occupy, emits no utterance of pleasure or distress. Its life processes continue so long as material remains, and are regulated mechanically.

To understand this all that is necessary is to extend the considerations which have been suggested to us in our very cursory study of the nervous mechanism by which the working of the heart and of arteries is governed, to those of locomotion and voice. Both of these we know, on experimental evidence similar to that which enables us to localise the vascular centre, to be regulated by a centre of the same kind. If the behaviour of the brainless frog is so natural that even the careful and intelligent observer finds it difficult to attribute it to anything less than intelligence, let us ask ourselves whether the chief reason of the difficulty does not lie in this, that the motions in question are habitually performed intelligently and consciously. Regarded as mere mechanisms, those of locomotion are no doubt more complicated than those of respiration or circulation, but the difference is one of degree, not of kind. And if the respiratory movements are so controlled and regulated by the automatic centre which governs them, that they adapt themselves perfectly to the varying requirements of the organism, there is no reason why we should hesitate in attributing to the centres which preside over locomotion powers which are somewhat more extended.

But perhaps the question has already presented itself to your minds, What does all this come to? Admitting that we are able to prove (1) that in the animal body, Product is always proportional to Process, and (2), as I have endeavoured to show you in the second part of my discourse, that Descartes' dream of animal automatism has been realised, what have we learnt thereby? Is it true that the work of the last generation is worth more than that of preceding ones?

If I only desired to convince you that during the last half-century there has been a greater accession of knowledge about the function of the living organism than during the previous one, I might arrange here in a small heap at one end of the table the physiological works of the Hunters, Spallanzani, Fontana, Thomas Young, Benjamin Brodie, Charles Bell, and others, and then proceed to cover the rest of it with the records of original research on physiological subjects since 1831, I should find that, even if I included only genuine work, I should have to heap my table up to the ceiling. But I apprehend this would not give us a true answer to our question. Although, etymologically, Science and Knowledge mean the same thing, their real meaning is different. By science we mean, first of all, that knowledge which enables us to sort the things known according to their true relations. On this ground we call Haller the father of physiology, because, regardless of existing theories, he brought together into a system all that was then known by observation or experiment as to the processes of the living body. But in the "Elementa Physiologiæ" we have rather that out of which science springs than science itself. Science can hardly be said to begin until we have by experiment acquired such a knowledge of the relation between events and their antecedents, between processes and their products, that in our own sphere we are able to forecast the operations of nature, even when they lie beyond the reach of direct observation. I would accordingly claim for physiology a place in the sisterhood of the sciences, not because so large a number of new facts have been brought to light, but because she has in her measure acquired that gift of prevision which has been long enjoyed by the higher branches of natural philosophy. In illustration of this I have endeavoured to show you that every step of the laborious investigations undertaken during the last thirty years as to the process of nutrition, has been inspired by the previsions of J. R. Mayer, and that what we have learnt with so much labour by experiments on animals is but the realisation of conceptions which existed two hundred years ago in the mind of Descartes as to the mechanism of the nervous system. If I wanted another example I might find it in the previsions of Dr. Thomas Young as to the mechanism of the circulation, which for thirty years were utterly disregarded, until, at the epoch to which I have so often adverted, they received their full justification from the experimental investigations of Ludwig.

But perhaps it will occur to some one that if physiology founds her claim to be regarded as a science on her power of anticipating the results of her own experiments, it is unnecessary to make experiments at all. Although this objection has been frequently heard lately from certain persons who call themselves philosophers, it is not very likely to be made seriously here. The answer is, that it is contrary to experience. Although we work in the certainty that every experimental result will come out in accordance with great principles (such as the principle that every plant or animal is both, as regards form and function, the outcome of its past and present conditions, and that in every vital process the same relations obtain between expenditure and product as hold outside of the organism), these principles do little more for us than indicate the direction in which we are to proceed. The history of science teaches us that a general principle is like a ripe seed, which may remain useless and inactive for an indefinite period, until the conditions favourable to its germination come into existence. Thus the conditions for which the theory of animal automatism of Descartes had to wait two centuries, were (1) the acquirement of an adequate knowledge of the structure of the animal organism, and (2) the development of the sciences of physics and chemistry; for at no earlier moment were these sciences competent to furnish either the knowledge or the methods necessary for its experimental realisation; and for a reason precisely similar Young's theory of the circulation was disregarded for thirty years.

I trust that the examples I have placed before you to-day may have been sufficient to show that the investigators who are now working with such earnestness in all parts of the world for the advance of physiology, have before them a definite and well-understood purpose, that purpose being to acquire an exact knowledge of the chemical and physical processes of animal life, and of the self-acting machinery by which they are regulated for the general good of the organism. The more singly and straightforwardly we direct our efforts to these ends, the sooner we shall attain to the still higher purpose—the effectual application of our knowledge for the increase of human happiness.

The Science of Physiology has already afforded her aid to the Art of Medicine in furnishing her with a vast store of knowledge obtained by the experimental investigation of the action of remedies and of the causes of disease. These investigations are now being carried on in all parts of the world with great diligence, so that we may confidently anticipate that during the next generation the progress of pathology will be as rapid as that of physiology has been in the past, and that as time goes on the practice of medicine will gradually come more and more under the influence of scientific knowledge. That this change is already in progress we have abundant evidence. We need make no effort to hasten the process, for we may be quite sure that, as soon as science is competent to dictate, art will be ready to obey.

