

Introductory Lecture on Scientific Geography. By Lieut.-General
R. STRACHEY, R.E., F.R.S.

IN June last the Council of this Society determined to offer increased encouragement to the extension in a scientific direction of the Geographical work which the Society is designed to promote, and it was resolved that, amongst other means to this end, not less than three of the ordinary evening meetings should be devoted to the delivery of Lectures on Physical Geography in its several branches, and on other truly scientific aspects of Geography in relation to its past history, or to the influences of geographical conditions on the human race. It has further been thought desirable by the Council that this, the first of these Lectures, should be of an introductory nature; that it should indicate the general scope of those that are to follow it, and thus supply, so far as your time and my ability will permit, an outline of the principal scientific aspects of Geography, to be filled in with more ample details by succeeding lecturers.

In accepting this task at the request of the Council, I have been very sensible of the extreme difficulty of doing justice to it, and I must ask those among my hearers whose knowledge of the matters of which I shall have to speak exceeds my own, to view leniently any errors into which I may fall, or any want of due proportion that in their better judgment may be found in my treatment of the wide range of subjects over which a review of scientific Geography will necessarily lead me.

Science, whether applied to Geography or any other matter, is, in truth, nothing more than well-arranged knowledge, and its methods though first developed by the study of abstract quantity and of the physical forces of nature, are applicable to all the objects of our senses and the subjects of our thoughts. The foundation of all knowledge is the direct observation of facts, in which condition it is termed empirical; the conclusions obtained by the application of thought to the facts thus observed constitute science, which by a process of classification and comparison seeks for the causes of which observed phenomena are the results.

The comparatively late application of strictly scientific method to Geography was a necessary consequence of the conditions under which the facts it deals with have been acquired. Geography is that branch of study which has for its object a knowledge of the earth. In its earliest shape it viewed the earth almost exclusively as the habitation of man. The inquiries it made concerned the distribution of the land and water, the positions of

the continents, islands, and seas, and of the plains, mountains, and rivers; the manner in which the land was divided into various countries, and occupied by various nations; the divisions of countries into provinces, and the situation of the chief cities; and it took note of many other matters concerning the language, customs, and modes of government, as well as of the climate and products of all the countries found on the earth. As travel extended and knowledge advanced, the earlier impressions of travellers as to the striking differences between distant countries were supplemented by the perception of co-existing similarities. Attention was drawn to the peculiarities which persistently characterise, at places widely separated, the great regions of cold and heat, the mountains and plains, the coasts and interior of the continents; to the local and periodical variations of temperature and climate, and of seasons of wind and rain, over certain areas of land and sea; and to the distribution of the principal branches of the human race and of the families of plants and animals. A large stock of facts of different classes was thus accumulated. But before these observations could be viewed as a connected whole, or the true significance of their mutual relation could be properly appreciated, it was necessary that considerable progress should have been made in many special branches of physical knowledge. The ancient sciences of mathematics and astronomy had first to receive the enormous additions which followed the revival of learning in the sixteenth century. The modern sciences of chemistry and physics, biology the science which was born yesterday, and geology the science which was born to-day, had all to throw their light on the facts which scientific navigation had brought together from every sea and land, before that conception could be formed of the close inter-dependence of all we see upon the earth, which renders possible a true science of Geography.

For the aim of this branch of science is to ascertain by what agencies and by what process the earth has acquired its existing forms and characteristics. And this inquiry appears to establish that the phenomena observed on the surface of our planet are in their chief features attributable,—first, to the action of the great physical forces, attraction and heat, controlled by the earth's figure and its movements on its axis and round the sun; and, secondly, to the configuration of the surface, and the distribution of sea and of low and high land: and moreover, that all the phenomena of animate as well as inanimate nature have been in the past, as they still are, governed and determined by these same forces and influences.

We further learn that the figure itself of the earth, and the outlines of its surface, have been due to the former condition of the planet, and to the gradual changes it has undergone in cooling from a previous much higher temperature; that these and other causes have operated through a past into the obscure distance of which our vision cannot pierce, and are still at work, producing changes of surface, from which, as direct consequences, arise modifications of climate, and corresponding variations in the forms and distribution of living creatures, vegetable and animal. In this manner has been evolved the face of nature as we now see it; nature, which working with never-varying forces through ever-varying forms, appears to man in the present as his type of stability, while leading from the hidden shapes of an impenetrable past to those of an unknown future.

It is evident that the original investigation of the causes of terrestrial phenomena requires a knowledge of physical science, both wide and deep. But though this be true, it puts no serious difficulty in the way of imparting a thoroughly sound knowledge of the results, when once attained, to those whom want of leisure and perhaps of ability, prevents from going more deeply into these subjects. Nor need such a knowledge as is thus gained be either superficial or of small value; in the words of John Mill, "to have a general knowledge of a subject is to know only its leading truths, but to know these thoroughly, so as to have a true conception of the subject in its great features;" and it is hardly needful to insist on the advantage of having true conceptions in place of false or none, of such familiar objects as those which Physical Geography deals with. I therefore ask you, without hesitation, to discard all objections to including scientific geography in the course of an ordinary education, which are founded on the variety and complexity of the subjects it includes. These objections have, in truth, their origin in the too general absence of scientific knowledge which characterises a generation that has not itself received even an elementary education in physical science; standing in the same position with regard to these matters, as men who can neither read nor write stand in to the world of letters. It is one of the special functions of associations such as the Geographical Society, to aid in removing obstacles like these from the way of improved education: our Society may justly claim some pre-eminence in the steps it has already taken in this direction; and I feel satisfied that your intelligent support will be given to its steady progress in the same course.

In proceeding to present to you, in a succinct form, a connected view of the principal matters that fall within the range of scientific Geography, I shall first touch upon those that more closely depend on the figure and movements of the earth viewed as a whole, and afterwards pass on to those in which the influence of local conditions becomes more marked; the former, speaking generally, affect more immediately inorganic, and the latter, organic matter.

