Heavens Fold, Glacier National Park, Mont. From forest to peak 2000 feet. (U. S. Senate Report No. 580.)

HIGH SCHOOL GEOGRAPHY

PHYSICAL, ECONOMIC, AND REGIONAL

BY

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PARTS I. AND II.

PHYSICAL AND ECONOMIC

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PREFACE

THAT the better part of geography is to be found in a study of relationships is the conviction of all geographers. Only by such study can an affirmative answer be given to Jowett's question, "Can geography be used to make students think?" There is no subject which presents a greater number and variety of relationships than geography. It leaves hardly any field of human knowledge untouched, and is the mutual debtor and creditor of all. It is capable of yielding a purely scientific discipline "uncontaminated with the worship of usefulness," and it can be made as baldly "practical" as the commercial spirit requires. The higher interests of education demand a judicious combination of pure and applied science.

The most important thing about the earth is the fact that it is a human planet, that men not only live upon it, but make, somehow, a living out of it. The earth as a planet, a machine which "goes" and "works," an organism which has grown and developed in the past and will continue to do so in the future, has never been so thoroughly studied and understood as it is to-day. The main result of such study, under the name of physical geography, has been a favorite subject in secondary schools. Some special phases of human activity, more or less closely related to the earth, such as products, manufactures, trade, races, customs, language, religion, and government, are everywhere taught under the names of commercial and political geography. But these different kinds of geography are seldom brought closely together, and the crowning relationship of all geographic science, the relation of the human species to its natural environment, is generally missed or but dimly seen.

To get a view of the earth, not only as the home of man, but as the garden in which he has grown, the school in which he has been educated and civilized, the environment in which still higher ideals may be attained, is the object of modern geographical study. This can be accomplished only by taking an economic standpoint, from which the dependence of human life upon natural conditions and the influence of those conditions upon human life can be most clearly seen. This book is an attempt to present such a view and to treat the leading facts and principles of geography as factors in the human struggle for a better living, that is, for the highest possible civilization. Physical geography, a view of the earth as it would be if no man had ever lived upon it, forms the necessary basis. The first part of this book is called physical geography because the principal subject discussed in it is the natural earth, but the treatment is more brief than in many recent textbooks. Many topics of great interest to the student of pure science are omitted or lightly touched, preference being given to those features and processes which have directly "helped or hindered man in his progress." The fact is constantly kept in mind that man is himself a part of nature and the picture is painted from the beginning against a strong background of human life.

The second part is called economic geography because the point of view is reversed, and the outlines of household management practiced by the great human family in its terrestrial home are presented against the background of the natural earth already shown. It is hoped that by this method of treatment the peculiar interest and value of physical geography will not be lost, while its use as a foundation for economic geography will give added attraction and stability to both. Parts I and II are planned to furnish as much material as can be used in a high school course of five or six months.

For those schools which devote a longer period to the study of geography, Part III furnishes a more detailed, intimate, and graphic study of the same theme. The natural earth is still the basis and is divided into natural provinces arranged in a few groups, forming typical environments in which the economic adaptations of human life must be broadly similar, varying only with the stage of civilization of the inhabitants. Where the civilization of a natural environment is not native, but has been introduced from some other more favorable environment, interesting contrasts appear; but in every case the possibilities are strictly limited by natural conditions. North America is found to present all the typical natural environments of the world except the strictly equatorial. A detailed discussion of these with references, more or less extended, to similar environments in other parts of the world, serves to bring out all the principal kinds of adaptation to natural environment which the human race has achieved, and gives a bird's-eye view of world economies. This part of the book comes near to being a concrete example of a recent definition of economic geography as "the study of the different types of environments in the relations they bear to the activities of human life."

The treatment by natural rather than by political and, consequently, artificial divisions is attended by no serious difficulty except in the handling of statistics, which are always compiled according to political units. The result is some slight want of exactness in figures, but as these are constantly changing, the defect is not great. The author recognizes the fact that such treatment is an innovation in some degree revolutionary; but he believes that the advantage it gives in showing the essential relationships of geography more than compensates for all difficulties, and that when once understood it will be accepted and welcomed.

Reports of committees of the National Educational Association and of the Association of American Geographers have recently outlined in some detail courses in geography for secondary schools. While this book has not been written on the plan of conforming to the requirements of either, it will be found to cover substantially the ground of both.

An unusual number and variety of maps have been introduced in the hope of leading teachers and students to a better appreciation and use of this unrivaled method of geographical expression.

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PART I. PHYSICAL GEOGRAPHY

CHAPTER I

EARTH, SUN, AND MOON

The Earth is a globular mass of rock, water, and air, tied to the sun by gravitation and revolving around it at a distance of about 93,000,000 miles. The core or central body of the earth is probably a solid ball of hot nickel-iron, with an outer crust largely composed of oxygen and silicon combined with other elements to form various kinds of rocks. The whole solid earth may be called the *rock sphere* (*lithosphere*). The depressions in the crust are occupied by a thin sheet of water which covers nearly three fourths of its surface and constitutes the *water sphere* (*hydrosphere*). The rock and water spheres are surrounded and inclosed by an *atmosphere* of nitrogen, oxygen, and other gases, the extent of which is not definitely known.

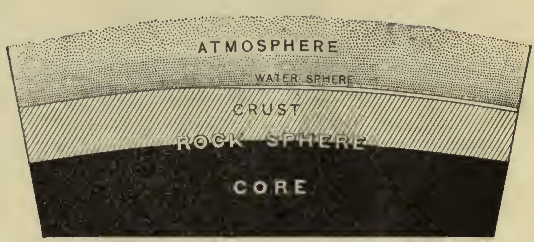


Fig. 1. — Section of part of the earth.

The atmosphere is as truly a part of the earth as the rock, but this fact is often disregarded and the word *earth* is used to mean only the solid and liquid mass. In this sense the earth is a slightly compressed spheroid, its polar diameter being 7,899.6 miles, its equatorial diameter 7,926.6 miles, and its circumference about 24,900 miles.

Men do not live upon the surface of the earth, which is the outer surface of the atmosphere, but hundreds of miles below, on or near the surface of the rock and water spheres, which is commonly called *the face* of the earth.

The Sun is a bright star, about 110 times the diameter of the earth. The body of the sun is surrounded by an atmosphere consisting of white-hot vapors of various metals, which radiate heat and light in every direction. The heat and light from the sun penetrate the earth's atmosphere and reach the land and water. The earth rotates on its shortest axis once in 24 hours, thus exposing different sides to the sun and causing an alternation of sunlight and shadow, or day and night. The rotation of the earth is clearly shown by the apparent movement of the stars from east to west.

Latitude and Longitude. — The earth's rotation not only divides time into short periods of light and darkness, but also furnishes fixed points from which to measure distances and fix locations.

If a mark is made upon the surface of a smooth, uniformly colored ball, it is impossible to describe its position for want of other points of reference. If the ball is set to spinning like a top, the rotation establishes an axis and two poles at opposite ends of it. A line may be drawn around the ball midway between the poles which will be an *equator*, or divider of the surface into two equal parts. A line may also be drawn from pole to pole at right angles to the equator. Then the position of any point on the ball may be determined and described by its angular distance from each of these lines. This is the meaning and purpose of latitude and longitude.

Latitude (breadth) is angular distance from the equator toward each pole and is measured in degrees up to 90 degrees. *Longitude* (length) is angular distance from a line arbitrarily fixed at right angles to the equator, each way around to the opposite side of the earth, and is measured in degrees up to 180 degrees. For convenience a set of lines is imagined or drawn parallel with the equator, called *parallels*, and another set at right angles to the equator, called *meridians*. These lines form a network, which divides the face of the earth into quadrangles indispensable in surveying and mapping.

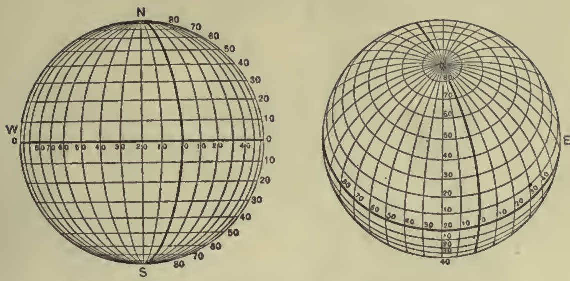


Fig. 2. — Parallels and meridians.

The number of parallels and meridians is unlimited. Portions of some of them are surveyed and located on the ground and form boundaries of states, counties, townships, and sections. They are drawn upon a map at any convenient distance apart, and the network is used to locate the desired features. The meridian passing through Greenwich, near London, is now used as a base line or prime meridian throughout the world. The axis of the earth always maintains the same direction in space, the north end of it looking toward a point in the heavens near the star Polaris, "the north star." To an observer at the equator Polaris is on the northern horizon (Fig. 3); but if he travels northward the star rises higher above the horizon until at the north pole it is directly overhead. Hence directions and latitude may be determined by observing the stars.

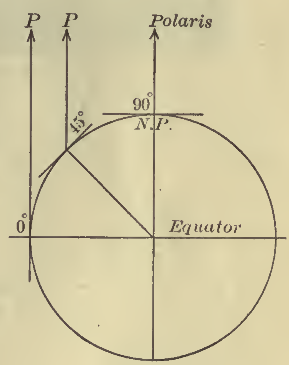


Fig. 3.

The Seasons. — The earth revolves around the sun in a nearly circular orbit, requiring a little more than 365 days to complete one revolution. The revolution of the earth may be seen by noticing that the groups of stars visible at any given hour of the night change from week to week, and month to month. If the axis of the earth were perpendicular to the plane of its orbit, its revolution would bring no change except in the appearance of the heavens at night, and would be of little importance; for in that case the line dividing the lighted side of the earth from the dark side would always pass through the poles, half of the

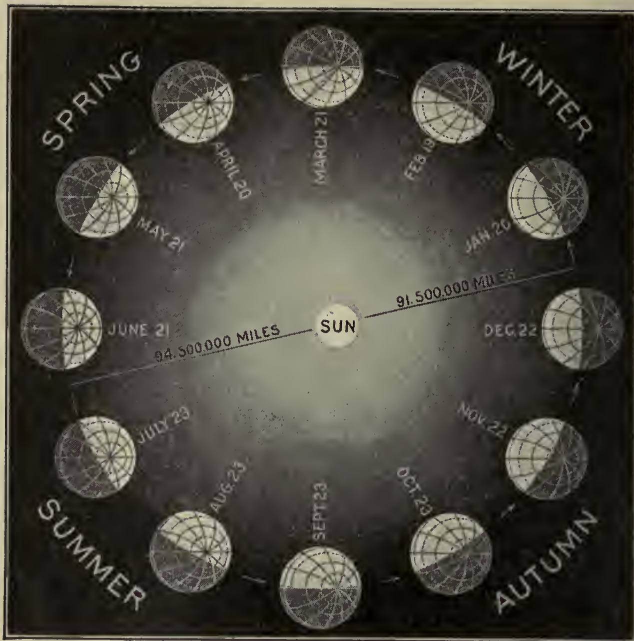


Fig. 4. — Position of the northern hemisphere throughout the year.

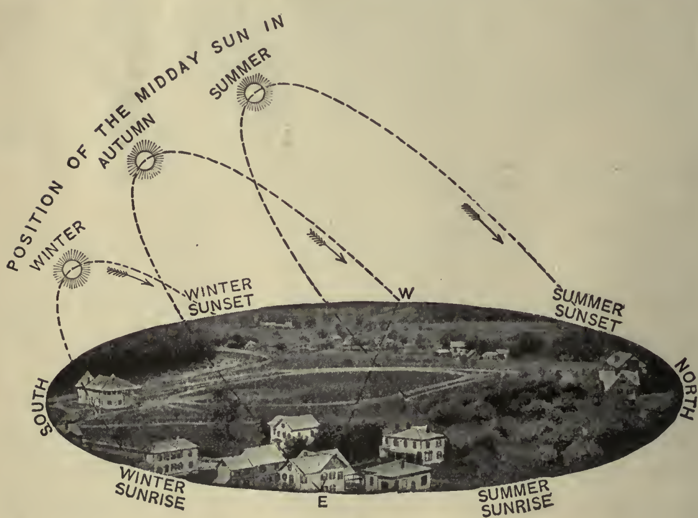


Fig. 5. — (From Todd's New Astronomy.)

northern and half of the southern hemisphere would always be in the light, and day and night would be everywhere and always of equal length, as in Fig. 6 *B*. But the earth's axis is inclined about 23° 30′ from a perpendicular to the plane of its orbit, and always in the same direction. As the earth moves around the sun, the northern and southern hemispheres are turned toward the sun alternately and each in turn receives more than an equal share of sunlight, as in Fig. 6 *A* and *C*. When either hemisphere is turned toward the sun, every place in it is in sunlight more than half the time, and the days are longer than the nights. When it is turned away from the sun the reverse is true.

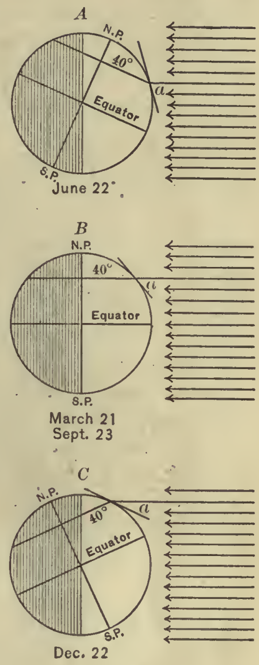


Fig. 6.

Fig. 4 shows the conditions in the northern hemisphere for each month of the year. Fig. 5 shows the apparent path of the sun in the heavens at different seasons in middle northern latitudes. The long path of the sun above the horizon in summer brings long days and a warm season; the short path in winter brings short days and a cold season.

The sun's rays have greater heating power at noon than in the morning or evening because they then pass through less air,

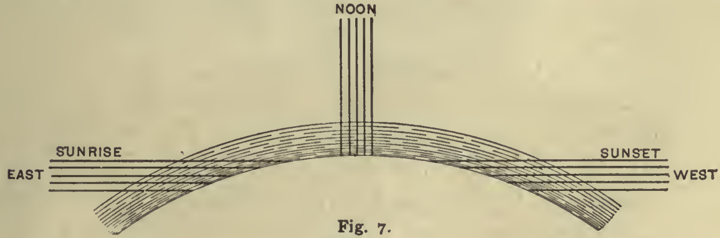


Fig. 7.

strike the earth more nearly at right angles, and are spread over less surface (Fig. 7). When the days are long the sun's rays are more nearly direct and their heating power is greater than when the days are short. Thus the inclination of the earth's axis brings about a variation in the length of the day and in the angle of the sun's rays, and these changes work together to make the months successively warmer or colder.

The most important points in this cycle of changes are: (1) *The vernal equinox*, March 21, when the sun is vertical at the equator and shines to either pole. The days and nights are everywhere of equal length and the angle of the sun's rays is the same at corresponding latitudes in both hemispheres. (2) *The summer solstice*, June 22, when the sun is vertical at the tropic of Cancer, 23° 30′ north of the equator, and shines 23° 30′ beyond the north pole to the Arctic circle. In the northern hemisphere the days are longer and the sun's rays more direct than at any other date. (3) *The autumnal equinox*, September 23, when the conditions are the same as at the vernal equinox; (4) *The winter solstice*, December 22, when the sun's rays are vertical at the tropic of Capricorn, 23° 30′ south of the equator, shine 23° 30′ beyond the south pole to the Antarctic circle, and fall short of reaching the north pole. In the northern hemisphere the days are shorter and the sun's rays are more slanting than at any other date. The change of conditions from one of these dates to the next is gradual.

The inequality of day and night and the variation in the angle of the sun's rays increase toward the poles; therefore the contrast between summer and winter increases in the same direction. The presence of permanent ice and snow in the polar regions renders the seasonal differences there less than they otherwise would be. Between the tropics the differences of temperature are slight and the seasons are distinguished as wet (summer) and dry (winter). The year of four strongly marked seasons is found only in middle latitudes.

Economic Relations. — The light and heat of the sun furnish the energy which keeps things alive and moving on the earth. The supply is not continuous and uniform, but subject to the interruptions of day and night and the variations of the seasons. Plants and animals are very sensitive to these changes, which impose upon them alternating periods of activity and rest. Outside the polar regions, every space of 24 hours is divided into a period of daylight and a period of darkness. In daylight plants and animals, including man, are generally active in obtaining food and acquiring whatever is necessary or desired for subsistence. Darkness is generally a period of rest during which they assimilate food, build up tissue, repair waste, and renew strength. For men the regular and frequent recurrence of periods of sleep, preferably during the hours of darkness, is absolutely necessary to health and efficiency.

The influence of change of seasons upon plants is very great. In equatorial regions vegetation is luxuriant at all times, but alternations of wet and dry periods induce some variation in the rate of growth. Where the contrast of seasons is strong, more than half the plants pass the cold or dry season in the form of seed, and more than half the animals live less than a year. Many animals live over the winter by migrating to a warmer region, by using the food stored during the summer, or by lying torpid. Men whose occupation is directly dependent upon plants, as farmers and gardeners, do little through the winter, or change their work.

Solar and Civil Days. — The rotation and revolution of the earth furnish two units for reckoning time, the day and the year. The period from the moment when the sun reaches his highest point in the heavens and is on the meridian, to the moment when he next reaches the same point, varies from day to day. The average length of this period is divided into the hours, minutes, and seconds shown by ordinary clocks and watches. For convenience the ordinary or civil day is made to begin and end at midnight, and is of the same length in every part of the world. Inside the polar circles the civil day does not always correspond to actual day and night, since the time from sunrise to sunset varies from a few minutes to six months.

If the earth's face were plane, sunrise, noon, and sunset would each occur over every part of it at the same moment, but as the spheroidal earth rotates, sunrise, noon, and sunset travel continuously westward at the rate of 15 degrees of longitude every hour. When it is noon at Greenwich it is about 7.00 A.M. at New York, 6.00 at St. Louis, 5.00 at Denver, and 4.00 at San Francisco. So each meridian has its own sun time, slower and earlier than the meridians east of it, faster and later than those west of it. The longitude of any place may be measured by the difference of time between it and Greenwich, one degree for every four minutes.

Standard Time. — For people who stay at home their own local mean sun time is the most convenient; but for travelers, and especially for railroad companies, it is advantageous to

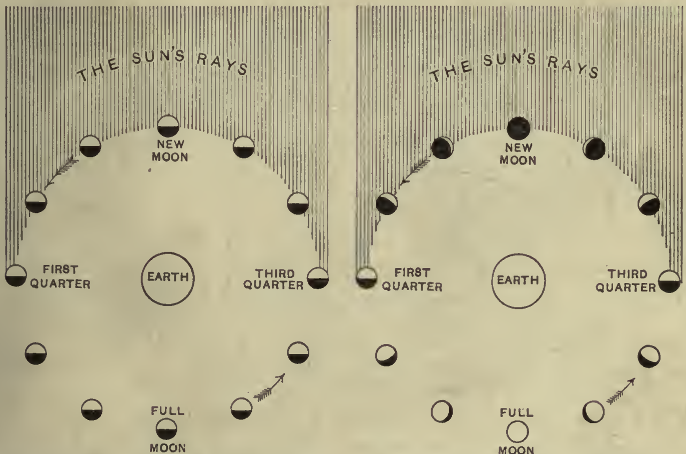
Fig. 8.

adopt standard meridians 15°, or one hour, apart, and to use the time of each meridian over a certain area on each side of it. In North America five standard time belts are in use: Atlantic or 60th meridian time (four hours slower than Greenwich time), Eastern or 75th meridian time, Central or 90th meridian time, Mountain or 105th meridian time, and Pacific or 120th meridian time. The boundaries of these belts are irregular. When a traveler crosses the boundary of a time belt, he sets his watch forward, or back, one hour. Nearly all civilized countries have adopted standard time meridians.

International Date Line. — If one travels westward, sun time becomes slower at the rate of one hour for every 15 degrees of longitude, and in going around the earth a watch must be set back, in all, 24 hours, which would cause the traveler to lose one day from his calendar. If he travels eastward, sun time grows faster at the same rate, and a watch must be set ahead to correspond. Thus one would add a day to his calendar. Hence it is found necessary to fix upon an arbitrary line for the correction of the calendar. This is called the international date line, and for all vessels is the meridian of 180°. Whenever a ship crosses this line to the westward, a day is added to the reckoning, but if to the eastward, a day is dropped from it.

The Calendar. — The calendar now in use in most of the civilized world was adopted by Pope Gregory XIII in 1582. The earth completes one revolution around the sun in 365 d. 5 h. 48 m. 46 s. The calendar is made to agree approximately with the solar year by having three successive years of 365 days each and then a leap year of 366 days. An extra day added every fourth year is a little too much, and therefore century years, like 1900 and 2000, are leap years only when divisible by 400.

The Moon, Month, and Week. — The division of the year into months and weeks was originally suggested by the changes



Phases as seen from above moon's orbit. Phases as seen from the earth.

Fig. 9.

of the moon. The moon revolves around the earth from west to east in about $29\frac{1}{2}$ days. When it is between the earth and the sun the dark side is turned toward us and is called new moon (Fig. 9). About a week later half of the lighted side is visible and is called first quarter. When the moon is on the opposite side of the earth from the sun its lighted side is turned toward us and is called full moon. Then again, about a week later, half the lighted side is visible and is called last quarter. The intervals between these changes are variable, but average about seven days. The calendar weeks and months do not coincide with the periods or phases of the moon, and the number of days in successive months varies in an arbitrary and irregular manner.

The year is naturally divided by the solstices and equinoxes into four seasons: spring, March 21 to June 22, 93 days; summer, June 22 to September 23, 93 days; autumn, September 23 to December 22, 90 days; winter, December 22 to March 21, 89 or 90 days. Although the Gregorian calendar is imperfectly adjusted to the natural time periods of day, week, month, and year, any change in it would cause so much disturbance and confusion as to make it undesirable, if not impossible.

Maps and Map Projections. — The special means of expression in geography is the map, because a map shows the facts of distribution better than anything else can. A map is a drawing which shows the position, direction, distance, and area of objects upon a horizontal plane, as though a portion of the earth's surface were stripped off, spread out flat, and reduced in size. The one thing essential for a good map is that the position of every feature shown be located correctly; if this is done, the directions, distances, and areas will be correct. No absolutely correct map of any portion of the earth's surface can be drawn, because it is impossible to flatten a spherical surface into a plane surface without distorting it.

The indispensable basis and guide in the construction of a map is the network of parallels and meridians. Numerous projections or plans for drawing the parallels and meridians are in common use. Some show the forms more correctly than others, some distort forms for the sake of showing areas correctly, while others are very erroneous as to forms and areas but correct as to directions. The best maps for common use are designed to show forms, areas, and directions with as little error as possible.

The *orthographic* projection (Fig. 10) is a picture of a globe as it appears from a distance many times its diameter. Straight parallel lines, projected through the parallels and meridians of the globe upon a plane surface perpendicular to them, locate the network of the map. Such a map is correct near the center, but around the edges the areas are greatly reduced.

Fig. 10. — Orthographic projection.

Fig. 11. — Stereographic projection.

The *stereographic* projection (Fig. 11) is a picture of a transparent hemisphere as it would appear to the eye placed at the middle point of the surface of the opposite hemisphere. In this map the areas are reduced near the center and enlarged toward the edges.

The *globular* projection (Fig. 12) is a picture of a transparent hemisphere as it would appear to the eye placed at a distance 1.707 times the radius of the sphere from its center. In this map the parallels along any meridian and the meridians along any parallel are very nearly equidistant. It shows both form and area with less error than any other projection, and

Fig. 12. — Globular projection.

is especially advantageous for maps of the hemispheres used in teaching.

In the *cylindrical* projection the surface of the sphere is conceived to be that of a cylinder of the same diameter, cut lengthwise and flattened out. The meridians are straight, parallel, and equidistant. If the parallels are projected stereographically, the length of the cylinder is twice the diameter of the sphere (Fig. 13 *A*), and areas are increasingly exaggerated toward the poles.

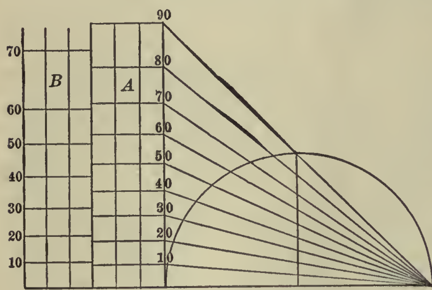


Fig. 13. — Cylindrical projections.

Mercator's projection (Figs. 13 *B* and 14) is cylindrical, but the parallels are so spaced that the degrees of latitude are proportional to the degrees of longitude. It is the only projection on which directions are absolutely correct, and hence it is much used by sailors. It is the best for maps of winds and ocean currents in which true directions are required. Cylindrical projections have the advantage of showing all the more important parts of the earth upon one continuous sheet, but on account of the enormous exaggeration and distortion of areas in the higher latitudes, they should never be used in teaching children and should always be corrected by reference to a globe.

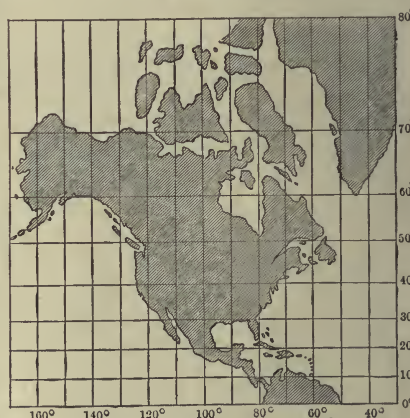


Fig. 14.— Mercator's projection.

Mollweide's equal-area projection (Fig. 16) shows the whole face of the earth upon one continuous sheet, one hemisphere in the center and half of the other on each side. Near the center forms are but slightly distorted and distances are nearly correct. In the marginal portions distortion is considerable, and north-south distances are exaggerated; but this projection has the advantage of showing areas correctly. Hence it is used for maps in which a comparison of areas is important.

In the *conical* projection (Fig. 15) the surface represented is conceived to be that of a cone cut lengthwise and flattened out. The parallels are arcs of equidistant, concentric circles, and the meridians are radiating straight lines intersecting the parallels at right angles. For areas of no great extent in latitude, such as the United States, a map on this projection is very nearly correct.

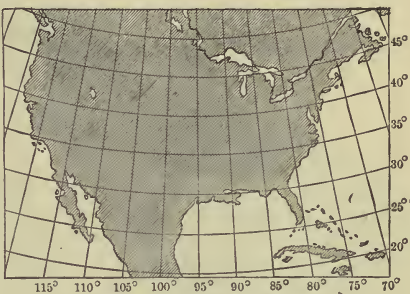


Fig. 15. — Conical projection.

Map Scales. — The scale of a map is the ratio which distances and areas on the map bear to the actual distances and areas on the earth. Scales are expressed by ratios, as 1 : 1,000,000, which means that one inch on the map corresponds to one million inches on the earth; or in linear units, as 1 inch = 1 mile; or by graduated lines. For small areas the scale may be large, one foot or more to the mile; for large areas it must be small. On maps of large areas no uniform scale can apply exactly to all parts.

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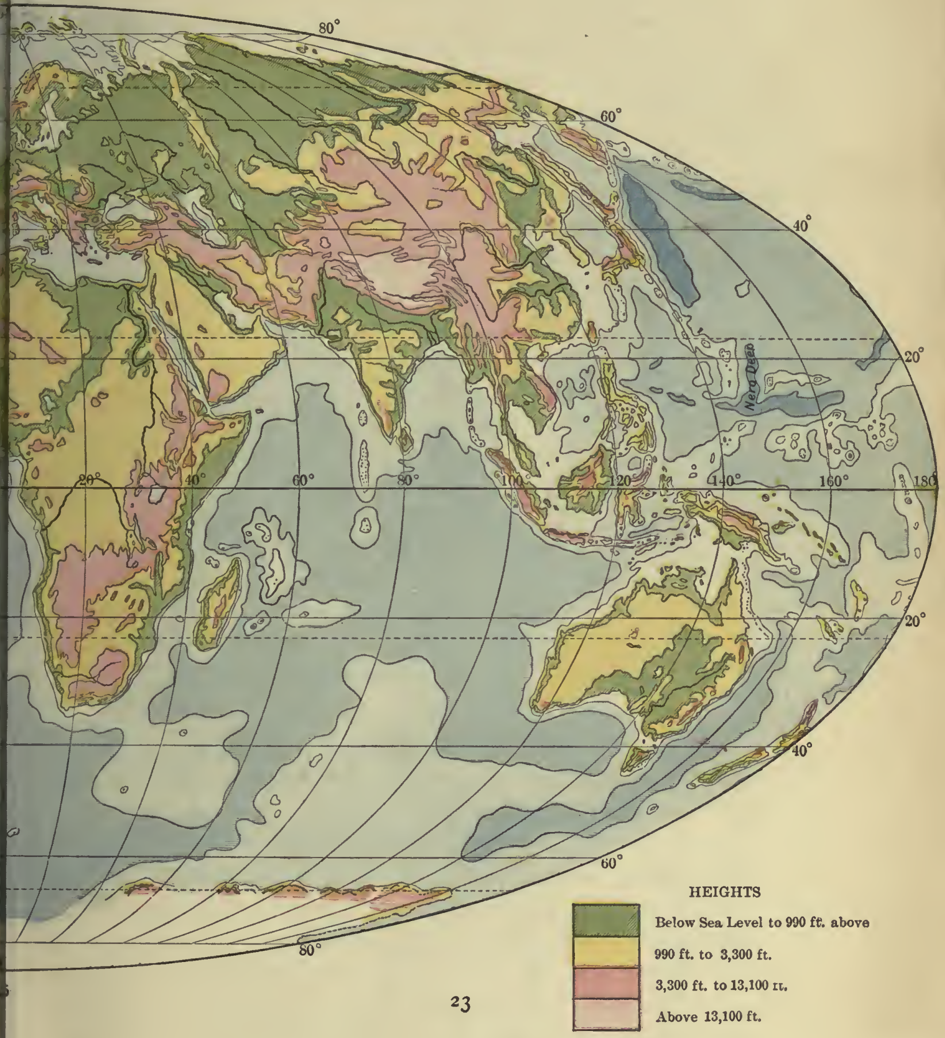


CHAPTER II

THE PLAN OF THE EARTH

The Earth Crust. — If the water were out of the way so that the whole surface of the earth crust could be seen, two contrasted areas would appear. One third of it is a broad, irregular, elevated table or platform, roughened by mountains, plateaus, hills, and valleys. The rest of it is a steep-sided, smooth-bottomed depression, lying about $2\frac{2}{3}$ miles below the elevated surface. The elevated area is the *continental platform*, and the depressed area is the *oceanic basin*. The highest point known (Mt. Everest in central Asia) is 29,000 feet above sea level, and the lowest point known (Nero Deep, near the Ladrone Islands, western Pacific Ocean) is 31,614 feet below sea level. The difference or range of elevation is about $11\frac{1}{3}$ miles.

This is only one seven-hundredth part of the diameter of the solid earth, and if represented upon a globe seven feet in diameter would be about one eighth of an inch. The earth crust is much smoother in proportion to its size than the skin of an orange.

The Margin of the Continental Platform. — The sea water not only fills the oceanic basin full, but also spreads out over the lower part of the continental platform until the outer edge of the platform is about 660 feet under water. The continents and large islands all stand upon the platform and are bordered by a belt of shallow water (Fig. 16). The lowlands less than 660 feet above water, and the adjacent *continental shelf* less than 660 feet under water, constitute an unstable portion of the earth crust which has risen and sunk many times. Where the slope is so gentle, slight movements up or down make great changes in the outlines and area of the land.

If the crust should rise 660 feet, the shore line would recede to the outer edge of the shelf and the total land area would be increased about 20 per cent. If the crust should sink 660 feet, the shore line would advance upon the land and about 30 per cent of the present land area would be flooded by the sea. Much greater up-and-down movements than these have occurred in the past. Rivers carry down the waste of the land and deposit it upon the continental shelf, spreading out material for the rock strata of new lands which may sometime rise from the sea. The shallow waters of the shelf are the home of abundant plant and animal life, and the site of the great fishing grounds of the world. Because of the shallowness tides rise higher along the shores than they do in deep water, and make it possible for large ships to reach ports like Montreal, Glasgow, and London, situated far up the bays and rivers. The relations of the continental shelf to the land and its inhabitants are far closer than those of the deep ocean basins.

Arrangement of the Great Crust Features. — The continental platform which supports the great land masses forms a nearly continuous belt around the earth at about 70° N. Lat. (Fig. 16). From this belt three arms extend southward, the American to about 57° S. Lat., the Eurafrican to about 37° S. Lat., and the Asia-Australian to about 45° S. Lat. An Antarctic continent of undefined extent surrounds the south pole. The oceanic basin forms a continuous belt around the earth at about 60° S. Lat., from which three arms extend northward, interlocking with the continental arms. Of these the Pacific basin is roughly circular in outline, the Atlantic arm is long, narrow, and S-shaped, while the Indian arm is short and broadly triangular. The Arctic basin occupies an area around the north pole, the limits of which are not accurately known. Each continental arm is broken nearly midway of its length by a cross projection of the oceanic basin, the American by the Gulf of Mexico and Caribbean Sea, the Eurafrican by the Mediterranean Sea, and the Asia-Australian by the straits of the Indian archipelago.

Land and Water Hemispheres. — About 70 per cent of the land lies north of the equator and about 86 per cent of the sea lies south of it. If a map of a hemisphere is drawn with London as a center, it will include about 82.5 per cent of all the land, and the opposite hemisphere with its center near New Zealand will include about 63 per cent of all the sea. The land hemisphere thus drawn is 46.7 per cent land, and the water hemisphere is 90 per cent sea (Figs. 17 and 18).

Fig. 17.

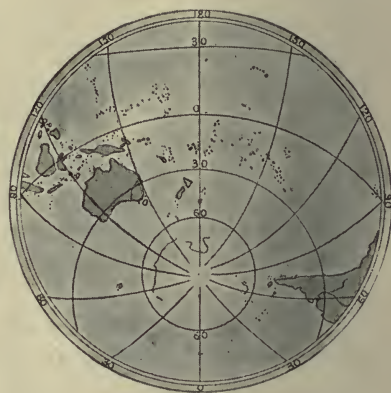


Fig. 18.

The Arrangement of Land Masses. — The continental land masses conform roughly to the position and shape of the continental platform and are thus divided into seven continents, Europe, Asia, and North America lying close together in the northern hemisphere; South America, Africa, Australia, and Antarctica lying wholly or partly in the southern hemisphere, and more widely separated from one another.

Fig. 19.

If a globe is viewed in such a position that the center of Asia (E. Long. 90°, N. Lat. 50°) is the center of the visible hemisphere (Fig. 19), it will be seen that the other continents are arranged around Asia with some approach to symmetry. Europe is but a large peninsula projecting westward. Africa lies close against the southwestern shores of Eurasia, and is tied to it by the Isthmus of Suez and the shelf at the mouth of the Red Sea. Directly northward of Asia, across the narrow polar basin, lies North America, connected by the shelf of Bering Sea and Strait. To the east of south the submarine platform of the Malay archipelago stretches away to Australia. In past ages America and Australia have been connected with Asia, and Africa with Europe, by land bridges, and to-day every part of the continental lands except Antarctica can be reached from Asia without crossing a strait more than 250 miles wide. The central position of Asia and the continuity of the radiating arms of the continental platform, furnishing easy routes of travel to nearly all habitable lands, have been of great importance in controlling the migration and dispersal of plants, animals, and men. There would be no insuperable difficulty in building a continuous railroad from Cape Horn to the Cape of Good Hope, with branch lines to Liverpool and Lisbon, while Australia could be connected with the system by a short ocean ferry.

Eastern and Western Hemispheres. — The earth has been somewhat arbitrarily divided into an Eastern and a Western Hemisphere. In the Eastern Hemisphere Europe, Asia, and Africa compose the "Old World"; in the Western Hemisphere North and South America are called the "New World." There is no reason to think that any part of the land of the Old World is actually older than some parts of the New World. The human species probably originated in Asia, and the earliest records of human history are found in Asia and Africa, but Australia was not discovered by Europeans until 100 years after the discovery of America by Columbus. Asia and Europe form physically one continuous land mass and are often treated as one continent under the name of Eurasia, but for historic reasons geographers usually regard them as distinct.

Northern and Southern Continents. — The continents naturally fall into two groups which are strongly contrasted in physical characters, in their relations to plant and animal life, and in the part they play in human history. About four fifths of the area of the northern continents lies in those temperate latitudes which are most favorable for the development of human faculties; while about four fifths of the area of the southern continents lies in the hot belts, between the parallels of latitude 30° north and south, where the climate is oppressive and plants and animals are either absent on account of aridity, or are able on account of humidity to compete successfully with man in the struggle for possession. The southern continents are isolated from the northern and from one another and are relatively inaccessible. They contain less than one eighth of the world's population. Consequently they are in their human relations, as well as in their physical conditions subordinate appendages of the great northern land masses.

Asia. — The central and largest continent spreads a vast expanse from the equator far into the polar regions, too shapeless to suggest any geometrical figure. The eastern side presents to the Pacific a belt of mountainous peninsulas and off-shore islands, which border the shelf for 6,000 miles. The southern margin is cut by deep notches into three massive peninsulas. On the west it is imperfectly separated from Europe by the Black and Caspian basins, and other depressions which once connected them with the Arctic Ocean. On the north low plains slope gently to the icy sea. The body of the continent consists of a mass of plateaus and mountains, the loftiest in the world, the culminating core of which is Tibet.

From the Tibetan center, highlands trend southeastward toward Australia, northeastward toward America, westward into Europe, and southwestward into Africa. The average elevation of Asia is 3,120 feet, 25 per cent of it is below 660 feet, and 14 per cent is above 6,600 feet. Asia contains 30 per cent of all the land and more than half of all the people on the globe.

Europe, a westward projection from Asia between the Arctic Ocean and the Mediterranean Sea, is characterized by many peninsulas and inclosed seas, which penetrate far into the interior. These give it the longest coast line in proportion to its area of all the continents, and furnish unequaled facilities for travel and trade by water. The highlands of Asia are prolonged through southern Europe by less lofty ranges of folded mountains to the shores of the Atlantic. These are flanked by plateaus and lesser ranges of moderate height. In the northwest the rugged peninsula of Scandinavia presents a bold front to the sea. The body of the continent is a low plain, no point of which is as much as 1,000 miles from the sea.

The mean height of Europe is 990 feet, 57 per cent of it is below 660 feet, and less than 2 per cent is above 6,600 feet. Although it contains only 6.7 per cent of the land, favorable conditions have made it the home of one fourth of the human race, and the dominant influence in modern civilization.

North America is built on the triangular plan, with its longest side next to the Pacific, extending in a double curve more than 6,000 miles, and bordered by the lofty Cordilleras. The continental limits are extended far northward by the half-drowned, ragged land patches of the Arctic archipelago, to which is attached the largest of islands, Greenland. The southeastern side is paralleled for about half its length by the low Appalachian highland. The southern extremity tapers off into the crooked Isthmus of Panama, which connects it with South America. The body of the continent is made up of the largest continuous low plain in the world. It resembles Eurasia as the left hand resembles the right, presenting to the Atlantic a low and broken coast, penetrated on the south by the Mexican and Caribbean mediterranean, on the north by Hudson Bay, and between the two by drowned river valleys, all of which give access to the interior plains.

Lying on the opposite side of the north Atlantic from Europe, and 2,000 to 3,000 miles distant, North America has felt the influence of European civilization more strongly than any other land. Like Eurasia, it faces the Atlantic and presents to the Pacific a high and forbidding back. Its average elevation is 2,300 feet, 33 per cent of it is below 660 feet, and 6 per cent is above 6,600 feet. Its area is 16 per cent of the land, and its population 7.5 per cent of the inhabitants of the world.

South America is a simplified copy of North America, resembling it in triangular form tapering southward, and in having a high western margin, low interior plains, and for the most part a low Atlantic coast. It is characterized by the smoothness of its coast line and the magnitude of its rivers, of which the Amazon is, in area of basin and volume of discharge, the largest in the world.

Settlers have found it much more difficult to penetrate and occupy than North America, and its inhabitants, still largely of native Indian blood, are on the whole much less advanced in civilization. Its average elevation is 1,900 feet, 43 per cent is below 660 feet, and 9 per cent is above 6,600 feet. It contains 11 per cent of the land, and 2.4 per cent of the people of the world.

Africa resembles the Americas in triangular outline, but is the most compact and unbroken of the continents. About 70 per cent of its surface is a plateau with steep margins. Although its northern coasts are in close touch with Eurasia and have shared in its history and civilization, the great desert of Sahara has been an almost impassable barrier to penetration from that side. On the east and west, deserts, dense forests, rapids and falls in the rivers, and an unhealthful climate, have combined to prevent occupation and to retard progress in culture.

Its native peoples have remained for thousands of years in a condition of savagery which justifies the name of "the dark continent." Nearly every square mile of it is now under the influence and partial control of European people, and its future seems hopeful. Its average elevation is 2,130 feet, 15.4 per cent is below 660 feet, and 2.4 per cent is above 6,600 feet. It contains 20 per cent of the land area, and 8.6 per cent of the population of the world.

Australia, including New Guinea and Tasmania, is a simplified copy of Africa, with the southern extension greatly reduced in size. Its surface is largely a dry plateau, with folded mountains on the east and north (in New Guinea).

Isolated and cut off from the great centers of plant and animal life since early geologic times, all its indigenous inhabitants are of a very primitive type. On this account they offered little resistance to European colonists, who within the last century have taken complete possession of the habitable parts of the mainland. Its average elevation is 1,150 feet, 36 per cent is below 660 feet, and less than one per cent is above 6,600 feet. It now supports, on 6 per cent of the land area, one third of one per cent of the population of the world.

Antarctica. — That there is an area of continental land around the south pole, about half as large again as Europe, seems now to be definitely settled, but it is so deeply buried in snow and ice that its outlines and surface are imperfectly known. Its average elevation is twice as great as that of any other continent. It is now in the twentieth century becoming a field for systematic exploration. On account of severity of climate and difficulty of approach, sojourn, and travel, the progress of discovery will be slow and costly. It contains no permanent human inhabitants, and little life of any kind, except sea birds which nest and breed upon its coasts.

Islands. — Nearly all the large islands and many small ones stand upon the continental shelf and are therefore *continental.* Greenland, the Arctic archipelago, Newfoundland, and the Greater Antilles belong to North America; the British and Mediterranean islands to Europe; New Guinea and Tasmania to Australia; Ceylon, the Malay archipelago, the Philippines, Japan, Sakhalin, and Nova Zembla to Asia. Madagascar, New Zealand, Iceland, and perhaps Spitzbergen and Franz Josef Land occupy detached portions of the continental platform. The numerous small islands of the Pacific and some in other parts of the sea are the tops of submerged mountain ranges or volcanic peaks which rise from the deep sea floor, and are therefore *oceanic.*

Oceanic islands are of small area, isolated by wide stretches of deep water, and have little variety of resources. Consequently, they constitute an environment unfavorable for the development of the higher animals, including man. The part which they have played, or ever will play, in the life history of the globe is very small.

Summary. — The principal features of the land relief of the globe consist of a nearly continuous belt of highland near the shores of the Pacific and Indian oceans, and wide areas of lowland bordering the Atlantic and Arctic oceans. Consequently nearly all the large rivers flow into the Atlantic and Arctic, Asia only contributing streams of the first class to the Pacific and Indian drainage. These facts account for the greater importance, in modern times, of the Atlantic and of the lands bordering upon it.

CHAPTER III

WORLD ECONOMY

THE earth is a sort of organism of which all the parts work together harmoniously like those of a plant or animal. No part of the earth is dead, but like a tree it is most active on the outside. Everything that goes on in the world is made possible by a multitude of conditions which probably do not exist in the same combination upon any other planet.

The position of the earth — its distance from the sun — determines the amount of heat which it receives. This is sufficient to maintain at all places upon the face of the earth a temperature which never falls lower than about 120 degrees below the freezing point of water (– 88° F.), and never rises higher than about 120 degrees above the freezing point (152° F.). This makes it possible for large quantities of water to exist in each of three forms — solid ice, liquid water, and gaseous vapor.

The form of the earth determines the angle at which the nearly parallel rays of the sun strike its face at different latitudes, and consequently the amount of heat received per square mile. This gives a variety of temperatures, ranging from the torrid to the frigid.

The attitude of the earth, or the inclination of its axis, in combination with its daily and yearly motions, determines a change of seasons, or variation of temperature, at all latitudes, and prevents both the constancy which would exist if the earth's axis were perpendicular to the plane of its orbit, and the excessive variation which would result if the axis were nearly parallel to that plane.

The revolution of the earth around the sun at a nearly uniform speed in an orbit which is nearly circular brings about the regular succession of seasons and years, each of which is of moderate length. The succession of warm and cool, or wet and dry, seasons gives to plants and animals alternating periods of comparative rest and activity.

The rotation of the earth upon its axis exposes the greater part of its face to alternations of heat and cold, light and darkness, at short intervals, and imposes upon living beings correspondingly short and frequent periods of activity and rest. It also enables men to look out at night into space, see the moon and stars, and learn something of the universe of which the planet earth forms an insignificant part.

The structure of the earth includes solid, liquid, and gaseous spheres. The size and weight of the solid sphere largely determine the force of gravity, which is sufficient to prevent the atmosphere from escaping into space and to give it such composition and density as to support plant and animal life. The attraction of the earth also determines the weight of every object upon its face, and the strength or rigidity of plants and the muscular power of animals are nicely adapted to support or to move their own and other weights. The earth crust gives a firm support for all creatures which live upon the land, and to plants soil for anchorage and a storehouse of available food. The depressions in it form basins which hold most of the water and prevent it from covering the crust completely. Although the form and surface of the crust are continually changing, the changes are slow, and the crust is relatively the most fixed and stable part of the earth outside the core.

Circulating Systems. — In contrast with the rigidity of the crust, the fluid masses of water and air are very mobile and make it possible for extensive systems of currents to circulate in the atmosphere, in the sea, and on the land.

The air is seldom, if ever, perfectly still. Driven by the heat of the sun, it is rising, or settling, or moving horizontally in broad streams which cover thousands of miles and extend around the earth. The whole mass is whirling in great spirals from equator to poles and back again, forming a planetary wind system, analogous to the circulation of blood in animals. Driven by the winds, the surface waters of the ocean are in perpetual motion, drifting around and across the basins. The water of the sea evaporates, mingles with the air, spreads over the land, falls as rain or snow, and runs back again into the sea, completing a third circuit. The land is attacked by the air, worn away by the water, and carried into the sea. The water penetrates the earth crust and, circulating through it, dissolves, deposits, and concentrates metallic ores and other minerals, sometimes bringing them to the surface in mineral springs and geysers. Thus the earth has three great circulatory systems, active in its solid as well as its fluid parts, which keep its materials in motion and make its face to undergo perpetual change.

The water supplies plants and animals with food and also with a circulating fluid which distributes new material to their tissues and brings away waste. The air supplies plants with carbon which forms the bulk of their food, and both plants and animals with oxygen which they breathe and by which they maintain the chemical changes upon which life depends. The air penetrates to the bottom of the sea and makes the whole mass of water habitable by millions of living forms.

Solar Energy. — The sun shines down through the atmosphere and into the water, and its light, heat, and chemical rays furnish the power or energy which keeps things moving and alive upon the face of the earth.

The air and water absorb and retain the heat of the sun, tempering its intensity by day, preventing its too rapid escape by night, and maintaining over nearly the whole face of the earth such a temperature as plants and animals require. Not far below lies the fervent heat of the interior, and not far above, the intense cold of stellar space.

The Plan of the earth presents a vast expanse of water broken at intervals by large and small masses of land. While the land masses predominate in the northern hemisphere, their longer axes extend north and south through so many degrees of latitude as to traverse all the zones of climate. This variety is made still greater by diversities of elevation, relief, and distance from the sea. The number and variety of living forms probably decrease from near sea level downward to the deep sea floor and upward to the mountain tops, but the great expanse of sea surface and the low average elevation of the land make a very large proportion of the face of the earth available for a dense population of some kind. The arrangement and variety of situation, relief, soil, and climate have brought about a corresponding variety of living forms, each adapted to the peculiar set of conditions under which it lives. Probably no large part of the sea or land is entirely devoid of life; but the sphere of life is strictly confined to the thin shell of the earth where land, water, and air intermingle.

Human Life. — The most important and interesting thing about the earth is the fact that men live upon it. So far as we know this is the only human planet. Man was originally a land animal, and upon the land a large majority of human beings will always live. But using the land as a base, man has extended his field of activity over the sea and into the lower atmosphere.

He requires a constant supply of oxygen from the air, and a supply of food at short intervals, which he gets from plants, animals, and water. He must also maintain his body at a constant temperature, which he does by the consumption of food on the inside and the use of clothing, shelter, and artificial heat on the outside. For clothing, building materials, and fuel he is again dependent upon plants, animals, and rocks. He could not live many minutes upon the moon, which has no soil, water, air, or vegetation. From the natural resources of the earth he has learned to obtain much more than the bare necessities of life, which he shares with other animals. He has learned to satisfy his ever-growing wants for safety, comfort, and luxury, and to gratify his hunger for knowledge, his taste for beauty, his love of social enjoyment, and his longing for the things which he finds most valuable.

Geography has something to say about all these things, and seeks to understand how they have come to be where and what they are. It studies the world organism and tries to discover how men can live in it and lead so many different kinds of life as they do in different parts of it, what natural conditions help or hinder them, and how they may use the organism to better advantage in the future.

CHAPTER IV

THE LAND

Structure. — The ground upon which we stand, walk, and work is a part of the earth crust, the outer shell or layer of the rock sphere. The crust contains hundreds of species of minerals, mixed together in different combinations to form rocks. A large mass of any solid mineral or mixture of minerals is called *rock*. Almost everywhere, except upon very steep slopes, the ground is composed of loose, incoherent material, commonly called earth or soil, and distinguished as clay, sand, gravel, pebbles, boulders, or mixtures of them. They are all fragments of older rocks which have been broken up and decomposed. This sheet of loose, fragmentary material may be hundreds of feet thick, and is called *mantle rock*, because it overlies and covers the other rock. The upper foot or two of mantle rock is generally mixed with *humus*, or decayed vegetable matter, and constitutes *the soil*, in the strict, or agricultural, sense of the word.

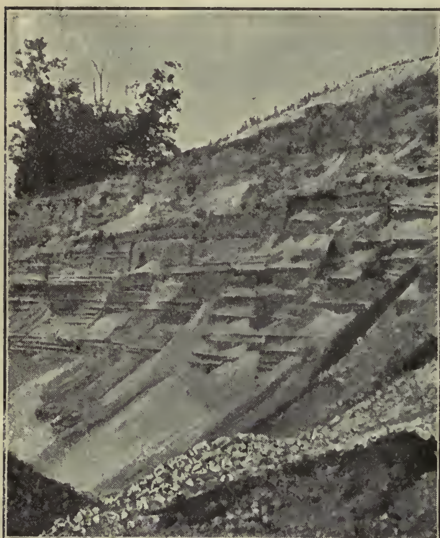


Fig. 20. — **Stratified sand and gravel, Terre Haute, Ind.**

Bed Rock. — If a boring is made anywhere down through the mantle rock, it will be found to be underlain by *bed rock*, a compact, coherent mass, which is not easily broken up or removed. Bed rock often projects through the cover of mantle rock and is exposed to view upon a hillside, in the face of a cliff, or along the bed and banks of a stream. Such an exposure of bed rock on the surface is called an *outcrop*. In most places the upper part of the bed rock is stratified, that is, it lies in distinct sheets or layers called *strata* (singular *stratum*). The common

Fig. 21. — Stratified bed and mantle rock, Erie County, N. Y.

kinds of stratified bed rock are shale, sandstone, conglomerate, and limestone. They are also called *aqueous* or *sedimentary* rocks, because they have been formed by the accumulation of sediment in bodies of water.

In some places immediately beneath the mantle rock, and everywhere beneath the stratified bed rock, lies a mass of unstratified rock, which owes its form and structure to cooling from a plastic or molten condition.

Melted rock has risen from great depths and has cooled in the cracks and between the layers of stratified rock, or has escaped to the surface and spread out over the country. Rocks which have solidified from a molten

Fig. 22. — Unstratified igneous rock, Hoboken, N. J.

state are called *igneous*. Lava, of which there are many varieties, is a common form of igneous rock. Some rocks which were originally sedimentary, have been changed by heat and pressure, but have not been melted, and

Fig. 23. — Contorted gneiss, a metamorphic rock, near Hudson Bay. (Can. Geol. Surv.)

are called *metamorphic* or altered rocks. Igneous and metamorphic rocks are often distinguished as *crystalline*, because they are mainly or wholly composed of crystals, which are often conspicuous from their shape, color, and sparkling luster. Granite is a good example of crystalline rock.

Economic Relations. — The surface, soil, vegetation, and value of a region depend largely upon the kind of rock which underlies it. The common kinds of both mantle and bed rock are dug or quarried for use in constructing roads, streets, bridges, houses, and public buildings, while the finer kinds, like marble and granite, furnish beautiful material for buildings, monuments, and statues. All the useful minerals, such as coal and the ores of the metals, are obtained from the earth crust, generally from the bed rock by *mining*. Thus the agricultural and mineral wealth of a country depends upon the structure of the earth crust.

Relief Maps. — Many devices are in use for showing elevation and form, or *relief*, upon a map. One of the most common and generally useful is by "overlaying" with different colors to show successive stages of height and depth, as on the map, Fig. 16. Such a map shows general elevation within certain limits, but fails to show the details of form. Each boundary line of a color or shade is level, or everywhere at the same distance, 990 feet, 3,300 feet, etc., above or below sea level, measured vertically. These lines of equal elevation upon a map are called *contour lines*, or simply *contours*. By drawing contours at small intervals relief may be shown with any desired degree of precision, and colors become unnecessary.

The United States Geological Survey is making a topographic atlas of the United States, of which about one third is now completed. The contoured maps in this book, Figs. 28, 30, 31, 35, etc., are taken from it. They show the relief, drainage, and *culture* or human features, such as towns, houses, and roads, with great detail and precision. It is worth while to learn to use these maps, which are among the best made of any country in the world.

Fig. 24 shows a sketch or picture of a landscape, and Fig. 25 a contoured map of the same region. In the foreground is a portion of the sea, the shore line of which forms the basal or zero contour. Contours are drawn upon the map at intervals of fifty feet *measured vertically* from the sea level, and they mark the lines where the seashore would be if the sea should rise fifty, one hundred, etc., feet. Where the slope is steep, one would have to travel only a short distance to rise fifty feet; hence the contours are close together. Where the slope is gentle, one would have to travel far to rise fifty feet; hence the contours are farther apart. By shortening the contour interval to ten or five feet, as may be done upon a large-scale map, the elevation of every point may be shown very precisely. For showing

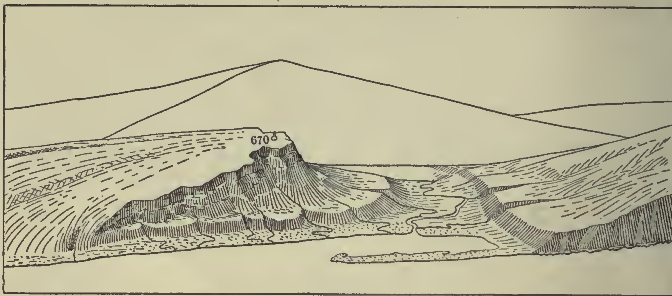


Fig. 24.

Fig. 25.

exact elevation no device is equal to the contoured map; but it has the disadvantage of not being *graphic*, that is, of not being understood by everybody at a glance.

A very common device for showing relief upon a map is the use of *hachures*, or fine lines running up and down the slopes, and so drawn as to show the steepness of the slope by the depth of shading. Hachured maps may be made very graphic and almost equal to a picture. Figs. 26 and 27 show the relation between contoured and hachured maps of the same area. A combination of the two is the best possible method of showing relief upon a map.

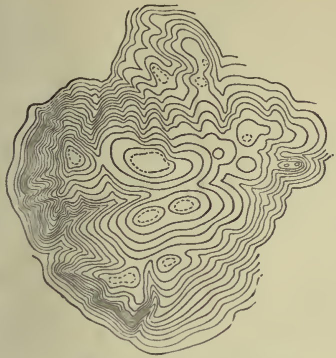


Fig. 26. — Contoured map.

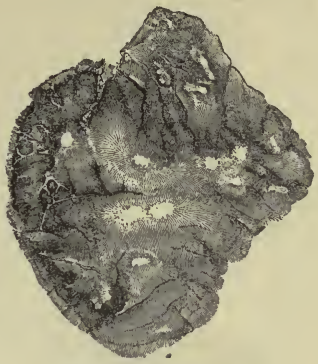


Fig. 27. — Hachured map.

Land Forms. — The surface of the land presents a variety of forms which differ widely in outline, elevation, slope, mass, and structure. The inequalities of surface found in any region constitute its vertical *relief*. A smooth, level plain might be said to have in itself no relief, but if it stands at a higher level than some adjoining land or water surface, it would have relief in relation to the lower surface.

The design upon a coin stands out in relief above the general surface of the metal. If the elevations are low and the depressions shallow, the surface has low relief; if the elevations are high and the depressions deep, the surface has high or strong relief. In common speech the roughness of the country means about the same as relief.

The large and controlling features of land relief are plains, plateaus, mountains, hills, and valleys. The internal forces of the earth have raised some portions of the land and depressed other portions, producing plains, plateaus, and mountains which mark the main features of the design. External forces, acting chiefly through air and water, have roughened a large part of the surface into an intricate pattern of smaller features, including ridges, valleys, hills, hollows, mesas, and basins.

Plains. — Plains, or lowlands, are broad, smooth, gently sloping tracts of land not far above sea level. The borders of a plain may be sharply defined by the abrupt slopes of a mountain

Fig. 28. — Coastal plain, drowned valley, barrier beach, and lagoon, New Jersey.

Scale about 1 mile per inch. Contour interval 10 feet. (Barnegat Sheet, U.S.G.S.)

range, or they may rise by an almost imperceptible grade to the height of a plateau, or slope gently to and beneath the waters of the sea. Plains are generally overspread with a deep layer of mantle rock brought down from higher land by streams, glaciers, and winds, or produced by the decay of the bed rock underneath.

Structural Plains. — The flatness of the great low plains of the world is due to various causes. Most plains are underlain by sedimentary rocks, the strata of which have not been much disturbed from their originally horizontal position. The surface is flat because the strata beneath it lie flat. When the surface thus conforms to the structure of the earth crust, the plain is called *structural*. It is like the cover of a closed book (Fig. 36).

The best examples of the structural plain are found in the lowlands which border the coasts of the continents, and are called *coastal plains* (Fig. 28). They are generally narrow, but sometimes, as in the case of the plains along the Atlantic and Gulf coasts of the United States, they stretch back hundreds of miles to the plateau or mountains which lie behind them. Coastal plains are formed by the slow rising of the sea bottom until it emerges from the water. They are covered with layers of imperfectly consolidated sediment which has been brought down in previous ages from older lands and deposited offshore. They are continuous with the submerged plain of the continental shelf. They are usually the latest additions to the continent and are composed of materials recently deposited; hence such lands are young in every sense. Old coastal plains sometimes occur in the interior of the continents, far from the sea. They were formed in the same way as the others, along the shore of a sea which has long since disappeared, and are now far inland because other plains and even mountains have risen between them and the present coast line. A strip of country extending from Wisconsin to New York along the south side of the Great Lakes is an old coastal plain. The most extensive plains in the world occur in the interior of continents, as in North America, South America, and Eurasia. These are for the most part structural plains, underlain by nearly horizontal strata.

Worn-down Plains. — Some large plains owe their flatness and low elevation to erosion. Once high and rough, they have been worn down by weathering and the work of streams and glaciers to a nearly even surface not far above sea level. Such plains are seldom as smooth as coastal plains, but are studded with low, rounded hills, composed of materials less easily eroded than the rest. They are called *worn-down plains*, *peneplains*, or *plains of degradation* (Figs. 29, 30).