SECTION F

GEOGRAPHY

OPENING ADDRESS BY SIR JOSEPH D. HOOKER, C.B., K.C.S.I., F.R.S., &c., PRESIDENT OF THE SECTION

On Geographical Distribution

It has been suggested that a leading feature of the sectional addresses to be delivered on the occasion of this, the fiftieth anniversary of the meetings of the British Association, should be a review of the progress made during the last half century in the branches of knowledge which the sections respectively represent.

It has further been arranged that, at so auspicious an epoch, the sections should, when possible, be presided over by past Presidents of the Association. This has resulted in almost every sectional chair being occupied by a President eminent as a cultivator of the science with which his section will be engaged, though not the one I have the honour of filling, which, from the fact of there being no professed geographer amongst the surviving past Presidents, has been confided to an amateur.

Under these circumstances I should be untrue to myself and to you, if I presumed to address you as one conversant with geography in any extended signification of the word, or if I attempted to deal with that important and attractive branch of it, topographical discovery, which claims more or less exclusively the time and attention of the geographers of this country. It is more fitting for me, and more in keeping with the objects of this Association, that I be allowed to discourse before you on one of the many branches of science the pursuit of which is involved in the higher aims of geographers, and which, as we are informed by an accomplished cultivator of the science, are integral portions of scientific geography.[1] Of these none is more important than that of the distribution of animals and plants, which further recommends itself to you on this occasion from being a subject that owes its great progress during the last half-century as much to the theories advanced by celebrated voyagers and travellers as to their observations and collections.

Before, however, I proceed to offer you a sketch of the progress made during the lifetime of the Association in this one branch, I must digress to remind you, however briefly, of the even greater advances made in others, in many cases through the direct or indirect instrumentality of the Association itself, acting in concert with the Royal and with the Royal Geographical Societies.

In topography the knowledge obtained during this half century has been unprecedently great. The veil has been withdrawn from the sources of the Nile, and the lake systems of Central Africa have been approximately localised and outlined. Australia, never previously traversed, has been crossed and recrossed in various directions. New Guinea has had its coasts surveyed, and its previously utterly unknown interior has been here and there visited. The topography of Western China and Central Asia, which had been sealed books since the days of Marco Polo, has been explored in many quarters. The elevations of the highest mountains of both hemispheres have been accurately determined, and themselves ascended to heights never before attained; and the upper regions of the air have been ballooned to the extreme limit beyond which the life-sustaining organs of the human frame can no longer perform their functions. In hydrography the depths of the great oceans have been sounded, their shores mapped, and their physical and natural history explored from the Equator to beyond both polar circles. In the Arctic regions the highest hitherto attained latitudes have been reached; Greenland has been proved to be an island; and an archipelago has been discovered nearer to the Pole than any other land. In the Antarctic regions a new continent has been added to our maps, crowned with one of the loftiest known active volcanoes, and the Antarctic ocean has been twice traversed to the 79th parallel. Nor have some of the negative results of modern exploration been less important, for the Mountains of the Moon and many lesser chains have been expunged from our maps, and there are no longer believers in the inland sea of Australia or in the open ocean of the Arctic pole. Of these and many others of the geographical discoveries of the last half-century full accounts will be laid before you, prepared for this section by able geographers; of whom Mr. Markham will contribute Arctic discovery; Sir Richard Temple, Asiatic; Lieut.-Col. Sir James Grant and Mr. H. Waller, African; Mr. Moseley, Australian; Mr. Trelawny Saunders, Syrian (including the Holy Land); the Hydrographer of the Admiralty will undertake the great oceans, and Mr. F. Galton will discuss the improvements effected in the instruments, appliances, and methods of investigation employed in geographical researches.

Of other branches of science which are auxiliary to scientific geography, the majority will be treated of in the sections of the Association to which they belong; but there are a few which I must not, in justice to the geographers who have so largely contributed to their advance, leave unnoticed.

Such is Terrestrial Magnetism,[2] which had as its first investigators two of our earliest voyagers, the ill-fated Hudson and Halley, who determined the magnetic dip in the north polar and tropical regions respectively. Theirs were the precursors of a long series of scientific expeditions, during which the dipping needle was carried almost from Pole to Pole, and which culminated in the establishment, mainly under the auspices of this Association, of the magnetic survey of Great Britain, of fixed magnetic observatories in all quarters of the globe, and of the Antarctic expedition of Sir James Ross, who, since the foundation of the Association, planted the dipping needle over the northern Magnetic Pole, and carried it within 200 miles of the southern one.

