greenwich
MAP TO ILLUSTRATE
the distribution of
CHARACTERISTIC BIRDS
Sea Level
20,000 ft.
10,000 ft.

The African Region is inhabited by the huge apes, the gorilla and chimpanzee; the true baboons; hyenas; the African lion, the African elephant, and rhinoceros; camels, giraffes, and zebras; the gnu and the African buffalo; numerous antelopes; the hippopotamus; the hy'rax (a gregarious little animal living in holes among the rocks and believed to be identical with the "coney" of the Bible); the Cape ant-eater; and the ma'nis (from a Latin word, meaning *ghosts*, so called from its habit of seeking food by night) or scaly ant-eater, whose body, limbs, and tail, are protected by an armor of overlapping horny plates.

The Australian Realm comprises Australia, Tasmania, New Guinea, New Zealand, the Moluccas, Arru, and the Solomon Islands, Polynesia, and the smaller intervening islands.

Batrachians.

1. Salamander (a name given to most of the batrachians with persistent tail, but whose gills disappear at maturity). 2. Menobranchus, or the fish-lizard, which retains its gills through life; two species inhabit the fresh waters of the United States. 3. Amblystoma, or spotted eft; one species burrows in the ground. 4. Larval (*immature*) salamanders. 5. Flying tree-toad.

It is the home of the duck-billed ornithorhynchus, various forms of the echidna, and of the Marsupials or pouch-bearers, which are the predominating and almost exclusive mammalian inhabitants of Australia, Tasmania, and New Guinea. To the latter group belong the kangaroos, the wombat, the koala (*ko-ah'la*), or little native bear, the bandicoot (a small, rat-like animal, very destructive to crops), the phalanger (or Australian opossum), the Tasmanian devil (a small but ferocious mammal, allied to the native wolf), and the pouched dog. The dingo, or wild dog of Australia, is not a marsupial, but a true canine.

The Lemurian Realm consists of Madagascar and the Mascarene Islands. In its animal life it is very distinct from all other portions of the earth. It is the home of a large number of peculiar and beautiful lemurs; of a unique carnivorous family; and of an insectivorous group, only a single representative of which (a native of the West Indies) is found in any other part of the world. (*See Stanford's "Compendium of Geography."*)

The Antarctic Realm embraces the South Polar region, and extends northward far enough to include Tierra del Fuego and the Falkland Islands. It is mainly oceanic, but contains the few small groups of Antarctic islands. Hence, its characteristic mammals are dwellers in the sea, and most of them are of commercial importance. Among them may be mentioned the great sea-elephant, which is the largest of the seals, and certain whales and porpoises.

The larger Realms are divisible into *regions*, *provinces*, and *faunæ*. For example, the North-Temperate Realm is divided into a North American Region and a Europeo-Asiatic Region; the North American Region in turn is divided into three provinces—an Eastern, Middle, and Western. Again, each of these provinces is capable of subdivision into faunal areas or faunæ. In the Eastern Province, the following have been characterized: Floridian, Louisianian, Carolinian, Alleghanian, Canadian, Hudsonian, and Arctic, each of which has its distinctive animal inhabitants.

Economic Uses and Products.—Except in the tropics, it is doubtful if man could exist, either in the barbarous or civilized state, without making use of the lower animals.

Several kinds of mammals are of inestimable value as beasts of burden. The most important are horses (including mules and donkeys), cattle, camels, elephants, llamas, reindeer, and dogs.

A large and essential part of the food-supply of the various races of man is derived from the mammalia. Meats (both fresh and salt), fats, lard, milk, butter, and cheese, fall under this head.

Both savage and civilized man draw largely upon the various groups of mammals for their clothing, and for the articles in every-day use. Among the raw materials thus constantly employed are hides (furnishing leather of all kinds), pelts, furs, wool, hair, bristles, silk, ivory, whalebone, horns and hoofs, bones, tallow, oils, and manures. (*Consult Simmonds's "Animal Products."*)

Questions.—Illustrate the wide distribution of life upon the earth. State the principal differences between plants and animals. How do plants breathe? In what different ways do animals breathe? Show how plants consume the poisonous products of animal respiration. What is zoölogy? Can you name the subdivisions of the animal kingdom, explaining the appropriateness of each designation? Describe the protozoa. What are foraminifera? Infusoria? What is their range? How do sponges live? What creatures do the Cœlenterata comprise? Describe the jelly-fish; the sea-anemones. What animals are included under the head of Echinodermata? of Mollusca? of Arthropoda? of Elasmobranchii? Give some interesting facts regarding sharks; the torpedo; the economic value of mollusks.

What provision is made for the protection and propagation of our food-fishes? Why are such steps necessary? What can you say of the Batrachia? of the Reptilia? of birds and their economic uses? Into what groups have the Mammalia been divided? Name the chief marine mammals. Have you observed whether our salt-water fishes are capable of adapting themselves to fresh water, and *vice versa?* Give examples of species of animals that have become extinct within the historic period (*see p. 15*); of others now dying out. (*Read Harting's "British Animals Extinct within Historic Times."*) How only can the threatened extermination of many of our most valuable game-birds and beasts be averted? Define the duty of every citizen in this respect.

How far are the flora and fauna affected by climate? by differences of level? What has been the influence of man on the distribution of animals? Into what faunal regions has the surface of the earth been divided? Mention the characteristic fauna of each. Describe some animal products.

Man, though separated from the rest of the animal kingdom by the possession of spiritual and superior mental attributes, is related to the lower animals in physical structure and anatomical characters. Zoölogical classification being based upon these features, man finds a place in it, though at the highest point in the series. (*See Huxley's "Man's Place in Nature."*)

In the nomenclature of zoölogy, Man (*Homo*) forms the single species Homo sapiens (or *the wise*), belonging to the family Hominidæ (*mankind*), and the order Primates, which also includes the highest or man-like apes. (*See R. Hartman's "Anthropoid Apes," "International Scientific Series," No. 52.*)

Besides his merely zoölogical standing as one among other living beings, man is subject to classification in as many ways as there are natural groups of relationships growing out of his physical, social, political, and spiritual characteristics. On these are based division into races, families, towns, states, and nations, and religious organizations—the study of which gives rise to various sciences more or less intimately related.

The science relating to mankind in the widest sense, including all the others, is known as Anthropology (from *anthropos*, man, and *logos*, a discourse); that relating to the races of mankind is called Ethnology (from *ethnos*, a people, and *logos*); that treating of the social relations between individual members of the human species is *Sociology*.

Mankind is classified by Types, Races, and Peoples, as regards physical characteristics; and has become organized into nations, states, tribes, and other political groups, through the necessity for mutual protection, for the regulation of common interests, and for the preservation of the rights of individuals.

These organizations are of slow growth. The stage they have reached with any particular people corresponds to our idea of the progress of that people from savagery toward civilization. From history we know that the highest civilization of one age is, on the whole, of a lower grade than that which is afterward reached; so that civilization and enlightenment are progressive terms. Progress is greatly dependent upon intelligence, energy, and morality. But the physical characters by which man is classified are independent of his will or purpose, and seem to be derived from his original constitution. The fundamental idea of a race, therefore, is quite different from that of a nation.

A Type is an ideal standard with certain well-defined characteristics, to which individual human beings approach more or less nearly; and by comparison with which their general physical relations are determined or measured. A **Race** is composed of typical people related by blood and transmitting the race-characters to their descendants. A **People** is an assemblage such as we find actually existing in the world, where there are always some deviations from any specified type and some mixture of races, resulting from the constant intercourse of human beings belonging to different types and races.

While the type and race can be defined with precision, it is found in practice that the races assigned to a given type actually vary from its standard and from one another; the people composing a race also differ more or less among themselves, and no instance is known of an absolutely pure and unmixed race. A Nation is a political assemblage, consolidated by time and common interests, independent of race, and generally containing elements derived from several races; as in the case of the people of the United States. A race usually has representatives in several, or even many, different peoples and nations, and, if civilized, is spread widely over the earth. The same race may have representative groups, some in a barbarous, and others in a civilized, state.

Division into Types.—There are three types to which the races of mankind are now generally referred, and which are most conveniently defined as the White, Yellow, and Black types, formerly called the Caucasian, Mongolian, and Negro. The Malay and American groups, once regarded as equally distinct, are now referred to the Yellow type, of which they form branches.

The prevalent color is used to designate the types, for convenience, though the members of each type vary more or less in tint. The most important characters are found in the form of the nose and in the hair.

THE BLACK TYPE.

The Black Type, characterized by frizzly hair and flattened nose, is the least elevated in point of anatomical structure and general civilization. All its branches originally inhabited hot countries. The following table shows the chief races of this type, and their distribution:—

Africa.	Andaman Islands, etc.	Australia.	Tasmania.	Indo-Pacific Islands.
Negroes. Bantu. Nama. Bushmen.	Negritos.	Australasians.	Tasmanians.	Melanesians.

The Typical Negroes inhabit Central Africa, especially the Congo basin, and are characterized by frizzly hair, flattened nose, extremely dark complexion, and projecting lips and jaws. Among the principal tribes of this race are the Mandingo, Ashantee, Dahomey, and Kongo people. A group distinguished by peculiarities of language, but physically almost inseparable from the Negroes, are the Bantu peoples, who comprise, among others, the Zulus, Bechuanas, and western Kongo tribes.

The Nama and Koranna of South Africa, more widely known as Hottentots, have a less-projecting jaw, are shorter and lighter-colored, and speak a different language from the typical negroes. At present the blood of this race is much mixed, and a pure Hottentot is hardly to be found. They have been great sufferers in war with the Dutch and English of South Africa, and as a race are rapidly passing away.

The Bushmen, now nearly exterminated, are a small and extremely low race, of little intelligence and marked by peculiar anatomical features which indicate them as among the lowest examples of humanity. They live only in southern Africa, but were probably once widely spread over that continent. (*Read Stanford's "Compendium of Geography; Africa"; Appendix, by A. H. Keane.*)

The Negritos are an undersized race, represented by the Minkopi of the Andaman Islands, the Sakai of the peninsula of Malacca, and various black mountain-tribes of Formosa and other Asiatic islands. The Minkopi were long considered to be the most degraded of the human family, but a more thorough knowledge of them has shown this opinion to have been based on error. (*See E. H. Man's "On the Aboriginal Inhabitants of the Andaman Islands."*)

The Australasians, who occupy desert or sterile regions, are a tall and meager race, of low intelligence and degraded habits. They are very black, with nearly straight hair and long, narrow heads, small in proportion to their height. They go in bands without permanent habitations, wear hardly any clothing, and devour the most repulsive food.

The intelligence of this race seems to have culminated in the invention of the boomerang, a flat curved stick which they throw in such a

fashion as to make it return to them after describing a long curve through the air. (*Consult Low's "Native Tribes of South Australia."*)

The Tasmanians, now extinct, were a shorter and stouter people, with more frizzly hair and rounder heads than the Australasians. They inhabited the neighboring island of Tasmania. (*See Bonwick's "The Lost Tasmanian Race."*)

The Melanesians, sometimes called Papuans or Black Polynesians, inhabit many of the islands in the southwest Pacific, including Papua or New Guinea and the interior of some of the larger islands, such as Fiji, of which the coasts are occupied by the brown race of typical Polynesians. They are (for the most part) violent and ferocious savages, frequently cannibals; and many of their customs, as well as their color, recall those of certain African tribes. In a few localities, they have received missionaries and risen somewhat above their primitive barbarism. (*See Flower, "Journal of the Anthropological Society," London, 1885.*)

There are certain dark people in southern India and Ceylon who have been referred by some authorities to the Black Type of man, but by the majority of writers to the brunette group of the White Type. These are the Dravidians and Kolarians, chiefly distinguished from each other by their respective languages. The former speak a dialect claimed by some writers to resemble the Malayo-Polynesian tongues, while that of the Kolarians is said to have Mongolian features. In all probability these people are the result of a mixture of races.

The origin of the black races, generally in the most unhealthy regions of the tropics, has inured them to climatic influences which would quickly prove fatal to people of other types. It is well known that malarial fevers rarely affect negroes. For this reason, the black races have been invaluable as laborers in malarial regions, such as the site of the Panama Canal and the rich lowlands of the southern United States. The development of the cotton and tobacco industries, which early in its history placed the United States among the great commercial nations, could hardly have been effected without the labor of negroes; and to the forced training in steady work, which the otherwise evil institution of slavery brought upon his predecessors, is doubtless due much of the advance in character and civilization which separates the present American negro from the original African, and has given him a creditable place among the free citizens of a progressive nation.

Questions.—What are the relations of man to other living beings? What names are applied to man in the classification of zoölogy? How else may man be classified? Name the sciences which treat of mankind in general; of the races of men, and of their social relations. How is mankind classed in regard to physical characters? Give examples of the artificial divisions into which mankind has organized itself.

What is meant by a Type? a Race? a People? a Nation? Explain the essential difference between races and nations. Mention the three chief types of mankind. What features are used in discriminating them?

What are the characteristics of the Black Type, and the distribution of its chief races? Describe the typical Negroes; the Hottentots; the Bushmen; the Negritos; the Australasians. What part in the development of the United States has been taken by people of the Black Type?

THE YELLOW TYPE.

The Yellow Type, frequently called Mongolian, is the most widely distributed of all; its representative races are found from the borders of the Arctic Ocean to the tropical islands of the Pacific, and occupy large areas in Asia and America. It is characterized by a moderately prominent nose; a complexion varying from pale olive to dark brown; straight black hair; and a skull shorter in proportion to its breadth than in the races of the Black Type.

In minor characters, the Yellow Type is more varied than the others, and is divisible into three principal sections—the Mongolian proper, the Malayo-Polynesian, and the American.

The Mongolian section occupies the greater part of Asia, and portions of Eastern and Northern Europe and Northern America. It comprises the following races:—

Mongol-Altai.	Indo-Chinese.	Hyperboreans.	Esquimaux.
Turks.	Chinese.	Yukagirs.	Of Asia.
Yakuts.	Anamese.	Kariaks.	Of America.
Tatars.	Burmese.	Kamchatdales.	Of Greenland.
Kirghiz.	Thibetans.		Aleuts.
Mongols.	Tai.		
Ostiaks.	Coreans.		
Samoyeds.	Japanese.		

The Mongol-Altaic Race includes most of the nomads of Asia who move about, subsisting on their flocks and herds, over the western parts of the Asiatic plateaus and the plains of Western and Northern Asia. They are Mohammedans, or profess a religion of the Shaman'ic type (characterized by a belief in numerous spirits more or less controllable by sorcery), such as is common to many uncivilized peoples. The settled branches of the race have attained a higher degree of civilization, especially the Turks, who are Mohammedans. Six-sevenths of the population of Turkey, however, are of other races and religions, many professing Christianity.

The Yakuts occupy a large area in eastern Siberia and, though less civilized than the Turks, are an industrious and worthy people. The Samoyeds dwell near the Arctic Ocean and approach the Hyperborean group, with which some have connected them. The proper classification of these and many other peoples of the Yellow Type is far from settled; if divided according to their languages, as is generally attempted, the groups become very numerous, and the relationships difficult to determine. (*See Lansdell's "Through Siberia."*)

The Indo-Chinese Race comprises the more civilized and sedentary element of the Asiatic population of the Yellow Type. The typical people of this race are the Chinese.

The Chinese early attained a remarkable degree of civilization far in advance of that of contemporary European nations, but which suffered a singular arrest of development. They invented gunpowder, the magnetic compass, and block-printing; but have never brought any of these inventions to perfection. Their religion varies; that of the common people is a mixture of moral maxims, astrology, and the worship of ancestors.

Education, so far as reading and writing are concerned, is nearly universal, but the people are a prey to the most absurd superstitions, which stand in the way of any real progress. They are very industrious, matter of fact, and economical in their habits; Chinese merchants have a world-wide reputation for shrewdness. The surplus population among the lower classes in China is very great, so that there has been an emigration into adjacent countries wherever labor is required; but the habits of the coolies (*laborers*) are such, that in all civilized communities their existence in large numbers has been found socially undesirable and injurious. In Oriental countries the industry and steadiness of the Chinese, united to his thrift, make him an invaluable agent in developing their resources. (*Consult Williams's "The Middle Kingdom."*)

Among the upper classes, two curious customs are noted. The highest in rank, to indicate that they do not use their hands for labor, allow the nails to grow to as great a length as possible. This practice (noticed by Sir John Mandeville in his book of travels, 1356) also prevails among the Siamese and other nations which have been more or less under the control of China politically or socially in past ages. The second custom is that of compressing the feet of girls, so that they remain undeveloped and deformed through life.

Nearly related to the Chinese, long their virtual masters, are the Anamese, over whose territory the French have recently established a protectorate. More distinct are the Burmese, who form with the Thibetans a particular group.

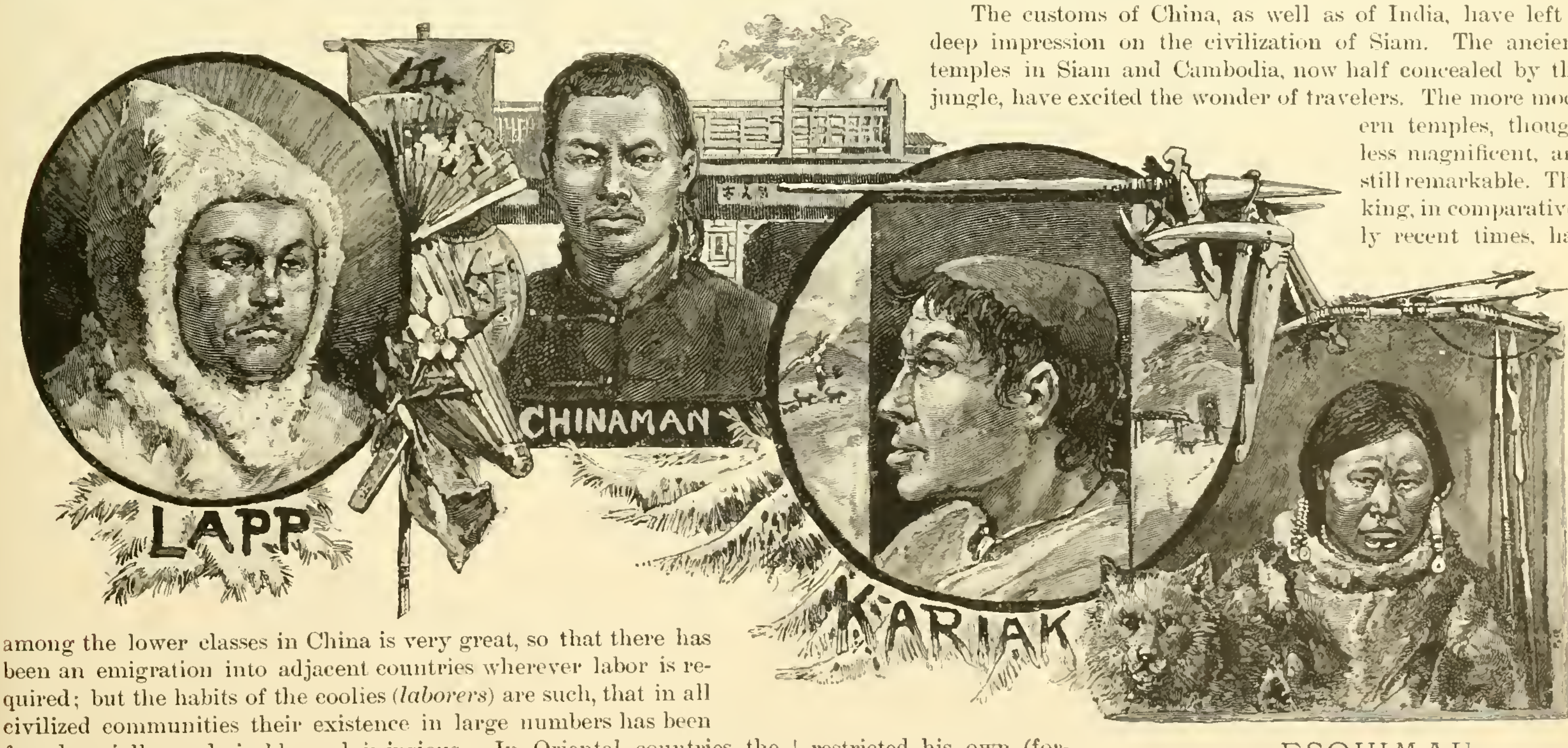
The inhabitants of Thibet are Buddhists. They are governed by a priesthood, to the chief of whom, called the Grand La'ma, supernatural attributes are ascribed. As a people they are chiefly remarkable for the fanaticism with which they oppose the admission of strangers to their territory. They live by agriculture and stock-raising. (*See C. R. Markham's "Mission to Tibet and Lhasa."*)

The Burmese have recently come under a British protectorate. They have a brown complexion, rather coarse features and physique, and live largely by agriculture, hunting, and by the products of their forests and mines of precious stones.