A large U-shaped area surrounding Hudson Bay, from Labrador to the Arctic Ocean, was once occupied by a mountain range which has been worn down to its very roots. It is composed largely of igneous and metamorphic rocks which must have been formed originally far below the

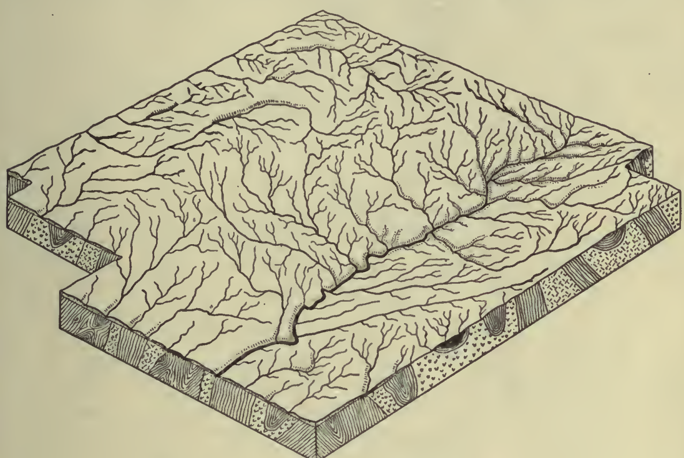


Fig. 29. — Stereogram of a worn-down plain.
Complex structure shown in section on the edges.

surface, and have been exposed by the removal of the rocks which once covered them (Figs. 23, 111). The structure is complex, that is, masses of different kinds of rock lie mingled together in almost every possible shape and position, and the present surface cuts across them without any conformity to their shapes and positions. This region is called the Laurentian peneplain. A similar plain in northern Europe occupies Finland, Lapland, and Sweden. Such plains are among the oldest lands on the globe, because it has required millions of years to wear them down to their present form and height.

Alluvial Plains. — Many plains, usually of less extent than those already described, have been formed by the spreading out of sheets of mantle rock over a surface previously more or less

Fig. 30.—Worn-down plain, Georgia and South Carolina. Scale about 2 miles per inch. Contour interval 50 feet. (Crawfordville Sheet, U.S.G.S.)

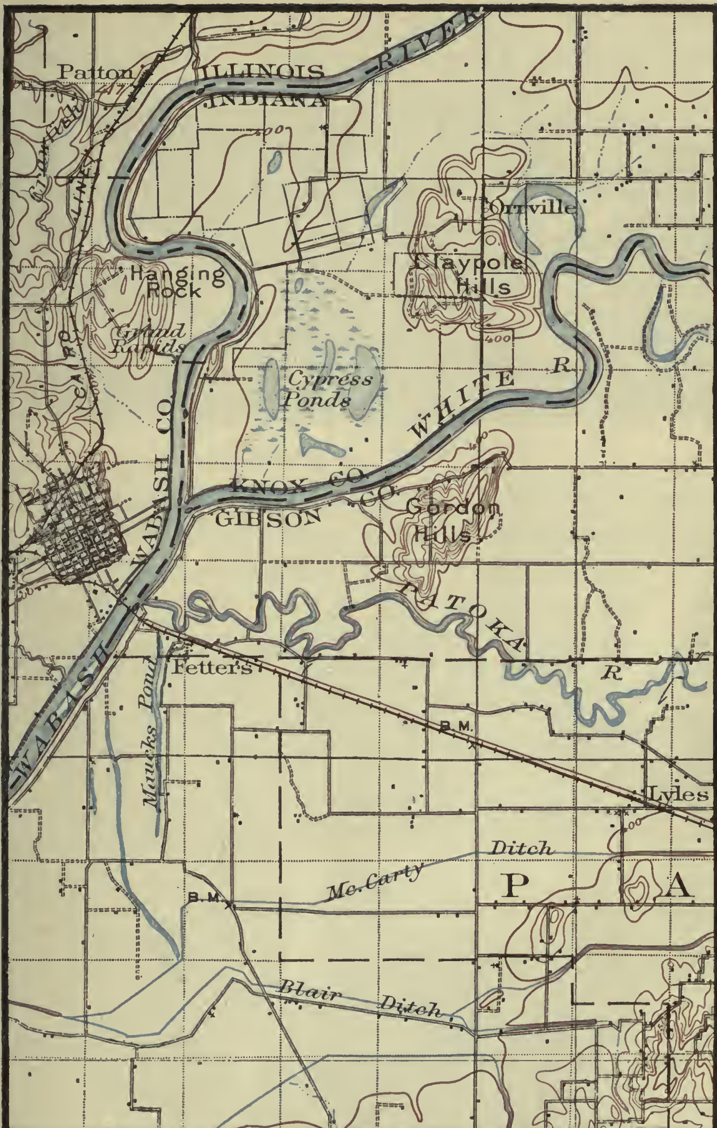


Fig. 31.—**Alluvial plain, Wabash River, Indiana and Illinois.** Scale about 2 miles per inch. Contour interval 20 feet. (Patoka Sheet, U.S.G.S.)

Fig. 32.—Alluvial plain, Wabash River, near Terre Haute, Ind.

uneven. A large river, more or less along its whole course, but especially toward its mouth, gets out of its banks in times of high water, spreads over the adjoining country, and deposits a coat of mud or sand, thus building up a smooth surface known

Fig. 33.—Lake plain, Clearwater, Minn. Outlet in the distance.

as a *flood plain* (Figs. 31, 32, 75, 76). When it enters the sea all its remaining load of sediment is dropped and the flood plain is built out into the water, forming a *delta* (Fig. 69). Plains thus made by the accumulation of river sediment are called *alluvial*. The alluvial plains of the Mississippi, Amazon, Ganges, Nile, and Hoang are among the largest in the world.

Lake Plains. — All streams which flow into a lake carry and deposit sediment until in time the lake basin may be filled up and converted into an almost perfectly level *lake plain* or *lacustrine plain* (Fig. 33). The famous wheat-growing district of Minnesota, North Dakota, and Manitoba is the bed of an old glacial lake.

Glacial Plains. — In North America and Europe millions of square miles have been covered by moving ice sheets, which, as

Fig. 34. — Glacial plain, Laporte County, Ind.

they melted, deposited vast sheets of mantle rock called *glacial drift*, of such thickness as to fill up, bury, and smooth over the irregularities of the bed-rock surface. The nearly level surface thus produced is called a *glacial plain* (Figs. 34, 35).

Alluvial, glacial, and lacustrine plains may be grouped together as plains of *accumulation* or *aggradation*.

Eolian Plains. — In regions of small rainfall and scant vegetation the loose mantle rock is lifted and drifted about by the winds, and some of it is carried entirely out of the region and

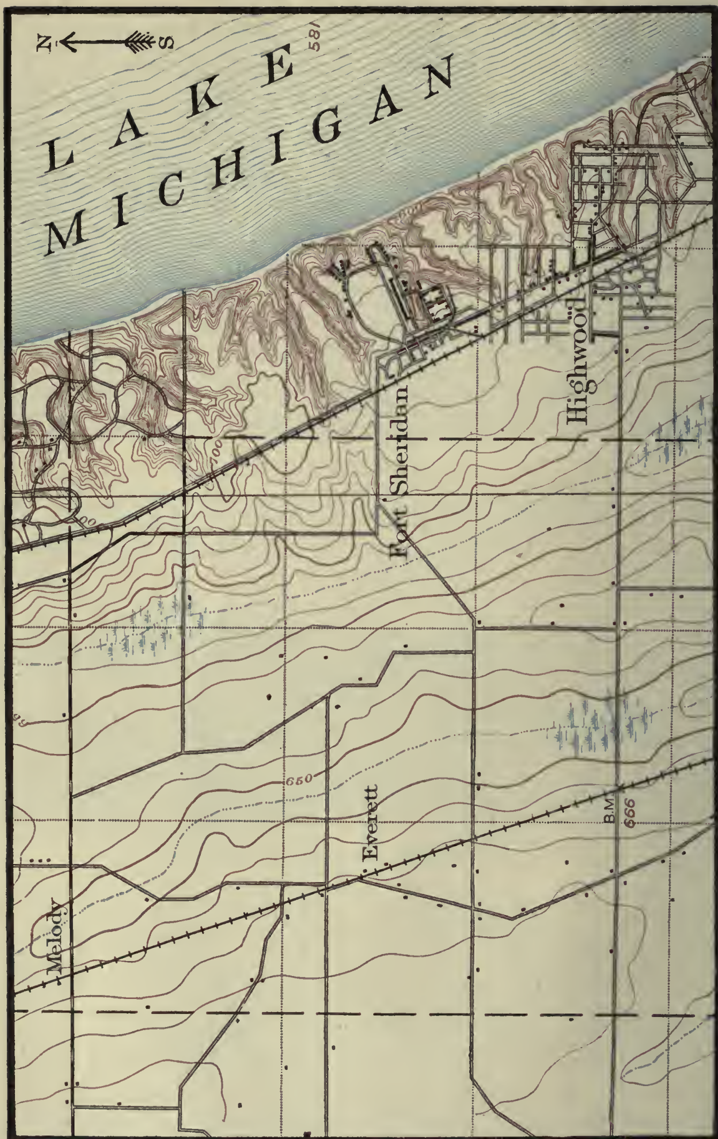


Fig. 35.—Glacial plain and cliff coast, Illinois. Scale about 1 mile per inch. Contour interval 10 feet. (Highwood Sheet, U.S.G.S.)

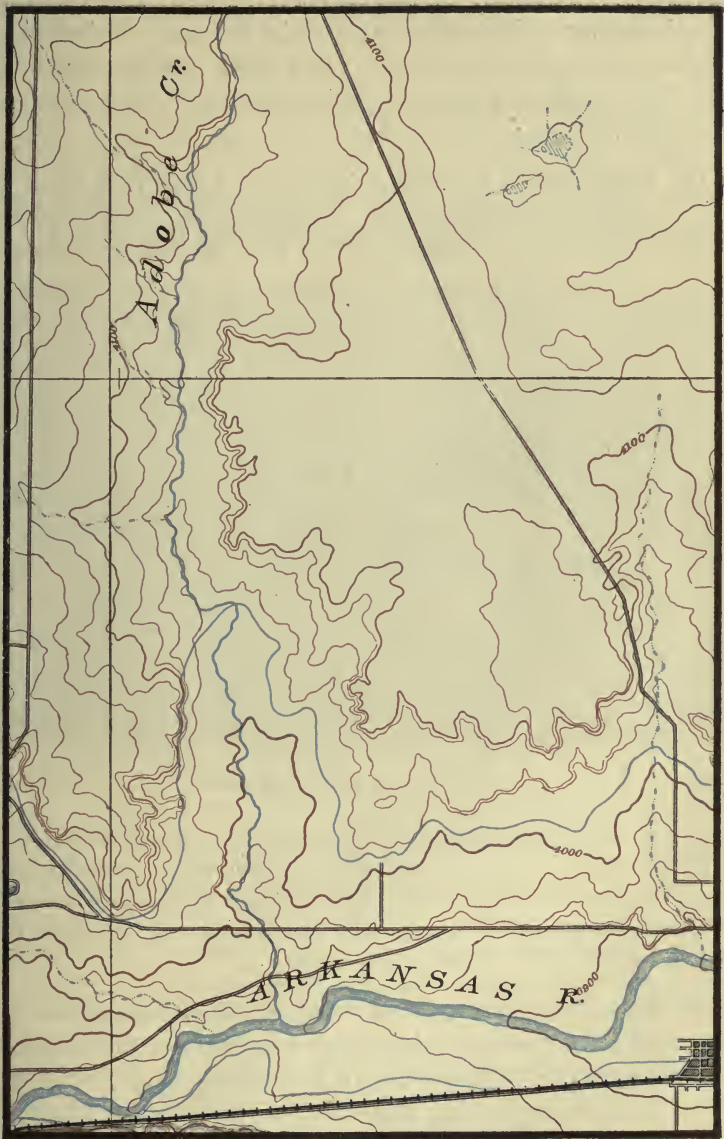


Fig. 36. — Portion of the High Plains, Colorado. Scale about 2 miles per inch. Contour interval 25 feet. Irrigation canal near 4000 foot contour. (Las Animas Sheet, U.S.G.S.)

deposited over neighboring lands or in the sea. This process, long continued, produces a worn-down plain, studded with knobs of resistant rock, and its level may be degraded even below that of the sea.

The Kalahari desert in South Africa owes its relief to this cause, and may be called a *wind-worn plain*. The material carried away from a wind-worn plain may accumulate upon neighboring lands in such quan-

Fig. 37. — Wind-worn plain, Algerian Sahara.

tities as to bury them hundreds of feet deep under a mantle of fine dust. In China thousands of square miles are covered with a material called *loess,* which has been blown from the dry plateaus of central Asia. Both the wind-worn plains and those made by the deposition of wind-blown dust are called *eolian plains* (Figs. 37, 141, 142).

Economic Relations. — On account of their accessibility, fertility, and mild climate, plains have ever been the most densely populated parts of the earth. It is probable that 75 per cent of the human race live less than 1,000 feet above the sea. The wealthiest and most highly civilized peoples of the world live on the plains, and there nearly all the great cities have sprung up. The most favored countries are those which possess broad plains traversed by great rivers and bordering upon the sea.

Alluvial, glacial, and lacustrine plains, on accoun of depth and fertility of soil, are the best agricultural regions in the world. Coastal plains are usually less productive. Worn-down plains are often infertile on account of lack of soil, but they sometimes support forests which yield valuable timber and swarm with fur-bearing animals, as in the Laurentian region of Canada. They are apt to be rich in mineral wealth, because long-continued erosion has laid bare veins of ore once deeply buried. The iron and copper mines of the Lake Superior region, the silver, cobalt, and nickel mines north of Lake Huron, and the diamond deposits of South Africa occur in worn-down plains. Eolian plains are generally deserts, not on account of poor soil, but because they occur only in regions where the rainfall is very scanty.

Plateaus. — Plateaus are broad masses of elevated land. They are high plains, and there is no fixed and definite line of demarcation between plains and plateaus. It is sometimes convenient to use 660 feet (200 meters), 1,000 feet, or even 2,000 feet above the sea to limit the height of plains.

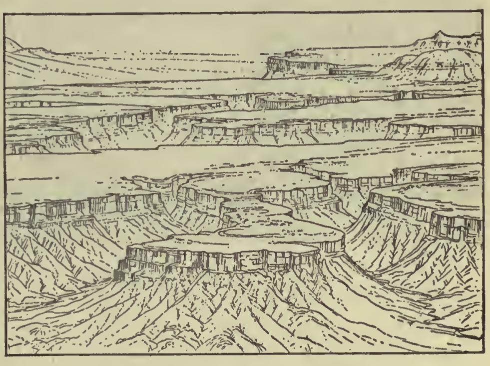


Fig. 38. — A plateau: Mesa Verde, Colorado.

In a region of low relief, a broad, massive elevation above 1,000 feet may be called a plateau, while in a region of high relief the name would be given only to a similar area above 2,000 feet. Plateaus may be as smooth and level as plains, as in the case of the High Plains east of the Rocky Mountains, but are generally more broken (Figs. 36, 38). They are often bordered or traversed by mountain ranges. Low plateaus may be called *uplands*, and high plateaus *highlands*.

Economic Relations. — On account of rougher surface, poorer soil, and colder and drier climate, plateaus are generally less favorable for human occupation than plains. In middle latitudes, plateaus of moderate height, such as the High Plains of the United States, and some of the plateaus of central Asia, constitute a region of *steppes*, covered with patches of grass, over which the people wander with their herds of horses, cattle, and sheep in search of pasture. Very high plateaus, such as Tibet, have an Arctic climate, and are almost uninhabitable. In tropical regions, plateaus such as those of Mexico, Peru, the Dekkan, and central Africa have a temperate climate, and are better homes for men than the hot and unhealthful plains which border them.

Mountains. — Mountain ranges are long, narrow ridges of great height. They are usually due to the folding, crumpling, and breaking of the earth crust along lines of weakness (Figs. 39,

Fig. 39. — Fold in the Jura Mountains.

41, and frontispiece). They are characterized by complex structure, steep slopes, and sharp crests. The crest is cut by notches, or passes, into a series of peaks, which from a distance look like the teeth of a saw. The notches seldom extend halfway down to the base. Mountain ranges seldom occur singly, but usually many ranges extending in the same general direction form a mountain system. All mountains owe their height to upheaval of the earth crust by internal forces, but their forms are due chiefly to erosion (Figs. 40, 44, 58, 60, 102, 103, 104, 105, 106, 109).

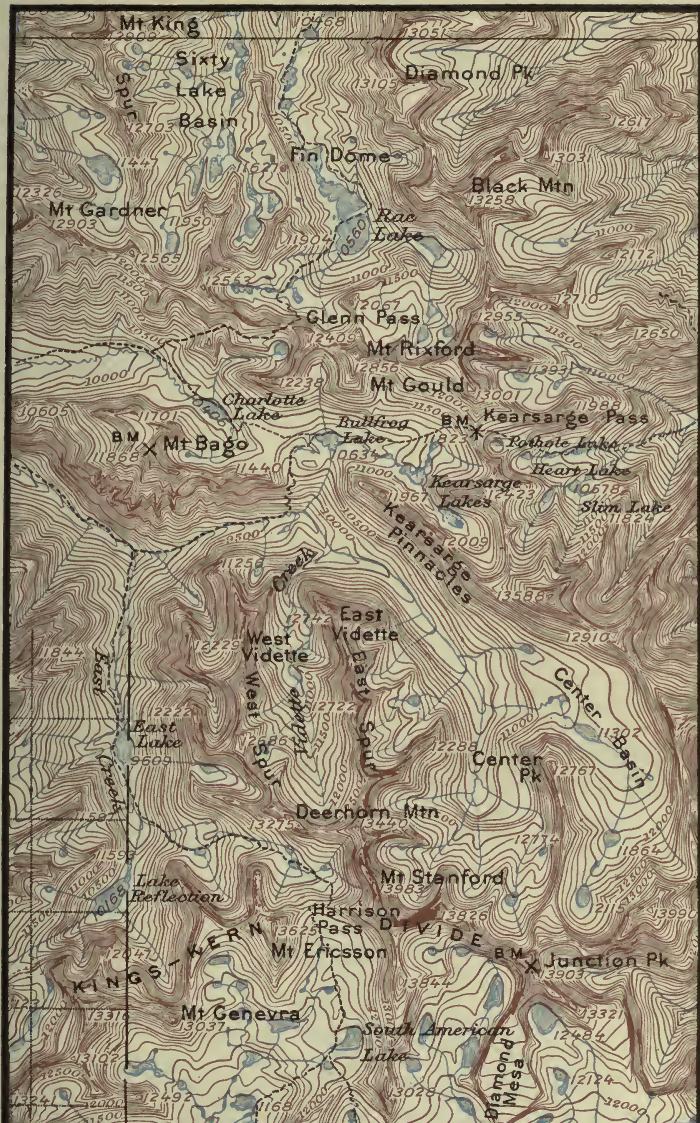


Fig. 40. — A portion of the Sierra Nevada, with glacial cirques and lakes, California. Scale about 2 miles per inch. Contour interval 100 feet. (Mt. Whitney Sheet, U.S.G.S.)

Fig. 41. — Folded rocks, Turkestan.

Fig. 42. — Dissected plateau, Toe River, North Carolina.

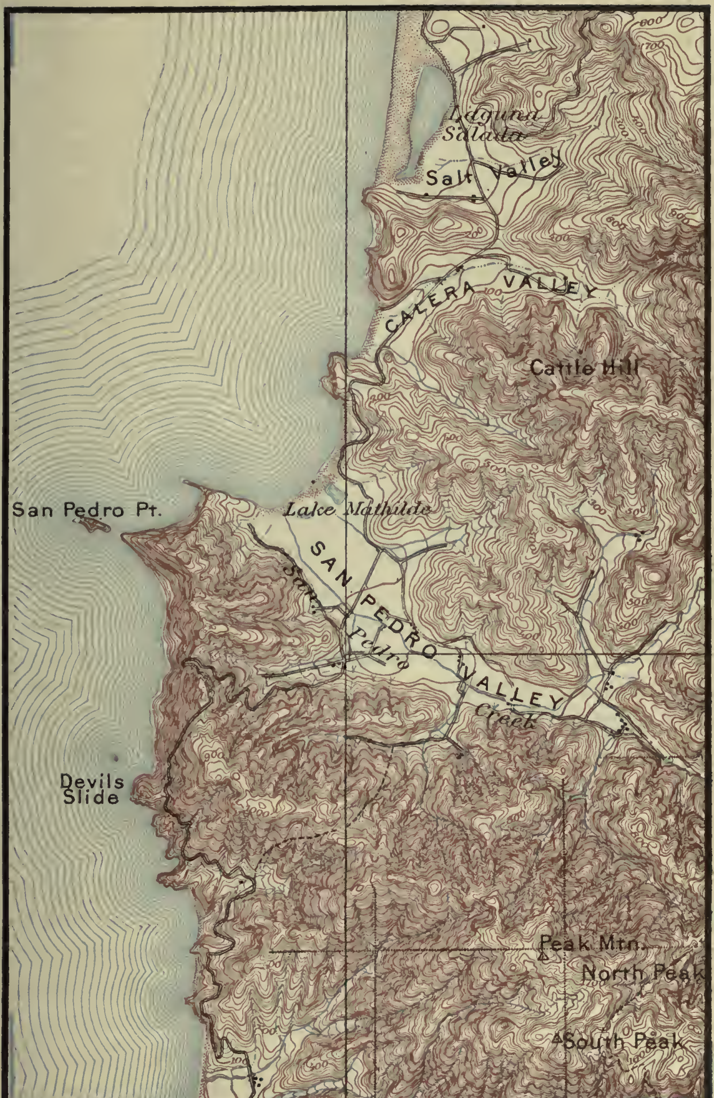


Fig. 43. — Dissected plateau and cliff coast, California. Scale about 1 mile per inch. Contour interval 25 feet. (San Mateo Sheet, U.S.G.S.)

Plateaus are sometimes dissected by a network of valleys into a system of sharp ridges and peaks which resemble in form "a sea of mountains," and are not improperly called mountains, although *dissected plateau* would be a more exact descriptive name (Figs. 42, 43, 73). The elevations left on worn-down plains or plateaus, projecting like nail heads or knots in an old floor, may be of mountainous size, like the White Mountains of New Hampshire. Isolated mountains or peaks, not forming a part of a range, are always remnants left by erosion, or of volcanic origin. Some of the most famous mountains of the world belong to the latter class, as Vesuvius and Etna in Europe and Kilimanjaro and Kenia in Africa (Figs. 51, 52, 53, 54).

Economic Relations. — Mountains are difficult to penetrate, to cross, or to live on. They are formidable barriers to the migration of plants, animals, and men, and the inhabitants upon opposite sides of a mountain range are often very unlike. The vertical height and steepness of mountains render travel and transportation among them costly in effort and limited in amount. The use of vehicles is often impossible, and neither man nor beast can climb up and down with a heavy load. The soil upon mountain slopes is thin and poor, and there are large areas of bare rock. The climate of mountains is severe in proportion to their height, and the higher summits are covered with snow and ice. Agriculture is impossible except in the valleys. Mountains act as condensers of water vapor and have a heavier rainfall than the adjacent lowlands. Most mountains are forested up to a certain height called the *timber line*. Where the forests have been burned or cut grasses flourish. Hence mountaineers are usually lumbermen or herdsmen. The upheaval of a mountain range breaks up the earth crust and produces many cracks in which the ores of metals may be deposited by deeply circulating waters. The rapid erosion of mountains removes the cover and exposes the veins of ore upon the surface. Therefore many of the richest mines of gold, silver, copper, lead, and other minerals occur in mountainous regions. The permanent population of mountains is sparse. The people are rude, hardy, and thrifty, because only such can make a living there, and luxuries are few.

They are free and liberty-loving because they can easily defend themselves against invaders. Conquered peoples may take refuge in the mountains, leaving the lowlands to be occupied by their more numerous conquerors. Towns and cities, such as Leadville and Cripple Creek in Colorado, sometimes spring up around a rich mine above the timber line, but the citizens are dependent upon the lowlands for everything they use. Mountain scenery is grand and picturesque, and the air is pure, invigorating, and in summer agreeable. Hence mountains are pleasure and health resorts for the people of the lowlands.

The Alps have become the playground of Europe, and are visited by about a million people every season. Railroads, coach roads (Fig. 295), and hotels are constructed for their accommodation, and the inhabitants reap a rich harvest from their guests.

Mountain streams have a rapid fall and constant volume which make them especially valuable for water power. As coal becomes more scarce and costly, manufacturers will seek water power to run their machinery, and mountainous countries, such as Switzerland, Italy, and Norway, may become great manufacturing countries.

Mountains are great soil factories, where bed rock is rapidly broken up and carried away by streams to be deposited in their lower valleys. The rich and populous plains of the Po, the Rhone, the Rhine, and the Danube have been built up by the waste of the Alps. The soil of the alluvial plains of the Mississippi, the Amazon, the Ganges, and the Hoang has been brought from the mountains in which these rivers have their sources.

Hills. — Hills are small elevations, and the distinction between hills and mountains is indefinite. In a region of moderate relief, like Pennsylvania, ridges 1,000 feet high are called mountains, while in a region of great relief, like Colorado, ridges 2,000 feet high are called hills.

While all great mountain ranges owe their origin to disturbance and upheaval of the earth crust, most hills are due either to the cutting out of the valleys between them, or to the heaping up of mantle rock by glaciers, ice sheets, and winds. Hence hills are of two classes, — hills of *erosion* and hills of *accumulation*.

Fig. 44. — Appalachian ridges and water gap, Pennsylvania. Scale about 1 mile per inch. Contour interval 20 feet. (Harrisburg Sheet, U.S.G.S.)

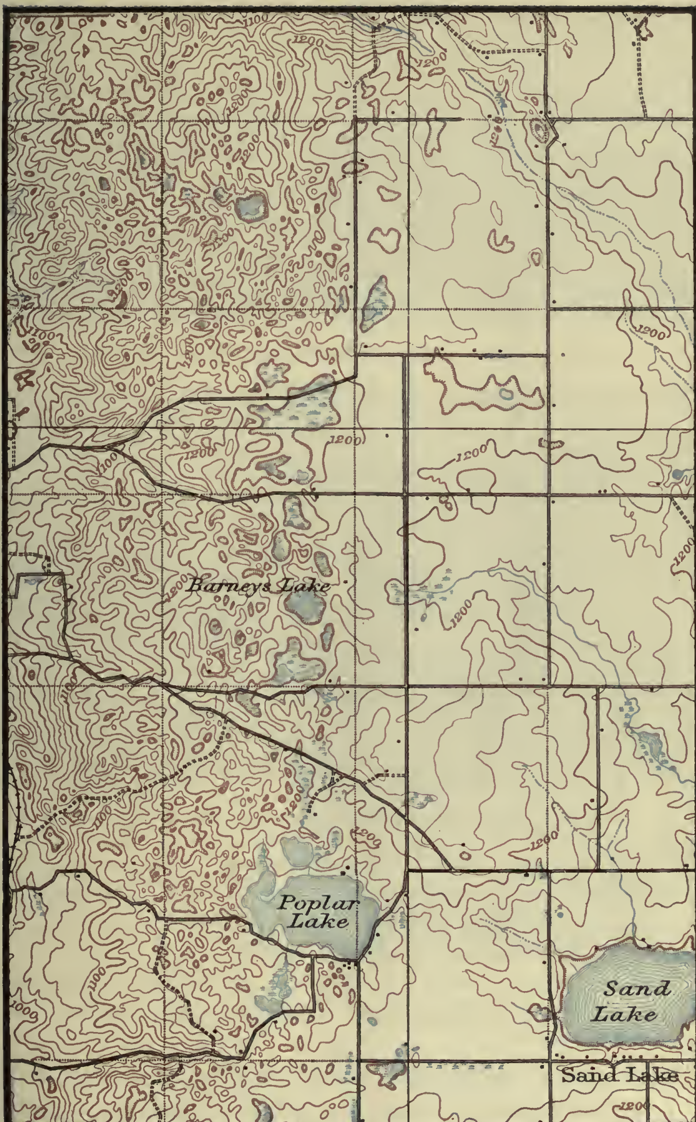


Fig. 45. — **Hills of accumulation, with basins, Wisconsin.** Scale about 1 mile per inch. Contour interval 20 feet. (St. Croix Dalles Sheet, U.S.G.S.)

Fig. 46. — Hills of erosion: Jacalitos Hills, California. (U.S.G.S.)

Fig. 47. — Hills and hollows of glacial accumulation, Victor, N. Y.

Hills vary in value according to their structure, size, and ruggedness. Sand hills are generally worthless, and if wind-drifted are destructive. Glacial hills may be as productive as plains, although less easy to cultivate. Some hills are forested, and some furnish good pasturage. A hilly country is always picturesque and attractive for its beauty. It presents a pleasing variety of slope and situation in contrast with the monotonous sameness of the plains.

Valleys. — Any depression between higher land on each side may be called a valley. Wherever parallel mountain ranges are upheaved, the corresponding depression between them is called an *intermont* valley. The Valley of California is an intermont

Fig. 48. — Kettlehole basins, Naples, N. Y.

valley between the Sierra Nevada on the east and the Coast Ranges on the west. Most valleys are long and narrow, but between hills and upon plains and plateaus there are many broad depressions, often occupied by lakes, which should be called *hollows* or *basins*.

Valleys are the most common of all relief forms, and most of them have been made wholly or partly by running water. That is a long story which will be told in some of the following chapters.

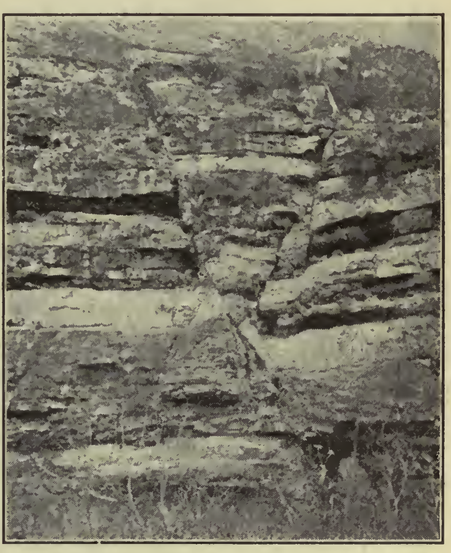


Fig. 49. — Faults.
Block between faults has dropped down.

Broken Block Lands. — Some regions resemble in relief a poorly laid pavement in which some of the bricks or tiles stand above or below the others. The earth crust has been broken by nearly vertical cracks into blocks which have been displaced, some upward and some downward, or tilted to one side. The cracks are called *faults*, and the process of displacement is *faulting*. The elevated blocks may form steep-sided table-lands, or, if tilted, sharp-crested ridges. The depressed blocks may form basins or *rift valleys*, according to their shape.

An area in Europe extending from central France to Hungary has been broken into many pieces, and faulted into a complex set of tables, ridges, and basins. The Mediterranean region is faulted on a very large scale. The Sierra Nevada of California is a faulted block, the eastern edge of which has been tilted up to form a very steep slope. Many of the mountain ranges of the Great Basin are tilted blocks.

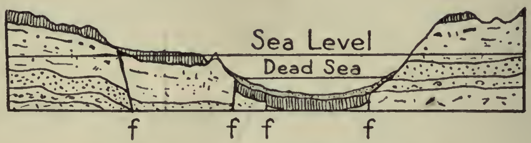


Fig. 50. — Cross section of rift valley.

The subsidence of a long, narrow block between two parallel faults produces a *rift valley*, of which the valley of the Rhine from Basel to Bingen is a good example. A rift valley on a grand scale extends from lakes Nyassa and Tanganyika, in Africa, through the Red Sea to the valley of the Dead Sea and the Jordan River in Asia, a distance of about 4,000 miles (Fig. 118).

Volcanic Lands. — Cracks in the earth crust often permit the escape of melted rock, steam, and hot gases from the interior. When this takes place with violent explosions and a brilliant display of fireworks the event is a volcanic eruption. Enormous quantities of lava (melted rock) in the form of dust, sand, and cinders are thrown into the air and spread over the surrounding country. Streams of liquid lava flow from the vent and, gradually cooling and stiffening, help to build up a volcanic cone or mountain to a height, in some cases, of three or four miles. The vent of a volcano is called a *pipe* or *chimney*, and there is, usually, a cup-shaped depression, or *crater*, at the top. The immediate cause of an eruption is the sudden expansion of water in the lava into steam. The melted rock comes from great depths and its origin is not fully understood. Volcanic eruptions produce a peculiar relief characterized by conical or domed elevations, standing singly or in groups and lines and

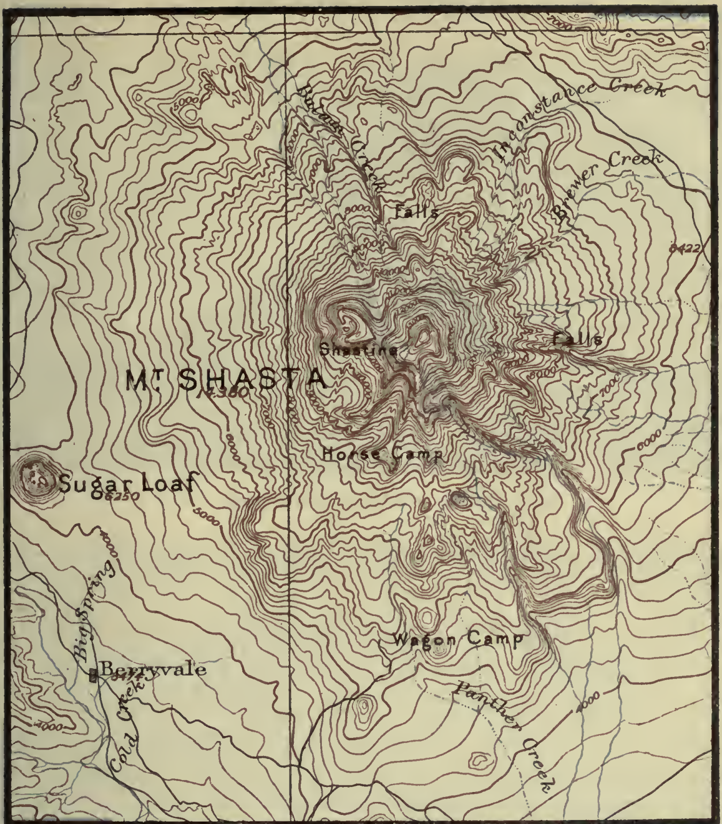


Fig. 51. — A volcanic cone: Mt. Shasta, California. Scale about 4 miles per inch. Contour interval 200 feet. (Shasta Sheet, U.S.G.S.)

Fig. 52. — Volcano, New Guinea.

varying in height from a few hundred to many thousand feet (Fig. 53).

Most of the numerous oceanic islands have been built up by volcanic eruptions in the bottom of the sea, and stand in lines along the course of submarine fissures. In India and in the states of Oregon, Idaho, and

Fig. 53. — Volcanic domes: Puys of central France.

Fig. 54. — Sundance Mountain, Wyoming. A dome of igneous rock.

Washington, lava has flowed quietly from cracks and flooded hundreds of thousands of square miles to the depth of several thousand feet, building up a lava plateau with a smooth surface resembling that of the sea (Fig. 57).

Economic Relations. — Volcanic eruptions are temporarily destructive to life and property. In 1902 an eruption of Mont Pelée in the island of Martinique, one of the West Indies, utterly destroyed St. Pierre, a city of 30,000 people, with its inhabitants, in a few minutes. Yet volcanic action is on the whole constructive rather than destructive. Vast quantities of water vapor and carbon dioxide are added to the atmosphere, and new supplies of rock material are transferred from the interior to the exterior of the earth. Volcanic dust (so-called ashes) is carried by the wind hundreds of miles and sown broadcast over the land, renewing the soil. Even lava beds, in the course of time, weather and crumble into rich earth and become available for the support of plant and animal life. By the agency of submarine volcanoes new lands are created amid the waste of waters.

Fig. 55. — Results of an earthquake in Japan.

Earthquakes. — Broken block and volcanic lands are especially subject to earthquakes. Volcanic eruptions often cause earthquakes which are locally violent, but affect only a small

VOLCANOES AND EARTHQUAKE AREAS

After de Martonne

Fig. 56.

area. Great disturbances which shake literally the whole earth are incidents in the process of faulting, and are due to the sudden slipping of the blocks along a crack in the earth crust. The movement of the blocks may be vertical or horizontal, and does not exceed a few feet. The jar travels through and around the earth in every direction, diminishing in intensity as the distance from the center of disturbance increases.

Economic Relations. — Near the center an earthquake is often exceedingly destructive to property and human life. Although the distance through which a building is moved may not exceed a small fraction of an inch, great speed is attained so rapidly that hardly any structure can withstand it. It is as if a railroad train should start from a state of rest and acquire a speed of sixty miles an hour in one second. When an earthquake occurs in the sea bottom or near shore, it produces enormous waves which may be as destructive as the quake itself.

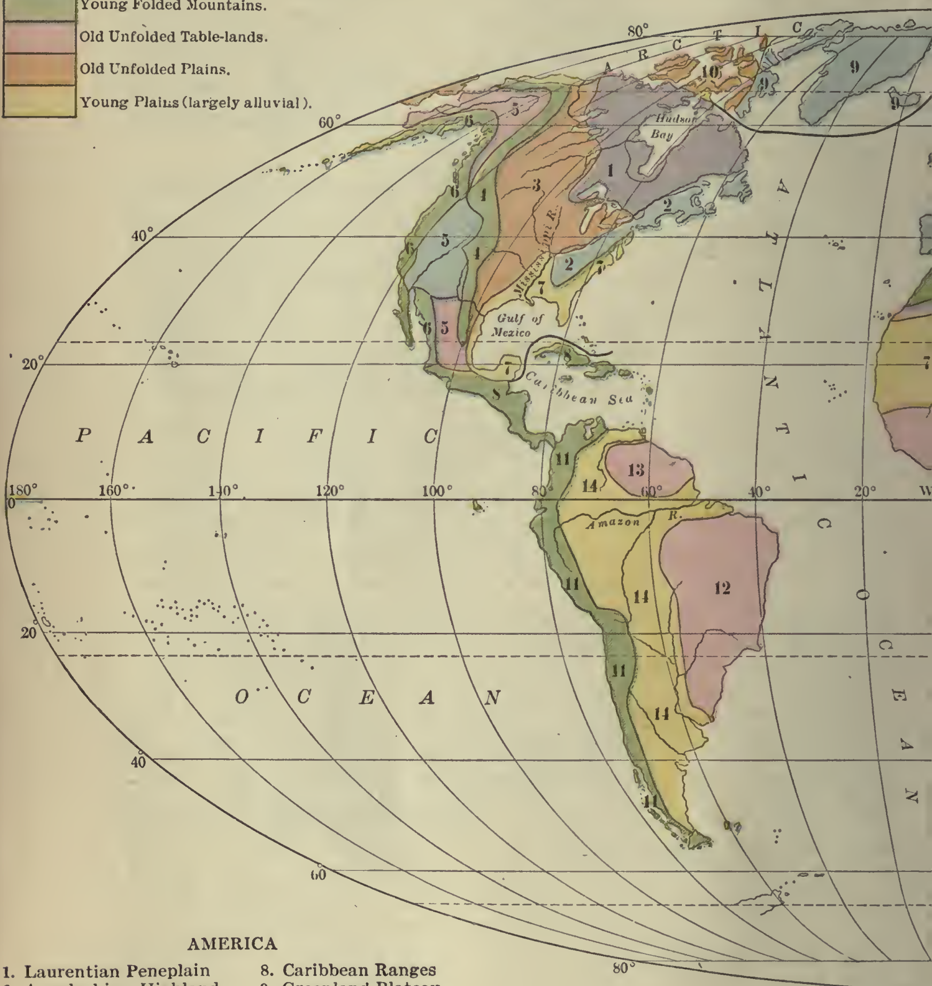
In Japan, where the ground seems to be never completely still, houses are built of very light materials. Structures of steel and concrete upon a solid rock foundation are least liable to injury. Buildings of brick and wood standing upon alluvial or newly made ground are most dangerous. Hundreds of earthquakes occur every year, but most of them are too feeble or too remote from centers of population to do serious damage. The principal areas subject to destructive earthquakes are shown on the map, Fig. 56.

Physiographic Provinces. — Fig. 57 shows the division of the land according to structure, and indicates broadly the causes and character of relief. These divisions constitute the great physiographic provinces of the land. This map should be compared with the relief map, Fig. 16.

PHYSIOGRA

After Herb

- Old Worn-down Plains.
- Broken Block and Old Folded Lands.
- Young Folded Mountains.
- Old Unfolded Table-lands.
- Old Unfolded Plains.
- Young Plains (largely alluvial).



AMERICA

1. Laurentian Peneplain
2. Appalachian Highland
3. Interior Plain
4. Rocky Mountains
5. Intermont Plateaus
6. Pacific Ranges
7. Coastal Plain
8. Caribbean Ranges
9. Greenland Plateau
10. Arctic Archipelago
11. Andes Mountains
12. Brazilian Plateau
13. Guiana Plateau
14. Interior Plain

PROVINCES

...difications

EURASIA

1. Baltic Peneplain
2. Scandinavian Highland
3. Mediterranean Highlands
4. Western Basins and Table-lands
5. Baltic-Black Plain
6. Interior Plain
7. Ural Mountains
8. Iranian Plateaus
9. Mongol-Tibetan Plateaus
10. Indo-Chinese Ranges
11. Chinese Plateau
12. Manchurian Plateau
13. Arabian Plateau
14. Dekkan Plateau
15. Caspian-Ob Plains
16. East Siberian Plain
17. Chinese Plain
18. Indus-Ganges Plain
19. Mesopotamian Plain
20. Malay Archipelago

AFRICA AND AUSTRALIA

1. Atlas Mountains
2. Central African Plateau
3. Saharan Plateau
4. Kong Plateau
5. Cape Plateau
6. Rift Valley
7. Niger-Libyan Plain
8. Australian Plateau
9. Australian Mountains
10. Australian Plain

CHAPTER V

GRADATION BY RUNNING WATER

Gradation. — If a building lot or the site of a town is rough, it is generally graded by cutting down the hills and filling up the hollows. The same process of grading is continually going on all over the surface of the land. The mountains and plateaus are being worn down and the material is carried away to lower levels. Valleys and basins are filled and plains are overspread with the waste of the highlands. The lowest and largest depressions of the earth crust are occupied by the oceans, therefore the process of gradation will not stop until all the land above sea level is carried away and deposited on the sea floor. Thus it happens that even lowlands are being eroded, although more slowly than highlands. Lowering the level of the earth crust by erosion is called *degradation;* raising its level by deposition is called *aggradation;* and the result of the two processes is *gradation*. Gradation is a very complex process carried on by many different agents, the work of each one of which must be studied separately.

Weathering or the Disintegration of Rocks. — Wherever bed rock is exposed to the action of air, water, and sun, it is broken up and decomposed into loose *mantle rock*, or rock waste. The oxygen of the air attacks some rock minerals, especially iron, which rusts and crumbles into powder. The carbon dioxide of the air combines with lime in the rocks to form limestone, which is dissolved away by water. In the daytime bare rocks become heated by the sun and expand; at night they cool rapidly and contract. This change of volume repeated many times causes the rocks to break up and scale off. Water frozen in pores and cracks breaks rock, as it breaks pitchers and pipes in the house.

Fig. 58. — Frost work, Pikes Peak, Colorado.

Mountain peaks, where freezing and thawing take place almost every day, are shivered to pieces and crumble into a heap of ruins. In arid regions sand blown by the wind rapidly wears away the hardest rocks. Unprotected telegraph poles are soon cut down by the sand blast. Unsupported rock masses are broken off and pulled down by gravity, and are reduced to smaller fragments by the fall. The growth of tree roots in cracks and the acids formed by decaying vegetation help on the process of rock destruction, while even burrowing animals contribute something to the result. The whole combination of processes by which massive bed rocks are converted into mantle rock is called *weathering*, and its products are clay, sand, gravel, pebbles, and boulders.

Fig. 59. — Erosion by wind and sand. (The Sphinx, Egypt.)

It is difficult to find an exposed surface of rock anywhere which has not been changed by the weather until it looks quite different from a freshly broken surface. Old monuments in cemeteries show the effects of exposure to air and rain. Buildings built at different times of the same kind of stone often reveal their relative ages by changes in color or surface, and in the course of centuries stone buildings may be badly damaged by the weather.

Movement of Mantle Rock. — Mantle rock sometimes remains in the place where it is formed, and may accumulate to

Fig. 60.—Cañon and talus slopes, Tongue River, Wyoming. (Note irrigation conduit.)

the depth of many feet. Air and vegetable acids, carried down into the cracks and crevices of bed rock by ground water, extend the weathering process in some cases hundreds of feet below the surface. But mantle rock is always in a condition to be moved by gravity, wind, or water. At the bottom of a steep cliff there is usually a *talus*, or heap of rock fragments fallen from above. On mountain sides enormous masses of rock sometimes slide down at once and bury forests and houses in the valley. Such an event is called a *landslide*. Streams of stones moving slowly but continuously down a steep slope are called *screes*. Even on moderate slopes there is a slow creep of the mantle rock

Fig. 61. — Landslide, Switzerland.

downward. Wherever mantle rock is fine and dry the wind blows it away, drifting sand and dust into dunes and ridges, spreading them over the neighboring country or carrying them out to sea. Glaciers transport rock fragments of all sizes, some as large as a house and some as fine as flour, which are left in a heap when the ice melts.

The most efficient agent in transporting mantle rock is running water. The rain washes dirt into the streams, which buoy up and carry away great quantities of clay, sand, and gravel. The swifter the stream, the coarser the material it can carry. Even large boulders are rolled over one another and along the stream bottom (Fig. 65). Their edges and corners are rounded off and the whole grist is rapidly ground finer. Where the speed of the current is checked a part of the load is dropped, the coarsest first; and gravel or sand bars and mud banks are built up along the stream. If the stream flows into a lake or the sea, its current is stopped completely and all its load of sediment settles to the bottom.

Summary. — Thus, by the various processes of weathering and erosion, important results are accomplished: (1) Soils, composed of various mixtures of clay, sand, gravel, and humus, are provided for the growth of vegetation; (2) the higher places of the earth crust are worn down or *degraded*, and the lower places are filled up or *aggraded;* (3) during this process of gradation the great land features are carved and molded into ever-changing patterns of relief.

Valleys and Streams. — If the course of a stream is followed up, it will be found to be joined at intervals on either side by *tributaries*, each of which flows in a valley usually proportioned to the size of the stream. The main stream and its valley grow smaller above the mouth of each tributary until they are reduced to a tiny rivulet flowing in a furrow, and finally come to an end at a spring, pond, or swamp, or upon the smooth slope of a hillside. If any tributary is followed up, it also is found to divide like the trunk of a tree into smaller branches and rivulets. The surface of the land on either side slopes toward the stream or one of its tributaries, and at the same time there is a continuous slope downstream from the head or tip of every branch.

If the slope is ascended from the stream, at a greater or less distance a point is reached where the surface begins to slope away from that stream toward some other stream. A more or less definite line may be found which marks the junction of the two slopes and separates the water flowing into one stream from that flowing into the other. If this *divide* or water-parting is followed, it is found to pass around the heads of all the tributaries and to inclose the *basin* or area from which water drains into the stream *system*.

Fig. 62. — Divide, Vigo County, Ind.

Run-off. — Some part of the rain falling upon any basin evaporates, a part sinks into the ground, and the remainder, called the *run-off*, flows away on the surface. Some of the water which sinks into the ground comes again to the surface and joins the run-off. The ratio of the run-off to the rainfall varies with the slope, structure, climate, and vegetation of the basin.

At first the run-off forms a thin and scarcely perceptible sheet; but it soon gathers into little rills which join one another and grow larger until they flow into one of the permanent branches of the stream system. The smallest branches flow only while it rains, and their grooves or gullies are dry most of the time. The permanent branches are supplied from ponds, swamps, glaciers, or springs.

Near the sources of the stream the slopes are apt to be steep, the current swift, the channel narrow and deep and perhaps interrupted by rapids and falls. The bed is strewn with boulders, pebbles, or coarse gravel (Figs. 60, 71, 73, 74, 77). Farther down, as the slope becomes more gentle, the bed is smoother, rapids are less frequent and are separated by long reaches of quiet water, and the channel becomes wider, shallower, and more crooked. The loose material is less coarse and consists chiefly of fine gravel and sand. Here the watercourse is likely to become double and to consist of a wide outer *valley* which the stream covers only at high water, and through which the narrower *channel* winds irregularly from side to side. Still farther down, the valley may become very much wider and consist of an extensive *flood*

Fig. 63. — Valley with bluffs, New York.

plain bounded by *bluffs*. Here the ordinary channel follows a meandering course, full of zigzag bends and horseshoe curves. The slope is gentle, the current sluggish, and the bed obstructed by sand bars and mud banks (Figs. 31, 32, 63, 70, 72, 75, 76). The stream finally flows into a larger stream, or into a lake or the sea.

Transportation of Sediment. — A stream of water is also a stream of mantle rock, by which the waste of the land is running away toward the sea. Some streams are clear, but they always contain a small quantity of invisible mineral matter dissolved out of the ground. A turbid or muddy stream is carrying mantle rock in *suspension*, which is kept from sinking by ripples, eddies, and cross currents due to irregularities in the bed. Most rock fragments when immersed in water are buoyed up to the extent of about one third of their weight, and are therefore more easily moved than when out of water. (Lift a stone out of water into the air.) In still water the finer particles of rock settle more slowly than the coarser, and in a current they are carried along more easily. (Shake up clay, sand, and gravel in a bottle of water and let them settle.) *The size of the particles of rock which a stream can carry in suspension increases rapidly as the speed of the current increases.* A current running one third of a mile an hour can carry clay; two thirds of a mile, fine sand; two miles, pebbles as large as cherries; four miles, stones as large as an egg.

A swift stream can carry more sediment of any kind in suspension than a slow one, and a stream of any speed can carry a larger quantity of fine sediment than of coarse; but the quantity of sediment which any stream can carry is limited. A stream which is carrying all the sediment it can is said to be *loaded*, or, less appropriately, *overloaded*. If the speed of a stream carrying a full load is slackened, its carrying capacity diminishes rapidly, and it immediately drops a part of its load, and always the coarsest first. If a current carrying a mixed load of clay, sand, and gravel is gradually brought to a standstill, it drops the coarse gravel first, then fine gravel, then coarse sand, then fine sand, and the clay last of all. Thus running water is the most efficient assorting agent known, and is often

Fig. 64. — Stream bed with banks of gravel dropped by the stream, Parke County, Ind.

used for that purpose. (Put clay, sand, and gravel in a pan of water, and by stirring, rinsing, and pouring wash out the clay first and then the sand.) If some of the sediment is much heavier than the rest, the heavier particles are left behind, while larger and lighter particles are carried away. (Put fine shot and gravel in a pan of water and wash out the gravel.) This is the reason why a miner can "pan out" coarse gravel and have fine gold dust left in his pan. If rock fragments are too large for a stream to buoy up and carry, it may push and roll them along the bottom.

The Speed of Streams. — A stream is swifter on a steep slope than on a gentle one. It is also swifter in the narrow parts of its channel than in the wide parts, because the same quantity of water must pass through both in the same time. Therefore any stream is swifter and more powerful at high water than at

Fig. 65. — Stream bed with boulders.

Fig. 66. — Alluvial cone.

low water. The greater the volume and speed of a stream, the greater the quantity and the coarser the quality of the sediment it can carry.

In times of flood, streams bring down great quantities of coarse material which they are obliged to drop as the flood subsides. When a stream is low in summer, it may not seem to be carrying any sediment at all, but its channel may be strewn with heaps of large stones which it brought down at the last spring flood. If a slow stream is loaded with fine sediment, any obstruction, as a boulder, log, fallen treetop, or even a small stake, may check the current sufficiently to cause a mud or sand bar to be deposited on the downstream side.

Deposition. — All the sediment carried by a stream must, sooner or later, be deposited at lower levels. Wherever the current is checked deposition is apt to occur. A stream flowing down a steep bank rapidly erodes a gully and deposits the material at the bottom of the bank in a conical or fan-shaped

Fig. 67. — Alluvial fan, Switzerland.

heap. Along the foot of a mountain range this process sometimes occurs on a large scale, each mountain stream building a steep *alluvial cone*, or a flat *fan* which may spread out several miles.

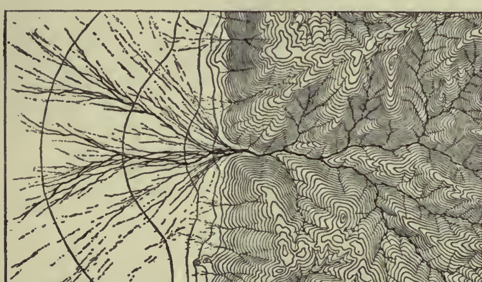


Fig. 68. — Contour map of alluvial fan. (U.S.G.S.)

Along the foot of the Wasatch Mountains, in Utah, and of the Sierra Nevada, in California, the alluvial fans are so large as to touch one another, forming a continuous *piedmont alluvial plain*. An alluvial fan sometimes affords extraordinary facilities for agriculture by irrigation. The water naturally spreads over the fan and can be easily guided to any part of it.

Fig. 69. — A part of the Mississippi delta. Numbers show depths in fathoms.

Whenever a stream overflows its banks it deposits sediment on the flooded ground and forms an alluvial plain, which in the lower course of a large river may become many miles in width. At the mouth of a river the alluvial plain may extend into a lake or the sea in the form of a *delta*, which is a flat alluvial fan built in the water. At the head of the delta the stream divides into *distributaries* and enters the sea by many mouths. The surface of a delta cannot be raised far above sea level, and is liable to be flooded by the river and by tides. The soil of delta lands is so fertile that it is often profitable to protect them by *dikes* or embankments, as has been done on a large scale at the mouth of the Rhine.

Sediment deposited by water is always more or less completely assorted, the finer from the coarser, and deposited in nearly horizontal strata. The stratified rocks which form a large part of the earth crust are nearly all made from sediment deposited by water.

Fig. 70. — Cut banks and bars.

The Crookedness of Streams. — The movement of water in a stream is retarded by friction against the bottom and banks, and against the air on the upper surface. Therefore the water moves fastest a little below the surface and along the line of the deepest channel. A flowing stream cannot be straight, because there is sure to be more resistance on one side than on the other, and a small obstruction is sufficient to turn the current toward the opposite bank. A strong stream on a steep slope is not easily turned aside and is comparatively straight, but the same stream on a gentle slope meanders from side to side and becomes very crooked. In a winding stream the current is swifter on the outside of the bend, and there it cuts away the bank and deepens its channel. On the inside of the bend the slower current is unable to carry its load and builds up a sloping bar of mud or sand. In this way the stream is constantly shifting its channel sidewise and widening its valley.

Fig. 71. — Gully in gravel.

Valley Forms. — A clear stream running over bed rock may dissolve it slowly, but a stream carrying a moderate load of sand and gravel uses them as tools with which it saws or files its way down through the hardest rocks. A swift stream erodes faster at the bottom than at the sides, and cuts a deep, narrow valley. A slow stream is usually unable to sweep its bed clear of sediment and therefore cannot cut it deeper. Its energy is expended in wearing away its banks, and in this way a small stream may

Fig. 72. — Meandering stream.

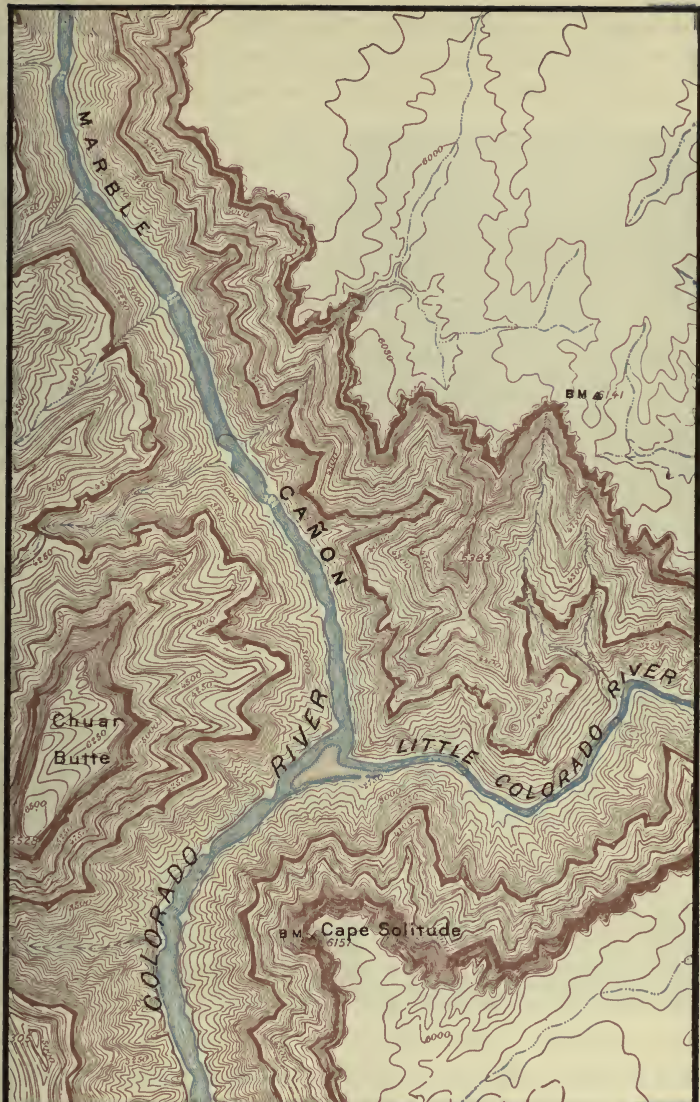


Fig. 73. — Portion of the Grand Cañon of the Colorado, and the mouth of the cañon of the Little Colorado River. Scale about 1 mile per inch. Contour interval 50 feet. (Vishnu, Arizona, Sheet, U.S.G.S.)

in the course of time make a wide valley. Its work may be done so slowly that scarcely any change is noticeable in a lifetime, but if it carries away only ten wagon loads of dirt from each mile of its course in a year, it can, in 50,000 years, make a valley 100 feet wide and 25 feet deep.

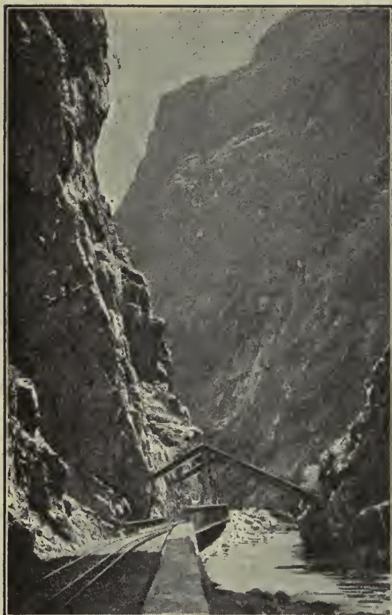


Fig. 74. — Royal Gorge, Colorado. 3000 feet deep.

A small but deep and narrow valley is called a *ravine* or *gorge.* In plateaus and mountains rivers are able to cut *cañons* of enormous dimensions. The Colorado River flows for about 1000 miles through a series of cañons, of which the Grand Cañon in Arizona is probably the most extensive cut anywhere in the face of the earth. It is 217 miles long, eight to fifteen miles wide, and about one mile deep. The river is not utilizable for navigation or irrigation, but the scenery of the cañon is unsurpassed for grandeur and beauty. The depth of the cut and the length of the main cañon and its tributaries present an exposure of rock strata so clear and extensive that geographers and geologists have probably learned more about the structure of the earth crust and the process of erosion from the Colorado cañons than from any other region in the world.