Nor is the geography of this half century less indebted to physicists, geologists, and naturalists. It is to a most learned traveller, and naturalist, Von Baer, that the conception is due that the westward deflection of all the South Russian rivers is caused by the revolution of the globe on its axis.[1] It was a geologist, Ramsay, who explained the formation of so many lake beds in mountain regions by the gouging action of glaciers. It was a physicist and mountaineer, Tyndal, who discovered those properties of ice upon which the formation and movement of glaciers depend. The greatest of naturalist-voyagers, Darwin, within the same half-century has produced the true theory of coral reefs and atolls, showed the relations between volcanic islands and the rising and sinking of the bottom of the ocean, and proved that along a coast line of 2480 miles the southern part of the continent of South America has been gradually elevated from the sea level to 600 feet above it. Within almost the same period Poulett Scrope and Lyell have revolutionised the theory of the formation of volcanic mountains, showing that these are not the long-taught upheavals of the crust of the earth, but are heaped up deposits from volcanic vents, and they have largely contributed to the abandonment of the venerable theory that mountain chains are sudden up-thrusts. Within the same period, the theory of the great oceans having occupied their present positions on the globe from very early geological times was first propounded by Dana,[2] the companion of Wilkes in his expedition round the world, and is supported by Darwin and by Wallace.

In Meteorology the advance is no less attributable to the labours of voyagers and travellers. The establishment of the Meteorological Office is due to the energy and perseverance of a great navigator, the late Admiral Fitzroy.

Another domain of knowledge that claims the strongest sympathies of the geographer is Anthropology. It is only within the last quarter of a century that the study of man under his physical aspect has been recognised as a distinct branch of science, and represented by a flourishing society, and by annual international congresses.

I must not conclude this notice without a passing tribute to a department of geography that has occupied the attention of too few of its cultivators. I mean that of literary research. Nevertheless, in this too the progress has been great; and I need only mention the publications of the Hakluyt Society, and two works of prodigious learning and the greatest value, "The Book of Marco Polo, the Venetian,"[3] and "A History of Ancient Geography,"[4] to prove to you that one need not to travel to new lands to be a profound and sagacious geographer.

I have asked you to accept the geographical distribution of organic beings as the subject which I have chosen for this address. It is the branch with which I am most familiar; it illustrates extremely well the interdependence of those sciences which the geographer should study, and as I have before observed, its progress has been in the main due to the labours of voyagers and travellers.

In the science of distribution, Botany took the lead. Humboldt, in one of his essays,[5] says that the germ of it is to be found in an idea of Tournefort, developed by Linnæus. Tournefort was a Frenchman of great learning, and, moreover, a great traveller. He was sent by the King of France in 1700 to explore the islands of Greece and mountains of Armenia, in the interests of the Jardin des Plantes, and his published narrative is full of valuable matter on the people, antiquities, and natural productions of the countries he visited. The idea attributed to him by Humboldt,[6] is that in ascending mountains we meet successively with vegetations that represent those of successively higher latitudes; upon which Humboldt observes: "Il ne fallut pas une grande sagacité pour observer que sur les pentes des hautes montagnes de l'Arménie, des végétaux des différentes latitudes se suivent comme les climats superposés l'un sur les autres"; but he goes on to remark, "cette idée de Tournefort developpée par Linné dans deux dissertations intéressantes (Stationes et Coloniæ Plantarum), renferment cependant le germe de la Géographie

[1] Major-General Strachey, in a lecture delivered before the Royal Geographical Society (*Proceedings*, vol. xxxi. p. 179, 1877), discusses, with just appreciation and admirable clearness, the interdependence of the sciences which enter into the study and aims of scientific geography, and which he enumerates under fourteen heads. This lecture contains the ablest review of the subject known to me. It might very well be entitled "The whole duty of the Geographer." Every traveller's outfit should include a copy of it, and one should accompany every prize given by the Geographical Society to students for proficiency in geographical knowledge.

[2] The subject of an able lecture "On the Magnetism of the Earth," delivered before the Royal Geographical Society by the Hydrographer of the Admiralty (*Proceedings*, vol. xxi. p. 20, 1876).

[1] Von Baer, "Ueber ein allgemeines Gesetz in der Gestaltung der Flussbetten," *St. Petersb. Bull. Sc.* ii. (1860).

[2] Dana in *American Journal of Science*, ser. 2, vol. iii. p. 352 (1847), and various later publications.

[3] By Colonel Henry Yule, C.B. (ed. 1, 1871; ed. 2, 1875).

[4] By S. H. Bunbury (1879).

[5] "Sur les lois que l'on observe dans le distribution des formes végétales" (Mémoire lu à l'Institut de France, January 29, 1816).

[6] I have been unable to find any such idea expressed in Tournefort's works. Edward Forbes, however, also attributes the idea to Tournefort (Memoirs of the Geology Survey, vol i. p. 351).

Botanique." Tournefort's idea was, however, an advanced one for the age he lived in, and should not be judged by the light of the knowledge of a succeeding century. He had no experience of other latitudes than the few intervening between Paris and the Levant. Humboldt himself did not suspect the whole bearing of the idea on the principles of geographical distribution, and that the parallelism between the floras of mountains and of latitudes was the result of community of descent of the plants composing the floras; not that it was brought about by physical causes. The idea of the early part of the eighteenth century is, when rightly understood, found to be the forerunner of the matured knowledge of the middle of the nineteenth.

