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On the Scope of Scientific Geography

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2.—*On the Scope of Scientific Geography.* By General R. STRACHEY,
R.E., F.R.G.S.*

THE chief object of the British Association for the Advancement of Science, is declared to be "to give a stronger impulse, and a more systematic direction to scientific enquiry;" and this Section of the Association deals with questions of Geography, in the hope that thereby the interests of science will be advanced. It is because I believe that geographers in general, and British geographers in particular, are apt to view geography too much as a field for adventurous and enterprising exploration, and too little as a subject for scientific investigation, that I have to-day proposed to discuss the question, What is the scope of Scientific Geography? In doing this I am glad to find that I shall be acting in the spirit of the excellent opening address of our President, who emphatically declared that he looked forward with eagerness to the growth of geography as a science in the usual acceptance of the term; and I will venture to hope that what I have to say to-day may in some degree contribute to the realisation of such a result.

Nothing is further from my intention than to undervalue the courage, the endurance, and the intelligence of the better class of geographical explorers, whether they belong to our own or any other country; or to depreciate the results of their labours, too often carried on, not only under circumstances of great personal discomfort or hardship, but also of extreme peril for their very lives. Neither do I question the absorbing interest that attaches, and rightly attaches, to many narratives of travels in little known regions, both by land and by sea. But it is necessary to remember, and remembering to affirm distinctly, that too often such narratives, whatever be their other merits, hardly deserve to be spoken of as scientific, and go little beyond an account of personal adventure, combined with a bare itinerary and a partial map. I do not desire to suggest that narratives of explorations or travels, which do not come up to a decided scientific standard, may not from other points of view be of much value, or that discussions of subjects not of a distinctly scientific character should necessarily be excluded from the matters brought before this Section of the Association: but I must unhesitatingly contend, that at any rate, so far as the British Association for the Advancement of Science is concerned, the most important aspect of geography is its scientific aspect; that this Section should have for its main object to realize more completely and more precisely the requirements of scientific method in relation to geography; and that each of us, so far as he is able, should strive to advance science, by respecting those requirements, and acting in accordance with them.

Science in its broadest sense is organized knowledge, and has for its aim the observation and classification of the phenomena of which we become conscious by means of our senses, and the investigation of the causes of which those phenomena are the effects. It is by means of the application of this conception of science to the class of ideas which we designate as Geography, that we shall obtain the true answer to the question, the solution of which I have proposed to undertake on this occasion.

The first task of the geographer, then, is to ascertain by observation, and delineate by maps and describe the forms and relative positions and characteristics of the various features of all regions of the earth. This supplies the first part of the requirements of a scientific pursuit of geography. It is

* Read before the Geographical Section of the British Association at Brighton, August, 1872.

that branch of the study which has been most fully carried out, and to it, indeed, the notion of geography is still popularly restricted.

But to transform any merely empirical collection of facts into science, the classification of the observed phenomena, and the investigation of their causes, still remain to be undertaken. The scientific geographer, therefore, proceeds, after having obtained such a fundamental series of simple geographical observations as that to which I have just alluded, to view them in relation to the multitude of co-existing phenomena which constitute the special characteristics of the several regions of the globe; and thence endeavours to deduce the laws in accordance with which these phenomena mutually depend one on another. This branch of geography is commonly spoken of as Physical Geography, but it is more correctly the science of geography.

The progress of geography has thus led from the first rough ideas of relative position of neighbouring places, to our present advanced state of knowledge of almost all parts of the earth's surface. By the gradual extension of observation to distant regions, and the ultimate adoption of correct notions of the form of the earth, the more serious errors of the earlier approximate ideas were corrected, and at length a foundation was laid for precise determinations of position and the accurate delineation of form in detailed maps. Coincident with these additions to the precise knowledge of the forms and positions of the great areas of land and sea, progress was made in the observation of other characteristics of various regions visited by travellers. The first impressions based on the striking differences seen in going from one country to another,—in the climate, the vegetable and animal productions, the people, their languages and customs,—were soon to be supplemented and corrected by the perception of similarities no less remarkable and real. The great regions of equatorial heat and polar cold, and the main characteristics of the mountain ranges, of the plains, and the seas, were quickly appreciated. The special variations of climate, of seasons, of wind and rain, that characterize various localities both on the land and the ocean, were observed and more or less fully understood. The grouping of certain plants and animals of peculiar structure or of peculiar families, in certain terrestrial or marine provinces, and the circumstances under which such groups varied from place to place, or reappeared more or less completely, and in identical or nearly identical forms, in widely separated regions, gave fresh occasion for observation and thought. Combined with these facts, and studied with them, were the physical peculiarities, the languages and the customs, and the history of the races of men, varying from country to country, but still often bearing a certain common stamp of similarity over large areas.