Upper, Middle, and Lower Parts of a Valley. — The headwaters of a large river are generally in highlands where the slopes are steep. The tributaries have a rapid fall and are often rushing torrents. Their erosive power is very great, but their volume is small. The valleys they cut are deep, narrow, strewn with large boulders, and interrupted by falls. In the middle part of its course the slope is more gentle, but the volume of water is larger, and it is here that the greatest amount of erosion takes place. The river carries away such quantities of sediment that its valley becomes both deep and wide. In the lower course the slope is very gentle, the current is feeble, and

Fig. 75. — Low water, Wabash River, Terre Haute, Ind.

the load too great to be carried. The land surface is not far above sea level, below which the river cannot deepen its valley. The current is continually obstructing itself by its deposits of

Fig. 76. — High water, Wabash River, Terre Haute, Ind.

sediment, which compel it to shift its channel. It cuts away its bank in one place and builds it up in another, developing a wide flood plain bounded by bluffs.

A stream which is actively deepening its valley is *young* (Figs.

Fig. 77.—Young valley. (Forty Mile Creek, Alaska.)

60, 73, 74, 77, 79, 83). A stream which has deepened its valley as far as possible, and has smoothed out rapids and falls, has reached *base level* and is *mature* (Figs. 63, 78, 79, 95). A stream which is widening its valley and aggrading its flood plain has reached a condition of *old age* (Figs. 31, 32, 64, 72, 79, 94, 97, 98).

Playfair's Law.—The relation of valleys and streams was stated by John Playfair in 1802:

"Every river appears to consist of a main trunk fed from a variety of branches, each running in a valley proportioned to its size, and all of them together forming a system of valleys, communicating with one another, and having such a nice adjustment of their slopes that none of them join the principal valley either on too high or too low a level: a circumstance which would be infinitely improbable if each of these valleys were not the work of the stream which flows through it."

Streams and Relief.—The first effect of stream erosion upon the land surface is to cut it up into a system of valleys with broad ridges or divides between. As the valleys grow deeper and wider, the divides grow narrower and are gradually eaten away until their crests are sharp; the whole surface consists of slopes, and traveling across it is "all uphill and down." When the surface has been made as rough as possible and there is little or no level land left, it is said to be *maturely dissected*, or simply *mature* (Fig. 78). After the stage of maturity, continued stream work makes the divides lower and the valley bottoms wider. The country begins to grow smoother, and in the course of time is reduced to a plain of low relief, not far above sea level (Figs. 29, 30, 79, 111), called a *peneplain* (almost a plain).

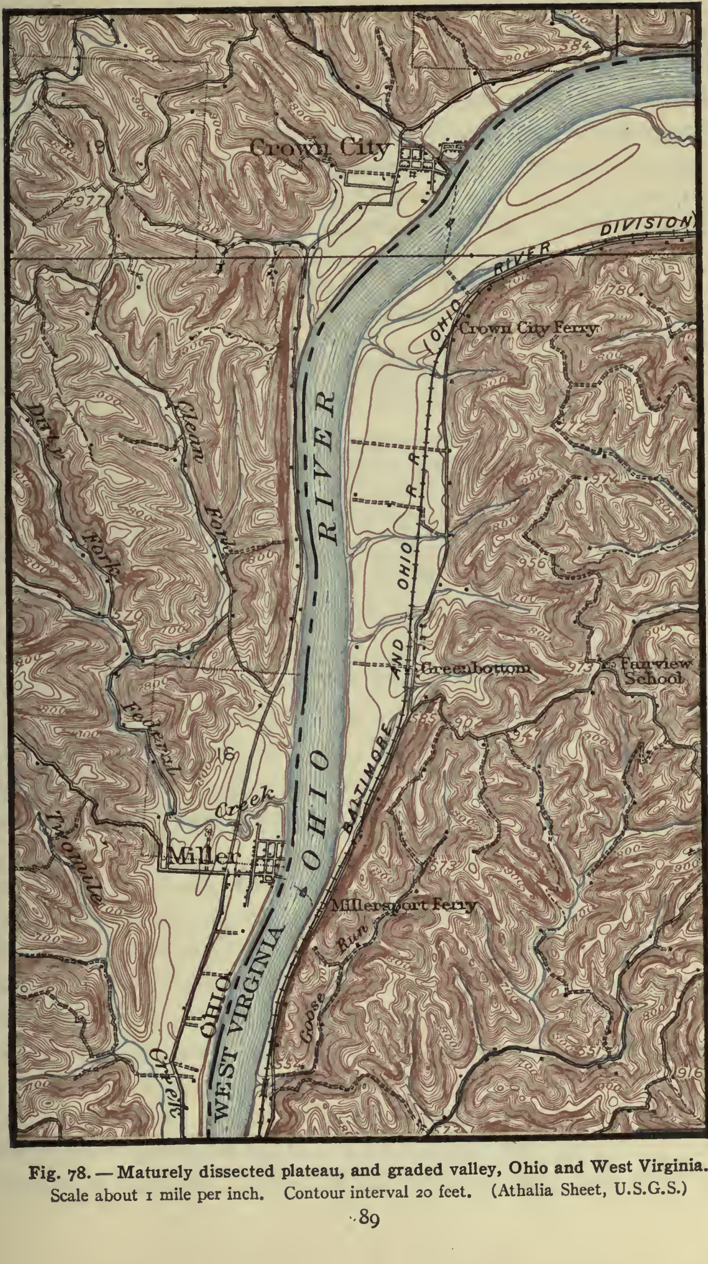


Fig. 78. — Maturely dissected plateau, and graded valley, Ohio and West Virginia.
Scale about 1 mile per inch. Contour interval 20 feet. (Athalia Sheet, U.S.G.S.)

During the earlier stages of stream erosion the land surface is made rougher, during the later stages it is made smoother, and the final result is to degrade the land and aggrade the sea bottom, until they are both graded nearly to sea level.

Upon a completely graded peneplain the processes of stream erosion cease, because the streams have no longer a slope sufficient to enable them to carry sediment. But if a peneplain is uplifted by internal forces the revived streams will begin the process of gradation all over again. Gradation goes on most rapidly on mountains because weathering is more active there, and the slopes are so steep that gravity and running water can pull down and carry away great quantities of mantle rock. Consequently mountains do not last long, and all high mountains are comparatively young. For the same reasons, plateaus are degraded more rapidly than plains. Heavy rainfall favors rapid degradation because water helps to decompose and wash away rocks, and streams are larger and more numerous in wet regions. Some kinds of rocks are more resistant to weathering and erosion than others, and are left projecting as the general surface is lowered. A covering of forest or other vegetation generally retards erosion.

Economic Relations. — The value of a region for human occupation depends largely upon the stage of gradation it has reached. Young, low plains are smooth, gently sloping, easily accessible, and generally productive. The work of gradation progresses slowly and can never produce a surface of strong relief. All human occupations may be carried on with ease, and in all stages plains are fitted to support a large population with a minimum expenditure of energy.

Young plateaus of moderate height are second in value only to plains. Gradation begins as soon as the surface is exposed above the sea, goes on during the long, slow process of upheaval, and usually before any great height is reached has progressed so far as seriously to roughen the surface. As dissection of the plateau approaches maturity, it is cut up into an intricate system of deep valleys and narrow ridges, which is as inconvenient as possible for carrying on any kind of human business (Figs. 43, 78, 79). In the stages beyond maturity, as old age approaches, the relief of a plateau becomes smoother, and as a peneplain it finally reaches a condition not essentially different from that of a region originally a low plain.

Most young mountains are high and extremely rugged, like the Alps, and are of all regions the most difficult of utilization by man. In some young mountains, like the Jura (Fig. 39),

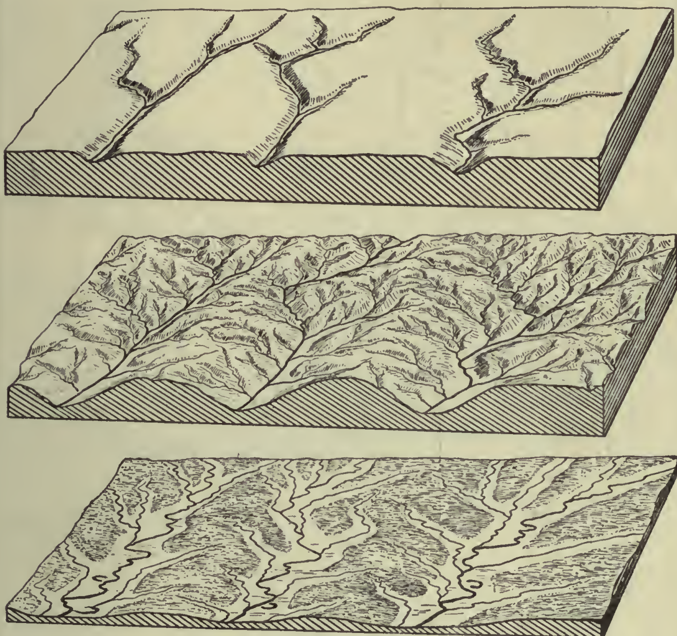


Fig. 79. — Youth, maturity, and old age.

the earth crust has been less violently disturbed, folded, and broken, and the region is correspondingly less forbidding. Such regions pass through changes somewhat like those of a plateau. As a rule, it is only in old age that mountain regions become so far worn down and smoothed off as to be fitted for occupation by any large number of people. The Appalachians furnish a notable example of an old mountain region. The general law is obvious that *lowlands are the homes of the most highly civilized peoples.*

Fig. 80. — Niagara Falls and Gorge. Scale about 1.25 miles per inch. Contour interval 20 feet. (Niagara Falls Sheet, U.S.G.S)

Waterfalls. — Wherever the slope of a stream bed is abrupt or steep, falls and rapids occur. They are usually due to an outcrop of resistant rock which the stream cannot wear down as rapidly as the softer material in other parts of its course. In a brook a tree root or a bed of clay on top of sand will make a fall. Glaciated valleys are often bordered by cliffs over which streams cascade. Such falls are sometimes of great height, like those of the Yosemite Valley in California (Figs. 84, 105), and many in Norway. Falls and rapids in large rivers generally occur where the stream crosses a bed of limestone, granite, or lava. The force of the falling water deepens the channel below the falls and undermines the cliff behind them, so that the falls retreat upstream, leaving a gorge below (Figs. 80, 81, 82, 86).

Fig. 81. — Gorge of Niagara River, made by retreat of the Falls.

The Niagara River falls over a limestone ledge into a gorge 400 feet deep and seven miles long, which the river has cut by the migration of the falls upstream. The gorge below the Victoria Falls on the Zambezi River in Africa, 500 feet deep and 40 miles long, has a peculiar zigzag course on account of cracks in the bed of lava. Rapids and falls are most numerous in mountains and plateaus, and in young streams everywhere. An old stream has had time enough to wear down and smooth out the irregularities of its bed.

Economic Relations. — Waterfalls are becoming more and more valuable as sources of power for running machinery. Most of them are not easily available because they occur in remote and inaccessible regions, but if the power cannot be brought to the present site of an industry, the industry may be moved to the place where the power is.

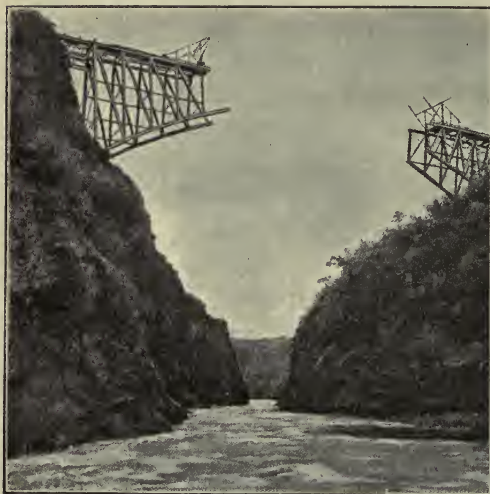


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Fig. 82. — Gorge of the Zambezi.

Of all the water powers in the world that of Niagara Falls is the most valuable, because of the large and constant volume of water, and still more because it is situated in the midst of a densely populated district. A part of their power is now used to generate electricity which is transmitted over wires to run railroads and factories, and to furnish light to cities within 150 miles. There is power enough at Niagara to supply four or five of the largest cities in America.

Waterfalls are among the most attractive scenic features of the world and have a high value apart from any use that can be made of their power. On account of their beauty and grandeur and because they are so easily accessible, Niagara Falls are visited by about 600,000 people every year. The use of the water for power seriously impairs their beauty and might entirely destroy it. Whether it would be better for the human race to keep the falls in their natural state to give pleasure to future millions, or to destroy them by diverting the water for power purposes, is an important practical question which the present generation is called upon to decide.

CHAPTER VI

THE ECONOMIC RELATIONS OF STREAMS

Drainage. — The first important function of streams is to drain the land by carrying surplus rain water to the sea. When a land surface is first exposed to stream action by elevation above the sea, or by the melting of an ice cap, the drainage is imperfect. Depressions are occupied by lakes, ponds, and marshes, which, if numerous, are sure indications of youthful drainage.

The glaciated regions of northern North America and Europe and the recently elevated land of Florida are conspicuous examples. On low plains and gentle slopes drainage develops slowly and remains imperfect for a long time. The shallow lakes of the glacial drift are being filled with accumulations of mud and peat which promise to be of value in the future for cement and fuel. Wet, undrained land is comparatively worthless for human occupation. It produces at best only inferior timber or coarse herbage. Artificial drainage by open ditches and tile drains may convert such land into excellent farms and gardens. The area of marsh lands in the United States which might be drained is larger than the area of arid lands that can be irrigated.

In a mature drainage system every part of the land is drained, and any drop of rain falling upon its basin may find its way to the sea. On plateaus and in mountainous and hilly regions, slopes are steep and drainage is often too rapid. The soil is washed away, the surface is cut up by gullies, and the lowlands are buried in sand and gravel. In the old countries where soil is precious this waste is sometimes checked by a series of dams. Such areas ought to be used for the growth of forests, which retard the run-off and prevent waste by erosion.

Erosion. — Streams are not currents of running water only, but also of running rock. Through them the solid land is draining away to the sea. Everywhere except in desert regions the details of landscape are due to stream or glacial action. Valleys are cut in the earth crust, thus making its materials accessible, revealing its structure, and producing a great variety of scenery. Rocks and minerals originally buried far below the surface have been uncovered and exposed. There would be no coal mines in

Fig. 83. — Watkins Glen, New York: A very young gorge in shale rock.

Pennsylvania if streams had not removed from the surface of that region beds of rock several miles in thickness. The cuts made by streams into the earth crust are invaluable to the geologist, because he finds there exposed all kinds of rocks and is able to study their composition and arrangement, to determine their origin and history, and to learn how the earth has been made. He finds in the rocks the fossil remains of thousands of plants and animals which no human being ever saw

Fig. 84.— **Yosemite Valley, California.** A glaciated valley 3,000 feet deep in granite rock.

alive, and is able to read the history of life on the earth during past millions of years.

Fig. 85. — Red Butte, Nebraska. (U.S.G.S.)

If it were not for stream erosion the surface of the land would be as monotonous and uninteresting as the bottom of the sea. There would be no ravines, gorges, cañons, cliffs, buttes, mesas, spurs, passes, or peaks. Even mountain ranges would be tame and unimpressive. The most famous scenery in the world, the Grand Cañon, the Yosemite Valley, the Niagara Falls and Gorge, the valleys of the Hudson and the Rhine, the Scotch Highlands, the English and Italian lakes, the fiords of Alaska and Norway, would not be in existence. Few things in nature are more attractive to men than running water. Without it the world would be a much less pleasant place to live in.

Fig. 86. — Taghannock Falls and Gorge, New York.

Water Supply. — One of the prime requisites for plant or animal life is an adequate water supply. Many species of shellfish, fish, frogs, insects, waterfowl, and higher animals, from the muskrat to the hippopotamus, find in streams a home and a storehouse of food. All the higher animals visit them frequently to drink. The hunter in pursuit of game, whether it be duck, deer, giraffe, lion, or elephant, lies in wait by the water's edge, where he knows thirst will bring his victim in due time. A man consumes nearly a gallon of water a day, and if it happens to contain the germs of disease it may be a fatal poison as well as a food. Travel and settlement have been strongly influenced by water supply. Springs have determined the location of trails, camps, homesteads, and villages.

Scattered and rural populations depend generally upon ground water obtained from wells, but in cities, where thousands or millions of people are crowded together upon a few square miles, wells are inadequate and dangerous. Large cities must almost always depend upon streams for water supply. A lake forms a natural reservoir of generally clear, pure water, and if necessary an artificial lake can be made by means of a dam.

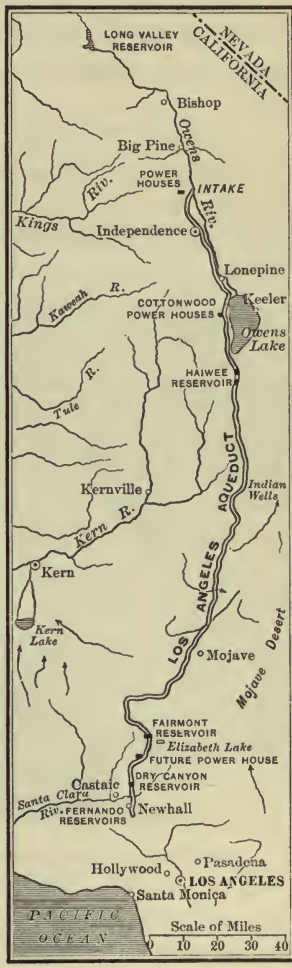

Fig. 87. — Los Angeles aqueduct.

Few cities are so fortunate as Chicago in having a fresh-water sea at its doors. Yet Chicago has had to reach out under the lake with a tunnel six miles long to obtain water free from pollution, and to spend thirty million dollars on a canal to carry away its drainage. St. Louis and New Orleans have the mighty flood of the Mississippi to draw upon. The water is muddy, but the mud is harmless and can be filtered out. New York has taken possession of the Croton River basin, and is now preparing to bring a larger supply from the Catskills. Glasgow brings water from Loch Katrine, 42 miles, Manchester from Thirlmere, 96 miles, and Liverpool from artificial Lake Vyrnwy, 67 miles. Los Angeles is constructing an aqueduct 250 miles long, and tunneling through a mountain range, to get water from Owens River. London has sanitary control of the whole Thames basin, which is hardly adequate to supply water to seven millions of people. No city can afford to spare pains or expense to obtain a sufficient and safe water supply.

Food Supply. — Nearly all streams contain fish of some kind, and in large rivers and lakes, such as the St. Lawrence system, fisheries form an important source of food supply. The rivers of the Pacific coast of America, from the Sacramento northward, once furnished in the form of salmon one of the most abundant food supplies in the world. The United States Fish Commission, and similar bureaus in other countries, have been organized to preserve and increase the supply of fish food by distributing eggs and fry and by regulating seasons and methods of fishing.

Travel and Transportation. — Streams furnish easy routes of travel and transportation. In new and undeveloped countries they are often the only practicable routes. They are extensions of sea facilities into the land, and of lowlands into highlands. Explorers, from Hudson, Champlain, and La Salle to Livingstone and Stanley, have penetrated the continents by way of great rivers. After a country has been long occupied by civilized people, rivers still remain cheap and ready-made freight routes, without expense for construction and maintenance.

The Amazon admits large vessels 2,000 miles into the interior of Brazil, and, with its many large tributaries, constitutes the only means of travel through an area nearly as large as the United States. The Belgian Kongo is being opened to trade and civilization by means of its rivers. In China one fourth of the human race depend upon their great waterways for circulation of people and goods. In Europe the Seine, Rhine, Elbe, Danube, and Volga are to-day great highways of commerce. North America has been settled largely through its great rivers, and while water transportation is now to a great extent superseded by railroads, the St. Lawrence and the Great Lakes transport as many tons of freight as the Mediterranean Sea.

Fig. 88. — Railroad following grade of Allegheny River. (U.S.G.S.)

Rivers have been at work for ages grading their valleys, and when man undertakes artificial highways he avails himself of their work. Canals and railways follow stream valleys wherever possible. Their construction would be everywhere more costly, and in rough and mountainous countries impossible, if the streams had not first cleared the way. Nearly every important city in the world is located upon a river and stands where it does because of the river.

Water Power. — Wherever water runs downhill, the force of gravity or the weight of the water can be used to drive machinery.

Fig. 89. — Water power on Genesee River, Rochester, N. Y.

The most valuable water powers are found at natural cataracts or rapids where the fall, usually distributed over many miles, is concentrated in a small space. In the absence of natural rapids or falls, an artificial fall must be made by means of a dam. For this purpose swift streams with deep, narrow valleys, like those of New England, are most advantageous. Abundant water power, with few exceptions, is found in highlands and along the upper courses of streams. For this reason mountainous countries such as Switzerland, Italy, and Norway are becoming important manufacturing centers.

Irrigation. — To have water to use whenever needed is an ideal condition for raising any crop, and is far better than dependence upon irregular and uncertain rainfall. Irrigation is as

Fig. 90. — Irrigating ditches in orange grove, Arizona.

old as civilization. It is a remarkable fact that the localities where civilization first appeared were deserts which, in their natural state, were almost uninhabitable.

Six or seven thousand years ago men learned to make use of the overflow upon flood plains and to improve and extend the natural process by means of reservoirs, canals, and ditches. In the valleys of the Tigris, Euphrates, and Nile, populous and powerful communities depended for existence upon irrigation. In the present century the British in Egypt have constructed immense dams which retain enough water to make thousands of acres of desert productive. The Turkish government is undertaking similar works to restore the ancient prosperity of Mesopotamia. Irrigation has been practiced from time immemorial in Turkestan, India, Spain, Italy, and Mexico. The United States government is now engaged in the construction of an extensive system of irrigation works which will result in the reclamation of millions of acres of arid land. Irrigation on a large scale is possible only in the lower courses of rivers where the valley is wide, or on plains and plateaus bordered by mountains from which the water may be distributed over the land.

The Utilization of Rivers. — A river is most usable for navigation when it has a large and comparatively constant volume of water, a small or moderate load of sediment, a graded slope, a gentle current, and a wide, shallow valley. Such rivers occur in plains and low plateaus of medium or heavy rainfall. A lake in the course of a river adds greatly to its advantages. The lake is wide, its water is deep and still, and its surface is level. The river below the lake is clear and not subject to floods or low stages of water. Drowning of the lower part of a river valley produces conditions similar to those of a lake.

Fig. 91. — Lake steamer.

In the possession of these characteristics the St. Lawrence is preëminent among the rivers of the world. Its valley is drowned to a point 900 miles from the sea, and the five Great Lakes have an aggregate length of nearly 1,500 miles, leaving only 300 miles of the system with any perceptible current. In sailing from Buffalo to Chicago, a distance of 800 miles, a vessel ascends only eight feet, or to Duluth, a still greater distance, only thirty feet.

In most streams there is some variation of volume dependent upon seasonal rainfall, snow melting, and evaporation. In the middle latitudes of Europe and eastern North America, high water is due to winter rains, or melting snow on frozen ground, and occurs in the late winter or spring. The Ohio, Seine, Rhine, Elbe, and Danube belong to this group. The rivers of northern North America and Eurasia derive their main water supply from melting snow and have high water in the spring. The floods are made much more extensive and prolonged by great ice dams in their lower courses, which persist and hold the water back long after the upper courses are clear of ice. On account of such conditions these rivers are of little use. They include the Yukon, Mackenzie, Saskatchewan-Nelson, Dwina, Petchora, Ob, Yenisei, and Lena.

In the tropical regions of South America and Africa and the monsoon regions of Asia high water occurs with the heavy rains of summer. The rivers of this class include the Orinoco, Amazon, Parana, Kongo, Zambezi, Nile, Ganges, Brahmaputra, Yangtse, Hoang, and Amur.

Rivers in mountains and high plateaus are utilizable chiefly for power in their upper courses and for irrigation in their lower. Their main water supply is from melting snow, and they are subject to great changes of volume. The most important flow from the interior highlands of North America and Asia, and in crossing arid lowlands in their way to the sea lose a large part of their volume by evaporation. Among these are the Missouri, Arkansas, Red, Colorado, Columbia, Euphrates, Tigris, Amu, Syr, and Indus. The rivers of southern Europe and California belong to this class, and being small, almost run dry in summer.

In desert and semi-arid regions the streams are generally intermittent or occasional, drying up a part of every year, or flowing only at irregular intervals. They are useful only for irrigation.

The Savannah River. — Some rivers are utilizable for all purposes. The Savannah River, between Georgia and South Carolina, is an example. Although the total length of its basin is only 250 miles, it traverses three distinct belts, — the mountain, the plateau, and the plain.

Its headwaters are in the Blue Ridge, where the rainfall is heavy, the slopes are steep, and there are many falls and rapids. One tributary, the Tallulah, presents a succession of good water-power sites for thirty miles, ending in a fall of 400 feet in five miles. This region should be wholly devoted to the growing of hardwood forests, and the power should be used to run sawmills and other machinery.

The second or piedmont belt is a farming region, and raises cotton. A group of reservoirs located at the foot of the mountains would prevent floods, store water for use during the low-water periods, and help in furnishing power for cotton mills and wood-working factories. At the lower edge of the piedmont plateau is the "fall line," where the river descends an escarpment to the coastal plain. The power here has made the city of Augusta, with twenty-one cotton mills.

Fig. 92. — The Savannah River.

From Augusta to its mouth, about 150 miles, the Savannah is a navigable tidal stream flowing in an alluvial valley. With its flow properly regulated, there would be a good depth of water all the year, and the harbor of Savannah at its mouth would be one of the best in the southern states. If the possibilities of the river were fully utilized, it would furnish power, cheap transportation, and a seaport for a rich agricultural and manufacturing community.

The Mississippi System. — Any one looking at a map of the United States would be impressed with the importance and advantages of the Mississippi River system which drains nearly half the country. The extreme headwaters on the west rise in the Rocky Mountains, and, flowing through narrow valleys and cañons, with numerous rapids and falls, furnish water power and opportunities to irrigate the dry plains below (Figs. 60, 74, 94). The eastern tributaries from the Appalachian Mountains and plateau have reached a later stage of development, and their valleys are generally mature and well graded, but rather narrow (Figs. 78, 95). The northern sources are in a region of numerous lakes which act as reservoirs and help to equalize the flow at all seasons. The branches of the system penetrate nearly every square mile of the interior plain, and furnished to the canoe of the Indian, and the white explorer and trader, easy routes of travel. The early settlement of the "Middle West" was largely accomplished by means of flatboats and steamers, and homesteads, towns, and cities were located along the streams, which continued to be the chief arteries of travel and trade until the advent of railroads about 1850. The lower Mississippi was closed to commerce during the Civil War (1861–65) and since that time its use for transportation has rapidly declined. The Mississippi system on the map appears to furnish thousands of miles of navigable waterway, but it has proved inadequate to the needs of to-day. The river towns which are still prosperous and growing owe more to the railroads than to the river. This condition is due chiefly to natural causes.

Western Tributaries. — The Missouri and other western tributaries north of the Red River receive most of their water from the mountains, and in crossing the plains traverse a region of scant rainfall. As a result the volume of water decreases toward their mouths by evaporation, and they are overloaded with sediment. Their channels are shallow, crooked, and constantly shifting by the cutting away of banks and the formation of bars. In some cases the river becomes *braided*, or divided into a network of small streams which spread out over an area a mile wide, but are not more than a foot deep. In the dry season the water may disappear from the surface, and the stream become apparently a river of sand. The volume of the Missouri varies greatly with the seasons. The water from the melting snows in the mountains reaches the lower river in June, when the volume may be thirty times as great as at low water in November. At high water it floods a wide area of bottom lands and scours

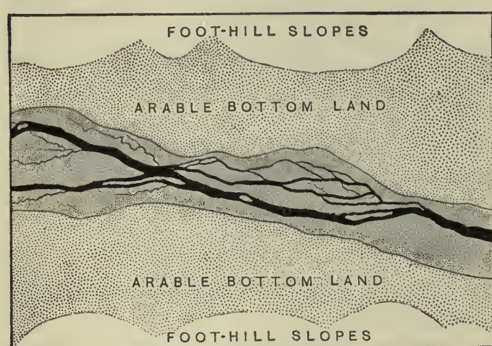

Fig. 93. — Braided stream.

out its channel to great depths, only to refill it as the current slackens. The Missouri is nominally navigable to Fort Benton, but navigation has been generally abandoned. Small steamers do a local business as feeders to the various railroads which cross the river.

Fig. 94. — Bighorn River in the plains, Wyoming. Irrigation canal on right bank.

The upper Mississippi drains a country of moderate rainfall and is not subject to extreme fluctuations in volume. It discharges nearly as much water as the Missouri, and is navigated without much difficulty as far as St. Paul.

The Ohio. — The Ohio basin receives a heavier rainfall than any other part of the Mississippi system, and the river discharges three fourths as much water as the Missouri and upper Mississippi combined. The large tributaries are not overloaded and contain no cataracts and few rapids. The valleys are generally narrow and bordered by high bluffs (Figs. 78, 95). The streams are subject to excessive fluctuations of volume. The rains and melting snows of spring sometimes raise the level of the Ohio at Cincinnati seventy feet above low-water mark, and the droughts of summer and autumn may reduce its depth to three feet. On a river whose level varies so much it is impossible to maintain permanent docks and landing places, the water front of towns is liable to be flooded or left out of reach by boats, and navigation is inconvenient and dangerous. In spite of these difficulties considerable business is done on the Ohio, chiefly in transport-

Fig. 95. — Ohio River, near Madison, Ind.

ing coal from Pennsylvania in barges, which are lashed together and pushed in front of a steamer. The United States government is now building a series of dams in the Ohio which will maintain a depth of nine feet at all seasons.

Fig. 96. — Ohio River barges and steamer. Landing place, Evansville, Ind.

The Lower Mississippi. — The lower Mississippi, from the mouth of the Ohio to the Gulf, flows through an alluvial valley

Fig. 97. — Lower Mississippi flood plain.

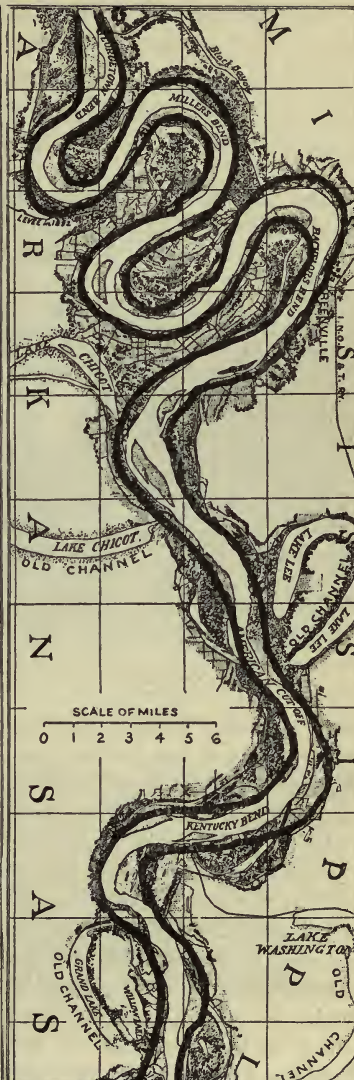

Fig. 98. — The Mississippi, near Greenville, Miss. The heavy lines show changes in channel in 12 years.

25 to 80 miles wide. The distance in a direct line is 600 miles, but by the course of the river 1,075 miles. The river is loaded with the mud of the Missouri and other western tributaries, and the fall is less than six inches per mile. Consequently the main channel is extremely tortuous and changeable.

The bank on the outer side of each bend and on the up-valley side of each tongue of land is rapidly cut away, while bars are built on the opposite sides. Thus the river continually grows more crooked. But occasionally the neck of land between two bends becomes so narrow that at high water the river cuts through and straightens itself. The new *cut-off* becomes the main channel, and the old bend is left at one side as a horseshoe lake (Fig. 98). Thus the deep-water channel, which steamers can follow, is constantly shifting, and does not remain in the same place from week to week. Landing places must be moved, and even town sites are washed away or left far from the river. The lower Mississippi carries the flood waters of the Missouri and Ohio, which sometimes combine to increase its volume to more than ten times its low-water volume. It rises 53 feet at Cairo, 36 feet at Memphis, 48 feet at Helena, 53 feet at Vicksburg, and 15 feet at New Orleans. Below the mouth of the Red the rise is small because the surplus water is carried away by the Atchafalaya and other distributaries. In the natural state of the river the flood waters spread out over the valley floor, and finally drain off through the *bayous*, or side channels, to the main stream farther down. As the river overflows its banks the current is checked rather suddenly, and the larger and coarser part of its load of sediment is dropped within a mile or two of the channel. Thus the river builds up its own banks above the general level of the flood plain, forming natural *levees* (Fig. 99). The floods leave a thin layer of fine and fertile mud over the submerged lands, which thus acquire a soil of great and frequently renewed fertility. But the floods are destructive to prop-

Fig. 99. — Natural levee, Wabash River, Ind.

erty, and render the utilization of such lands for agriculture difficult and precarious.

The governments of the United States and of the various states concerned have spent many millions of dollars in works designed to prevent floods and to improve the navigable channel. These works include the

Fig. 100. — A Mississippi levee, Greenville. High water above the level of the town.

construction of reservoirs at the sources of the upper Mississippi to store water for use during low stages, the dredging of channels across bars, and the protection of banks which are liable to be cut away. But the most important and expensive work done consists in the building of artificial levees or embankments of earth, which are now completed on both sides of the river nearly up to the mouth of the Ohio. Confining the flood water to the narrow space between the levees causes it to rise higher than before, and it sometimes runs over or breaks through, but about three fourths of the alluvial valley seems to be effectually protected from floods. Whether the confinement of flood waters will cause the river to scour out and deepen its channel, to the advantage of navigation, remains to be seen. A deep water way (fourteen feet) from the Great Lakes to the Gulf is greatly needed, but the expense of construction and maintenance would perhaps be too great for even so rich a country as the United States.

Fig. 101. — Mississippi steamer.

Fig. 102. — Bernina and Roseg glaciers, Switzerland. Note jagged peaks, smooth lower slopes, snow fields, and medial and lateral moraines.

CHAPTER VII

GRADATION BY ICE

While running water is the most effective agent in modifying the relief of the land surface, many important features are due to moving ice. On high mountains and in polar regions at low levels, more snow falls than can be melted, and it therefore accumulates from year to year. A bank of permanent snow slowly changes by thawing, freezing, and pressure into solid ice which drains away down the slopes, somewhat as water does.

Valley or Alpine Glaciers. — A valley or alpine glacier is a stream of ice, fed by a snow field above and following a valley

Fig. 103. — Confluence of three glaciers, Switzerland.

line down to the sea, or to warmer levels where it is melted and changed into a stream of water. In comparison with a river, an ice stream is slow, stiff, and awkward, progressing only a few feet a year, yet it accomplishes great results. At its very head

Fig. 104. — A cirque in the Sierra Nevada, California. (U. S. Bureau of Fisheries.)

Fig. 105. — Glaciated valley, Lauterbrunnen, Switzerland.

Fig. 106. — Nunatak Glacier, Alaska, discharging bergs into a fiord. Ice divide in the distance. (U.S.G.S.)

it freezes to loose rock fragments and drags them away from the valley walls and bottom. Thus a semicircular hollow is gradually eaten into the mountain side, which comes to resemble a gigantic armchair and is called a *cirque* (Figs. 104, 40). Several glaciers working on different sides may reduce the mountain summit to a thin, sharp, and jagged ridge. Great quantities of dirt and stones slide and fall from the steep sides of the valley upon the surface of the ice and are carried downstream. The ice is often a thousand feet or more in thickness, and its pressure on the valley bottom over which it slides amounts to many tons per square foot. The sand, gravel, and boulders frozen into the under surface convert the glacier into a powerful rasp which scratches, rubs down, and planes off the bed rock. The valley is deepened and widened into a rounded shape, like the letter U, easily distinguished from the sharp V-shaped valley of a river (Fig. 105).

If the glacier reaches the sea, the ice breaks off in large chunks, or *icebergs*, which drift about and are finally melted. In most cases a glacier is brought to an end far from the sea by melting, and the whole load of

Fig. 107. — Glacial drift, Ontario County, N. Y. Boulders in stream have been washed out of clay banks.

loose rock which it carries is left in a heap called a *terminal moraine*. A glacier can carry an almost unlimited load of sediment, fine or coarse. It carries a boulder as large as a house as easily and rapidly as a grain of sand. Therefore it has no power of assorting materials, as running water has, and does not deposit them in layers. *Glacial drift* is recognizable as a mixture of mantle rock of different kinds and sizes, from clay as fine as flour to boulders weighing many tons, all mixed together in a heap or spread out in a sheet.

Fig. 108. — Glacial boulder, Indiana.

A valley glacier often consists of a trunk stream with many tributaries like a river system. The main ice stream deepens its valley faster than the weaker tributaries can, so that a glaciated valley from which the ice has disappeared is characterized by numerous waterfalls, where the streams from the "hanging" tributary valleys cascade down to the floor of the main valley (Figs. 84, 86, 105). In an old glaciated mountain system, such as that of Alaska, all the valleys are deeply filled with ice which streams from the divides and snow fields in various directions, so that it is possible to pass easily

Fig. 109. — Peaks worn down to snow level, Alaska.

from one side of the range to the other over ice divides (Fig. 106). The peaks left projecting like islands above the snow surface, and exposed to severe and continuous frost action, become extremely jagged and disintegrate down to snow level, which thus acts as a base level of erosion (Fig. 109). Below the upper limit of snow the rocks are protected from frost, but exposed to the abrasive and smoothing action of moving ice. Thus a valley which has been formerly occupied by a glacier may present a striking contrast between the smooth and polished surface of its lower slopes and the rough and splintered surface above (Figs. 102, 103).

Valley glaciers and glaciated mountain valleys furnish some of the most impressive and fascinating scenery in the world. They have a peculiar charm for the physiographer, the artist, and the adventurous pedestrian who uses the ice surface as a path by which to climb the peaks or cross the range.

Ice Caps.—An ice cap is a mass of snow and ice which accumulates upon a plateau and moves outward in all directions, as molasses candy spreads out on a plate. Existing ice caps vary in dimensions from twenty miles in diameter in Iceland to those of Greenland and Antarctica, where an area larger than the United States is completely buried. Fifty thousand or a hundred thousand years ago North America north of 40° N. Lat. and Europe north of 50° were nearly covered by a succession of ice sheets which profoundly modified the relief, drainage, and soil. The glaciated area may be roughly divided into two contrasted parts: (1) the area of ice accumulation and erosion, corresponding to the upper and middle course of a river; (2) the area of ice destruction and drift deposition, corresponding to the flood plain and delta portion of a river.

American Ice Sheets. — In America the snow and ice accumulated on the Cordilleras of Canada and around Hudson Bay, and extended southward to the Columbia, Missouri, and Ohio rivers. Near the centers of accumulation the ice was perhaps two miles thick, and in moving outward it swept away the mantle rock, wore down the less resistant bed rock, and left a surface of peculiar relief, characterized by shallow basins and low, rounded hills, with no regularity in shape or arrangement.

The basins, filled with water, constitute the innumerable lakes which cover southern Canada with tangled chains of waterway. The great lakes around the border of the severely glaciated area, from Ontario to Great Bear, owe their form, size, and ex-

Fig. 110.—Ice sheets of North America.

istence largely to the work of the ice sheets. The general elevation of the country was reduced some hundreds or perhaps thousands of feet, and the bed rock was left bare or covered with thin, coarse mantle rock. This of itself renders agriculture generally impossible. The vegetation growing on such a soil consists of coniferous forest, dense and of great value for timber in favorable localities, thin and worthless in unfavorable. On account of poor drainage, "muskegs," or marshes covered with mosses and shrubs, are numerous and extensive. The economic products of the country consist almost entirely of furs, of which it furnishes a large part of the world's supply. Lumbering is carried on in those parts accessible to markets, and in recent years the great mineral wealth of the region is being utilized.

Fig. 111. — Laurentian peneplain.

The Area of Glacial Drift. — The area of ice destruction and drift deposition lies chiefly south and west of the chain of great lakes in northeastern United States and southern Canada. Here the ice was relatively thin and its erosive power was generally

Fig. 112. — Terminal moraine, Sheboygan County, Wis.

feeble. In melting it deposited its whole load of mantle rock in a continuous sheet, from a few feet to several hundred feet

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in thickness. The bulk of the drift is composed of *boulder clay*, a stiff clay containing many pebbles and boulders of various

Fig. 114.—Drumlin, Macedon, N. Y. (Partly plowed.)

sizes. Generally west of Pennsylvania the old valleys were filled and the general level of the country slightly raised. The surface was converted into a smooth plain of accumulation

Fig. 115.—Esker, Freeville, N. Y.

(Figs. 34, 35), varied by many ridges and belts of hills which mark the temporary position of the ice edge.[1] East of Ohio the

[1] Glacial drift ridges are:

(1) *Marginal moraines*, formed by an accumulation of drift along the edge of the melting ice sheet (Figs. 45, 112).

(2) *Kames*, irregular heaps of sediment deposited at the point where a stream of water escaped from the ice margin (Fig. 47).

(3) *Eskers*, sharp winding ridges of sand and gravel deposited in stream channels on or under the ice.

(4) *Drumlins*, lenticular or prismatic hills of clay, formed under the ice at some distance back from its edge.

glacial drift was too thin to do more than slightly modify the previous rough relief of the country. All the drainage systems, from the Columbia to the Ohio, were greatly changed by valley filling, damming, and ponding, displacement of channels, and transference of tributaries from one system to another.

Fig. 116.—Relation of the drift sheet to agriculture.

Economic Relations. — Of more importance than these changes is the fact that the glacial drift, brought from the north and east and liberally spread out over the country to the south and west, constitutes a rich, deep, and enduring soil, which makes the northern states

Fig. 117.—The continental glacier of Europe.

and southern Canada east of the Rocky Mountains the greatest food-producing region of the world, and one of the most densely populated parts of North America. This region also owes to the ice sheets the most important inland waterway in the world, the Laurentian Great Lakes. The states heavily coated with glacial drift have a population of about thirty millions, or forty-five to the square mile. The states south of the glacial boundary have a population of about twenty-seven millions, or thirty-two to the square mile.

European Ice Sheets. — In Europe the main region of ice accumulation was in Scandinavia and Finland, and the region of ice destruction and drift deposit in central Russia and north Germany. The same contrasts between the two in relief, drainage, and soil are found as in North America. Scandinavia and Finland form a country of lakes and forests with a very small area of arable land, while Germany and central Russia are rich agricultural states. The European glacial drift is not generally so heavy or so productive as the American, and lying in higher latitudes has not influenced products and population to any such extent.

CHAPTER VIII

STANDING WATER

Lakes, Ponds, and Marshes. — Lakes, ponds, and marshes are bodies of standing water which occupy depressions in the land surface. Lake basins are due to a variety of causes. The largest basins have been produced by the warping or breaking of the earth crust by internal forces. In some cases these basins are so large that the excess of rainfall over evaporation is insufficient to fill them, and the lake has no outlet. Salts brought by streams in solution accumulate, and the water becomes a brine. Of such lakes the Caspian Sea is the largest and the Dead Sea the lowest, 1,300 feet below sea level. The Great Basin in western United States contains many lakes, of which Great Salt Lake in Utah is the largest. They are all subject to fluctuations of level and area, according to the seasons, or the periodic variations of rainfall. Many of the smaller ones are temporary, containing water for a few days or months, or lasting for a year or two before they dry up. Most of the lakes of central Africa lie in the course of the great rift valley (p. 64). Some of them have no outlet, but the great lakes Nyassa, Tanganyika, and Victoria are sources of the Zambezi, Kongo, and Nile. The great lakes of North America lie along the southwestern border of the Laurentian peneplain (p. 45), from New York nearly to the Arctic Ocean.

Fig. 118. — East African lakes and rift valley.

Their basins are due primarily to warping and stream erosion, but have been considerably modified by glacial action. On account of their size and location, the Laurentian lakes are of special importance. Lakes Superior, Michigan, Huron, Erie, and Ontario form the largest connected body of fresh water on the globe. Their form and relative positions suggest that their basins are parts of an old river valley which has been divided by a series of dams. Their great depth, extending in all except Lake Erie below sea level, may be due to glacial erosion.

During the retreat of the North American ice sheet and subsequently the Laurentian lakes were subjected to many changes of form, area, and outlet. Their waters at different periods overflowed through the upper Mississippi, the Illinois, the Wabash, the Ottawa, and the Mohawk (Fig. 113). Their former outlets at Chicago, Fort Wayne, Ind., Rome, N. Y., and Nipissing, Canada, furnish easy routes for canals and railroads. Lake Winnipeg is a shrunken remnant of Lake Agassiz, which, held in by an ice dam on the north, once covered 110,000 square miles in Canada, Minnesota, and North Dakota, and emptied through the Minnesota River. The sediment deposited upon its bottom now forms the soil of the famous wheat fields of the Red River region.

Glacial Lakes.—Lakes are nowhere else so numerous as in the regions formerly covered by the North American and European ice sheets, as large-scale maps of Canada, northeastern United States, Sweden, and Finland will show. Glacial lake basins are hollows in bed rock eroded by moving ice, or hollows made by irregular deposition of drift. Many are partly or wholly due to drift dams in the course of a stream. Some are kettleholes left by the melting of detached blocks of ice (Fig. 48).

Fig. 119. — Glacial lake, Derwentwater, England.

The courses of terminal moraines are generally marked by thousands of small lakes, as may be seen in Indiana, Michigan, Wisconsin, Minnesota, and northern Russia and Germany.

Alpine Lakes. — Long, narrow, and very deep lake basins which occur in mountain regions, and are hence called alpine lakes, are characteristic

Fig. 120. — Glacial lake, Lima, N. Y.
Esker in left margin.

Fig. 121. — Alpine lake, Lugano.

results of ice work. The Italian, Swiss, and Scotch lakes and Lake Chelan in Washington belong to this class and are unrivaled for scientific interest and for grand and picturesque scenery. The Finger Lakes of New York, on the northern slope of the Appalachian plateau, are of similar but less extreme character, and are probably due to similar causes.

Fig. 122. — Finger lake: Hemlock Lake, N. Y.
Valley is 13 miles long, half a mile wide and 1,000 feet deep.

Volcanic Lakes. — Lakes are in some cases due to the damming of a stream valley by a flow of lava from a volcano. Old volcanic craters sometimes fill with water, forming lakes of which Crater Lake, in southern Oregon, is a famous example. It is five miles in diameter and bounded by precipitous cliffs from 500 to 2,200 feet high. The water is 2,000 feet deep.

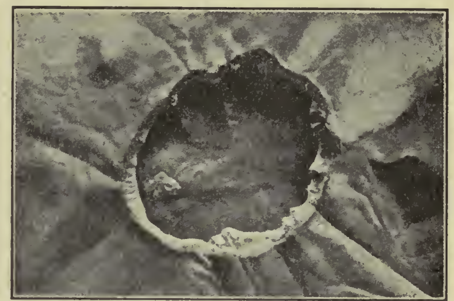


Fig. 123. — Model of the basin of Crater Lake, Oregon. (U.S.G.S.)

Life History of Lakes. — In arid regions, where the rainfall is insufficient to equal the water lost by evaporation, the lakes have no outlet and are salt. They often dry up, leaving beds of salt, soda, borax, and other valuable minerals. In regions of abundant rainfall lakes overflow at the lowest point of the basin rim. As the outlet stream cuts its channel deeper, the water is drained away and the lake level is

Fig. 124. — Lake filling with vegetation. (Fletcher's *Soils.*)

lowered. This process is often hastened by cutting an artificial ditch which may drain the lake completely, leaving rich agricultural land. At the same time inlet streams are filling up the basin with sediment and will in time convert it into a lacustrine plain. Therefore lakes are among the most short-lived of natural features and are always relatively young.

In the case of small, shallow lakes, their destruction is hastened by the growth of vegetation. Aquatic plants, which absorb the greater bulk of their food from the air, grow and decay year after year, until the basin is filled with vegetable matter and the lake is converted into a marsh, peat bog, or wet meadow. Some lake basins fill with marl, which is valuable as a fertilizer and for making cement.

Economic Relations. — Lakes act as reservoirs which regulate the flow of outlet streams and prevent both floods and extreme stages of low water. They are also settling basins for sediment, so that a stream flowing out of a lake is usually clear. The Niagara and St. Lawrence rivers are striking examples of streams which are clear and subject to slight changes of volume. Large lakes furnish the best of inland waterways (p. 100). The smaller ones are sources of food supply and add greatly to the variety and beauty of landscape. Lakes are everywhere favorite summer resorts, which attract thousands of people who find pleasure and recreation in camping, boating, fishing, and bathing. The "Chautauqua," or summer assembly for religious, educational, social, and sanitary purposes, takes its name from Lake Chautauqua in New York.

Gradation by Standing Water. — Seas and lakes are bodies of standing water but not of still water. Their waters have no general and continuous movement in one direction, as a stream has, but under the influence of the wind and the moon are agitated by waves, currents, and tides. These movements accomplish their most important work along the margin where land and water meet, and produce a characteristic series of coast forms. These may be found in miniature along the shore of almost any small lake or pond.

Beaches and Bars. — Where the coast land is low and the coast waters are shallow the waves build up a ridge of sand or gravel which is as high as the highest storm waves can lift the material. Behind this *beach* there is generally a strip of shallow water called a *lagoon*. A *barrier beach* is a long, continuous ridge some distance off shore (Fig. 28). Where the shore line is indented by a bay the beach is often extended across its mouth, forming a *bay bar*.

Fig. 125. — Beaches and lagoons, Cayuga Lake.

A bar built out from shore into deeper water is called a *spit*, and if bent back at the end, a *hook*. Barrier beaches and bars,

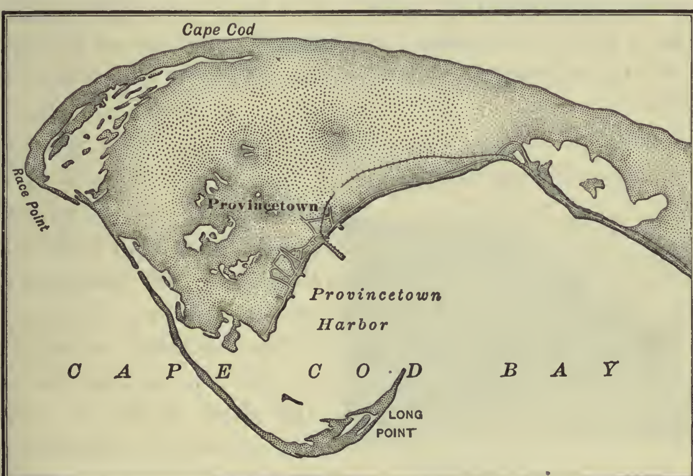


Fig. 126. — The end of Cape Cod, Massachusetts. Two hooked spits.

as the names imply, render a coast difficult of access from the water and form serious obstructions to commerce. The lagoons, inlets, and bay mouths are usually too shallow to admit vessels of considerable size. Where the tides are high and strong enough to keep the inlets scoured out, good harbors are found. On a low, sandy coast wind and waves work together and dunes are combined with beaches.

The Gulf and Atlantic coasts of the United States south of Cape Cod present perhaps the longest stretch of barrier beach coast in the world. On the coast of Texas the beach extends 100 miles without a break. Galveston and other bays are rendered inaccessible except by artificial channels. The keys and reefs of Florida are peculiar in being partly the work of coral animals. Along the coast of Georgia and South Carolina the tides are strong enough to break up the beach into the so-called "sea islands," and the numerous deep inlets lead to good harbors. From Charleston to New York the coast is bordered by a nearly continuous beach, which sweeps in long, gentle curves from point to point. Behind it is a belt of lagoons and tidal marshes, expanding in North Carolina into shallow sounds. This coast belt is interrupted by the drowned valleys of the Chesapeake, Delaware, and Hudson, which let deep tide water and the largest vessels far into the interior. The beaches of New Jersey and Long Island are popular summer resorts. Railroads have been built to and along them, and towns and cities have sprung up, with hotels and places of entertainment for visitors, who come by the hundred thousand to enjoy the sea breezes and the bathing (Fig. 28).

Sea Cliffs. — Where the coast land is high and the coast waters are deep, the waves pound against the shore with tremendous force and undercut it into a vertical cliff. The fragments are rolled over, ground up, and carried away by the *undertow*, or backrush of water along the bottom. The result of this is a platform or terrace a little below sea level, partly cut into solid rock, partly built of mantle rock, and bordered by a constantly retreating cliff. The character of a cliff coast varies with the kind of rock. If the rock is of uniform hardness and without joints or seams, the cliff is smooth and unbroken, like

Fig. 127.—Sea cliff, Lake Erie.

the chalk cliffs of England and France and the clay cliffs of Lake Michigan (Fig. 35). Such a coast may be entirely without indentations or harbors. If the rock is complex in material and structure, the waves soon eat away the weak places and leave the more resistant masses standing out as promontories and islands (Fig. 43). Small isolated masses of rock along the shore are called *skerries* in Norway and *stacks* in Scotland. Such a coast may be extremely jagged and dangerous to shipping, while at the same time it offers numerous coves where small boats may find shelter and concealment.

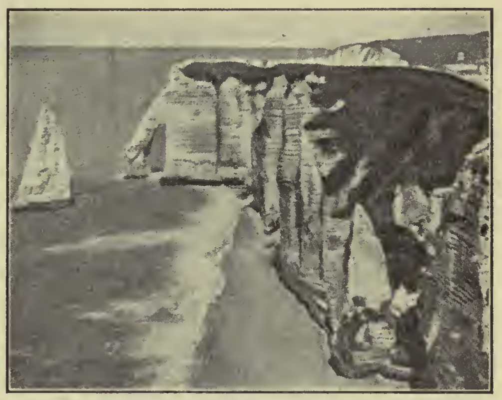


Fig. 128. — Chalk cliffs, France. Arch and stack.

Economic Relations. — On the whole, the general result of the work of standing water is to cut the bordering lands down to its own level and to surround itself with barriers which make access to the land more difficult. If it were not for the power of running water and ice to break through the barriers, ocean and lake commerce would be much more restricted than it is.

CHAPTER IX

GRADATION BY GROUND WATER AND WIND

The Ground Sea. — A large part of the rainfall sinks into the ground and penetrates the earth crust to great but unknown depths. The ground water may be thought of as forming a sea many miles in depth and extending through the rock sphere beneath the land surface from ocean to ocean. Thus the water sphere is really continuous around the globe. The upper surface of the ground sea, called the *water table*, is not level, but is roughly parallel with the surface of the land. In lakes, marshes, and streams the water table stands at the surface of the ground. In regions of small rainfall it may lie a thousand feet or more below the surface. The level of the water table is not constant at the same locality, rising during a wet season and sinking during a dry season. The water of the ground sea is seldom at rest. In compact rocks the movement is very slow, in porous rocks more rapid, and in rocks traversed by open joints and cracks there is a circulation in streams comparable to that on the land surface.

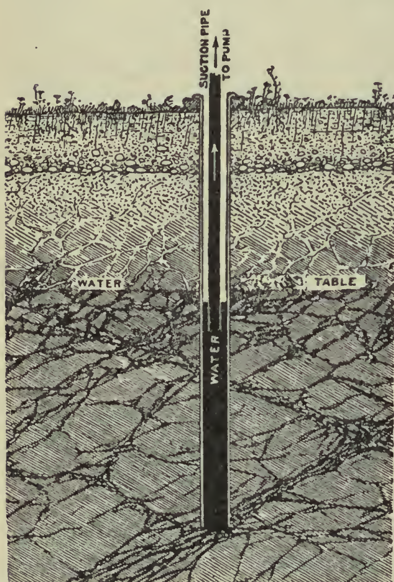


Fig. 129. — Section of fissured rock and well. (U.S.G.S.)

Work of Ground Water. — Most of the minerals of the earth crust are more or less soluble, and as the ground water penetrates more deeply it becomes more highly charged with them. Its temperature also increases with the depth, and the lower parts of the ground sea are probably composed of hot water saltier than the ocean.

Fig. 130. — Hot spring deposits, Algeria.

In many places the deep ground water rises to the surface, forming mineral springs. These waters contain gases, sulphur, iron, and various salts in solution, which render them of value in the treatment of disease.

Fig. 131. — Old Faithful geyser, Yellowstone Park.

Hot Springs, Ark., and Saratoga Springs, N. Y., are famous health resorts, and there are hundreds of similar character in all parts of the world. In old volcanic regions the earth crust is hot near the surface, and steam generated in subterranean conduits throws out columns of hot water, forming *geysers*, or spouting springs. The geysers of the Yellowstone Park are unsurpassed in number, variety, and size. As hot ground water rises toward the surface the pressure upon it diminishes, it cools and deposits the minerals held in solution, eventually filling the passage. In this way ores of gold, silver, and other metals are concentrated and placed within reach of the miner.

Limestone is a very soluble rock, and in some limestone regions the earth crust is honeycombed with underground drainage channels, leaving few streams on the surface. Some of the channels have been enlarged by solution and the falling in of the roof to a diameter of hundreds of feet and a length of many miles. Most of the great caves of the world are in limestone rock, among them Mammoth Cave in Kentucky, and Wyandotte Cave in Indiana.

Fig. 132. — Mouth of cave, Indiana. Roof of stream channel fallen in.

Economic Relations. — Ground water is everywhere a common source of water supply for domestic use. The outflow of natural springs is sometimes large and of good quality, but the main dependence is upon wells. If a hole is sunk into the ground to a point below the water table, it will fill up to that level with water. In shallow wells the largest supply is obtained from strata of sand and gravel. Such wells, especially in towns, are unsafe for domestic use, on account of pollution by drainage from cesspools, sewers, barnyards, and other sources of filth. The clearest and most agreeable well water may be the most dangerous. Deep wells are less liable to contamination.

In some cases water flows from a well without pumping, or even spouts into the air like a fountain. Very deep flowing wells are called *artesian*. The water of a flowing well comes from a porous stratum which outcrops on the surface somewhere at a higher level than the mouth of the well. The outcrop and source of supply may be hundreds of miles from the well.

Over a large area of the plains east of the Rocky Mountains artesian wells are common, some of which furnish water enough to irrigate a hundred-acre farm. The water comes from thick strata of porous sandstone which

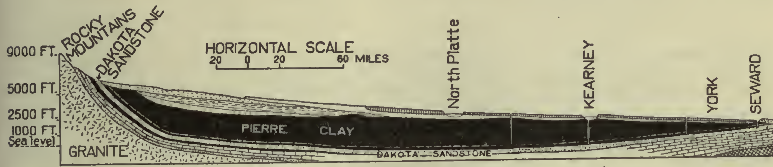


Fig. 133. — Cross section from Rocky Mountains across Nebraska. Dakota sandstone under Pierre clay carries water from Rocky Mountains and supplies artesian wells on the plains. Note nearly horizontal strata of plains turned up against granite core of the mountains. (U.S.G.S.)

underlie the plains at considerable depths. The sandstone outcrops along the foothills of the mountains, where it absorbs the rainfall and transmits the water eastward. Whenever a well penetrates the overlying strata and reaches the sandstone, water rises to the surface.

Ground water plays an important part in the work of gradation by extending the processes of weathering and rock decay to great depths, and by promoting chemical changes and transporting material in the earth crust.

Fig. 134. — Artesian well, North Dakota.

Work of Wind. — Wherever fine, dry mantle rock is exposed without a cover of vegetation the wind is able to transport it in almost unlimited quantities. As in the case of running water, both the quantity and the coarseness of sediment which running air is able to carry increase in a high ratio to the velocity, but air is so much less dense than water that its sediment is generally limited to dust and sand. Only tornadoes are capable of lifting pebbles and boulders. The wind is therefore a delicate assorting agent, and its deposits may usually be recognized by the fact that they have been thoroughly winnowed. Unlike running water, air moves in broad sheets and carries material as freely up a slope as down. There is a strongly marked rhythm in its motion, and its effects are a combination of those of currents and waves.