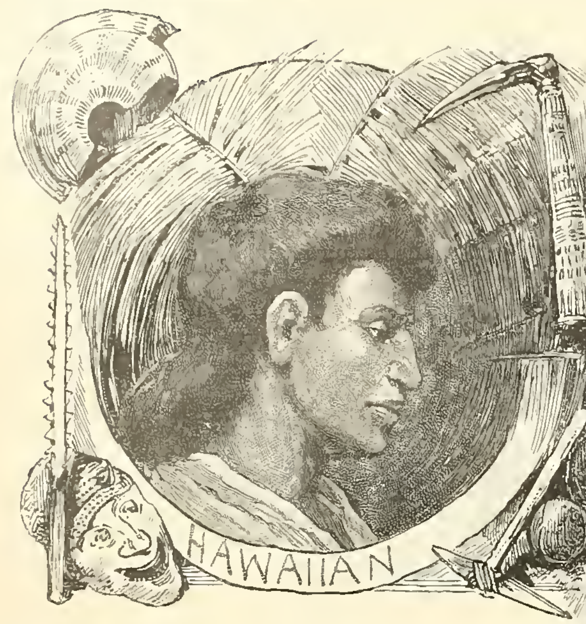
Their government was an absolute despotism. They are Buddhists by religion, and their country contains numerous remarkable shrines and temples. They build their houses of one story, that no one may walk over their heads. Their arts and manufactures are in a poorly developed state and resemble those of India, having, probably, with their alphabet, been introduced with Buddhism from that country (*See Scott's "The Burman and his Notions."*)

The Siamese are another exclusively Buddhist people, with a somewhat lighter complexion and greater capacity for progress. They shave the head, except a top-knot, and are among the few people in the world that crop short the hair of their women. Though having many customs in common with the Burmese—such as regarding albino elephants as holy, and building houses of only one story—they are separated from that people by language, and to some extent by physical features.

The customs of China, as well as of India, have left a deep impression on the civilization of Siam. The ancient temples in Siam and Cambodia, now half concealed by the jungle, have excited the wonder of travelers. The more modern temples, though less magnificent, are still remarkable. The king, in comparatively recent times, has restricted his own (formerly despotic) power, and governs with the advice of a council of nobles. In both Burma and Siam, however, nobility is not necessarily hereditary, but depends much on royal favor. Slavery and polygamy exist, and great brutality is shown in the punish



ESQUIMAU



ment of offenders. (*Compare Carl Bock's "Temples and Elephants": and Mrs. Leonowens's "English Governess at the Siamese Court," 1870.*)

The Buddhist religion, which is professed by some four hundred and fifty million people of the Yellow Type, now has its metropolis in Thibet, with many followers in Ceylon, Siam, Burma, Corea, and Japan. Formerly it was the popular religion in India and parts of China, but has fallen into neglect there at the present time. The philosophy of this religion contains much that is admirable as moral teaching, and has been welcomed by students in civilized countries on that account. Its aim, to be absorbed from self-consciousness into the substance of Deity, as a reward for charity and self-sacrifice—or, as the Buddhist would say, "to enter Nirvana"—responds, with an idea of restfulness, to the desires of the care-worn soul of man in all ages.

But, as religions are to be judged by their results, Buddhism in practice must be considered a failure. Its founder, Gautama, afterward called Buddha (*the Enlightened*), a native of India, died of a surfeit. Its priests, considering prayer a means of accumulating credit with the Deity, and in proportion to the number of petitions, have assumed that the turn of a wheel, carrying the prayer printed on paper, is equivalent to offering the petition verbally. Little hand-wheels with thousands of printed prayers wound on them are commonly sold, and are whirled with the left hand, while the other is employed by the Buddhist in his ordinary labor. Larger prayer-mills are set going by water-power, and the wheel grinds out prayers while the owner sleeps.

The priests are at once tyrants and mendicants. The hierarchy of Thibet is all-powerful in that country, and in its forms and constitution curiously resembles the organization of the European church in the Middle Ages. The purest variety of Buddhism is that now existing in Ceylon, but it is mixed with idolatry and many gross superstitions.

The Japanese and Coreans form another group. The Coreans are tributary to China, are largely Buddhists, and practice Chinese methods in education and dress, architecture, and many arts. Long secluded from civilization, they have lately been forced to admit foreigners, and show some tendency to adopt progressive methods. Physically they resemble the Chinese. (*Consult Griffis's "Corea, the Hermit Nation."*)

The Japanese are a small race, with brown complexion and of inferior muscular development. They are remarkable among uncivilized people for the facility and rapidity with which they have adapted themselves to European ideas of government and education. For centuries they lived almost exclusively by agriculture and their fisheries; they were governed directly by a series of powerful feudal chiefs; and they scrupulously excluded all foreigners from their shores, except at a few commercial stations. In a few years all this has been changed. The Japanese have established a government on modern principles, entered into diplomatic relations with European and American nations, opened institutions of learning, and engaged in an extensive commerce.

A very prominent characteristic of the Japanese people is their refined taste in decorative art and its application to objects of daily use, especially those of pottery and porcelain, or those wrought in wood or bronze. This art is supposed to have originated in Corea; its development in Japan has been the marvel of artists the world over. (*See Morse's "Japanese Homes and their Surroundings."*)

The Hyperbo'reans (*beyond Boreas*, the north-wind), so called because they live in the northern part of Siberia, form a group rather than a race. Many of the tribes constituting this group are nearly extinct. They are mostly nomads, living on their herds of tame reindeer, like the Samoyeds and Lapps. (*See Kennan's "Tent-Life in Siberia."*)

The most important people of the group are the Kariaks of the extreme northeast of Siberia and Kamchatka. A section of this people, called Chuk-chi, have attracted some attention because, being confounded with certain tribes of Esquimaux settled among them, they were supposed to form the connecting link between the native races of Asia and America. This is now known to be an error.

The Esquimaux are a remarkably uniform race, of Mongolian physique. They live on the Arctic shores of America, Asia, and the archipelago north of America, of which Greenland forms a part. (*See Crantz and Egede's "Greenland."*)

The Esquimaux have mastered the means of existence amid ice and snow, by methods which show extraordinary ingenuity. A few small bands have been driven across Bering Strait, at a comparatively recent date; others extend southward on the shores of Alaska nearly to Mount St. Elias. Across the whole northern border of America to Greenland, they show an extraordinary uniformity of language, arts, and mode of life. The stunted mixed tribes of Danish Greenland have usually been taken as the type of the race; but the Esquimaux of Northwest America show a much finer physical development, as do also the recently discovered wild tribes of East Greenland. The natives of the

Aleutian Islands, though now Christianized and civilized, are a branch of the Esquimau race modified more than any of the others by the isolation and peculiar conditions of their island homes. (*Consult Rink's "Tales and Traditions of the Esquimaux"; and Dall, "Contributions to North American Ethnology," vol. i., pp. 93-106.*)

Some peoples of Northern Europe, the Lapps and Finns, belong physically to the Yellow Type, and are generally associated with the Mongol-Altaic race, though their language and habits have been much modified by contact with other races. (*See Tromholt's "Under the Rays of the Aurora Borealis," vol. i.*) The Magyars (*mod'jors*) of Austria-Hungary are a people of Mongolian origin, and the only branch of that race which has attained to the spirit of modern civilization.

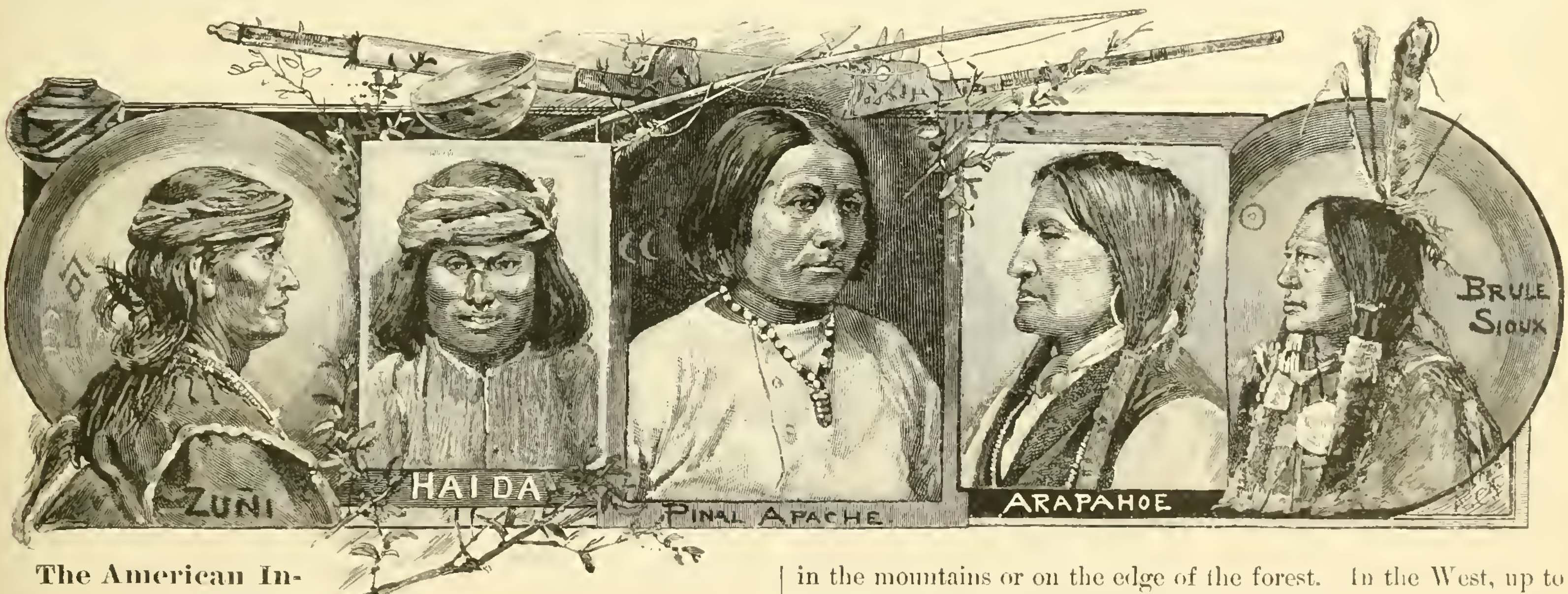
The Malayo-Polynesian Section of the Yellow Type of man comprises the brown people of the Pacific islands, Hawaii, Tahiti, and many others, the Maories of New Zealand, and the Malays of Southeastern Asia. (*Compare Captain James Cook, "Voyages to the South Seas"; Hochstetter's "New Zealand."*)

These people display the highest type of physical beauty among the yellow races. The original stock is supposed to be best represented by the inhabitants of the Hawaiian islands and the Marquesas. The Malay tribes had occasionally risen, as in Java, to a superior degree of civilization before feeling the influence of Europeans, but the Malay stock is believed to contain a mixture of several races. At the present day, the Ho'vas of Madagascar and the Hawaiians have adopted more or less completely the manners and religion of civilization; and other Polynesians are following in their steps. The Malays, on the other hand, have degenerated rather than improved. (*See Forbes's "Naturalist's Wanderings in the Eastern Archipelago."*).

epithet "Red," so often applied to the Indian, is, in general, singularly inaccurate. It arose from the fact that the Caribs, a race inhabiting the Antilles at the time of their discovery by Columbus, had a ruddy complexion, which they heightened by the use of red ochre. From them, the misnomer of "Red-skin" was extended to the people of North America in general. (*See Nadaillac's "Prehistoric America."*)

At the time of the discovery of America, the natives differed in the development of their social system, in arts, language, and mode of life. Among all the tribes, one feature was characteristic—the welfare of the community was the chief object of duty—comparatively little was left to the will or preference of the individual, and the complexity of these social restrictions increased with the civilization of the tribe or people. The common notion of the enjoyment of a free and untrammeled existence by the wild Indian is wholly false. There were, perhaps, no people in the world so bound by a multitude of customs, which were enforced more vigorously than most written laws of civilized lands. The exact mode of cutting his hair, the place where he must sit in the lodge or hut, the very phrases he must use in addressing his relatives or associates, were all rigidly fixed. (*Consult Morgan, "Contributions to North American Ethnology," vol. iv.*)

The Indians are now known to belong to a great number of groups, characterized by differences of language; but they may be conveniently classified according to their mode of life. The least elevated tribes were more or less nomadic, with no permanent houses or villages. In the East they lived in tents or lodges, during the fishing-season by the rivers or sea, during the hunting-season



The American Indians are the last section of the Yellow Type to be considered. The aboriginal peoples of the two Americas, from Patagonia to the Arctic regions, have many features in common. The general structure of their languages is similar, in spite of wonderful diversity of detail. The stage of progress from barbarism which most of them had reached at the time of Columbus, was, with certain exceptions, much the same. Even the so-called civilization of the ancient Mexicans and Peruvians, much misunderstood, and consequently misrepresented by early historians, as well as by some modern writers, was of a nature entirely compatible with development from the state of which the average Indian was then a type.

The American race is characterized by long, black, straight hair, black eyes, large and generally coarse features, high cheekbones, a prominent but not large nose, and a complexion varying from ruddy to pale olive through various shades of brown. The

in the mountains or on the edge of the forest. In the West, up to a recent period, such tribes followed the migrations of the buffalo and other large game. They could easily retreat before the whites, and often may have saved themselves when the more settled and civilized tribes stood by their homes until both were destroyed.

Mound-Builders.—In those regions where the climate made it easier to obtain a living by regular labor, settled villages, defended by fortifications, existed, and agriculture formed an important pursuit. Large quantities of corn and pumpkins were grown; mounds of earth were erected for defense, as sites for altars or temples, over the bodies of distinguished chiefs and warriors, and as common grounds for games or athletic exercises; perhaps, for other purposes, also. Such mounds were constructed and in use by the Natchez and other Southern tribes at the time of their discovery. (*See Lucien Carr's "Mounds of the Mississippi Valley."*)

Mounds, apparently erected for similar purposes, are found from the mouth of the Mississippi northward to Hudson Bay, and are especially remarkable in the Ohio Valley. It is supposed by the most recent investigators that the peoples or tribes who constructed these works, and who are popularly styled "Mound-builders," were not dissimilar to the known mound-building tribes (such as the Iroquois, Creeks, and Natchez). It is thought that they were dispersed or destroyed by war or pestilence, and that their territory was subsequently occupied by nomadic or less advanced nations. (*See Squier, "Smithsonian Contributions," vol. ii., p. 83.*)

Cliff-Dwellers.—In the Southwest, the absence of timber resulted in the use of stone or sun-dried brick, as a material for building, by the settled tribes. The large tribal structures, curiously arranged for defense, were called by the Spaniards pueblos (*villages*). For retreat in case of need, some of the natives built on ledges in front of cliffs, or on isolated rocks, almost inaccessible houses which have received the name of "Cliff-dwellings." Certain of these were inhabited for long periods; but most of them, probably, served only as places of refuge; and some have been found which, though carefully finished, seem never to have been occupied.

Aztecs and Peruvians.—In the fertile plateau of Mexico and in the highlands of Peru and Bolivia, the highest American civilization was reached. Here, though the use of iron was unknown, large temples and stone cities were built, roads made, aqueducts constructed; and the arts of weaving, gold and copper working, carving, and sculpture, attained a remarkable degree of progress. The worship of the sun and moon, the deification of dead heroes, and even human sacrifices on a grand scale, were prominent features of the religious system. A complicated calendar and some rude attempts at partly phonetic hieroglyphic writing were found by the Spaniards in Mexico. (*See Habel's "Central American Investigations," "Smithsonian Contributions," vol. xxii.*)

At present, the ancient civilization is known only by the ruins of its temples, and from early Spanish records. Pueblos, as at Zuñi, are still inhabited, protected by the desert, but the Indians of the Mississippi and Ohio Valleys and the Atlantic slope, know their old homes no more.

Remnants of some tribes are now settled in the Indian Territory reserved for their use by the Government, and are more or less civilized and prosperous. Nearly all the Indians of the United States are now on government reservations; while in South and Central America and Mexico, though diminished in numbers, many thousands of the wild tribes still continue in nearly their original mode of life.

Of existing American peoples the Tupi and Guarani tribes, widely spread in Brazil, the Mayoruna of eastern Peru, the Tehuelches and Araucanians of southern South America, may be cited. In North America are the Algonquins, of whom the Arapahoes are a tribe; the Athabascans, to which group the Apaches belong; the Sioux, widely spread northwest of the Mississippi; and the Zuñis, one of the tribes still dwelling in pueblos. Of a strongly marked group found on the shores of northwest America, the Haida and Tlinkit peoples are among the most noteworthy. They are a laborious and settled race, remarkable for their proficiency in carving and for their independent manners. (*See Dall's "Alaska and its Resources," part ii., chapter iii.; G. M. Dawson's "On the Haida of Queen Charlotte Islands."*)

Questions.—What are the characters of the Yellow Type? Into what sections is it divided? Name the races of the Mongolian section. Enumerate the chief peoples of the Mongol-Altaic race; of the Indo-Chinese race; of the Hyperborean group. Characterize the Chinese; the Burmese; the Siamese. What contrast exists between the theory and practice of Buddhism? Describe the Coreans; the Japanese. For what are they particularly remarkable?

Who are the Hyperboreans? What people of this group is the most noteworthy, and why? Characterize the Esquimaux. How are they distributed? What is the physical difference between the Danish Esquimaux and the uncivilized tribes? What other people, now civilized, form a branch of the Esquimau stock? What European peoples are of Mongolian origin? Which of them has become entirely civilized and progressive? Of what peoples is the Malayo-Polynesian section composed? What are their relations to civilization?

By what social and physical characters are the original inhabitants of America connected? Why have they been called Red Indians? How did they differ at the time of the discovery of America? What common feature was characteristic of their social life? What distinctions in their mode of life enable us to classify the American tribes? Who and what were the Mound-builders? the Pueblo people? What relation to the pueblo settlements had the cliff-dwellings? Where was the highest type of American culture reached? What were its chief features? State the present condition of the American tribes in North and South America.

THE WHITE TYPE.

The White Type of mankind is that with which we are most familiar, and of which the enlightened and progressive nations of the world are chiefly composed. It is characterized by a prominent nose, with medium or non-projecting jaws, and straight or curly hair, abundant on the face and person; the average capacity of the brain is greater than in the other types. The White Type is divided into two sections, the Blondes and Brunettes, or light and dark races. Some of the latter are very dark, but are separated by the nature of the hair and other characteristics from races of the black type.

The Blonde races include the Teutonic, Caucasic, Afghan, and Berber stocks; the Brunette races are the Latin or Romanic, the Semitic, the Hamitic, most of the Asiatic Aryans, the Maiotze of China, and the Ainos of northeastern Asia and Japan.

The Teutonic or Indo-Germanic Race contributes the majority of the people making up the nations of England and her colonies, the United States, Germany, the Scandinavian kingdoms, Holland, and, to a less extent, Russia.

The Teutonic peoples passed through many changes and migrations before the era of civilization. The contrast between the Celts (Irish, Welsh, Highlanders) of Britain and the typical English is in large part a contrast between the descendants of historically early and later emigrants from the European Continent, both offshoots from a still earlier exodus of Aryan peoples from the Asian plateaus.

The Caucasic Race includes the Circassians and Georgians, with other people living on or near the mountains of the Caucasus, between the Black and Caspian Seas. The people of the Caucasus gave their name to the White Type, so generally called Caucasian, because the earlier writers on the subject supposed them to be physically the finest modern examples of the type existing in an unmixed state. Later travelers believe the reputation undeserved, or much exaggerated.

The Afghan Race occupies the mountain-region between Russian Turkestan on one side, and Persia and India on the other. This race is mixed, and the name Afghan includes many brunettes, partly at least of Semitic origin.

The Berber Race is a blonde people of North Africa, especially of Morocco and Algeria, whose mode of life is much the same as that of the surrounding darker races.

The Romanic Race includes the dark people of southern Europe—the Italians, French, Spanish, Portuguese, Greeks, etc.

They derive their name from the fact that their languages are mostly related to the Latin, spoken by the ancient Romans. They are chiefly derived from emigrants of Aryan extraction, known as Pelasgians.