The intimate relation between geography and astronomy is at once suggested by the essential importance to the geographer of a knowledge of the methods of determining the magnitude and true form of the earth, and of ascertaining position on its surface. It is of the highest interest to contemplate how man, with no other aid than his wonderful reasoning faculty, deduced from observations of the apparent motions of those heavenly bodies from which an impassable gulf divides him, the exact figure and dimensions of the globe on which he stands, of which he had as yet seen but a very small part; and how he extended this knowledge to the magnitude, the distances, and the laws that regulate the movements, of the whole planetary system to which the earth belongs.

Leaving the obscure origin of conceptions on these subjects to be sought for in Babylonia or Egypt, it is to Greece that we turn to find the first definite scientific opinions. Thales of Miletus, 640 years before the Christian era, already taught that the earth was a sphere. To his successor, Anaximander, is attributed the invention of maps; and his disciple, Pythagoras, suggested the true doctrine of the revolution of the earth on its axis and round the sun, though this conception dropped out of sight for centuries.

Eratosthenes, of the Greek school of Alexandria, in the third century before Christ, is said to have first determined the magnitude of the earth, adopting for the purpose the principle still in use.

Hipparchus, of the same school, who lived a century later, was the greatest of the Greek astronomers, and his additions to the science were truly remarkable. He discovered the precession of the Equinoxes, or the periodical change of direction of the earth's axis from east to west, in the opposite direction to its motion in its orbit; and the eccentricity of the sun's apparent orbit, the inequality of its motion, and its distance from the earth. To him is due the system of fixing geographical position by means of latitude and longitude, and the method of calculating longitudes from eclipses of the moon.

Ptolemy, about 150 A.D., was the last eminent man of this

school. He collected all determinations of latitude and longitude of known places, and laid the foundation for correct methods of projection for geographical maps or charts. He is better known, however, by his treatise on Astronomy, which long continued to be the great authority on such subjects, and which caused his name to be given to the conceptions of the solar system it contained, though these were really due to his predecessors.

From this time until the sixteenth century—a space of 1400 years—no additions of any importance were made to this science. The study was revived in the ninth century among the Arabs, by whom the treatise of Ptolemy was translated into Arabic; and it was mainly through the teaching of the schools established by the Mahometans in Spain, and thence transmitted to Italy, that the knowledge already acquired was retained, and eventually so vastly extended. It was a little after 1500 A.D. that Copernicus put forth the view, this time to be finally accepted, that the earth and planets move round the sun. The almost simultaneous discoveries at the commencement of the seventeenth century of Galileo and Kepler, completed and corroborated this theory, and so opened the way for that explanation of the whole series of astronomical phenomena by the operation of the law of universal attraction, which is due to the genius of Newton.

A great impulse was given to precise geographical knowledge by the invention of the telescope and the pendulum, and their application to astronomical and geodetic observations. These led immediately to more exact determinations of the figure and dimensions of the earth. The measurement of an arc of the meridian in 1669, by Picard, gave Newton the means of verifying his theory of gravitation, and led to the recognition of the earth's ellipticity, as well as of the variation of the force of gravity at the surface with change of latitude, indicated by the varying time of vibration of a pendulum. Nothing then remained to be done in this direction but by the employment of better methods in detail, and of improved instrumental appliances, to attain results of greater accuracy.

Methods of calculating latitude, and instruments suitable for applying these methods, were comparatively soon devised. The difficulty of determining longitude was far greater, nor could it be overcome until correct clocks were constructed. The use of chronometers, the discovery of the telescope, and the progress of mechanical art, which produced instruments capable of measuring angular distances with accuracy, created scientific navigation. The practical application of this science has in our time opened

out ways to the most distant parts of the globe, along which the skilful mariner passes in complete security at a speed which now makes every part of the habitable seaboard, however remote, more accessible than were many places in our own islands hardly a century back. To produce such practical triumphs the accurate representation of the surface by maps or charts was essential. The reproduction of the details of a spherical surface in a rigorously exact manner on a plane, such as a sheet of paper, being necessarily impossible, much ingenuity has been applied to devising the best methods for approximating to the truth. The exact measurement of the earth's dimensions, on which the accuracy of all delineations of the surface depends, is a task involving much difficulty, and calling for rare abilities in the geodetic surveyor.

And here let me dwell for a moment upon the very great practical value of those compendious contrivances for conveying information to the mind, diagrams and drawings, which are little, if at all, less valuable than written language. Their special power consists in bringing clearly within the reach of apprehension, at the same moment and in suitable juxtaposition, a great multitude of objects interdependent but different, and so producing an intelligent connected conception of the whole, often without effort, and always with a clearness that no verbal description could secure. I desire to invite particular attention to this subject, feeling assured of the utility of maps or illustrative diagrams in dealing with the many complicated phenomena that present themselves to the scientific student of Geography. A certain fair facility for making such maps or diagrams may be acquired as readily as writing. Man has long been distinguished from other animals by the faculty of speech, and Professor Huxley has lately reminded us that he is the only drawing animal. These faculties correspond with the "two ultimate modes by which it is possible to implant ideas apart from actual experience, viz., narrative and diagram;"* and he who possesses both tools doubles his power of obtaining and imparting knowledge.

Having thus traced the growth of our knowledge of the earth's figure, and the relation of geography to astronomy, I pass on to notice briefly the parallel onward course of geographical discovery.

Scarcely less admirable than the sagacity of the astronomers of the past, have been the enterprise and perseverance of that succession of able men who, by journeys over land and sea, have

* I have taken these words from an *Essay on Science and Language*, by my friend Colonel Dickens, R.A.

furnished positive evidence that the earth is in fact the globe which man's reason had taught it to be, and who have brought together, in defiance alike of the rigours of the elements and the barbarous nature of uncivilised man, the ample stock of knowledge which we now possess of the entire surface of the earth.

Like astronomy, Geography originated in Egypt and Greece. The earliest geographical conceptions were necessarily based on ideas of position in relation to the locality where the ancient geographers lived and wrote, and upon these the gradually increasing knowledge of the civilised world was engrafted, and developed around the eastern end of the Mediterranean Sea. Herodotus, writing 450 years before the Christian era, may be taken as the exponent of the earlier forms of Greek geography. The junction of the Mediterranean with the Atlantic was then known; ideas of the North and West of Europe were vague; the form and position of the Caspian were fairly ascertained; the descriptions of India do not extend beyond the Upper Indus; and the coasts of Asia seem to have been unknown beyond the Persian Gulf. The circumnavigation of Africa is referred to, but it may be doubted whether this was more than mythical.