One fourth of the land surface of the globe has less than ten inches of annual rainfall, and in such areas outside the polar regions wind action is generally more important than other processes. Rocks, subjected to great daily changes of temperature, crumble rapidly. The lighter mineral particles, like mica, are carried away by the wind, and quartz grains are left as sand. The sand itself is blown about and acts as a powerful erosive agent, undercutting cliffs and enlarging valleys. In general, mantle rock accumulates, and hollows at all elevations are filled. Some of it is transported entirely outside the desert region. A wind-worn surface is much less varied than a water-worn surface. While running water cannot erode below the level of the sea or of the lake into which it flows, there is no definite downward limit to wind erosion. Its tendency is to produce a stony peneplain with projecting knobs of hard rock and belts of drifting sand dunes (Fig. 37). When the surface is reduced below sea level, the sea is liable to overflow it and stop the process. The margin of the desert is indefinite and fluctuating. Its sands often encroach upon neighboring cultivated areas unless stopped by human agency.

Dunes. — A tornado in the desert may raise a sand column or spout many hundred feet and sustain it as long as the whirl of air continues, finally dropping it over the surrounding country, but the ordinary winds seldom lift sand more than a few feet. A slight lull causes most of it to be dropped, and it accumulates in the lee of any obstruction, as snow is drifted behind a fence. The pile of sand itself forms an obstruction beyond which more sand accumulates, and the drift or dune grows to be a hill with a long, gentle slope on the windward side and a steep slope on the leeward side. The wind blows the sand up the long slope and drops it in the eddy beyond. Thus the pile becomes a

Fig. 135.—Dunes, Algeria.

"marching dune" which slowly advances, burying forests, buildings, or whatever lies in its way. In the course of years the dune may move on far enough to uncover what it previously buried.

Coast Dunes. — The margins of seas, lakes, and retreating ice sheets are generally bare of vegetation, and present conditions favorable for wind action. Low windward coasts are often bordered by belts of drifting dunes, as in Holland, Germany, France, the Atlantic coast of the United States, and the east and south shores of Lake Michigan. The dunes form a barrier which protects the land from storm waves and high tides, but also makes commerce difficult (Fig. 28). In France the progress of the dunes inland has been stayed by the planting of pine trees. Moving sand is very unfavorable for the growth of vegetation, and forms the ground of nearly

Fig. 136. — Dunes near coast of North Carolina.

absolute desert. Sand dunes are among the most destructive agents in nature, and can be controlled only where some kind of vegetation can be made to grow upon them and hold them down.

Dust. — Very fine dust ejected from volcanoes to a height of many miles has remained in the air for months, and even years, before settling, and has been carried around the world. The snow fields in the interior of Greenland, far from any exposed ground, are covered with fine dust, which may settle upon it from extraterrestrial space. Dust from the Sahara is sometimes carried by the wind to northern Germany.

CHAPTER X

SOILS

THE loose rock material in which plants take root and find food is called *soil.* Practically the whole vegetative covering of the land, and consequently all animal and human as well as plant life, depend upon the soil for existence. Soils are portions of mantle rock and have been formed by the physical and chemical disintegration of bed rock by the agents and processes of weathering (p. 72). They may be thought of as "rock meal," or "rock flour."

Sedentary Soils. — Soils are at first *sedentary* or *residual,* that is, formed by the decay of the bed rock which lies under them, and vary according to the kind of rock from which they are formed. Sedentary soils are usually thin, but may accumulate to the depth of some hundreds of feet. They contain undecomposed fragments of bed rock, which increase in number and size downward.

Fig. 137. — Residual gravel, Texas.

Igneous rocks differ so widely in composition and texture that they weather into a great variety of soils, from very poor to very rich. Granite and gneiss often crumble at first into a barren gravel like that of the English moors. Chemical changes finally reduce the quartz to sand, and the feldspar and mica to clay, the latter being decomposed very slowly. The fertility of granitic soils is roughly proportional to the amount

Fig. 138. — Residual clay on shale, Indiana.

of feldspar present, quartz and mica being distinctly unfavorable. *Lava* soils vary in their rate of weathering and fertility with their chemical composition.

Limestone soils are famous for fertility, as in the bluegrass region of Kentucky and the prairies of Texas. The lime is dissolved and washed away, and the soil consists largely of the residue of insoluble impurities. *Sandstones* weather into sandy soils which are generally poor, but may be productive from the presence in the rock of other ingredients acting as a cement. *Shale* weathers into clay, which, if not too fine and compact, makes a good soil. *Conglomerate* weathers into gravel, which is apt to be very barren.

Colluvial Soils. — On moderate or steep slopes the native soil creeps slowly downward by the action of gravity, frost, and rain wash, and in arid regions sometimes accumulates in valleys between the mountains to a depth of several thousand feet. Such slowly moving soil masses are called *colluvial.*

Fig. 139. — Colluvial soil near Crawfordsville, Ind. The surface material creeps faster than that at a slight depth, tipping the trees.

Transported Soils. — The surface of plains, valleys, and lowlands is generally covered with soil which has been brought down from higher

SOILS

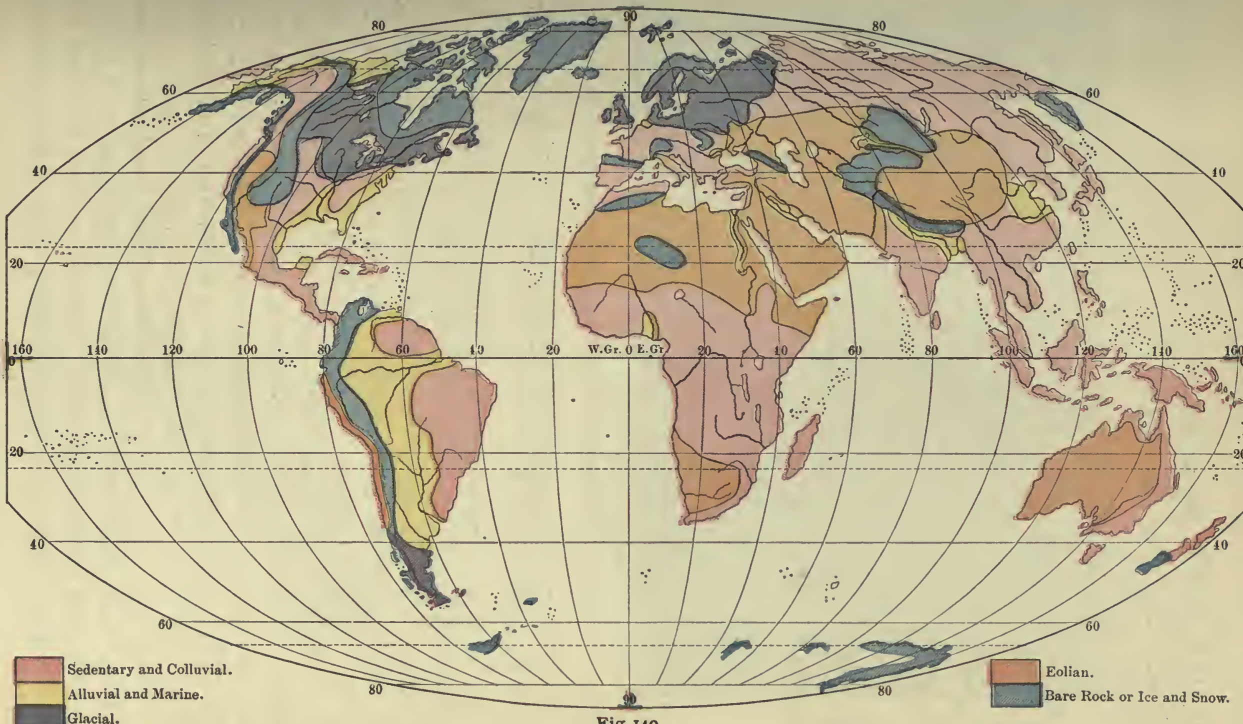


Fig. 140.

levels by water, ice, or wind. Transported soils are generally rich because they are derived from many kinds of rocks and

Fig. 141.—Eolian soil, "Palouse Country" of Oregon and Washington. (Fletcher's *Soils*.)

contain a mixture of minerals which is likely to include all kinds of plant food.

Alluvial soils are deposited by streams on flood plains, "bottom lands," and deltas, and are well known as exceedingly productive. Their productiveness is due to the variety of elements of which they are composed, to the fineness of division, and to their frequent renewal by deposits from flood waters. Great flood plains and deltas, such as those of the Nile, Hoang, Ganges, Rhine, and Po, have produced great crops for thousands of years and will continue to do so in future. The alluvial valley of the Mississippi and its tributaries is of the same character, but is not yet fully utilized (Fig. 97).

Glacial soils are the deposits from melting ice sheets (p. 122) and are more variable than alluvial soils, but generally not far behind them in productiveness. Glacial or boulder clay contains a great variety of minerals, finely ground and intimately mixed, and when it includes enough of sand and gravel to make it pervious and workable it is extremely rich and enduring. The glacial drift of the United States is one of the most valuable food-producing areas in the world (Figs. 113, 116, 117).

Eolian soils are deposited by the wind and are fine and sandy. Since they occur mostly in arid regions, where plant food is not washed out by rains, they retain the elements of fertility much better than the sands of humid regions. On desert sands, when wetted by slight rainfall, vegetation springs up at once, and if kept moist by irrigation becomes remarkably luxuriant.

Physical Composition of Soils. — Physically soils consist of clay, silt, sand, gravel, pebbles, and humus.

Clay is an extremely fine, soft powder produced by the chemical decomposition of various minerals, of which feldspar is the most important. It consists of thin, rounded scales from $\frac{1}{250000}$ to $\frac{1}{5000}$ of an inch in diameter. When wet, clay swells up into a sticky, plastic substance which shrinks in drying to a tough, coherent mass. It is very retentive of water, gases, and minerals in solution and presents such a large surface for the plant rootlets to work upon that clay soils are "strong." At the same time clay acts as a cement which holds other ingredients together and renders soil difficult to till.

Silt and *sand* are rock powders produced by the mechanical pulverization of various minerals, of which quartz is by far the most abundant. Common sand consists almost entirely of quartz crystals more or less rounded. If the crystals are unworn and angular, the sand is "sharp." The diameter of silt grains is from $\frac{1}{5000}$ to $\frac{1}{500}$ of an inch, that of sand grains from $\frac{1}{500}$ to $\frac{1}{25}$ of an inch, but even the finest silt can be recognized by its harsh, gritty feel between the fingers or teeth. Pure silt or sand is incoherent and easily worked, but does not retain moisture well, and is less fertile than clay.

Gravel is composed of generally hard, rounded grains or pebbles from $\frac{1}{25}$ of an inch up to 2 or 3 inches in diameter, and is looser and more permeable than sand.

Humus is a loose, black mold produced by the partial decay of vegetable matter, and is an essential ingredient of all good soils.

Types of Soils. — The common types of agricultural soils are classified as follows:

Sandy soils	contain	80 % sand,	10 % clay.
Sandy loams	"	60–70 % "	10–25 % "
Loam soils	"	40–60 % "	15–30 % "
Clay loams	"	10–35 % "	30–50 % "
Clay soils	"	10 % "	60–90 % "

Gravelly and stony loams contain gravel and pebbles and are common in regions covered with glacial drift.

Peat and *muck* soils are formed by the decay of vegetation in shallow lakes, ponds, and swamps. Some clay and silt are blown in by the wind and carried in by streams. They contain from 30 to nearly 100 per cent of humus. If the vegetable matter is sufficiently decayed and is mixed with considerable mineral matter, good drainage renders such soils productive.

Loess soils are peculiar deposits consisting of a mixture of silt and clay laid down partly by wind and partly by water, and are generally very productive. They cover extensive areas along the borders of the glacial drift in the United States and Europe. The loess of China is an eolian deposit blown from the central plateaus and is in some places 1,000 feet thick (Fig. 142).

Adobe soils are peculiar to semi-arid regions and common in southwestern United States. They are very sticky when wet, and hard when dry, but are unusually rich in plant food.

Alkali soils are common in arid regions. They contain large quantities of common salt, carbonate and sulphate of soda, and other compounds which are brought to the surface in solution and left by evaporation of the water as a whitish or black crust. Few plants will grow in such soils, but they can be improved by irrigation and drainage, which wash out the salts.

Tropical Soils. — The high temperature of tropical regions favors rapid decomposition of soil ingredients and hastens all chemical changes. The luxuriance of tropical vegetation is not wholly due to the heat and moisture of the air, but also to the fertility of the soil, which is therefore in part responsible for

Fig. 142. — Loess deposits, eroded, China.

the easy-going and indolent ways of tropical people. Tropical soils are exceptionally rich in humus, but plant food is rapidly leached out by the heavy rains. They are often of a deep-red color due to the diffusion of iron oxide. The red clay soils produced by the weathering of volcanic rocks are called *laterite* (brick earth). The name is often applied to any red soil.

Chemical Constituents of Good Soil. — For plant growth at least seven chemical elements must be present in the soil in soluble form, — nitrogen, potash, phosphorus, lime, iron, magnesium, and sulphur. The last three are usually present in such abundance as to require no attention, but the first four are sure to be exhausted by continuous cropping and must be supplied artificially. Therefore, nitrogen, potash, phosphorus, and lime are the essential ingredients of all fertilizers. The total quantity needed is relatively small because plants obtain about 90 per cent of their substance from the carbon and oxygen of the air.

Soils contain air and other gases which are necessary to plant life. The roots of most plants need air to breathe, and for farm crops the soil should be well ventilated by tillage and underdraining. The presence of air hastens the chemical processes which render plant food available, and thus increases fertility.

Plants as Soil Makers. — Plants perform a very important work in soil-making. Two years after an eruption of Krakatao, a volcano in Sunda Strait, which destroyed all vegetation, the surface of the lava was found to be slimy with microscopic plant life, active in breaking down silicates into clay, combining elements, and preparing soil for higher plants. Most soils swarm with bacteria, fungi, molds, and algæ which literally eat the rocks, and by living upon mineral matter produce humus. They flourish best in warm, moist, well-ventilated soils, where they hasten the decay of vegetable matter. Some are injurious, but most of them are harmless and many are beneficial. It has been said that the soil is not primarily a medium on which to grow herbs and trees, but a domain created by the activities of low forms of life for their own benefit, and that the higher plants exist by virtue of these, just as animals live by virtue of the herbage.

Temperature of the Soil. — The temperature of the soil is as important for plant growth as that of the air above it. Few seeds will germinate if the soil temperature is below 45 degrees, and 65 to 100 degrees is most favorable. Gravelly and sandy soils are warmer than clay. Wet soils are cold because much of the heat received from the sun is used up in evaporating water; consequently soils are warmed by drainage. Lands which slope toward the sun are warmer than those sloping away from it, and dark-colored soils absorb more heat than light-colored. The temperature of the soil is raised by the fermentation and decay of vegetable and animal matter.

Soil Water. — All fertile soils contain large quantities of water. The *free* or *ground* water fills the spaces between the particles up to the level of the water table (p. 132). The depth of the water table may generally be determined by the height at which water stands in surface wells. If the water table stands too near the surface, the plant roots may be drowned and the soil is of little value until it is drained.

Above the water table the surface of each soil grain is covered by a thin film of water which sticks to it and supplies the plant roots with food. The driest road dust contains some *film water*, and a good soil may hold more than half its weight. Film water is mostly derived from the free water below, but a little may be absorbed from the air. Film water is constantly rising from the water table and evaporating from the surface of the ground. Thus plants are kept alive through a dry season.

The water contains salts in solution which are left by evaporation, forming a surface crust. It is often important to conserve the film water by checking evaporation. This may be done by tillage, which pulverizes the crust, or by covering the surface with a mulch of vegetable matter or even of fine dust. The finer the soil the more surface the particles present for film water and the plant food it contains. Therefore "fineness is richness." A good soil may contain from 250 to 450 billion particles per ounce, and the aggregate surface of all the particles in one cubic foot may measure from one to four acres.

The life and growth of plants require a very large quantity of water, which they obtain entirely from the soil. Average farm crops use from 300 to 400 tons of water per acre. Plant roots absorb food only when it is dissolved in soil water, and the solution is so weak that to get food enough they must use great quantities of water, most of which escapes by evaporation through the leaves. Under ordinary conditions, production is almost directly proportional to the water supply during the growing season. Including losses by run-off and evaporation from the soil, a rainfall of from 5 to 25 inches just before and during the growing season is necessary to produce farm crops. In middle latitudes the rainfall of autumn and winter is of little benefit to the farmer, who must depend upon the rains of spring and early summer.

Irrigation does not add anything to the actual quantity of water on the land, but utilizes for crop growing water which would naturally evaporate or run off to the sea. Water is obtained from lakes, streams, and wells, and is distributed over the fields at times and in quantities which can be regulated according to the needs of the crop (Figs. 36, 60, 90, 94). The product per acre of irrigated lands far exceeds that of lands naturally supplied with water, but the area of lands which can be irrigated is relatively very small. Irrigated lands in India aggregate 25 million acres, in Egypt 6 million, in Italy 3.7 million, and in the United States 10.5 million. The area in the United States which may possibly be irrigated is estimated at 75 million acres, which is less than one-tenth of the total arid region.

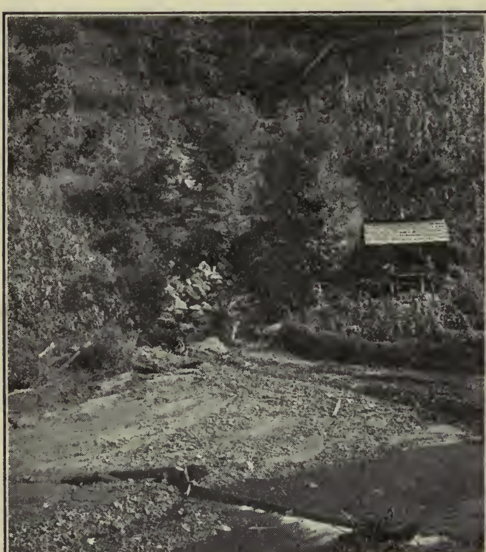


Fig. 143. — Soil wash and gullying, North Carolina.

The Conservation of Soils. — Soil is especially subject to erosion, and is carried away by every stream, to be finally deposited in the sea. In some places the soil is liable to removal by the wind. A covering of vegetation, especially a forest, largely prevents the washing away of soil. On forested slopes the cutting of the trees is often followed by rapid gullying and destruction of the land for any useful purpose, while the valleys below suffer almost as much from excess of mantle rock brought down and deposited. In old countries a series of "breaks" or dams is sometimes built across the valley to stop the waste of soil. All such regions are more valuable if kept in forest, which can be thinned out at intervals and renewed by planting. Many species of grass, sedge, rush, willows, and other plants which form a dense network of roots are useful as soil binders.

Soil and Population. — The population which any given region, or the world as a whole, can support is strictly limited by the amount of water available for crops. This is as true in humid as in arid regions. Notwithstanding the large proportion of the face of the earth occupied by water, less than half the land surface has sufficient rainfall to support a moderately dense population, and one third of it is either frozen or too dry for agriculture. As long as men depended chiefly upon agriculture for a living, population was necessarily most dense on fertile and easily cultivated soils, and these were generally alluvial. To-day the density of population is greatest in manufacturing regions, where the character of the soil is of no importance. Facilities for transportation are so great that food and clothing may be supplied from distant lands, and the best agricultural regions have a relatively sparse or medium population. In the most advanced industrial countries, like the United States, the population of purely agricultural counties and states has remained stationary, or has grown actually smaller for several decades. This is due to improvements in farm machinery, which enable one man now to do the work done by four or five men fifty years ago.

CHAPTER XI

THE SEA

THE sea is a continuous body of salt water which covers about 72 per cent of the surface of the earth crust. The average depth of the sea is a little over two miles, and its greatest about six miles. Its depth in proportion to its area would be like that of a lake three miles wide and one to six feet deep, and would be represented on a seven-foot globe by a film of water from one twentieth to one third of an inch thick. The relative shallowness of the ocean basins is of importance from the fact that they are not deep enough to hold all the water, which consequently spreads over the low margins of the continental platform and covers more than one sixth of it (p. 24). The sea surrounds four great land masses and thousands of islands, and is divided into five great oceans (Figs. 16, 17, 18, 150).

The Oceans. — *The Southern Ocean* forms a continuous belt around the earth south of 40° S. Lat., and is a means of communication between the other oceans which open into it. It is about 1,600 miles wide, comprises about one fifth of the sea area, and is more than two miles deep.

The Pacific Ocean comprises about 40 per cent of the sea area, or nearly 30 per cent of the face of the earth. It is roughly circular in outline, with a diameter of about 10,000 miles, and is nearly surrounded by land except on the south. Its bed is broken by numerous ridges which bear upon their crests thousands of small islands. It also contains many holes where the water is five or six miles deep.

The Atlantic Ocean is 9,000 miles long, and between Africa and South America only 1,700 miles wide. Its greatest depths are from four to five miles. It forms a broad channel of communication between the north and south polar waters. It comprises about one fourth of the sea area.

The Indian Ocean has been called " half an ocean " because it extends northward only to the tropic of Cancer. Its area is about one eighth of the whole sea, and its average depth is over two miles.

The Arctic Ocean is small and nearly inclosed by land at about 70° N. Lat. An opening 1,200 miles wide between Norway and Greenland connects it with the north Atlantic. A large part of it is covered with drifting ice, and its depths are little known. Soundings by Nansen north of Eurasia and by Peary at the pole show that it is more than 9,000 feet deep.

Sea Water. — The sea water contains about $3\frac{1}{2}$ per cent of mineral matter in solution, more than three fourths of which is common salt. Most of this mineral matter has probably been brought by rivers from the land. While sea water contains minute quantities of almost every known element, more than 97 per cent of the dissolved matter consists of salts of soda, magnesia, and lime. The gases of the atmosphere penetrate the sea in varying proportions to the bottom. The quantity of oxygen diminishes and that of carbon dioxide increases with increasing depth.

Temperature. — The temperature of the surface water of the sea is between 30° and 40° F. near the poles and between 70° and 90° near the equator (Fig. 150). The temperature of the deep bottom water varies from 29° in the polar regions to 35° under the equator.

The layer of water warmer than 40° is nowhere more than 4,800 feet deep, and generally much less. Eighty per cent of all the water in the sea has a temperature below 40°. This is due to the fact that the heat of the sun does not penetrate the water more than about 600 feet, and to the creep of the cold bottom water of the Southern Ocean into the Pacific, Atlantic, and Indian, crowding the warmer equatorial waters upward. Owing to many physical causes the temperature of the sea is more constant than that of the land, the seasonal change being seldom more than 10 or 20 degrees. Lands swept by winds from the sea have an oceanic climate marked by relatively small differences of temperature between summer and winter.

Pressure and Density. — The pressure of sea water is equal in all directions and increases at the rate of more than one ton per square inch for every mile of depth. The density varies with the temperature, pressure, and quantity of salts in solution. The density of the surface water is greatest in tropical regions of small rainfall and rapid evaporation, and least in the equatorial regions of heavy rainfall and the polar regions of freezing and melting ice.

Waves. — Waves are usually produced by the friction of the wind. They present a series of parallel or irregular ridges and hollows which follow one another across the surface of the water. They are very superficial, seldom disturbing the water to a depth greater than 100 feet. Each wave appears to consist of a ridge or mound of water moving forward with the wind, but

Fig. 144. — Breakers.

in the open sea the water really moves up and down in a circular or elliptical path. A field of standing grain in the wind or a cloth shaken up and down may be thrown into similar waves. Waves 10 or 15 feet high lift and drop a vessel about ten times a minute. Storm waves sometimes reach a height of 50 feet and travel 60 miles an hour, passing a given point at the rate of about four a minute. In shallow water the front slope of the wave becomes steeper and the crest higher, until finally it falls forward and breaks, rolling over and over like a barrel. On a shelving shore such *breakers* may reach a height of 100 feet or more, and hurl forward many tons of water, striking blows like a hammer and pounding cliffs, breakwaters, and lighthouses to pieces. The undertow, or backward rush of the water along the sea bottom, is efficient in grinding up and removing rock fragments.

Waves are the principal agents in breaking down the seaward margin of the land and in building beaches, bars, and spits (p. 129). Their effects are on the whole unfavorable to man by rendering navigation more difficult and dangerous and the coasts of the land less accessible. Shipwrecks are generally caused by waves. Mariners sometimes succeed in calming the sea and making a space of relatively smooth water around a ship by pouring overboard a quantity of oil. The floating oil so reduces the friction of the wind upon the surface of the water that wave motion nearly ceases.

Tides. — The level of the sea is subject to a regular, periodic rise and fall which is called the *tide*. It varies in amount at different places. On the deep, open ocean it is probably less than one foot. On the coasts of oceanic islands it is not more than six or seven feet, while at the heads of funnel-shaped inlets, such as the Bay of Fundy, it amounts to as much as fifty feet. If we should watch the tide from any point along the coast at low water, we should see the rocks, bars, and portions of the beach and sea bottom laid bare; then the water would slowly *flow* or creep up for several hours and cover them. High water would be followed by an *ebb* or fall, lasting six hours or more. The interval between two periods of high water or low water is twelve hours and twenty-six minutes, but it is not always equally divided between ebb and flow, the rise being generally more rapid than the fall.

The difference of level between high and low water varies not only at different places but at different times at the same place. These phenomena must have been observed by all peoples who have lived along the shore of the sea, and it must have been noticed at a very early period that the times of high and low water have some relation to the position and phases of the moon. The connection between the moon and the tides was not understood, however, until Newton's discovery of the law of gravitation.

If the earth were a globe of water, it is easy to understand how the attraction of the moon would draw it out of shape and

Fig. 145.—High tide, North Haven, Maine.

produce a slight elongation in the direction of a line connecting the earth and moon. The effect upon the spheroidal shell of sea water is the same as though it were a complete sphere.

Fig. 146.—Low tide, North Haven, Maine.

If the moon were always above the same point on the earth, there would always be high water at that point, the moon would cause no change in the level of the sea anywhere, and consequently there would be no lunar tides; but as the earth rotates on its axis from west to east, the point directly under the moon and the other points of high and low water travel around the earth from east to west at the same rate as the apparent motion of the moon.

Thus every part of the sea has two stages of high water and two of low water within the time between two transits of the moon over any given place (24 hours and 52 minutes). The period is more than twenty-four hours, because the moon is actually moving in its orbit eastward in the

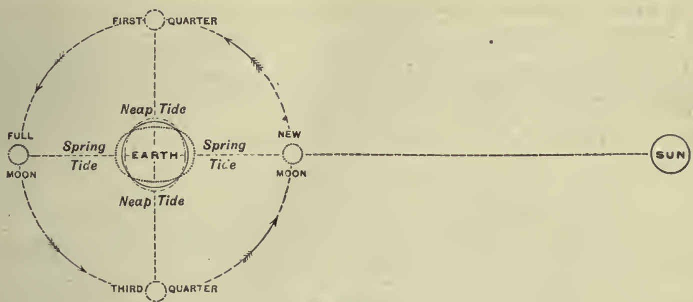


Fig. 147.

same direction as the rotation of the earth, and after one rotation of the earth on its axis, it takes fifty-two minutes for any given point on the earth to overtake the moon.

The sun also produces tides in the sea in the same manner as the moon, but on account of its greater distance the solar tides are much smaller than the lunar. At new moon and full moon the sun, earth, and moon are all in the same straight line, as shown in Fig. 147, and the lunar and solar tides combine to produce a greater rise and fall than usual, called *spring* tide. At intermediate periods the sun and moon act at right angles to each other and produce a smaller rise and fall than usual, called *neap* tide.

The increased rise of the tide in shallow water near shore, in river mouths, and in wide-mouthed indentations of the coast enables large vessels to penetrate the land. The inward movement of water during a rising tide gives sufficient depth and a favorable current for ingoing vessels, and the outward flow during a falling tide is favorable for outgoing vessels. These conditions are especially important on coasts where the continental shelf is wide, and in estuaries and drowned valleys like those of eastern United States, the British Isles, France, the Netherlands, and Germany.

Currents. — Under the influence of the prevailing winds the surface waters of the sea are driven in wide, shallow streams, or currents, from shore to shore. Deflected by the land masses, they perform great circuits in the ocean basins on each side of the equator. The map on pages 160–161 shows the location and direction of the principal ocean currents. What may be called the trunk streams are the north and south equatorial currents, which, under the influence of the trade winds (Figs. 170, 171, 172), flow westward in broad belts and are turned northward and southward by the eastern shores of the continents. Helped on by the prevailing westerly winds, they recross the oceans in middle latitudes, and, returning toward the equator on western shores, complete the circuits. The eddy in the north Atlantic is joined by a large branch from the south equatorial current and attains exceptional speed, depth, and temperature off the coast of Florida, where it is called the Gulf Stream. This current loses velocity and depth, and, north of 40° N. Lat., spreads out into a sheet of warm surface water which drifts at the rate of a mile or so a day far into the Arctic Ocean.

This large body of warm water in the north Atlantic raises the temperature of the winds which blow over it and contributes to the mildness and humidity of climate in western Europe. The water returns from the Arctic Ocean southward along the east coast of Greenland and Labrador, forming a reversed eddy of cold water.

In the north Pacific the Japan Current, or Kurosiwo, behaves in a similar manner.

In middle southern latitudes the circuit in each ocean is partly merged into the west wind drift, which circulates eastward around the earth in the Southern Ocean. In the northern part of the Indian Ocean the direction of circulation is reversed in winter by the northeast monsoons (Fig. 150).

As a general rule between 40° N. Lat. and 40° S. Lat. the currents bring relatively warm water to the eastern coasts of the continents and relatively cool water to the western coasts. In higher latitudes this rule is reversed. By this circulation of waters the temperatures of the oceans are partly equalized, and, through the influence of the water upon the temperature of the winds blowing over it, the climate of the continents is greatly modified. The most notable effects, due in part to the ocean currents, are the mild winter temperatures and heavy rainfall of western Europe and northwestern North America, and the cool summers of northeastern North America and Asia and southwestern South America.

Ocean currents bring food supply to fixed marine animals such as the coral polyps, which flourish best in the strong, warm equatorial currents, and also to fish which swarm in the cool waters off Newfoundland, Alaska, Norway, and Japan. Most of the numerous small islands in the Pacific,

Fig. 148. — Coral reef, Australia.

and some in other tropical waters, have been built by coral animals, which flourish in such numbers that their skeletons, converted into limestone rock, are piled up by the waves into low ring-shaped reefs and islands.

Economic Relations. — The sea never affords a home or fixed habitation for man. It is essentially a wide, empty space which he cannot occupy or permanently control, but which he can cross whenever he chooses. It therefore plays two contrasted parts in human affairs. It is at the same time a barrier which separates one people from another, and a broad, free, uncrowded highway of communication between them. It keeps nations apart and forms the most easily defended boundary of states, and it brings all the nations of the world together, enabling them to exchange goods and ideas. It is generally barren and unproductive in itself, but the people who use it most become rich, powerful, and enlightened.

With the introduction of steam vessels in the early part of the nineteenth century, the transformation of the sea from a barrier of separation to a highway of communication was begun. The change may now be said to be complete, and constitutes the most important adaptation yet made by man to his environment. More than by any other means, the mobility and circulation of men and goods has been promoted by the use of the sea. Since man is essentially a land animal, adaptation to the sea is for him more difficult than to the land. Consequently the use of the sea has required and developed the highest types of intellect. It requires more skill and courage to command an ocean vessel than to run a railroad train. A modern first-class passenger and freight steamship or a battleship is the most complex and costly piece of mechanism on a large scale man has yet achieved. To construct and run it requires all the material and mental resources of engineering. The profits and rewards of ocean traffic are so large that the great nations of the world rival one another in the invention and construction of merchant vessels to carry their goods, and of warships to protect them.

The sea promotes civilization also by bringing people into many-sided relationships. Along its land boundaries a nation is in contact with one or a few foreign neighbors, but if it has even one seaport it is brought in contact with people from

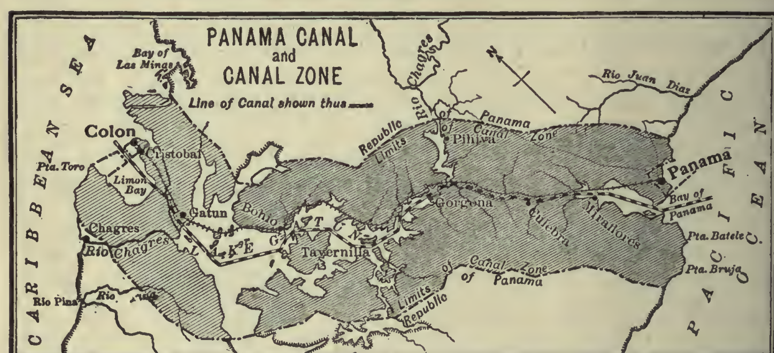


Fig. 149.—Map of Panama Canal and the Canal Zone.

nearly every part of the world. Sea trade is being greatly modified and facilitated by cutting through the narrow isthmuses at Suez and Panama. To go around the world by sea, it will soon be no longer necessary to sail around the Cape of Good Hope and Cape Horn, but by the short-cut canals the whole voyage may be made between 35° N. Lat. and the equator.

The great maritime nations have coöperated in making a careful survey of all the coasts of the world, and have published charts showing the depth of water, the trend of coast lines, and the position of islands and lighthouses, and giving sailing directions for the use of mariners. The great commercial peoples live around the north Atlantic, which thus becomes the oceanic center of the world. The north Pacific bids fair to become in the near future a secondary center of scarcely less importance.

Classification of Coasts (Fig. 150).

(1) *Folded mountain coasts, elevated.* — Slopes steep above and below water. Coastal plains and shelves absent or narrow. Large rivers, deltas, and estuaries rare. Fiords in high latitudes. Sea cliffs almost continuous. Few harbors available for seaports.

(2) *Folded mountain coasts, depressed.* — Coast line double. Outer line of partly submerged mountain chains, forming festoons of islands. Slopes very steep. Inner line of deep border seas with numerous gulfs, bays, and peninsulas. Very complex. Harbors numerous.

(3) *Fault scarp coasts.* — High, smooth, and unindented. Coastal plains and shelves absent or narrow. Estuaries and drowned valleys absent. Deltas at the mouths of large rivers only. Fiords in high latitudes. Harbors rare.

(4) *Plain coasts.* — Bordered by wide coastal plains and shelves. Slopes gentle. Barrier beaches, lagoons, and dunes extensive. Estuaries and drowned valleys numerous.

Fig. 150
MEAN ANNUAL SURFACE TEMPERATURES
SURFACE CURRENTS IN NORTHERN WINTER
AND COAST LINES


GREENLAND
EUROPE
AFRICA
TROPIC OF CANCER
GULF STREAM
STREAM DRIFT
CANARY CURRENT
NORTH EQUATORIAL CURRENT
GUINEA CURRENT
SOUTH EQUATORIAL CURRENT
BRAZILIAN CURRENT
NORTH EAST MONSOON DRIFT
SOUTH EQUATORIAL CURRENT
WEST AUSTRALIAN CURRENT
WEST WIND DRIFT
CURRENTS DURING THE SOUTHWEST MONSOON IN NORTHERN SUMMER
SOUTH WEST MONSOON DRIFT
SOUTH EQUATORIAL CURRENT
L.L. POATES ENG. CO., N.Y.

CHAPTER XII

COASTS AND PORTS

Independently of the work of standing water, the large features and general character of coast lines depend primarily upon the present and past relief of the land. If in the past the land has stood higher than at present and the streams have graded their valleys down to base level, then sinking of the land drowns all the bars, lets tide water far up the valleys, and converts them into long, deep arms of the sea. Many of the best harbors in the world are such *drowned valleys*, or *estuaries* (Figs. 153, 154, 155). A coast line which is rising, or has been recently elevated, is established upon what was formerly sea bottom, and is therefore smooth and only slightly indented by stream valleys. It is apt to be bordered by cliffs and to present few inlets to the land. The gulfs and bays are generally curved in outline and wide open to the sea (Fig. 43).

The Southern Continents. — Of all the continents Africa has the simplest and smoothest coast line (Figs. 16, 150). More than half of it is bordered by plateaus and mountains, and between Guinea and Good Hope and on the Red Sea it is bounded by a fault scarp. Much of the Sahara coast is low, but there are no rivers or inlets except the mouth of the Nile. The coast of Australia resembles that of Africa. But one large river enters the sea. The south coast is smooth and cliffed, with but one large break, — Spencer Gulf, — which is a rift valley (p. 64). The east coast is bordered on the land side by mountains and on the sea side by the Great Barrier coral reef. On the Atlantic side of South America a coastal plain extends from the northern end of the Andes Mountains to Cape St. Roque, and from the mouth of the Plata to the Strait of Magellan, including the deltas of the three great rivers of the continent. Between Cape St. Roque and the Plata low plateaus and mountains rise from a shore which is little indented.

The Pacific Coast of America. — The Pacific coast of America extends about 12,000 miles along the foot of a lofty mountain system. The slopes above and below sea level are steep, and the streams are generally insignificant. Only the Colorado and the Columbia cut through the mountain barrier and bring large volumes of water from the interior. One flows into the Gulf of California, the only long sea arm on the coast and probably a rift valley. The other has a wide estuary. South of 40° S. Lat. and north of 50° N. Lat. this coast is cut into a ragged fringe of long, narrow, steep-walled inlets and high peninsulas, bordered by outlying islands. These arms of the sea are of great depth and often extend as far below sea level as their walls rise above it. They are called *canals* and *fiords*. These coasts are swept by west winds from the ocean, which bring a heavy rainfall. On account of large volume and steep slope the streams have great erosive power, and are able to cut valleys far back into the mountains. On account of high latitude and altitude the snowfall is heavy enough to fill the valleys with ice and to bring about glaciation, which has been more extensive in the past than it is at present. The ice has widened and deepened the valleys, converting them into fiords (Figs. 106, 152, 153, 154). The great depth of water, amounting in some cases to

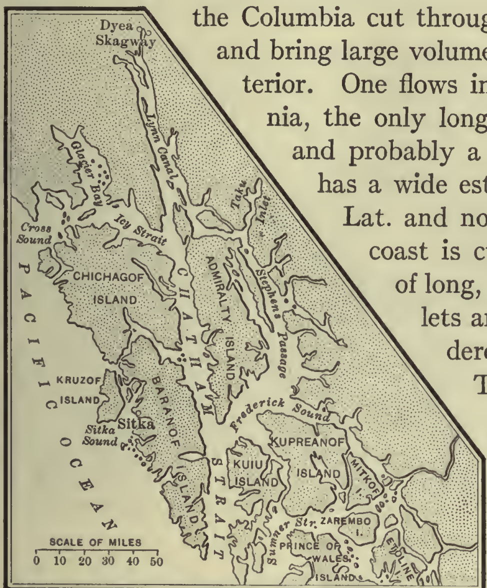


Fig. 151. — Canal coast, Alaska.

4,000 feet, is partly due to sinking of the land. Glaciation has been more severe on some coasts than on others, but all fiord coasts owe their distinctive characters to ice action. Fiord coasts occur also in Norway, Iceland, Scotland, New Zealand, Greenland, and Spitzbergen.

Even after the ice has disappeared fiord coasts are generally unfavorable for human occupation. Deep harbors are superabundant, but the shores are so high and precipitous that landing is difficult, and there is little room for settlement. Land resources are small and population sparse. The people are compelled to take to the sea for a living and become fishermen and sailors. In the past, when the sea was not so well policed as at present, the Norwegian fiords were the nesting places of pirates, who raided and plundered their richer neighbors. The scenery of the Norwegian fiords has long been famous as among the grandest, but is inferior to that of Alaska, where the combination of sea, mountain, forest, and glacier is unrivaled in the world. Fiord coasts of a mild type, such as those of Scotland and Maine, attract thousands of visitors by their agreeable summer climate and picturesque scenery.

Fig. 152.—Fiord, Norway. Glacier in the distance.

Asia. — The Pacific coast of Asia is characterized by a series of island chains arranged in festoons which inclose deep border

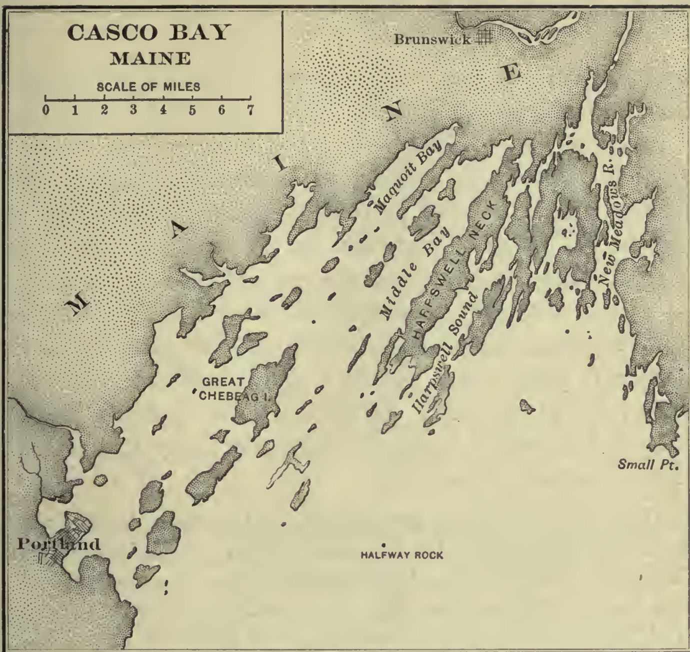


Fig. 153.—Part of the Maine coast. Fiords and islands.

seas between them and the mainland. The islands are mountainous and volcanic, and their slopes plunge seaward into very deep water (Fig. 16). It looks as if the earth crust of Asia had slid toward the sea and wrinkled up around the edge. The mainland coast abounds in peninsulas, bays, and gulfs of varied size and character, and many large, navigable rivers flow into the border seas. This coast in complexity and accessibility is unequaled elsewhere in the world.

Between the South China Sea and the Bay of Bengal the ends of parallel mountain ranges project into the sea, but the rivers have smoothed the coast line by filling in the spaces between the ranges. The head of the Bay of Bengal is occupied by the enormous delta of the Ganges-Brahmaputra. The coasts of India, Persia, and Arabia are defined by lines of fracture, and are generally high and without indentations. The lowlands about the mouth of the Indus and the nearly inclosed Persian Gulf lead to valleys which are desert except for irrigation.

North Atlantic Coasts. — The north Atlantic exceeds all other oceans in the number, variety, and area of its coast waters. The basins of the Caribbean Sea and Gulf of Mexico are very deep and bordered by submerged mountain ranges forming a festoon of islands similar to those of Pacific Asia. The Mediterranean Sea with its branches, on account of its area, depth, and complexity, might be considered a distinct ocean basin. It is nearly divided by mountain ranges, partly submerged, into four great basins and several smaller ones. Its varied character is partly due to the faulting and sinking of great blocks of the earth crust. Inclosed by the shores of three continents, it has been a center of human activity and civilization for five thousand years.

The North and Baltic seas are shallow, but penetrate the land almost as far as the Mediterranean. On the American side the Gulf of St. Lawrence, leading to the chain of Great Lakes, occupies an analogous position. The shallow pan of Hudson Bay occupies a sunken portion of the interior plain of North America behind the highland of Labrador, as the White Sea lies on the European plain behind Scandinavia.

The American and European coasts of the north Atlantic are low and not bordered by highlands except in the north. Many of the river mouths are drowned, forming estuaries. The American and European Mediterraneans are so nearly tideless that the rivers have been able to build great deltas such as those of the Orinoco, Mississippi, Ebro, Rhone, Po, and Nile.

Arctic Coasts. — The coasts of the Arctic Ocean are almost everywhere low and bordered by a wide coastal plain and shelf. The White Sea and the Gulf of Ob are the only important arms. Large rivers, such as the Mackenzie, Petchora, Yenisei, and Lena, have built deltas. On account of the severe climate, and the persistence of snow and ice on land and sea, the Arctic coasts are comparatively inaccessible and unfavorable for human occupation.

Coast Factors. — The degree of indentation of a coast may be expressed mathematically in different ways. If the length of the actual mainland coast line of each continent is divided by the circumference of a circle having an area equal to that of the continent, the following ratios, or *coast factors*, are obtained:

North America	4.9	Australia	2.0
Europe	3.5	South America	2.0
Asia	3.2	Africa	1.8

That is, North America has a coast line nearly five times as long as the shortest possible, while the coast line of Africa is less than twice as long as necessary.

If the mainland area of each continent is divided by the length of its coast line, the following ratios are obtained:

Europe has 1 mile of coast line to		151 square miles of area.		
North America	"	"	164	"	"
Australia	"	"	242	"	"
Asia	"	"	368	"	"
South America	"	"	386	"	"
Africa	"	"	593	"	"

That is, Europe has nearly four times as much coast line in proportion to its area as Africa, and North America has more than twice as much as South America. These facts help to explain why Africa is shut in, isolated, and backward, while Europe has been the center of the highest civilization for 3,000 years, and why North America has become the chief center of civilization outside of Europe.

Ports. — A harbor is primarily a place of shelter from storms. A port is a gateway or place of entrance. In a commercial sense a port is a place where vessels are loaded and unloaded. The existence of a good port depends upon many conditions:

(1) *Accessibility from the water;* that is, a channel deep enough for large vessels, not too crooked, free from rocks and shoals, and not subject to fogs.

(2) *A harbor* well protected from winds and waves, free from ice and strong currents, large enough to furnish anchorage for many vessels, and deep enough to permit them to float near shore.

(3) *A long, low coast line*, where wharves may be built to bring vessels and vehicles alongside of each other.

(4) *Accessibility from the land* by river, canal, or railroads.

River Ports. — The great ports of the world are, with few exceptions, situated at or near the mouths of rivers, usually as far inland as large vessels can go. The distance of the port from the river mouth is greatly increased by the drowning of the lower valley and the occurrence of tides. These conditions may convert a coastal plain with small, shallow rivers, a line of barrier beaches, and a wide coastal shelf, into a first-class commercial seaboard. The Atlantic coasts of North America and Europe furnish striking examples (Fig. 16).

Delta Ports. — In the delta of a large river there is usually one distributary channel which is deep enough for ocean vessels, and on this, at some point where the land is safe from tidal overflow, a seaport is apt to be located. New Orleans, the Rhine ports, and Calcutta are examples. The growth of a sand bar off the mouth of the channel and the shifting of the discharge to some other channel are difficulties liable to occur.

New Orleans, eighty miles from the sea, is above the point where the Mississippi divides into the "passes" of the "goosefoot." A sufficient depth of water was maintained through the South Pass for about thirty years by Captain Eads's jetties, which are embankments designed to narrow the channel, quicken the current, and compel it to remove the bar. A jetty is now being built at the mouth of the Southwest Pass (Fig. 69).

Lagoon Harbors lie behind beaches, bars, spits, or reefs. They are well protected, but are usually too shallow to admit the largest vessels without artificial deepening (Fig. 28). Galveston, Tex., Venice in the Adriatic, and Danzig on the Baltic, are situated on or behind barrier beaches.

Fiord Harbors. — Fiords afford excellent harbors as far as depth of water, clear entrance, and complete protection are concerned, but are seldom favorable for ports on account of high, steep shores and inaccessibility from the land. It is only where these features exist in moderate degree that considerable seaports occur, as Christiania, Norway, and Glasgow, Scotland. In the latter case the fiord cuts entirely through the marginal highland and penetrates the lowland, where the little river Clyde has been enlarged to a canal which admits vessels of all sizes.

Where the sinking of the land has drowned a series of valleys parallel with the coast, a chain of islands is separated from the mainland by straits, sounds, and canals (p. 163), which form an "inside passage," protected from the open sea and traversable by large vessels. The northwest coast of North America and the east shore of the Adriatic furnish striking examples (Fig. 151).

Round Inlets. — A coast inlet with a rounded or semicircular outline is called a *cuvette*, meaning a bowl or basin. Cuvettes are sometimes due to faulting along a succession of curves, as on the west coast of Italy and south coast of France. The greatest seaports of the Mediterranean — Marseilles, Genoa, and Naples — are situated upon such bays.

Deep Straits connecting large bodies of water are highways of commerce, and are apt to develop important seaports, of which Constantinople and Singapore are examples.

Artificial Harbors. — All harbors have to be improved more or less by artificial works to accommodate large shipping. Wharves must be built, alongside of which vessels may be tied, and facilities for transferring cargoes must be furnished. Often channels must be deepened by dredging, and in some cases canals are dug to admit ocean vessels to inland cities.

Ships reach Amsterdam only by the North Sea Canal, recently constructed. A canal 35 miles long has converted Manchester from an inland manufacturing city to a seaport and financial center. At Hamburg $44,000,000 has been spent in providing wharves and basins, and London is facing the necessity of spending $100,000,000 to improve the port and hold supremacy in trade. Large sums have recently been spent in making artificial harbors at Puerto Mexico, and Salina Cruz, the termini of the railroad across the Isthmus of Tehuantepec, in Mexico, and at Colon and Panama where the Panama Canal reaches the sea.

In cases where it is impossible to extend the sea into the land, the land is built out into the sea in the form of a breakwater, which creates an artificial lagoon harbor behind it. At San Pedro, California, the breakwater is nearly two miles long.

Lake Ports are generally situated on river harbors and are improved by dredging the river mouth and building a breakwater outside. The harbors of Chicago, Cleveland, and Buffalo are of this character.

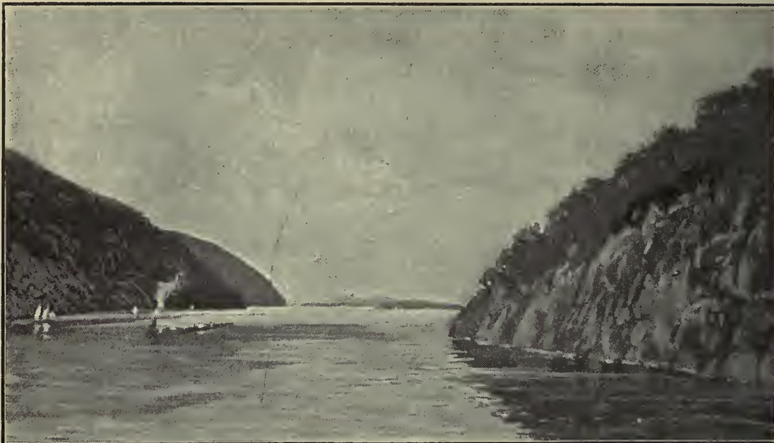


Fig. 154.—Drowned valley of the Hudson: a fiord.

The Port of New York. — New York is situated upon a harbor of a mild fiord type, combined with a lagoon. The lower Hudson is a fiord which has been partly filled with sediment. The East River and Long Island Sound constitute an "inside passage" between the mainland and Long Island. The fiord and passage expand at their junction into the deep upper bay. The tidal currents are strong enough to scour out the channels. The shores furnish fifty miles of wharf line with deep water, and there is room enough to build piers at right angles to the shore, so as to accommodate a large number of ships. The lower bay is an antechamber of an entirely different character. It is a shallow indentation partly fenced from the open sea by the barrier beach of Coney Island and the spit of Sandy Hook, both of which are growing farther into the bay and threatening to close it. Much difficulty and expense are incurred in maintaining a channel deep enough for the largest vessels.

Fig. 155
NEW YORK CITY
AND VICINITY

CHAPTER XIII

THE ATMOSPHERE

Composition. — The atmosphere, or gaseous portion of the earth, forms a complete spheroidal shell which surrounds the solid and liquid globe, and not only rests upon the surface of land and sea, but also penetrates them to a great depth. Its thickness, which is not definitely known, is certainly several hundred miles and may be many thousand. Its bulk is almost entirely made up of five gases, which are present in the proportions given in the following table:

COMPOSITION OF THE AIR

Gas	Per cent of Volume	Density
Nitrogen	76.95	.971
Oxygen	20.61	1.105
Water vapor (average)	1.40	.624
Argon	1.00	1.380
Carbon dioxide (average)	0.03	1.529
Air	99.99	1.000

These gases are not united or combined in any way, but are almost entirely independent of one another. They act like five separate and distinct atmospheres occupying the same space at the same time. The space which each gas occupies is determined by the balance between its own expansive force, tending to make it expand indefinitely, and gravitation, which holds it down to the earth. Carbon dioxide, being the heaviest of all these gases, does not extend so far upward as the others. Oxygen is a little heavier than nitrogen, and its relative proportion decreases in the upper air. Water vapor is the lightest of all, but its existence as vapor is so far dependent upon a warm temperature that it is absent at great heights.

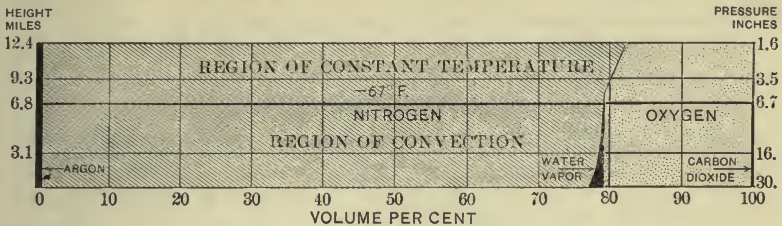


Fig. 156. — Composition of lower atmosphere.

Properties and Functions. — *Oxygen* combines freely with nearly all the elements, and in its numerous compounds forms about half of the whole weight of the globe. By the process of respiration it supports the life of all plants and animals, and it is the universal agent of combustion. By respiration, combustion, decay, and other processes of oxidation the quantity of oxygen in the air is being continually diminished. This loss is partly compensated by the oxygen set free from plants in the process of food manufacture.

Nitrogen is extremely inert and enters into combination with other elements with difficulty. To it is due nearly three fourths of the pressure and density of the air. Without it birds could not fly, clouds and smoke would settle to the ground, and the force of the wind and the loudness of sound would be proportionately diminished.

Argon resembles nitrogen, with which it was confounded until near the end of the nineteenth century.

Carbon dioxide (CO_2), or carbonic acid gas, is a compound of carbon and oxygen formed in the active, growing parts of plants and in the tissues of all animals and given off by them in the process of respiration. It is also produced by the combustion of all the ordinary forms of fuel, and sometimes escapes in large quantities from active volcanoes, old volcanic regions, and from many mineral springs. It forms the chief food supply of plants. The green parts of plants in the sunlight absorb carbon dioxide, separate it into its elements, retain the carbon, and give off the oxygen. Carbon dioxide plays an active part in rock formation, entering into combination with lime and other bases to form limestones. It also enters largely into the composition of the bones and shells of animals. While the absolute quantity of carbon dioxide is the least of all the principal constituents of the air, the part it plays in the economy of nature is second to none.

Water vapor is supplied by evaporation from all damp surfaces, but chiefly from the sea. When cooled it condenses again into water and forms clouds, rain, and snow. The quantity present in the air at different times and places is very variable, amounting sometimes to five per cent.

Dust. — The lower air generally contains more or less matter in the form of dust, analogous to the sediment suspended in running water. Dust consists of finely pulverized rock lifted by the wind or blown to great heights by volcanic eruptions, carbon particles from the smoke of fires, particles of plant and animal tissue, vegetable spores, bacteria, and other minute organisms. A cubic inch of air in dry regions may contain thousands of these particles.

Dust in the air diffuses and scatters the rays of sunlight. In a dustless atmosphere all shadows would be a deep black, and the sky itself would appear black. Dust scatters the blue rays more than the red, and is the chief cause of the blue color of the sky and of the red and yellow colors at sunrise and sunset. Dust plays an important part in the formation of fog and clouds by supplying nuclei upon which the water vapor begins to condense. The dense fogs of London and other cities occur when the air is full of smoke particles. Minute organisms in the air furnish the germs of disease and the agents of decomposition, as when fermentation is set up in cider or grape juice exposed in open vessels.

Temperature. — The temperature of the air is determined by the amount of heat received and absorbed from the sun and earth. As the sun heat passes through the air on its way to the earth, about one third of it is absorbed by the air and goes to raise its temperature, while the remaining two thirds reaches the surface of the land and water. A part of this is reflected back without warming the earth, and another part, being absorbed, goes to raise or maintain the temperature of the land and water. The warm earth in turn warms the air next to it slightly by conduction and still more by radiating its heat upward.

The lower air absorbs much more heat than the upper air, and consequently is maintained at a higher temperature. This is due largely to the presence of cloud, fog, dust, and smoke. The larger proportions of carbon dioxide and water vapor in the lower air also increase its absorptive power for heat. Curnts of warm air are constantly rising from land and water and oling by expansion. In consequence of these conditions, the mperature of the atmoshere falls at the rate of bout one degree for every oo feet of ascent, from sea vel up to a height of six r seven miles (Fig. 156).

Distribution of Light and Ieat. — If the earth were a at disk and one side were lways turned toward the un, the sun's rays would trike everywhere at the ame angle and every part f that side would be contantly and equally lighted nd heated (Fig. 157, *A*). If spheroidal earth stood till, the same half of it vould be always lighted nd warmed, but not uniformly. The spot where the direct rays strike would be strongly lighted and would become very hot, but the more slanting rays would cause the light and heat to decrease in every direction to the margin of the hemisphere. The dark side of the earth would be uniformly cold. Thus the light and heat belts would be arranged concentrically around the center of the lighted side (Fig. 157, *B*). If such an earth should

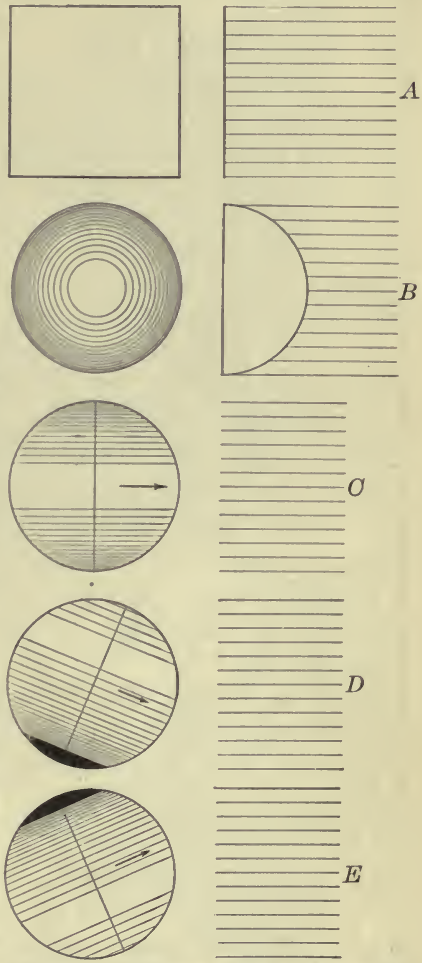


Fig. 157. — **Distribution of light and heat on the earth under various conditions.**

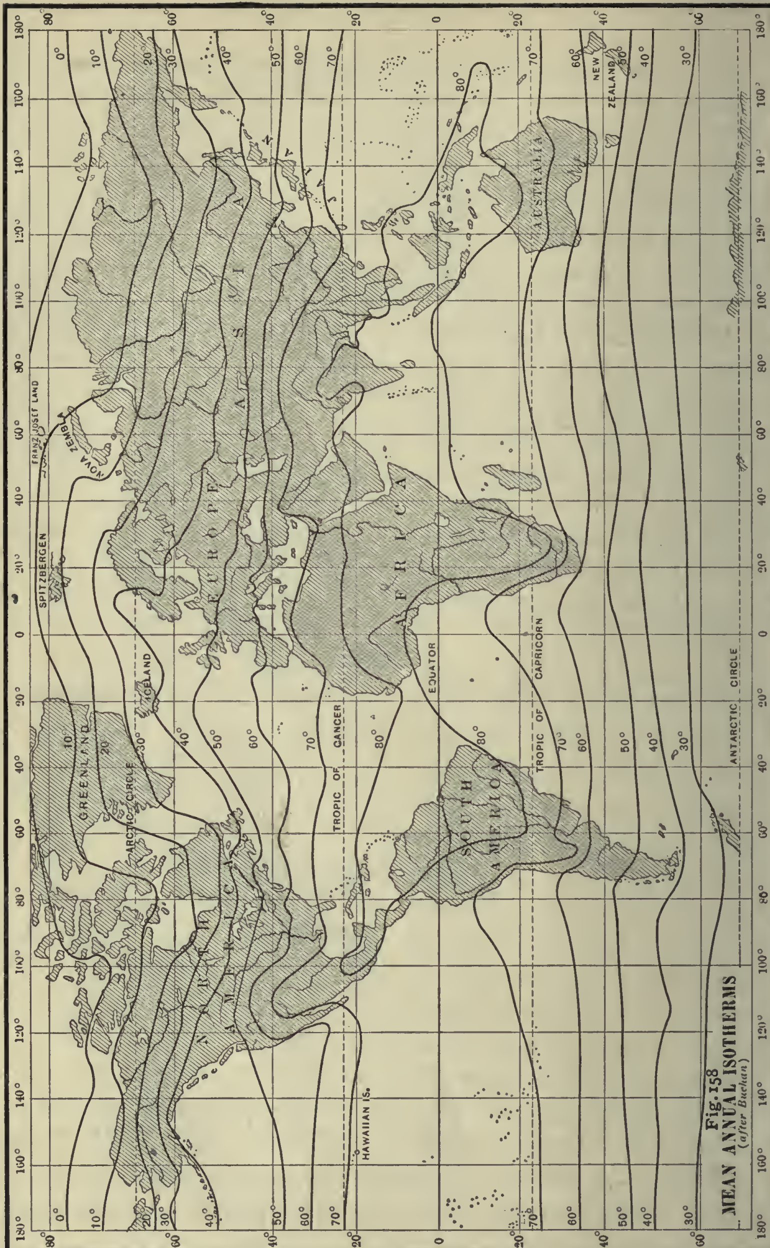


Fig. 158
MEAN ANNUAL ISOTHERMS
(after Buchan)

begin to rotate with the sun directly over the equator, the light and heat belts would be strung out into zones extending around it parallel with the equator, the light and heat would decrease everywhere uniformly from the equator to the poles, and all places would have days and nights of equal length. Our earth is in about that condition in March and September (Fig. 157, *C*). If a spheroidal, rotating earth should begin to revolve around the sun with its axis inclined so that the sun is not always over the equator, the light and heat belts would follow the sun, swinging back and forth, north and south, once in every revolution. The days and nights would not be of the same length at different places or at the same place at different times. Thus a change of seasons would occur such as we have upon our earth (Fig. 157, *D* and *E*).