The Semitic Race includes the Arabs, the Aramaic or Syrian peoples, and many of the Oriental Israelites. The Moors of Morocco, the Himyarites, and others in Abyssinia and northeastern Africa, though mixed, have a large share of Semitic blood.

Questions on the Ethnological Map.—In what latitudes has man attained the highest development? How does climate affect animal and vegetable life? How, the civilization of man? What race is most widely distributed over the earth? Which occupies the most territory? Note generally the geographical position of the several races. To what race do the Turks belong? the Maoris? the Aztecs? the Esquimaux? the Sioux? the Aleuts? the Tlinkit people? What races inhabit the steppes of eastern Europe, and of northern and central Asia? What people are native to the Arctic Archipelago? Find the geographical home of the negro. What regions are occupied by Malayo-Polynesians?

Point out the most important peoples of the American race in North and South America. Which of these gives its name to a sea? to a district of Canada? to an important group of islands belonging to the United States? to cities in Iowa and South Dakota? Do you know of any rivers or lakes that bear Indian names? What portions of America are not inhabited by the "Red Race"?

How far has emigration and colonization affected Africa? Indicate the country of the Hovas; of the Hottentots; of the Bantu; of the Caffres; of the Fulah; of the Gallas; of the Copts. What representatives of the White Race are met with in Africa? in China and Japan? Name some of the most remarkable of the mixed races of western Europe. To what extent has immigration from Europe to Australia, and to Central, South, and Danish America, affected the aboriginal tribes?

In what part of the world do the Dravidians live, and to what race do they belong? the Tatars? the Kirghiz? the Athabascans? the Basques? the Papuans? the Yakuts? the Berbers? the Magyars? the Lapps and Finns? the Samoyeds? Mention the countries occupied by Teutonic, Slavic, Celtic, and Romanic peoples of Aryan parentage. (See map showing distribution of the Aryan race in Europe on the introductory page of Quackenbos's "History of Ancient Literature.") To what race do the Jews belong? To the Semitic branch of the White Type. Point out the people who dwell in pueblos. What can you say of the Fuegians? They are a race of degraded savages, related to the Patagonians, but physically and intellectually inferior; they clothe themselves scantily in guanaco and seal skins, and subsist mainly on fish. Attempts to Christianize them have failed. Name some islands that are occupied by the black races; certain peninsulas that are the abode of people of the Yellow Type.

Among ancient nations, the Semitic race was pre-eminent in spiritual gifts, intelligence, and in commerce and maritime enterprise. Through a Semitic people, the Hebrews, we have received the Bible and the Christian religion; from another, the Phœnicians, our alphabet; the Arabic numerals, the elements of chemistry, physics, medicine, and astronomy, were, in the form in which they have come to us, the products of Arab learning and ingenuity. The Mohammedan religion, next to the Christian the most powerful in its influence on mankind, is of Semitic origin. Among the extinct Semitic peoples are the Assyrians, Carthaginians, Phœnicians, and Canaanites. (*See Lady Duff Gordon's "Last Letters from Egypt."*)

The Hamitic Race includes the Egyptians, Libyans, and Numidians, or Ethiopians.

Of this race are the Copts, the Kabyles of North Africa, and the Somali and Galla people of the region about Abyssinia. To it also belonged the ancient Egyptians. Its actual representatives are of very mixed blood, and contain the darkest examples of the White Type of man.

The Asiatic Aryans comprise the Hindoos, the Persians, the people of Kafiristan sometimes called Galchas, the Armenians, Baluchees, Kurds, and Parsees.

The origin and migrations of the Aryan stock, from which so many races and powerful nations have sprung, are still subjects of controversy. It is generally conceded that the original home of the Aryans was in central Asia; that they spoke a language most nearly related to the Sanskrit of India; and that they were a pastoral people. From the cradle of their race, in prehistoric times, great bodies successively migrated in different directions, ultimately making permanent settlements in Persia, northern India, and various parts of the European Continent. These emigrants were the progenitors of the Aryan and Teutonic nations. (*See Professor Max Müller's article entitled "Aryan," Encyclopædia Britannica, vol. ii., p. 672.*)

The Maiotze, of southeastern China, and the **Ainos,** of Japan and the Kurile Islands, are generally admitted to be of the White Type. They are as yet imperfectly known, and their ultimate relations to other races of that group are yet to be investigated.

The Maiotze are definitely known not to be Mongolians. The Ainos were apparently the original inhabitants of Japan, before the advent of the Japanese. They are noted for their profuse growth of hair, and their mild and amiable manners. They are in a very low state of culture. (*Consult Miss Bird's "Unbeaten Tracks in Japan."*)

Questions.—What are the characteristics of the White Type? Into what sections is it divided? Why is it difficult to classify civilized peoples? Name the Blonde races; the Brunette races. What nations are chiefly formed by members of the Teutonic race? To what is due the contrast between the British and Irish Celts on the one hand, and the typical Englishman on the other? Of what people is the Caucasic race composed? How did the name of this small nation become applied to all people of the White Type?

Who compose the Afghan race, and what other race has mixed with it? What region does it occupy? Describe the Berber race; the Romanic race. Why are the latter so called, and from what people are they supposed to have sprung? What modern peoples are Romanic? What people are included in the Semitic race? How has this race been distinguished? What essentials does modern civilization owe to people of this race? What great religions have been received through Semitic peoples? What remarkable peoples of antiquity, now extinct, were Semites? (On the Semitic family of languages, ancient and modern, and the distribution of the Semites in antiquity, *consult Quackenbos's "History of Ancient Literature," pp. 17, 85, 104, 114.*) Enumerate the peoples of the Hamitic race; the Asiatic Aryans. What is supposed to have been the history of the Aryan stock? What people of China and Japan are supposed to be of the White Type? Define the general nature of the differences that exist between the principal races of men.

MINERAL PRODUCTS AND THEIR DISTRIBUTION.

Economic Geology.—In the opening chapter of this work, on the Structure of the Earth, was presented an interesting scientific consideration of the subject of geology in connection with its relations to Physical Geography. The science of geology, however, is also of singular practical value to civilized man, in that it teaches him how and where to find in the several classes of rocks those mineral products so essential to his welfare—the materials used in the construction, adornment, lighting, and heating, of his dwellings and factories; in the manufacture of his tools and machinery; in the enrichment of exhausted soils; the substances employed in the various arts; the pigments and dyes; the mineral medicines; the precious metals, and the gems.

Geology furnishes, moreover, the necessary data for the valuation of land as regards its agricultural and mineral resources; determines the feasibility of proposed road, railway, and canal construction, and of river improvement; and defines the prospective profit in newly opened mines and quarries. (*Read Professor Page's "Economic Geology."*)

Man can make little progress in civilization without availing himself of the mineral and metallic stores hidden in the earth's crust. The earliest records of the human race represent the most enlightened communities as familiar with metallurgy; while those who fashioned their utensils and weapons out of stone lived in a state of general savagery. The presence of useful and precious minerals has had much to do with the settlement of important regions, and the development of agricultural and manufacturing industries. (*See Professor Joly's "Man before Metals."*)

Forms of Minerals.—Mineral bodies occur in a solid, liquid, and gaseous form. While few are now met with in a state other than solid, there is reason to believe that many of our familiar minerals once existed as gases or liquids, and that their present structure was determined in the process of solidification.

Bodies that have thus resulted are divided by mineralogists into two classes: I. Amorphous (*without a form*), having no regular figure, breaking with equal facility in all directions, equally hard and elastic throughout; for example, common iron-ore. II. Crystalline, having a definite geometrical form bounded by plane surfaces symmetrically arranged, more easily separable and conducting heat more rapidly in certain directions, as a rule not equally hard and elastic throughout; for example, the diamond. The same mineral body sometimes occurs both in a crystalline and amorphous condition, as gold. (*Consult Professor Egleston's "Lectures on Crystallography."*)

The Geographical Distribution of Minerals, unlike that of plants and animals, does not depend on climate or elevation above sea-level. Mineral bodies are not confined to particular sections of the globe. Some occur near the surface in alluvial soil or the sandy beds of rivers; others lie deeply imbedded in the earth's crust, and are obtained only with great expense and labor. Many of the most important deposits are found in mountainous regions.

METALS AND METALLIC ORES.

Classification of Metals.—Among the subjects of economic geology, that of metallic substances possesses singular interest and value. To metals, man owes his ascendency over Nature; restricted to wood, bone, and stone, he must have remained a savage. (*Compare Dr. Abbott's "Primitive Industry, or Illustrations of Handiwork in Stone, Bone, and Clay."*)

The most important metals are gold, silver, plat'inum, mercury, iron, lead, copper, tin, zinc, nickel, and antimony. The first two are called Precious Metals. They occur chiefly in a native state, but alloyed to some extent with each other. Platinum is also met with native; the others are generally found as ores—that is, in chemical union with other substances. The total value of the mineral production of the United States in 1896 was $746,768,000.

Gold, the most valuable of the metals, has been prized from the earliest ages. Gold jewelry and vessels are found in Egyptian tombs (visit the Abbott collection in the library building of the New York Historical Society), and ancient Etruscan artists worked the metals into exquisite ornaments. A knowledge of the metallurgy of gold at less remote periods was wide-spread.

Gold occurs in nature chiefly in the metallic state—frequently in octahedral crystals, more commonly in irregular masses called "nuggets," from a few grains to many pounds in weight, or in the form of dust and "scales." Its color is yellow of some shade; it retains its luster in the air, and its solid form in a temperature below 2,000°; it is from sixteen to nineteen and a half times as heavy as pure water. Gold is extremely malleable and ductile; it may be beaten into leaves only $\frac{1}{282000}$ of an inch in thickness; a single grain of it can be drawn into a wire five hundred feet long. The test for gold is its resistance to common reagents; it is soluble in nitro-muriatic acid (*aqua regia*). Native gold is soft; when alloyed with copper which heightens its tint, or with silver which lowers it, the metal becomes sufficiently hard to be coined into money or manufactured into ornaments. (*See Egleston's "Metallurgy of Gold, Silver, and Mercury in the United States."*)

Gold is widely, though sparingly, distributed over the earth, occurring in veins of quartz, or scattered in stream-drifts of sand and gravel.

In quartz-mining, the rock is got out, sometimes from considerable depths, and reduced to powder by machinery, so as to detach every particle of metal. The quartz is then washed away with water, quicksilver being used to combine the fine metallic particles with itself in an "amalgam," from which the gold is afterward separated. When gold occurs in deposits of gravel, which from the surface down may be as thick as 500 feet, it is obtained by hydraulic mining.

The Richest Gold-Fields in the world lie in the region between the Pacific Ocean and the Great Plains of North America. Since the discovery of gold in California, in 1848, the total yield of the United States has been not far from $2,000,000,000; in 1896, the value of the product was $52,886,200. Mexico and Central America also contain valuable gold deposits; while in the Yukon districts of Alaska and of the adjoining territory of the Dominion of Canada are some of the richest mining areas at present known. There are gold-bearing localities also on the Atlantic slopes of North America, and rich gold-veins in Brazil, Guiana, and among the Andes.

The Australian gold districts, which have been ranked next to California in importance, cover an extensive area. New Zealand and Japan as well contain large deposits. Valuable deposits have recently been discovered in Tasmania. The amount of gold produced in Continental Europe, principally in Austria-Hungary, is estimated at about $5,000,000 a year; while the mines on the eastern slopes of the Ural Mountains have long been richly productive. Native washers still obtain small quantities of the precious metal in the highlands of India.

In Africa, formerly, the principal gold-bearing regions were on the west coast—the English piece called the guinea was so called because originally coined from gold exported from the Guinea trading-stations. But, more recently, alluvial deposits have been worked in the mountains of the Transvaal; and the discovery, in 1886, of gold-bearing "reefs" of great richness has attracted thousands of miners to these South African gold-fields. Since then they have proved among the most valuable in the world.

The value of gold at present in circulation among the great commercial nations has been estimated at about $4,000,000,000.

Silver is much more abundantly distributed than gold. It is rarely found native in "strings," "plates," and "nuggets," but usually occurs as an alloy in combination with gold, lead, mercury, copper, or sulphur. It is both malleable and ductile.

Like gold, silver has been used from early ages for coinage and the manufacture of ornaments and household utensils. The most productive mines have been those of Mexico; but while their yield has of late diminished, that of our own mines has largely increased, and the region between the Rocky Mountains and the Sierra Nevada has now taken the foremost rank in the production of this precious metal. The silver-bearing mines of Colorado are the largest producers. The amount of silver produced in the United States in 1896 was over 58,000,000 fine ounces. South America contains silver deposits of great value; while the Spanish mines are the most productive in Europe.

The value of silver at present in circulation throughout the civilized world is estimated at more than twice that of gold. The value of silver relatively to that of gold is subject to constant change. The ratio of silver to gold increased from 14.94 in 1687, to 31.60 in 1895.

Platinum (from a Spanish word *plati'na*, meaning *little silver*) was discovered to be a distinct "noble metal" about the middle of the last century. It occurs only in a metallic state, is one of the heaviest of metals, and from its wonderful resistance to heat is used almost exclusively for chemical utensils—crucibles, evaporating dishes, and stills.

The Russian government for a time struck platinum coins, but discontinued the practice on account of the fluctuations in the value of the metal. About three tons are annually produced, most of it on the eastern slopes of the Ural Mountains. This valuable metal is also found in some of the gold-washings of California and of the South American mines and in Australia.

Mercury, of brilliant white color, and distinguished from all other metals as the only one that is liquid at ordinary temperatures, is also known as quick (or *living*) silver. At 37.9° below zero Fahr., it freezes; at 675° F., it boils and is vaporized.

Mercury occurs sometimes pure, in the form of globules, generally as a red sulphide called *cinnabar*. Of European mines, those of Almaden *(almah'den)* in Spain and Idria in Austria, with those of Italy and Russia, furnish most of the mercury of commerce. The first are now almost equaled by those of New Almaden in California.

Mercury is used in the construction of thermometers, barometers, and other philosophical instruments. Its affinity for gold and silver makes it valuable in the process of extracting these metals from quartz, as already indicated. Two chlorides are used in medicine—calomel and corrosive sublimate. Blue-pill (mercury rubbed up with confection of roses) and mercury with chalk have long been popular remedies.

Iron, the most useful metal, is also the most abundantly and widely disseminated. In a pure state, it is characterized by luster and hardness, and when broken across exhibits a ragged fracture. Great heat is required to melt it. When white-hot it becomes soft, and can be forged into any shape, which it retains when cooled. Two white-hot masses of iron admit of being *welded*—i. e., pressed or heated together into one.

Iron is characterized by great strength and tenacity; it is both ductile and malleable, as well as elastic. Hence its use from early ages in the manufacture of cutting-instruments, both weapons and tools, and its intimate connection with the progress of civilization.

Iron-ore is abundant in different parts of the United States and Europe. Great Britain stands first, among European countries, in the manufacture of iron. Swedish iron has a high reputation.

Iron is used in three forms:

Cast-iron, made directly from the ore, contains from 2.5 to 5 per cent. of carbon, and is capable of taking the minutest forms from the mold. It is the cheapest variety, and is used for a thousand purposes.

Wrought-iron contains from .2 to .5 per cent. of carbon, and is made from cast-iron by diminishing the proportion of this element. It possesses great tenacity, and can be rolled into plates or sheets as thin as paper. Nails, wire, etc., are made of wrought iron.

Steel is iron combined with from ½ to 1½ per cent. of carbon. It is harder, whiter, and more elastic, than either cast or wrought iron, and takes a higher polish. It may be tempered to different degrees of hardness, and is employed for making the rails for railroads, plates for iron-clads, and other countless objects.

Iron has been used in the treatment of diseases from an early period. It promotes the reproduction of blood-corpuscles in the disease known as anæmia, characterized by pallor and general depression. Mineral waters containing iron are also popular blood-tonics.

Copper.—Next in usefulness to iron stands copper, so called from the Island of Cypress, whence the Romans derived their principal supply. It has been used from prehistoric times in the form of an alloy called *bronze*. Archæologists have given the name of Bronze to a remote age in which this metal was extensively employed in the manufacture of arms, ornaments, etc.

Copper is of a brilliant-red color; it is both malleable and ductile, and tenacious like iron. It occurs in numerous ores, as well as in a native state. Malachite, a green carbonate, is a beautiful and valuable ore. The sulphate, *blue-stone*, is used in the arts.

The richest copper-mines in the world are in Montana, and on the shores of Lake Superior, in Northern Michigan, where blocks of native metal weighing two hundred and fifty tons have been found; pieces of from ten to fifty tons are not uncommon. Chile produces large quantities of this metal; while the most productive copper region of Europe is Spain, whose mines were worked by the Romans.

Lead, a soft, bluish-gray metal, easily manipulated, is invaluable in the arts. It was known to the ancients, and used by the Romans, as with us, for the manufacture of water-pipes. Combined with other metals, it produces valuable alloys, like pewter, solder, and type-metal.

The chief lead-producing countries are the United States, England, and Spain. Most of the silver mined is found in combination with lead, the ores of which are melted on a large scale in the West for the purpose of obtaining this precious metal.

Tin is a soft, silvery-white, highly lustrous, and very malleable metal, a good conductor of heat and electricity, and not easily affected by moisture; hence its value for the manufacture of domestic utensils. It is largely employed for coating other metals. The oldest tin-mines are those of Cornwall in England, which have been worked from ancient times; the richest are those of Tasmania, the Malay Archipelago, and Bolivia.

Zinc is a soft metal with bluish-gray tint, harder than tin, and extremely malleable when heated so that it can be rolled into plates. Sheets of zinc are largely employed for roofing, and lining surfaces that come in contact with water, as this metal displays a peculiar resistance to oxidation. Therefore it is used for coating iron, which, when thus protected from rusting, is known as *galvanized* iron. Zinc is mined in Europe, in Northern Africa, and the United States.

Nickel is a brilliant metal whose value is derived from the fact that it combines in itself the characteristics of iron with some of those of the precious metals. As it does not tarnish by long exposure to the air, it is extensively employed in electroplating. German silver is an alloy of nickel, copper, and zinc.

Nickel is found in Pennsylvania, Oregon, and Nevada; in parts of Europe, and in New Caledonia. The mines of the Sudbury district in Canada furnish the greater part of all the nickel produced in the world. (The student is referred to *Professor Egleston's "Lectures on Mineralogy," and Professor Dana's "System of Mineralogy."*)

BUILDING-STONES, FUELS, ETC.

The Limestones constitute an extremely useful group, widely distributed over the earth. They are of close grain, and hard enough to be cut into blocks. When truly crystalline, they are known as *marbles*, and are susceptible of a high polish. They vary in color from a grayish or neutral tint to the exquisite waxy white of the statuary marbles.

Quarries are worked in different parts of the United States; the marbles of Vermont have a high reputation for beauty. The finest stone for statuary purposes comes from Carrara (*kăr-rah'rah*), Italy.

Limestones are absorbers of water, and hence, when subjected to sudden changes of weather, are apt to become rotten and disintegrate. Stones near the top of a quarry are often cracked and broken, while those taken from greater depths are perfect.

Granite is a mass of flesh-colored crystals of feldspar, and bright flaky crystals of mica, imbedded in quartz (*see p. 10*). As a building-stone, it is nearly imperishable. Granitic rocks are characterized by ruggedness. (On the limestones and marbles, *see Ansted's "The Great Stone-Book of Nature," p. 70.*)

Sandstones are composed of particles of sand or pebbles in some way adherent or cemented together. When the pebbles in the mass are of conspicuous size, it is called pudding-stone. The colors vary according to the composition. Some sandstones are exceedingly durable; others, like the brown-stone so much used for the fronts of buildings, easily decay and splinter.

The Clays and Chalks.—Clay is a chemical combination of a mineral called alumina with silica. In an absolutely pure state it is seldom met with in nature, being always combined with water, and generally mixed with sand and other impurities. A characteristic property of clay is its plastic nature, which renders it capable of being fashioned into any shape when moistened; if then exposed to great heat, it is deprived of the water without losing its form, and remains permanently hard. Thus clay is manufactured into bricks, tiles, drain-pipes, pottery, etc.

From superior varieties of brick-clay, terra-cotta work is made. China-clay, from which porcelain is manufactured, is a still finer variety. Originally obtained from China, it is still known by its native name of *kaolin*. Beds of kaolin have been discovered in the United States. Fuller's earth, another clay so called because formerly used in *fulling* or cleaning cloth, possesses the property of readily absorbing grease. Fire-clay is used in making crucibles for melting glass and the metals. Clay that has been subjected to enormous pressure is known as *slate*, and has a variety of practical applications.

Chalk is almost absolutely pure carbonate of lime. Examined under the microscope, it is found to consist of minute shells, "thousands of which would be required to bury a pin's-head."