Alexander's expedition, 330 B.C., reached the Indus; some of the Greeks who accompanied him went into India Proper; while on his return Nearchus followed the coast from the Indus to the Persian Gulf.

Up to the Augustan age, the only additions to Geography were obtained through the Roman conquests in Western and Northern Europe. In the time of Pliny, the coasts of Asia had hardly been traced with certainty beyond the mouths of the Ganges, and only vague conceptions of China had been formed. These had become more defined, and extended to the Malay Peninsula, Sumatra, and Java, by the time of Ptolemy, A.D. 150.

Till the end of the twelfth century, the further progress of geographical, like that of all other branches of knowledge, was very inconsiderable. Something was done by the Arab geographers in the early period of the growth of Mahometan power, and something by Norwegian Vikings. But in the thirteenth and following centuries, when the civilisation of Europe was becoming consolidated, the spirit of enterprise was gradually awakened, and led to great results.

The institution of the orders of friars, the desire to spread Christianity, and the terror produced by the incursions of Jenghiz Khan into Eastern Europe, were followed by journeys, of which one of the most remarkable was that of the monk Rubruquis into Central Asia. The growth of commercial activity sent forth the

Polos on similar expeditions. The knowledge of Central and Eastern Asia thus obtained, formed almost the whole of our stock up to our own time.

The formation of the powerful republics of Venice and Genoa, and the spread of their commerce, under the stimulus of many causes of which the Crusades may be reckoned as one of the most prominent, led somewhat later to the development of maritime habits, knowledge, and enterprise, among the nations bordering the Mediterranean, which at length found their expression in the series of great voyages of discovery which are among the most remarkable events of the world's history.

The Portuguese, as the result of systematic and continued effort, reached and doubled the Cape of Good Hope, arriving on the coasts of Western India in 1497. Nearly at the same time Columbus, following a truly scientific course of induction, for the first time so applied by man, embarked on the celebrated voyage which led him to the West Indian Islands in 1492, and which was soon succeeded by those in which he reached the continent of South America, near the mouths of the Orinoco. Cabot rediscovered the coast of Newfoundland. In the first half of the sixteenth century, Magellan started on the voyage in which the circumnavigation of the globe was for the first time accomplished by a circuit round South America and through the Pacific. Cortez advanced into Mexico; Pizarro and others turned southward along the Pacific to Peru and Chili. The Portuguese gradually explored the southern coasts of Asia, reaching the Moluccas and southern China; and the coasts of Japan and northern China became known through the Portuguese pirates. The beginning of the seventeenth century supplied a knowledge of the coasts of Australia, the Dutch from their colonies in Java having sailed round the west and north coasts in 1627, and discovered, under Tasman, the south coast, New Zealand, and Van Diemen's Land.

Thus in a period of less than 150 years was acquired the knowledge of the main outlines of the great areas of land and sea, to complete which in more exact detail has been the task of succeeding generations.

The later voyages of the seventeenth century were undertaken chiefly by privateers and buccaneers, of whom Drake and Dampier were the chief. Towards its end began the expeditions specially despatched by various countries for purposes of scientific discovery; and second to none have been those sent out by England, beginning with Halley, including the voyages of Cook, and ending with those of Nares. ;

In our own time geographical exploration has been chiefly directed to the Arctic regions, and the interior of the great continents of Africa, Asia, and Australia; and it was in the earlier part of the present century that arose the conception of scientific geography, in connexion with which will ever be remembered the name of Alexander von Humboldt.

The study of Magnetism has an unusually close connexion with the progress of geographical research.

The general properties of the magnetic needle were known and applied to navigation in Europe as early as the tenth or eleventh century, but much earlier by the Chinese. The variation of the declination, or deviation of the needle from the true north, at different places, was probably known before the time of Columbus, but to him seems to be due the observation of the gradual change which takes place in sailing westward across the Atlantic, until a line of no variation is reached, beyond which the variation becomes easterly. The conception of the earth being a magnet is due to Gilbert, an Englishman, about 1600 A.D. Halley, about 1700 A.D., suggested the idea of four poles of magnetic force, to the influence of which the complicated movements of the needle might be referred.

The results of magnetic observation as now collected, establish that there are, in fact, four magnetic poles, and that the magnetic force exhibits a series of periodical variations, both in respect to its direction and its intensity, dependent on the time of day, of the year, and the succession of years, as well as on the place of observation. The variety and complexity of these phenomena are great, and they are regarded as the results of electrical currents, established at or near the earth's surface, and due in some unknown way to the earth's revolution on its axis and round the sun, and to the heat emitted by that body. The application of the study of magnetism to practical navigation in these days of iron ships becomes a matter of very great importance.

The impress of the movements and figure of the earth is everywhere seen underlying the almost infinite variety of phenomena brought to our knowledge by the more and more complete exploration of the surface. It is these which determine the amount of heat received from the sun at any part of the earth; and regulate the distribution of temperature on which immediately depends the distribution of life. Everywhere we find alternations of what I may term terrestrial work and rest, consequent on the daily, and yearly movements of the globe, which, subject to the influences due to the spheroidal form of the earth and the direction of its axis of rotation, give rise to the varying length of days and of

seasons at different places, and to a multitude of other recurring phenomena which characterise the animate and inanimate world. Day and night, summer and winter, active life and sleep, or hibernation, periodical winds diurnal or prolonged, seasons of rain and drought, are among the best known of these. The tides and the less well-known but equally regular periodical oscillating movements of the atmosphere obey the same general laws. A great number of other secondary phenomena carry out similar effects through all parts of the earth, and into all the operations of nature, both on the land and in the waters; for instance, in the currents of the ocean, the periodical rise and fall of rivers, the migrations of animals, the increase and decrease of disease among men.