Heat Belts. — A state of things exactly as described above exists on our earth so far as the light belts are concerned, which always extend around the earth parallel with the equator; but the heat belts are bent out of shape by land and water, by winds, and by ocean currents. The land is heated and cooled more rapidly than water, consequently continents are warmer in summer and colder in winter than oceans which receive the same amount of heat from the sun. In summer the heat belts are bent away from the equator over the land and toward the equator over the water; in winter, the reverse. Heat belts cannot be bounded by parallels of latitude, like the tropics and polar circles, but by *isotherms*, or lines of equal temperature (Figs. 158, 159, 160), which are quite crooked.

Winds and ocean currents carry their temperatures, whether warm or cold, to the regions toward which they move, and sweep the isotherms along with them. In general, currents of air or water moving from the equator carry warmth with them and bend the isotherms poleward, and currents moving toward the equator carry coolness and bend the isotherms equatorward.

The isotherms as a whole shift north and south with the seasons according to the varying angle of the sun's rays. They are not in exactly the same positions on any two successive days. Their

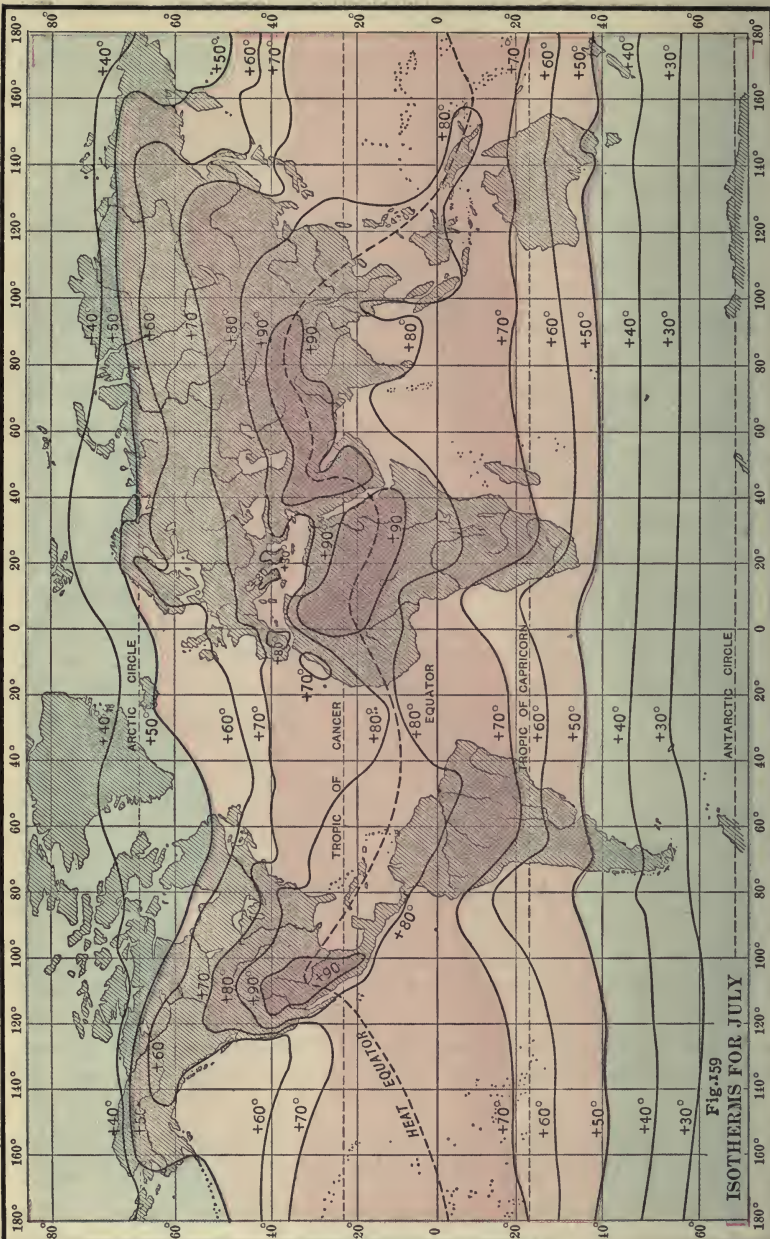


Fig. 159
ISOTHERMS FOR JULY

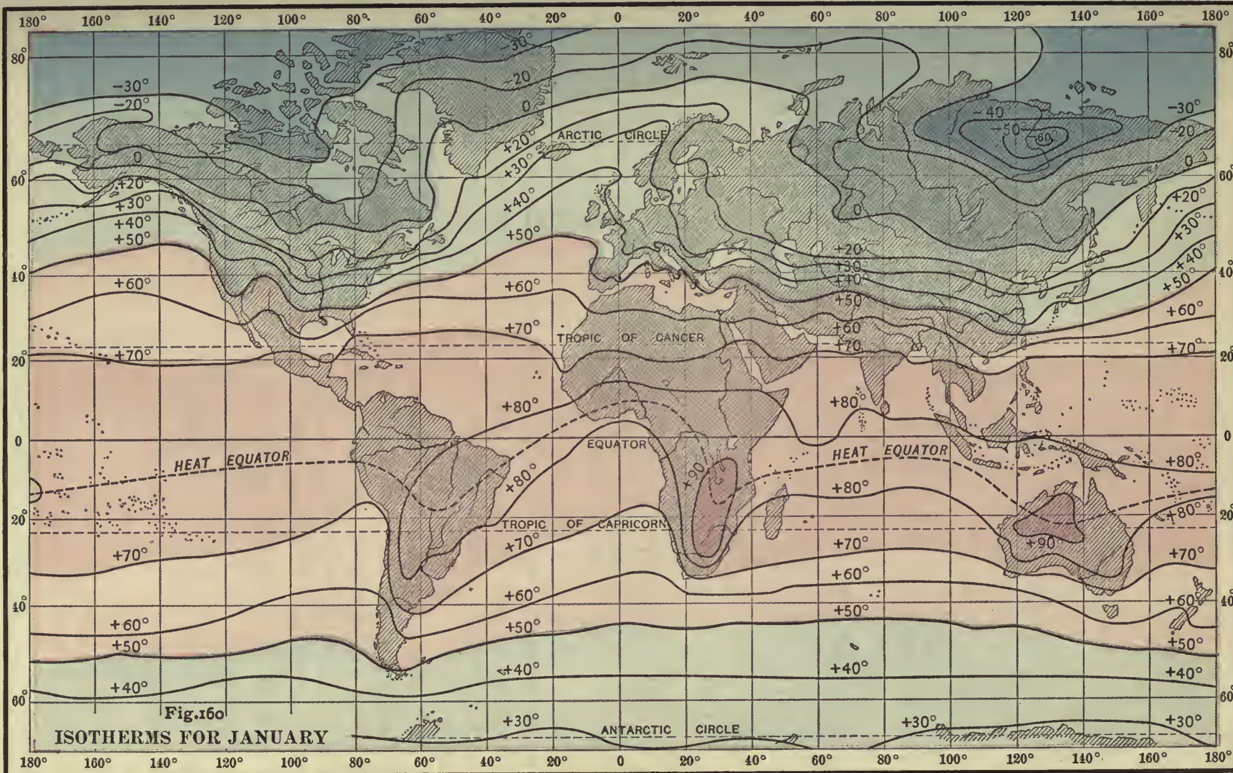


Fig. 160

ISOTHERMS FOR JANUARY

positions in July and January, the months of extreme position, show the character and extent of the shifting (Figs. 159, 160). Instead of calculating the temperature by months, it may be calculated for a series of years, and the resulting isotherms show the mean annual temperatures (Fig. 158).

Range of Temperature. — The mean annual temperature of any place is important, but the temperature of the warmest month and day, and that of the coldest month and day, are more important. The difference between the temperature of the warmest month and that of the coldest month at any place is called the *annual range*. The difference between the temperature of the warmest day and that of the coldest day is called the *absolute* annual range. The range of temperature is greater on land than on water in the same latitude.

Bodies of water are warmed more slowly than land in the day and the summer, and cooled more slowly at night and in the winter. The relatively uniform temperature of the ocean throughout the year and the extreme variations of temperature on land cause a marked contrast between oceanic and continental climates. The range of temperature increases with latitude, because in the course of a year both the angle of the sun's rays and the length of day and night vary more toward the poles than near the equator. The range of temperature is greater in the northern hemisphere than in the southern on account of the large land areas in one and the expanse of water in the other (Fig. 161).

The mean annual temperatures at London, New York, Seattle, and Yokohama are about the same, but the annual range at London and Seattle is about 20 degrees, and at New York and Yokohama about 40 degrees. This is due to the prevailing westerly winds, which blow from the ocean in one case and from the land in the other.

Zones of Temperature. — Along any meridian the temperature changes gradually, but it is convenient to divide the face of the earth into zones bounded by certain definite isotherms. In middle and high latitudes the summer temperatures are far more important than the winter temperatures, because they determine what plants can grow, what crops can be raised, and the number of people any region can support. The annual isotherm of 70° in each hemisphere is not far from the tropics, and is practically the limit of tropical plants such as palms, bananas, and dates. The isotherm of 50° for the warmest month in each hemisphere is about the polar limit of cereal grains and forest trees. Beyond that men maintain themselves only with great difficulty. These lines surround two caps of polar climate, between which lies the whole habitable world. This again is divided into a zone of tropical climate and two zones of temperate climate, of which the northern is much wider than the southern and covers the most favorable regions for human life (Fig. 162).

There are many schemes for dividing the earth into zones of temperature, among which this is one of the simplest and most useful. For some purposes a more exact and detailed subdivision is necessary.

Temperature Belts. — Temperatures above 70° may be called hot, between 70° and 50° temperate, and below 50° cold. If the isotherms of 70° and 50° for July and January are drawn on the same map, the result is a system of nine zones which show the annual and seasonal conditions of temperature with sufficient exactness (Fig. 164).

In the equatorial zone, which lies approximately between the tropics, the average monthly temperature is above 70° at all seasons. The subtropical zones are hot with a temperate season, or temperate with a hot season. In the temperate zones the monthly temperature would be between 70° and 50° at all seasons, if it were not for the influence of the land masses. In the northern hemisphere these truly temperate conditions are reversed over nearly all the land surface of the zone. In North America and Eurasia wide areas have hot summers and cold winters, and the climate deserves the name of *intemperate*. These regions have a temperate climate in spring and fall, a hot summer and a cold winter. In the southern hemisphere these intemperate conditions prevail only in small portions of South America and Australia. The rest of the zone is truly temperate. The cold temperate zones have a temperate climate with a cold season, or a cold climate with a temperate season. In the polar caps the monthly temperature is below 50° at all seasons.

Pressure. — At sea level a cubic foot of air weighs about one ounce and a quarter, and the weight of all the air above sea level produces an average pressure of 14.74 pounds upon every

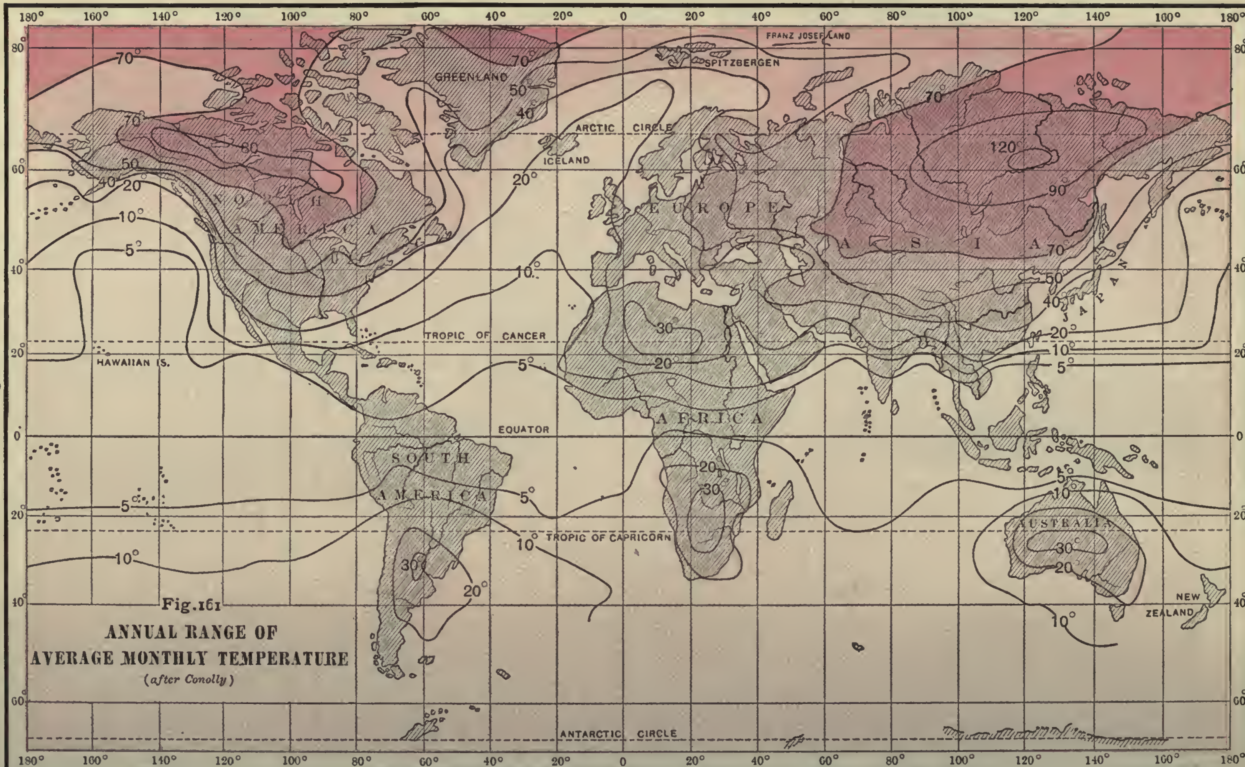


Fig. 161
ANNUAL RANGE OF
AVERAGE MONTHLY TEMPERATURE
(*after Conolly*)

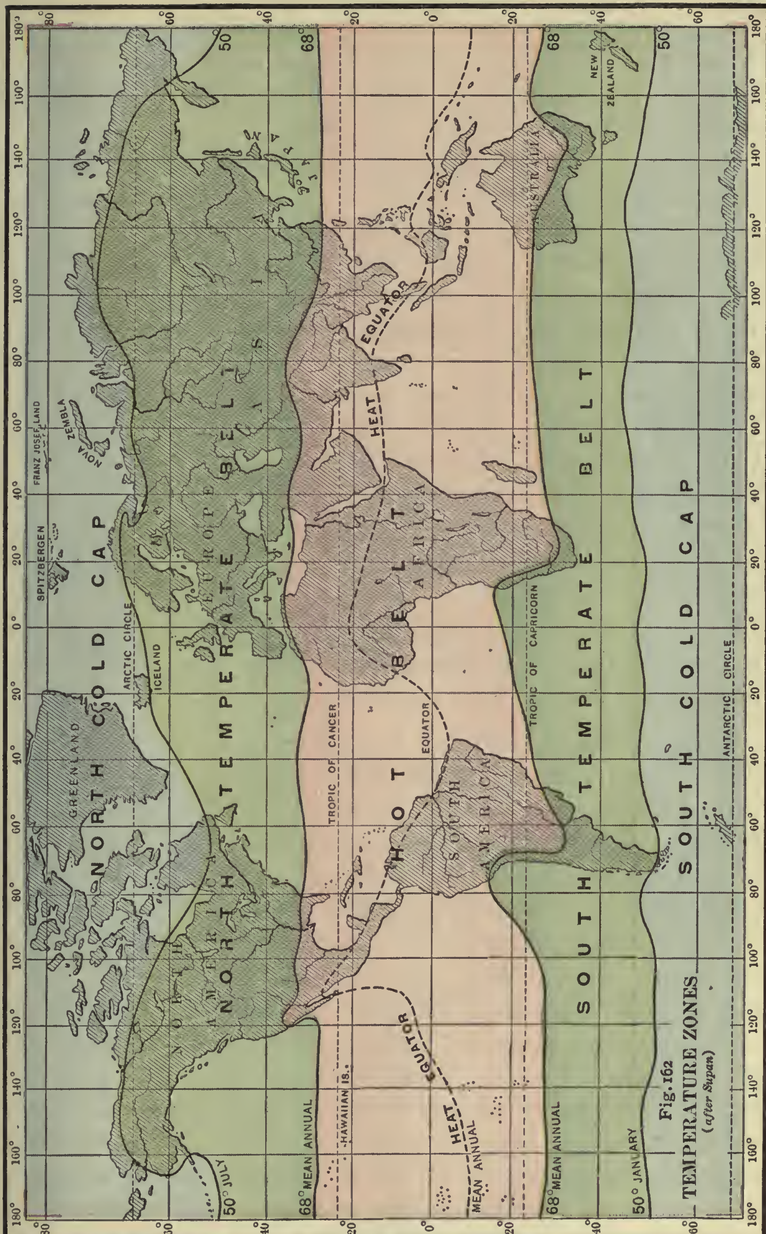


Fig. 162
TEMPERATURE ZONES
(after Supan)

square inch of surface. This pressure is equal in all directions, — downwards, upwards, or sidewise at any angle. The pressure of the air is measured by the *barometer*.

Density. — The air being easily compressed, its density is proportional to the pressure to which it is subjected, and consequently diminishes as the height above the sea increases. Density and pressure are also influenced by other conditions, of which temperature and humidity, or quantity of water vapor it contains, are the most important. When air is heated it expands and becomes less dense. The same effect is produced by the addition of water vapor. On warm, damp days the pressure and density are less, and the barometer stands lower than on cold, dry days.

The distribution of pressure is shown on a map by *isobars*, or lines drawn through places where the pressure is the same (Figs. 165, 166).

Fig. 163. — Two forms of the barometer.

Laws of Winds. — Of all the materials of the earth, the air is the most mobile and sensitive to change. When air is heated or made more damp by the addition of water vapor, it expands and becomes less dense than the surrounding air, which crowds in from all sides and buoys the lighter air upward. The updraft in a chimney or over an open fire, and the slower movement of the air toward the fire, furnish familiar examples of convection currents on a small scale. Every wind that blows is a part of a similar movement, in which gravitation pulls heavy air downward and compels light air to move upward. In the regions of ascending and descending air the movement is usually imperceptible and a calm prevails, but between these regions, which may

TEMPERATURE BELTS

Fig. 164

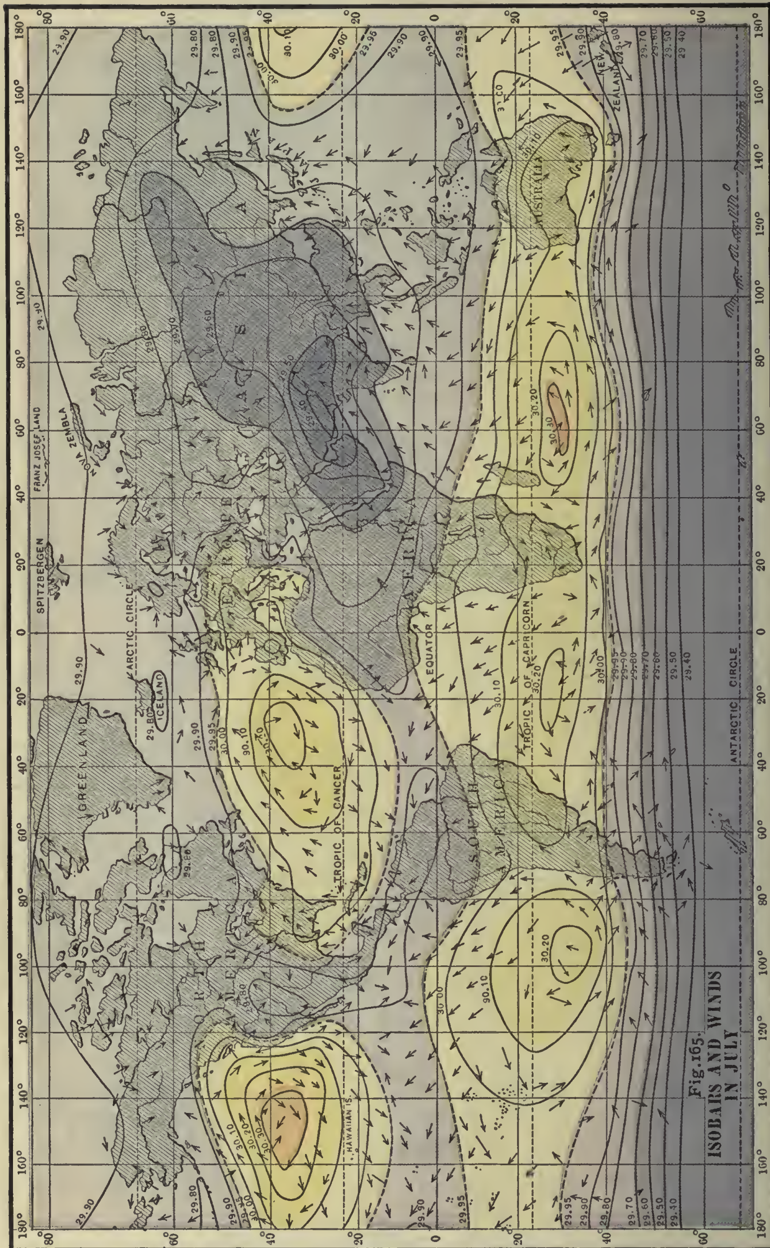


Fig. 165. ISOBARS AND WINDS IN JULY

L.L. POATES ENG. CO., N.Y.

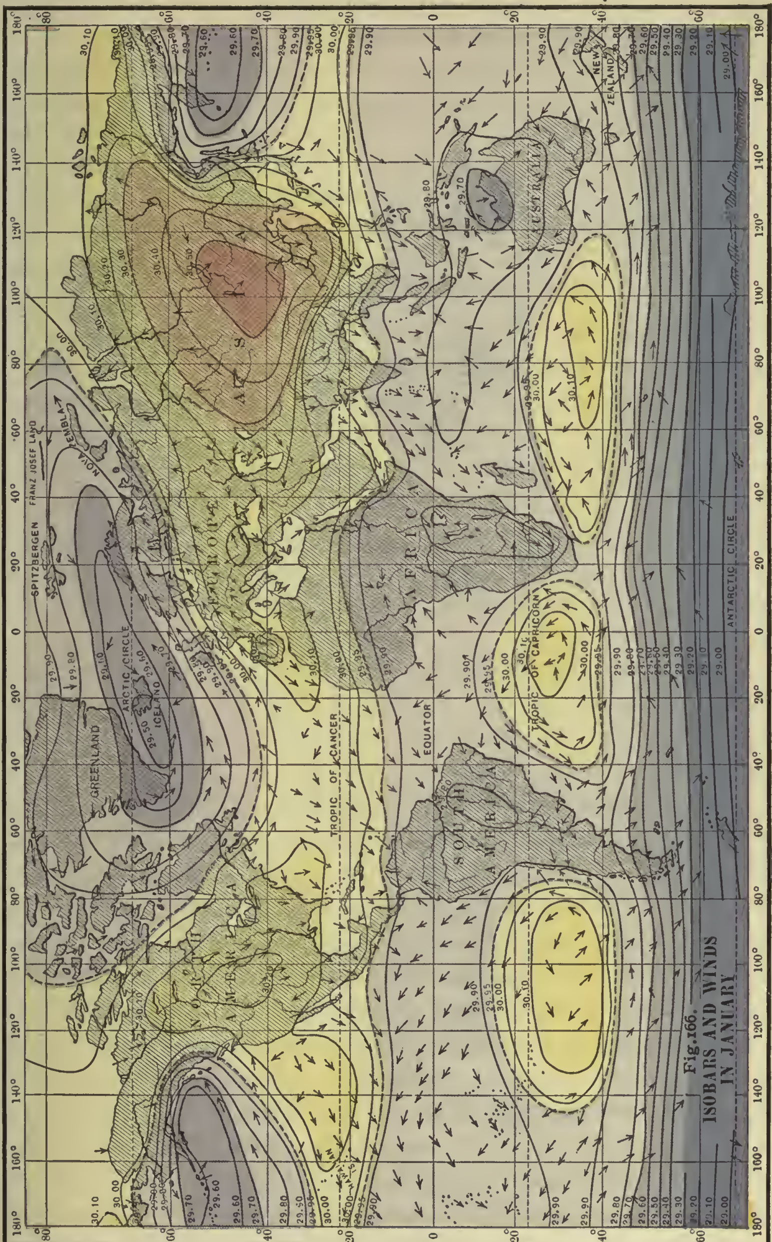


Fig. 166.
ISOBARS AND WINDS
IN JANUARY

L.L. POATES ENG. CO., N.Y.

be hundreds or thousands of miles apart, horizontal currents exist which constitute the surface winds. Where the pressure as measured by the barometer is high the air is heavy and settling; where the pressure is low the air is light and rising.

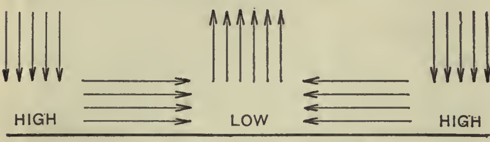


Fig. 167.—Pressure and direction of wind.

Hence the first law: *Winds always blow from regions of high pressure to regions of low pressure* (Figs. 177–180).

Gravitation acting alone would make air move from a region of high pressure to a region of low pressure by the shortest path, crossing the isobars at right angles, just as it makes water flow down a slope by the steepest course; but other influences make the course of the wind less direct. Second law: *The rotation of the earth turns winds blowing from any direction to the right of a direct course in the northern hemisphere, and to the left in the southern.*

The greater the difference of pressure between two regions the faster the air moves. Third law: *Where the isobars are close together the winds are steady and strong, and where the isobars are far apart the winds are light and shifting.*

Distribution of Pressure. — On account of the constantly high temperature near the equator the pressure there is generally low (Figs. 165, 166), but in middle latitudes the land is colder than the water in winter and warmer in summer, and this produces rounded or elliptical areas of high and low pressure which change their positions with the seasons. In the northern winter very high pressures prevail over the interior of Asia and North America, and low pressures over the north Atlantic and Pacific oceans. In summer the conditions are reversed. In the southern hemisphere the land masses never get cold enough to have higher pressures than the oceans. In winter (Fig. 165) a belt of high pressure extends along the southern tropic nearly around the earth, crossing land and sea except a gap in the south Pacific.

In summer (Fig. 166) the heated continents break this belt into three parts, one over each ocean. In spite of the very low temperatures in the polar regions, the pressures there are generally low because there is less air above them.

Cyclones and Anticyclones. — The winds blow outward from centers of high pressure in all directions. The movement starts along radial lines like the spokes of a wheel, but the rotation of

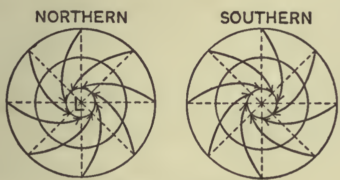


Fig. 168. — Cyclone.

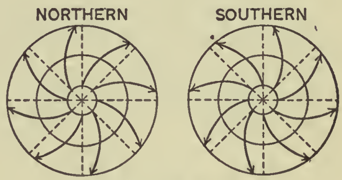


Fig. 169. — Anticyclone.

the earth (second law) changes it to a spiral movement clockwise in the northern hemisphere and counterclockwise in the southern (Fig. 169). The winds blow inward toward centers of low pressure from all directions, but the rotation of the earth gives them a spiral motion counterclockwise in the northern hemisphere and clockwise in the southern (Fig. 168). As the winds approach the center, they are crowded into a narrower space, their velocity increases, and their paths become more nearly circular until a whirl or eddy is set up. The movement is like that of water running out through a hole in the bottom of a bowl, only the air escapes upward instead of downward. A mass of air moving spirally inward toward a center of low pressure is called a *cyclone*. The path of the wind in a cyclone in the northern hemisphere is a curve like the figure 6; in the southern hemisphere like a reversed 6. A mass of air moving spirally outward from a center of high pressure is called an *anticyclone*.

Wind Belts. — The prevailing low pressures in the equatorial regions and the presence of areas of high pressure in the tropical regions divide the earth into wind belts, which are more regular in the southern hemisphere than in the northern. Near the equator the air is always warm and rising, a condition which produces a belt of *equatorial calms*. Between the equatorial calms and the southern tropical regions the general movement is toward the equator and westward, producing a belt of constant *southeast trade winds*. South of the southern tropical regions the air moves steadily and strongly eastward in a great spiral whirl around the polar region, producing a belt of almost *constant west winds*. The movement of air within the Antarctic circle is not well known.

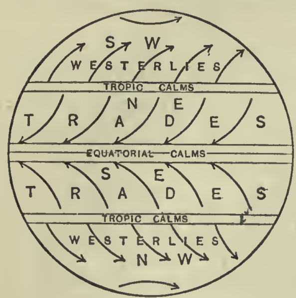


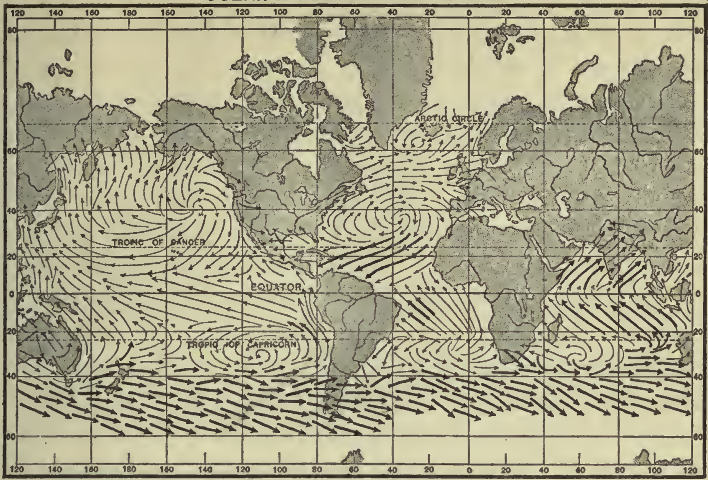
Fig. 170.

Between the equatorial calms and the northern tropical regions is a belt of *northeast trade winds*, but these are not so regular and constant as the southeast trades. North of the northern tropical regions there is a belt of *prevailing westerly winds*, but on account of the large land masses, with their changing temperatures and pressures, these winds are not so regular and constant as the west winds of the southern hemisphere. There is something like a north polar whirl, but it is broken up by the areas of low pressure over the oceans in winter and over the continents in summer. Along the southern tropic and a little north of the northern tropic there are belts of relatively high pressure, where the air is descending, and from which the trades and westerly winds blow. These are called the *tropical calms*. The conditions in the southern hemisphere show what the planetary system of winds would be if the land masses did not interfere. This ideal system, to which the actual system approaches more or less closely, is shown in Fig. 170, which should be carefully studied and used as a key to the actual system.

The wind belts, like the temperature belts, shift north and south with the seasons, following the position of the vertical sun in the heavens (Figs. 165, 166, 171, 172).

Monsoons. — The greatest disturbing influence in the wind system is the large land mass of Asia. In winter it is an area

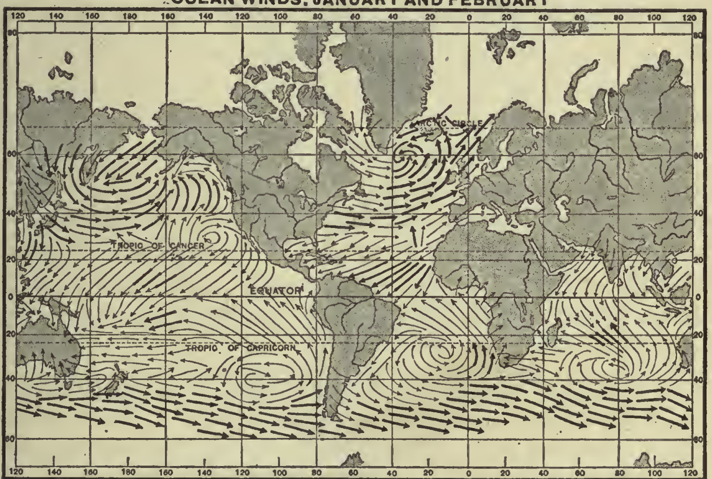
OCEAN WINDS. JULY AND AUGUST



Less than 18 Miles an hour ⟶ } Variable Winds
Over " " ⟶ }
⟶ Steady "

Fig. 171.

OCEAN WINDS. JANUARY AND FEBRUARY



Less than 18 Miles an hour ⟶ } Variable Winds
Over " " ⟶ }
⟶ Steady "

Fig. 172.

of low temperature and very high pressure, from which the winds blow outward in all directions (Fig. 172). In summer it is an area of high temperature and low pressure, which deflects the belt of calms far north of the equator (Fig. 171). At this season the southeast trades over the Indian Ocean cross the equator and, turning eastward, become the *southwest monsoon*, while over the western Pacific the northeast trades become southerly and southeasterly winds (Fig. 171). These directions are opposite to the wind directions in winter. Winds which are thus reversed with the seasons are called *monsoons*. Less important monsoon regions exist upon the west coasts of Africa and South America.

Economic Relations. — Winds are of the greatest importance to the life of plants, animals, and men because they transfer great masses of air from one part of the earth to another. They carry the conditions of temperature and moisture which exist in the regions from which they come to the regions over which they blow, and as they go on they themselves gradually acquire new conditions. Winds blowing over warm waters become warm and laden with water vapor, which they let fall as rain upon the land. Winds from a large land mass are dry and may be the cause of desert conditions in lands to which they blow. Winds moving from a warmer to a colder region bring warm, damp weather, and winds blowing from a colder to a warmer region bring cool, dry weather. Winds blowing from the ocean against a mountain range or plateau bring heavy rainfall to the windward side and little or no rain to the leeward side (Fig. 185). Rising air is always cooled and generally causes cloud to form and rain to fall. Descending air is warmed, and brings clear, dry weather.

Most changes of weather are due to changes in the direction of the wind. Some winds are agreeable and favorable to life; some bring suffering, destruction, and death. Even light breezes effect a continual change of air, which brings more food to plants and animals and removes waste and injurious gases.

CHAPTER XIV

MOISTURE IN THE AIR

Capacity and Humidity. — The atmosphere, as well as the ocean, is a great reservoir of water. Everywhere over the face of the earth the air contains a variable quantity of invisible vapor, which may amount to as much as five per cent. If all the vapor in the air should be condensed and fall as rain, it would be sufficient to cover the whole face of the earth with water to the depth of one inch. Water is constantly evaporating from the sea, lakes, rivers, and land surface. Even ice evaporates, but the higher the temperature of the water the more rapid is the evaporation. The quantity of water vapor which can exist in any given space increases with the temperature of the vapor, whether the space is already filled with air or not. Warm air can contain more vapor than cold air because the air determines the temperature of the vapor in it. When the space or air contains all the vapor it can hold, it is said to be *saturated*. The table on page 194 gives the weight of vapor which can exist in a cubic foot of space or air at various temperatures. These quantities are called the *capacity* for vapor.

When water evaporates it expands instantly to about 1,700 times its liquid volume, and the vapor rapidly diffuses itself through the air in the vicinity. The evaporation and diffusion are hastened by currents of air which carry the vapor away from the evaporating surface. The dryness or dampness of the air is measured not by its *absolute humidity*, or the quantity of vapor actually present in it, but by its *relative humidity*, or the ratio of its absolute humidity to its capacity. If the air out of doors is at a temperature of 32°, and contains two grains of vapor in each cubic foot, it is very damp, because it is nearly saturated; but if the same air is brought into the house and heated to 70°, it becomes very dry, because

GRAINS OF WATER VAPOR IN A CUBIC FOOT OF SATURATED SPACE OR AIR AT VARIOUS TEMPERATURES

10°	.776	34°	2.279	58°	5.370	82°	11.626
12°	.856	36°	2.457	60°	5.745	84°	12.356
14°	.941	38°	2.646	62°	6.142	86°	13.127
16°	1.032	40°	2.849	64°	6.563	88°	13.937
18°	1.128	42°	3.064	66°	7.009	90°	14.790
20°	1.235	44°	3.294	68°	7.480	92°	15.689
22°	1.355	46°	3.539	70°	7.980	94°	16.634
24°	1.483	48°	3.800	72°	8.508	96°	17.626
26°	1.623	50°	4.076	74°	9.066	98°	18.671
28°	1.773	52°	4.372	76°	9.655	100°	19.766
30°	1.935	54°	4.685	78°	10.277	102°	20.917
32°	2.113	56°	5.016	80°	10.934	104°	22.125

it is then only one fourth saturated. This is the reason why air in heated rooms in the winter is generally too dry for comfort and health, and pans of water should be placed where they will supply more moisture.

Unsaturated air is always ready to take up more moisture, but if saturated air at any temperature is cooled a part of the vapor immediately condenses into water. If a bright tin cup is filled half full of warm water, and cold water or ice is added, the cup will generally get cold enough to cause a deposit of dew on the outside. The dew is formed by condensation of vapor from the air. This is the reason why a pitcher or glass of cold water will sometimes "sweat" in warm weather.

If the water in the tin cup is stirred with a thermometer, the temperature observed at the moment of the first appearance of dew is called the *dew point*. It is the temperature of saturation, and from it the absolute humidity may be found by consulting the table. The capacity of the air may be found by noting its temperature and again consulting the table. The absolute humidity divided by the capacity gives the relative humidity. If the temperature of the air is 70°, its capacity is 7.980 grains to the cubic foot. If the dew point is 40°, the absolute humidity of the air is 2.849 grains, and its relative humidity is 2.849 ÷ 7.980, or 35.7 per cent. That is, the air is 35.7 per cent full, and is moderately dry.

Condensation. — When air is cooled below its dew point, some of the vapor condenses into dew, frost, fog, cloud, rain, or snow. The atmosphere is cooled and its vapor condensed by several processes.

1. *Expansion.*— Whenever air rises it expands, and, without any transfer of heat to other bodies, it is cooled one degree for every 183 feet of ascent. As soon as the temperature falls below dew point and condensation begins, cooling is retarded or stopped. Descending air is always warmed by compression one degree for every 183 feet of descent; hence condensation seldom occurs in descending air.

2. *Radiation.* — If the air stands or passes over or near cooler objects, as the ground, the sea, snow, ice, or a mass of cooler air, it radiates its heat, its temperature falls, and condensation may occur. This usually takes place when winds blow from warmer to cooler regions.

3. *Conduction.* — Air in contact with a cooler body loses heat by conduction. This process is less important than is commonly supposed, because air is a poor conductor of heat and only that portion which actually touches a cooler body is cooled in this way. Dew and frost are generally deposited from air in contact with a cold surface.

4. *Mixture.* — When warm air is mixed with cool air, the temperature of the mixture may fall below the dew point and condensation may take place.

Fig. 173.—Fog seen from mountain top above it, California.

Clouds. — When water vapor is condensed in the air, it becomes visible as fog or cloud, which is composed of minute particles of liquid water or ice, a sort of water dust. Fog is

Fig. 174. — Upper part of cumulus clouds.

Fig. 175. — Stratus clouds.

formed at or near the surface of land or water, cloud at higher altitudes. Clouds usually settle slowly and, on reaching a layer of warmer or drier air, evaporate. If condensation continues they are renewed above as fast as they evaporate below.

Cumulus clouds are rounded masses which look white in sunlight and dark in shadow. They begin to form at the level where a rising column of air reaches the dew point, and may be piled up to a height of five miles or more. They are common in equatorial regions and on calm summer afternoons, when the air which starts upward in the morning has reached a sufficient height. They often bring showers and thunderstorms and hence are sometimes called "thunder heads."

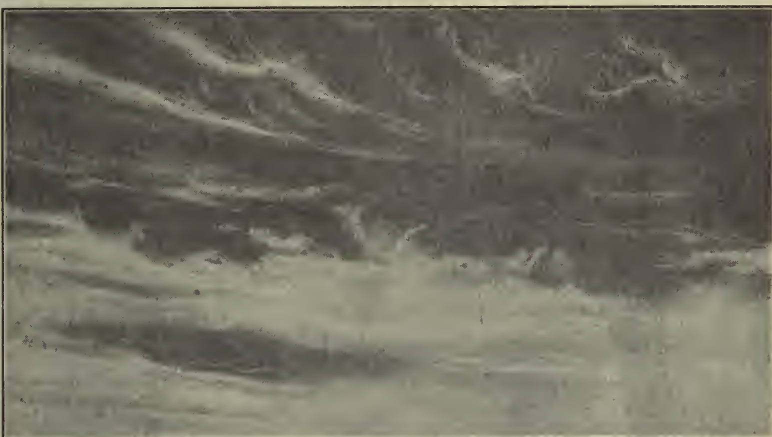


Fig. 176. — Cirrus clouds.

Cirrus clouds are light, feathery clouds formed at great heights, where the vapor condenses into minute crystals of snow or ice.

Stratus clouds lie in low, horizontal bands, or continuous sheets.

Nimbus or storm clouds are stratus clouds from which rain or snow falls when the sky is overcast.

There are many forms and varieties of cloud intermediate between cumulus, cirrus, and stratus, of which a dozen or more are common and have compound names, such as strato-cumulus, cirro-cumulus, and cirro-stratus.

Precipitation. — When clouds become sufficiently dense the air is no longer able to buoy up or evaporate them, and the water falls as rain, or, if the temperature of the cloud is below freezing, as snow or hail. Snowflakes are formed by the direct condensation of vapor into six-angled crystals of many symmetrical forms, which are usually tangled together before reaching the earth. Hailstones are rounded masses of snow and ice which have passed through several layers of alternating warmer and colder air.

Precipitation is measured by the *rain gauge.* Any open vessel with vertical sides will serve the purpose. The amount of rainfall or precipitation is measured in inches of depth of water caught, snow being first melted. In middle latitudes one inch of rain a day is a large fall, but sometimes an inch falls in an hour. In tropical regions a rainfall of 40 inches has been recorded in a single day. One inch of rain amounts to 113 tons of water on one acre of surface.

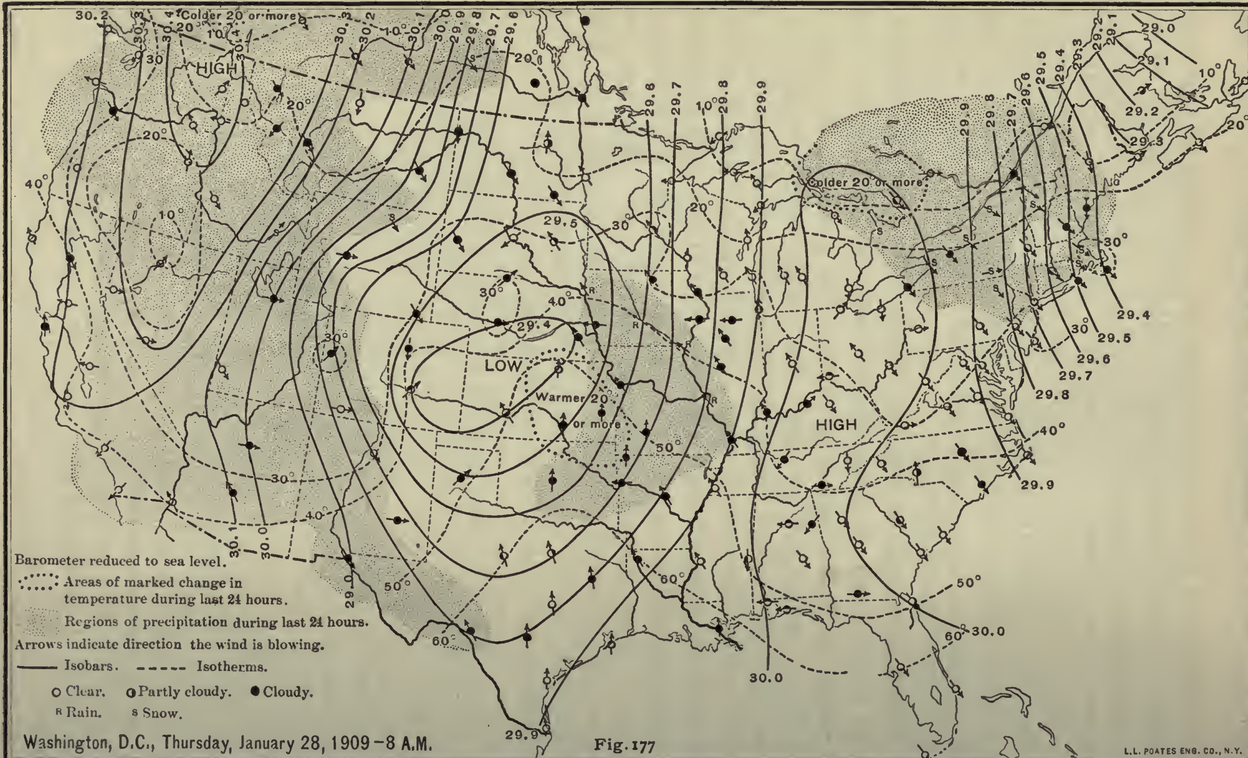
Dew and Frost. — Dew and frost are produced by the condensation of vapor upon any cold surface. The deposit is heavier during clear, still nights and upon surfaces which radiate heat freely. On still nights the cooler air settles into valleys and depressions and produces heavier dew or frost there than on elevations. A slight cover, as a tree, or even a piece of paper, may prevent cooling to the dew or frost point.

The dates of the last killing frost in the spring and the first in the fall are very important as limiting the growing season for crops. In central United States the date of the first frost in the fall may vary as much as a month in different years, and its occurrence a month earlier than usual may result in millions of dollars' damage to the corn crop. A temperature near freezing may be destructive to fruits which are in blossom or approaching maturity, and even trees and vines themselves may be killed. Orchards and fields are sometimes protected by a covering of light cloth, like a tent, by ditches or pipes containing hot water, by fires, or by filling the air with smoke which acts as a blanket. The presence of a body of water, even a small pond, may be sufficient to prevent unseasonable warm spells in the spring and early frosts in autumn. For this reason the shores of lakes Ontario, Erie, and Michigan and the Finger Lakes of New York are bordered by belts of vineyards, peaches, and small fruits.

Storms. — Outside the tropics a large part of the rainfall is brought by storms, or temporary disturbances which travel through the atmosphere along definite paths. They bring to the regions over which they pass shifting winds and usually cloudiness and precipitation. If no precipitation occurs they are called wind storms. The winds may be gentle or extremely violent, as in the hurricane and tornado. In nearly all storms the movement of air is spirally inward, toward and around a center of low pressure, and they may be described as traveling cyclones. They may be of any size from a summer dust whirl a few feet in diameter, to a storm which covers half a continent. The whirls travel in the direction of the general air current, but, like eddies in a river, continually take in new air in front as they leave other air behind.

Weather Bureaus and Maps. — Benjamin Franklin was probably the first man to observe that, while long rain storms were brought to New England by winds from the east, they began earlier at points farther west. To account for these facts he conceived the idea of a large whirling storm which passed across the country from west to east. Within the last fifty years the Weather Bureaus of the United States, Canada, and European countries have learned that in the northern belt of prevailing westerly winds there is a continual procession of cyclones moving eastward around the earth. By following their progress from day to day, a Weather Bureau is able to predict their arrival and the kind of weather they will bring.

In America and Europe hundreds of observing stations have been established, from which telegraphic reports are sent to a central station at a given hour twice a day. From these reports weather maps are made, showing the temperature, pressure, wind direction, state of the sky, and precipitation at that hour for the whole country. By means of these maps forecasts are made of what the weather is likely to be for the next 24 or 48 hours. It is sometimes possible to forecast the weather for a week or ten days. The intervals between the cyclones are occupied by areas of relatively high pressure, or anticyclones. As the procession of cyclones and anticyclones passes across the country it brings corresponding changes of weather, a knowledge of which is of the greatest importance to farmers, sailors, boatmen, shippers, and all people whose business or pleasure depends in any degree upon the weather. Figs. 177–180 show typical examples of cyclones and anticyclones, but their study should be continued by the use of the daily weather maps issued by the nearest Weather Bureau station.



Barometer reduced to sea level.

Areas of marked change in temperature during last 24 hours.

Regions of precipitation during last 24 hours.

Arrows indicate direction the wind is blowing.

—— Isobars. - - - - - Isotherms.

O Clear. Partly cloudy. ● Cloudy.

R Rain. S Snow.

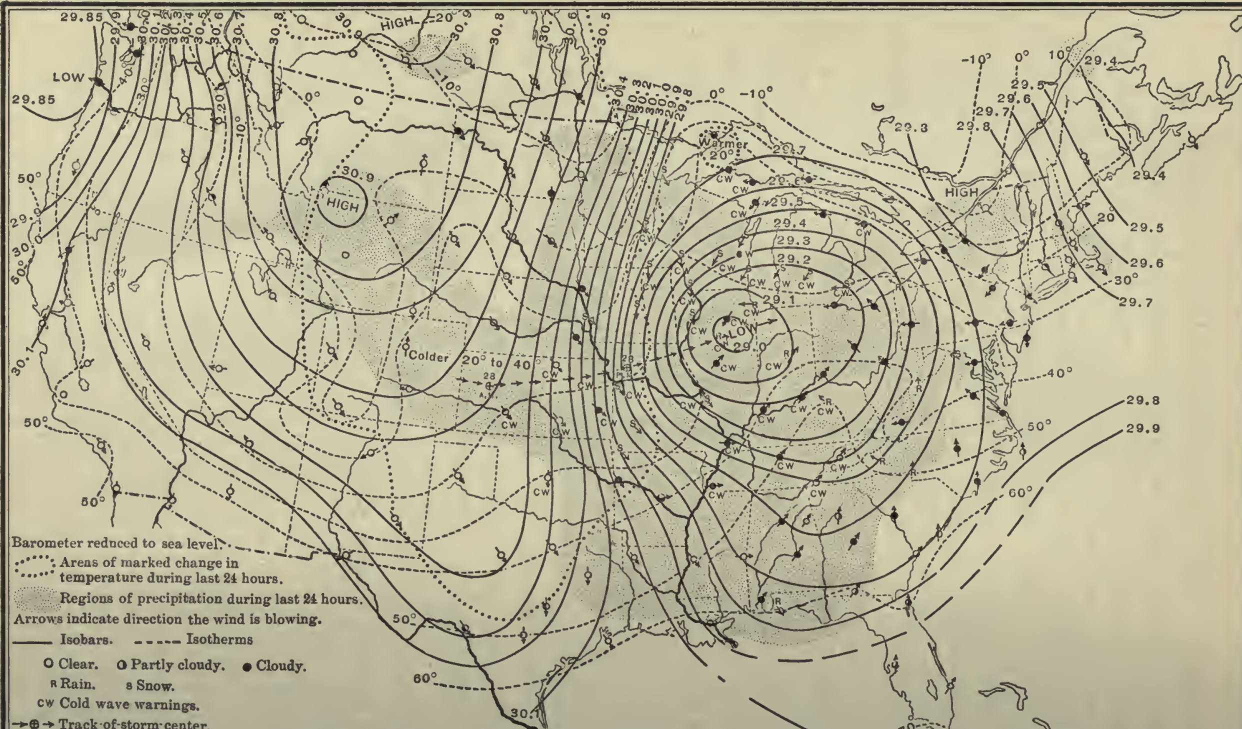
Washington, D.C., Thursday, January 28, 1909 – 8 A.M.

Fig. 177

Cyclones. — The cyclone shown in Fig. 178 (January 29) is a mass of warm, damp air, and therefore of low pressure, which covers a rounded area more than 1,000 miles in diameter. The pressure is lowest at the center, near Chicago, and increases in every direction toward the circumference. The whole mass is moving in a spiral whirl inward and counterclockwise. In the southern quarter the winds are from the southwest and south, in the eastern quarter from the southeast and east, in the northern quarter from the northeast and north, and in the western quarter from the northwest and west. The southerly and easterly winds bring to the southeast side temperatures above freezing, while on the northwest side northerly winds bring temperatures mostly below freezing. As the air approaches the center it rises and escapes upward. As it rises and whirls it expands and air from all sides is mixed together. By expansion and mixture the warm, damp air from the Gulf and Atlantic is cooled, and its vapor condenses into a layer of cloud which covers nearly the whole area of the cyclone. Snow or rain has been general in the cyclonic area during the past twenty-four hours and is still falling over half of it. The cyclone is moving eastward and carrying with it warm, cloudy, and stormy weather, which clears up as the storm passes.

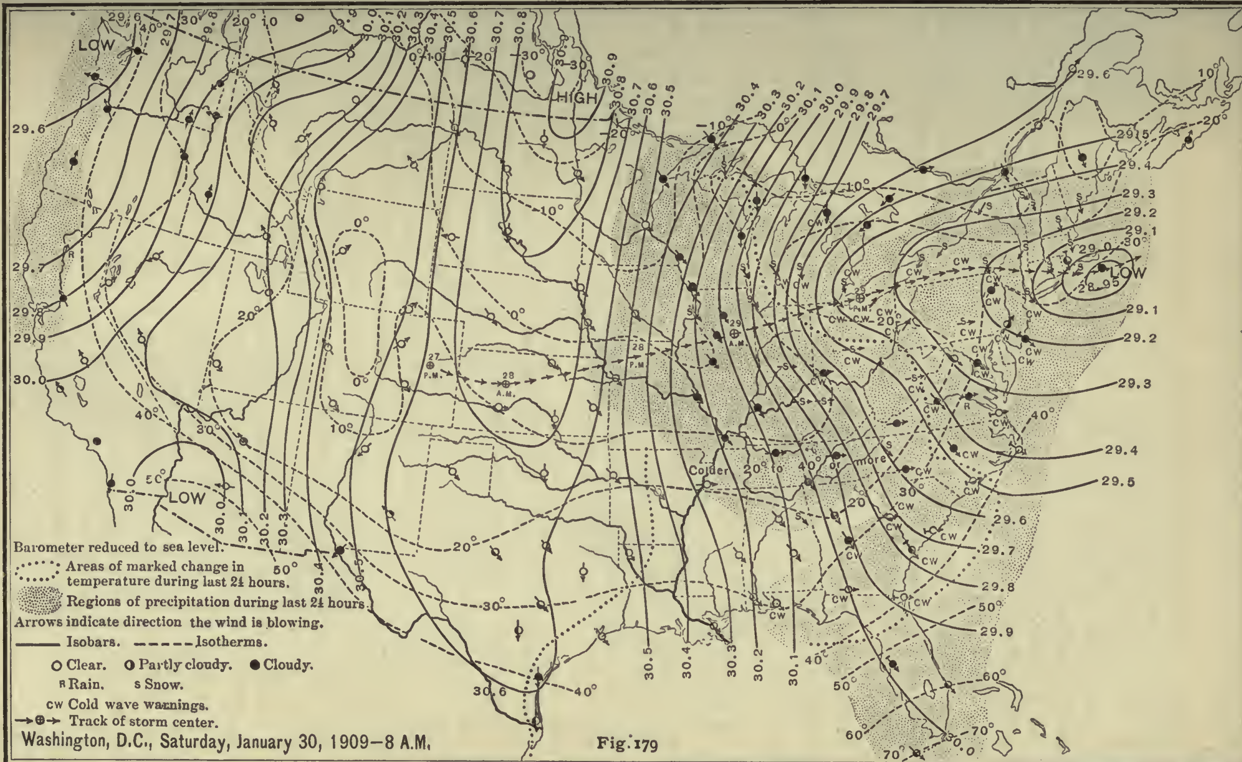
Anticyclones. — The anticyclone shown in Fig. 180 (January 31) is a mass of cold, dry air, and therefore of high pressure, which covers an area measuring about 1,200 miles east and west and a much greater distance north and south. The pressure is highest, 30.6 inches, at the center from Lake Superior to Texas, and diminishes toward the circumference. It may be compared to a long, smooth ridge upon which heavy rain is falling and the water draining off down the slopes. In like manner the air settles downward and spreads out from the center.

Water would run down the slopes of the hill by the steepest and most direct path, but the rotation of the earth causes the air to move slantingly down the slope of pressure along lines to the right-hand of the shortest path to the bottom. The north-south elongation of the anticyclone causes the principal slopes to be toward the east and west, and accordingly at



Washington, D.C., Friday, January 29, 1909—8 A.M.

Fig. 178



Washington, D.C., Saturday, January 30, 1909—8 A.M.