Chalk has a marked affinity for water; a cubic foot of it will absorb two gallons, or nearly one-third of its own volume. Its chief use is in the manufacture of lime for mortar or fertilizing purposes.

Mineral Fuels.—The Coals.—One of the most important of minerals is coal—fossil vegetable matter grown and deposited during the Carboniferous Age (*see p. 14*). There are two kinds of coal—Anthracite (from the Latin word *anthrax, hard*), which is dense and heavy, and burns slowly; and Bituminous, which is soft, and burns with a bright flame and thick smoke like the mineral resin bitumen. A third substance called *lignite* is intermediate between wood and coal; jet is a kind of lignite.

Both anthracite and bituminous coal are found in immense quantities throughout the world. (On ancient forests and modern fuel, *see Ansted's "The Great Stone-Book of Nature," p. 193.*)

Petroleum, or Rock-Oil.—Crude petroleum is composed of a number of hydrocarbons like naphtha and bitu'men; it also contains impurities. It occurs in the stratified rocks of all ages; and geologists are of opinion that it owes its origin to the decomposition of organic remains, both animal and vegetable, by natural processes of distillation, in the deep-seated layers of the earth's crust.

In some places petroleum oozes up and flows out in springs; elsewhere, it is obtained by boring into the earth. A liberal flow of oil indicates the presence of a great subterranean reservoir. From petroleum are made, by distillation, kerosene, lubricating oils for oiling machinery, naphtha, paraffine, and other products of value. (*Consult Professor Winchell's "Sketches of Creation," p. 277.*)

Rock-Salt is widely distributed through the stratified rocks. It is believed to be produced by deposit or crystallization from condensing and evaporating bodies of saline waters, and is always mixed with impurities to a greater or less degree. As a proximate principle, salt is found in every fluid and tissue of the human body except the enamel of the teeth; hence it must be supplied freely with articles of food, and is an essential in habitable regions.

MINERAL PRODUCTS DERIVED FROM THE SEVERAL ROCK-SYSTEMS.

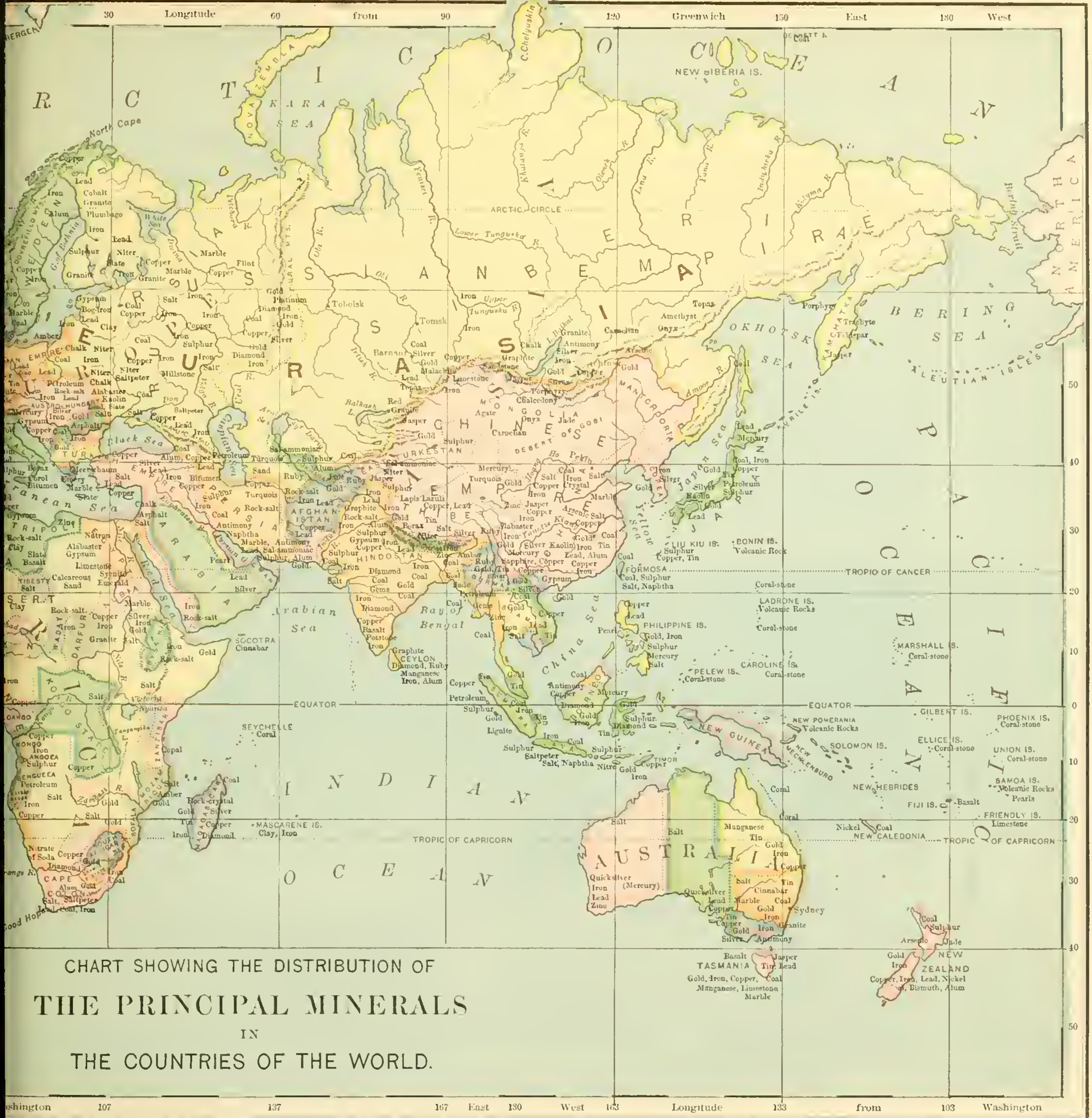
(*Selected from a Summary prepared by Professor Page.*)

SYSTEMS OF STRATA.	INDUSTRIAL PRODUCTS
Quaternary.	Sand for mortar and glass-making, gravels, clays, marls, peat, bog-wood, guano (mineralized droppings of sea-birds, valuable as a manure), copal from the soil of old forest-growths, naphtha, petroleum, asphalt, coral-stone.
Tertiary.	Flint gravels, clays of various qualities, gypsum (plaster-of-Paris), lignites or wood-coals (used for fuel, gas-making, etc.), amber.
Cretaceous.	Chalk, limestones, fire-stones, lignites, and bituminous coals.
Jurassic.	Brick-clays, sandstones, freestones, flag-stones and tile-stones, iron-stones, jet.
Triassic.	Alabaster, rock-salt, brine-springs, shell-limestones.
Carboniferous.	Sandstones, limestones, bituminous and anthracite coals, iron-ore, veins of lead, zinc, and antimony.
Devonian.	Sandstones of various colors and qualities, flag-stones, tile-stones, limestones, metalliferous veins of iron oxide, lead, copper, and silver.
Silurian and Cambrian.	Sandstones, limestones, slates, veins of gold, platinum, silver, mercury, copper, tin, lead, iron, etc.
Laurentian and Metamorphic.	Slates, marbles, asbestos, meerschaum, graphite (used in manufacture of lead-pencils), veins of precious and useful metals
Volcanic Rocks, produced by the discharges of volcanic matter.	Lavas (used for building, road-materials, etc.), pumice, obsidian, or volcanic glass (used by ancient races for the manufacture of implements), sulphur, borax.

Questions.—Explain the province of economic geology; the relation between a knowledge of the metals and man's progress in civilization. In what forms do mineral bodies occur? How have they been classified? What can you say of their distribution? Name the most important metals. Which are distinguished as *precious?* Describe gold. How does it occur, and where is it mined? How do the several gold-bearing localities respectively rank in importance? What is the estimated value of gold now in circulation? Can you answer the same questions in regard to silver? What can you say of platinum? Mercury? Iron? Copper? Lead? Tin? Zinc? Nickel? Specify the various uses of these metals. Compounds of which are used as medicines?

Enumerate the building-stones. Describe the various kinds of limestones. What are sandstones? Whence come the finest marbles? What is granite? What can you say of the clays and chalks? What minerals are derived from fossil vegetation? Explain the origin of rock-oil; of rock-salt.

Questions on the Map s
tion of Metals and Precious
the map above, what metals do you infer
over the earth? Point out the localit
abundantly. Locate the gold-fields of N
Transvaal. What countries of South An
What European state produces the most
on the slopes of the Ural Mountains?
Mountains? among the Pyrenees? In w
ica are there silver-mines of great va
emerald, and ruby fields? Where else
Find the location of the oldest tin-mi
Mention the chief lead-producing count



the Distribu-
—From a study of
widely distributed
h gold occurs most
ea; of Australia; of
this precious metal?
at metals are found
of the Carpathian
ies of South Amer-
er-mines? diamond,
found? emeralds?
world; the richest.
out the regions in

which zinc is mined. Give an idea of the wide distribution of iron. Of what sections is nickel characteristic?

Where on the map do you find building-stones mentioned? (See also maps, pp. 12 and 13, 128 and 129.) What is marble? Of what countries is it a product? What is granite, and how far north is it found? Where do you find porphyry? asbestos? chalcedony? feldspar? mica? slate? graphite? alabaster? In what regions is volcanic rock met with? lava? coral-stone (almost exclusively used for building in the Bermudas)? basalt (out of which Fingal's Cave has been worn by the action of the waves—see p. 22)? rock-crystal (from which imitation gems are made)? kaolin and other clays? copal and amber? cinnabar, or red sulphide of mercury? bismuth and antimony? niter and sal-ammoniac? From what part of the world does meerschaum come? Where in Africa do you meet with syenite (Scotch granite), from which the ancient Egyptians cut their obelisks?

Point out the great coal-beds of the world; the principal petroleum-fields; the sulphur-producing regions; the borax-yielding localities. Where are there valuable pearl-fisheries? Whence come the finest white pearls? What grand divisions produce the most precious stones? Where is the opal found? the topaz? the sapphire? onyx? amethyst? carnelian? malachite? the turquoise? What valuable mineral productions are found in Borneo? in Tasmania? in Japan? in New Zealand? in Mexico? in Central America? in the Dominion of Canada? Leaving gold and silver out of account, name the grand division that yields the most abundant and most varied mineral treasures. What parts of the earth are most barren of metallic products?

PRECIOUS STONES.

The Diamond.—The most valuable of precious stones is the diamond—pure crystallized carbon—the most highly refractive and the hardest of gems, and the only one that is combustible. This latter property was discovered in 1691 by Cosmo I. of Tuscany, who ignited the diamond with a burning-glass; and later it was found that when burned in a crucible this gem converts iron into steel. The diamond generally occurs as an octahedron, and surpasses all other gems in the property of dividing light into colored rays, causing that peculiar flash of prismatic hues called its *fire*.

Diamonds are rated by the *carat*. The term carat is derived from the name of certain small leguminous seeds which, when dried, are quite constant in weight. They were used in India for weighing gems.

In 1871, the syndicate of Parisian jewelers, goldsmiths, and gem-dealers, suggested .205 of a gramme as the value of a carat; and this was confirmed in 1877, all the leading diamond-dealers of London, Paris, and Amsterdam, accepting it. The English carat is equal to 3.1683 + grains (commonly reckoned as 3.17 grains) troy, hence there are 151½ carats in an English troy ounce. The jewelers' carat is subdivided into halves, quarters, eighths, sixteenths, thirty-seconds, and sixty-fourths. A quarter-carat is called a grain; pearls are always sold by the grain.

Diamond-Mining.

The earliest known mention of diamonds is supposed to be that in the Indian epic "Mahâbhârata" (*mă-hah'bah'-ră-tă*), B. C. 1000. Before 1728, the date of the discovery of the Brazilian mines, all diamonds were brought from India and Borneo. There are three distinct diamond-producing regions in India; the familiar word Golconda is not the name of a mine, as popularly supposed, but merely the general term for the market where diamonds were bought and sold. To-day all the mines are nearly closed.

Indian diamonds occur in a conglomerate, and also in alluvial or superficial deposits, together with pebbles, ferruginous quartz, and jasper. Early methods of mining were very crude. The conglomerate was dug out, and carried to small square reservoirs, raised on mounds, where it was carefully washed and sorted, the wet diamonds being readily recognized by their peculiar vitreous luster.

At present India yields very few stones, while Borneo produces only about three thousand carats annually. Diamonds are also mined in New South Wales, and are met with in California, the Ural Mountains, North Carolina, and Georgia. In 1856, the "Dewey Diamond," that cut eleven and a half carats, was found near Manchester, Virginia.

South African Diamond-Fields.—By far the greatest portion of the diamonds now obtained come from the mines of South Africa, which were discovered, near Hopetown, in 1867, by some Dutch children. They are situated in Griqualand West, now a part of Cape Colony, in latitude 28° 40′, longitude 25° 10′, east, about 640 miles northeast of Cape Town and 500 miles from the sea-coast. Although they are at an elevation of nearly 4,000 feet above the sea-level, the heat is excessive during the summer months, when the work is principally carried on. There are four large mines, all within a radius of a mile and a half. The celebrated Kimberley covers seven and a half acres.

The African mines were originally worked in individual claims, 3,143 in number, each thirty-one feet square, with a roadway seven and a half feet wide between each pair of claims. These small claims are now consolidated into about ninety large companies and private firms having a gross capital of nearly $50,000,000. Thirty-three million carats (over six and a half tons) of diamonds have already been taken out, valued in the rough at £45,000,000, and after cutting at £90,000,000. The absorption of the smaller by the larger companies (*unification*) is constantly going on, and it is proposed to consolidate all the companies into one gigantic monopoly.

Ten thousand natives, each receiving one pound a week, are employed in the mines under the supervision of twelve hundred European overseers.

The enormous sum of over £1,000,000 is annually expended for labor. This mammoth investment of European capital has been profitable to the shareholder, and it would have been still more so were it not for the thievishness of the native diggers, who, instigated by the vicious whites that congregate on the fields, steal and dispose of from one-fifth to one-fourth of the entire yield. More improved methods of surveillance, recently introduced, have diminished this loss. None but authorized agents are permitted to purchase or possess rough diamonds, and a large detective force is on the alert to prevent any infringement of the rules. The lengths to which the natives and their white accomplices go in their fraudulent traffic may be judged from the fact that chickens have been decoyed to the mines by them and made to swallow diamonds. A *post mortem* recently held on the body of a Caffre who had died suddenly, revealed the fact that death was caused by a sixty-carat diamond which the native had swallowed. (On the mines of Griqualand West, *consult Leyland's "A Holiday in South Africa," p. 93.*)

Theory of Formation.—At the Kimberley mines, the diamonds were first obtained on the surface in a yellow earth, the result of the decomposition of strata found 100 feet below, and known as "blue stuff." Scattered through it are angular pieces of carbonaceous shale, garnet, mica, etc. At a depth of 600 feet, a hard rock (peridotite) was found, containing the same shale. This shale has evidently been altered by the action of heat produced by the penetration of the volcanic rock through it; and this heat, causing the liberation of some volatile hydrocarbon, has doubtless produced the diamond. The mines are so surrounded by carbonaceous shale that they form, as it were, "pipes" in the center of it.

In the Kimberley mine a depth of 600 feet has been reached. The number of obstacles which have been successfully overcome and the novel machinery in use make the mining at Kimberley the most systematic of the kind in the world. Progress has been rapid. On the site of the desert there is now a city of 30,000 inhabitants, with water-works, electric lights, railroads to the coast, and many other improvements of modern civilization.

Brazilian Mines.—In Brazil, diamonds are found in several localities. At Diamantina, in Minas-Geraes, 4,000 feet above the sea, the stones occur usually in the gravel and sands resulting from disintegrated rock. Up to 1850, over 7,000,000 carats, worth £11,000,000, had been taken from the Minas-Geraes mines alone. Perhaps the entire yield from Brazil may be estimated at 13,000,000 carats, worth £20,000,000.

The beds of rivers have been turned aside to aid in the search for diamonds, but the methods of mining have always been very crude. Little machinery has been used, the work of sorting being performed by slaves, who were rewarded for any exceptional find.

THE TIFFANY DIAMOND. NATURAL SIZE. CROWN, SIDE, AND ANGULAR VIEWS.

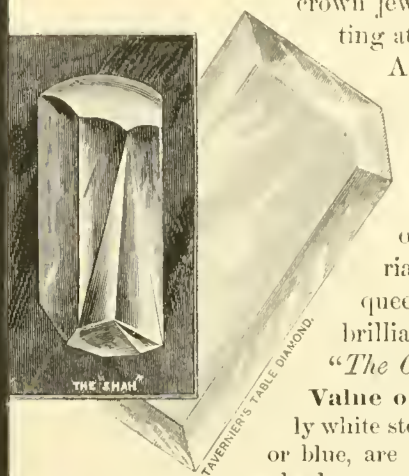
Remarkable Diamonds.—Some diamonds are celebrated for their size or the interesting legends connected with them. The Regent, or Pitt diamond, weighing $136\frac{14}{16}$ carats, and originally purchased by Lord Pitt for £1,000, is the finest large diamond in the world. It was discovered in India, in 1701, and weighed 410 carats in the rough. Valued at 12,000,000 francs, it was the most precious of the French crown jewels, and was one of the few retained by the government at the great sale in 1887.

The finest blue diamond is the "Hope," which is almost sapphire-blue and weighs $44\frac{1}{4}$ carats. It is an Indian stone and evidently part of Tavernier's blue diamond which was stolen from the Garde Meuble in 1792. It was purchased by Mr. Henry Hope for £18,000. The Dresden Green Vaults contain the finest green diamond, a pear-shaped $48\frac{1}{2}$ carat brilliant, the "Dresden Green."

Among the largest diamonds is the Orloff in the scepter of the Emperor of Russia, weighing 193 carats. It is fabled once to have formed the eye of an Indian idol, and to have been stolen by a French deserter. In the Russian treasury is also the Shah, 86 carats. Tavernier's Great Table weighed $242\frac{5}{16}$ carats.

The Tiffany yellow diamond, the largest diamond in America, is a flawless double-cut brilliant. It was found in South Africa, weighs $125\frac{3}{8}$ carats, is of a rich orange-yellow color, and is the finest yellow diamond in the world. It is valued at $100,000.

The "Great Mogul" was described by Tavernier, the famous traveler, in 1678. He states that its weight was originally $793\frac{5}{8}$ carats, but in cutting it was reduced to $279\frac{9}{16}$ through the stupidity of the cutter, who is said to have been fined his entire fortune for his carelessness. This magnificent stone was named after the founder of the so-called Mogul dynasty in India. It has disappeared, though some identify it with the Koh-i-Nûr (*Mountain of Light*), which weighed when first brought to England, $186\frac{1}{16}$ carats, but was reduced by recutting, in 1852, to $106\frac{1}{16}$ carats. The Koh-i-Nûr, "the great diamond of romance," is now among the English crown jewels. Barbot valued it before recutting at £140,000.



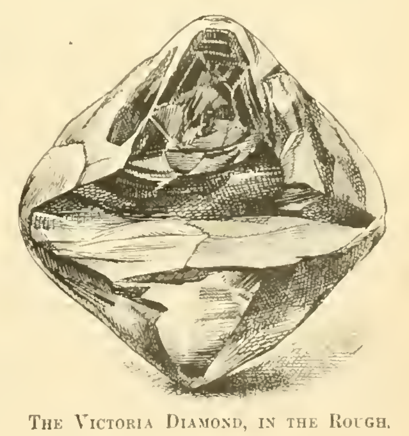
A diamond, weighing $457\frac{1}{2}$ carats, was brought from the Cape in 1884; it has been cut into a brilliant of 180 carats, valued at £200,000. The finding of this stone is enveloped in mystery. The name "Victoria" was given to it in honor of the queen, and it is undoubtedly the largest brilliant in the world. (*Read Streeter's "The Great Diamonds of the World."*)

Value of Diamonds.—In diamonds, perfectly white stones or decided tints of red, rose, green, or blue, are most highly prized. Fine cinnamon, and salmon or brown, black or yellow stones, are also esteemed. If flawless and without tint of any kind, they are termed "first water." If they possess a steely-blue color, at times almost opalescent, they are called blue-white. Such are usually Brazilian stones. Exceptionally perfect stones are termed gems, and for such there is no fixed value, the price depending on the purity and the brilliancy of the stone.