The labours of Linnæus, himself a traveller, and whose narratives give him high rank as such, paved the way to a correct study of botanical geography. Before his time little or no attention was paid to the topography of plants, and he was the first to distinguish, to lay down rules, and to supply models for these two important elements in their life-history — namely, their habitats or topographical localisation, and their stations, or the physical nature of their habitats. In his "Stationes Plantarum,"[1] Linnæus defines with precision twenty-four stations characterised by soil, moisture, exposure, climate, &c., which, with comparatively slight modifications and improvements, have been adopted by all subsequent authorities. Nor, indeed, was any marked advance in this subject made, till geological observation and chemical analysis supplemented its shortcomings. In his essay "De coloniis plantarum," published fourteen years after the "Stationes,"[2] he says, "Qui veram cunque et solidam plantarum scientiam aucupatur, patriam ipsarum ac sedem cujusque propriam haud sane ignorabit," and he proceeds to give an outline of the distribution of certain plants on the globe, according to climate, latitude, &c., and to indicate their means of transport by winds, birds, and other agencies. India (meaning the tropics of both worlds) he characterises as the region of palms; the temperate latitudes, of herbaceous plants; the northern, of mosses, algæ, and coniferæ; and America, of ferns;—thus preparing the way for the next great generaliser in the field.[3]

This was the most accomplished and prolific of modern travellers, Humboldt, who made botany a chief pursuit during all his journeys, and who seems, indeed, to have been devoted to it from a very early age. His first work was a botanical one, the "Flora Friburgensis," and we have it on his own authority that three years before its publication, when he was only just of age (in 1790) he communicated to his friend G. Förster, the companion of Cook in his second voyage, a sketch of a geography of plants. It was not, however, till his return from America that his first essay on Botanical Geography[4] appeared, which at once gave him a very high position as a philosophical naturalist. Up to the period of its appearance there had been nothing of the kind to compare with it for the wealth of facts, botanical, meteorological, and hypsometrical, derived from his own observations, from the works of travellers and naturalists, and from personal communication with his contemporaries, all correlated with consummate skill and discussed with that lucidity of exposition of which he was a master. The great feature of this essay is the exactness of the methods employed for estimating the conditions under which species, genera, and families are grouped geographically, and the precision with which they are expressed.

This was succeeded in 1815, and subsequently, by four other essays on the same subject. Of these the most valuable is the "Prolegomena,"[5] in which he dwells at length on the value of

[1] *Amœnitates Academicæ*, vol. iv. p. 64, 1754.

[2] *Ibid.* vol. viii. p. 1, 1768.

[3] Between the dates of the writings of Linnæus and Humboldt, two notable works on geographical distribution appeared. One by Frid. Stromeyer ("Commentatio inauguralis sistens Historiæ Vegetabilium Geographicæ specimen," Göttingen, 1800), is an excellent syllabus of the points to be attended to in the study of distribution, but without examples; the other is a too general work by Zimmermann, entitled, "Specimen Zoologiæ Geographicæ, Quadrupedum Domicilia et Migrationes sistens," Lugd. Bat. 1777, which he followed by "Geographische Geschichte des Menschen und der allgemein verbreiteten vierfüssigen Thiere, nebst einer hieher gehörigen zoologischen Weltcharte, Leipzig, 1778-1783."

[4] "Essai sur la Géographie des Plantes," par A. de Humboldt et Aimé Bonpland; rédigée par A. de Humboldt, lu à la Classe des Sc. Phys. et Math. de l'Institut Nationale, 17 Nivôse de l'An 13. 1805.

[5] "De Distributione Geographica plantarum secundum Cœli temperiem et altitudinem Montium, Prolegomena." This appeared in quarto in the first volume of the "Nova Genera et Species Plantarum" in 1815, and separately in an octavo form in 1817. Humboldt's other works on geographical distribution are "Notationes ad Geographiam Plantarum spectantes," 1815; "Ansichten der Natur," 1808, and ed. 2, 1827; "Nouvelles Recherches sur les lois que l'on observe dans la Distribution des formes végétales" (1816); and an article with a similar title in the "Dictionnaire des Sciences Naturelles," vol. xviii p. 422, 1820.

numerical data, and explains his "Arithmeticæ botanices," which consists in determining the proportion which the species of certain large families or groups of families bear to the whole number of species composing the floras in advancing from the Equator to the Poles, and in ascending mountains. Some kinds of plants, he says, increase in numbers relatively to others in proceeding from the Equator to the Poles, as ferns, grasses, amentiferous trees, &c.; others decrease, as Rubiaceæ, Malvaceæ, Compositæ, &c.; whilst others still, as Labiatæ, Cruciferæ, &c., find their maximum in temperate regions, and decrease in both directions. He adds that it is only by accurately measuring this decrease or increase that laws can be established, when it is found that these present constant relations to parallels of temperature.[1] Furthermore, he says that in many cases the whole number of plants contained in any given region of the globe may be approximately determined by ascertaining the number of species of such families.

The importance of this method of analysing the vegetation of a country in researches in geographical botany is obvious, for it affords the most instructive method of setting forth the relations that exist between a flora and its geographical position and climatal conditions.

Humboldt's labours on the laws of distribution were not limited to floras, they included man and the lower animals, cultivated and domesticated, as well as native; they may not be works of the greatest originality, but they show remarkable powers of observation and reflection, astonishing industry, conscientious exactitude in the collection of data, and sagacity in the use of them; he is indisputably the founder of this department of geographical science.