Though many of the effects observed would equally follow as consequences of the sun moving round the earth as a centre, yet direct evidence that the converse is the case is to be found both in the movements of the atmosphere and in the currents of the ocean. The winds and waters, as they pass over the surface of the earth, acquire a velocity of revolution corresponding with the latitude, being greatest at the equator, and diminishing gradually towards the poles. The velocity thus acquired gives an eastward impulse to all air or ocean currents moving from the equator towards the poles, and an apparent westward impulse to air and water moving the other way. This has long been recognised as the true cause of the peculiar directions of trade-winds and monsoons; and more recently as the efficient agency in determining the direction of the south-west and north-east gales that characterise our own coasts. The revolving storms or cyclones which are among the most terrible of the natural adversaries of man, carry with them an awful testimony to the true direction of the earth's revolution on its axis from west to east.

As the facts which most directly depend on the form and movements of the earth became more completely known, and as the related conceptions arising from their study were more clearly developed, an inquiry naturally began into the nature of the earth's solid crust, and of the forces by the action of which the surface has received its existing outlines, elevations, and depressions. The science of Geology is the result; and the relation of this science with Geography is what we have next to consider.

A very little observation and thought threw discredit on the ancient cosmogonies, and showed that they failed to give any satisfactory solution of the problems submitted by the advance of geographical knowledge. If the extravagant myths of Asiatic origin, which peopled the earth millions of years ago with races

of anthropomorphic demi-gods and heroes descended from the sun and moon, could not bear the test of facts; neither have those traditions fared much better which unveil the earth fully equipped with all the present forms of life, and specially prepared to be the dwelling-place of man no more than a few thousand years ago. Precise observation has now supplied satisfactory proof that the earth's surface, with all that is on it, has been evolved through countless ages, by a process of constant change. Those features that at first sight appear most permanent, yet in detail undergo perpetual modification, under the operation of forces which are inherent in the materials of which the earth is made up, or of those developed by its movements or by the loss or gain of its heat. Every; mountain, however lofty, is being thrown down; every rock, however hard, is being worn away; and every sea, however deep, is being filled up. The destructive agencies of nature are in never-ceasing activity: the erosive and dissolving power of water in its various forms—the disintegrating forces of heat and cold—the chemical modification of substances—the mechanical effects produced by winds and other agencies—the operation of vegetable and animal organisms—and the arts and contrivances of man—combine in this warfare against what is. But untiring nature immediately builds up again that which it has just thrown down; hand in hand with this destruction, nay, as a part of it, there is everywhere to be found corresponding reconstruction. If continents disappear in one direction, they are rising into fresh existence in another. Though the ocean tears down the cliffs against which it beats, the earth takes its revenge by once more upheaving the ocean's bed. And thus the globe has passed in succession through an infinitude of anterior states, by small modifications extending over a vast period of time, but not differing in essentials from those which are now seen to be going on.

The far greater heat of the interior of our globe, which increases about 1° Fahr. for every 50 or 60 feet of depth, gives us conclusive evidence that it has reached its present condition from a former state of much higher temperature. As the exterior gradually cooled, contractions necessarily ensued with consequent change of form and dimensions; and to these, acting in combination with gravity, were due the disturbances of the earth's surface, which have caused its greater irregularities. The strains set up by these forces may have continued to cause movements for a vastly prolonged period, and are probably still in action. Recent speculation has suggested that even volcanic phenomena may be

consequences of the heat developed by the intense pressures set up by the mechanical forces concerned in these movements of the cooled outer solid crust, and not results of the very high temperature which almost certainly still subsists at great depths in the interior.

In the absence of any direct means of ascertaining the condition of the earth's interior, aid has been sought from astronomical science, by which it has been established, that the thickness of the solid outer shell of the earth must be considerable; and that if the interior is in a fluid state at all, it must be covered by a great thickness (probably not less than several hundred miles) of solid, comparatively unyielding matter; and it is argued with apparent force that no connexion can exist, by which molten matter could pass between such depths and the surface.

As the mountain ranges are areas of elevation due to the pressures developed by the contractions of the surface, so the chief valleys commonly follow fissures along the lines of rupture; and their directions are determined by the lines of tension produced by the same mechanical strains which accompanied the elevations; mathematical science here, too, has come to the aid of geography and geology, in suggesting explanations of many characteristic directions of the elementary portions of mountain masses.

In the ocean we see the waters of the earth accumulated in the depressions formed on the surface in past time. The great continents occupy the areas that have risen in comparatively recent periods, and the clusters of islands probably indicate the remains of former continents now disappearing. We find in many directions evidences of movements on a very large scale, which lead to the conclusion that most of the existing great mountain chains have received their present prominent altitudes in almost the latest geological periods; and that during, or since those periods, the forms of the land and sea have greatly altered. Other indications, however, are not wanting, that some of the great features of land and sea, as we now find them, have been preserved for very long periods, and these may possibly be relics of the earliest forms taken by the surface soon after it attained a solid condition.

There was at first no little disinclination to accept theories which required vast periods of time in order to account for the observed facts of geology by forces now in operation. But these difficulties have at length disappeared, and with them the school that explained the great differences between the past and the present, by a series of catastrophes, or convulsions of nature, for which we have no authority in actual experience.

Should any difficulty arise in conceiving how such vast movements as those of which we see the results in mountains like the Himalaya or the Andes, and in the analogous depressions of the bed of the ocean, can have been produced by a mere secular change of the earth's temperature, I would remind you that the forces called into action by the earth are proportionate to its magnitude, and that its parts must be viewed in relation to that magnitude also. It has been calculated on sound data that the contraction of the diameter of the earth, consequent on the fall of temperature from a fluid state to its present condition, has been about 190 miles. At this rate a subsidence of 5 miles, which is the approximate greatest depth of the ocean, would correspond to a fall of temperature of about 200° Fahr. But the actual elevations and depressions of the surface have probably been produced by a comparatively much smaller loss of heat, being due rather to tangential strains than to any direct subsidence.