The term "first water" varies in meaning according to the class of goods carried by the dealer using it. It is impossible to estimate the value of a diamond by its weight—color, brilliancy, cut, and general perfection of the stone, are all to be taken into account. Of two stones, both flawless and weighing ten carats, one may be worth $600, and the other $12,000. Exceptional stones often bring special prices, whereas off-color or imperfect stones sell at from $50 to $75 per carat, regardless of size.

The probable value of all the diamonds in the world is about $1,000,000,000. The world's diamond-trade is carried on by about eight thousand dealers, with a total stock of not far from $350,000,000. The stones are prepared for market by, perhaps, forty-five hundred cutters and polishers, principally in Amsterdam, Antwerp, Paris, and the Jura. A limited amount of cutting is also done in England and the United States.

The Ruby and the Sapphire are varieties of the species corundum. The yellow variety is known as Oriental topaz, the green as Oriental emerald, and the purple as Oriental amethyst. The two latter forms are rare. The sapphire belongs to the hexagonal system, is next to the diamond in hardness, and is composed of nearly pure alumina.



THE VICTORIA DIAMOND, IN THE ROUGH. NATURAL SIZE.
(From a photograph.)

The most highly valued rubies, which are of the color of pigeon's blood, are found near Mandalay, in Burma. In Ceylon they occur of a lighter color, and in Siam of a very dark red. Although the diamond is more generally esteemed, the rarity of rubies of from three to four carats' weight is such that they are worth five to ten times as much as diamonds of the same size. The choicest colors of the sapphire are the cornflower and the velvet-blue.

The Chrysoberyl gems, next to the sapphire in hardness, include the varieties of yellow, brown, green, and an endless number of intermediate shades. The variety of chrysoberyl in which impurities are found between the layers, or the layers are so arranged by twinning that, if the stone is cut across the layers, the light is condensed in an even line, is called chrysoberyl cat's-eye.

Beryl is a silicate of glucina and alumina. Golden-colored beryl is found in Maine, Pennsylvania, and Connecticut. When the beryl is

Pearl-fishing.—Pearl Shells.

colored with chromium, we have the emerald. The finest emeralds are from the Muso mine, near Bogotá, where they occur in a rock containing bituminous concretions filled with fossils. This mine has been worked for the past three centuries by Europeans, and was previously operated by natives and ancient Peruvians.

Some of the finest crystals of emerald known have been found in Alexander County, North Carolina ; one weighing ten ounces, but of small gem value, has been found there. When really fine and flawless, emeralds rank with diamonds in value. (*See George F. Kunz's "American Gems."*)

Topaz occurs yellow, blue, cherry, green, and white. Tourmalines are found in Brazil, Siberia, and in remarkable perfection at Paris and Auburn, Maine.

Quartz gems are pure silica colored by iron or other oxides. When pellucid the crystalline varieties are called rock-crystal ; when colored purple or violet by oxide of manganese, amethyst. The crypto-crystalline varieties of quartz are chalcedony, gray, bluish-gray, or brown, with a waxy luster. When banded with rock-crystal, jasper, etc., it is called agate. When translucent like horn, yellow, yellowish-brown, or red, it is called carnelian. When in bands of white, gray, and other colors, it is called onyx (used for cameos); with moss-like markings produced by oxide of manganese or iron, moss-agate. Moss-agate occurs in immense quantities in parts of the West; agatized wood (in which the wood-fibers are changed to agate by the infiltration of silicious waters) is found in Arizona and the Yellowstone Park.

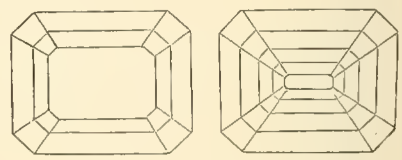
Noble opal is milky, almost opaque, with a play of brilliant, red, green, orange, and other hues. Hungary, Honduras, and Mexico, are the localities for this stone. When yellow, red, and green colors combine like flashes of fire, the name fire-opal is given to it. This species is found mostly in Mexico. California furnishes beautiful opalized wood.

Pearls are small bodies found either in mother-of-pearl shells or in those with a nacreous lining. They are formed either by a disease, by the presence of a parasite, or by an effort on the part of the mollusk to rid itself of some foreign substance which has found its way into the shell.

Pearls are composed of many layers of carbonate of lime with organic matter between, are not always entirely pearly throughout, and invariably have some small central core or nucleus. Round pearls of fine luster and color are very valuable, and their value increases rapidly with their size.

The finest white pearls are from India, the Persian Gulf, and Panama; the finest black and gray pearls, from the coast of Lower California. Beautiful pink-tinted pearls are often secreted by the common brook-mussels. One valued at over $2,000 was found near Paterson, New Jersey, in 1856, and quite a number have been met with in Ohio, Tennessee, Kentucky, and Texas, and also in England, Scotland, and Germany.

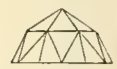
The Forms in which Gems are cut, are divided into two groups—those with plane and those with round surfaces. To the first belong the brilliant, step or trap cut, and the table-cut or rose-cut; to the second, the single, the double, and the hollow cabochon or carbuncle cut.



CROWN. BACK, OR PAVILION.

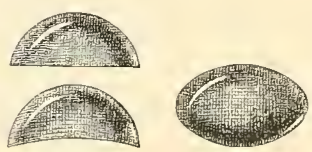
Step or Trap Cut.

The brilliant cut is usually modified, but when perfect fifty-eight facets are required—thirty-three constituting what is called the crown or upper part, the large facet being termed the table, and twenty-five the back, pavilion, or base. The small facet at the bottom is called the collet or culet, and the edge of the stone the girdle. This form of cut is most extensively used for diamonds, but is occasionally employed for other stones.

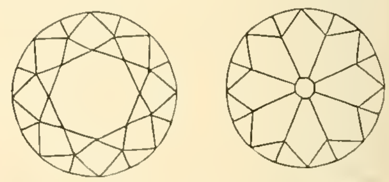


Rose.

Emeralds, rubies, sapphires, and other colored stones, usually have the step-cut, so called from the fact that the facets on the crown are in a step-like series, and below the girdle are three or more diminishing zones terminating in a culet. The en-



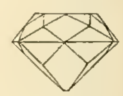
Single, Hollow, and Double Cabochon.



CROWN. PAVILION, OR BASE, SHOWING COLLET.

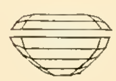
Brilliant Cut.

cabochon or carbuncle cut is that in which the top is rounded off and the back flat, hollowed out, or the same as the top. Garnets, turquoises, opals, cat's-eyes, are cut in this manner. In the rose-cut, the back is flat and the top covered with triangular facets generally from twelve to twenty-four in number.



Brilliant Cut Side View.

Imitation Stones.—Rhine stones, the Lake George, California, Swiss, and Swedish diamonds, with the so-called diamond-coated stones, are all paste or lead glass. These imitations have been recently improved by the addition of little metal cups or coatings filled with mercury, for which reason they are known as foil-backs, brilliants, etc., but the hardness of all is below that of flint-glass. Paste gems are made of silica and oxide of lead, colored with metallic oxides to produce the required shade of color.

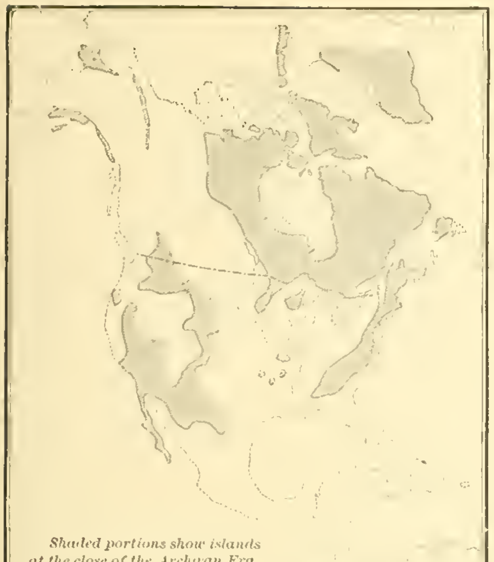


In doublets, the crown is made of quartz, garnet, or some equally cheap and hard stone; but all below this is paste of the desired color, the two parts being joined by cement or fire.

Imitation pearls are small, blown spheres of slightly opalescent glass, roughened and lined with a preparation made from the scales of a small fish found in Switzerland (the bleak), and then filled with wax.

Questions.—What can you say of the diamond ; its value ; the theory of its formation ; the localities at which it is mined ? Describe some remarkable diamonds. What are rubies ? Sapphires ? Emeralds ? Where are these stones obtained ? Name and describe other precious stones used as ornaments. What are pearls, and whence are they obtained ? Describe the forms in which gems are cut. How are imitation stones made ?

GEOLOGICAL HISTORY OF THE UNITED STATES.



North America at the Close of the Archæan Era.

The Growth of the North American Continent.—It is believed that the earth existed first as a body of heated vapor. Next it condensed to the condition of igneous fluidity, after which a crust was formed over it by cooling. Nothing remains of this primitive surface; but from its ruins have been accumulated immense masses of crystalline or granitic minerals which are called Archæan rocks (*see p. 10*). These materials, reclaimed from a universal ocean, became islands, and constituted the foundations of continents. Their emergence was due partly to igneous protrusion, and partly to actual uplifting through lateral pressure.

The first map shows the appearance of these islands at the close of the Archæan era, for the Continent of North America. The largest area occupies the eastern part of the Dominion of Canada, with the Adirondack and Minnesota peninsulas. Nearly parallel to its southeastern shore, in what became the Atlantic slope, appeared the narrow strip, 2,000 miles long, from Newfoundland to Alabama. Nearly parallel to the southwestern shore appeared the larger and broader island constituting the foundation of the Cordilleras, probably extending beneath the present surface to Alaska. Areas of less consequence are Greenland, part of Alaska, and the iron-rocks of Michigan, Missouri, Arkansas, etc.

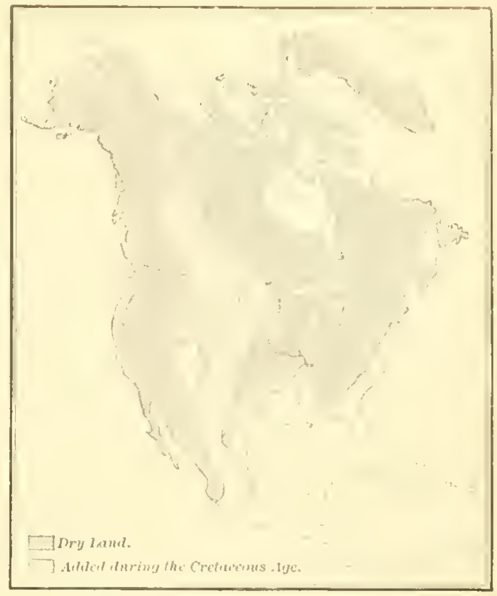
Elevation of Land being produced by lateral pressure, it is easy to understand how basins may appear between the ridges. Three such depressions originated very early. The one of most interest is encircled by the long Atlantic island and the southern Canadian shore (or, more definitely, the Black Mountains of North Carolina, the Blue Ridge of Virginia, the Highlands of New Jersey and New York, the Green Mountains of New England, the Adirondacks of New York, the Canadian highlands, and the Minnesota Archæan peninsula). The other basins were those of Hudson Bay and the Cordilleras.

The Next Phase of the Growth consisted in the development of a sea-beach around every island, together with the accumulation of the finer sediments in deeper water. This work was performed by rivers and marine waves and currents, and was continued until the ocean was excluded from the basins of the eastern and western parts of the United States, and great thicknesses of sedimentary rocks were deposited.

For a time, the land and water showed no signs of life.

In the Palæozoic era, there were first the humbler forms of marine life, such as sponges, corals, molluscous shells, and crustacea, with sea-weeds; and afterward, powerful cuttle-fish living in chambered shells, immense fish with enameled plates, and amphibians; while the land-vegetation, consisting of pines, ferns, and tree club-mosses, grew luxuriantly, and its remains accumulated in beds of coal.

The Appalachian Revolution. At the close of the Palæozoic era, the long Atlantic island was crowded toward Canada, and the early marine deposits adjoining were folded into long, narrow, level-topped ridges and plateaus, extending from the Catskills to Tennessee and Alabama. These disturbances have been termed the *Appalachian revolution*, because they gave rise to the peculiar Appalachian Mountains and the great Appalachian Valley, continuous from the Gulf of St. Lawrence to Alabama.

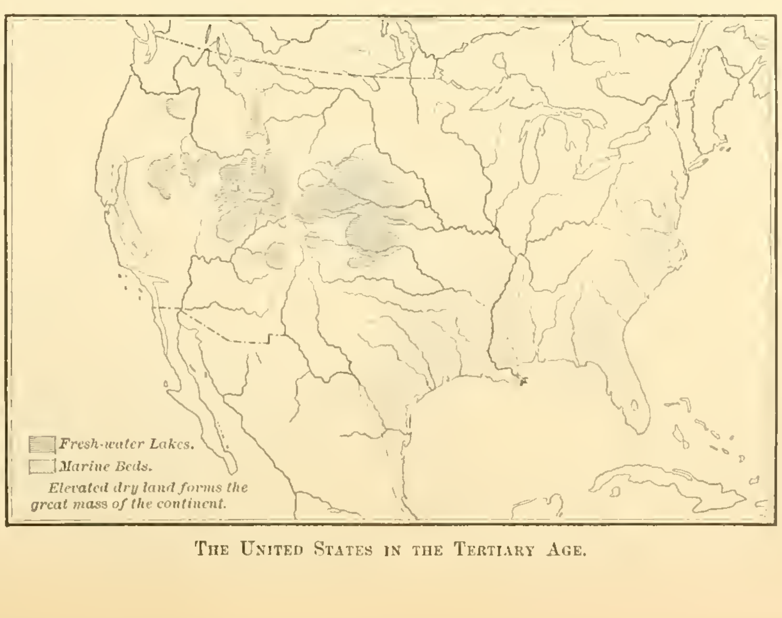


North America in the Cretaceous Age.

Not less important was the change in the life, coeval with the purification of the atmosphere by the withdrawal of carbonic acid. Air-breathing reptiles, birds, and marsupials, swarmed on the new land with its forests of cycads, tree-ferns, and exogens.

The aspect of the continent toward the close of this age of reptiles, or the Cretaceous period, is shown in the second map. At its dawn the land occupied two areas, separated by a shallow sea extending from Texas to the mouth of the Mackenzie River in the Arctic region. At its close the gap between the two islands was filled, and the two parts were united into one area, extending from the Atlantic to the Pacific, and from the Arctic Ocean to the mouth of the Ohio.

In the Neozoic Era, the additions to the coast have been most considerable in the Carolinas and Gulf States, as shown in the third map. A part of this addition—the Georges and Newfoundland banks—is now submerged. The force of elevation has been most prominent in the region of the Cordilleras, where the land has been raised bodily thousands of feet with very little increase of area. The map also shows the location of several fresh-water lakes. These were larger at first than subsequently, and they have now dwindled to very insignificant proportions, as in the Humboldt and Great Salt Lakes. The largest and earliest lay between the Rocky and Wasatch ranges, and was a little later divided by the east and west Uinta Mountains into two. One of considerable consequence lies chiefly in New Mexico, upon the headwaters of the San Juan River. The largest lake shown upon the map was the White River basin, upon the eastern slope, in Nebraska and Kansas, which existed in the middle part of the age. Others were situated in Colorado, Montana, Oregon, Nevada, and elsewhere. The latest were Lake Bonneville, of which Great Salt Lake is the briny residuum, and Lahontan, in Nevada, whose waters contained much lime.



The United States in the Tertiary Age.

Mammals of the Tertiary Age.—Around these lakes flourished uncouth beasts, suggestive of rhinoceroses, hippopotamuses, elephants, bears, etc.—but each united in itself the characteristics of two or more of our common mammals. For instance, one was part bear and part elephant; another combined the features of the deer, camel, and pig. Near the close of Neozoic time, and contemporary with the earliest men, American mammals attained their highest development.

PHYSICAL FEATURES OF THE UNITED STATES.

Geographical Position and Area.—The United States occupies the middle portion of North America. It extends from the Atlantic to the Pacific Ocean, and is bounded on the north by the Dominion of Canada, on the south by Mexico and the Gulf of Mexico. It is included between 24½° and 49° of north latitude, and spreads over 58° of longitude. Besides this main body, the United States comprises a detached area—the territory of Alaska, which forms the northwestern portion of North America, and which extends, in a narrow tongue, southeastward along the Pacific coast nearly to Washington.

The United States, excluding Alaska, contains an area of 3,026,500 square miles. The area of Alaska is estimated at about 530,000 square miles; thus the total area of the United States is approximately 3,556,500 square miles. (On the areas of the States, *see Gannett's "Bulletin of the Tenth Census."*)

SURFACE STRUCTURE.

The Average Elevation of the country, excluding Alaska, is not far from 2,600 feet. Of its area, a little more than one-third has an elevation less than 1,000 feet, about one-fifth has an elevation greater than 5,000 feet, while less than one per cent. is over 10,000 feet above the sea.

The greatest elevation is in the Sierra Nevada, of California, where Mount Whitney reaches an altitude of 14,898 feet. The greatest depressions of the surface are not far removed from this region of greatest elevation. These are in Death Valley, in southeastern California, and the valley of Soda Lake, in southern California, which are 100 to 300 feet below the level of the sea.

Primary Features of Relief.—In studying the physical geography of the country, we should first consider its great features of relief, as these determine, to a large extent, its river-systems, its temperature, rainfall, and vegetation.

These primary features are: I. A great elevated plateau or table-land, capped by mountain-ranges, which, with its slopes, comprises about one-half—the western half—of the country. This is the Cordilleran or Rocky Mountain Plateau. II. A great valley, lying east of the plateau and drained by the Mississippi River and its tributaries, with the Great Lakes. III. A smaller system of elevation lying east of this valley, the Appalachian Highlands, from which the country slopes gradually to the shores of the Atlantic.

The Cordilleran Plateau.—The western border of the summit of the Cordilleran Plateau is outlined by the Sierra Nevada and the Cascade Range, in California, Oregon, and Washington. The eastern border traverses western Texas, eastern Colorado, central Wyoming, and western Montana, being outlined by the eastern ranges of the Rocky Mountain System. From its summit, the Great Plains, which form its eastern slope, grade gently down to the Mississippi Valley.

The elevation of the summit of this plateau ranges from 4,000 to 10,000 feet, being highest in central Colorado. From this highest region the plateau slopes gently in all directions—to the southward, so that at the Mexican boundary it is not more than 4,000 feet high—to the northward and northwestward, in which direction it drops off to 4,000 feet at our northern boundary. To the westward, it slopes down to the depression drained by the Colorado, beyond which it rises in Utah and eastern Nevada, to sink again in western Nevada and eastern California.

The surface of the plateau is diversified by a great number of smaller elevations and depressions, most of the former being abrupt upon both sides, and therefore to be classed as mountain-ranges. Some of them, however, have gentle slopes upon one side, while the other side is abrupt and cliff-like. Such are known as "mountains lying down."

The Cordilleran Ranges.—The mountain-ranges of this region are very numerous. Indeed, over extensive areas, the country is but a succession of mountains and valleys. Almost all the ranges trend nearly north and south. To this rule there are very few exceptions, and this regular trend indicates that the uplifting forces must have been similar in all cases.

The bordering ranges, the Sierra Nevada and the Cascade on the west and the Rocky Mountains on the east, are the highest and most massive of the whole system. The first rises in a long intricate system of foot-hills from the great valley of California to summits ranging from 12,000 to nearly 15,000 feet above the sea, whence it plunges down abruptly to the plateau on the east. The Cascade Range is a line of extinct volcanoes, which commences with Mount Shasta in California, and runs across Oregon and Washington. The range has a general altitude of about 8,000 feet, while above it tower mountain-cones 4,000 to 6,000 feet higher.

The Rocky Mountains consist of several ranges forming a double and in some cases a triple line, inclosing between them high valleys, known as parks, such as the North, South, Middle, and San Luis Parks, of Colorado. In these ranges, scores of peaks exceed 14,000 feet in height, while hundreds rise above 13,000 feet.

In southern Wyoming there is a break in the continuity of these ranges—a broad gap, of which advantage has been taken in building the Union Pacific Railroad. The traveler on this road sees the Rocky Mountains only at a distance; the hills which he crosses at Sherman, and which he rounds in the Laramie Plains, being merely spurs from the great ranges of Colorado. The line of mountains is taken up again in northwestern Wyoming by the Big Horn and Wind River Ranges, and is continued northward across Montana by the Missouri Range, which extends to the northern boundary of the United States. These ranges are not as high as those of Colorado; the Wind River Range is the highest, having peaks which reach 13,000 feet, while few mountains in western Montana are more than 10,000 feet above the sea. (*Consult Gannett's "Dictionary of Altitudes in the United States," United States Geological Survey.*)

In southwestern Wyoming a system of low ranges puts off southward and westward from the Rocky Mountains, in the form of a spur from the main system. In Utah these ranges increase in altitude, and become known as the Wasatch, which attains a mean height of 10,000 to 11,000 feet. They fall off in southern Utah, and become merged in a series of plateaus, decreasing in elevation southward.