No material advance was made towards improving the laws of geographical distribution[2] so long as it was believed that the continents and oceans had experienced no great changes of surface or of climate since the introduction of the existing assemblages of animals and plants. This belief in the comparative stability of the surface was first dispersed by Lyell, who showed that a fauna may be older than the land it inhabits. To this conclusion he was led by the study of the recent and later tertiary molluscs of Sicily, which he found had migrated into that land before its separation from the continent of Italy. Just, he adds, as the plants and animals of the Phlegræan fields had colonised Monte Nuovo since that mountain was thrown up in the sixteenth century; whence, he goes on to say, we are brought to admit the curious result, that the fauna and flora of Val de Noto, and of some other mountain regions of Italy, are of higher antiquity than the country itself, having not only flourished before the lands were raised from the deep, but even before they were deposited beneath the waters.[3] The same idea occurred to Darwin, who, alluding to the very few species of living quadrupeds which are altogether terrestrial in habit, that are common to Asia and America, and to these few being confined to the extreme frozen regions of the North, adds, "We may safely look at this quarter (Behring's Straits), as the line of communication (now interrupted by the steady progress of geological change), by which the elephant, the ox, and the horse entered America, and peopled its wide extent."[4]

The belief in the stability of climatal conditions during the lifetime of the existing assemblages of animals and plants was also dispelled by the discovery, throughout the northern temperate regions of the old and new worlds, of Arctic and boreal plants on all their mountains, and of these fossilised on their lowlands, and which discoveries led to the recognition of the glacial period and glacial ocean.

The first and boldest attempt to press the results of geological and climatal changes into the service of botanical and zoological geography was that of the late Edward Forbes, a naturalist of genius, who, like Tournefort, chose the Levant as the field for his early labours. In the year 1846, Forbes communicated a paper to the Natural History section of this Association, on the distribution of endemic plants, especially those of the British

[1] Humboldt's isothermal lines and laws of geographical distribution are obviously the twin results of the same researches, one physical, the other biological.

[2] I do not hereby imply that no progress was made in the knowledge of the facts of distribution, for, over and above many treatises on the distribution of the plants of local floras, there appeared, in 1816, Schouw's "Dissertatio de sedibus plantarum originariis"; which was followed in 1822 by his excellent "Grundtrack til el almendelig Plante-Geographie," of which the German edition is entitled, "Grundzüge einer allgemeinen Pflanzengeographie."

[3] "Principles of Geology," ed. 3, vol. iii. p. 376, 1834.

[4] *Journal of Researches in Geology and Natural History, &c.*, p. 151 1839.

Islands, considered with regard to geological changes.[1] In this paper the British flora is considered to consist of assemblages of plants from five distinct sources, which, with the exception of one, immigrated during periods when the British Isles were united to the continent of Europe, and have remained more or less localised in England, in Scotland, or in Ireland. Of these he considered the Pyrenean assemblage, which is confined to the west of Ireland, to be the oldest, and to have immigrated, after the eocene period, along a chain of now submerged mountains, that extended across the Atlantic from Spain to Ireland, and indeed formed the eastern boundary of an imaginary continent of miocene age, which extended to the Azores Islands, and beyond them. This, the "Atlantis" of speculative geologists, has long since been abandoned. The second assemblage is of plants characteristic of the South-West of France, which now prevail in Devon, Cornwall, and the Channel Islands; their immigration he assigns to a miocene date, probably corresponding to the red crag. The third assemblage is of plants of the North-East of France, which abound in the chalk districts of the South-Eastern counties of England; their immigration is referred to the era of the mammaliferous crag. The fourth is of Alpine plants now found on the mountains of Scotland, Wales, and England; these were introduced mainly by floating ice from Scandinavia during the glacial period, when the greater part of the British Isles were submerged, its mountain tops forming part of a chain of islands in the glacial sea that extended to the coast of Norway; this was during the newer pliocene period. Lastly, the Germanic plants were introduced during the upheaval of the British Islands from the glacial ocean, and as the temperature was gradually increasing; these are spread over the whole islands, though more abundant on the Eastern side. At the commencement of this immigration England was supposed to be continuous with the Germanic plains, from which it was subsequently severed by the formation of the English Channel. Also, at the commencement of this immigration, Ireland was assumed to be continuous with England, to be early severed by the formation of the Irish Sea; which severance, by interrupting the migration of Germanic types, accounts for the absence of so many British animals in the sister island.

I have thus briefly related Forbes' views, to show how profoundly he was impressed with the belief that geographical and climatal conditions were the all-powerful controllers of the migrations of animals and plants. Forbes was the reformer of the science of geographical distribution.[2]

Before the publication of the doctrine of the origin of species by variation and natural selection, all reasoning on their distribution was in subordination to the idea that these were permanent and special creations; just as, before it was shown that species were often older than the islands and mountains they inhabited, naturalists had to make their theories accord with the idea that all migration took place under existing conditions of land and sea. Hitherto the modes of dispersion of species, genera, and families had been traced; but the origin of representative species, genera, and families remained an enigma[3]; these could be explained only by the supposition that the localities where they occurred presented conditions so similar that they favoured the creation of similar organisms, which failed to account for representation occurring in the far more numerous cases where there is no discoverable similarity of physical conditions, and of their not occurring in places where the conditions are similar. Now under the theory of modification of species after migration and isolation, their representation in distant localities is only a question of time and changed physical conditions. In fact, as Darwin well sums up, all[1] the leading facts of distribution are clearly explicable under this theory; such as the multiplication of new forms; the importance of barriers in forming and separating zoological and botanical provinces; the concentration of related species in the same area; the linking together under different latitudes of the inhabitants of the plains and mountains, of the forests, marshes, and deserts, and the linking of these with the extinct beings which formerly inhabited the same areas; and the fact of different forms of life occurring in areas having nearly the same physical conditions.