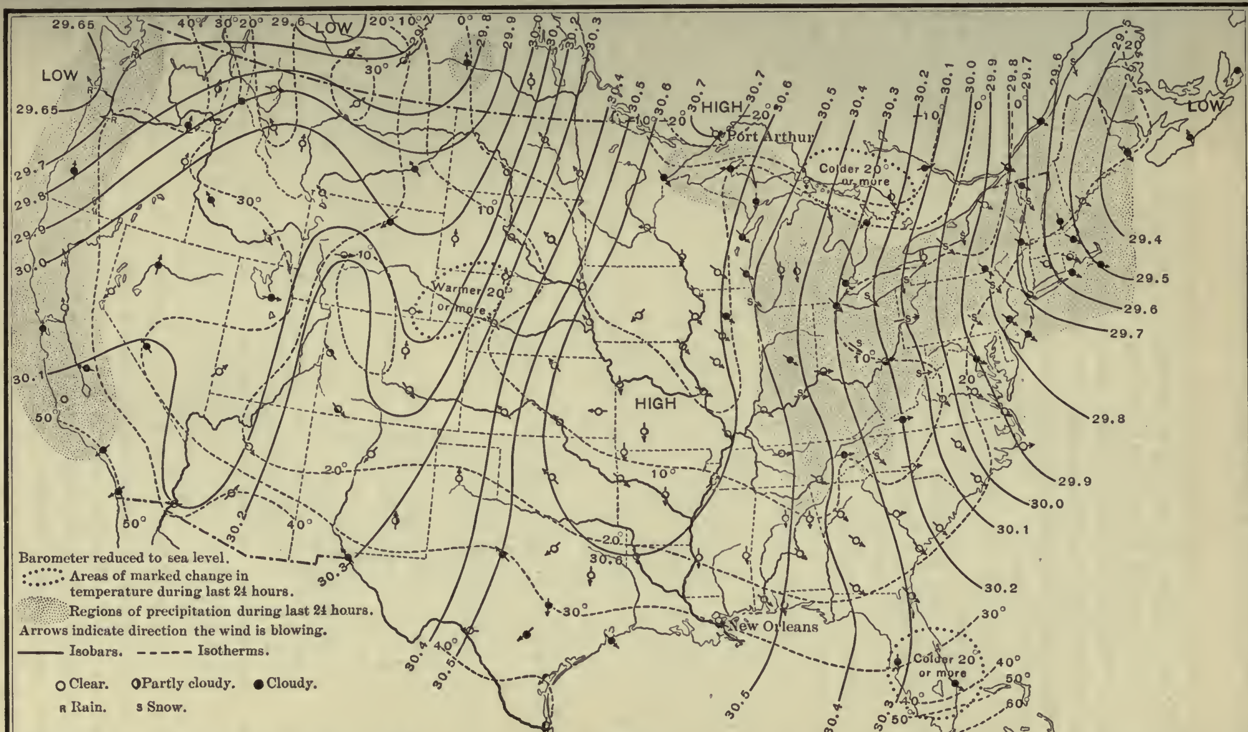
Fig. 179

most places in the eastern half the winds are from the northwest and north, and in the western half from the southeast. The northerly winds bring clear, cold weather which extends from Port Arthur, where the thermometer stands at 20° below zero, to New Orleans, where the temperature is below freezing. On the west side the temperature rises, and it is as warm in northern Montana as in Florida. The anticyclone brings into the midst of the country dry, clear air, which is cold on account of free radiation, and the temperature changes more rapidly along east-west than along north-south lines. It will move eastward and carry its clear, cold weather to the Atlantic coast. The progress of low temperatures eastward in front of an advancing anticyclone is called a *cold wave.*

Procession of Lows and Highs. — Figs. 177–180 show a regular procession of cyclones and anticyclones moving eastward during four days.

On January 28 a cyclone, or "low," is passing from New England over the Atlantic Ocean. A long ridge of moderately high pressure extends from the upper lakes to Florida, with north and northwest winds and generally clear sky. On the west it descends to a large oval area of low pressure, with spirally inflowing air, general cloudiness, and a patch of rain east of the center. The Pacific states are covered by a feeble anticyclone, or "high."

On January 29 the same elements appear with changed positions, areas, and intensities. The principal center of low pressure has moved from Kansas to Illinois, and the winds have increased in velocity. The force of the winds is indicated by the closeness of the isobars. The barometer at the center has fallen to 29 inches. The air is crowding rapidly in from all sides and streaming upward. It whirls as it rises, and warm, damp air from the Gulf and Atlantic is mixed with cold air from the interior of the continent. Damp air is cooled by expansion and mixture, and condensation takes place, resulting in cloudiness almost everywhere, rain in the southeast quarter, and snow in the north and west. The southerly winds have raised the temperatures in the southeastern states 10 to 20 degrees above those of the previous day. The high on the Pacific coast has expanded and developed until it covers the western half of the country, the pressure at its center in Wyoming being 30.9 inches. The slope to the east is steep, and high northwest winds carry freezing temperatures to New Mexico. The central and southern states are dotted with cold-wave warnings, which mean that the temperature will fall 20 to 40 degrees in the next twenty-four hours.



Washington, D.C., Sunday, January 31, 1909—8 A.M.

Fig. 180

On January 30 the principal low center has moved to the southern coast of New England. Across the middle of the country a ridge of very high pressure extends north and south, with steep and regular slopes to the ocean on both sides. Another low is coming in from the Pacific. The winds have a high velocity almost everywhere. In the east they are in accordance with the slopes, but in the west they are more irregular on account of the influence of the mountains. A large area of snowfall extends from Wisconsin to Maine and as far south as Virginia. Over the west of the country clear, cold weather prevails, with temperatures from $-30°$ at Winnipeg to below freezing in the Gulf and southern border states. The highest temperatures are in Florida and along the Pacific coast. The cold-wave warnings have been shifted to the Atlantic coast.

On January 31 the storm center has disappeared over the Gulf of St. Lawrence, and the ridge of high pressure has moved a few hundred miles eastward. The cold wave has reached the extremity of Florida, and nearly the whole country is left with clear, cold, dry, pure, and invigorating air. The rain, snow, and high winds have washed dust from the air and from houses, and the cold air under high pressure has crowded foul gases out of every crack and cranny. At the same time, the low temperatures and blinding snowstorms in the northern states bring more or less hardship and danger to man and beast, and sometimes blockade railroads for many days. Freezing temperatures in the southern states may do vast damage to fruit orchards. On the whole the benefit is probably much greater than the loss or injury. The procession of lows and highs renders the weather very variable, bringing a change from relatively cool, clear, and dry to relatively warm, cloudy, and rainy weather, or the reverse, two or three times a week.

Weather Forecasts and Warnings. — The United States Weather Bureau issues forecasts of the weather every morning, which are published in the principal newspapers and posted at post offices throughout the country. Responsible persons who promise to post the forecasts in a public place may receive them on request free of charge; some newspapers publish also the weather map. They constitute the most trustworthy predictions of the weather that can be made, because they are based upon actual knowledge of the atmospheric conditions which prevail over the continent and surrounding oceans. The forecasts are made for large areas and cannot prove correct in every detail at every locality. The eastward movement of lows and highs is sometimes slower and sometimes faster than usual. Rarely a storm center moves backward to the west for a short distance. Occasionally an area of low pressure divides or dies out or a new one is rapidly formed, and such events cannot be foreseen.

Storm warnings are displayed at all sea and lake ports for the guidance of mariners and shippers, and thus great loss of life and property is prevented. Notice of the advance of a cold wave is given 12 to 36 hours before it arrives, and in consequence millions of dollars' worth of property is protected and saved. Frost and flood warnings are issued whenever occasion requires for the benefit of fruit growers, river men, and owners of property along streams.

Hurricanes. — In tropical and temperate latitudes cyclonic storms occur of such violence as to be among the most destructive of natural agencies. Some of them are so small as to permit their whirling motion to be generally recognized, and are called "cyclones" in popular speech. In late summer and autumn the West Indies are visited by destructive *hurricanes* which arrive from the southeast. They begin in the equatorial calms and increase in size until they reach a diameter of 100 to 300 miles (Fig. 181). On the land they destroy almost everything, — forests, crops, buildings, and people. On the sea they are very dangerous to shipping and pile up the water until it sweeps over the coast lands, flooding fields and towns.

Fig. 181. — Path of the Galveston hurricane.

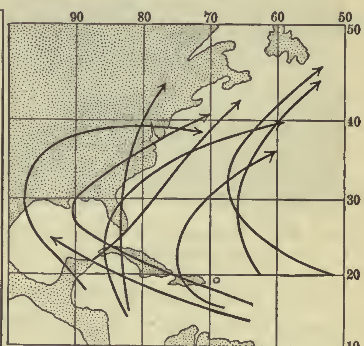


Fig. 182. — Paths of West Indian hurricanes.

When they approach the coast of the United States they usually turn to the northeast and die away in the north Atlantic Ocean (Fig. 182). Occasionally a hurricane turns westward near Florida and passes over the land, as did the one which destroyed the city of Galveston, Texas, in October, 1900 (Fig. 181). Similar storms occur in the Pacific Ocean near the Philippine

Islands, and in the Indian Ocean both north and south of the equator. In those regions they are called *typhoons*.

Tornadoes.—The tornado or "cyclone" of the western and southern states is even more violent than the hurricane, but fortunately much smaller. It appears as a whirling, funnel-shaped cloud, the small end of which sweeps the ground and overturns or carries away everything in a path from a few rods to a half mile in width. The wind sometimes reaches a velocity of 200 miles an hour and nothing movable can resist it. Although many stories of its power are apparently incredible, it is difficult to exaggerate the truth. Trees of all sizes are uprooted or twisted off, buildings are demolished and their fragments scattered over the neighborhood. Boulders, masses of iron, and even railroad engines, are lifted from their places. Animals and human beings are whirled about and carried long distances, often being torn in pieces or killed by collision with other objects. Wires and straws driven into hard wood testify even more strongly to the incredible violence of the wind.

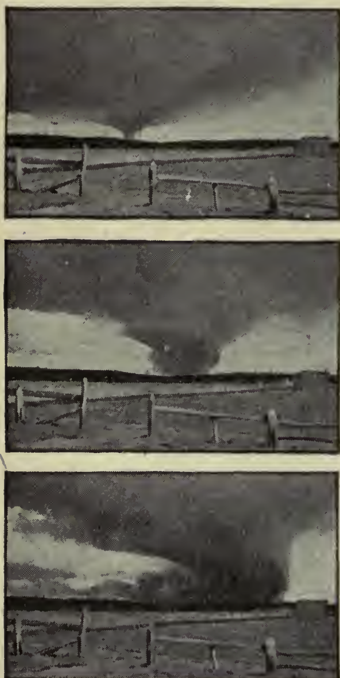


Fig. 183.—Progress of a tornado, Newcastle, Neb., April 30, 1898.

The tornado travels about 40 miles an hour and seldom lasts more than two hours. The average number in the United States is about 150 a year. They are most frequent in Kansas, Iowa, Missouri, Illinois, and Georgia, but may occur anywhere east of the meridian of 100° and south of the parallel of 45°. In some states people dig holes in the ground, called "cyclone cellars," into which they may retreat for safety on the approach of a tornado.

Fig. 184. — Effects of a tornado, Minnesota.

Thunderstorms. — Thunderstorms are seldom cyclonic, but result from the rapid rising of currents of warm air until heavy cumulus clouds are formed at the top. They bring violent gusts and squalls of wind and a downpour of rain, which leave the air cool, clear, and bracing. In the United States a thunderstorm moves eastward at the rate of 20 to 50 miles an hour, and grows larger as it progresses. It may attain a length, from side to side, of 100 miles, and a breadth, from front to rear, of 30 miles, and continue from 2 to 12 hours.

Rainfall. — There is probably no spot on the face of the earth where it never rains or snows. The mean annual rainfall, as far as measured, varies from less than one inch to more than 400 inches. Less than 10 inches in any region means a desert or tundra. At least 20 inches are generally necessary for forests and for agriculture without irrigation. The lands most favorable for human occupation have from 20 to 60 or 80 inches (Fig. 185), while 100 inches or more may be counted as undesirable excess.

Even a small amount of rain falling during the growing season is of more value for grass and crops than a large amount falling in the autumn and winter. A good crop of corn has been raised in Kansas with a rainfall of only eight inches for the year, but most of it fell in spring and early

MEAN ANN

RAINFALL

...tson

35

summer. Winter rains supply ground water, fill wells, springs, and streams, and saturate the subsoil from which trees draw most of their water supply. On a map showing regions of small (less than 20 inches), medium (20 to 60 inches) and large (more than 60 inches) rainfall (Fig. 185) several general laws of rainfall appear.

Laws of Rainfall. — 1. *Disregarding small patches, the principal rainfall regions extend north and south, cutting across the temperature zones.* This is due to the fact that the large land masses extend north and south across the path of the prevailing winds.

2. *The coasts of the continents receive more rain than the interior, and windward coasts receive more than leeward.* Most of the rainfall is first evaporated from the oceans, carried as vapor by the winds, and condensed as it is cooled by rising over the lands.

3. *Highlands act as screens which stop most of the moisture on the windward side and cut it off from the regions on the leeward side, producing a rain shadow,* just as opaque bodies cut off light and cast dark shadows.

4. *In the equatorial zone as a whole, the rainfall is much heavier than in higher latitudes.* This is the result of two causes. Air at a temperature of 70° can contain and carry nearly twice as much vapor as air at 50°, and more than four times as much as air at 30° (see table, p. 194). Warm, damp air is lighter than cool, dry air, and is compelled to rise by the pressure of heavier air around it, and by rising the vapor is cooled and condensed. Somewhere between the tropics, swinging north and south with the changing position of the sun in the heavens, is the *heat equator* (Figs. 159, 160), or line passing through the point of highest temperature on each meridian. The heat equator carries with it a belt of calms and rising air, in which copious rain falls in the afternoon and evening every day. This belt of daily rains crosses the geographical equator twice a year, and touches the northern tropic in July and the southern in January. Thus the regions of heavy rainfall stretch across the lands from tropic to tropic, and have one or two rainy seasons, each of which lasts a month or more. During the rest of the year the trade

winds blow, bringing more or less rain from the ocean to east coasts and slopes and unprotected lands of the interior (Figs. 186, 187). Where the trade winds blow from large land masses or over highlands they bring a dry season, or in some cases a desert is the result. In monsoon regions, like southeastern Asia from India to Japan, the winds bring rain from the ocean in summer and dry weather from the land in winter (Figs. 186, 187).

5. *The subtropical zones, as a whole, receive less rainfall than any other part of the land, outside the polar regions, and may be called the desert belts.* This is due in part to the high pressure which exists there, especially in winter. The general movement of the air is downward and outward to the north and south. Descending air is warmed by compression and hence cannot bring rain. In north Africa and southwestern Asia, the winds blow from Eurasia and are dry. Here the Sahara, Arabian, and Persian deserts stretch from the Atlantic to India, covering an area larger than the whole of Europe. In southwestern United States and northern Mexico, desert conditions are intensified and extended by mountain ranges which shut out the moisture from the Pacific and Gulf of Mexico. In South America the deserts of Peru and Chile are rendered almost rainless by the lofty chain of the Andes on the east. The Kalahari desert in southwest Africa and the desert of central Australia lie in the rain shadow of the highlands on the east.

6. *In the temperate zones the prevailing winds from the west bring copious rains to the west coasts* of North America, Europe, southern South America, and New Zealand. In central Europe the rains extend halfway across the continent, but in northern Europe and North and South America they are stopped by mountain ranges near the coast.

7. *The eastern half of North America, from the Gulf to Hudson Bay, is saved from being a desert by the cyclonic winds which bring rain from the Gulf and Atlantic.* The interior of North America is dry because the high mountains shut out rain from the west, and the cyclonic winds from the southeast lose most of their

SUMMER RAINFALL
(*After Supan and Others*)

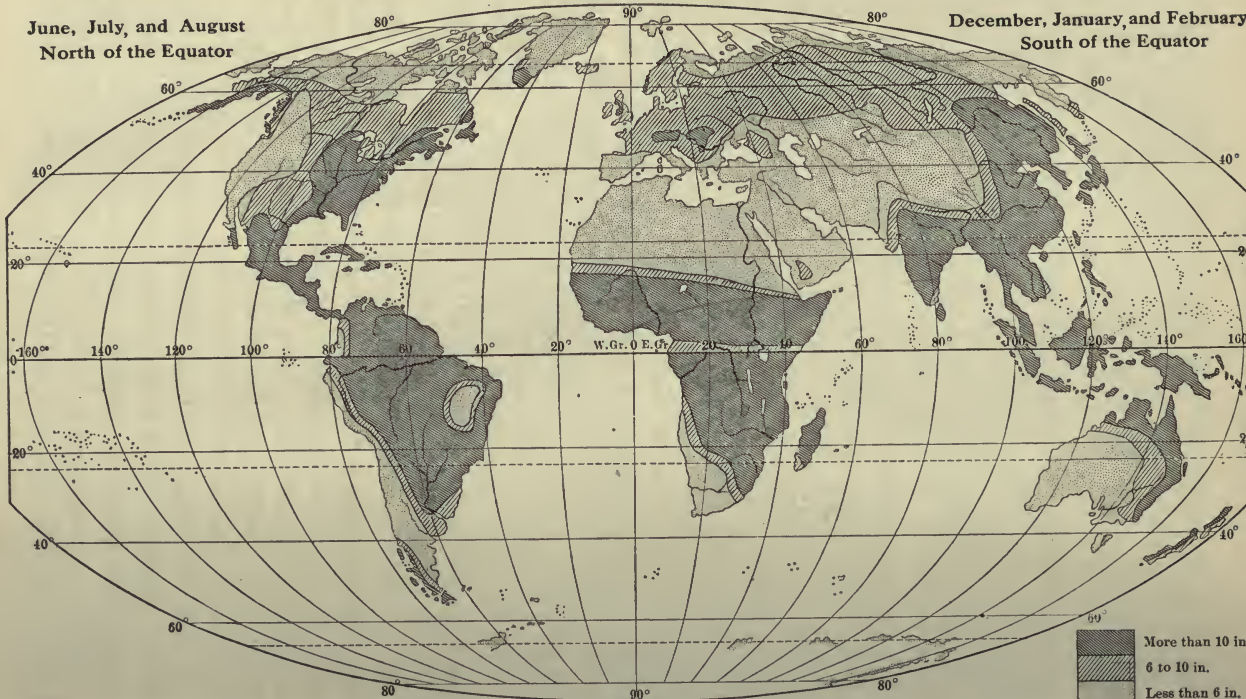


Fig. 186.


WINTER RAINFALL
(After Supan and Others)
December, January, and February
North of the Equator
June, July, and August
South of the Equator
More than 10 in.
6 to 10 in.
Less than 6 in.
W.Gr. 0 E.Gr.
90°
80°
60°
40°
20°
160°
140°
120°
100°

Fig. 187

moisture before they reach so far inland. Central Eurasia is dry because it is too far from the Atlantic, and the monsoon rains from the Indian and Pacific are shut out by lofty mountains, which inclose the deserts of Tibet, Gobi, and the Ural-Caspian basin.

8. *The polar caps have little rainfall because the air is too cold to carry much vapor.*

About half of all the land receives too little rainfall to support more than a scanty population. Only about one third of the land receives between 20 and 60 inches of rain, the amount most favorable for thriving, civilized communities.

The maps of seasonal rainfall, Figs. 186, 187, show that very few places in the world receive heavy rainfall in winter.

CHAPTER XV

CLIMATE

Factors of Climate. — Climate includes all those conditions of the atmosphere which affect plant and animal life, among which temperature and moisture are the prime factors. The presence of dust and disease germs affects the healthfulness of the air and forms a factor of climate. The climate of any region is determined by its latitude, relief, prevailing winds, and position in relation to the great features of land and sea, and is thus a resultant and expression of all the physical influences and conditions which exist there. It is mainly climate which, in turn, controls, directly or indirectly, the life of plants, animals, and men. Therefore climate may be regarded as the middle link in the chain of geographical causes and consequences. It furnishes the key to a full understanding of geographical conditions.

The Equatorial or Tropical Zone. — In equatorial lowlands the temperature is constantly high with small range, and the rainfall is generally heavy. As the belt of calms, with low pressure and ascending air, follows the vertical rays of the sun northward and southward, it brings a rainy season in spring and fall near the equator and in summer near the tropics. Near the equator the two rainy seasons may overlap, and on highlands exposed to trade winds from the ocean the rainfall is well distributed throughout the year.

Equatorial regions where all seasons are sufficiently wet are occupied by dense evergreen forests (Figs. 192, 193). In regions where, on account of elevation or protection by highlands, the rainfall is moderate or there is a strongly marked dry season, the forests thin out or disappear and give place to *savannas* covered with coarse grass and scattered trees (Fig. 200). In the monsoon region of southeastern Asia there is a hot summer with heavy rainfall, and a cool, dry winter. The monsoon forests are almost as luxuriant as the equatorial, but are nearly leafless in winter.

The Subtropical Zones. — In the subtropical zones of high pressure and descending air, and extending into the temperate zones, vast tracts of arid lands occupy about half the land surface of the globe. On account of the dryness and clearness of the air, arid regions are subject to extremes of temperature, the deserts of Africa, Arabia, North America, and Australia being the hottest regions of the world. The daily range is sometimes from above 100° in the daytime to near freezing at night.

In the deserts vegetation is confined to scattered thorny bushes which are often leafless (Figs. 191, 192, 204, 205). The deserts are bordered by savannas or steppes, where a thin growth of bunch grass furnishes pasturage (Figs. 192, 201, 202, 203). The soil needs only water to make it productive, and wherever sufficient ground water exists oases of dense vegetation arise (Fig. 206).

Mediterranean Climates. — Some regions in or near the belt of tropical calms have a climate which is transitional between that of the subtropical zone and that of the temperate zone. The rainfall is generally small, but not so little as to produce desert conditions. The summers are too dry to be favorable for grass, and pasturage is relatively poor. Frost rarely occurs, and the range of temperature is small. The climate is characterized by uniformly mild, dry weather, free from sudden or great changes. The skies are generally clear, and warm days alternate with cool nights.

In these regions people can live most of the time out of doors, and the climate is probably the most agreeable and healthful in the world. Hence they are noted as health and pleasure resorts. These conditions prevail in most of the coast lands and islands of the Mediterranean Sea, and constitute what is often called the Mediterranean climate.

Conditions similar to those of the Mediterranean region prevail in California, central Chile, south Africa, and southwest Australia (Fig. 188).

The Temperate Zones. — The so-called temperate zone in the northern hemisphere is broken up by the land masses and mountains into regions which have diversified and even strongly contrasted climates. Nearly all parts of North America and Asia between 30° and 50° N. Lat. are characterized by hot summers and cold winters, less than half the year being really temperate. The interiors of North America and Eurasia have an extreme continental climate of great range of temperature and small rainfall, which, in areas screened by mountains, is so intensified as to produce bleak steppes and deserts almost as barren as the Sahara (Fig. 192). The mid-continental ranges of temperature are carried by the prevailing westerly winds over the east coast lands of North America and Asia, but cyclonic winds from the Gulf of Mexico and Atlantic and the summer monsoons from the Pacific bring a moderate rainfall (Figs. 185, 186).

East Coast Climates. — Those parts of the United States and southern Canada lying east of the meridian of 100° have a continental climate with four strongly marked seasons and a large range of temperature (Figs. 161, 164). On the Gulf coast these conditions are modified by nearness to the ocean and the tropic. Throughout the region the climate is made changeable by the frequency of cyclones and anticyclones, especially in winter, when alternations of cold, clear weather, and mild, cloudy weather with rain or snow, occur every three or four days.

Northwest winds, blowing out from an advancing center of high pressure, bring a cold wave with zero temperatures as far south as St. Louis and Philadelphia, and freezing temperatures in Florida. Southerly winds blowing toward a center of low pressure carry cloud and rain, changing to snow in the north, across the country to and beyond the Great Lakes (Figs. 177–180). These irregular changes are very noticeable in spring, when alternations of almost summer weather with wintry spells occur from March to May. In summer the cyclonic changes are much feebler and less frequent. In autumn the change of seasons is more gradual than in spring, and clear, mild days and frosty nights may persist without notable storms until December.

Almost everywhere east of the meridian of 100° the annual rainfall is above 20 inches, increasing from northwest to southeast to above 50 inches on the Gulf coast. It is well distributed throughout the year, with a maximum in spring and early summer when crops are growing. Midsummer and early autumn are usually dry and favorable for harvest (Figs. 185, 186, 187).

Most of this region was originally covered with a heavy forest of deciduous trees, green in summer and bare in winter. Toward the north and on the Appalachian highlands the forests are partly or wholly of evergreen coniferous trees (Fig. 192). Towards the west the forests pass gradually into *prairies*, or tracts on which grasses form a dense, continuous sod or turf, trees being absent except along the streams.

In Asia the countries which most nearly resemble eastern United States in climate and products are Manchuria, Korea, northern China, and Japan.

West Coast Climates. — The west coast lands of North America and Europe are exposed to the westerly winds from the ocean and have a truly temperate, oceanic climate, almost as equable as that of the equatorial zone. The narrow strip of country between the mountains and the Pacific in Alaska, British Columbia, Washington, and Oregon has a mild, moist climate, with heavy precipitation in winter (Figs. 185–187). In the north the summers also are rainy and the snowfall is sufficient to maintain large glaciers upon all the mountains. The strip is covered with dense forests of pine, fir, spruce, cedar, and redwood, which yield a greater value of timber to the square mile than any other in the world (Fig. 192).

The countries of western Europe belong to the same climatic belt as the Pacific states of America. They are exposed to the westerly winds blowing from the north Atlantic, the waters of which are abnormally warm for their latitude on account of the drift of the Gulf Stream from tropical regions. The winds themselves are the chief cause of the ocean drift, and are therefore both directly and indirectly the cause of the mild climate. Their influence is greatest on the west coast and diminishes gradually inland, but south of Norway there are no mountains to shut out moisture from the interior.

In winter the winds are stronger and more southwesterly in direction, and the isotherms extend almost north and south, the temperature decreasing from west to east (Figs. 160, 171, 172). The range of temperature is small, and the rainfall large, with excess in autumn and winter. The air is constantly damp, and rain falls on more than half the days in the year. In autumn and winter fog and drizzling rain prevail. The winds from the ocean and the cloudiness combine to prevent great or sudden changes of temperature. Cyclones and anticyclones pass across these countries from west to east, but bring much smaller contrasts of weather than in eastern America. Spells of freezing weather are not prolonged or severe, and occasional falls of snow on the lowlands do not remain long upon the ground. Hardy plants blossom out of doors all winter, and work in the fields can be carried on every month in the year. The frequent rains are very favorable for grass, which covers unplowed ground with a thick sod even among the trees of the forest. The country looks fresh and green at all seasons. The Mediterranean countries have a climate like that of California, the British Isles like that of Oregon and Washington, and Norway resembles British Columbia and southern Alaska. The small range of temperature and large rainfall, with excess in autumn and winter, change gradually eastward to continental conditions of large range and small rainfall, with excess in summer. In general the climate of central Europe resembles that of eastern United States, with the direction of east-west change reversed. A person traveling from France to central Russia would notice the same kind of changes as in traveling from Maryland to Colorado. A traveler from southern France to Sweden would experience changes similar to those from Florida to Quebec. The natural vegetation and cultivated crops of Europe have about the same range as in the United States, with local variations.

Climate and Civilization. — The middle latitudes of North America, Europe, and eastern Asia are the homes of the most advanced and progressive peoples of the world. The climate is not oppressive and overpowering as in the equatorial and polar regions. The contrast of seasons is stimulating to human effort, which must be expended in the summer to provide food and shelter for the winter, while the winter brings a period of comparative leisure and rest. The energy received from the sun can be utilized to greater advantage than elsewhere to supply human wants. Conditions of climate and vegetation are more capable of human control than in the regions of perpetual heat or perpetual cold, and human intelligence and labor bring a greater return of wealth than anywhere else in the world.

In the southern hemisphere the only lands which resemble the United States and Europe in climate and products are Chile, Argentina, Uruguay, eastern Australia, and New Zealand. Their natural resources and future possibilities are great, but for the most part they lack development for the want of sufficient population.

Cold Temperate Zones. — The northern cold temperate zone extends across North America and Eurasia. The climate is that of continental lands in high latitudes. The winter temperatures are the lowest in the world, except in Antarctica; the summers are cool and the range of temperature is very large (Figs. 159, 160, 161). The long days of summer, during which the period of sunshine varies from 16 to 24 hours, compensate for the low altitude of the sun above the horizon, and days with temperatures above 70° occur. The growing season is short, but may be warm enough to ripen wheat even on the Arctic circle. The rainfall is generally less than 20 inches (Fig. 185), but is more efficient than an equal amount in lower latitudes because evaporation is less. During more than half the year the ground is covered with snow, which plays an important part in protecting the roots of trees from severe frost.

A belt of coniferous forest extends across the continents from ocean to ocean, interrupted by patches of "muskeg" swamp and prairie (Figs. 192, 197, 199).

In the southern cold temperate zone, the narrow extremity of South America presents two strongly contrasted regions. The west coast resembles southern Alaska in small range of temperature, heavy rainfall, and dense coniferous forest. In Tierra del Fuego the climate is stormy and inclement at all seasons, and snow falls every month in the year. East of the mountains the rainfall is too scanty for forests, and Patagonia is an arid steppe (Fig. 185).

The Polar Caps. — In the north polar regions the climate is still more severe than in the cold temperate zones. The winters are not colder but longer, and the cool growing season is reduced to two months or less. During the winter the sun does not rise at all for a period of from one day to six months. The sky is generally clear, but violent storms of wind are frequent. There is no spring, but winter holds with slight mitigation until June, when the ice begins to break up and summer comes on with a rush. The summers are cold and foggy, and in September winter sets in again with full severity. The annual precipitation is less than 10 inches, but there is so little melting that on moderate elevations snow and ice accumulate from year to year. The ground is permanently frozen to great depths and never thaws for more than a few feet on top.

The Arctic borderlands of America and Eurasia are occupied by *tundras* (Figs. 192, 208), where the only vegetation consists of lichens, mosses, and stunted shrubs, which never grow higher than the level of the snow surface in winter.

Greenland and Antarctica are buried under vast sheets of ice, upon which no living thing exists. Bare land appears around the shores, where sea-birds, mammals, and in the north a few thousand Eskimos find means of support.

Alpine Climate. — The climate of lofty mountains and plateaus resembles that of the polar caps. Between the tropics, surfaces above about 15,000 feet in elevation are covered with permanent snow and ice. In middle latitudes perpetual snow descends to about 10,000 feet, and in polar regions nearly to sea level. The height of the snow line varies not only with the temperature but with the amount of snowfall, and is different on the windward and leeward sides, and on north and south slopes, of the same range. The rainfall generally increases with the altitude to a height which varies on different mountains and then diminishes. The belt of heaviest rainfall below the snow line is generally forested (Fig. 198).

Tropical plateaus between 5,000 and 13,000 feet in elevation are generally more healthful and suitable for human occupation than the lowlands. In the northern Andes and Mexico nearly all the cities and areas of dense population are found upon the highlands. In Mexico the traveler can ascend in a distance of 100 miles from the hot, damp coast land to a temperate plateau and cold mountain heights, through as many belts of climate as he would traverse in traveling from the tropic to the polar circle.

Climatic Regions. — The map, Fig. 188, shows how the land areas may be divided into regions bounded approximately by isotherms and lines of equal rainfall, in each of which the principal factors of climate are nearly uniform. These are grouped under twelve types, and all the regions be-

CLIMATIC REGIONS

Fig. 188

longing to the same type, wherever they occur, have essentially the same climate. This map should be compared with the maps of temperature belts and of annual and seasonal rainfall (Figs. 164, 185, 186, 187). The following table explains the map and briefly characterizes each type.

1. **Equatorial and Tropical.** — All seasons hot and range small.

Amazon Type. — Equatorial. Rainfall above 60 inches. No dry season. Am. 1 – Am. 3.

Caribbean Type. — Tropical. Rainfall generally 20 to 60 inches (except in 5). Dry winter. Car. 1 – Car. 5.

2. **Subtropical and Warm Temperate.** — Always temperate or with a hot season.

Arizonan Type. — Always dry. Rainfall generally less than 10 inches. Ar. 1 – Ar. 5.

Californian Type. — Dry summer. Rainfall generally 20 to 60 inches. Cal. 1 – Cal. 5.

Mexican Type. — Dry winter. Rainfall generally less than 60 inches. Mex. 1 – Mex. 4.

Floridan Type. — No dry season. Rainfall less than 80 inches. Fl. 1 – Fl. 5.

3. **Temperate and Intemperate.** — Temperate, with a cold season, or with a cold and a hot season.

Oregon Type. — Oceanic. Small range. Rainfall generally 20 to 60 inches. Or. 1 – Or. 3.

Mississippian Type. — Continental. Large range. Rainfall 20 to 60 inches. Miss. 1 – Miss. 4.

Interior Type. — Continental. Large range. Rainfall less than 20 inches. Int. 1 – Int. 3.

4. **Cold Temperate.** — Cold with a temperate season.

Alaskan Type. — Oceanic. Small range. Rainfall in some parts above 60 inches. Al. 1 – Al. 3.

Canadian Type. — Continental. Large range. Rainfall mostly less than 20 inches. Can. 1 – Can. 2.

5. **Polar and Alpine.** — Always cold.

Polar Type. — Rainfall generally less than 10 inches. Pol. 1 – Pol. 4.

CHAPTER XVI

PLANT REGIONS

The Distribution of Plants. — The distribution of plants over the face of the earth and the kind of vegetation found in any region are nicely adjusted to a combination of conditions, of which air, light, water, soil, and temperature are the most important. Green plants absorb about 75 per cent of their weight from the air in the form of oxygen and carbon dioxide. The

Fig. 189. — Zonal arrangement of plants.

absorption of carbon dioxide is done by the leaves and other green parts in the sunlight and cannot take place in the dark. Plants absorb from the soil through their roots large quantities of water containing compounds of nitrogen, potash, phosphorus, lime, and other elements in solution. Most of the water, after circulating through the plant, evaporates from the leaves. For all plants there is a certain range of temperature within which they are able to survive, and a smaller range within which they grow vigorously. Hence plants are arranged in zones, roughly corresponding to the zones of temperature. Within the zones of temperature the distribution of plant societies is determined largely by the available soil water. Thus the variations of soil water break up the plant zones into plant regions, just as the rainfall breaks up the temperature zones into climatic regions. The natural vegetation of any region is a striking and intelligible expression of the physical conditions of structure, relief, and climate which prevail there, and, consequently, of the natural influences exerted upon animal and human activities. Vegetation is a key which unlocks the chain of geographic causes and consequences.

Water Plants. — A large class of plants flourish only in water or in very wet soil. (1) Floating or submerged plants are characterized by thin walls through which water is absorbed by all parts of the plant. Roots, being unnecessary, are absent or used for anchorage only. The plant is supported by the water, and has no need of stiffness; hence it is soft and flexible. Numerous species of seaweed belong to this class, some of which attain such dimensions as to rival the largest of land plants. Bladderworts and duckweeds are common floating plants in fresh-water lakes and ponds. (2) Many plants are rooted to the soil, but have submerged or floating leaves; for example, pondweeds and water lilies. The submerged leaves are commonly narrow and threadlike; the floating ones very broad (Fig. 190).

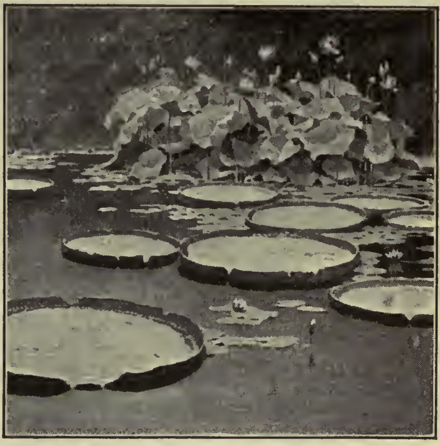


Fig. 190. — Water plants.

(3) Swamp or marsh plants are rooted in water or very wet soil, while their stems and leaves are exposed to the air. Many societies of them are common in temperate climates; among them may be found cat-tail flags, reed grass, sedges, willows, alders, tamarack, and cypress.

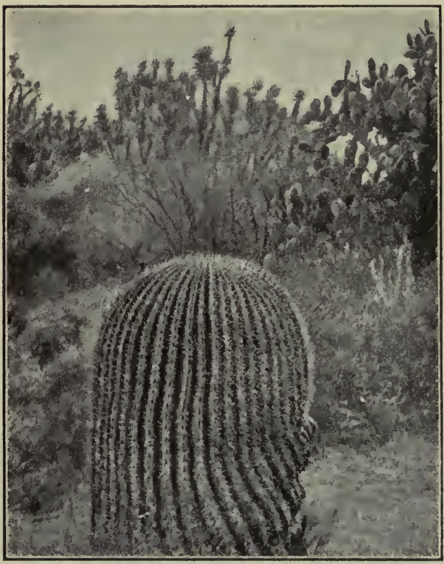


Fig. 191. — Drouth plants. Barrel cactus, Mexico.

Drouth Plants are adapted to thrive in a dry soil and climate. They generally have an extensive root system in proportion to the size of the plant, a small leaf surface, and a thickened epidermis. Many plants survive regular periods of drouth by the disappearance of root, stem, and leaves, and the reduction of the individual plant to seeds, bulbs, or tubers. The shedding of leaves is a provision against destruction by the dry as well as the cold season. The reduction of the leaves to threads or needles, as in the pine and other species of coniferous trees, and the total absence of leaves, as in the cactus, are efficient means of withstanding drouth. The perfection of these adaptations is probably found in the melon cactus, in which the whole plant is reduced to a spiny, thick-skinned, globular mass.

Intermediate Plants. — The class of plants adapted to a medium supply of water comprises about 80 per cent of all known forms and constitutes the more common vegetation of temperate regions.

Salt Plants. — Some species of plants are able to grow where the soil water is impregnated with common salt or alkali, which would be fatal to most plants. Salt plants are found along the seashore, in tidal marshes, around salt lakes, and in arid regions.

Plant Regions. — The land surface may be divided according to its vegetative covering into woodland, grassland, and desert.

1. *Woodland.* — Trees are deep-rooted and their growth is not dependent on frequent rain or a rainy growing season, but

on the presence of water within reach of the deep roots. They require a warm growing season, a moist subsoil, and calm, damp air in winter. They may thrive where long seasons of drouth recur periodically. They are not limited by low temperature in winter, if protected by a snow covering, but suffer from dry winds when the ground water is frozen.

2. *Grassland.* — Grasses are shallow-rooted and their growth is dependent upon a moist superficial soil. They require frequent, even if small, rainfall during the growing season. They endure extreme drouth during the season of rest.

3. *Desert.* — Deserts are due to dryness of the ground or low temperature. Except on ice caps, vegetation is not absent but sparse. There is always much vacant space, and the plants do not struggle against one another for room, but against unfavorable conditions of soil and climate. Fig. 192 shows the distribution of the principal types of vegetation. It should be compared with the map of climatic regions (Fig. 188).

Wet Woodland. — *Tropical Rain Forest.* — In the climatic regions of the Amazon type, where the temperature is constantly high and the rainfall above 60 inches, the growth of vegetation is luxuriant. Dense forests of very tall trees, overgrown with climbing plants and air plants, and crowded with underbrush, occupy the country and almost shut out large animals and men. The trees have large, thin leaves with smooth, glossy skin to shed water, and are green all the year round. The number of species growing together is very large, but palms and tree ferns are characteristic. This woodland can hardly be penetrated except by way of the streams, and is more difficult to cross than a desert.

If men, with great labor, make a little clearing in it to plant crops, the native vegetation springs up again so rankly that the work of clearing must be done over again every year. The heavy rainfall leaches and washes away the soil, which is soon exhausted. The hot, damp air is unhealthful and oppressive, and the scattered inhabitants, overcome by the forces of nature, are unable to rise above a state of savagery. These conditions prevail in a large part of the Amazon basin, in west equatorial

PLANT REGIONS

After Schimper and Others

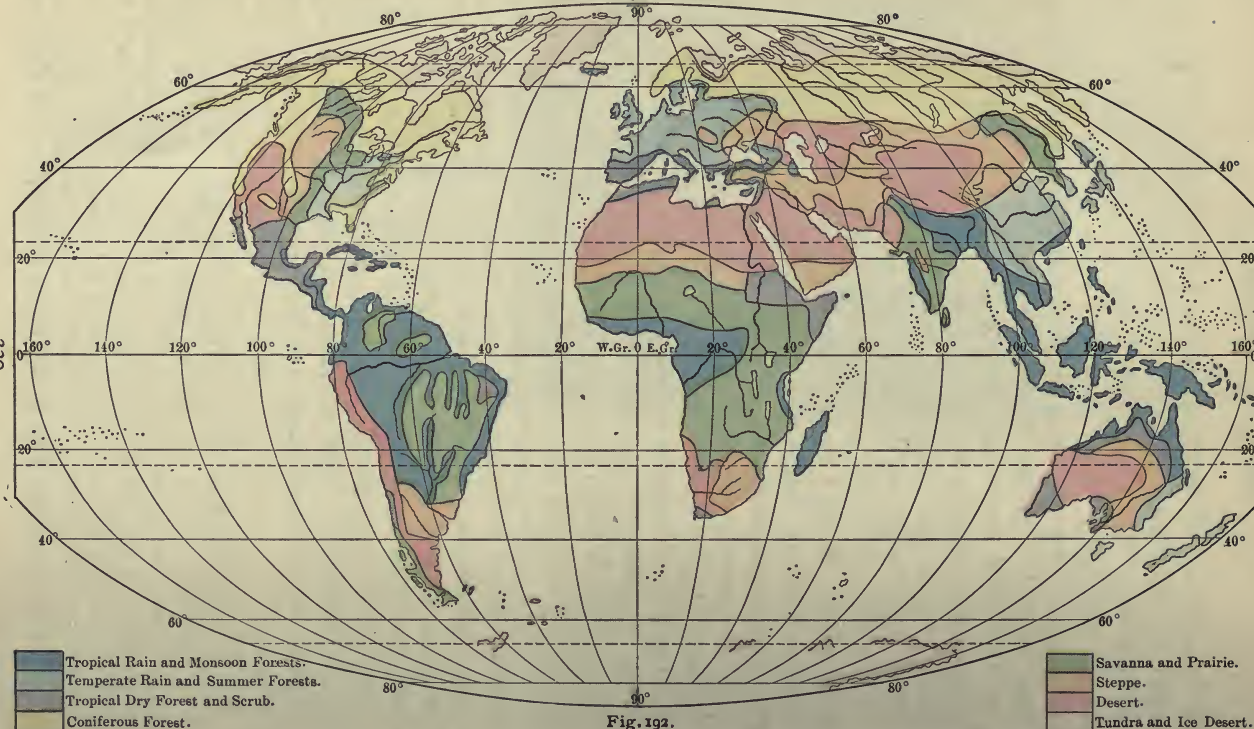


Fig. 192.

Africa, and in the East Indies. European peoples have made some progress in establishing colonies in all these regions, and have stimulated the natives to gather and grow valuable tropical products, such as rubber, sugar, coffee, spices, chocolate, tapioca, tobacco, fruits, oils, and medicines.

Fig. 193. — Tropical rain forest, Java.

Monsoon Forests. — In some parts of the monsoon region of southeastern Asia the rainfall is more than 60 inches, but occurs mostly in summer, while the winters are relatively cool and dry. In the rainy season the forests are much like the tropical rain forest, but in the dry season are leafless.

Temperate Rain Forest. — In the climatic regions of the Floridan type the conditions are similar to those of the tropical rain forest, except that the temperatures are not so high and the rainfall is not so heavy. They are occupied by a mixed forest of evergreen and deciduous trees. Climbing and air plants, ferns, and tree ferns are abundant. The multiplicity of species is very great. The camphor tree of Formosa, the eucalyptus of Australia, and the palmetto and live oak of Florida are characteristic. These forests are much less formidable than the tropical rain forests. They have been largely cleared and the lands now support a moderate or dense population of civilized people. The principal crops are rice, corn, wheat, sugar cane, cotton, semi-tropical fruits, and, in China, tea.

Fig. 194. — Temperate rain forest, Florida.

Temperate Summer Forest. — The climatic regions of the Oregon and Mississippian types are very favorable to the growth of trees which have broad, soft, thin leaves in summer and are bare in winter. The oak, beech, maple, elm, chestnut, ash, linden, and sycamore are characteristic and widely distributed. Climbing plants and air plants are rare, but grasses and herbaceous plants growing among the trees are relatively abundant.

These forests furnish the world's supply of hardwood timber for fuel and construction. In the United States and Europe they have been largely destroyed to clear the land for agriculture. The combination of forest and grassland, natural or artificial, affords good conditions for agriculture and stock raising, and makes these regions preëminent in the production of foodstuffs and the homes of the richest and most progressive peoples.

Fig. 195.—Temperate summer forest, North Carolina. (U.S.G.S.)

Dry Woodland. — *Tropical Dry Forest.* — In the climatic regions of the Californian type and some of the Mexican type trees grow in clumps rather than in forests. The leaves are evergreen, small and thick, with a leathery skin. The myrtle, holly, laurel, box, cork oak, oleander, cypress, and olive are characteristic species. Lilies, tulips, hyacinths, and other herbaceous plants growing from bulbs and tubers are numerous. Grass is scanty and poor, and sheep and goats are kept in preference to cattle. In the Mediterranean region olive oil largely takes the place of meat and butter. Grapes and tropical fruits flourish, while grain is grown in the cool, moist season or by means of irrigation.

The plateau of the Dekkan (Mex. 4, Fig. 188) is protected by bordering heights from the excessive monsoon rains. Two or more crops a year are often raised, some suitable to the hot, wet season (June to October), and others to the cool, dry season (November to March). Thus the same area may produce large crops of wheat, rice, and cotton. The monsoon rains are so variable from year to year that the crops often fail, and on account of the dense population a dry year may bring a serious famine in which thousands starve to death. Irrigation is practiced, and India is dotted with storage tanks and wells. About 50,000 miles of canals carry off flood waters, and in the dry season distribute water to the fields.

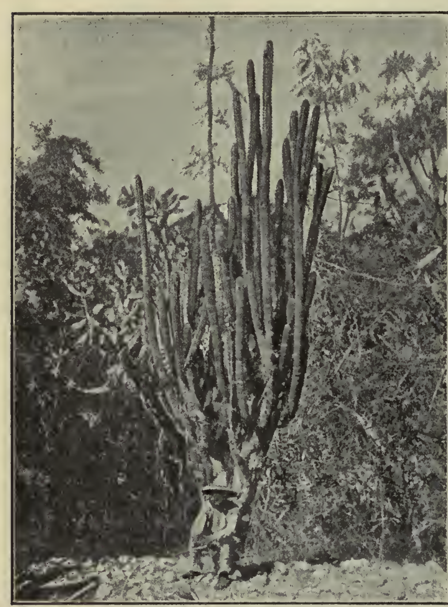


Fig. 196.—Tropical dry forest, Mexico.

Extreme forms of tropical dry forest are *thorn forest* and *thorn scrub*, in which all woody plants are dwarfed, scraggy, thorny, and tangled, forming thickets difficult to penetrate (Fig. 196). The dwarf oak, acacia, and mesquite are characteristic. Thorn forests occur in scattered patches in the borderlands around deserts and grasslands. It is called *chapparal* in North America, *catinga* in Brazil, and *scrub* in Australia (Fig. 203).

Temperate Dry Forest (Coniferous).—Climatic regions of the Alaskan and Canadian types are generally occupied by evergreen coniferous forests. Most of the species have a central trunk, with horizontal or pendent branches in whorls, and their fruit is a cone. The needle-shaped or scale-shaped leaves, with a hard skin, are adapted to dry and frozen soils and strong winds. The pine, fir, spruce, cedar, and larch extend throughout the cold temperate belts and on mountain sides in all latitudes, and furnish the world's supply of soft-wood timber.

The valuable products are timber, as yet largely unavailable for want of means of transportation, and the furs of numerous small animals, such as

Fig. 197. — Coniferous forest, Great Bear Lake, Canada.

Fig. 198. — Spruce forest, Colorado.

the fox, sable, marten, mink, otter, badger, beaver, and muskrat. Canada and Siberia have been for centuries the chief sources of furs, and there is no indication that the supply is diminishing. The population is generally very sparse. Coniferous forests sometimes occur on poor, porous soils, in wet, warm regions, as the long-leaved pine of the southern United States

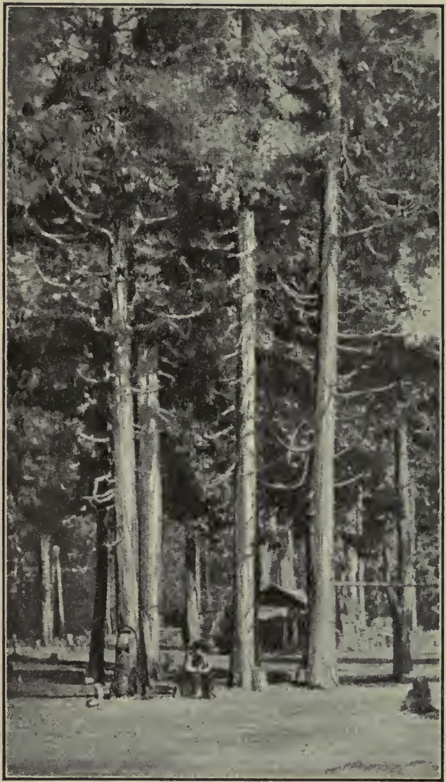


Fig. 199. — Cedar forest, Oregon. (U.S.G.S.)

Grassland. — *Savanna.* — In climatic regions of the Caribbean type, the vegetation consists chiefly of tall, stiff grasses growing in dense tufts. Low, deciduous trees with parasol-shaped tops are scattered about and give the landscape a parklike aspect (Fig. 200). A large part of central Africa is occupied by such savannas, the home of immense numbers of large animals, — the elephant, rhinoceros, hippopotamus, giraffe, lion, leopard, buffalo, zebra, and nearly one hundred species of antelopes. It is the finest country in the world for "big game."

The abundance of animal life has been a serious hindrance to human occupation and control, but is itself an evidence of what might be done there with domestic animals. The success of native agriculture, carried on with rude implements and methods, in raising corn, bananas, millet, beans, sheep, goats, and cattle, suggests great possibilities for the future. Under the control of Europeans the black natives are prevented from robbing and killing one another, and are settling down into peaceful and orderly industrial communities. The natural conditions are favorable for their redemption from primeval savagery and for the occupation of the country by civilized peoples.

Fig. 200. — Savanna with fringing forest, East Africa.

A part of Brazil is a plateau with moderate rainfall, and the forests are replaced by *campos*, or undulating grassy tracts, with clumps of trees in the valleys. In Venezuela the rain shadow of the Guiana highlands produces the *llanos*, which have a warm, rainless winter of five months, during which all vegetation apparently dies. When the summer rains appear grass and herbaceous plants spring up and grow luxuriantly. In swampy depressions and along streams oases of stunted trees rise like islands from the sea.

Prairie. — In the drier parts of climatic regions of the Mississippian type, forests give place to prairies, or open tracts of meadow, covered with a thick, continuous sod of grasses and other herbaceous plants. Fringing forests of small trees along the streams do not occupy more than 20 per cent of the area. The soil is especially fertile and easily worked. Such lands lie all ready for human occupancy, and are at once available with small expenditure of labor. The American prairies are one of the most productive agricultural regions in the world.

Steppe. — Climatic regions of the Interior type, and other

Fig. 201. — Bunch grass. (U.S.G.S.)

temperate regions with a rainfall between 10 and 20 inches, are covered with bunch grass, which does not form a continuous sod or grow very high. It cures on the ground into a nutritious hay. Trees are very rare. Vast areas of this kind exist in the interior of Eurasia, where they are called steppes. They have been for many centuries the home of nomad peoples, who have no fixed habitation, but wander about with flocks and herds of cattle, horses, camels, sheep, and goats in search of pasture. The similar regions of North America have been ranged over by herds of cattle under the care of "cowboys," but are now being divided up and fenced into cattle and sheep ranches. By irrigation and

Fig. 202. — Steppe, South Dakota. (U.S.G.S.)

dry farming agriculture is generally encroaching upon the areas of pasture.

Fig. 203.—Steppe and thorn scrub, South Africa.

The *pampas* of Argentina include prairie and steppe lands, hitherto used for raising sheep and cattle for wool and hides. As railroads are extended they are being converted into wheat fields. The *veldt* of the Transvaal, in South Africa, is a similar region, where cattle raising is combined with some agriculture (Fig. 203). The Australian *bush* between the desert and the eastern mountains, belongs to the same class, and supports millions of sheep and cattle. Steppe lands are "belts of herbage strown between the desert and the sown," and will always be important sources of meat, wool, and hides.

Fig. 204.—Sage brush desert, Arizona.

Deserts. — In desert regions the rainfall is generally less than 10 inches, but desert conditions may occur where the rainfall is much larger if rapid evaporation or subterranean drainage leaves the soil and subsoil too dry. Great deserts occur in climatic regions of the Arizonan, Interior, and Polar types.

Warm Deserts. — In tropical and temperate deserts vegetation is limited to drouth and salt plants only. The root system is large and shallow, and the leaf surface is greatly reduced. There are few leaves at once, and in many forms no leaves at all, their functions being performed by the stems. Desert plants respond quickly to a slight fall of rain, and pass through their stages of leaf, flower, and fruit rapidly. They are characterized by thick skin, hairs, spines, resins, and spongy tissue for storing water. The cactus, agave, sage brush, and creosote bush are typical forms. Where sufficient ground water exists, permanently or temporarily, oases occur and support a sparse population. The air of the desert is pure and stimulating, and acts directly, along with the hard conditions of life, to render animals and men lean, hardy, restless, and fierce.

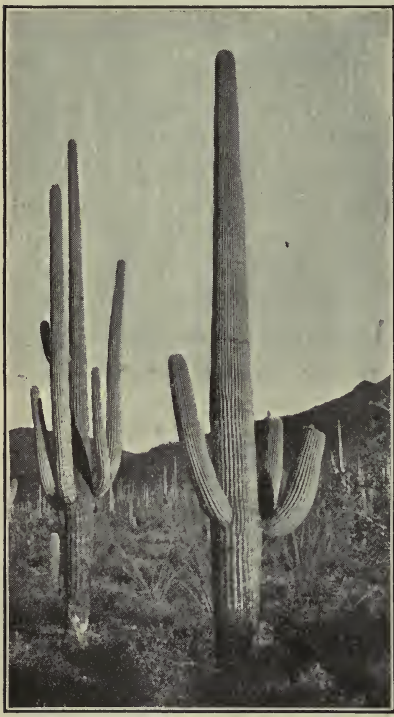


Fig. 205. — Giant cactus, Arizona.

Polar and Alpine Deserts. — Along the polar borders of coniferous forests and above the timber line on mountains, the growing season is short and plant growth is very rapid. Patches of herbaceous plants have rosettes of leaves next to the ground and send up short stems bearing bright-colored flowers. Trees,

Fig. 206. — Date palm oasis, Sahara. Note flat-roofed houses.

when present, are stunted, scraggy, and twisted. Shrubs spread out close to the ground in dense mats.

Tundras. — In high latitudes and altitudes the ground is perpetually frozen, thawing only to the depth of a few inches in

Fig. 207. — Alpine desert, Bolivia.

summer. The principal vegetation consists of lichens and mosses, upon which caribou, reindeer, musk oxen, and hares find subsistence. Willows, larches, and junipers occur in the form of

Fig. 208. — Tundra, Lapland.

dense cushions, which do not rise above the level of the snow surface of winter.

Ice Deserts. — Ice caps are entirely devoid of vegetation, except the occasional appearance of microscopic algæ known as "red snow."

In cold deserts the possibilities of human life are reduced to the lowest limits. In Europe the Laplanders maintain a semicivilized life by keeping herds of reindeer. In Asia the Chukchis, and in America the Eskimos, depend largely upon the sea, in which fish, birds, seals, and walrus abound.

CHAPTER XVII

THE GEOGRAPHY OF ANIMALS

Water Breathers and Air Breathers. — The most important distinction among animals due to adaptation to geographical environment is that between those which absorb oxygen from solution in water and soon die out of water, and those which absorb oxygen from the air and soon die when immersed in water. The conditions of life in the water are more simple and less varied than in the air. The water furnishes nearly uniform pressure on all sides of the body, and little energy is expended in supporting weight; hence the form and surface of the body, the structure of the skeleton and muscular system, and the character and arrangement of the limbs are adapted to propulsion through the medium. A comparison of a fish and a cat will show a remarkable contrast in these particulars. The water breathers include all fish, most shellfish, such as oysters and clams, most crustaceans, such as crabs and lobsters, and a vast number of lower and less familiar forms of animal life. The temperature of water is uniform over wide areas, and far less changeable than that of the air. Food supply is more generally diffused in water than on land, and many aquatic animals are fixed to one spot and have their food brought to them by currents. Hence the water breathers belong entirely to the less highly developed classes. The demands upon them are comparatively few and simple, and their lives do not require the numerous and complex activities and abilities of life in the air.

Marine animals depend directly or indirectly for food upon the vegetation which flourishes in the sea or the organic matter brought by rivers from the land. Life in the sea is most abundant in the shallow waters of the continental shelf (p. 24), which are penetrated by the heat and light of the sun, and where the bottom is covered with mud from the land. The open sea is inhabited near the surface by great schools of fish and swarms of invertebrate animals, many of which are minute in size. The abundance of mineral matter in solution, the volume of sunlight, and the uniformity of temperature are favorable to the growth of microscopic plants in such numbers as to furnish an ample food supply for all.

The sea is probably rather densely inhabited at all depths, but those animals which live constantly below a few hundred feet are difficult to catch, and our knowledge of them is imperfect. Deep-sea animals exist

Fig. 209.—Deep-sea fish, with lanterns.

under conditions of great pressure, low and unchanging temperature, and absolute darkness. Most of them are degenerate descendants of surface and shallow water forms. Some are eyeless and some are provided with lantern organs which generate a dim light. Owing to the great area and depth of inhabited waters, the number of marine animals probably exceeds all others.

Some animals are amphibious, spending a part of their lives in water and a part in the air. Many insects are hatched and pass their larval stage in water, but live their adult life in air. Tadpoles have gills and are true water breathers, but change into frogs, toads, or salamanders, which are air breathers. A few animals have both gills and lungs throughout life and can live in either medium. Among the higher animals some assume the aquatic form and habit, but are not water breathers. Among birds the

Fig. 210. — Marine mammals.

penguins swim vigorously under water in pursuit of fish. Even some mammals, which suckle their young and cannot live more than a few minutes under water, have assumed the aquatic form and habit. Such are the whale, dolphin, porpoise, sea cow, seal, and walrus. The last two are ice-riding animals, vigorous swimmers which spend a part of the time on the polar ice.

Fig. 211. — Penguins. Wings are used for swimming. (Shackleton's *The Heart of the Antarctic.*)

Fliers and Walkers. — Another distinction among animals, scarcely less important geographically, is the division of air breathers into fliers and walkers or crawlers. Most birds and insects and a few mammals have become highly specialized for locomotion in the air. The buoyancy and resistance of the air are slight compared with water, and flying requires a more complex body structure than swimming. The insect body is small and very light, with a thin outer shell, provided with one or two pairs of delicate wings. The muscles inside the shell are capable of moving the wings at a high speed, amounting in the house fly to 330 strokes a second. The bones of the bird are hollow and filled with air for lightness, the fore limbs are provided with a complex arrangement of interlocking and folding feather vanes, the breast bone and muscles are strongly developed for moving the wings, and the tail feathers act as a rudder.

Fig. 212. — Soaring bird.

Among the more powerful birds, flight has attained the climax of natural locomotion. The passenger pigeon can fly 100 miles an hour, the eagle and condor can rise to great heights and soar almost without effort, while the albatross and frigate bird make journeys of thousands of miles across the sea. Yet no animal can live in the air indefinitely without alighting on land or water for rest and food.

Animal Adaptations. — The adaptations of animals to food supply, climate, enemies, and breeding are innumerable. A few of the more striking cases may be noticed.

Most insects are vegetable eaters and live upon the juices and leaves of plants. Many eat dead animal matter or are parasitic on live animals.

The large majority of birds live on seeds, fruits, and insects. Sea birds are fish eaters, and birds of prey catch land animals alive. A few are scavengers of carrion.

Mammals, with few exceptions, are land animals and walk, run, or jump. A few species swim (p. 245). Bats are the only mammals that really fly. Most mammals are plant eaters (herbivorous) or flesh eaters (carnivorous), but bears, swine, and men eat all kinds of food. Plant eaters have cutting teeth for cropping herbage, and flat grinders for chewing it. The large ones are hoofed animals, including cattle, sheep, goats, deer, antelopes, the giraffe, camel, horse, hog, hippopotamus, rhinoceros, and elephant. The small plant eaters are gnawers (rodents), such as the squirrel, prairie dog, beaver, rat, mouse, guinea pig, and rabbit. The flesh eaters live mostly upon the plant eaters and generally have claws and sharp teeth for catching, holding, and tearing their prey. The large ones are bold and fierce, with keen senses and quick intelligence, as shown by the cat, lion, tiger, leopard, panther, dog, fox, wolf, bear, otter, and weasel. The small ones live chiefly upon insects, as the mole and the bat. The plant eaters in a wild state are in constant danger of attack from the flesh eaters, and few of them have adequate means of defense. Their safety lies in flight or concealment; hence the majority have keen senses and are slender, agile, and built for speed.

Fig. 213.—Plant eater: caribou.

Fig. 214.—Flesh eater: lion.