An illustration may assist you in forming a truer estimate of the irregularities of the earth's surface, which, though apparently great, are insignificant when viewed in relation to its actual dimensions. This hall might contain a globe 40 feet in diameter. If it represented the earth it would be on a scale of 1 foot to about 200 miles, and 1 inch would be equivalent to a distance of $16\frac{2}{3}$ miles, or 88,000 feet. On such a globe the difference between the polar and equatorial diameters would be less than 1 inch, and the greatest elevations in Britain would rise to about the thickness of a three-penny bit. The highest mountains and the deepest seas would be shown by elevations and depressions of hardly more than $\frac{1}{3}$ of an inch; and if they were distributed as such features are on the actual earth, they would be visible only with difficulty, and to your unaided eyes would in no way interfere with the apparent perfect smoothness of the globe's surface.

But the irregularities of the surface constitute only a small part of the effects of internal heat on the earth. Mineralogy is the branch of science which treats of the many simple and compound substances, that have issued under the operation of chemical forces from the vast laboratory contained within the cooling crust of the once incandescent globe. The spectroscope shows that the original materials of which all these substances are made up are the same as those that constitute the sun and other heavenly bodies, thus confirming the conjecture that all of those bodies are the results of the aggregation of matter once diffused in space. The waters of the ocean we must regard as a residual liquid product, resulting after those combinations were completed which supplied

the solid parts of the earth. In like manner, the atmosphere is the residue of the gaseous matter, after all the requirements of the laws of affinity had been elsewhere complied with; and it is not a little remarkable that these two subsidiary collections of matter, as I may term them, the air and the sea, which constitute a mere film on the earth's surface, should exercise so predominant an influence on terrestrial economy.

The area of the dry land is very greatly exceeded by that which is covered with water. The whole surface of the earth being 196 millions of square miles, about 51 millions are land, and 145 millions water. The average height of the land above the sea-level is also very much less than the average depth of the sea-bottom below that level, so that a rearrangement of the surface is quite possible by which the whole of the land might be submerged with comparatively little disturbance of the present level of the sea, or reduction of its average depth.

The mobility of water, and its properties in relation to heat, more especially that of evaporation, make the ocean one of the most important elements of terrestrial existence; it furnishes to the atmosphere the moisture which is one of the essentials of life, and serves by the circulation of its waters to equalise greatly the temperature of the globe, moderating the extremes both of heat and cold. The greater or less proximity of the sea directly affects climate; and the relative position of land and sea areas frequently determines the directions of the prevailing winds, while the formation of the coasts, their directions, and the depth of the bottom, immediately affect the flow of oceanic currents, and the distribution of heat through their means. The position and magnitude of mountain-ranges have also often an indirect influence on these actions of the ocean; they lead to the discharge into it of great volumes of fresh water from rivers, whereby currents are originated or modified, and they cast on its surface those vast masses of floating ice, which carry the temperature of the polar regions with them, far into the temperate zone.

The application of mathematical reasoning to the complicated phenomena of the tides of the ocean offers a striking illustration of the success of such methods, and of their great practical utility. They have supplied the theoretical knowledge which enables us to calculate, after a comparatively short preliminary process of observation, the daily and hourly periods and extent of the rise and fall of the tides at any part of the ocean; thus meeting one of the great wants of the seaman. The attraction of the sun and of the moon directly tend to produce a tidal

wave which shall follow the apparent place of the moon, moving from east to west, or in the opposite direction to that of the earth's revolution; but though this result is actually produced in the more open part of the ocean, yet the distribution of the great masses of land is such that the law can only very partially be complied with; in fact, in our own seas the tidal wave moves generally from west to east, or diametrically in the opposite direction to that of the force which generated it. This affords another of the numerous illustrations of how greatly local conditions of surface affect the operation of the great forces set up by nature.

Among the influences which give to the earth the characteristics that most immediately affect its fitness for occupation by man, those of the atmosphere are, without doubt, the most prominent. These influences, under the general designation of climate, are constantly affecting us. Of all branches of science, that which treats of the atmosphere—Meteorology—is at the present time certainly the most backward. The reasons are not far to seek. The air is invisible, and, for the most part, inaccessible. The changes it undergoes take place with great rapidity; they are difficult to observe, and, from their great complexity, difficult to grasp. It is pretty certain that the essential causes which operate on the atmosphere are changes of temperature; but the application of mathematical reasoning to the movements of elastic fluids when submitted to changes of temperature, is accompanied with great difficulties, and very little has been done to grapple with them. What we know then of these subjects is as yet almost exclusively empirical. Our instrumental appliances are here far in advance of our theories, and it is not to be disguised that great waste of labour too frequently results from an exaggerated refinement in observation, which has no real value.

The air, though highly attenuated, constitutes a fluid-medium beneath which the whole surface of the earth is immersed, and by which all that is on it is surrounded, supported, and penetrated. The air is the vehicle through which warmth and moisture, and the gaseous necessities of life are supplied to all that is on the earth. With the ocean, the air performs the part of equalising temperature, and preventing excessive accumulations or losses of heat; and as the ocean supplies the source of moisture, so the air distributes it, first absorbing and then delivering it up at some distant place. The very great activity of the air in carrying out these functions is truly remarkable. If the whole quantity of moisture in the air at any moment were condensed so as to leave it absolutely dry, the resulting stratum of water, i

distributed evenly over the whole earth, would be less than 1 inch in depth. Yet it is estimated that the mean rainfall over the whole globe is not less than 60 inches in the year, and falls of ten times this amount are known to occur in some localities. Actual observation of the velocity of the wind at marine stations, shows that such results may readily be due to the almost unceasing passage of saturated air over the regions where, and during the time in which, rain thus falls, and to the unceasing renewal of the supply of moisture by evaporation. The relatively very large total sea-area has an important effect in facilitating the supply of the rain that falls on the land; and the actual distribution over the earth both of heat and moisture is largely dependent on the local distribution of the land and ocean areas.

Our observation is almost necessarily limited to the lower regions of the air. But it is to be remembered that three-fourths of the air in weight is found within 30,000 feet, and nine-tenths of the watery vapour and half the air within 20,000 feet of the surface. Hence it is certain that the movements near the surface are those that chiefly affect all conditions of climate, though no doubt there are great movements in the upper regions to bring about the restoration of equilibrium, which is being constantly disturbed below.