With the establishment of the doctrine of the orderly evolution of species under known laws, I close this list of those recognised principles of the science of geographical distribution which must guide all who enter upon its pursuit. As Humboldt was its founder, and Forbes its reformer, so we must regard Darwin as its latest and greatest lawgiver. With their example, and their conclusions to guide, advance becomes possible whenever discovery opens new paths, or study and reflection retraverse the old ones.

And it was not long before palæontology brought to the surface new data for the study of the present and past physical geography of the globe.

This was the discovery in Arctic latitudes of fossil plants whose existing representatives are to be found only in warm temperate ones. To Arctic travellers and voyagers this discovery is wholly due. Of these I believe I am correct in saying that Sir John Richardson was the earliest, for he, in the year 1848, when descending the McKenzie River to the Polar Sea in search of the Franklin Expedition, found in lat. 65° N. beds of coal, besides shales full of leaves of forest-trees belonging to such genera as the maple, poplar, taxodium, oak, &c. In the narrative of his journey[2] Richardson mentions these fossils, and figures some of them; and in a subsequent work[3] he speaks of them as "leaves of deciduous trees belonging to genera which do not in the present day come so far north on the American continent by ten or twelve degrees of latitude." This discovery was followed, in 1853, by the still more remarkable one, by Capt. M'Clure and Sir Alexander Armstrong (during another search for Sir John Franklin), of pine cones and acorns imbedded in the soil of Banksland, in lat. 75° N., at an elevation of 300 feet above the sea level. And again in 1854 Dr. Lyall found extensive accumulations of similar fossils near Discoe in Greenland (lat. 70° N.), during the return of Sir Edward Belcher's searching expedition. Nor are these fossils confined to America: they have been found in Spitzbergen, in Siberia, and in many other localities within the Polar area as well as south of it, proving that forests of deciduous trees, in all respects like those of the existing forests of the warm temperate regions, approached to within ten degrees of the Pole. The first of these collections critically examined was Dr. Lyall's; it was communicated to Prof. Heer of Zurich, the highest authority on the flora of the Tertiary period, and described by him,[4] as were also subsequently all the other collections brought from the Arctic regions.[5]

The examination of these fossil leaves revealed the wonderful fact that, not only did they belong to genera of trees common to the forests of all the three northern continents, such as planes, beeches, ashes, maples, &c., but that they also included what are now extremely rare and even local genera, as sequoia, liquidamber, magnolia, tulip-trees, gingkos, &c., proving that the forests were of a more mixed character than any now existing. These results opened up a new channel for investigating the problem of distribution, and the first naturalist to enter it as a botanist, Dr. Asa Gray, who pursued it with brilliant results, embodied in a series of memoirs on the vegetation of the United States of America, and of which my notice must be most brief.

When studying the collections of Japanese plants brought by the officers of Wilkes' expedition, Dr. Gray found cumulative evidence of the strong affinity between the flora of Eastern Asia

[1] *British Association Reports*, 1845, pt. ii. p. 67, and *Annals and Magazine of Natural History*, vol. xvi. p. 126. This the author followed by a much fuller exposition of the subject, which appeared in the *Memoirs of the Geological Survey of the United Kingdom*, vol. i. p. 336 (1846), entitled "On the Connection between the distribution of the existing flora and fauna of the British Isles, and the geological changes which have affected their area, especially during the epoch of the northern drift." After many years interval I have re-read this Memoir with increased pleasure and profit. The stores of exact information which he collected concerning the plants, the animals, and the geology of Europe and North America, appear to me to be no less remarkable than the skill with which he correlated them and educed from the whole so many very original and in great part incontrovertible conclusions.

[2] I cannot dismiss the subject of the geography of the British flora without an allusion to the labours of Hewett Cottrell Watson, who, after a life devoted to the topography of British plants, was laid in the grave only a month ago. Watson was the first botanist who measured the altitudinal range of each species, and, by a rigidly statistical method, traced their distribution in every county, and grouped them according to their continental affinities, as well as by the physical conditions of their habitats.

[3] The representation of species Forbes alludes to as "an accident . . . which has hitherto not been accounted for" (*Mem.* Geol. Survey, vol. i. p. 351).

[1] Of the many pre-Darwinian writers on distribution who advocated the Lamarckian doctrine of evolution, I am not aware of any who suggested that it would explain the existence of representative species, or indeed any other of the phenomena of distribution. Von Baer, however, in the very year of the publication of the first edition of the "Origin of Species," expressed his conviction, chiefly grounded on the laws of geographical distribution, that forms now specifically distinct have descended from a single parent form. See "Origin of Species," ed. 5, Historical Sketch, p. 23.

[2] "Boat Voyage through Rupert's Land and in the Arctic Sea," vol. i. p. 186. [3] "Polar Regions," p. 289.

[4] "Ueber die von Dr. Lyall in Grönland entdeckten fossilen Pflanzen." *Zürich Vierteljahrschr.* vol vii. p 176 (1862).