It was by the gradual accumulation and classification of such knowledge that the scientific conception of geographical unity and continuity at length became possible; and thence was derived the conclusion that, while each different part of the earth's surface had its own particular characteristics, the general system of animate and inanimate nature was one and the same everywhere; so that the special features of every region are due to the operation of particular local causes or conditions acting in conjunction with the universal laws of organic and inorganic matter.

Scientific geography has, then, for its aim the investigation of those local conditions of the earth's surface, which I have spoken of as being the efficient causes of a large portion of the natural phenomena which come within the range of geographical research; and the enquiry, in the one direction, how such local conditions arose, and in the other, how they became the active agents in producing the phenomena in question.

The field into which we are thus led is almost conterminous with the entire circle of human knowledge. And although such a result may at first seem to

indicate that the task set before us is beyond our powers from its vastness, yet there is, I think, no real ground for such a fear. Scientific geography views, as a connected and interdependent whole, the numerous classes of natural phenomena, each of which forms the ground-work of a separate well-defined section of knowledge. And in carrying out such an aim, the geographer proceeds in no respect on a different method from that followed by other scientific enquirers. In every branch of science the student has to rely on the researches and the conclusions of those who cultivate other branches of knowledge. Indeed, it is for the very reason that the progress of knowledge has been so great, that the special branches into which it is divided are so numerous, and that the difficulty of original research being attempted by any one person in more than some single branch is thereby so much increased, that it becomes not only useful, but essential, to obtain the best possible view of the aggregate result of all the forces of nature in a connected form, such as that which I have represented to you as constituting the true scope of scientific geography.

The better to enable you to realize in a clear manner my own conceptions of this subject, and to test, and, if necessary, to correct them by reference to your own conclusions, I will now proceed to specify, somewhat more in detail, the system according to which geographical observations should, in my estimation, be treated, to comply with the requirements of scientific method.

In undertaking the precise study of the earth's surface, we speedily find that to admit of the correct delineation of its features, or the preparation of accurate maps, a knowledge of the true form and exact magnitude of the earth is essential. On proceeding to measure the earth's dimensions, we are brought to consider it as one of the constituent parts of the solar system, and to perceive that its form has been imparted to it by the operation of the universal force of gravity, the great power which underlies every fact of nature, and, so to speak, maintains the existing frame-work of all existence within the solar system. To give precision to our ideas of position on the earth's surface, we adopt, for reference, imaginary circles of latitude and longitude, in dealing with which we are compelled to seek the aid of mathematical and astronomical science. In all these operations it becomes necessary, in order to secure such accuracy in our results as is now felt to be essential, to proceed with the most careful attention to, and knowledge of, the laws of gravitation, of heat and light, failing which, satisfactory progress would very soon be arrested. To obtain exact results from observations made with optical instruments, knowledge of many of the phenomena of light—that wonderful force which we bring into our service—is requisite. To admit of the exact measurement of distances, a knowledge of the laws of heat in affecting the expansion of the materials composing our measuring rods is necessary. To determine with precision, from astronomical observations, the latitude of any place, a rigorous examination of the directive force of gravity or the position of the plumb-line is called for. Thus, at the very outset, the study of many of the elementary physical forces is rendered obligatory on the scientific geographer.

The preparation of maps of the horizontal projection of the surface almost immediately leads us to the consideration of another element of position, namely, elevation. To determine this with accuracy, we must fix upon a datum surface from which to reckon our distances or altitudes, and the mean level of the sea has been accepted for this purpose. But here again, excepting at places near the sea, the necessary datum cannot be exactly ascertained without reference to the form of the earth and the direction of the force of gravity; moreover, the complications everywhere arising from the periodical changes in the sea-level, and the consequent difficulty of

determining the true mean level, and the instability of the earth's surface itself, to which all measurements of the sea-level must be referred, give rise to various delicate questions calling for special treatment. Such difficulties suggest, if they do not indeed require, fresh investigations into other classes of facts.

The importance, in a strictly scientific point of view, and quite apart from their practical utility, of correct maps, indicating as far as possible the elevations or depressions of surface and other physical facts, should be distinctly appreciated. There is no other means by which we can be so thoroughly impressed with those relations of position and magnitude which constitute so large a portion of the ground-work of geographical investigation, and maps and graphic representations of various classes of phenomena, may be regarded as essential instrumental appliances or apparatus for assisting the operations of the mind, such as we have to seek in every branch of scientific enquiry.