The principal periodical winds—such as the trade winds, the monsoons, the land and sea breezes—are easily explained, and are found to be essentially dependent on periodical variations of atmospheric pressure, accompanying variations of temperature due to geographical conditions. The proximate causes of the more characteristic winds of the north of Europe, and especially of our own islands, appear to be also well made out. They, too, are disturbances of pressure; the rapidity and intensity of which and the manner of their transfer from one area to another, determine the force of the wind, the direction in which it blows, and the manner in which it veers. But how the changes of pressure are produced, and what causes the transfer of the disturbed area in a definite direction (usually from west to east) we have still to learn; though here, too, it is obvious that the formation of the surface, the distribution of the land and sea areas, and of the ocean-currents, are among the principal agencies at work. The winds of our islands have commonly, more or less distinctly, the gyrotory character which is one of the secondary results of the revolution of the earth. The precise conditions under which the great cyclones or hurricanes of the tropics are generated have still to be discovered, but we have a sufficient know-

ledge of the manner of their occurrence to enable the instructed mariner in most cases to escape their worst consequences. That these winds also are strictly due to local terrestrial influences cannot be doubted.

The action of the periodical winds in producing the seasons of rain in the tropical and semi-tropical regions of the earth, is of the greatest practical moment, the water-supply and the production of the ordinary food-crops being often wholly dependent on such rains; and the search of science into the controlling causes of their failure and abundance, may result in enabling us so to foresee the possible occurrence of drought as to guard against its worst consequences.

The immediate dependence of rainfall on local geographical features is too well known to call for more than a passing remark. The presence of mountains forming a barrier in the path of the vapour-bearing winds may determine, on the one side a climate of perpetual cloud and rain, and on the other vast tracts of desert. Where no mountains exist to cause condensation such winds pass on, leaving deserts behind them, and carry their waters to fertilise more distant lands.

A well-known consequence of the physical properties of the air becomes apparent under the influence of elevation of surface, in the gradual reduction of temperature observed as we ascend mountains. This amounting to 1° for about 300 feet of elevation, gradually produces a change of conditions similar to that caused by receding from the equator towards the poles; and at the greatest elevations an arctic climate is established even under a tropical sun.

The great ranges of mountains entering the regions of perpetual snow, which traverse the tropics or approach them, are among the sublimest of the sights furnished by nature. Here, by the intrusion of the solid terrestrial surface into the upper parts of the atmosphere, the low temperature, which otherwise could have produced no effect on the earth, is brought into active operation; and the results are carried down in the form of great rivers, which fed by the melting fields of ice, or the copious condensation of rain on the mountain slopes, fertilise the plains beneath as they pour forth their never-ceasing streams.

Whether in the shape of glaciers in their mountain beds, or as the floating fragments of glaciers that form icebergs, or when merely producing disintegration in the fissures of rocks, ice is one of the most energetic of destructive agents. The recurrence of glacial epochs with alternations of periods of greater heat, in

the earth's past history, of which geology supplies apparent evidence, is of much interest, and has given rise to much speculation. Among possible causes of this are to be reckoned the variations of the form of the earth's orbit, which, combined with the changes of position of the axis in relation to the points of least and greatest distance from the sun, due to precession, appear capable of producing very considerable effects on the summer and winter temperatures of the two hemispheres, without affecting the mean temperature of the globe. Actual displacements of the earth's axis of rotation have also been suggested as a means of accounting for these great local changes of temperature; but the evidence in this direction has hardly yet been carried beyond arguments, based on mathematical reasoning, to show that such displacements are not incompatible with established facts.

A few words will indicate the magnitude of those forces which are called into silent and comparatively unobserved operation in the atmosphere by the sun's heat. It has, as I noticed, been estimated that on the average 5 feet of water falls annually as rain over the whole earth. If we suppose that the condensation takes place at an average height of 3000 feet above the surface, the force of evaporation must be equivalent to a power capable of lifting 5 feet of water over the whole surface of the globe 3000 feet during the year. This would involve lifting 322,000 millions of pounds of water 3000 feet in every minute, which would require about 300,000 million horse-power constantly in operation. This calculation does not include the force required for the transport of the rain in a horizontal direction. But such numbers cease to convey any precise signification, and I will therefore add, that the engines of the largest ironclad do not exceed 8000 or 9000 horse-power. Of the huge energies thus exerted a very small part is transferred to the waters that run back through rivers to the sea, and a still smaller fraction is utilised by man in his water-mills. The rest is dissipated in tending to equalise the temperature of the celestial spaces and what is therein.

We have now seen how, under the action of inherent or external forces, the globe has been moulded to its present form, and has received the existing configuration of its surface; and how from these have resulted all local characteristics of climate, fitting it for the support of life. We thus find ourselves at the mysterious line which separates inorganic from organic matter.

Of the origin of life, either when or how it began, we know nothing; all that can be said is that the earlier conditions of the earth were altogether incompatible with life as we know it. For

thousands of years, as the globe cooled down, its surface must have been deluged with boiling water; and until a temperature had been established not very greatly exceeding that of the present, none of the forms of life found in the oldest fossiliferous rocks could have subsisted. And life is restricted to a very thin stratum at the surface, hardly more than one thousandth part of the earth's diameter—the proportion of a coat of varnish to an ordinary globe.

The old received sharp distinction between animal and vegetable is quite broken down. The bond that subsists between things with and things without life, is testified by the identity of the elements of which they are all composed; the absence from the materials of which the earth is formed, of a single one of certain elementary substances, such as oxygen or carbon, would have rendered what we know as life wholly impossible. The only conclusion is that life is in its nature analogous to other properties, of whose connexion with matter we are equally ignorant; and that it is in fact in some unknown way a necessary adjunct or consequence of matter in certain conditions.

Scientific theories of life must be based on the study of the structure and distribution of existing plants and animals, and of the corresponding facts established by the aid of geology. These teach that all things having life exist in groups, such as vegetables and animals, mammals and birds, cats and dogs, and so forth; among which may be traced various degrees of structural affinity, gradually increasing, until we at length reach individuals known to be related by descent from a common ancestor. We also find that the assemblages of creatures in countries easily accessible to one another, and alike in climate, closely resemble one another; that as distances increase, and communication becomes less easy, and climate less similar, differences in forms of life are more marked; and that great distance and complete separation are generally accompanied by a total change of forms. Distance in geological time has the same effect as distance in space; the further we go back into the past, the more different were the forms of life from what they now are.