Stretching eastward from the Wasatch in northern Utah, is a range which is exceptional in the fact that its trend is east and west. This is the Uinta Range, which forms the southern limit of a great desert expanse, known as the Green River Basin.

Between the Wasatch and the Sierra Nevada, the country is traversed by numerous narrow ranges separated by valleys differing in width, but in the main broad. Most of this region—which comprises the western half of Utah, nearly all of Nevada, and parts of eastern California and southern Oregon—is drained to neither ocean; its scanty rainfall is either absorbed by the thirsty soil, or evaporates.

West of the Sierra Nevada and the Cascade Range lies a broad valley, separated from the Pacific coast by the Coast Ranges. This valley is, in California, occupied by the Sacramento and San Joaquin Rivers, in Oregon by the Willamette, and in Washington by numerous smaller

streams. It is terminated on the south by an extension or spur from the Sierra Nevada, which swings around to the westward and joins with the Coast Ranges in southern California.

The Coast Ranges form a system consisting of many ridges, closely parallel to the coast. They range in height from 8,000 feet in Oregon and northern California, to 3,000 feet in southern California.

The Great Plains.—From the eastern base of the Rocky Mountains, where the elevation of the plateau is from 4,000 to 6,000 feet, the country slopes gently and almost imperceptibly to the eastward. This long incline is known as the Great Plains. It is a monotonous, rolling, treeless expanse, stretching in endless billows from the northern to the southern boundary, with a breadth of from 500 to 700 miles. It comprises western Texas, eastern New Mexico, Colorado, and Wyoming, and the greater part of Montana, together with western North and South Dakota, Nebraska, Kansas, and Oklahoma.

Near the foot of the slope, the Great Plains merge gradually into the prairie region, where luxuriant vegetation takes the place of sparse bunch-grasses, and groves of trees appear as precursors of the forests which cover the country farther east.

The Great Valley of the United States stretches from the northern boundary of the country to the Gulf of Mexico, and from the western foot-hills of the Appalachian Mountains westward to an ill-defined line along the slope of the Great Plains. The southern and much the larger portion is drained by the Mississippi and a few smaller streams to the Gulf of Mexico. The northern part is drained by way of the Great Lakes and the St. Lawrence River to the Atlantic, with the exception of a small area in Minnesota and North Dakota, the surplus waters of which flow off by way of the Red River to Hudson Bay.

The surface of the valley is generally quite level and uniform. Across northern Michigan, Wisconsin, and Minnesota, runs a line of elevation, separating, in part of its course, the waters of the Mississippi from those of Lake Superior. Again, in southern Missouri, northwestern Arkansas, and in Indian Territory, there is an extensive, confused mass of hills, rising from 1,500 to 2,000 feet above the sea. These are known as the Ozark Hills or Mountains. Over much of Ohio, Kentucky, Tennessee, and southern Indiana, the surface is somewhat broken, but there are no hills of any considerable height. Many of the streams of the valley flow between high bluff banks, reaching in the cases of the Mississippi and the Missouri, an elevation of 300 to 400 feet. (*See Foster's "The Mississippi Valley."*)

The Appalachian Mountain System, while inferior to the Cordilleras in length, height, and breadth, is a feature of relief of great importance, especially as it occurs in the midst of a comparatively densely-settled region. The system extends from northern Alabama in a northeastern direction through New England, into the Dominion of Canada. Toward the northeast, it loses its character to a great extent, and is represented by short ridges, such as the Green Mountains of Vermont and the Berkshire Hills of Massachusetts, and by isolated groups, as the White Mountains of New Hampshire, the Adirondacks and Catskills of New York, and the scattered hills of Maine. Throughout New Jersey, Pennsylvania, and the southern states, however, it has a well-defined character. It consists of two principal members, the Blue Ridge and the Cumberland or Alleghany Plateau, separated by a long valley.

The Blue Ridge is the eastern range of the system. It appears first at the Highlands, on the Hudson ; it is cut through by the Delaware River at the Water-Gap, by the Susquehanna near Harrisburg, and by the Potomac at Harpers Ferry. The height of the range increases toward the south, and at the latter point its summit is 1,500 feet above the sea. At the Peaks of Otter, near where the James River finds its way through, the Blue Ridge is over 4,000 feet high. Thus far it is single, with a few short, low, outlying chains to the eastward. In western North Carolina, however, it widens out into a perfect complex of ranges and cross-ranges through which the rivers with difficulty force a passage. In this region are the highest summits of the system. Scores of mountains rear their heads more than 6,000 feet above the sea, while hundreds exceed a mile in height. Passing into northern Georgia and Alabama, the Blue Ridge rapidly falls down into hills, and soon disappears in the plain.

The Appalachian Valley stretches continuously from the Delaware southwestward to Alabama. It is occupied in turn by branches of the Delaware, Susquehanna, Potomac, James, and Kanawha Rivers, and finally by the head-waters of the Tennessee. The surface of the valley is in few places level ; it is traversed by numerous parallel ranges and ridges, long, narrow, and sharp, running with remarkable persistence in a uniform direction, for hundreds of miles. These ridges divide the valley into numerous long secondary valleys, parallel to the main one.

The western member of the system is known in Tennessee and Kentucky as the Cumberland Plateau, and in West Virginia and Pennsylvania as the Alleghany Plateau or Mountain. It is an inclined plateau, with a well-defined escarpment or cliff on the southeast, and with a gradual slope toward the northwest. Its western base is not well defined except in the northern part, where the Ohio flows around it. In Kentucky and Tennessee, it merges gradually into the comparatively flat country of the Mississippi Valley.

The Atlantic Plain.—East of the Appalachian System, the country becomes a plain, almost unbroken, except by the beds of streams. This plain slopes gently from the foot of the Blue Ridge to the Atlantic. In New England, the Atlantic Plain can hardly be said to exist, as the broken character of the country persists nearly or quite to the sea-shore.

COAST-LINE.

The Sea-coast of the country is varied in its character. Its length, including indentations, amounts to 12,600 miles. Of this extent, much the larger proportion, viz., 10,320 miles, belongs to the Atlantic and the Gulf of Mexico (6,860 to the former, and 3,460 to the latter), while the coast-line on the Pacific is but 2,280 miles in length. If we add to this the shore-line of Alaska (about 8,000 miles) and that of the Great Lakes, we have a total of 24,000 miles. Comparing the length of coast-line with the area of the country, we find that there is one mile of coast to each 150 square miles.

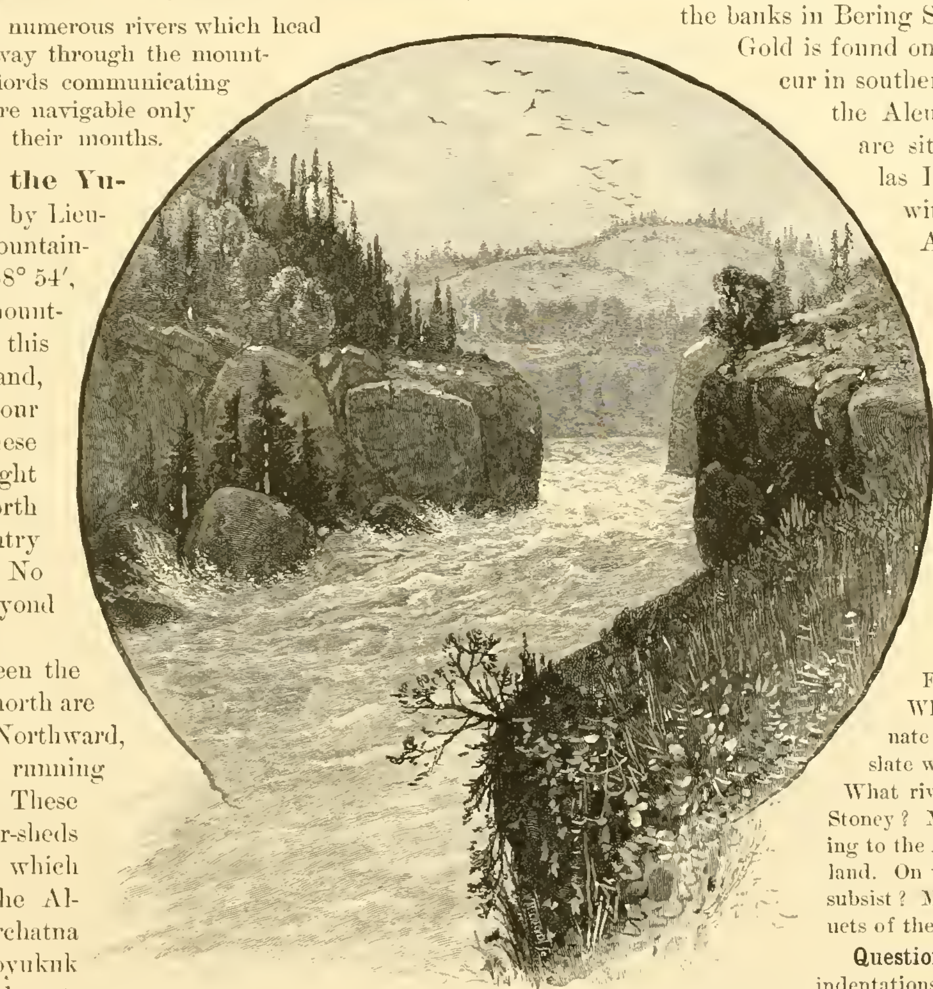
The Atlantic coast is as a whole very broken, with many fine harbors, which have contributed not a little to the high position which our country holds in regard to commerce. The coast of Maine, New Hampshire, and Massachusetts as far as Cape Cod, is an exceedingly broken one, being made up of long, rocky points, alternating with deep bays and arms of the sea, and fringed with numbers of islands. Good harbors are numerous.

In the neighborhood of Cape Cod, on the Massachusetts coast, the character of the sea-shore changes. Thence southward it is, in the main, low and sandy, but it is still somewhat broken, and affords many fine harbors, easy of access, such as those of New York, New Bedford, and Newport. With the shore of New Jersey, commences the reef feature, which extends, with occasional breaks, to the end of Florida, and even reappears at many points on the Gulf-coast.

The billows rolling in from the Atlantic, break when they reach shallow water, and deposit the sand held in suspension. In this way there has been built up a series of long, narrow, sandy islands or reefs, parallel to the main shore. The arm of the sea inclosed by the reef becomes more or less filled up by material brought down by streams, so that to-day we find areas back of the reefs in all stages of filling.

The Yukon is the great river of Alaska, and, indeed, is one of the large rivers of the globe. Rising in the heart of the Cordilleras, in latitude 60°, it flows at first northward, gradually making its way out of the mountains, as they trend to the west. Having cleared them, it, too, turns to the west, and then to the southwest, following the general course of the mountain-ranges, and finally enters Bering Sea through a number of mouths, forming a delta. It has a total length of more than two thousand miles, nearly all of which is navigable for light-draught vessels. Several large branches in Alaska swell its stream, together with the White, Pelly, Newberry, and Macmillan rivers in Canada.

The Yukon River was explored by Lieutenant Schwatka, who floated down its current on a raft from the head-waters to the delta. (*Read Schwatka's "Along Alaska's Great River."*)



Cañon of the Yukon, at the Head of Navigation, Eighteen Hundred and Seventy Miles from the Delta.
(From a photograph by Lieutenant Schwatka.)

In southeastern Alaska numerous rivers which head in Canada have cut their way through the mountains, and discharge into fiords communicating with the Pacific. These are navigable only for short distances from their mouths.

Alaska north of the Yukon, explored in 1883 by Lieutenant Stoney, is very mountainous as far up as latitude 68° 54′, when the limit of the mountains is reached. Beyond this the country is rolling land, with hills from three to four hundred feet high. These elevations decrease in height until latitude 70° 30′ north is reached, when the country becomes perfectly level. No rocks are met with beyond latitude 69° 30′ north.

The mountains between the Yukon and latitude 67° north are somewhat detached. Northward, the range is continuous, running nearly east and west. These mountains are the water-sheds of many rivers, some of which are quite extensive. The Allastook and the Ko Karchatna unite to form the Koyukuk River, which flows southwesterly into the Yukon.

The Inland or Notoak River, and the Putnam or Kubuk, discovered by Stoney in 1883, both flow in a westerly direction into Hotham Inlet. The Selawik River takes a westerly course and flows into Selawik Lake.

To the northward are several important rivers belonging to the Arctic System. The Colville, taking a northeasterly course; and the Chipp, or Ik-pik-puk, discovered by an officer of Stoney's command, in 1886, flowing northerly, are especially deserving of notice.

The Tundra.—The country in all valleys, lowlands, and to the north of the mountain limit, is tundra, interspersed with numerous lakes. Where the rivers flow through lowlands, the banks are barely discernible, and sometimes the streams spread out over the land for miles. Mosquitoes are the scourge of the tundra.

The Natives, by means of the rivers, visit the coast in the spring. Those going south leave the mountains as soon as the rivers break up, in June; those going to the northern coast follow the reindeer. These animals take to the tundra in summer, and return to the mountains in early winter. The people live principally on fish and the flesh of deer, with the berries and roots of the soil.

Economic Products.—Cottonwood, birch, and spruce, grow immediately on the banks of the rivers flowing to the south; but only scrub-willows are found about the head-waters of those flowing to the north. Cedar grows in southern Alaska.

There are many lakes in the mountains, some of them of considerable size and depth. Like the rivers, they abound in fish. Salmon swarm in the streams flowing to the south, and codfish on the banks in Bering Sea.

Gold is found on the Yukon, gold and silver occur in southern Alaska, and traces of gold in the Aleutian Islands. Valuable mines are situated at Juneau and on Douglas Island. Coal has also been met with in several localities. (On Alaskan fisheries, mineral wealth, etc., *compare Hallock's "Our New Alaska."*)

Questions.—Give the boundaries, area, and shape of Alaska. Describe its surface; its coast; its principal mountain-system. Where are its highest peaks? Describe the principal river of Alaska. By whom was it explored? Name the explorer of Alaska north of the Yukon. What mountains did he find between the Yukon and the Arctic? How high are they where he crossed them? From three to four thousand feet. What geological formations predominate in these mountains? In general, slate with quartz strata.

What rivers were discovered by Lieutenant Stoney? Mention two important rivers belonging to the Arctic System. Describe the tundra-land. On what do the natives of Alaska chiefly subsist? Mention the principal economic products of the territory.

Questions on the Map.—Name the main indentations of the coast of Alaska. How is Sitka situated? Describe Guyot Glacier; St. Michael Island; Nunivak; Unalaska. What has recently been discovered between Nunivak and St. Matthew Islands? A valuable cod-bank. Are there mountains on the northwest coast? There are no ranges on the coast south of Point Barrow, but rolling hills, increasing in height toward Cape Lisburne. Where is Mount Logan? Mount St. Elias? Where is Chilkoot Pass? Point out Copper River. From what lake in the Dominion of Canada do the head-waters of the Yukon issue?

How far north do trees grow? North of the Allastook there are no trees; a few bushes are found on the head-waters of the rivers flowing north. Are animals ever found on the tundra? What fish is abundant in the inlets and streams? The salmon. What other fish swarm along the coasts? Where are fur-seals found? sea-otters? For what fisheries is Kotzebue Sound noted? In what parts of the territory is gold found? silver? coal? copper? cinnabar? graphite? What valuable fur-bearing animals are native to Alaska? what important timber-trees? what peoples of the Yellow Type?

MAMMALS OF THE UNITED STATES.

The Wide Range of Physical and Climatic Conditions, which, as we have seen, characterizes the vast territorial domain of the United States, has resulted in producing the utmost variety and profusion of vegetation, and a corresponding abundance and diversity of animal life.

The ancient group of **Marsupials,** or pouched animals (*see p. 103*), is represented in the United States by two species of Opossums. One barely crosses our southern border; the other extends northward to New York, and is common from New Jersey southward.

The Sloths, Armadillos, and Ant-Eaters, are peculiarly specialized forms of a lowly organized group of mammals, which attains its greatest development in tropical America, and sends one representative, an armadillo, as far north as the southern border of the United States. Their abundant fossil remains show that at an earlier period in the earth's history they were much more numerous and diversified than at present.

The Manatee, or Sea-Cow, is a singular animal, living in shallow water in bays, lagoons, and large rivers, and subsisting on aquatic plants. Its fore-legs are modified into paddles, and its hind-legs are obsolete. It was formerly supposed to belong to the whale tribe, from which it is now known to differ widely, both in structure and habits. The Manatee is found on the Florida coast, and measures about ten feet in length. Other representatives of the group occur along the west coast of Africa, in the Indian Ocean, and at some of the Austro-Malay Islands.

Steller's Sea-Cow, which measured about thirty feet in length, formerly inhabited the shallow water surrounding Bering Island in the North Pacific, feeding upon sea-weed. During the winter of 1768, it was exterminated by the crews of vessels wintering at the island. A number of huge skeletons have been recently brought to our National Museum by Dr. Leonhard Stejneger.

The group **Insectivora** is represented by a number of peculiar genera — the Star-nosed Mole, named from a curious circle of tentacle-like feelers on the end of its snout; the Common Mole; the Hairy-tailed Moles; the singular Gibbs's Mole, intermediate between the Moles and Shrews; and the short-tailed and amphibious Shrews. Of the tiny Shrews, no bigger than one's finger, some species range northward beyond the Arctic Circle, and remain active throughout the long, cold winters.

The Bats, the only mammals possessing true wings and the power of flight, are abundant in temperate and tropical America. Most of them feed on insects exclusively; but at least one South American species, which extends as far north as Mexico, sucks blood from the larger mammalia. These bats sometimes do great injury to horses and cattle, not so much from the actual loss of blood they occasion, as from the inflammation which subsequently sets in.

The **Rodents,** or *gnawers*, are a very large and much diversified group, of which several families, many genera, and a great number of species, are peculiar to America. They may be distinguished at a glance from all other animals by their long, chisel-like front teeth, and by the absence of canine teeth. The Rats and Mice of the Old World were early introduced into this country, and have spread over nearly the whole of North and South America.

The following genera are common to the northern parts of both hemispheres: The Meadow-Mice, Lemmings, Rabbits, Coneys, Beavers, Squirrels, Ground-Squirrels, and Marmots. The remainder, comprising by far the greater number, are exclusively American. The Mouse family alone contains seven peculiar genera.

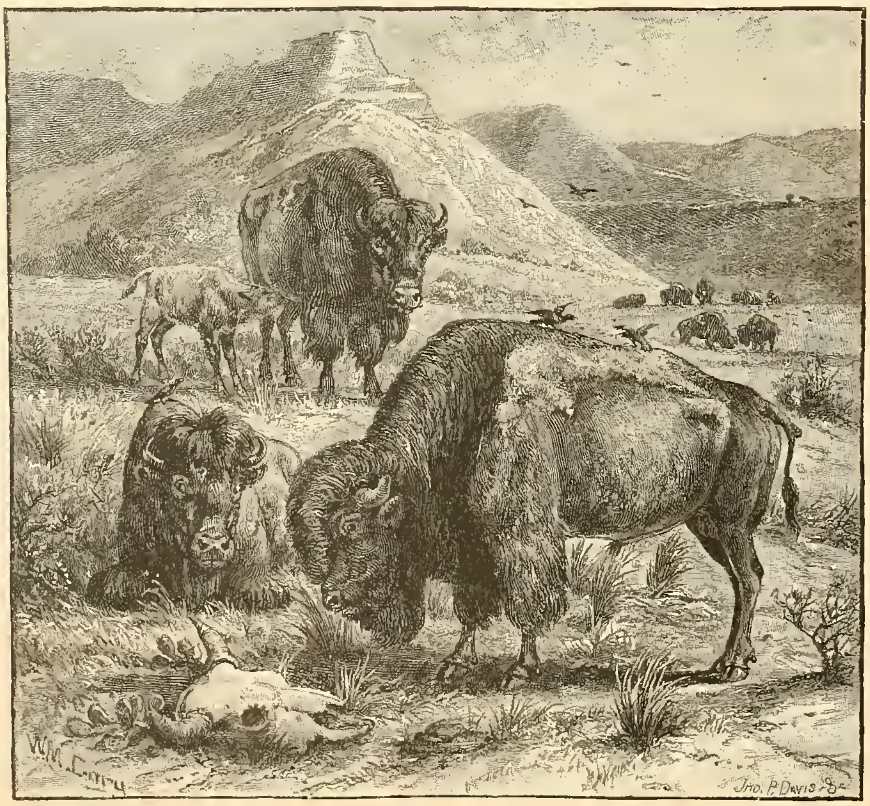
The Jumping-Mouse is not a mouse at all, but the type of a distinct family. It is a very pretty animal, with a prodigiously long tail and long hind-legs. It is found from the Atlantic to the Pacific, and from Hudson Bay and Great Slave Lake to Virginia and Arizona.