From the study of the external forms of the surface of the earth as regards horizontal extension and elevation, we naturally pass on to examine the character of its constituent parts, or the materials of which it is composed.

The broad distinction between the land and the sea is at once apparent.

The periodical variations of the level of the oceanic surface caused by the tides, lead us into enquiries which can only be prosecuted by help of astronomical and mathematical science. Other wide fields for investigation are opened to us, in the observation of the varying depth of the sea, the form of its bed, the currents that affect it, the waves that agitate its surface, the constitution and condition of its waters, and other characteristics which it presents to us.

The forms of the solid crust of the earth determine the outlines of the seas, in which the waters have collected under the operation of gravity, over the lowest parts of that crust. The tides, developed by the attraction of the sun and moon, are modified by the motion of the earth on its axis and in its orbit, as well as by the motions of the other heavenly bodies, and the local forms of the sea-bottom over which the tidal wave advances. The study of these phenomena, I may observe, is at the present time an object of special solicitude to the British Association, and that an application recently made to the Government for assistance in prosecuting researches into tidal phenomena has not been successful, arose, no doubt, from a want of due perception of their great physical importance. The ocean currents again, are due to the force of gravity put into operation by changes of temperature directly in case of the sea, or indirectly through the winds or changes of pressure in the case of the atmosphere. In all these intricate phenomena we find that the same two great powers of nature—heat and gravity—are the efficient causes at work, however various may be their precise modes of action, or the results to which they have given rise.

The examination of the land, and of the materials of which it is composed, brings us to the study of geology. By help of this science we may trace out the manner and time of the formation of the earthy or rocky deposits exposed to view on the surface, and explore in a partial manner the constitution of the subjacent strata of the crust of the globe: by it too, we may learn how and when the existing features of the earth's surface were impressed upon it; at what age of its history the continents and islands became dry land, the mountain chains were raised up, and the plains laid out; and how, in combination with these constructive agencies, a simultaneous incessant destructive action of the seas, of the rivers and other surface waters, has been carried on, tending, with more or less activity, to throw down the great monuments erected by the internal energies. By the light of geology we may, to some extent, ascertain the nature of the forces by which elevations of the surface have been caused, and the mechanical mode of their operation,

and so better obtain an insight into the essential natural relations of the mountains, the plains, and the valleys, the rivers, the lakes, and the seas. Such enquiries once more bring home to us the conviction, that the ever diversified details of the face of the globe on which we stand are in no true sense accidents, or the results of fortuitous chance, and as such, only worthy of being regarded with admiration by reason of their picturesque forms or their wonderful proportions; that they are, like all other works of nature, the direct, orderly, and necessary results of the action of forces, simple in themselves, and operating in accordance with well-known physical and mechanical laws. The perception of general characteristics of structure among the mountains, the plains, and the seas, that pass under our review, is indeed too often obscured and overshadowed by their magnitude, the multitude of their details, and the variety of their forms, which, by reason of their vastness, at first only produce impressions of hopeless confusion on the mind of every traveller or student; yet, when once the idea of their subordination to some common law is duly conceived, it will be found to receive confirmation at every fresh step we take.

From the solid mass of the earth we go on to observe the aërial covering with which it is surrounded. The extremely complicated phenomena which the atmosphere presents under the varying action of the light and heat radiated to the earth from the sun, supply the student with problems as difficult to investigate as they are numerous, and requiring for their solution the most ample knowledge of the laws that determine the action of the physical forces operative on inorganic matter. The diffusion of watery vapour in the atmosphere, and the variations of the temperature the pressure and density of the air thus charged with vapour, give rise to the great series of phenomena which are included under the general term climate. Of these the primary causes, whether of the changes of seasons, of the winds, or of rain, are the action and reaction of the mechanical and chemical forces set in operation by the sun's heat, varied from time to time, and from place to place, by the influence of geographical position and elevation above the sea, as well as by the condition of the surface, and possibly, too, by actual variations in the heating power of the sun itself, though of this we yet know too little to do more than refer to it as a possible cause of change. Position on the earth's surface in respect to latitude, combined with the diurnal and annual motions of the earth, are the conditions which determine the greater or less direct exposure of any place to solar radiation, and therefore the quantity of heat received there; elevation above the sea-level determines the density of the air, and the quantity of watery vapour it can contain, and, by reason of the laws of specific heat, the effect of the quantity of heat received at any place in determining the temperature of the air; while the condition or composition of the surface determines the degree of accumulation of heat, by reason of the varying power of absorbing or of radiating heat possessed by various substances. Further, the changes and motions set up by these forces are all liable to be modified under the laws of mechanical action, which govern an elastic fluid, like the atmosphere, distributed over the surface of a sphere itself in motion. Nor does this exhaust the elements of disturbance due to local conditions; for the mechanical action of ranges of mountains is of primary importance in determining the movements of masses of air on the earth's surface, and the numerous reactions consequent on those movements. The inequalities of the surface, which are insignificant when viewed in relation to the whole globe, are of the greatest importance in relation to the atmosphere. For, owing to the laws of elastic fluids, the great mass of the air and of the watery vapour it contains are concentrated very close to the surface. One-fourth of the air and one-half of the watery vapour are found below 8500 feet; one-half of the air and nine-