These were the phenomena to be accounted for. The problem was, whether or not this could be done by having recourse to the only means which direct observation shows to be capable of producing living creatures, propagation by generation through descent from parent to offspring. The answer has been given in the affirmative by Darwin, to whom we are indebted for a theory of life analogous in its breadth and the genius it displays to the great conceptions of Newton. Darwin has shown how pro-

pagation by descent, accompanied by certain small variations in the offspring, such as are known to occur, would be followed by the necessary preservation of some of the varieties to the exclusion of others, and how this would account for many of the facts observed, while inconsistent with none. To the preservation and destruction of forms by reason of favourable or unfavourable external conditions, he has applied the term Natural Selection. He has thus explained how it is that uniformity of conditions and facilities for diffusion over any area are found in connexion with similarity of forms of life throughout the area, and how any break of continuity of conditions, or surface, or time, involves differences in forms of life. Great tracts like northern Europe and Asia, extending along the same parallels of latitude, not broken up by high mountains, are biologically one. Great mountain ranges like the Himalaya, and great deserts, constitute impassable barriers. Isolated lands, like Australia, are almost wholly dissociated in their life from other countries. The same results are found in the seas. With the rapid variations of climate that occur on lofty mountains rising from tropical plains, are developed numerous forms of life; on those ranging through many degrees of latitude, as in the New World, there is greater variety of life, corresponding to greater variety of climate, than on those nearly following the same parallel as in the Old World. Extensive land areas appear requisite for the evolution and support of the larger forms of terrestrial life, while restricted areas are characterised by smaller forms and fewer of them.

The laws that govern the diffusion and limitation of vegetable and animal life are similar; but a satisfactory correlation has not yet been established between the geographical distribution of vegetables and animals. For, though some of the great natural provinces marked out on the earth's surface by characteristic assemblages of plants and animals, respectively, are more or less conterminous, this cannot be said to hold good as a rule.

Many apparent difficulties in accounting for the existing facts of distribution, are solved by a consideration of the many great changes that have taken place in the outlines of land and sea in past time. The data necessary for any complete solution of all the questions that arise are wanting, in consequence of our still very limited knowledge of the geology of many parts of the earth, and especially of extinct forms of life concealed beneath its surface. But every fresh fact discovered seems to strengthen the evidence of the actual occurrence of evolution, and of the general truth of Darwin's theory as to its essential factors.

The phenomena of which I have been speaking indicate much more than a simple conformity of life to the conditions under which it subsists; the conditions, in fact, have positively determined, and finally fixed, those forms that have been preserved, so that the general course of life, as it has been evolved in the past, is in essentials a mere sequel to the course of the material forms of the earth's surface.

Perfectly unbiassed evidence of the truth of this conclusion is found, in the tendency that had been shown before Darwin's great discoveries to give weight to geographical distribution in systematic classification. And though it be true that classification should rest wholly on morphological considerations, yet the structural likeness of forms geographically associated is often so complete, while so many links in the chain of evolution have been lost for ever, or still have to be found, that, on the one hand, distribution may without objection furnish collateral aid in the details of systematic arrangement, and, on the other, structural resemblances may serve to suggest changes of geographical conditions of which no other evidence remains.

The doctrine of dependence of life on external conditions includes life itself as an important concurrent agency in the general results observed. Thus, in order to supply the food and other requirements of animals, the presence of vegetables or other animals is necessary. To some animals, as well as to some plants, the shelter of forests or particular forms of vegetation is essential. Parasites need for their sustenance living plants and animals. The fertilisation and propagation of plants is very commonly due to insects; and the infrequency of certain forms of insect-life in some of the islands of the Pacific, is held by Wallace to be the true cause of the simultaneous infrequency of flowering-plants.

Nor is organic matter without a large reaction on the inorganic parts of the earth. The building up of coral-reefs; the laying out of extensive calcareous and siliceous deposits over the entire bed of the ocean; the action of vegetable life on the constituents of the atmosphere; the effects produced by vegetation in modifying the absorption and radiation of heat by the soil, and the conditions of moisture; afford instances of vital forces actively affecting the condition of the earth.

As life, viewed in one aspect, performs the function of sustaining life, so in another it works for destruction. It at once supplies food and the elements of decay. Among the latest results of science may be noticed those that trace epidemic diseases, with certainty among insects and plants, and with much probability among the

higher animals, to parasitical organisms; and show how these withdraw the necessary elements of healthy existence, and may at length lead to the total dissolution of the creature in which they are produced. And, like the forces connected with inorganic matter, life also follows the same incessant round of construction and destruction; it elaborates from the earth new combinations of matter, and again dissolves them, to restore to the earth the elements on which its own renewal depends.

In what I have been saying of living creatures, I have not distinguished man, for in all such respects he cannot be separated from the rest of the animate world in which he holds the most conspicuous place. The monuments of Egypt, which take us back perhaps 7000 years from the present time, mark a very brief stage in that journey through which we have come down from our four-handed progenitors. The human race existed in company with many mammalia now extinct, at a time far distant, when the outlines of sea and land and the conditions of climate over large areas were greatly different from what they now are; and modern researches have done much to exhibit its gradual progress to the historical period.

Man, with his special faculties and dispositions, all of which have been developed under the pressure of external influences, is still as directly dependent, in most respects, on the physical characteristics of the regions in which he dwells, as any other of the beings that possess the attribute of life. If, on one side, his ingenuity enables him to avoid the agencies which to other less sagacious animals are irresistible, and teaches him how to wield them for his own purposes, yet on the other, in doing this he is forced more completely than any other creature to shape his existence so as to conform to their inexorable sway.