A few are able to maintain themselves by strength, mass, and tough skin, as the bison, rhinoceros, hippopotamus, and elephant. The rodents are in danger from birds as well as beasts of prey, and find refuge by burrowing in the ground, in hollow trees, or about buildings.


Fig. 215.—**Hippopotamus.** Lives mostly in water with only eyes and nostrils above the surface.

Many animals of all classes are favored by protective coloration which makes them almost invisible in their usual haunts. Cases of this kind are most numerous among insects and birds, but the lion on the sand, the leopard, zebra, and giraffe in the forest, and the Arctic fox, hare, and ptarmigan on the snow, are striking examples.

Shelter.—The higher animals generally make use of some kind of a shelter, nest, or house, at least for the purpose of rest and rearing their young. Aquatic animals are generally homeless, but fur seals swim hundreds of miles to reach the islands where they annually congregate to bring forth their cubs. On land, animals burrow in the ground and make use of natural rock houses or dens. Beasts of prey find shelter and a sleeping place in some thicket. The hippopotamus spends the day in the water, with only his nostrils visible. The large plant eaters are generally homeless and their young are "precocious," or able to run with their mothers soon after birth. Constructive ability reaches a high development among birds, whose nests are often marvels of skill in the choice of site and in the adaptation of materials to home building. Yet the palm for such achievement must be given not to any bird, but to the beaver and the bee. The beaver gnaws down trees, builds an elaborate dam with timber and mud, raises his house of reeds above the surface of the pond, and enters it through a tunnel opening under water. Bees construct in a hollow tree a comb made of their own wax, in a form which gives a maximum of storage space with a minimum of material, and fill it with honey and pollen.

It is notable, however, that such feats are accomplished only by an organized community which rivals human society.

Distribution of Animals. — Animals are so much more mobile than plants that they have become more widely diffused, and the earth cannot be divided into animal regions so clearly distinguished as the plant regions. It may be said that every species of animal would be found in every part of the earth suitable for its maintenance, if it were not prevented by barriers of some sort which its individuals are unable to cross. The principal barriers to animal migration are water, climate, mountains, deserts, forests, lack of food supply, and enemies. Marine animals are generally limited to salt water, but some sea fish run up rivers to spawn and feed. The barriers in the sea are differences of temperature, pressure, and food supply. Shallow-water forms never venture far into the open sea because of lack of food. Deep-sea forms die when brought to the surface because of reduction of pressure. Those which swarm in warm surface waters would perish in waters a few degrees colder.

On land the most widely distributed animals are birds, bats, and some insects on account of their powers of flight. Those of smallest range are found among fresh-water fishes, which cannot cross from one stream system to another and are stopped by high falls, and snails, which are very poor travelers. For most land animals except fliers the sea is an absolute barrier to migration, and each land mass would have a fauna in most respects unlike every other if there had never been any land connection with some other mass. Mountain ranges are barriers more on account of climate and limited food supply than height and steepness. If they were not cold and barren most animals would be able to climb and cross them. Deserts are nearly as efficient barriers as the sea because they are almost equally foodless. Grazing animals cannot cross a wide belt of dense forest because of want of grass, and forest animals do not flourish in grassland. Although warm-blooded animals have the power to maintain their bodily temperature above that of the surrounding air and are generally protected by a coat of hair, wool, feathers, or fat, these things are not sufficient to enable them to live in all climates. Domestic cattle would soon perish in Greenland, where the musk ox seems not to suffer at temperatures of eighty degrees below zero. Polar bears brought to temperate regions must be constantly supplied with ice.

Fig. 216. — Musk ox.

Animal Realms. — *The Northern Realm.* — The northern continents are close together, and in the past have been so connected as to give a continuous land area from Norway eastward around to Labrador. The bulk of these continents lies in temperate regions between the tropic and the polar circle, and there is no impassable north-south mountain barrier. Consequently the fauna throughout this vast area presents a striking similarity, with a multitude of minor differences. It is especially the home of the hoofed grass eaters, — cattle, deer, sheep, goats, horses, and camels. While beasts of prey are not absent, the species are relatively few in num-

Fig. 217. — Animal realms and regions.

ber and inferior in size. These natural conditions have been intensified by man, who has killed the flesh eaters and bred the grass eaters. North Africa has recently been connected by land bridges with Europe, and belongs to the Northern realm, which finds its southern land boundaries along the tropic in the natural barriers of the Mexican plateau, the Sahara and Arabian deserts, and the great mountain ranges of southern Asia.

Fig. 218.—Zebra.

The Indo-African Realm lies between the tropics and includes Africa south of the Sahara, Asia south of the Himalayas, and most of the islands of the East Indies. It is far richer in number and variety of species than the Northern realm. The plant eaters are well represented by wild cattle, asses, and horses in Asia and by antelopes and zebras in Africa; but the flesh eaters are even more conspicuous,

Fig. 219.—Chimpanzee.

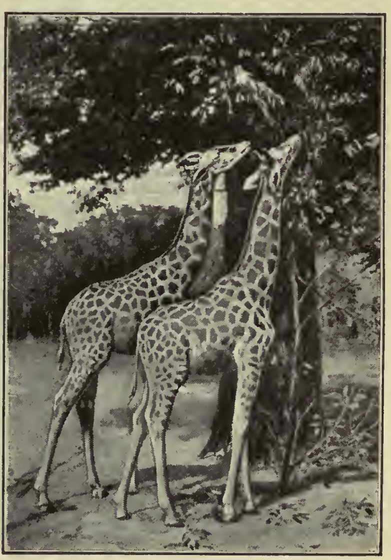


Fig. 220.—Giraffes.

including the lion, tiger, leopard, and panther, the largest and most ferocious of their class. It is the home of the largest land animals, — the rhinoceros, hippopotamus, and elephant, — and of the tallest, — the giraffe. It is well supplied with four-handed folk, containing all the manlike apes, the gorilla, chimpanzee, and orang, and all the tailless monkeys, besides baboons, gibbons, and lemurs. Among its birds are eagles, vultures, ostriches, guinea fowls, peafowls, pheasants, and the jungle cock. Crocodiles and venomous serpents abound. More than half its mammals and birds do not occur elsewhere. In number, variety, and beauty of butterflies and beetles it is unrivaled. Central Africa is now the richest region in the world for big game, but white men will soon exterminate many of the species unless they are protected by law.

Fig. 221.— Ostriches.

The South American Realm is almost wholly tropical and includes the most extensive and luxuriant forests in the world. Large animals of the higher classes are singularly few. Notwithstanding the existence of the pampas, llanos, and campos (pp. 237, 239), which are vast seas of grass, the hoofed grass eaters are poorly represented by a few deer, the llama and three other small species of the camel family, the peccary, and the tapir. Horses, cattle, and sheep have been introduced from Europe. The beasts of prey are the puma, panther, and jaguar, the latter a match for the lion. Among animals peculiar to this realm are the little arma-

Fig. 222.— Llama.

dillos, the sluggish sloths, the toothless anteaters, and the long-tailed monkeys. Yet it is surpassingly rich in the lower forms of life, and is the paradise of naturalists. In birds, reptiles, fishes, and insects it is the most populous part of the world. Five sixths of the birds do not occur elsewhere. There are 400 species of humming birds. Among its serpents are the anaconda and boa constrictor, the largest of their kind; and turtles, crocodiles, and alligators abound.

Fig. 223. — Tapir.

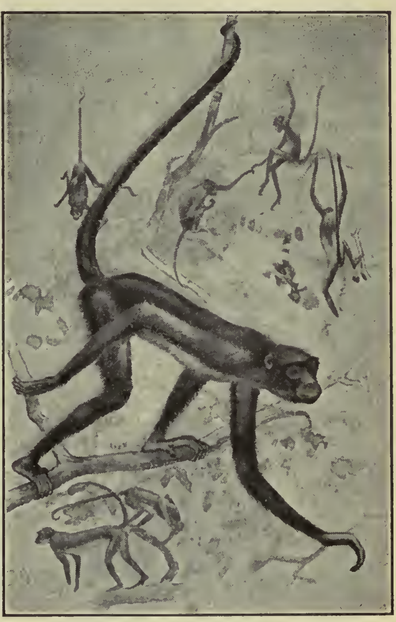


Fig. 224. — Monkey.

Most of the animals in the world would thrive in South America if they could get there.

The Australian Realm, including Australia, New Zealand, New Guinea, and some small islands, presents the poorest and strangest assemblage of animals in the world. Most of its mammals belong to the small and unique group which carry their young in an abdominal pouch formed by a fold of skin. The largest is the kangaroo, as tall as a man, and making prodigious leaps with its powerful hind legs and tail. These and several species of large and almost wingless birds, the emus and cassowaries, are the most prominent of the native inhabitants.

Fig. 225. — Emu.

Fig. 226. — Kangaroo.

Flesh eaters are represented only by dogs. These lands have been long separated from the other continents by deep water, which has kept out all the larger and higher forms, including beasts and birds of prey. They are a sort of museum in which weak and inferior species, long ago destroyed in other lands, have been protected from enemies and preserved. The thoroughness of this protection is shown by the fact that rabbits introduced from Europe have so multiplied in the absence of enemies as to become a serious pest.

Islands are poor in species of both animals and plants in proportion to their distance from the continents. Mammals are often entirely wanting. Birds and insects, which can fly, and reptiles, whose eggs are not killed by salt water, are more numerous.

CHAPTER XVIII

THE HUMAN SPECIES

Man as an Animal. — Compared with the animals which are physically best equipped for the struggle for existence, man is in most respects inferior. He cannot fly, is a slow and awkward swimmer, and is easily outstripped in running. For defense he has no horns, or hoofs, or beak, or claws, and his teeth are small. His skin is soft, thin, and almost naked. The young require parental care for many years. His structure indicates descent from ancestors of apelike habits, living in trees and on fruits. The physical characters which render him superior to all other animals pertain chiefly to the feet, hands, and skull. The feet and limbs are used for locomotion only, and he can stand and walk erect. The hands and arms are highly perfected and left free for use solely as organs for grasping, holding, and performing delicate and complex movements. The skull has more than twice the capacity of that of any ape. Its sutures do not unite for twenty years or more, thus enabling the brain to attain a weight in proportion to the total body weight four to thirty times that of other intelligent animals. The long period of growth, and the size and complexity of the brain, render possible a development of the mental powers which sets the human species apart from

Courtesy of the University Society.

Fig. 227. — Negro boy and apes.

all the other inhabitants of the earth, and almost immeasurably superior to them. With few exceptions, man is the only species in which the individuals coöperate in a complex way for the benefit of the community. It is by living in societies that man has become educated and civilized. "Man has not made society, but society has made man." All those things which are the result of human thought constitute a realm by itself, which may be called the *mind sphere* (*psychosphere*).

Enemies. — Man's worst enemies are no longer beasts of prey and venomous serpents, although these are still formidable in Africa and India, but the minute organisms which infect his body with disease. Many tribes of American Indians have been exterminated by smallpox and measles. To-day parts of central Africa are being depopulated by sleeping sickness. The plague is carrying off the people of India by the hundred thousand. Asiatic cholera and yellow fever, bred in the tropics, have repeatedly carried death into temperate countries. Malarial fever renders many parts of the equatorial regions almost uninhabitable by white men. Yet no one of these diseases is more destructive than the "white plague" of tuberculosis, which causes as many deaths in the United States every year as did the whole Civil War. All these diseases and many more are caused by microscopic plants or animals which multiply in the blood, and have been unrecognized until recently. Medical and sanitary science has discovered means of defense against many of these enemies, and may be expected to conquer all of them in time.

Varieties and Races. — Of all species of animals, man is the most widely distributed. His intelligence enables him to live in all lands and all climates between Greenland and Tierra del Fuego, and from marshes and islands near sea level to the high Andes and Himalayas. From his cradle land, which was probably in southern Asia, he seems to have migrated in all directions, without definite purpose or destination, wherever the land connections of those remote times furnished a road. Led on by the pursuit of food, or driven from place to place by enemies, he penetrated every unoccupied land, and while still in a very rude stage of culture took possession of most of the habitable world. In the struggle for existence under such a great variety of conditions, men, like other animals, necessarily developed differently and unequally. Hence arose four distinct races, differing in physical and mental characteristics. The hot, moist equatorial forests of central Africa produced a *black race* (Ethiopian), which spread over tropical Africa and the whole

Fig. 228. — Ethiopian race.

of Australia, which formed a new center, where men of a somewhat different and lower type were developed. The high, arid

Fig. 229. — Mongolian race.

Fig. 230. — American race.

plateaus of central Asia produced a *yellow race* (Mongolian), which spread over nearly the whole of Asia and the neighboring islands. The American continent produced a *red race* (American), perhaps originally a branch of the yellow, which occupied its whole area for many centuries without interference from the rest of the world. North Africa and western Europe gave birth to a *white*

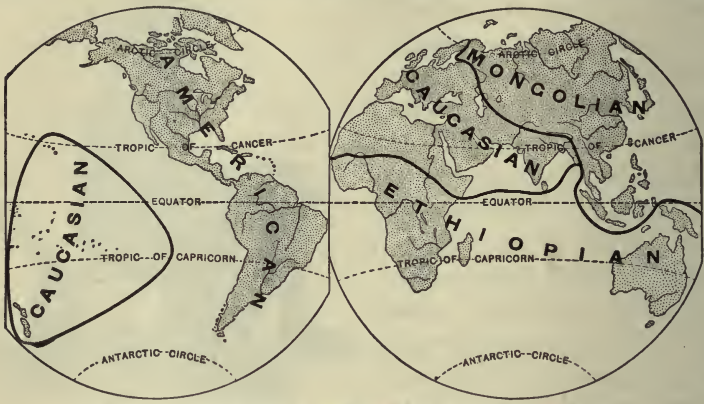


Fig. 231. — Distribution of races previous to modern migrations.

race (Caucasian), which, in historic times, has spread thence over northern and southern Asia, America, south Africa, and Australia, dispossessing or gaining control of the aboriginal races. Fig. 231 shows the distribution of the four races as it was previous to the modern migrations which began in the sixteenth century. The table on page 259 shows their distinctive characteristics and present distribution.

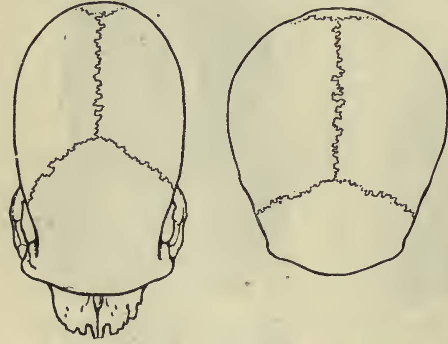


Fig. 232. — Long skull and broad skull.

Types of the Caucasian Race. — The peoples of each race, though alike in the characteristics mentioned on page 259, differ in many minor details. Among the peoples of the Caucasian race there are three well-marked types, Baltic, Alpine and Mediterranean:

	Ethiopian or Black Race (Fig. 228)	Mongolian or Yellow Race (Fig. 229)	American or Red Race (Fig. 230)	Caucasian or White Race (Figs. 233–235)
Home	Central Africa.	Central Asia.	America.	Europe, north Africa.
Color	Chocolate to black.	Yellowish to brown.	Coppery red.	Pale white to nearly black.
Hair	Black; frizzly, woolly, or shaggy.	Black, long, straight, coarse; beard scanty.	Black, long, straight, coarse; beard scanty.	Flaxen, red, brown, or black; straight, wavy, or curly; beard heavy.
Skull	Long and narrow.	Broad and round.	Variable.	Variable.
Jaws	Projecting.	Slightly projecting.	Massive.	Not projecting, small.
Lips	Thick and rolling.	Rather thin.	Medium.	Thin, or rather full.
Nose	Broad and flat.	Small and concave.	Large; straight, or aquiline.	Straight and narrow, with high bridge.
Eyes	Large, round, black; yellowish cornea.	Small, black, and oblique.	Small, black, and deep-set.	Blue, gray, brown, or black.
Culture	Very low; no science or letters; arts confined to agriculture, weaving, pottery, woodwork, and the use of simple implements of iron.	Ranges from savagery to civilization; agriculture and some arts well developed; letters common, but science and literature stagnant.	Ranges from the lowest savagery to low civilization; agriculture and the arts moderately developed in the highest; letters and science rudimentary.	Civilized, or enlightened; arts, industries, science, literature, and social institutions highly developed.
Present range	Africa, United States, West Indies, Brazil, Peru, Guiana, Australia, New Guinea, and neighboring islands.	All Asia, except India, Persia, Arabia, and Afghanistan; East Indies and Asiatic islands; northeastern Europe, Turkey.	Most of South and Central America, Mexico, Alaska, and Canada, and some small areas of the United States.	Europe, north and south Africa, northern and southern Asia, India, America, Australia, New Zealand, and many other islands.

1. *Baltic.* — Blond or florid, with flaxen or reddish glossy hair, blue eyes, long skull, and tall stature. Scandinavians, North Germans, Dutch, English, Scotch, Irish, and their descendants in America, Australia, and south Africa; West Persians, Afghans, many Hindus, and some other peoples of southwest Asia.

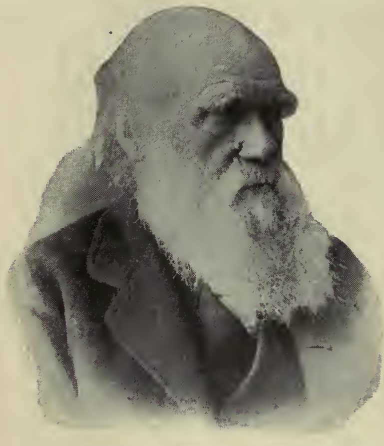


Fig. 233. — Baltic type. Darwin.

Fig. 234. — Alpine type. Pasteur.

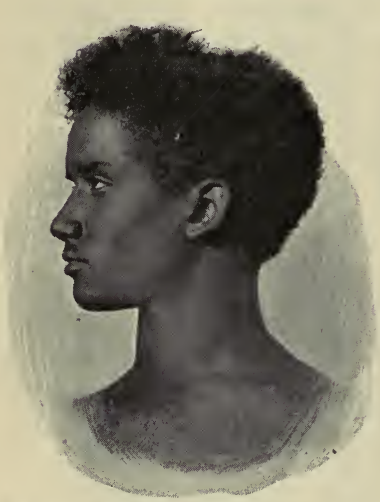


Fig. 235. — Mediterranean type. — A Sicilian.

2. *Alpine.* — Light brown or swarthy, with brown, wavy dull hair, brown, gray, or black eyes, broad skull, and medium stature. Most French and Welsh, South Germans, Swiss, Russians, Poles, Bohemians, and other peoples of southeastern Europe; Armenians, East Persians, and the peoples of the eastern Pacific islands.

3. *Mediterranean.* — Olive brown to almost black, with dark

DENSITY OF POPULATION
(*After Supan and Others*)

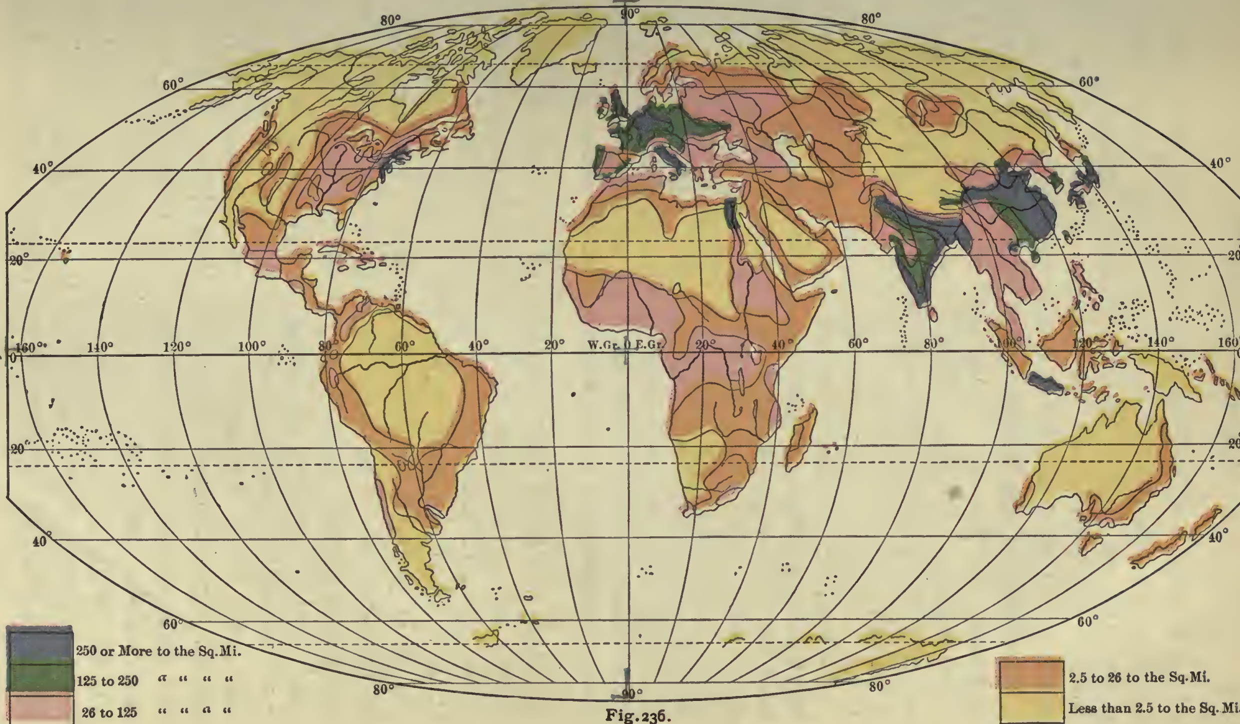


Fig. 236.

or black wiry hair, dark or black eyes, long skull, and small stature. Spanish and Portuguese and their descendants in America; some French, Welsh, and Irish; Italians and Greeks; Berbers, Egyptians, and other peoples of north Africa; Arabs, Syrians, and other peoples of southwest Asia; some Hindus.

Population of the World. — The population of the world has increased 250 per cent in the last century, and now exceeds 1,600 millions. Of these about 51 per cent are Caucasian, 36 per cent Mongolian, 11 per cent Ethiopian, and 1 or 2 per cent American.

The map, Fig. 236, shows that the large groups of dense population are all in the northern continents and mostly between the tropic and the polar circle. About 75 per cent of the world's population live between the annual isotherms of 40° and 70°; this is not wholly due to the direct influence of temperature, but largely to the difficulty of maintaining human life in the midst of luxuriant tropical vegetation. The most habitable parts of the world lie between the tropical forests and deserts and the cold temperate coniferous forests. More than 70 per cent of the world's population live in regions having a rainfall between 20 and 60 inches.

"Man is a deep-sea inhabitant of an ocean of air," and thrives best where there is the greatest depth of atmosphere above him. In 1880, 93 per cent of the people of the United States lived at elevations of less than 1,500 feet above the sea, and it is probable that the proportion is not very different for the whole world to-day. The possibilities of population in any region depend primarily upon the number of people that can be fed. Therefore the highest densities may be looked for in warm lowlands without excessive rainfall, and in cooler and drier lands which can import a part of their food supply from abroad. In such cases accessibility from the sea is an important factor. The former conditions are exemplified in southeastern Asia, where half the people of the world live almost entirely on their own products, and the latter conditions in western Europe, where one fifth of the world's population live largely by buying food from America, eastern Europe, and Asia.

PART II. ECONOMIC GEOGRAPHY

CHAPTER XIX

NATURAL RESOURCES AND FOOD SUPPLY

Natural Resources. — Wherever and however men live, they are dependent upon the natural resources of the earth for a living. A naturalist on the coast of Australia relates how he came across a band of "black fellows," as the natives are called, at their camp, or rather lying-down place, for they had no huts or shelter of any kind. He hired them to show him the nests of a certain species of bird, promising to give them plenty of biscuit after they had shown the nests. They were all clothed in natural attire, the brown-black skin in which they were born, with the addition of a thick coat of white clay and red and yellow ochre on their faces and chests. Each man carried one or two spears, which he threw at the birds flying overhead. One climbed a tree, tore off some onion-like plants growing on the upper limbs, and threw them down to his companions, who ate them all up before he got down to claim his share. Along a stretch of rocky shore were many crabs, which the blacks caught and ate raw and alive. They also found sea snails with shells three or four inches long, which they strung on a reed stem to hang in the sun until the animal should die and putrefy, so that it could be drawn out and eaten. Some bulbs like Indian turnip were dug up and tied in their hair, to be cooked in the future. A lizard and a grub six inches long were tussled for, torn in pieces, and swallowed on the spot. The nests having been found and the biscuits handed over, the blacks filled themselves and lay down to sleep. They cared no more for the traveler or his biscuit. One had a short pipe tied to his arm, and was persuaded by the promise of tobacco to pilot the traveler back to the shore.

The wants of these savages are almost as simple as those of the animals around them, and they exercise but little more forethought than the animals in providing for them. The European colonists and their descendants living in the same country make use of a hundred natural resources of which the savages never dreamed. They grow wheat, corn, grapes, oranges, and other fruit, raise sheep and cattle, and mine coal, gold, copper, and tin. They have abundance of bread, meat, and fruit to eat, and clothing to wear. They use stone, brick, timber, and iron in constructing houses, vehicles, and ships. They travel with horses, steam cars, and automobiles. They use gold and silver for ornament and coinage. They exchange their own products with all the rest of the world for comforts and luxuries which they do not find at home. Their wants increase as the means of supply increase, and there is no limit to the number of things they can use. Yet the civilized man is as dependent upon natural resources as the savage.

Fig. 237. — Australian natives.

Utilization of Natural Resources. — Most natural resources must be worked over and utilized by human labor. Crude minerals are manufactured into implements and machinery, soils are made to yield food products, forests are converted into houses and ships. Man's desire to consume and his ability to produce have increased together with the progress of civilization. The earth is not only the home of man but also his workshop and school — a great "manual-training high school." While he has made it more habitable, comfortable, and luxurious, it has made him civilized. The study of those natural resources which are useful to man, and of the uses which men make of them, constitutes the science of *economic geography*.[1] It discusses the *influence* of natural environment upon human activities, and the conscious *reaction* of man upon his environment. It recognizes the relationship between nature and human welfare, and considers how the earth is fitted for the development of civilization.

The economic progress of man means his ability to make a better living, and depends upon natural resources and human faculty. Natural resources are practically unchangeable from age to age, but man, through the experience of thousands of years and by his increasing knowledge of nature, may improve his condition indefinitely.

Chief Natural Factors. — The chief natural factors of economic geography are (1) *the substratum*, or *ground*, including minerals, soils, and ground water, (2) *climate*, (3) *plants*, and (4) *animals*. Each of these factors contributes to human welfare directly, and also through its influence on the other factors.

Soil and ground water combine with climate to determine the character of vegetation. Plants manufacture food for animals, and both for man. Plants and animals are our neighbors and kinsmen, closely related to us physiologically, and more remotely by descent from common ancestors. They have developed with man, and their control and conquest have been comparatively easy.

Some natural resources essential for the existence of man are almost everywhere present, and so abundant as to require little or no attention.

[1] Economy means literally *housekeeping*, or household management.

Among these are air, water, insolation, and land. We live at the bottom of an ocean of air, which penetrates water and solid earth to great depths. The supply is inexhaustible, and it is difficult to shut it out; yet in mines and tunnels, fans and pumps are employed to insure safety, and in crowded rooms, houses, and cities a sufficient supply of good air is a serious problem. On the sea and in deserts the traveler must continually look to his water supply or pay the penalty with his life, and water for irrigation is a costly commodity. In well-watered regions some energy and expense are generally necessary to secure good water for domestic use, and in cities one of the largest items of public expenditure is for water. Insolation, or radiant energy from the sun, penetrates the atmosphere, and furnishes heat and light to every part of the face of the earth during half of each year. It makes plants grow, enables animals to live, and supplies all the power available for human industries.

Land, as *terra firma*, or a ground upon which men can stand, walk, live, and work, is abundant and, as yet, largely unoccupied. There is room enough in the state of Texas to contain all the people in the world and to give every man, woman, and child a space as large as an ordinary city lot. Most of the land is covered by some kind of soil which is workable and fertilizable, and its total productive capacity is sufficient to support many times the present population of the world. The substratum is only superficially known and used except in mining, which is limited in depth to about one mile. Its surface is generally traversable by roads.

Food Supply.—The only absolutely necessary thing which man must procure to live is food. A part of this is easily obtained from the mineral world in the form of air, water, and common salt, but man cannot live upon mineral food alone. He must depend upon plants to convert mineral matter, air, water, and salts into organic substances which he can assimilate. Generally he robs plants of the food which they have stored up for the next season or the next generation. Bulbs, thickened roots, tubers, fruits, nuts, and grains are local concentrations of food stuff in the plant which form staple articles of diet for men almost everywhere. The animal body contains still more concentrated food stuff, and almost every part of it except hair, feathers, and bones are eaten by men. Shellfish, fish, worms, reptiles, birds, and all the higher animals are caught, hunted, or bred. Materials provided by animals for the support of their young, such as eggs and milk, are of special value because they can be used without killing the animal which produces them.

Collective Economy. — The simplest way of getting a living is that in which men make no effort to produce anything, but live by *plucking* or collecting whatever nature provides, as in the case of the Australian black fellows. This is, of course, very inefficient, but in tropical countries nature is so prolific that people can live with little effort.

On the coral islands of the Pacific a few coconut trees will support a large family. No implements, or only very simple ones, are required. There is no incentive to stimulate discovery and invention, and men remain in a state of savagery. Tropical forests, savannas, and oceanic islands are most favorable for plant collection on account of the abundance and variety of edible fruits and nuts. Various species of palms, such as the oil palm, date palm, sago palm, and coconut palm, are important sources of food supply. The yam, a root resembling the sweet potato, and the banana, the most prolific of all food plants, flourish spontaneously and render labor almost unnecessary.

Fig. 238. — Top of coconut palm.

Fishing, hunting, and trapping are forms of collective economy which require considerable effort and skill. Implements and weapons, such as fishhooks, lines, nets, spears, harpoons, bows and arrows, must be designed and made, and the successful chase of the larger animals demands trained powers of body and mind.

Hunting furnishes a limited and precarious food supply, abundant at one time and scanty at another. A large territory is necessary to support a few people. The North American Indians of Columbus's time depended

HUMAN ECONOMIES

After Bartholomew

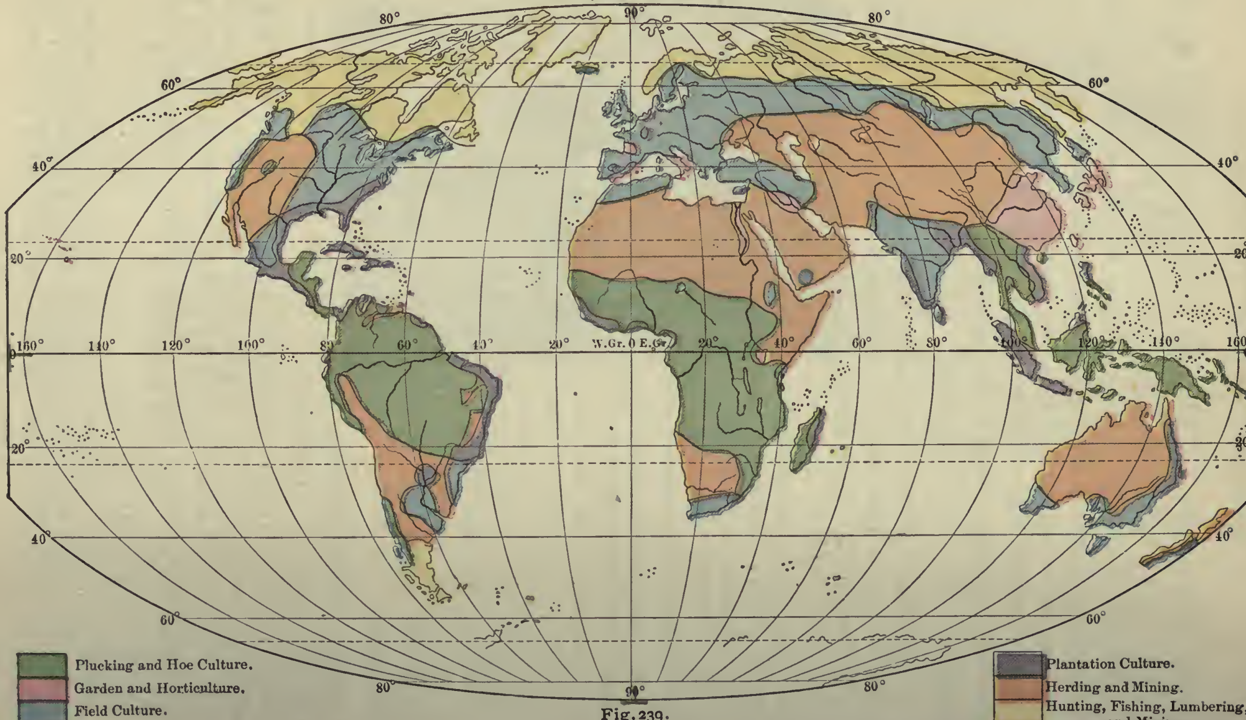


Fig. 239.

upon the chase, and there were probably not more than one million of them on the continent north of Mexico. Hunting, trapping, and fishing survive and continue among highly civilized peoples. They are still the chief occupations in the great forest belts of the cold temperate zone. Fishing is carried on in favorable coast waters in all latitudes, but is most productive on both shores of the north Atlantic and north Pacific.

Fig. 240. — Hoe culture.

Agriculture. — The domestication of plants is a long step toward a large and regular food supply. It was at first haphazard from seed accidentally sown. The planting and care of cultivated plants was begun and carried on entirely by women, who loosened the soil in favorable spots with a stick, planted seed, and cultivated the growing crop with rude hoes. This was the beginning of *hoe culture*, which now prevails in the equatorial forests and savannas of South America, Africa, and the East Indies. The banana, manioc, and yam are the staple crops (Fig. 249). As hoe culture becomes more efficient it develops into *garden culture*, which is intensive agriculture in small plots, the work being done mostly by hand. With heavy fertilization, several crops a year and a maximum production are possible. It prevails in densely populated sub-tropical countries where labor is cheap, as in China, Japan, India, Egypt, and some parts of France,

Fig. 241. — Garden culture.

Spain, and Italy. The value of the land is sometimes as high as $1,000 an acre. Special crops, such as celery, onions, vegetables, small fruits, and flowers are grown by improved methods of garden culture in many parts of the world.

Agriculture could not reach its highest stage of efficiency until animals were domesticated and trained for draft. Then a heavy, crotched stick could be used as a plow, from which the many forms of plows and cultivators now in use have been evolved. Thus has arisen the prevalent and, on the whole, the highest form of agriculture, *field culture*, carried on in fields and

Fig. 242. — Field culture.

farms of moderate size, largely by the use of animal power. A variety of crops are grown, and domestic animals are bred for food as well as for power. Field culture is general in the temperate regions of North America and Europe, and in smaller areas in the other continents. Labor is relatively costly. The laborers are free, and often independent owners of the land they cultivate, with small or moderate capital.

In *plantation culture* (Figs. 245, 248, 260, 261) special crops, such as cotton, sugar cane, coffee, tea, and rubber, are grown on large tracts. The laborers are often of inferior native or imported races, and under some form of servitude; ownership and control being in the hands of foreign proprietors with large capital.

This is the only practicable way, it is said, of utilizing the labor supply and developing the agricultural resources of tropical countries. Natives of such countries will not work steadily even for large wages, and are made to work, if at all, under some sort of compulsion. White men, as a rule, can not work in tropical countries; the proprietors find, therefore, that forced native labor, or none at all, are the only alternatives.

Cereal Grains. — The most valuable domesticated food plants are the cereal grains, — wheat, corn (maize), rice, oats, rye, and barley, — all of which are species of grass, and have been greatly modified and improved over the original wild forms.

Wheat probably originated in the highlands of western Asia. It is now extensively grown in the temperate and cool temperate regions of North

Fig. 243. — Harvesting wheat.

America and Europe, but is profitable on tropical plateaus and even on tropical lowlands as a winter crop. It requires a cool, moist growing season and a warm, dry ripening season. There are hundreds of varieties, each adapted to special conditions of soil and climate; hence its range is very wide, extending from the tropic to the polar circle. The world's wheat crop now exceeds 3,000 million bushels annually. Of this more than half is raised in temperate Europe, and one fourth in temperate North

America. The subtropical countries of Europe and Asia produce about one fifth. There was a total increase of nearly one fifth in the ten years 1900–1910, which is approximately equal to the increase of population in wheat-eating countries. The average yield per acre is from eight bushels in Russia to thirty bushels in France, and could be doubled by more scientific farming. The possible world's wheat crop of the future is closely connected with the available supply of nitrogen and phosphorus (p. 145). The possibilities of wheat growing in southern South America are great, but as yet slightly developed. The United States, Canada, Russia, Roumania, Hungary, India, and Argentina raise wheat to sell, of which Great Britain is the largest purchaser. The people of France, United States, Great Britain, and Austria-Hungary consume the most wheat per capita.

Corn. — Indian corn[1] or maize originated in the subtropical plateaus of America. It was the only cereal known to the American Indians, and is the one best fitted for primitive hoe culture. Next to rice it is now the largest of the world's cereal crops and probably the largest of all food crops. It requires a longer and warmer growing season than wheat, and many days of bright sunshine to ripen it. Hence its range is from middle temperate to sub-tropical latitudes, and it is excluded from oceanic climates of cool summers and much cloudiness, such as that of the British Isles. The world's crop is about 3,800 million bushels, of which the United States produces about 3,000 million bushels. It is grown to a limited extent in southern Europe, Argentina, and south Africa. More than half the corn crop is fed to animals, chiefly swine and cattle, and thus converted into pork and beef. It is also extensively used in the manufacture of starch, grape sugar, beer, and alcohol. The stalks and leaves furnish excellent fodder for cattle. The direct use of the grain for human food is increasing, but in this it still falls far short of wheat.

Fig. 244. — Corn field.

[1] Corn is the common name of maize in the United States, but in Great Britain corn is a general name for all grains. In England the word usually means wheat, and in Scotland oats.

Oats. — The second largest cereal crop in temperate climates is oats, nearly 3,600 million bushels, of which the United States and Russia produce about 1,000 million bushels each, and Germany more than half as much. Oats thrive in a cooler and damper climate than wheat, and hence have a larger range. Most of the crop is fed to horses, but it is excellent for human food and its use is increasing.

Rye. — Rye is a hardier grain than wheat, and can be grown with profit on soils where wheat cannot. It is used extensively by the peasants of Russia and Germany as a substitute for wheat in making "black bread," and in many countries in the manufacture of distilled liquors. The world's crop is about 1,500 million bushels, of which Russia produces one half and Germany one fourth.

Barley. — Barley has a wider range of latitude than any other cereal. It was once the chief breadstuff of the civilized world, but is now mostly fed to stock and converted into malt for brewing beer. The world's crop is nearly 1,300 million bushels, one fourth grown in Russia and the rest well distributed throughout the grain-producing countries.

Rice. — The chief cereal grain of warm, wet climates is rice. It is the principal food crop of southeastern Asia from India to Japan, and the

Fig. 245. — Rice field.

breadstuff of nearly one third the human race. There are several varieties, but those extensively grown are water plants and require flooded fields during most of the season. Hence alluvial and delta lands with abundant water under control are most favorable. The grain is not generally ground to flour, but the processes of hulling and polishing to remove chaff and skin are complex and costly. With the use of improved machinery, similar to that used for wheat, the rice crop of southern United States is increasing rapidly and now amounts to 21 million bushels a year. It is impossible to ascertain the total world's crop, but it probably exceeds that of any other grain.

Fig. 246. — Potato field.

Root Crops. — Root crops are well adapted for hoe culture, and are generally indicative of a lower stage of civilization than grain crops.

In tropical countries the yam, sweet potato, manioc (cassava), and taro can be raised with little labor and furnish a large amount of bulky food. The manioc of the Amazon basin is the source of tapioca used in temperate countries for desserts, and is being grown in the United States as food for cattle. The most valuable root crops are potatoes and sugar beets. The potato originated in the high plateaus of tropical South America, but from its common use in Ireland has acquired the name of Irish potato. The world's crop is about 7,400 million bushels, of which Germany and Russia produce more than half. Potatoes are used in Europe as a source of starch and alcohol.

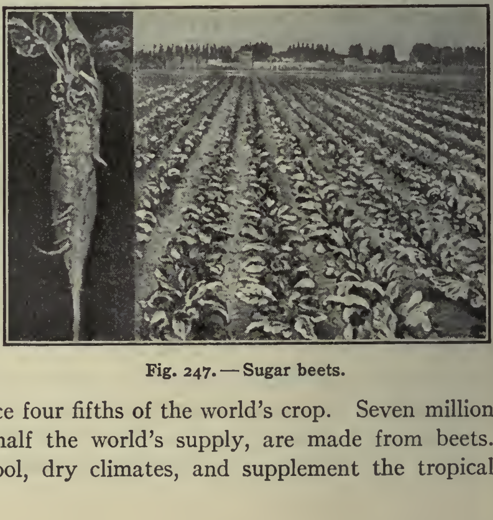


Fig. 247. — Sugar beets.

Sugar Beets are grown chiefly in Europe. Germany, Austria-Hungary, Russia, and France produce four fifths of the world's crop. Seven million tons of sugar, or nearly half the world's supply, are made from beets. They are profitable in cool, dry climates, and supplement the tropical supply of sugar from the cane. The pulp from which most of the sugar has been extracted is used to fatten swine.

Fig. 248. — Cutting sugar cane, Louisiana.

Sugar Cane. — Sugar is not merely a luxury and a condiment, but a valuable and stimulating food. Its use has grown in a few centuries to enormous proportions. The source of the largest supply is the sugar cane, a species of tropical grass. It is grown from cuttings planted in deep, rich, moist, but well-drained soil, and requires a hot season of seven or eight months to mature. The canes are cut and passed between rollers, which press out the juice. The liquid is purified and evaporated until the sugar crystallizes. It is afterwards refined to remove the coloring matter and again crystallized into white sugar. India, Java, Cuba, United States, Hawaii, and Porto Rico produce three fourths of the world's supply.

Fig. 249. — Banana and manioc.

Fruits. — In tropical countries fruits are the mainstay of life; in temperate countries they are in some degree superfluities and luxuries. The

Fig. 250. — Date palms.

quantity and variety of tropical fruits spontaneously produced encourage collective economy only.

The banana and its near relative, the plantain, are the most prolific of all food plants and will support five times as many people per acre as grain. In the East Indies the mango and breadfruit, and in the oases and irrigated tracts of the subtropical deserts the date palm, are in themselves sufficient to feed a dense population. In the Mediterranean region the olive takes the place of butter and meat. The citrus fruits, including many varieties of the orange, lemon, and lime, have become plentiful in the principal markets of the world. The grape has a wider range than the fruits above mentioned, and is common both fresh and in the form of raisins and wine. France produces more wine than any other country. Of the strictly temperate climate fruits, apples are the most important, with pears, peaches, and plums as a secondary crop. Cold storage and rapid transportation bring the fruits of all climes to every civilized man's door, and at almost all seasons. Fruit raising partakes of the character of both plucking and agriculture, but in the temperate zones it is fast becoming a highly specialized branch of scientific agriculture.

Fig. 251. — Vineyard, New York.

The Domestication of Animals. — The domestication of animals was as important a step in human progress as the domestication of plants. One and perhaps the chief cause of the backward condition of the American Indians before their contact with Europeans was the lack of domestic animals: the only animals which they domesticated were small species of the camel family in the Andes, and the dog. In well-populated countries the dangerous, destructive, and least useful animals have been exterminated, and many of the useful wild animals nearly so. Domestic animals have been bred, spread, multiplied, diversified, and improved until they have lost to a large extent their ancestral characters.

Herding. — In Eurasia domestic animals have been bred since prehistoric times. A lasso stage, in which wild animals

Fig. 252. — Herding in Asia. Tents and utensils are easily moved.

are caught alive, is intermediate between hunting and breeding. The vast steppe regions of central Eurasia have been for thousands of years the home of peoples whose chief occupation is herding. Their wealth consists of flocks and herds of cattle, horses, sheep, goats, and camels, which are driven from place to place in search of fresh pasturage. Hence the people are nomadic, having no fixed home, and their houses, usually tents, and domestic utensils are all designed to be easily movable. Political organization and centralized government are almost impossible, and the place of both is filled by patriarchal rule, in which the head of the family exercises control over a group, consisting of a family of blood relatives, with their wives, children, servants, and dependents. The story of Abraham, Isaac, Jacob, and Joseph in the book of Genesis gives a vivid picture of nomadic, patriarchal life as it was three thousand years ago, and as it still exists to-day.

Cattle. — Of all the domestic animals, horned cattle are the most important and valuable for their flesh, milk, and labor. A damp, temperate climate, with quick-growing grass, is most favorable for cattle. Mountainous and oceanic lands produce the best milk, steppe regions the best meat. The Mediterranean climates, with dry summers, are distinctly unfavorable. In some parts of Africa cattle cannot exist on account of a disease communicated by the bite of the tzetze fly.

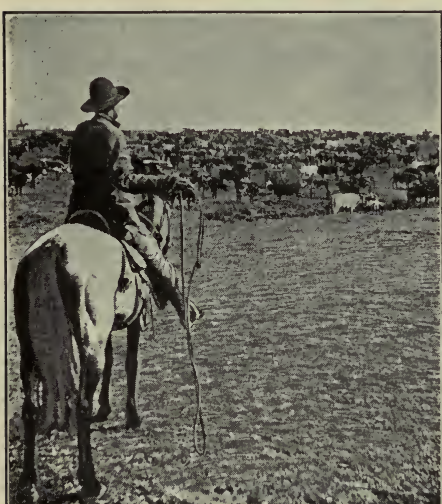


Fig. 253. — Herding cattle, United States.

Cattle are numerous in all the good agricultural countries of the world, and number about 430 millions. Europe has about 113 millions, India 90 millions, the United States 72 millions, and Argentina 30 millions. In the "Great Plains" or steppe region of North America the vast herds of wild bison, or buffaloes, which once occupied them, have been displaced by domestic cattle under the care of "cowboys." The cattle thrive on the nutritious bunch grass, which cures spontaneously on the ground, and some live out all winter by scraping away the snow with their hoofs. When the grass is covered with ice and sleet the losses from cold and starvation are very large. The former free range on public lands is now generally broken up and fenced into large ranches under private ownership, and the cattle are fed in the winter with cut hay. The farmers of the middle western states buy large numbers of young cattle from the ranches to fatten on corn and fodder. Kansas City, Omaha, St. Louis, and Chicago are the principal cattle markets and slaughtering and packing centers of the world.

The pampas of the Plata region of South America furnish a vast extent of pasturage which has never been fully utilized. Herds of cattle have been bred there and slaughtered for their hides only, but with cold storage and improved means of transportation the flesh is also marketed. South Africa, Australia, and New Zealand are also favorable regions for cattle raising. Eastern United States and Canada, Ireland, the Netherlands, Denmark, Sweden, Finland, France, and Switzerland are the leading dairy countries.

The zebu or humped cattle of India are adapted to savannas, and the water buffalo, or carabao (Fig. 254), is the principal beast of burden and draft in China, Japan, and the Philippines, being as well adapted for service in tropical swamps as the camel for the desert. On the plateaus and mountains of Asia, above 6,000 feet, the yak is the most hardy beast of burden, and is used also for milk and flesh.

Sheep.—The sheep is a steppe animal and does best in dry subtropical and temperate lands (Fig. 202). Sheep will live upon short, scanty pasturage where cattle would starve, and if permitted will do serious injury to grazing grounds. Large,

Fig. 254.—Water buffalo or carabao, Siam.

coarse-wooled sheep are bred for mutton, and smaller, fine-wooled animals for wool. In a wet climate the wool is poor, and in a hot climate it is scanty. Australia, the Plata countries, Russia, and the United States lead in the production of wool, mutton, and hides. Frozen mutton is shipped from Australia and New Zealand to Europe. The total number of sheep in the world is estimated at more than 575 millions.


Fig. 255. — Goat, Switzerland.

Goats are hardy animals, and will pick up a good living from coarse, rough herbage which cattle and sheep would not eat. In mountainous countries and regions of scant summer rain, they are bred for their flesh and their milk, which is very rich. Goat and kid skins are used extensively in the manufacture of gloves.

Horses. — The horse attains his highest perfection on the steppes, where he is admirably adapted for riding, and is used in the chase, in herding, and in war. Eastern Europe and north Africa have been repeatedly invaded and overrun by horsemen from the Asiatic steppes. The horse's leg is a combination of levers which makes it mechanically the most efficient of animal motor machines. In Asia mares are bred for their milk, which forms the staple food of many nomad peoples. The flesh is sometimes eaten. The horse is most used among the most advanced peoples, and may be regarded as the characteristic animal of civilization.

Many varieties have been developed for speed, beauty, and strength and used for riding, driving, and draft. Horse racing is a favorite sport among British, French, and American people. No other animal is so intimately related to human activities, and in spite of the multiplication of other means of locomotion, the horse is not likely to lose his place as the most useful servant of mankind. The number of horses in the world is about 95 millions.

The *ass*, or donkey, or burro, is less intelligent than the horse, but more hardy and sure-footed. He thrives on coarse fodder, is strong in proportion to his size, and is very useful as a beast of burden in rough countries. The *mule*, a cross between the ass and the mare, inherits the good qualities of both parents, and will perform hard service in rough and hot countries where the horse would fail. In 1898 it was found necessary to supply the British army in South Africa with mules shipped from the United States at a cost of $1,000 a head.

Fig. 256. — Burro.

Swine. — Pork has come to be second only to beef in the meat supply of the world. The hog is omnivorous in his diet and never-failing in appetite. He is the only animal that, beginning at birth, can gain, on the average, a pound a day in weight for 250 days. He is the poor man's animal, because he can subsist largely upon the waste products of the forest and farm. In China swine are the only large domestic animals, and pork is the only flesh food used by the common people, except birds and fish. More swine are raised in the United States than in any other country, and a large part of the corn crop is converted into pork. There are not less than 180 million swine in the world.

Camels. — The camel (Fig. 293) is the domestic animal of the warm deserts, to which he is wonderfully well adapted. His feet are expanded into large pads, which prevent his sinking into the sand. His stomach is triple and can hold several gallons of water. His nostrils are slits which can be voluntarily closed when the air is full of wind-driven sand. His hump is a mass of fat, which is absorbed when food is insufficient. He can carry a load of 400 to 1,000 pounds, drink brackish water, and go a month without drinking. In the deserts of Asia and north Africa he is the indispensable beast of burden. In disposition he is stupid and vicious.

Four small species of the camel family are natives of the Andes mountains. The *llama* (Fig. 222) is used in Peru and Bolivia as a beast of burden, but will carry a load of only 80 pounds. The *vicuña* and *guanaco* are raised for flesh and wool, and the *alpaca* furnishes a hair of considerable value for dress goods.

Reindeer. — The reindeer bears the same relation to the tundra as the camel to the warm deserts. Its foot is adapted to snow as the camel's to sand. It is bred in northern Eurasia for milk, flesh, and draft. A Lapland family may keep a herd of 500 reindeer. They have recently been introduced into Alaska and are found very serviceable.

Dogs. — The dog was originally a wolf which hung around human habitations to steal food. He was at first tolerated and finally adopted as a domestic parasite. He is the only animal except the cat which man has come to regard as a member of the family. He has been found useful as a scavenger, for food, herding, hunting, and draft; but the large majority of dogs are of no use except as pets and companions. In ice deserts, tundras, and cold temperate forests in winter, dogs are indispensable draft animals, all travel and transportation being by dog sledge. The Arctic or Eskimo dog is but little better than a wolf in disposition, but he is strong and hardy, can live on frozen fish, and can sleep out of doors in any weather.

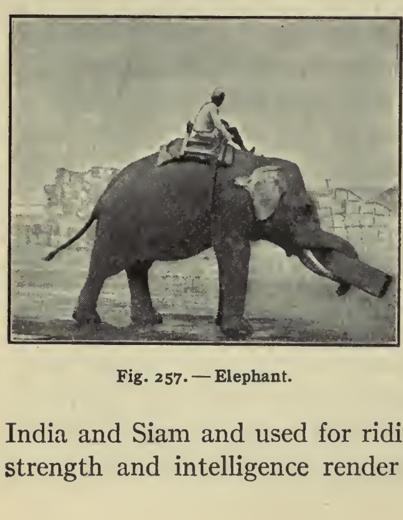


Fig. 257. — Elephant.

Elephants. — The elephant is kept in domestication in India and Siam and used for riding, hunting, and display. His strength and intelligence render him valuable in more menial employments, such as hauling and piling timber. The wild African elephant has been hunted for pleasure and for his tusks, which furnish ivory, until the species is threatened with extinction.

Fig. 258. — Poultry.

Poultry. — The domestic birds include the common fowl, goose, duck, pigeon, turkey, guinea fowl, peafowl, and ostrich. The common barnyard fowl, descended from the wild jungle cock of India, is one of the most valuable of animals. Many varieties have been developed by breeding and have spread to nearly all parts of the habitable world. The flesh and eggs are so palatable and nutritious as to be generally esteemed as semi-luxuries. The total value of poultry and eggs produced in the United States annually is about $400,000,000.

Geese and ducks are waterfowl bred for flesh, eggs, and feathers. Domestic pigeons are largely "fancy" birds, bred to many fantastic forms and used to a limited extent as food. The turkey, the only domestic bird native to America, is scarcely known elsewhere. The guinea fowl from Africa and the peafowl from Asia are more ornamental than useful. The African ostrich (Fig. 221) is valuable for his plumes.

Insects. — The only domesticated insects are the silkworm and the bee.

The breeding and care of the *honey bee* has become a highly specialized art in nearly all civilized countries. The honey is made by the bees from the nectar of flowers and stored in combs or cells of wax for their own use and for feeding the young. With proper management a swarm of bees will produce a large surplus beyond their own needs.

The *silkworm* is the caterpillar of a moth which spins a cocoon yielding the fiber of raw silk. The caterpillars are hatched and fed upon the leaves of mulberry trees which are grown for the purpose.

Fig. 259. — Feeding silkworms.
The silkworms are the white objects in the trays.

China, Japan, Italy, and France furnish nearly all the raw silk that is produced.

Physiological Luxuries and Medicines. — There is a large class of substances, mostly of vegetable origin, which have little or no value as food, but which men use internally for various purposes. They include spices, condiments, and flavors which give food an agreeable taste or stimulate digestion, stimulants and narcotics which produce agreeable sensations, and medicines which relieve pain or assist in the cure of disease.

Condiments and Spices. — In the Middle Ages, spices were among the most valuable goods which could be marketed in Europe, because they rendered dried and salted meats and poorly cooked food more palatable. Arabia was called "the land of spices" because the supply came through that country from the Far East. The blockade of the caravan routes by the Turks stimulated efforts to open a sea route to the "spice islands" and led directly to the voyages of Da Gama around Africa and of Columbus to America.

Mustard is now the most important condiment and the most widely distributed. It is made from the seed of several plants grown in Europe, the United States, Asia, and the East Indies. *Vinegar*, made from cider, wine, and other alcoholic liquors, is in common use in all civilized countries.

Spices are tropical products grown in India, Ceylon, China, the East and West Indies, Zanzibar, Mexico, and South America. Pepper is made from dried berries, cloves from flower buds, nutmegs from fruit stones, cinnamon from bark, and ginger from roots. Cayenne or red pepper and vanilla are the fruits of plants grown chiefly in Mexico.

Stimulants and Narcotics. — *Alcoholic liquors* are used by people of nearly all races, countries, and classes. Their use is prohibited among the believers of the Mohammedan religion. They are made by the fermentation of sugar derived from fruits, grains, roots, or any material containing starch. The yeast plant, a microscopic organism, is the only agent known by which sugar can be converted into alcohol cheaply and on a large scale. The yeast is added to a solution containing sugar or allowed to grow from spores everywhere present in the air.

Wines of many varieties are made from the fermentation of grape juice, and are the common beverage in the warm temperate regions of Europe. *Beer* is made from barley or corn and is a favorite drink in northern Europe. Distilled liquors contain a much higher percentage of alcohol than wine or beer. *Whisky* is distilled from corn, rye, and potatoes, *brandy* from wine, and *rum* from sugar cane. In Japan *sakê* is made from rice, in Mexico *pulquê* from the century plant, and in India *toddy* from the coconut palm. From any of these sources pure alcohol may be obtained by careful distillation, and is manufactured in large quantities, not for drinking, but as a chemical product used in many important arts and for fuel. Alcohol has no direct food value, but is a stimulant and intoxicant, more or less injurious to body and mind.

Fig. 260. — Coffee plantation, Straits Settlements.

Coffee, tea, maté, and *cocoa* are mild stimulants, not intoxicating, and generally harmless. *Coffee* is the seed of a small tree grown by the plantation system chiefly in Brazil, and in smaller quantities in Venezuela, Central America, Java, Mexico, and the West Indies.

The total crop is about 2,400 million pounds, of which Brazil furnishes three fourths. It is used more largely in the United States than in any other country.

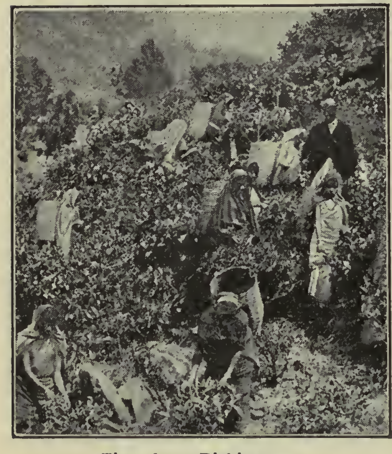


Fig. 261. — Picking tea.

Tea is the dried young leaves of a shrub which yields best on tropical highlands with warm, rainy summers. China and Japan have had until recently a monopoly of tea growing, but now the plantations of India and Ceylon furnish three fifths of the 680 million pounds exported. Russia and Great Britain are the largest consumers of tea. *Yerba maté*, or Paraguay tea, consists of the dried leaves of a tree growing wild in southern South America and possesses the same stimulating qualities as tea. Its use is local, very little being exported.

Cocoa and *chocolate* are prepared from cacao beans, the seeds of a tree which grows in the lowlands of tropical America, the East Indies, and west Africa. They contain a mild stimulant and a large percentage of oil, starch, and albuminoids which render them highly nutritious.

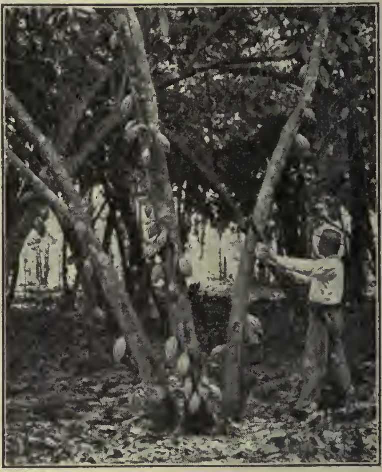


Fig. 262. — Cacao tree.

Tobacco and *opium* are narcotic stimulants possessing decided physiological and medicinal properties. Tobacco, originally a native of America, has in the last 300 years extended over the entire world, and has come into general use among all kinds of people. Naturally a semi-tropical plant, it is now grown as far north as Connecticut, Wisconsin, and Germany. Its quality, flavor, and value are greatly modified by soil, climate, cultivation, and curing. It requires a growing season at least as long as corn, but is much more exhausting to the soil.

Fig. 263. — Tobacco field.

The whole plant is cut and hung up to dry, the leaves are stripped off and slightly "sweated" or fermented, the stems are removed and the blades rolled into cigars or put up in various forms for smoking and chewing. The "seed leaf" used for cigar wrappers is grown in Sumatra, the Philippines, and the Connecticut valley, where the gross value of the crop is sometimes $10,000 an acre. The relation of tobacco to the human race is unique. Purely a luxury, and with no beneficial effect upon the system, it is a mild narcotic which, though usually injurious, is not ruinous, and has an attraction for people of all classes, from the most degraded to the most refined, possessed by no other substance except, perhaps, alcohol. The United States and India produce more than half the crop of 2,200 million pounds.