tenths of the vapour are below 19,000 feet, which hardly exceeds the average elevation of the highest ranges of the Himalaya; while three-fourths of the air is probably within reach of the influence of the highest masses of those mountains.

For the complete solution of the numerous problems that arise in connexion with atmospheric phenomena at any place, a comprehensive knowledge of all the local conditions is thus as essential as a knowledge of the fundamental physical laws which govern the forces more directly called into operation. And the final result of our investigations in this direction is to show that the whole character of the climate of any region may depend, not only on the conditions to which I first referred,—geographical position, elevation, and condition of surface—but as much, or even more, on such circumstances as the direction of the coast-line with reference to that of the earth's motion on its axis; the position of the locality with reference to the chief neighbouring areas of land and sea, whether, for instance, such areas be, respectively, to the east or west of it; the exact distribution of the elevated lands that occur within and around the region, alike with respect to position, direction, and altitude.

From the footing gained by means of such studies we are enabled to advance to the comprehension of the phenomena attending the distribution on the earth of living creatures, vegetable and animal. We have been led to see how, under the action of internal forces, extending into the remotest periods of the past, the surface of the earth has been moulded to its present form, and has received its present distribution of land and sea, of plain and mountain; how, by reason of this configuration of the surface, special characteristics of climate have been impressed on each different region; and how the local atmospheric conditions which fit the earth's surface for the support of life, or otherwise, have been brought about. As we proceed we shall continue to find that the same law of mutual interdependence prevails in all parts of the fabric of nature, animate as well as inanimate.

The phenomena of life, though, in all respects, subject to the same general mechanical and physical laws that are operative in the case of inorganic matter, are further complicated by the superposition of the vital force. Subject to the special laws of life, we find that living creatures are acted upon by the external conditions under which they exist, in a manner quite analagous to that in which inorganic matter obeys the influences to which it is subjected under varying circumstances in various places. Observation has proved that there exists one general system of life, vegetable and animal, which is co-extensive with the earth as it now is, and with the whole history of living creatures, carrying it back as far as we are able by the help of geological research. Within such a general system there are further found, as universally, special subordinate systems of living creatures occupying various localities under various external conditions; and, although we can speak less confidently of the external conditions in the past, the local variation of type is indicated as constantly in all former geological epochs, from which we can obtain any evidence, as it is now. The circumstances under which change of position on the earth's surface is found to be accompanied by variations of climatic condition, will as certainly be accompanied by variations in the living creatures upon it. Almost as universally, it may be said, that similarity of such conditions is accompanied by similarity of forms of life, and often it is complete identity that will be found.

Of the laws of life which regulate the extremely complex phenomena to which I am now referring, that which operates most directly in determining the character of the living creatures in any region, is the law of propagation by generation or descent. The immediate corollary of this law is that of geographical distribution around local centres, under which the animals and plants

of every locality tend to disseminate themselves to all neighbouring places. So far as the conditions of existence are favourable to such diffusion, it extends; and where they are incompatible, it ceases. It would carry me beyond the limits of my subject to enter in more detail into the secondary causes which determine the extent to which diffusion of life is possible, and all that I need further say on the subject is to offer a few remarks on the manner in which this law specially comes within the field of observation of the geographer.

The study of the plants and animals found to exist at any locality will more or less satisfactorily furnish the means of tracing back the stock from which each has sprung, and the regions of which they are specially characteristic, and in which they appear to have originated, and from which they appear to have been diffused. It will readily be seen that the considerations which arise in discussing such questions will involve a knowledge of the conditions of climate, using that term in its widest sense, peculiar to each locality and the countries adjacent to it, as well as of the changes which the earth's surface may have undergone during the period in which the diffusion of the races of living creatures which are the subjects of our researches has been going on, and the corresponding changes of climate which may probably have accompanied such changes of surface.