The arts of civilisation by which man secures advantages not to be obtained from the unaided forces of nature, have now transferred the chief seats of his power from the warmer latitudes where existence was in times past most easy, to colder climates where the conditions are more favourable to the continued exertion of his intelligence. Civilised man compels the earth to increase its vegetable and animal produce, for the supply of his growing numbers. He breaks into the store of minerals hid away below the surface and converts them into power. He makes the ocean a highway over which he rides to pursue his ends in all parts of the globe; and thus uses an obstacle impassable to most living things, as the principal means of his own migrations.

But geographical features will ever continue to determine the

course of man's career, and to regulate his movements, be they directed by peaceful or warlike desires. History will always tell how nations have been born, have grown, and have perished, under the influence of causes that can be traced back to the material earth; and whether we call it mother country or fatherland, the soil under our feet, as in the Greek fable, is the true source from which we draw our bodily, mental, and social strength.

I shall close this review of the subjects comprised in scientific geography, which the forthcoming series of lectures, to which this is the prelude, are designed to illustrate, by briefly recalling the chief topics to which I have directed attention.

1. The figure and movements of the earth, and the progress of our knowledge of them.
2. The progress of geographical discovery, and its results.
3. Geographical methods, instruments, and maps.
4. The magnetism of the earth.
5. The ocean, its depths and circulation.
6. The tides of the ocean.
7. The dry land, continents and islands, mountains and plains.
8. The mineral constituents of the earth.
9. Volcanic action and the interior of the globe.
10. The atmosphere and the distribution of heat on the earth.
11. The winds and fall of rain.
12. Regions of ice and glaciers.
13. The distribution of vegetable and animal life in the present and past.
14. The races of men, and their dependence on geographical conditions.

These are the studies through which scientific geography will lead you, teaching you to view the earth in its entirety, bringing together the great variety of objects seen upon it, investigating their connexion, and explaining their causes; and so combining and harmonising the lessons of all the sciences which supply the keys to the secrets of Nature. Geographical knowledge may be aptly compared to the setting in which are gloriously held together the bright gems of science, to form an intellectual diadem for man. This study best supplies those wide fields of observation which are the true and only sources from which we draw our intelligence and originality; for the mind has no power of absolute production, but only of perception and comparison. It is the power of applying with rapidity and precision the thoughts suggested by external objects and their mutual relations, that constitutes originality and gives the means of invention. And this is as

true of imagination as of reason. For by the influence and study of external nature are formed and developed man's emotional, intellectual, and moral faculties.

The emotions created by the vast extent of ocean, its ever-moving surface, the changing outlines of land and sea, the richness and luxuriance of the vegetable clothing of the earth, the astonishing variety of animal forms, the many diverse races of men, the never-ceasing transformations of the clouds as they float overhead, the play of light and colour over the whole of these objects, the firmament set with stars that bounds our vision and expands our conceptions when we gaze into the unknown depths of space, the large serenity of nature at rest, her overwhelming violence in convulsion—these emotions are the source of all our ideas of the beautiful and sublime.

The strong stimulus afforded to curiosity and observation by the varied scenes of nature, is the necessary antecedent of that ferment of the mind which precedes intellectual activity. Hence the constant succession of new objects which greets man as he changes his place on the globe, exciting in him an interest not awakened by scenes of long-continued familiarity, is one of the most active agencies in arousing his desire for knowledge, the acquisition of which, as it is among the few permanent springs of our own enjoyment, so constitutes our best or only means of adding to the well-being of others.

The contact with other living beings which is a direct result of geographical discovery, teaches us man's true place in nature; our intercourse with other races of men in other countries teaches us what is humanity, and gives those lessons of civilisation needed to overthrow the narrow prejudices of class, colour, and opinion, which bred in isolated societies, and nourished with the pride that springs from ignorance, have too often led to crimes the more lamentable because perpetrated by men capable of the most exalted virtue.

Let past experience be permitted to show us the one way to certain future progress, the way opened by the increase of true knowledge; let us complete that conquest over our globe which is so eloquently described by the poet, when he makes the earth on the setting free of Prometheus, the type of human intelligence, burst forth in a song of triumph over the destiny of man, her latest born:

“ The lightning is his slave; heaven's utmost deep
Gives up her stars, and like a flock of sheep,
They pass before his eyes, are numbered, and roll on.
The tempest is his steed; he strides the air,
And the abyss shouts from her depth laid bare,
‘ Heaven, hast thou secrets? man unveils me; I have none.’ ”

The PRESIDENT said they had listened to a lecture of the greatest interest, full of wise suggestions and instruction. In showing how enlarged was the scope of Geography, General Strachey had done good service. He had pointed out that mere descriptive geography was a very small portion of the great subject which the science embraced, and had thereby encouraged the Society to pursue the course of lectures which it had been thought desirable to begin. He was sure that all present would join in a sincere vote of thanks to General Strachey for his able and instructive address. Before the Meeting separated he wished to mention something which had only just come to the knowledge of the Council. The German Geographical Society at Berlin held a meeting on the 3rd instant, to hear an account of their travels from two successful African explorers who had just returned home—Dr. Lenz and Dr. Pogge. The latter gentleman had made a most remarkable journey, which would give him a high place in the list of African travellers. He had succeeded in penetrating from St. Paulo de Loanda to the capital of the renowned African potentate Muata Yauvo (or Yambo), a remote district which had hitherto never been reached by any explorer, and even but by few coloured Angolan traders. The capital, Musumbé, lay to the north of Kabebe, the seat of government of the preceding monarch, and many days' journey to the west and north of Cameron's line of march. Dr. Pogge travelled for the sake of pleasure as a hunter of the larger African game, and not as a scientific explorer; but some of the information he had obtained was of the highest interest, particularly as regards the healthiness and beauty of the interior plateau. He did not believe the Lualaba flowed into the Congo, but seemed to entertain no doubt that the Kasai or Cassabé was the upper course of the great river.

At the next meeting of this Society two interesting papers would be read—one by Lieutenant Young, who had just returned from Lake Nyassa, where a steamer had been launched and a settlement formed; and the other by Mr. Price, the adventurous missionary who hit upon the happy idea that a bullock-waggon road could be formed between the East Coast and Lake Tanganyika, and who had made an experimental journey with bullocks, and taken them to the upper highlands. He was now busy getting the most perfect bullock-cart that the manufacture in England could produce.