[5] "Flora fossilis Arctica."

and Eastern North America, to the exclusion of the western half of that continent; and also that Europe and Western Asia did not share in this affinity. But what especially attracted his attention was, that this affinity did not depend only on a few identical or representative genera, but upon many endemic genera of exceptional character, and often consisting of only two almost identical species. This led to a rigorous comparison of those plants with the fossils from the Arctic regions whose affinities had been determined by Heer, and with others which had been meanwhile accumulating in the United States, and had been described by Lesquereux; and the result was what I may call an abridged outline history of the flora of North America in its relations to the physical geography of that country, from the Cretaceous to the present time.

The latest researches which have materially advanced our knowledge of the laws of distribution are those of Prof. Blytt of Christiania. His essay on "The Immigration of the Norwegian Flora during alternately Rainy and Dry Periods" has for its object to define and localise the various assemblages of plants of which that flora is composed, and to ascertain their mother-country and the sequence of their introduction. The problem is that of Prof. Forbes, which I have already described to you, only substituting Norway for the British Isles. Both these authors invoke the glacial period to account for the dispersion of Arctic plants, both deal with a rising land, both assume that immigration took place over land; but Prof. Blytt finds another and most powerful controlling agent, in alternating periods of greater moisture and comparative drought, of which the Norwegian peat bogs afford ample proof. These bogs were formed during the rise of the land, as the cold of the glacial period declined. They are found at various heights above the sea in Norway; the most elevated of them are of course the oldest, and contain remains of the earliest immigrants. The lowest are the newest, and contain remains of the latest introduced plants only. The proofs of the alternating wet and dry seasons rest on the fact that the different layers of peat in each bog present widely different characters, contain the remains of different assemblages of plants, and these characters recur in the same order in all the bogs. First there is a layer of wet spongy peat, with the remains of bog-mosses and aquatic plants; this gradually passes upwards into a layer of dry soil containing the remains of many land plants, and prostrate trunks of trees, showing that the country was forested. To this succeeds wet spongy peat as before, to be again covered with dry peaty soil and tree trunks, &c., and so on. From an examination of the plant remains in these formations Prof. Blytt draws the following conclusions:—

The Norwegian flora began with an immigration of Arctic plants during a dry period, evidence of which he finds in the presence of the remains of these beneath the lowest layer of peat. As the climate became warmer and the land rose, a rainy period set in, accompanied by an immigration of sub-Arctic plants (juniper, mountain ash, aconites, &c.), which to a great extent replaced the Arctic flora, which is impatient of great wet. This was the period of the first peat-bog formation. It was followed by a dry period, during which the bogs gradually dried up; while with the increasing warmth, deciduous trees and their accompanying herbaceous vegetation were introduced. The succeeding rainy season produced a second peat-formation, killing and burying the deciduous trees, the increasing warmth at the same time bringing in the Atlantic flora, characterised by the holly, foxglove, and other plants now confined in Norway to the rainy Atlantic coast. To this succeeded a third period of drought, when the bogs dried up, and pine-forests with their accompanying plants immigrated into Norway, to be in like manner destroyed and buried by bog earth during the next following rainy period; and it was during these last alternations that the subboreal plants now affecting the lowest south-eastern districts of Norway were introduced; and the sub-Atlantic plants, the most southern of all the types which are confined to the extreme south of the country.

It would be premature to regard all Prof. Blytt's recurrent periods as irrefragably established, or his correlations of these with the several floras as fully proved; but there is no doubt, I think, that he has brought forward a *vera causa* to account for the alternation of dry country with wet country plants in Norway, and one that must have both actively promoted the first introduction of these into that country, as also influenced their subsequent localisation. It would strengthen Prof. Blytt's conclusions very much if his alternating periods of rain and drought should be found to harmonise with Mr. Croll's recurrent astronomical periods, and with Mr. Geikie's fluctuations of temperature during the decline of the Glacial epoch: so would also the finding in the bogs of Scotland a repetition of the conditions which obtain in those of Norway; and there are so very many points of resemblance in the physical geography and vegetation of these two countries that I do not doubt a comparison of their peat formations would yield most instructive results.

Thus far all the knowledge we have obtained of the agents controlling geographical distribution have been derived from observations and researches on northern animals and plants, recent and tertiary. Turning now to the southern hemisphere, the phenomena of distribution are much more difficult of explanation. Geographically speaking, there is no Antarctic flora except a few lichens and sea-weeds. The plants called Antarctic,[1] from their analogy with the Arctic, are very few in number, and nowhere cross the 62° of south latitude. They are, in so far as they are endemic, confined to the southern islands of the great southern ocean, and the mountains of South Chili, Australia, Tasmania, and New Zealand; whilst the few non-endemic are species of the nearest continents, or are identical with temperate northern or with sub-Arctic or even Arctic species. Like the Arctic flora, the Antarctic is a very uniform one round the globe, the same species, in many cases, especially the non-endemic, occurring on every island, though there are sometimes thousands of miles of ocean between the nearest of these. And, as many of the island plants reappear on the mountains above mentioned, far to the north of their island homes, it is inferred on these grounds, as well as on astronomical and geological, that there was a glacial period in the southern temperate zone as well as in the northern.