I shall not attempt to discuss any of the great and perplexing questions that meet us in our efforts to solve the mysteries which surround the origin of life on the earth, or of man among living beings. Neither need I dwell upon the special faculties and dispositions that distinguish man from other animals, and serve to complicate the efficient causes of the positions which are now occupied, and the influences now exercised on each other and on the material earth itself, by the various races of men on our globe. It will suffice if I state that everywhere we find the condition of man, and of the various groups and grades of beings in common with which he possesses the wonderful attribute of life, to be directly, and, in many cases, almost wholly, dependent on the physical characters of the regions which they severally occupy; that the multifarious denizens of earth, air, and water, animal and vegetable, man, beast, bird, fish, or other living creature, the forests which clothe the mountain slopes, the pastures or harvests of the plains, the brilliant flowers of the alpine regions, the scanty covering of lichen which marks the last effort of vegetable life; each takes up its proper place, and retains possession of its own particular domain upon the earth, under laws which, whatever be their complication, are unfailing in their operation, and extend in their application, both in respect to space and time, as far as human observation has yet reached; and that, for the full apprehension of the value of each different series of such phenomena or facts, it becomes necessary to view them in combination, to perceive their mutual connexion, and to take in the idea of their forming a consistent and self-supporting whole.

Such, then, is my conception of the scope of scientific geography, and of the demands it makes upon us. That it may be difficult to realize this ideal in its completeness I will not deny; nor should I be surprised if it appear altogether unattainable to a generation that has not received even an elementary education in physical science. As education has till now been conducted, a man who becomes desirous of devoting himself to scientific exploration will commonly be in the position of one who, when entering on a literary career, should find it necessary to begin learning how to read and write. But I look forward with confidence to the results that will follow when every child is started in life with general, but correct, conceptions of the fundamental facts and laws of nature. A course of instruction, for instance, on such an admirable plan as that pursued by Mr. Hale, and explained to us by him at our last meeting, could not fail, if generally adopted, to turn out young men viewing the earth on which they live in a totally different spirit, and from a totally different stand-

point, from that of the present generation. And you will observe that this conception of scientific education, far from excluding the study of man and his history, mental and social, requires it as an indispensable portion of the knowledge of surrounding nature. A great statesman in his ignorance, and a little statesman in his insolence, may assume that men of science, as those who study physical science are commonly called, are disabled by their researches in the field of nature from comprehending and interpreting humanity. We, on the contrary, hold that there can be no true knowledge of man, without knowledge of that which is not man, and that it is only when he is viewed in his real position, as one amongst many phenomena, that any accurate conception can be formed of his powers and their limits.

As I before suggested, progress in science depends on the intelligent co-operation of inquirers in all its numerous branches, and my desire is now again to impress upon you that it is the proper function of the scientific geographer to bring together into a connected view the varied facts of nature, as analyzed and explained by the several classes of observers and thinkers who devote themselves to the special branches into which science divides itself. For success in such a task a knowledge of the results of those special branches of investigation is necessary, and in proportion as this knowledge is wide and complete will our power to cope with that task be increased.

The easy inference from all this is, that the more scientific education is extended, the greater will be the field from which to provide travellers possessed of the desired scientific qualifications, and the more rapid will be our progress towards the accumulation of the varied stock of knowledge required to complete a scientific body of geography. The labours of our illustrious countrymen Darwin and Joseph Hooker, who stand at the head of the scientific travellers of this, or perhaps of any time, and who have, I suppose, done more for the advancement of scientific geography than almost any men living, will serve as an example to show how great is the value to science, in all its branches, of the observations and explorations of travellers endowed with more than the ordinary share of scientific instruction. What these men, who have so justly earned the high title of philosopher, have done for our science, others may do, if they follow the same path.

3. *On the Place of Geography in Education.** By the REV. E. HALE, M.A., F.R.G.S., Assistant Master at Eton.

I AM a schoolmaster—seeking rather for information than able to give it—hoping to awaken such interest in others who are skilled in scientific learning, that they will give the benefit of their ideas and more impartial judgment to its professional teachers, who are the obscure pioneers of what is probably a great educational movement.

Every man from his birth is brought into contact with his fellow-men and with Nature. Nature and Man should be, and are intended by the Creator to be, in harmony with each other. The great aim of education should be to teach the relations in which each man stands to Man and Nature,—to teach each man in such a way that he should be best fitted to fulfil his social duties, best fitted to understand and employ advantageously the forces and powers of Nature.

Since the days of the Greek philosophers until quite recently, all those who have taught, have (some perhaps unconsciously) had in view the idea of teaching

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