Another very distinct family contains the small animals that, for want of a better name, are usually known as "Kangaroo Rats and Mice." They have exceedingly long hind-legs, but their most striking peculiarity is their external cheek-pouches, which are lined with fur. This last peculiarity is shared by another family, comprising the Pocket-Gophers, which have very short hind-legs and live in underground tunnels like the Moles. Both groups inhabit the West and Southwest, but are not found in the Eastern States.

There remains still another family of Rodents peculiar to North America. It contains a single genus of burrowing animals, called Show'tls. They have broad, flat heads, exceedingly short tails, and are about the size and color of the musk-rat. They are confined to a narrow strip along the Pacific coast from California to British Columbia, and are interesting from their antiquity. The family has no near relatives among existing mammalia, and must be regarded as a relic of the past.

The so-called "Prairie-Dogs" are Rodents, related, on the one hand, to the Marmots, and, on the other, to the Ground-Squirrels. They live in large colonies on the barren plains of the far West, subsisting on such scant vegetation as the region affords. Owls and rattlesnakes take possession of their deserted burrows, and sometimes prey upon their young.

The arboreal Porcupines, characterized by their spiny armature, inhabit the forest-regions of America, from the limit of trees west of Hudson Bay to Paraguay. The South American species have long tails, which in most cases are prehensile; while those from the United States have short, thick tails. They live in trees, and subsist almost wholly upon leaves and the smaller branches.



THE BISON, OR AMERICAN BUFFALO.

The Bison.—The most conspicuous of North American mammals are the Ungulates, or *hoofed* quadrupeds. First of these is the Bison, or American Buffalo, now rapidly approaching extinction. It formerly ranged over nearly the whole of the United States; and in the days of that daring hunter and intrepid explorer, Daniel Boone, it was exceedingly abundant in Kentucky, where, according to his own account, he saw it "browsing on the leaves of the cane, or cropping the herbage on these extensive plains, fearless, because ignorant, of the violence of man." Another writer, in 1784, said that the herds of Buffaloes which resorted to the salt licks of Kentucky, "by their size and number, fill the traveler with amazement and terror, especially when he beholds the prodigious roads they have made from all quarters, as if leading to some populous city; the vast space of land around these springs desolated as if by a ravaging enemy; and hills reduced to plains."

As late as the beginning of the present century it still existed in parts of West Virginia, Kentucky, and Tennessee, and a few years earlier in western Pennsylvania. The last Buffaloes east of the Mississippi are said to have been killed in northern Wisconsin, in the year 1832, by Sioux Indians.

Before the railway penetrated to the Pacific, the long wagon-trains of emigrants, in crossing the plains, were stopped frequently, and for hours together, by passing herds of Buffaloes which blocked their way; and in more recent times, railroad-trains were detained from the same cause. The number of individuals composing these great assemblages was beyond computation. Formerly immense herds of these animals dotted the great plains of the West, from the Saskatchewan to Texas and New Mexico. Their flesh supplied food to the Indian, the explorer, and frontier settler; and their hides were made into clothing, robes, and the covering for wigwams and tents—the one animal furnishing both food and shelter. For a time their numbers seemed to defy diminution, but the white man's greed of gain has proved too much for them. Countless thousands have been butchered for their hides, and now they are on the verge of extermination. Two small herds still inhabit the Yellowstone National Park, and a few exist outside. There is said to be a mountain-race of the Buffalo which lives in deep forests and never mixes with the Buffalo of the plains; but this point has not yet been settled. (*Consult Allen's "North American Bisons, Living and Extinct."*)

Our Buffalo has a near relative in the Auroch, or European Bison, which was formerly abundant throughout northern Europe, but which, like our own species, has been nearly exterminated, and is now said to be confined to the Caucasus and a small Russian forest in Lithuania.

The Rocky-Mountain Sheep, or Big-horn, is more than twice as large as the domestic sheep, adult males weighing upward of three hundred pounds. The horns of the ram grow to enormous size, while the ewe's horns are small and shaped like those of a goat. The true home of the Big-horn is in rugged, inaccessible parts of lofty mountain-ranges. In the Rocky Mountains it occurs from near the Mexican border to the Arctic Circle, and in the Pacific region from southern California to northern Alaska. The Big-horn has a near ally in the Wild Sheep of Kamchatka and the Stanovoi Mountains.

The Mountain-Goat is a beautiful animal, about the size of the domestic sheep, but far more slender and graceful. Like the Big-horn, it is an expert climber, and makes its home high among the mountain-peaks where the hunter follows it with difficulty. It does not occur so far south as the Big-horn, and its favorite haunts are at even greater altitudes. It inhabits the higher parts of the Rocky Mountains in Idaho and Montana, and the Sierra Nevada in California, and thence extends northward into Alaska. Apparently, it is more common in British Columbia than elsewhere.

The Mountain-Goat is not a goat at all, but an Antelope, with shining black horns, and clad in long, white hair. Its immediate ancestors are extinct, but it is related, on the one hand, to the chamois of Europe, and, on the other, to the prong-horned antelope of our western plains.

The graceful **Prong-horned Antelope** is the type of a distinct family. It is a beautiful animal, a little larger than a sheep, and inhabits the great plains of the West, over which it roams in herds or droves varying in number from a few individuals to as many hundreds. Its curiosity prompts it to approach objects of unusual appearance, and this habit is taken advantage of by the hunter, who, concealing himself in the grass or behind a rock, and displaying a red handkerchief, sometimes succeeds in drawing it within gunshot. Its flesh is much esteemed.

The Moose is the largest and most remarkable member of the deer family. It inhabits the coniferous evergreen forests of the northern United States and Canada, extending into the barren grounds in Alaska. In winter it feeds chiefly upon the bark and branches of small trees which its huge size and peculiarly modified snout enable it to reach and grasp with ease. The Indians prize its flesh, and use its skin in making snow-shoes, moccasins, and the covering of their lodges. The Elk of the north of Europe is a near ally of our Moose.

The Wapiti, or American Elk, is another noble representative of the deer family. It is smaller than the moose, but very much larger than any of the deer. Though once abundant over almost the whole of the United States and the southern parts of the Dominion of Canada, it is now confined to limited areas in the West, and its utter extermination is greatly to be feared within a few years. The Indians rarely killed more than was needed for their own use, and never caused any appreciable diminution in the numbers of any species. Not so with the white man, on whose vandalism it is a lamentable comment that such splendid animals as the Bison and the Elk are now on the verge of extinction.

Of **the Deer proper**, there are three species and several varieties, or subspecies, in the United States. The Virginia, or "White-tailed" Deer, has the widest range, being found over the whole of the United States and the southern portions of Canada. The Mule-Deer is a western animal, most abundant in the upper Missouri region and west of the Rocky Mountains; while the Black-tailed Deer has the most limited range of all, being confined, so far as known, to a narrow strip along the Pacific coast.

The flesh of all of the deer tribe, called venison, is excellent food, and their hides are made into moccasins, snow-shoes, clothing, and a variety of articles indispensable to the Indian, and of great value to the frontiersman.

The Caribou, or Reindeer, is an inhabitant of the far north. It is found throughout the greater part of Canada, from the Atlantic to the Pacific, and it even enters the United States in Maine, New Hampshire, and in the Rocky Mountains. Its flesh is one of the most important elements in the food-supply of the Esquimaux and the northern tribes of Indians, and its skin furnishes the best material known for the garments of dwellers in Arctic latitudes. A related species is found in the north of Siberia and Europe, and is domesticated and trained as a beast of burden. (*Compare Judge Caton's "Antelope and Deer of America."*)

The Peccaries are small wild hogs, ranging from Texas and Arizona to Paraguay. They are the only American members of the swine family. They usually move in small droves, and when wounded are ferocious and dangerous assailants.

The next group, **the Carnivora,** contains all the remaining mammals. The teeth, in all carnivorous animals, are separable into incisors, canines, and molars, and their crowns are covered with enamel.

The Walruses and most of **the Seals** are circumpolar in distribution, being residents of the Arctic Seas of both hemispheres. The true Fur-Seal and the Sea-Lions inhabit the North Pacific. Many thousands of Fur-Seals resort to the Pribilof Islands, off Alaska, to breed, and most of the pelts which supply the markets of the world are obtained there. The Seals of the North Atlantic are Hair-Seals, and are valuable for their oil and hides, the latter furnishing the material from which most of the so-called "Russian leather" and "patent leather" is made. These animals furnish the Esquimaux with much of their food and clothing.

The species for whose capture the Newfoundland and Greenland "seal-fisheries" are carried on are the Harp and Hood. The male Hooded Seal is a large and powerful animal with an inflatable proboscis, which it blows up when angry. It is the most savage of the Seals, and when guarding its family on the ice fiercely attacks any one who approaches too near. Related to the Hooded Seal is the Sea-Elephant of the South Pacific, a representative of which inhabits the coast of Lower California. It has been slaughtered for its oil and hide, till now it is on the road to extermination. (*Consult Allen's "Pinnipedia [Seals and Walruses]."*)

The Sea-Otter, whose fur is more costly even than that of the fur-seal (single skins being worth about one hundred dollars), is a highly specialized offshoot of the Weasel family, modified for a strictly aquatic life. It inhabits our northwest coast from northern California to Alaska, and occurs also in Kamchatka and the Kurile Islands.

The Wolverine, or Glutton, of which so many curious tales are told, inhabits the boreal coniferous forests of both hemispheres.

The Skunks range over the whole of North and South America, except the Arctic portions. They are beautiful animals, black and white in color. They feed chiefly upon mice and insects, and are friends to the farmer, notwithstanding the fact that they occasionally steal some of his chickens.

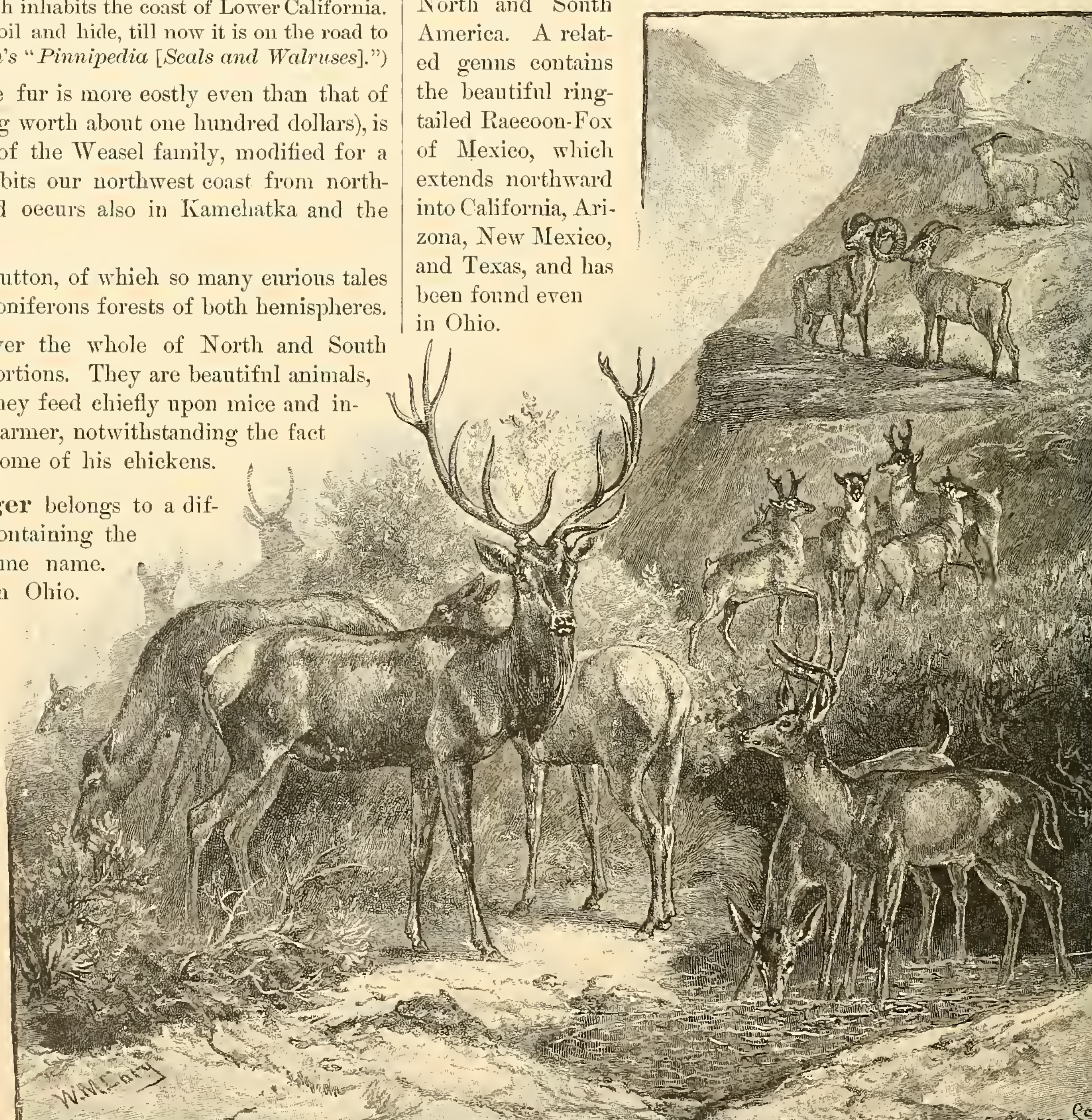
The American Badger belongs to a different genus from the one containing the European animal of the same name. Our Badger is still found in Ohio. Indiana, and Michigan, and thence westward to the Pacific. In a north and south direction it extends from the plains of the Saskatchewan to Mexico or Middle America.

The Lynxes, Wolves, Foxes, Sables, Weasels, Ferret, Mink, and Otter, of North America, though specifically separable from their European congeners, are not sufficiently different to merit special notice. (*Consult Richardson's "Fauna Boreali-Americana."*)

The Cougar, or Puma, called "Panther" in the Eastern States, and "Mountain-Lion" in the West, deserves special mention, from the fact that it is the largest representative of the cat family inhabiting the United States. It is true that the Jaguar, the largest of American Cats, has been taken along our southern border, but it can be regarded only as a very rare straggler from the tropics. The head of the Cougar is round and cat-like, and it lacks the mane, which gives the true lion much of its majestic appearance. The normal food of the Cougar consists of the various species of deer, which it captures by stealthily creeping within leaping distance and springing suddenly upon their backs. Along the frontier it often commits serious depredations, by carrying off colts, calves, sheep, and pigs. Its range is remarkable; it is found from Patagonia to Canada. (*Read Merriam's "The Mammals of the Adirondack Region," p. 29.*)

Of the Bears, the Polar or Ice Bear is circumpolar in distribution, inhabiting the Arctic regions of both hemispheres, and preying chiefly upon seals. The Black and Grizzly Bears are not found except in America, though the former has a near relative in Siberia.

The Raccoons are exclusively American, and inhabit both North and South America. A related genus contains the beautiful ring-tailed Raccoon-Fox of Mexico, which extends northward into California, Arizona, New Mexico, and Texas, and has been found even in Ohio.



ELK, BLACK-TAILED DEER, PRONG-HORNED ANTELOPE, ROCKY-MOUNTAIN SHEEP, MOUNTAIN-GOAT.

Fossil Mammalia.—No part of the world is richer than America in fossil remains of the higher vertebrates. In comparatively recent times, elephants, mastodons, wild horses, and several species of bison now extinct, were abundant in North America; and in the western United States the deeper strata reveal the former presence here of camels, rhinoceroses, and other animals now found only in tropical parts of the Old World, together with whole families totally unlike any existing kinds; and others, still, which throw much light on the ancestry of most groups of living mammalia.

Numerous connecting links have been discovered showing the relation between forms now widely distinct, bridging over many of the gaps supposed to separate the larger groups, pointing out the line of their evolution, and breaking down many of the hard and fast lines by which they were formerly characterized.

Fossil bones of the progenitors of the modern horse, reaching far back in time, have been found in great abundance in certain parts of the West. These fossil remains furnish an excellent example of a series of connecting links, showing the steps by which a small, four-toed quadruped has become gradually modified into a large, single-toed animal specialized to attain a high rate of speed.

(On the Birds of the United States, *consult Baird, Brewer, and Ridgway's "North American Birds."*)

VEGETATION.

Native Food-Plants.—None of the plants that produce the great staples of commerce are natives of the United States. Edible small fruits, such as the strawberry, raspberry, blackberry, and huckleberry, are indigenous and widely distributed.

Excluding Alaska, we may divide the United States, as regards character of vegetation, into five regions, three of them forest-clad, and two distinguished by an absence of trees.

Forest-Regions.—I. The region east of the Mississippi River, with the exception of most of the State of Illinois. This is now the most densely populated portion of the continent. In many parts, the forests which originally existed have been cleared, and have given place to farms. In the northern part, the forests are composed of pines, firs, hemlocks, birches, and poplars; in the central portion, oaks, chestnut, maple, black-walnut, button-wood, and tulip-tree prevail; while in the south, in addition to these latter, many other species occur, notably magnolias, bald cypress, and palmetto.

II. The Rocky Mountain Region, a belt of country extending from western Texas and New Mexico to Idaho and Montana. Here the forests are mainly coniferous, pines and spruces being the most abundant trees, with some poplars and birches.

III. The Pacific Region, embracing the Sierra Nevada and Cascade Mountains and the Pacific coast area. Here are found the most majestic forests of North America. They are mainly coniferous, consisting of pines, hemlock, firs, and the gigantic redwood and mammoth trees of California. Oaks and maples also occur.

Forestless Regions.—I. The Prairies and Great Plains of the central portion of the continent, extending from the Rocky Mountains eastward to the Mississippi Valley, and including, also, most of Illinois. The natural vegetation consists mainly of grasses, an abundance of other herbaceous plants, and some shrubs. There are no forests, but trees grow to a limited extent along the rivers.

II. The Great Basin Region, lying between the Rocky Mountains and the Sierra Nevada, and extending from Arizona to the British boundary. Much of this territory is desert, supporting sage-bush, grease-wood, cactuses, yuccas, and other herbaceous and woody plants.

The Pacific coast of southern Alaska has a very moist climate, and is heavily wooded, pines growing to an enormous size. The interior and northern coasts of the territory are cold and barren, the character of the vegetation being that of all Arctic regions. On the southern coast, barley and garden vegetables are raised.

Vegetable Products.—Of spontaneous products, the most important are the various woods, yielding lumber annually to the value of more than $200,000,000. The cultivated products include Indian corn and the other grains, potatoes, cotton, hemp, hay, sugar-cane, and tobacco. Indian corn is our most important grain-crop, and is raised in the greatest quantities in the Ohio and upper Mississippi Valleys. The annual yield is more than two billions of bushels.

Wheat is grown in almost all the Northern States and on the Pacific coast. Rye, oats, and buckwheat, are also widely cultivated in the North. Rice is raised exclusively in the Southern States, the product being more than 100,000,000 pounds annually.

Potatoes are mainly cultivated in the Northern States, and sweet-potatoes mostly in the South. Cotton is the most important crop of the Southern States, from 7,000,000 to 9,000,000 bales being produced annually. Hemp and flax are largely grown in the Southern and Western States respectively, as is hay in the Middle and Western.

The cultivation of sugar-cane is confined mostly to Louisiana; sorghum is widely grown in the North and South Central States, and in the North considerable sugar is made from the sap of the sugar-maple. Tobacco is raised in many parts of the United States, but most abundantly in the South Central and South Atlantic States.

Large quantities of tropical fruits and garden vegetables are produced in Florida, oranges being a characteristic crop.

MINERALS.

The Mineral Wealth of the United States is phenomenal. Coal, iron, silver, gold, petroleum, copper, and lead, are widely distributed. Besides these substances, there are mined large quantities of zinc, quicksilver, and salt; while nickel, cobalt, manganese, chromium, and other scarce metals, are produced in small amount.