Opium is the dried juice of the white poppy grown in India, China, Persia, and Turkey. It is smoked in small pipes as a narcotic by the Chinese and other Oriental peoples. Its effects are much more serious than those of tobacco, and opium smoking in China has become a national danger. Morphine, laudanum, and other derivatives of opium are extensively used in medicine to relieve pain, but should never be taken except under the direction of a physician, since there is grave danger of acquiring the opium habit, which is very difficult to cure.

Medicines. — Medicines are largely extracted from crude drugs, or the dried bark, leaves, and seeds of plants. The varieties in common use are very numerous, and most of them are of great value for the relief and cure of disease. Of substances which are purely medicinal, wholly beneficial, and almost invaluable to man, *quinine* may be taken as a type. It is obtained from the bark of the cinchona tree, a native of the tropical South American forest. The natural supply has long been insufficient, and the cinchona plantations of Java now furnish 86 per cent of the 17 million pounds of bark required to supply the world. Quinine is the only safe and efficient antidote to malaria, and without it the occupation of the tropics by white men would have been impossible.

CHAPTER XX

CLOTHING AND CONSTRUCTIVE MATERIALS

Clothing. — After food, the object for which the greatest amount of human energy is expended is clothing. Clothes are not naturally as important as they seem. They are not required and are not worn for protection by half the people in the world. The natives of Tierra del Fuego in 55° S. Lat. go naked and do not appear to suffer. In tropical regions the common people wear very little clothing, and that chiefly for ornament. Civilized people are prevented from going naked by a sense of modesty, and a sense of what is becoming or in fashion determines the material, cut, style, color, and other details. The simplest of all dress is the coat of clay and mineral paint used by the Australian black fellow, or the mixture of grease and soot with which a Central African belle anoints herself. They are regarded as ornamental, and they furnish some protection against insects. Some articles of clothing have come into use for convenience in carrying small articles, as the belt around the waist, and bands around the arms. Simple clothing is often made of leaves, bark, grass, or straw, more or less skillfully braided or woven together. In regions of cold winters, men rob animals of their fur, feathers, and skins.

All these things are obtainable by collective economy, but herding and agriculture are necessary to supply light, pliable, comfortable, and durable garments, which are generally woven from some kind of fiber, and are therefore called *textiles*. The principal vegetable fibers are cotton and linen, and the principal animal fibers are wool and silk.

Cotton. — The hairs which cover the seeds and fill the bolls of the cotton plant furnish the best fiber known for cloth and small cordage. It is strong, soft, fine, flexible, and easily dyed and washed, — an almost ideal combination of qualities. Cotton produces the best fiber in a tropical climate near salt water. It is grown from seed, cultivated like corn, and picked usually

Fig. 264. — Cotton field, South Carolina.

by hand. The seeds are separated from the fiber by a machine called a gin, and contain an oil valuable for food and for soap making.

On account of the large amount of hand labor required, cotton has generally been grown by the plantation system. The invention of the gin, the spinning jenny, and the power loom, in the latter part of the eighteenth century, made it possible to utilize large quantities of the fiber, which stimulated production and increased the supply until cotton became the cheapest and most plentiful of all textiles. The invention of a successful machine for picking cotton will put cotton cloth practically within reach of every human being. The world's cotton crop is about 10,000 million pounds, of which the United States produces two thirds, India one seventh, and Egypt one twelfth.

Linen. — Linen is made from the fiber of the stem of the flax plant. The process of separating it from the wood and preparing it for spinning is long and difficult. Hence linen is far more expensive than cotton, and is used for laces, napkins, and articles of luxury. Flaxseed furnishes linseed oil, which is indispensable in mixing good paint. Russia produces about four fifths of the world's supply of flax.

Wool. — The animal fibers most useful for cloth are obtained from sheep, goats, and camels, including the alpaca and vicuña. Sheep's wool is used in all cold countries for heavy clothing, especially that worn by men. Australia, Argentina, and Russia produce about half the wool supply.

Silk. — The silkworm spins a cocoon of fine, lustrous, elastic threads which form the raw silk of commerce. A large amount of hand labor is required in feeding and caring for the worms, unwinding the threads, and preparing them for the loom, hence the industry is confined to countries where wages are low.

Artificial silk, but little inferior to the natural fiber and much cheaper, is now being manufactured. For serviceable clothing silk is inferior to cotton and wool, but is superior in beauty. It is used extensively for laces, ribbons, and velvets.

Fig. 265. — Rubber trees. The marks on the trees are cuts in the bark, from which to collect the sap.

Rubber. — The milky sap of various species of tropical plants forms a gummy mass when dried, and is used to render textiles waterproof. Most of the supply is obtained from native wild plants of Brazil and central Africa, but rubber plantations are increasing in number and importance.

Furs and Leather. — The skins of animals have always formed an important part of human clothing, either cured with the fur on or converted into leather. Deerskin was the chief reliance of the North American Indian, as sealskin is of the Eskimo, and sheepskin of the shepherd peoples of Eurasia.

Among highly civilized peoples furs have become articles of luxury, and some, such as seal, otter, ermine, marten, sable, beaver, and silver fox, command fabulous prices. Canada and Russia are the principal fur-producing countries. Leather, made by soaking hides in a solution of tanbark or other chemical agent which renders them tough and impervious to water, has become an indispensable article for shoes and gloves. Thus men protect their extremities which are most exposed to rough usage. Leather is made from the skins of cattle, horses, swine, sheep, goats, dogs, and many other animals.

Fig. 266. — Straw hut, Hawaii.

Shelter. — Few, if any, human beings live so simply as never to need shelter of any kind. Some kind of a lair is necessary as a place for rest and sleep. A tree, forest, overhanging rock, or cave may furnish shelter from heat, cold, wild animals, or enemies, and men soon learn to improve these natural advantages. Sticks, grass, leaves, and boughs are among the most easily available materials, and a large part of the human race still live in more or less elaborate huts made from them. With the progress of the mechanic arts men have become able to use trees for timber and to construct from them commodious and luxurious homes. Hence have arisen all the refinements of lumbering, carpentry, and cabinet work.

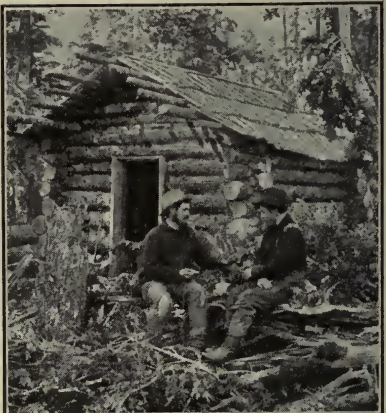


Fig. 267. — Log house.

Among the early inhabitants of Europe were the cave men, who inhabited the natural limestone caverns, furnished them with the skins of wild beasts, and even decorated their walls with paintings. In some parts of France inhabited houses and even churches are still made by enlarging and improving natural caverns. In China thousands of people live in houses dug out of the soft but firm deposits of loess (p. 144), and the pioneer in the American prairies and steppes often lives at first in a "dugout"

Fig. 268. — Rock house, France.

Fig. 269. — Sod house. (U.S.G.S.)

or in a sod house. The Eskimo finds chunks of frozen snow cut to proper shape the best material for building a hut adapted to his needs in an Arctic climate. In countries of small rainfall and with alluvial or adobe soils, sun-dried bricks are easily made and built into huts or houses which are comfortable and permanent.

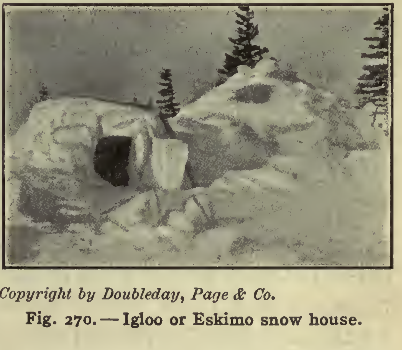


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Fig. 270. — Igloo or Eskimo snow house.

In most parts of the world clay is plentiful, from which bricks can be made and hardened by burning into excellent building materials. Many kinds of rock, such as sandstone, limestone, granite, and slate, are quarried and used to construct the most substantial and imposing buildings. For many thousand years various ores, especially those of iron, have been mined and smelted and the extracted metals used in all sorts of construction. Hence the industries of quarrying, mining, and metallurgy have grown to enormous proportions. These industries belong to scientific collective economy, since they collect and utilize natural materials, but do not produce them as in agriculture or stock raising.

Fig. 271. — Redwoods, Oregon. 200 to 300 feet high.

Timber. — Of all materials for construction wood is the most generally useful, and for most purposes that furnished by the coniferous forests (pp. 234–236) is the best.

Pine, spruce, fir, hemlock, larch, cedar, and redwood lumber is light, strong, durable, and easily worked, and can be had in pieces of large dimensions. None is better than the white pine of North America, which is ten times as strong as steel of equal weight. The yellow or hard pine of the southern states is full of resin, from which turpentine, rosin, and tar are extracted. The timber is hard, strong, durable, and fit for heavy construction, while its beautiful color and grain make it desirable for inside work in houses. The Douglas fir of the Pacific coast of North America is especially valuable in ship-building on account of the length and size of timbers which can be cut from it. California redwood, a near relative of the Sequoias, or "big trees," is famous for the size of the individual trees and the yield of merchantable lumber per acre. Redwoods grow from 200 to 300 feet high, with a diameter of

10 to 20 feet, and so close together that it is difficult to drive a wagon between them. The redwood forests are confined to the Coast Ranges of California and Oregon, and at the present rate of cutting are likely to disappear at an early date. White spruce is being cut at a rapid rate for the manufacture of paper pulp. White cedars are used largely for posts, telegraph poles, and shingles; and red cedar, or juniper, is familiar in lead pencils. These cedars are well distributed throughout the forest regions of the United States and Canada. The hemlock of the north and the cypress of the south are inferior to the pine as timber trees, but are used as a substitute for it. The Norway spruce, the European pine, fir, and larch, and the Indian cypress and deodar are among the chief timber trees of their respective countries. The area of coniferous forests in northern North America and Eurasia is very large (Fig. 192). No part of it is more valuable than that on the Pacific coast from California to Alaska.

The broad-leaved and generally deciduous timber trees are more widely distributed and of greater variety than the coniferous trees.

The tulip tree, poplar, and linden, or basswood, common in eastern United States, furnish soft, light wood easily worked. The linden is com-

Fig. 272. — Floating logs to a sawmill. (U.S.G.S.)

mon in Europe. Of close-grained hardwoods the maple, beech, birch, and sycamore, or plane tree, exist in many species throughout temperate North America and Europe. Among the coarse-grained hardwoods the oaks hold the first place in number of species, wide distribution, and value of timber.

They are the most abundant timber trees of eastern North America and Europe, and extend across south central Asia to Japan. Cork is the bark of a species of oak growing in the Mediterranean region. The ash, chestnut, elm, hickory, locust, and many other less important trees furnish wood of much value for various purposes. Among the woods famous for their beauty of color and grain, and commanding high prices for furniture, cabinet work, and interior finish, the black walnut, butternut, cherry, and gum are native to eastern United States. Still more highly prized is mahogany, imported from tropical America and west Africa to Europe and the United States. Rosewood and ebony are tropical woods used entirely for fancy or ornamental purposes. One of the most valuable of all woods for heavy construction is the teak of India, Indo-China, and the East Indies. The gum or eucalyptus trees of Australia are not much inferior to teak.

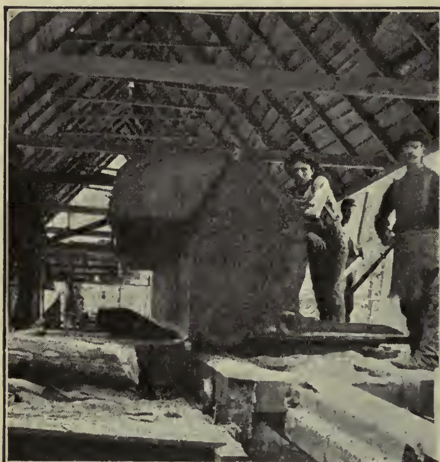

Fig. 273. — Sawmill, North Carolina. (U.S.G.S.)

Lumbering. — Lumbering is a form of specialized collective economy, which consists in cutting trees into logs and transporting them by sled, wagon, rail, or water to mills to be sawed, planed, and otherwise elaborated for particular uses.

Fig. 274. — Burned forest, Washington. (U.S.G.S.)

The people of Europe and the United States have destroyed their native forests to such an extent that timber has become scarce and high-priced.

The future supply must be largely imported from the northern forests, or much of the land originally timbered must be reforested. The conservation of forests, which includes the cutting of timber without unnecessary waste, the prevention of forest fires, and the replanting of tracts of little value for other purposes, is one of the most important problems of present-day economics. The science of forestry has been highly developed in Germany and is being taken up in the United States.

Fig. 275. — Result of deforestation, China. The land has been ruined by erosion.

Paper. — Paper is made from various vegetable fibers by grinding and digesting to a pulp, which is then rolled into sheets. Fine book and writing papers are made from linen, coarse wrapping paper from straw, and newspaper from wood pulp. The spruce forests of North America are being rapidly used up in the manufacture of wood pulp.

Clay. — Of all minerals used in construction, clay is the most widely diffused and readily available. It is a product of the decay of feldspar. By mixing, molding, and heating, common

Fig. 276. — Clay works.

clay is made into building, paving, and fire brick, tiling, sewer pipe, and pottery. Pure clay, or *kaolin*, is mixed with other materials to make fine porcelain and chinaware.

Cement. — Mortar made of quicklime and sand is generally used to bind brick and stone work together. In recent years, owing partly to the increasing cost of wood, hydraulic or Portland cement, made by heating and grinding a mixture of clay and lime, has come into general use. The mixture of cement, sand, and gravel or broken stone called *concrete* is really an artificial conglomerate, and is displacing brick and other materials in paving and house building. When reinforced by an imbedded framework of steel, concrete is superior to steel or stone alone for bridge construction.

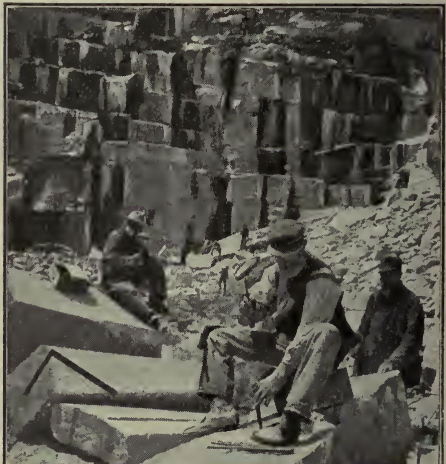

Fig. 277. — Quarrying granite, New Hampshire.

Building Stone. — Stone is used the world over for foundations, bridge piers, docks, breakwaters, pavements, public buildings, and costly private structures. Its value depends upon many factors, such as ease of quarrying and working, strength under a crushing load, hardness, color, and resistance to weather.

Probably limestone is most extensively used, but sandstone, granite, and volcanic rocks of various kinds are valuable. Metamorphic limestone, or marble, on account of its beautiful colors and the high polish of which it is capable, is a favorite ornamental stone for buildings, monuments, statuary, and furniture.

Quartz, the most abundant of all solid minerals, occurs in massive quartzite and sandstone, in common sand, and in transparent crystals. It has many colors.

Agate, amethyst, onyx, chalcedony, carnelian, chrysoprase, heliotrope, jasper, opal, and many other varieties of quartz are semi-precious stones prized for their color and luster. Millstones, grindstones, and whetstones are fine-grained sandstones. Flint is a hard variety of quartz which was used all over the world before the discovery of iron for weapons and cutting implements. *Glass* is made by heating a mixture of pure quartz sand and soda ash to a very high temperature. Most glass articles are shaped by blowing air into melted glass through a metal tube. Various ingredients are added to give color, luster, and other special qualities.

Ores and Metals. — An ore is a mineral from which a metal may be profitably extracted. Most ores have been deposited by solution in ground water which rises from the depths of the earth, and occur in fissures called veins, lodes, and leads; consequently valuable deposits of ore are found chiefly in mountainous regions, where the earth crust has been broken, and in old, worn-down plains (pp. 44, 53, 58) from which a great thickness of the crust has been removed by erosion.

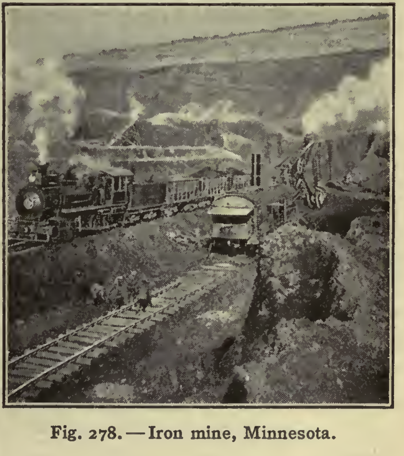

Fig. 278. — Iron mine, Minnesota.

Iron. — Of all the metals, iron is the most useful to mankind. No people have ever been able to attain a high state of civilization without the use of iron. It is the physical basis of modern industry. Its extraction from the ore is difficult and requires such a high temperature that the progress of the human race was delayed thousands of years for lack of it.

As long as all implements and tools were made of wood, with points and cutting edges of stone, no great material civilization was possible. Iron is supreme because it is abundant, strong, and workable. When hot it can be hammered into shape, when melted it can be cast in molds, and in the form of steel it can be given a high degree of hardness and elasticity. If kept dry it is very durable, but if damp it rapidly rusts.

Iron ores are smelted with charcoal or coke, and limestone to absorb impurities, in a furnace which is raised by a blast of hot air to a tempera-

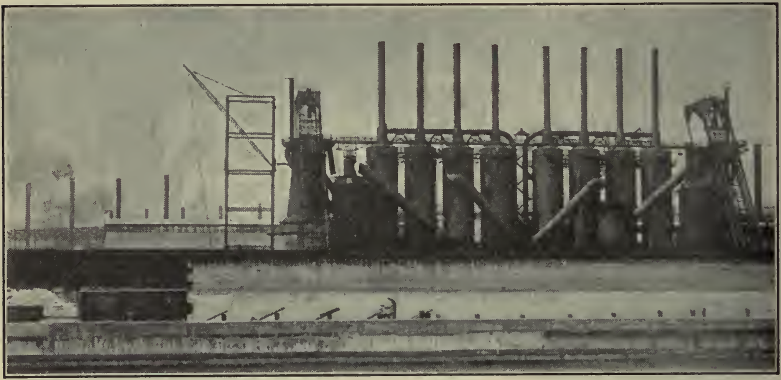

Fig. 279. — Blast furnaces, Gary, Ind.

ture of nearly 3,000 degrees. The liquid metal drawn from the furnace is pig or cast iron, which is moderately hard and relatively brittle, but can be cast in molds of almost any desired size and shape. Cast iron, when purified, forms wrought iron, which is soft and flexible but tough and malleable. By various processes cast iron can be converted into steel, which possesses all the best qualities of iron. It can be cast, hammered, rolled into railroad rails, bars, beams, girders, and sheets, and tempered for cutting tools and springs.

Iron is the most widely diffused of metals, and iron ores are found in every land; but the best ores, which furnish most of the world's supply, are mined in the Lake Superior region of the United States and Canada, in Great Britain, Germany, Belgium, and Spain. Sweden has immense masses of high-grade ore not yet fully developed. The United States is far in advance of all other countries in the production of iron ore, pig iron, and steel, with Germany and Great Britain as second and third in rank. The quantity of iron used is the best measure of industrial progress.

Copper. — Next to iron, copper is probably the most important metal. It is workable, durable, and moderately hard. Before the discovery of iron smelting, bronze, an alloy of copper and tin, played the part now taken by iron and steel, and it is still used for statuary and ornamental work.

Brass is an alloy of copper and zinc. The peculiar value of copper lies in the fact that it is one of the best known conductors of heat and electricity, and can be drawn into strong wire. Hence it is indispensable in the development of modern electrical industry. The mines of Arizona, Montana, and Michigan produce more than half of all the copper mined. Mexico, Spain, and Japan rank next after the United States.

Lead. — Lead is a soft, heavy metal easily melted or shaped in the cold. It is used for shot, bullets, roofing, and plumbers' work. Solder, pewter, and type metal are alloys of lead.

White lead, a compound of the metal, is one of the essential ingredients of good paint. Lead occurs with silver in Idaho, Utah, and Colorado, and with zinc in Missouri. The United States, Spain, Germany, and Australia produce three fourths of the world's supply.

Zinc. — Zinc is a hard, white metal which is not corroded by air or water. It is extensively used as a coating for sheet steel to prevent it from rusting. Such sheets, under the name of galvanized iron, are used for tanks, roofing, cornices, spouts, water pipes, and domestic utensils. The United States, Germany, and Belgium yield four fifths of the world's supply.

Tin. — Tin is a soft, white metal which was once semi-precious on account of its scarcity and the demand for it in making bronze. It is very useful in the form of tin plate, which consists of sheets of iron coated with tin and used for roofing and "tinware." The tin mines of Cornwall, England, have been worked for 2,500 years, but the Malay Peninsula and neighboring islands now furnish three fourths of the supply.

Aluminum. — Aluminum, the lightest of the commercial metals, is also the most abundant, being the base of all clays and forming eight per cent of the earth crust. The difficulty of extraction from its ores makes it costly. In color, luster, and polish it resembles tin. It does not corrode, is workable, and is a good conductor of electricity. It is about one third as heavy as iron and may be substituted for it in places where lightness and strength are desirable. Its workable ores are rare. The metal is extracted at Niagara Falls, New York, and at several other places.

Mercury. — Mercury, the only metal liquid at ordinary temperatures, is invaluable in the extraction of gold from its ores, in the manufacture of thermometers, barometers, and other scientific instruments, and in silvering mirrors. Spain furnishes one third and California one fifth of the supply.

Precious Metals. — Gold and silver are known as precious metals on account of their high value. An ounce of gold is worth a little over twenty dollars, and an ounce of silver from fifty cents to one dollar. For use in the arts gold is inferior to copper, and silver is inferior to tin. Their value depends essentially upon their beauty, which makes them desired for ornament; hence gold is the common material used for jewelry, and silver for tableware. Gold has a rich yellow color and a brilliant luster which does not readily tarnish. It is easily workable, but too soft for use unless alloyed with copper or silver to harden it. Silver is white, less lustrous than gold, and more easily tarnished; hence it is far inferior in value, although more useful in the arts. Gold has become the standard of value and a medium of exchange of the civilized world and is used chiefly for coinage, while silver is the metal for coins of less value.

Fig. 280. — Washing gold, Guiana.

Gold is found disseminated in veins, lodes, or reefs of quartz and other minerals, and in alluvial sands and gravels. It is separated by crushing the ore, when necessary, washing out impurities with running water, and dissolving the gold with mercury. Gold is extracted from low-grade ores by a solution of potassium cyanide. The world's output of gold is about $400,000,000 annually, of which South Africa produces about two fifths, the United States one fourth, and Australia one sixth.

Silver is obtained largely from lead and gold ores, as well as from ores worked for silver alone. Its extraction is difficult and complicated. The amount mined is largely in excess of gold, but its total value is less. The United States and Mexico produce each about one third of the world's product.

Tools. — Man is the only animal that uses tools. It is doubtful if apes and monkeys, who have hands and could use tools, ever spontaneously use even a stick or a stone for any purpose. Primitive tools were of the simplest character. A stick, smoothed, straightened, and pointed, with the end hardened in the fire or tipped with an animal tooth, developed into the spear and harpoon. A stone thrown from the hand or from a sling of bark or hide, a club weighted at one end or made more effective by the insertion of sharp teeth or stones, a flake of flint or broken volcanic glass with a cutting edge, were the rude forerunners of the rifle, cannon, ax, sword, scythe, knife, and razor.

Fig. 281. — Primitive tools and weapons.

The invention of the bow and arrow gave their possessors such an advantage in range and accuracy of aim as to rank in importance with the discovery of gunpowder. The invention of pottery, made at first by daubing a basket with clay, then molding the clay without the basket, made it possible to store and carry liquids and to cook food by boiling. The smelting of iron ore put into men's hands at once a superior material for all sorts of implements, weapons, and utensils, enabled them to work wood into boats, houses, and furniture, and vastly to improve their agriculture. Chiefly by the utilization of wood and iron man has arrived at his present stage of economic development, in which by the use of machines he has increased production in an incalculable ratio beyond what he could do with his bare hands. The grain binder and thresher, the steam plow, the cotton gin, the power loom, the linotype, the cylinder press, the pipe organ, the electric crane, the steel steamship, the steam turbine, the gas engine, the dynamo, the trolley car, the automobile, and the aeroplane are only complex tools for doing work efficiently and on a large scale. They are extensions and improvements of the natural machines, — the human leg and arm.

Technical Materials. — The complex activities of civilized men require a vast variety of materials for a vast variety of purposes. They are derived from many natural sources and are artificially made. To describe them and their uses in detail would require a large volume. The following are some of the most important in each class.

Fertilizers. — The natural supply of plant food in good soils is generally sufficient except in nitrogen, phosphorus, and potash (p. 145). Hence these elements are important ingredients of artificial fertilizers, and in old and densely populated countries their supply is a serious problem.

Nitrogen is furnished by animal matter, and is a constituent of common stable manure. Guano is the dung of fish-eating sea birds, which has accumulated upon islands in the almost rainless region off the coast of Peru, in some places to the depth of 200 feet. It contains large percentages of both nitrogen and phosphorus, and many million tons have been shipped to England and other countries of western Europe. Bat guano, obtained from caves, is used for the same purpose. Chile saltpeter (sodium nitrate), containing a large percentage of nitrogen, occurs in extensive deposits in the desert of Atacama (Peru and Chile), and has been mined and exported to Europe for many years. The supplies of guano and nitrate are limited and exhaustible, but the nitrogen of the air is inexhaustible. It has been discovered that clover, alfalfa, peas, beans, and other plants of the same family, have upon their roots nodules containing bacteria, or microscopic plants, which absorb and assimilate nitrogen from the air. When the roots decay the nitrogen becomes available for the next crop. Artificial nitrate is now being made from air and lime by electricity in Norway, where water power is cheap. Thus the nitrogen problem seems to be definitely solved.

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Fig. 282. — Tubercles on the roots of soy bean. (Fletcher's *Soils*.)

Phosphorus. — Animal matter generally contains phosphorus as well as nitrogen, but it is present in large proportions in fish and in the bones of herbivorous animals. Near the seashore fish which are not fit for food are caught in nets and liberally applied to the land. Beds of phosphate rock in southern United States and other localities are composed largely of the teeth and bones of marine animals. Such deposits are of greater real value to the human race than gold mines. The phosphorus in them is in an insoluble form, and must be chemically treated to make it available for plant food. Large quantities of phosphatic fertilizer are made from slaughterhouse refuse and the bones of domestic animals.

Potash. — Wood ashes contain considerable quantities of potash salts, which are leached out with water and used in making fertilizers, glass, and soap. Potash salts are mined at Stassfurth, Germany.

Salt. — Many chemical compounds are found in nature which can be utilized in their natural state. The most important is common salt (sodium chloride). It is obtained by the evaporation of sea water and of other natural brines, such as the water of the Caspian Sea, Great Salt Lake in Utah, and the Salton Lake of California.

Strata of rock salt, left by the evaporation of ancient seas, sometimes 1,000 feet thick, occur in the earth crust. The solid salt is sometimes mined like coal, but since it is frequently impure it is often cheaper to dissolve the salt in water and evaporate the brine. There are famous salt mines in Poland, Germany, Austria, Spain, England, New York, and Louisiana. Salt is used almost universally as a food and as a preservative. It is also the source from which many compounds are manufactured, among which soda ash, used in making soap, glass, and baking powder, is the most important.

Fig. 283. — Salt works, France.

Sulphur is obtained from volcanic regions, where it sublimes from the hot rock, and by roasting pyrite, a mineral common in coal mines. Sicily, Louisiana, and Japan are the chief sources. It is one of the most important of chemicals, indispensable in the manufacture of matches, gunpowder, and vulcanized rubber. The fumes of burning sulphur are a cheap and efficient bleaching agent and disinfectant. It is the basis of manufacture of sulphuric acid and a long series of derivative compounds which rival in number and variety of uses those derived from common salt.

Pigments. — Substances used to give color to paint are in some cases natural minerals and in others artificial products. The ochres are yellow, brown, and red compounds of iron, both natural and artificial. White lead, red lead, litharge, and chrome yellow are made from lead, zinc white from zinc, vermilion from mercury, and chrome red from chromium.

Oils. — There are many vegetable oils in use for food for men and animals, for soap and candle making, lubrication, illumination, and dressing skins. Olive oil is the most valuable and takes the place of animal fat and flesh in the Mediterranean countries. Palm and coconut oil are products of tropical regions, and cottonseed and maize oils of temperate. The most important animal fats and oils are lard from hogs and tallow from cattle and sheep, used for food and for making soap and candles. Oil is obtained from the menhaden fish, and the whale fishery was once the chief source of illuminating oils. Right whales are now nearly exterminated. Soap is made from vegetable and animal fats by boiling them with lye (caustic soda or caustic potash). Glycerin is a by-product.

Essential Oils are not fats, will not make soap, and are soluble in water. They are distilled from various plants and are in common use as medicines and flavoring extracts. Camphor is the only solid essential oil, and is obtained entirely from the Japanese island of Formosa. Oil of peppermint, lemon, vanilla, wintergreen, sassafras, bitter almonds, anise, cloves, and many others are well known.

Resins and Gums. — Resins and gums are vegetable products used in making soap, paint, varnish, and mucilage. Crude turpentine from the hard pine tree is the most important. It is separated by distillation into spirits of turpentine, used for mixing paints, and rosin, an ingredient of many soaps.

Gum arabic, from the savannas of Africa, is the base of mucilage. Copal, dammar, and lac, which is produced by an insect, make fine varnishes. Chicle, produced only in Yucatan and used only in the United States, forms the body of chewing gum. Amber is a fossil gum from the shores of the Baltic Sea, used for ornament and the mouthpieces of pipes.

Dyestuffs. — Dyestuffs are mostly of vegetable origin. Indigo, madder, and logwood are the most important. The natural supply is now almost entirely superseded by artificial dyes, made in great variety from coal tar.

The number of useful commodities, natural and artificial, has probably never been estimated, but would run into the tens of thousands. The number of kinds of articles procurable in any civilized town of 50,000 inhabitants, not including medicines, is not less than 1,000.

CHAPTER XXI

HEAT, LIGHT, AND POWER

Heat. — The development of civilization is characterized not only by a vastly increased utilization of material resources, but no less by growing dependence upon immaterial resources, especially heat, light, and power. The discovery of the use of fire, at first accidental from lightning or a volcano, was a step second in importance to none in the rise of man.

The invention of methods for kindling fire when wanted has exercised a marked influence upon human progress. The savage rubs two sticks together until they ignite, — a thing not easy to do. Our ancestors of only a century ago depended upon sparks struck by flint and steel, while with us lucifer matches are the cheapest and most abundant of devices. While artificial heat is not needed for comfort in tropical regions, fire enables men to cook food, and this will always be its prime function. The use of fire to maintain bodily temperature became necessary as men migrated into higher latitudes and altitudes. The burning of brick and pottery, the smelting of ores, the working of metals, and the manufacture of glass require the highest temperatures attainable by the use of fuel. Some modern industries, such as the extraction of aluminum, are made possible only by the electric arc at 6,000°.

Fig. 284. — Savage kindling a fire.

Light. — Artificial light is an unappreciated luxury. Julius Cæsar wrote his Commentaries by the light of a dull, smoky lamp, made by dipping a loose wick in an open dish of oil. In the Middle Ages houses and streets were lighted with flaring torches made by burning various combustibles in an iron basket. In the height of the whale-fishing industry sperm-oil lamps gave a brilliant light, but were costly and unsafe. Within the memory of men now living the common people had no better illuminant than a pine knot or a "tallow dip" candle. It was not until the latter half of the nineteenth century that the discovery of petroleum gave to everybody a cheap and efficient light. Coal gas has been used in cities for lighting about a century, and now electricity turns night into day.

Power. — The ultimate source of nearly all the power available for doing work on the earth is insolation, or radiant energy from the sun. Sunlight makes plants grow, and vegetation is the source of food which gives animals strength, and of fuel which, when burned, may run a heat engine. The sun heats different parts of the atmosphere unequally and thus makes the wind blow. The sun evaporates water from the sea, which, falling as rain on land, runs off in streams which furnish water power.

Man Power. — Primitive man was dependent upon his own muscles. He traveled and used implements and weapons, but he did not travel fast, build large structures, or transport much freight. He had only two legs and two arms, both weak and short, and with them alone he could not rise above savagery. Human power and labor is still indispensable and always will be.

The greatest amount of human labor is employed in the most advanced industrial communities. It has often been thought that machines would do away with human labor, but they generally increase the number of persons that can find employment and the total amount of muscular energy expended. This is true in manufacturing industries and transportation. Agriculture seems, so far, to be an exception to the rule. The use of agricultural machinery reduces the number of laborers employed, and exclusively rural districts are decreasing in population. This may be a temporary phase, to be followed by the reverse as agriculture becomes more scientific and intensive.

Labor Supply. — The problem of obtaining a sufficient supply of unskilled human labor is one of the most serious which confronts the civilized world to-day. For the most rapid advancement labor should be plentiful, but the supply probably never will equal the demand. Facilities for cheap transportation render possible a circulation of labor, the people of those countries which have a surplus migrating to those which have a deficiency. Indian coolies are transported to South Africa to work in the gold mines, and Jamaica negroes to Panama to dig the canal. Three hundred thousand Italians come to the United States in a single year, one third of whom return to Italy sooner or later. Thousands cross the sea to work in America during the season or as long as the job lasts, and go back home when business is dull. The United States, Canada, Australia, and South Africa, young and growing countries, need the largest supply of unskilled labor. Great Britain, France, and Germany are now self-sufficing, and Spain, Portugal, Italy, and Austria-Hungary have a surplus; but as these countries develop they will not continue in such a condition. Russia, the Balkan countries, India, China, the East and West Indies, and north and central Africa have a large surplus of labor. The African supply increases under civilized control, and the abolition of war and slavery; but the people often lack efficiency, are difficult to control, are unaccustomed to manual labor, and have a high death rate. These defects are characteristic of the natives of tropical countries generally. The people of northern India are industrious and of good physique, but race and religious prejudices, and sensitiveness to climate interfere with their transference to other countries. The people of south and Asiatic Russia, the Balkan states, and the Turkish Empire are semi-European, but rather unintelligent. The Chinaman is docile, peaceable, hardy, easy to feed, and of high efficiency. He does not assimilate with other peoples, and the white man's prejudice against him is so strong that he is excluded by law from the United States and Australia, where a large supply of labor is most needed.

Animal Power. — Domestic animals lifted men out of savagery. America remained barbarous for centuries largely because of the lack of domestic animals. Many of the larger animals are used more or less for power, but the horse is the most generally efficient. The early civilization of Eurasia was largely the result of horse power used for mobility and transportation. The horse survives the introduction of mechanical and chemical power in agriculture, trade, and war, but his importance is relatively declining. The time may come when he will be excluded from cities and used more for pleasure than for business.

Wind Power. — There is no lack of wind power in any part of the world except the calm belts, and it is inexhaustible. Until a century ago all large vessels were propelled by the wind, and sailing vessels still comprise about one eighth of the world's shipping. Wind power is used in Holland and the United States in small units for pumping water and grinding grain. Its use is restricted only by its inconstancy. If means are ever devised by which power can be cheaply stored for use during a calm, the wind may yet drive the machinery and do the work of the world.

Fig. 285. — Windmill, Holland.

Fuel. — The use of power from sun heat stored in vegetable matter was made possible by the invention of the steam engine, which is really a heat engine. It was first made practical by Watt, about 1770, and was successfully applied to vessels by Fulton, in 1807, and to land locomotives by Stephenson between 1815 and 1830. The importance of its effects cannot be calculated. By it man's legs and arms have been multiplied, lengthened, and strengthened enormously. It has made world commerce and world power possible. For all practical, human purposes, it has reduced the size of the earth to about one tenth its former dimensions, and has correspondingly promoted the unity of mankind, making all men neighbors.

Wood has always been the fuel most used for domestic purposes, and the boilers of the first steam engines were heated with wood. While forests are more valuable for construction than for fuel, the world's supply of wood of little value for anything else than to burn is very large.

Peat. — When vegetable matter decays under water it is converted into a brown or black, spongy mass, called peat, muck, or turf. A cool, moist climate is most favorable for its formation, and it has accumulated in the glacial lake beds and bogs of northern Europe and America in large but unmeasured quantities. When dried it forms as good fuel as wood, and in countries where coal and wood are scarce peat is in common use. It is sometimes pressed by machinery into briquettes and used for industrial purposes. Russia, Germany, Sweden, Denmark, Holland, and Ireland are peat-using countries.

Coal. — Coal is fossil fuel, the concentrated residue of a luxuriant vegetation which flourished millions of years ago. It was first converted into peat, then buried under accumulations of sediment, and transformed by heat and pressure into coal. *Lignite*, or brown coal, has been changed so little as to retain the appearance of wood, and has about half the fuel value of the best coal. Very extensive beds of lignite exist in the United States and other countries, but are as yet little used. *Bituminous* or soft coal, containing from 60 to 85 per cent of carbon, is widely distributed, and the world's main reliance for industrial fuel. Large quantities are converted by heating into coke, which resembles anthracite. It is also the source of illuminating gas. *Anthracite* or hard coal contains from 85 to 98 per cent of carbon, and is of the highest value for most purposes. The area of the coal fields of the world is estimated at 650,000 square miles, of which two fifths belong to the United States and one third to China.

Fig. 286. — Coal mine.

The yield of coal per square mile is very variable, the seams in some areas being few and thin, and in others numerous and thick. Coal is mined in England to a depth of over half a mile. The world's output is about 1,200 million tons annually, of which the United States mines about two fifths, Great Britain one fourth, and Germany one fifth. About half of it is used for power purposes. Coal and iron form the basis of modern industrial civilization. In the production and consumption of both these articles per capita, the United States, Great Britain, Belgium, and Germany are, in that order, the leading countries.

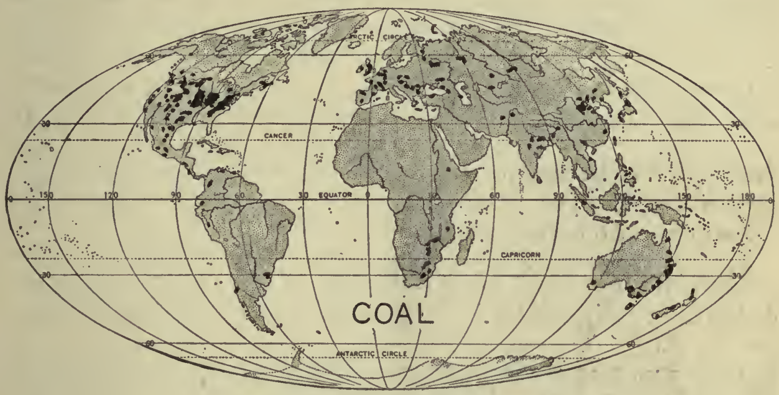

Fig. 287. — Coal-producing regions.

The British coal fields are small in area but very rich, and have been the chief source of British wealth and sea power. In the fourteenth century the use of coal in England was prohibited by law on account of supposed injury to health. Now ten millions of people are living in British coal fields to make use of it. The anthracite or "smokeless coal" of south Wales is used for war vessels, and for smelting ores sent from distant lands for that purpose.

The exhaustion of the British coal supply in the near future is a serious question. The present century may see it so far reduced as to render British competition with manufacturers elsewhere difficult or impossible. On the continent of Europe coal of generally medium or inferior quality exists in strips and patches from Belgium to the Black Sea. The coal fields of China are very large and rich, but as yet wholly undeveloped.

The southern continents are poorly supplied with coal, Australia being most highly favored. While coal occurs in all lands from Greenland to Antarctica, North America perhaps contains as much coal as all the rest of the world. The principal coal fields are (1) the Appalachian, from Nova Scotia to Alabama; (2) the Interior, from Ohio to Kansas and from Texas to Alberta; and (3) the Pacific, from Washington to Alaska. Anthracite is confined to eastern Pennsylvania and a few patches in the Rocky Mountains. On account of easily available coal and iron, great manufacturing industries have grown up around Pittsburgh, Cleveland, and Chicago, and the urban industrial and commercial district of the Atlantic seaboard is near the coal fields. The remarkable development of railroads in the United States and Canada is largely due to the wide distribution of coal. The consumption of coal in the United States nearly doubled in the ten years from 1900 to 1910. No coal is being formed in the earth at the present time, and the supply cannot be anywhere inexhaustible. At the present rate of increase of consumption, the world's store may be used up in 500 or 1,000 years. Its duration will probably be prolonged by the increased use of other sources of power.

Petroleum. — Rock oil is a product of the natural decomposition of organic matter in deep-seated strata of the earth crust,

Fig. 288. — Oil wells and tanks, Russia.

and is obtained from wells. It is not found in the same strata with coal. Of the 280 million barrels consumed annually, the United States produces nearly two thirds and the Caspian field in Russia more than one fifth.

Oklahoma, California, Illinois, Texas, Ohio, West Virginia, and Pennsylvania are important oil-producing states. Much oil is pumped through underground pipe lines to refineries at Cleveland, Toledo, and Whiting, Ind., and to the Atlantic coast cities. Petroleum is used in its crude form as fuel for engines, but it is refined by distillation into a large number of products, the most important of which are kerosene, gasoline, lubricating oils, and paraffin. Kerosene is the cheapest and most efficient illuminant the world has ever known. Gasoline has recently attained prime importance for power by the development of the internal-combustion or gas engine, which is especially adapted for small units, and is displacing the steam engine for many purposes. As a liquid fuel easily converted into a gas it has no rival except alcohol.

Natural Gas. — Gas is the most convenient form of fuel, and a cheap and abundant supply of it is of great value. Gas made artificially by heating coal has long been used for lighting and cooking, but its cost precludes its general use. Natural gas, produced by the distillation of organic matter in the earth crust, is of general occurrence in connection with petroleum.

Burning springs have attracted attention in many countries since the earliest times. Those on the shores of the Caspian Sea have been objects of veneration by the Persian fire worshipers since a period before the Christian era. About 1886 gas began to be obtained in large quantities from wells in Pennsylvania, Ohio, and Indiana, and used for lighting, heating, and industrial purposes. It was conducted in pipes to towns within 200 miles of the wells, and the "gas belt" became a busy manufacturing region, especially of those articles requiring high temperatures, such as glass, tin plate, brick, pottery, and steel specialties. West Virginia, Illinois, and Kansas also became prominent gas-producing states. Half the gas was wasted, and the supply for manufacturing and general heating was practically exhausted in about twenty years. In some cases gas was followed by petroleum in the same fields and wells, and finally both were displaced by salt water.

Explosives. — Gunpowder, giant powder, nitroglycerin, dynamite, cordite, and other high explosives are fuels which burn rapidly and suddenly liberate large volumes of gas, and are used in hunting, war, and blasting rock.

Water Power. — The power of water to drive machinery is proportional to the quantity and the head or height of fall. Natural cataracts in large streams furnish most power, but are not always most available. Dams are constructed to concentrate the fall at one place and to store water, and are most efficient in streams of steep slope and narrow valleys, like those of New England. Good water powers are abundant in mountainous regions, remote from centers of population, but the development of electrical science has made such power more available.

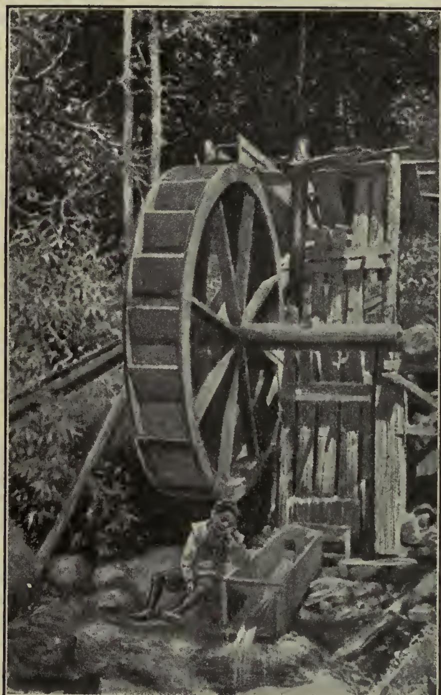

Fig. 289. — Water wheel, Georgia.

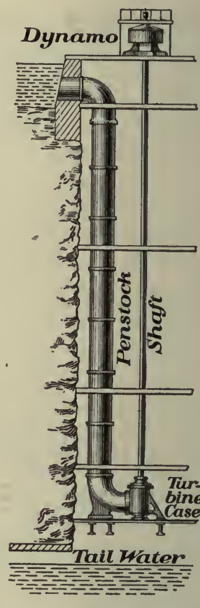

Fig. 290. — Arrangement of hydro-electric machinery at Niagara Falls.

Electricity is not a source of power, but a convenient form in which power can be distributed. The cars of city and interurban lines are run by electricity generated at one or more power stations and transmitted over copper wires. Water power is used to generate electricity, which is used to do work at places sometimes 200 miles distant. The greatest source of hydro-electric power now in use is Niagara Falls (pp. 93, 94, 101). As coal becomes more scarce and costly, mountainous countries, such as Italy, Switzerland, and Norway, will become, by the use of water power, or "white coal," important centers of industry.

Wave and Tidal Power. — The movement of waves and the rise and fall of tides are possible sources of power, but on account of inconvenience and uncertainty they are little used.

Metals. — Some metals, chiefly zinc, iron, lead, and copper, are used in electric batteries to generate power for special purposes, but are too costly for use on a large scale. Radium and the group of allied metals recently discovered are capable of liberating enormous quantities of power. They are now extremely rare and costly, but suggest interesting possibilities for the future.

Solar and Terrestrial Heat. — To contrive a system of lenses and mirrors by which the direct rays of the sun may be so concentrated as to become commercially available for heat, light, and power has been the dream of engineers, but has never yet been realized. The internal heat of the earth is second in quantity only to that received from the sun. If any means could be devised for utilizing it, it would be sufficient for human needs as long as the earth remains inhabitable. Perhaps the source of the power of the distant future will be in the nature of an artificial geyser or volcano.

CHAPTER XXII

MANUFACTURE, TRADE, AND TRANSPORTATION

Manufacture. — Nearly all natural products must be more or less modified artificially to render them serviceable to man. In low stages of culture all of this, and in all stages much of it, is done literally by hand. With the progress of the industrial arts, a larger and larger portion is done by tools and machines, which are extensions and improvements of the human hand.

In simple societies each family or group does this work for itself and at home. In more advanced and densely populated countries a division of labor arises by which an individual or family makes some special article at home for hire or for sale and exchange. Sometimes a traveling artisan goes from house to house to make shoes or clothes. These phases of *domestic manufacture* prevailed until the introduction of machinery and mechanical power. These made necessary the *capitalistic* or *coöperative factory,* in which an individual or company provides a large building equipped with machines and employs many operatives to work in it for wages. The distribution of hydro-electric power has brought about in some places and industries a partial return to domestic manufacture, in which individuals or small groups operate machines at home.

Conditions of Manufacture. — To make any line of goods on a large scale with profit many conditions are necessary. Buildings, machinery, power, heat, and raw materials must be supplied at the plant. A sufficient supply of skilled labor must exist in the immediate neighborhood. Since factory hands can produce little or no food, a sufficient food supply must be within reach. Lastly, the manufactured goods must be got to market. The location of a successful factory is determined by all of these conditions.

If the raw material is bulky, it costs too much to transport it far, and it is manufactured near the supply. This is the case with sugar cane, from which the sugar is extracted on the plantation, but shipped long distances to be refined. Grain is threshed on the farm, but may be sent any distance to a mill. South American hides are tanned in Massachusetts because capital, skilled labor, tanning materials, and a market for leather exist there more abundantly than in Argentina. The manufacture of cotton, wool, and silk is largely independent of the place of production of the raw fibers, and is carried on where power, skilled labor, capital, and markets combine to make it profitable. Half the cotton grown in the United

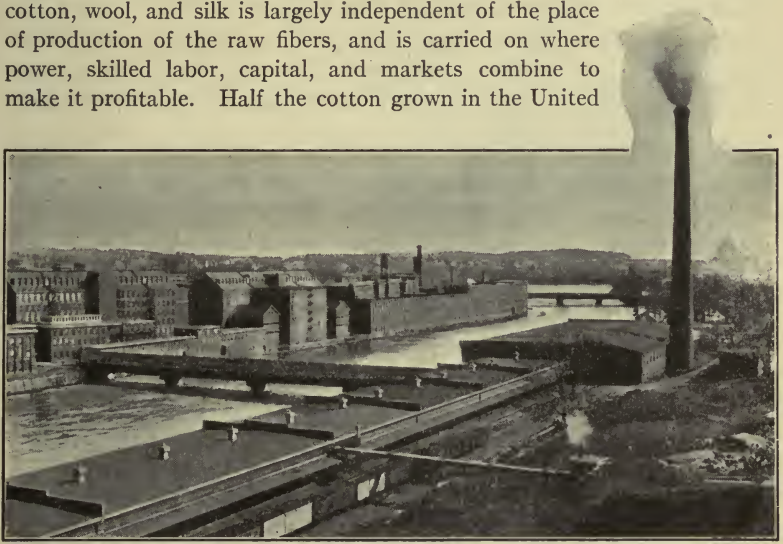

Fig. 291. — Factories. Manchester, N. H. On the Merrimac River.

States is sent to England to be made into cloth. The manufacture of iron and steel involves the use of very heavy materials — ore, coke, and limestone. It is carried on where the three can be brought together at least expense and the products find a ready market, as in western Pennsylvania, eastern Ohio, and northern Illinois. The higher the value of the finished goods the less dependent is their manufacture upon any conditions except skilled labor. The most general and potent control of the location of manufactures is transportation. Great seaports such as London and New York, and lake ports, river ports, and railroad centers such as Cleveland, Chicago, Cincinnati, and St. Louis, attract all kinds of manufacture, because of the facility with which everything needed may be obtained and the goods sent to market. Great Britain is an example of the same thing on the largest scale Having power, labor, and capital at home, by the possession of a vast merchant marine and a navy which commands the sea, the British people have grown rich by importing nearly all their food and raw materials from the ends of the earth and sending their products to all the markets of the world.

The United States is by far the greatest manufacturing country in the world, the total value of its products amounting to 15,000 million dollars annually. In respect to area it should be compared with all Europe, and in respect to population with Germany and Great Britain combined. Great Britain is second in value of total product, Germany third, and France fourth, but Belgium and Denmark each exceeds Germany and France in value per capita.

Trade. — The most general fact learned from a study of physical and economic geography is that natural conditions and resources, and human life and culture, differ in different parts of the world. The differences, both in kind and degree, are almost innumerable. Differences in natural conditions — land, water, relief, soil, climate, and the rest — involve differences of resources, and these in turn determine occupations, products, and modes of human economy. It is the business of geography to study and explain the relationships which natural conditions and resources bear to human economies.

Few if any countries can supply anywhere near all the products which its inhabitants want and can use. It would be futile to try to raise corn and cotton in England, sugar cane in Canada, or coffee and spices in the United States. Italy has no coal or gold, and Switzerland, Holland, Denmark, and Ireland have no ores of any kind. Every community can furnish, raise, or manufacture some things to better advantage than others, and the community which undertakes to be independent and supply everything it needs, without help from other communities, will be obliged to limit its wants, which means a relatively low stage of culture and comfort. Out of these conditions arises trade, commerce, or the exchange of commodities between different individuals, families, communities, and countries. Trade is the most complex and important of all the adaptations to his environment which man has accomplished.

Transportation. — All trade depends upon the transportation of goods from one place to another, and has developed with the increase of facilities for transportation. Methods of transportation are either animal or mechanical, or a combination of the two.

Porterage. — The simplest form of transportation is porterage, in which loads are carried by men's hands and arms, or on their backs or heads. Although it is inefficient and expensive, it increases in amount with the increase of trade. The initial and the final movement of goods will always be chiefly by hand, as coal is shoveled into the car in the mine and into the furnace in the house.

Fig. 292. — Porters, China.

Porterage prevails among savage peoples, in tropical forests and savannas, and in mountainous countries. Among the North American Indians the men killed the game, while the squaws brought in the meat, and carried the tents, utensils, and babies on their backs. In central Africa negro porters are the chief reliance. About thirty men are required to carry a ton twenty-five miles a day, and they must be fed. The cost of transportation from the Guinea coast to Lake Tchad, about 600 miles, is $360 a ton. The cost on the Uganda railway for nearly the same distance is ten cents a ton. In the high Alps every peasant man, woman, and child carries a loaded basket fastened to the shoulders.

Fig. 293. — Loaded camels, Egypt.

Pack Animals. — Animals are a great improvement on the human porter, and the dog, ass, mule, horse, ox, camel, and elephant are all used as beasts of burden (Figs. 256, 293). Probably the camel is the most efficient, carrying a load up to 1,000 pounds. Caravans of 13,000 camels, carrying goods of a total value of $800,000, cross the Sahara, occupying two years for a round trip.

Vehicles. — Vehicles propelled by man or animal power are the first and simplest of mechanical aids to transportation.

Fig. 294. — Straw-covered bullock cart, Ceylon.

The North American Indians used the *travois*, consisting of two poles fastened to a dog's or horse's back with ends dragging on the ground. Cross pieces furnished a bed for carrying a load. The invention of the wheel was a great step in advance, and led to the development of innumerable vehicles, from the Chinese wheelbarrow to the railroad car and the autotruck.

Roads. — The use of wheeled vehicles renders necessary the construction of roads, of which the modern railroad is the

Fig. 295. — St. Gothard coach road, Switzerland.

most highly perfected. An ideal road must be smooth, hard, and level. These conditions are more or less fully obtained by grading, or cutting down elevations and filling depressions to reduce the slope as much as possible, and by surfacing the road with wood, gravel, stone, brick, asphalt, cement, or steel. Rivers and straits are crossed by bridges or tunnels. Mountain barriers are overcome by long detours, loops, and zigzags to lengthen the line and reduce the slope, and often by a tunnel at the summit (Figs. 295, 296).

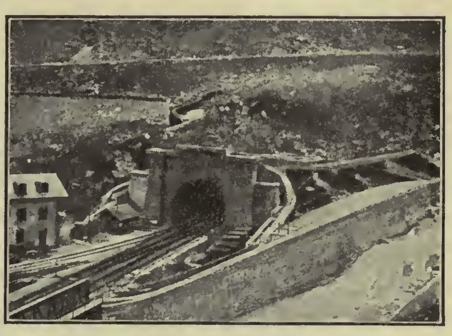

Fig. 296. — Mouth of tunnel, St. Gothard railway.

The Forth bridge in Scotland, the East River bridges at New York, the bridge across the St. Lawrence at Montreal, and several across the Mississippi are among the largest and most costly structures erected by man. Even these are surpassed in magnitude and difficulty of engineering by the Mt.

Fig. 297. — Forth bridge, Scotland.

Cenis, St. Gothard, and Simplon tunnels in the Alps and the Hudson River tunnels at New York. A tunnel under the English Channel is seriously planned, and one under Bering Strait proposed. The Rocky Mountains and the Alps are crossed by many railroads, and the Andes by one.

The railway mileage of the world is over 600,000 miles, of which North America has nearly one half and Europe one third. The network of railroads is much more dense in eastern United States and western Europe than elsewhere. Belgium and the Netherlands have the greatest density, or the largest mileage per square mile of area. The longest and most numerous railroad lines extend east and west. Eight transcontinental lines cross North America and one crosses northern Eurasia. A north-south "pan-American" line from Canada to Argentina, and a "Cape to Cairo" line in Africa are probabilities of the near future. The development of the gas engine and the automobile has given a new impetus to road construction for vehicles of moderate size.

Water Transportation. — Transportation by water is easier and cheaper than by land. Its advantages are that water surfaces are level, or, in the case of navigable rivers, have a gentle slope. There is generally no expense for construction and maintenance, friction and resistance are small, the vehicles may be very large, and the power required for a given load is less than on land.

Fig. 298. — Dugout, with outriggers, Philippines.

Boats of many kinds are in use, from the single log or raft, inflated oxhide, dugout, canoe, and rowboat to the modern steamship of 40,000 tons burden, steaming 600 miles a day and burning a ton of coal per mile. The growth of ocean trade has led to the construction of ship canals, of which the Suez and the Panama are the most important (pp. 158, 159). The Atlantic Ocean, surrounded by important peoples, is most used. The Indian is a connecting link between the Atlantic and the Pacific, and the Pacific is the ocean of the future. Half the ocean commerce of the world is carried on between Europe and North America, one eighth between Europe and the Orient and Australia (Suez route), and one eighth between Europe and Africa.

The St. Lawrence River, with its connecting lakes and canals, furnishes the greatest inland waterway. The great possibilities of the Amazon and the Kongo are as yet little utilized. The Mississippi may regain the trade lost for want of improvement. The civilized world has entered upon an era of water transportation, and the development of waterways is one of the great economic problems of the twentieth century.

Fig. 299. — Ocean steamer: the Olympic.

World Trade.—The larger part of the world's trade is domestic, consisting of an exchange of goods between the different parts of the same country. It is impossible to estimate its total amount. Of foreign commerce, or the exchange of goods between different countries, an account can be made with considerable accuracy. The value of all the goods exchanged between nations is about 28,000 million dollars annually, of which the trade of Europe is 64 per cent, America 18 per cent, Asia 11 per cent, and Africa 4 or 5 per cent. Among nations Great Britain leads with 20 per cent, and is followed by Germany with 14 per cent, United States with 11 per cent, and France with 8 per cent. The little countries of the Netherlands and Belgium have the largest foreign commerce in proportion to population.

In trade there are two great movements, one in a north-south direction between the temperate regions and the tropics, and one in an east-west direction between temperate countries in different stages of development. At present the east-west movement is greater, but it may not always remain so.

The present supremacy of the temperate zone, due to coolness and healthfulness, may, by the control of disease and the use of artificial refrigeration, pass to the tropics. Men may devise means of keeping cool in the torrid zone as they have of keeping warm in the frigid. Power and raw materials are plentiful in tropical regions, and centers of industry and population may shift toward the equator.

Summary. — Every natural resource has existed upon the earth since the first appearance of man, and no natural resource has yet been fully utilized. Probably natural resources exist of which mankind is still ignorant. Every human want, art, and economy had its simple beginnings in the lowest stages of savagery and has persisted through all stages of culture. As each want, art, and economy developed, it has influenced more and more every other. The development of civilization and scientific economy has not released men from dependence upon natural resources, but only multiplied the number and increased the complexity of such relations. Modern industrial civilization is as truly based upon grass, trees, coal, iron, and copper as Eskimo life upon snow, seals, and walrus.

The most favored countries possess lands in all climates, from tropical to cold temperate, of varied rainfall, relief, soil, and mineral wealth, and accessible to the sea. In all these respects the United States approaches ideal conditions. France equals or surpasses it on a small scale. Russia lacks only seacoast. China, Australia, and Argentina have a hopeful future. Most of the European states and Japan are less favored, but may extend their territories and supplement their resources by colonization.

The geologist sees no reason to doubt that the earth is destined to remain habitable for a longer period in the future than it has been in the past. The human race is still in its infancy, and is barely beginning to realize the possibilities of its earthly possessions. Man is yet to have his day, and his kingdom, in which he shall control the forces of nature and have dominion over the planet, is yet to come.

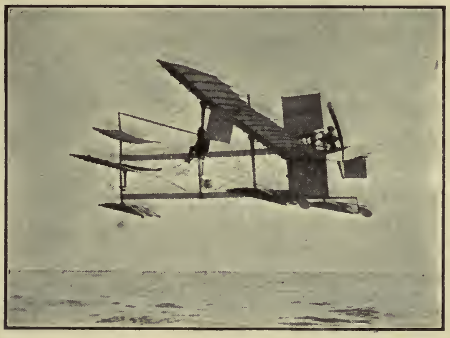

Fig. 300. — Aëroplane.

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