The total value of the mineral production of the country, in 1896, was nearly $747,000,000. Of this enormous sum, the value of the coal mined was about one-fourth; that of iron, a little more than one-fourth; while silver and gold contributed respectively about one-ninth and one-nineteenth.

Coal occurs in beds, stratified, like other rocks. It is one of the most common and widely distributed of all mineral products. Both the anthracite and bituminous varieties are mined; most of the former in Pennsylvania. The latter is mined in greater or less quantity in twenty-nine of the states and territories; but of all these, Pennsylvania is the largest producer. Bituminous coal is found in all parts of the Cumberland Plateau, from Pennsylvania to Alabama; it underlies the greater portion of the northern half of the Mississippi Valley, and it abounds upon the Western Plateau. Cannel coal is mined in Kentucky.

In the United States the coal-basins have a known area of not less than 150,000 square miles, and ours is one of the great coal-producing countries of the world. In addition, we have not less than 100,000 square miles of productive coal areas in the rocks of the Cretaceous and Tertiary Systems west of the Rocky Mountains.

The total production of coal in 1896 was about 186,000,000 short tons, of which nearly 49,000,000 tons were anthracite, 137,000,000 tons bituminous, and 55,000 tons cannel coal. Our country is excelled in coal-production only by Great Britain. Of the amount mined in the world, we produce nearly one-third.

Iron is the most generally distributed of the metals. Its ores are widely found, but not everywhere in such location and purity as to make the mining and smelting of them profitable. It is mined in twenty-four of the states and territories; principally, however, in northern Michigan and Wisconsin. In 1896, the Lake Superior region produced about two-thirds of the total product of nearly 15,000,000 long tons. Pennsylvania, Ohio, Illinois, Alabama, and New York, also mine large amounts. In the production of iron and steel, the United States is nearly equaled by Great Britain.

The Precious Metals are found mainly among the mountains of the Cordilleran Plateau. A small amount of gold and silver is mined upon the Atlantic slope, principally in the Carolinas, in Georgia, and Alabama. In 1896, the United States exceeded all other countries in the production of gold and silver. The value of the gold produced was nearly $53,000,000; California leading with more than $15,000,000. In the amount of silver produced, Colorado stands at the head with 8,500,000 fine ounces. The United States is the largest silver producer in the world.

Petroleum, or rock-oil, is contained in strata of porous rocks, and in subterranean cavities. The oil is reached by boring wells down to these reservoirs, when it either flows to the surface, or is drawn up by pumping. It is collected into large tanks, and distributed mainly by means of lines of pipes, connecting the regions of production with the great cities. This method of moving the crude oil does away with handling it in barrels. Petroleum is abundant in northwestern Pennsylvania, southwestern New York, Indiana, Ohio, and West Virginia, and is found in several other states. In 1896, the product was over 60,000,000 barrels.

In many localities in the oil-fields natural gas has been discovered, and a number of cities in Pennsylvania, Indiana, and Ohio, use it for fuel and light.

Copper is mined chiefly in Montana, in northern Michigan (on the shores of Lake Superior), and in Arizona. In 1896, the Montana mines yielded about one-half the total amount of copper (260,000 long tons) produced in the country. In Montana and Arizona, carbonates and sulphurets of copper are mined and smelted.

Lead and Zinc.—Nearly 170,000 short tons of lead were produced from United States ores in 1896. This came mainly from Colorado and Utah, where it is mined in connection with silver, the silver-ores being lead-ores as well. Smaller quantities are produced from districts in Missouri, northwestern Illinois, southwestern Wisconsin, and southeastern Kansas, where the ore is found in irregular deposits, associated with zinc-ores. The total product of zinc, in 1896, was about 70,000 metric tons, four-fifths of which came from these mines, the remainder being from New Jersey and other Eastern States.

The only ore of **Quicksilver** is the sulphuret, known as cinnabar. Mines of this metal are worked in the Coast Ranges of California, and their production in 1896 was more than 33,000 flasks, or 2,525,000 pounds.

Tin-Ore has been found in a few localities in the United States, but nowhere in sufficient quantities for profitable mining. In the Black Hills of South Dakota, several mines have been opened, but they are not worked to any great extent. (*See Ludlow's "Black Hills of Dakota."*)

Salt is obtained mainly from saline springs and wells, by evaporation. In this way immense quantities are manufactured in western New York, Michigan, Ohio, and Kansas, and to a small extent in other states. Rock-salt is mined in the Warsaw district of New York, in the Hutchinson district of Kansas, and in Avery and Jefferson Islands in southern Louisiana, in Utah, and in California. The total production of salt in 1896 was more than 13,000,000 barrels. New York holds the first rank as a producer of salt.

Precious Stones.—In the United States, the production of precious stones is confined chiefly to the output of sapphire and rubies from Montana, and turquoise from New Mexico. The value of these gems in 1896 amounted to about $200,000. Sapphires and rubies are also found in North Carolina, Georgia, southern Colorado, and Arizona.

Agates, fossil coral, chlorastrolites, and Thompsonite, are collected on the Minnesota and Michigan shores of Lake Superior. Turquoises of trifling value are sold in Santa Fé, and by the Indians along the line of the Arizona and New Mexico railroads.

Questions.—How do you account for the abundance and diversity of animal life in the United States? By what are the Marsupials represented? What is the manatee, and where is it met with? Give an account of Steller's sea-cow. What representatives has the group Insectivora in the United States? Describe the only mammals endowed with the power of flight. What species of rodents are familiar to you? Describe the prairie dog.

What can you say of the bison—its former range and present numbers? Is there a distinct mountain-race of the buffalo? State the habitat and peculiarities of the Rocky Mountain sheep; of the mountain-goat; the prong-horned antelope; the moose; the elk; the caribou; the white-tailed, black-tailed, and mule deer. (*Compare Physical Map of the United States, pp. 128, 129.*) What animals are included under the head of Carnivora? What can you say of the walruses and seals? Of the sea-otter? Of the American badger? Of the puma? Of the bears and raccoons? Of fossil mammalia?

What food-plants are native to the United States? Into what regions, as regards character of vegetation, has the country been divided? Specify the Forest regions (*see Map, pp. 128, 129*); the Forestless regions. Enumerate the characteristic products of each; also, the most important crops of the United States.

What are the principal mineral products of the United States? (*See Map, pp. 128, 129.*) What is their value, and what representation in this sum have coal, iron, gold, and silver? Where is coal found and mined? What was the production of coal in 1896? Where is iron found and mined? Where are gold and silver mined? What proportion of the world's product of precious metals is mined in the United States? Where is petroleum found? How is it obtained and transported? What is the annual product? What use is made of natural gas? Where is copper mined? Where are lead and zinc found? What is the annual production of these metals? Where is quicksilver mined? What was the production in 1896? What is the ore of quicksilver called? Where is tin found? From what source is salt produced? Where? Describe the salt-mines in Louisiana. What was the production of salt in 1896?

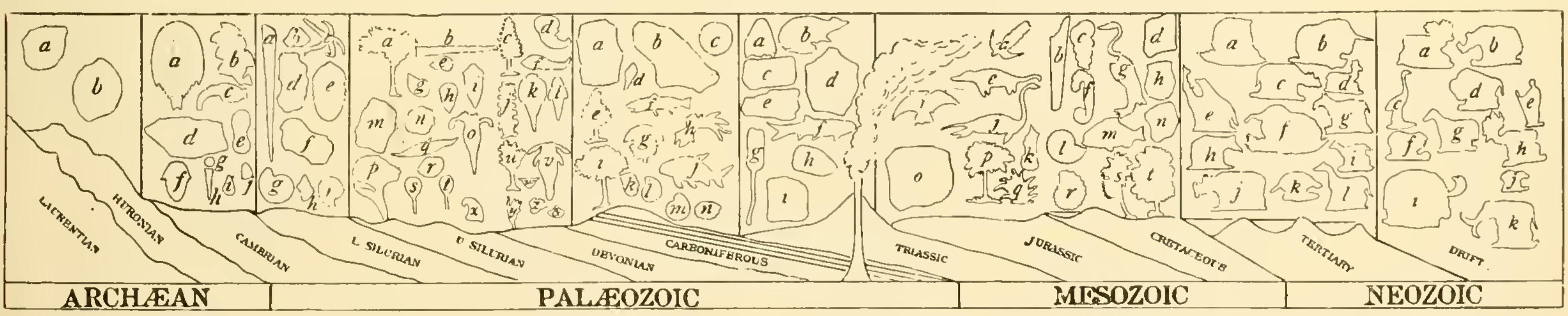
Questions on the Physical Map of the United States (*pp. 128, 129*).—What regions distinguished for certain products are shown on this map? In what part of the United States is the mineral region? Where else are valuable minerals met with? Are metallic ores generally found in highlands or lowlands? Point out the lumber region; the wheat region. What animals are native to the pasture region? Where are fur-bearing animals found? In what part of the country is the raising of domestic animals a characteristic industry?

Trace the isotherm of 56°. Why does it bend southward from the Susquehanna? then northward, passing through Indiana and Illinois? Why does it curve southwesterly from Kansas until it crosses the Texas boundary? Follow the isotherms of 40° and 64°. Why are they not characterized by as great irregularities? South of what isotherm does the cotton region principally lie? The rice region?

TABLE SHOWING APPROXIMATE COMPOSITION, COLOR, SPECIFIC GRAVITY, AND RELATIVE HARDNESS, OF GEMS.

	Hardness.	Specific gravity.	Colors.	Composition.
Diamond.......	10	3.52	White, red, green, black, pink, blue, brown, etc.	Carbon.
Sapphire........	9	4	Blue, shades of.	Alumina.
Ruby.	8.8	4	Red, shades of.	Alumina.
Chrysoberyl.....	8.5	3.7 { 3.76	Yell'w, brown, green	Alumina, 76; glucina, 18; ferrous oxide, 4; with trace of chromium.
" cat's-eye...	8 5	3.76	" " "	
Alexandrite	8.5	3.65	Dark-green by day, columbine-red by night.	
Spinel...........	8	3.65	Red, blue, gre'n, etc.	Alumina, 72; magnesia, 28.
Topaz	8	3.55	Yellow, blue, pink, white, etc.	Silicon, 15.5; oxyg n, 36.8; aluminium, 30.2; fluorine, 17.5.
Beryl........... Emerald	7 8	2.7	Velvet-green.	Silica, 66.8; alumina, 19 1; glucina, 14.1.
Aquamarine....	8	2.7	Sea-blue and green.	
Zircon.	7.8	4.1 to 4.6	Red, brown, yellow, greenish-white, etc.	Zirconia, 67; silica, 33.
Tourmaline......	7.5	3.1	Red, brown, yellow, greenish-white, etc.	Boro-silicate of alumina, lime, soda, lithia, with fluorine and ferric-oxide.
Phenacite..... ..	7.5	2.97	White.	Silica, 54.2; glucina, 45.8.
Garnet..........	7.3	3.75	Red, purple.	Magnesia, iron, lime, alumina, silica.
Iolite............	7.3	2.63	Blue one way, white the other.	Silica, 49; ferrous oxide, 7; magnesia, 9; alumina, 32.
Chalcedony...... Agate......... Jasper.......	7.3	2.66	Gray, bluish-gray, yellow, brownish-blue, etc	Silica with oxides coloring.
Essonite...	7	3.66	Honey-yellow.	Lime-alumina garnet.
Jadeite.........	7	3.35	Emerald, leek-gr'n.	Silica, 59; alumina, 23; with magnesia, lime, soda.
Spodumene......	7	3.2	Yellow, green, and colorless.	Silica, 64.2; alumina, 29; oxide of iron, 4; lithia, 6.
Quartz..........	7	2.65	Colorless, smoky.	Silica.
Amethyst.......	7	2.66	Purple, pink, violet.	Trace of manganese oxide, or iron.
Tiger-eye	7	3	Indigo-blue, yellow, green, brown.	Silica, 51; oxides of iron, 34.
Pyrite....	6.5	5.2	Brass-yellow.	Sulphur, 53.3; iron, 46.7.
Jade...........	6.5	3	White, green, or with blue tinge.	Silica, 58; magnesia, 27; soda, 12; oxide of iron, alumina, etc.
Hematite........	6.3	5.3	Metallic black.	Iron, 70; oxygen, 30.
Labradorite.....	6.3	2.72	Gray, with play of colors.	Silica, 55.5; soda, 4; alumina, 26.5; iron, 31; lime, 11.
Peridot.........	6.3	3.38	Olive-green.	Silica, 41; magnesia, 50; ferrous oxide, 9.
Moonstone......	6.3	2.58	White, with pearly reflections.	Silica, 64.5; alumina, 18.5; potash, 17.
Obsidian.... ...	6	2.4	Brown, black, mottled.	Silicate of potash and alumina.
Demantoid, or Green-garnet.	6	3.85	Yellow, green, emerald-green.	Silicate of iron, lime, traces of alumina and magnesia.
Turquoise.......	6	2.75	Sky-blue, blue-green, green.	Oxide copper, 5.3; oxides of iron and manganese, 2.5; alumina, 40.2; water, 19.3; phosphorus pentoxide, 32.8.
Opal...........	6	2.20	White-yellow, etc.	Silica, 90; water, 10.
Lapis-lazuli......	5.2	2.4	Azure blue.	Silica, 49; alumina, 11; oxide of iron, 4; lime, 16; sulphuric acid, 2.
Malachite.......	4	4	Green.	Copper oxide, 72; carbon dioxide, 20; water, 8.
Marble.........	3	2.6	Yellow, brown, gray, etc.	Carbonate of lime, 98; coloring and impurities, 2 and over.
Coral (precious)..	3	....	Red, yellow, pink.	Carbonate of lime, magnesia, trace of organic matter.
Pearl..........	3	2.7	White, gray, rose, black, brown.	Carbonate of lime with organic matter.
Amber	2.5	1.08	Yellow, brown, black, white.	Carbon, 79; hydrogen, 10.5; oxygen, 10.5.
Alabaster.......	2	2.32	White, pink, yellow.	Sulphuric acid, 44.8; lime, 33; water, 21.

EXPLANATION OF GEOLOGICAL CHART, PAGES 11 AND 12



Huronian.—*a*, *b*, *Eozoön*: Earliest remains of organized life; its nature is uncertain.

Cambrian.—*a*, *Paradoxides Davidis*: a trilobite; a crustacean two feet long belonging to the lobster family. *b*, *Oldhamia antiqua*: a sea-weed. *c*, *Hymenocaris vermicauda*: a crustacean; lobster family. *d*, *Oldhamia radiata*: a sea-weed. *e*, *Agnostus princeps*: an invertebrate. *f*, *Olenus micrursus*: a trilobite. *g*, *Obelelli nana*: a mollusk. *h*, *Theca corrugata*: a pteropod. *i*, *Lingula prima*: a mollusk. *j*, *Lingula Davisii*: a mollusk.

Lower Silurian.—*a*, *Orthoceras*: a cephalopod; cuttle-fish family. *b*, *Orthos lynx*: a mollusk. *c*, *Tæniaster spinosa*: a star-fish. *d*, *Buthotrephis gracilis*: a sea-weed. *e*, *Asaphus Powisii*: a trilobite crustacean. *f*, *Buthotrephis succuiosis*: a sea-weed. *g*, *Maluria magna*: a mollusk. *h*, *Murchisonia bicincta*: gasteropod. *i*, *Cyrtolites compressus*: gasteropod.

Upper Silurian and Devonian.—*a*, *Lycopoda*: a plant *b*, *Belemites sulcatus*: a cephalopod. *c*, *Conifer*: pine-tree family. *d*, *Zaphrentis Rafinesquii*: a polyp. *e*, *Bucana trilobata*: a mollusk. *f*, *Cephaspis Lyellii*: a fish. *g*, *Lituites cornuariates*: a mollusk. *h*, *Dalmania limulurus*: a trilobite crustacean. *i*, *Homalonotus delphinocephalus*: a trilobite crustacean. *j*, *Asterophyllites*: an extinct plant. *k*, *Pterichthys Millerii*: a crustacean. *l*, *Eurypterus pygmæus*: a crustacean. *m*, *Algæ*: sea-weed. *n*, *Halysites catenularius*: chain-coral. *o*, *Eurypterus remipes*: a crustacean. *p*, *Algæ*: sea-weed. *q*, *Placodermata*: a fish. *r*, *Spirifer Niagarensis*: mollusk. *s*, *Caryocrinus ornatus*: a crinoid sea-lily. *t*, *Ichthyocrinus levis*: a crinoid sea-lily. *u*, *Calamite*: a gigantic extinct marsh-plant. *v*, *Pterygotus Anglicus*: a crustacean. *w*, *Spirifer mucronotus* a brachiopod. *x*, *Platyceras angulatum*: a gasteropod. *y*, *Psilophyton*: a plant. *z*, *Platyceras dimuosum*: a gasteropod. *&*, *Spirifer cultrijugatus*: a mollusk.

Carboniferous.—*a*, *Annularia*: a plant. *b*, *Archegosaurus*: a lizard. *c*, *Palæchinus gigas*: a sea-urchin. *d*, *Macrocheilus fusiformis*: a gasteropod. *e*, *Sphenophyllum*: an extinct tree. *f*, *Coelacanthus elegans*: a fish. *g*, *Prestwichia anthrax*: a crustacean. *h*, *Stigmaria*: extinct plants, probably roots of sigillariæ. *i*, *Cryptogamous acrogen*: an arborescent fern. *j*, *Eurynotus crenatus*: a fish. *k*, *Pleurotomania carinata*: a gasteropod. *l*, *Nautilus Koninckii*: a mollusk. *m*, *Euomphalus pentangulatus*: a gasteropod. *n*, *Avinculo-pecten*: a bivalve mollusk.

Triassic.—*a*, *Skull of labyrinthodon*: a reptile. *b*, *Microbites antiquus*: a mammal, *c*, *Voltzia heterophylla*: an extinct plant. *d*, *Foot-prints of Brontozoum*: a reptile. *e*, *Tæniopteris vittata*: leaf of an extinct plant. *f*, *Palæoniscus maleopomus*: a fish. *g*, *Ecrinus lilliformis*: a crinoid, a sea-lily. *h*, *Bellamitella*: a polyp. *i*, *Pterophyllum Jægeri*: portion of an extinct plant.

Jurassic and Cretaceous.—*a*, *Archæopteryx*: the first bird, with reptilian characteristics. *b*. *Orthoceras*: a cephalopod. *c*, *Ammonites*: a mollusk. *d*, *h*, *n*, *Leaves from cretaceous trees*: deciduous exogens. *e*, *Ichthyosaurus*: a fish-like reptile. *f*, *Ancyloceras macrumullus*: a mollusk. *g*, *Hesperornis regalis*: a bird. *i*, *Pterodactylus*: a bird-like reptile. *j*, *Plesiosaurus*: a lizard-like reptile. *k*, *Ammonites Humphreysianus*: a cephalopod. *l*, *Toxocerus bituberculatus*: a mollusk. *m*, *Beryx Lewesiensis*: a fish. *o*, *Plants of the period*: fossil leaves. *p*, *Cycas Zamia*: a tree belonging to a family which still has living forms. *q*, *Acrogen*: an herbaceous fern. *r*, *Ammonites hoplites*: a mollusk. *s*, *Palm-tree*. *t*, *Oak*.

Tertiary.—*a*, *Megatherium*: a gigantic extinct mammal with affinities to the sloth. *b*, *Mastodon*: an extinct elephant-like mammal with four tusks. *c*, *Rhinocerotida*: an early extinct form of rhinoceros restored by Packard. *d*, *Cotylophora*: an extinct American antelope. *e*, *Mylodon*: an extinct mammal allied to the megatherium. *f*, *Dinotherium*: an extinct mammal, the largest that has ever lived. *g*, *Dinocerata*: an extinct form combining the characteristics of several existing families of mammals. *h*, *Listriodon*: an extinct tapir. *i*. *Xiphodon*: extinct mammal, light, and deer-like in form. *j*, *Dinoceras*: an animal belonging to the order Dinoceratæ. *k*, *Glyptodon*: a gigantic extinct armadillo. *l*, *Anoplotherium*: an extinct mammal, semi-aquatic in its babits, like the hippopotamus.

Drift.—*a*, *Alce*: moose. *b*, *Rhinocerotida*: extinct double-horned rhinoceros. *c*, *Dinornis*: gigantic extinct bird. *d*, *B. Americanus*: bison. *e*, *Homo*: man. *f*, *O. moschatus*: musk-ox. *g*, *Equida*: horse. *h*, *Rangifer*: reindeer. *i*, *Mammoth*: extinct hairy elephant. *j*, *Dicotyles*: peccary. *k*, *Elephant*.

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