The south temperate flora is a fourfold one. South America, South Africa, Australia, and New Zealand contain each an assemblage of plants differing more by far amongst themselves than do the floras of Europe, North Asia, and North America; they contain, in fact, few species in common, except the Antarctic ones that inhabit their mountains. These south temperate plants have their representative species and genera on the mountains of the tropics, each in their own meridian only, and there they meet immigrants from all latitudes of the northern hemisphere. Thus the plants of Fuegia extend northward along the Andes, ascending as they advance. Australian genera reappear on the lofty mountain of Kini-balu in Borneo; New Zealand ones on the mountains of New Caledonia; and the most interesting herbarium ever brought from Central Africa, that of Mr. Joseph Thomson, from the highlands of the lake districts, contains many of the endemic genera, and even species of the Cape of Good Hope. Nor does the northern representation of the south temperate flora cease within the tropics; it extends to the middle north temperate zone; Chilian genera reappearing in Mexico and California; South African in North Africa, in the Canary Islands, and even in Asia Minor[2]; and Australian in the Khasia Mountains of East Bengal, in East China and Japan.

So too there is a representation of genera in the southern temperate continents, feeble numerically compared to what the north presents, but strong in other respects. This is shown by the families of Proteaceæ, Cycadeæ, and Restiaceæ, abounding in South Africa and Australia alone, though not a single species or even genus of these families is common to the two countries; by New Zealand, with a flora differing in almost every element from the Chilian, yet having a few species of both calceolaria and fuchsia, genera otherwise purely American; whilst as regards Australia and New Zealand, it is difficult to say which are the most puzzling, the contrasts or the similarities which their animal and vegetable productions present.

These features of the vegetation of the south temperate and Antarctic regions, though they simulate those of the north temperate and Arctic, may not originate from precisely similar causes. In the absence of such evidence as the fossil animals and plants of the north affords,[3] there is no proof that the Ant-

[1] For accounts of the Antarctic flora see the "Botany" of the Antarctic Expedition of Sir James Ross, where the relations of the floras of the southern hemisphere with the Antarctic are discussed in introductory chapters.

[2] *Pelargonium Endlicherianum* in the Taurus is a remarkable instance.

[3] The only fossil leaves hitherto found in higher southern latitudes are those of beeches, closely allied to existing southern species, brought by Darwin from Fuegia. In one locality alone beyond the forest region of the south have fossil plants been found; there were silicified trunks of trees in lava beds of Kerguelen's Island (discovered by myself forty years ago). It is deeply to be regretted that searches for shales containing fossils were not

arctic plants found on the south temperate Alps, or the south temperate plants found in the mountains of the tropics, originated in the south; though this appears probable from the absence in the south of so many of the leading families of plants and animals of the north, no less than from the number of endemic forms the south contains. These considerations have favoured the speculation of the former existence, during a warmer period than the present, of a centre of creation in the Southern Ocean, in the form of either a continent or of an archipelago, from which both the Antarctic and southern endemic forms radiated. I have myself suggested continental or insular extension[1] as a means of aiding that wide dispersion of species over the Southern Ocean, which it is difficult to explain without such intervention; and the discovery of beds of fossil trunks of trees in Kerguelen's Island, testifies to that place having enjoyed a warmer climate than its present one.

The rarity in the existing Archipelago (Kerguelen's Island, the Crozets, and Prince Edward's Island) of any of the endemic genera of the south temperate flora, or of representatives of them, is, however, an argument against such land, if it ever existed, having been the birthplace of that flora; and there are two reasons for adopting the opposite theory, that the southern flora came from the north temperate zone. Of these, one is the number of northern genera and species (which, from their all inhabiting north-east Europe, I have denominated Scandinavian)[2] that are found in all Antarctic and south temperate regions, the majority of them in Fuegia, the flora of which country is, by means of the Andes, in the most direct communication with the northern one. The other is the fact I have stated above, that the several south temperate floras are more intimately related to those of the countries north of them than they are to one another.

And this brings me to the latest propounded theoretical application of the laws of geographical distribution. It is that recently advanced by Mr. Thiselton Dyer, in a lecture "On Plant Distribution as a Field of Geographical Research"[3]; wherein he argues that the floras of all the countries of the globe may be traced back at some time of their history to the northern hemisphere, and that they may be regarded in point of affinity and specialisation as the natural results of the conditions to which they must have been subjected during recent geological times, on continents and islands with the configuration of those of our globe. This hypothesis derives its principal support from the fact that many of the most peculiar endemic plants of the south have representatives in the north, some of them living and all of them in a fossil state, whilst the northern endemic forms have not hitherto been found fossil in the southern regions. So that, given time, evolution, continental continuity, changes of climate and elevations of the land, and all the southern types may be traced back to one region of the globe, and that one palæontology teaches us is the northern.

A very similar view has been held and published at the same time by Count Saporta,[4] a most eminent palæontologist, in a suggestive essay entitled "L'Ancienne Végétation Polaire." Starting from Buffon's thesis, that the cooling of the globe having been a gradual process, and the Polar regions having cooled first, these must have first become fit for organic life, Count Saporta proceeds to assume that the termination of the azoic period coincided with a cooling of the waters to the point at which coagulation of albumen does not take place, when organic life appeared in the water itself. I have discussed Count Saporta's speculations elsewhere[5]; it is sufficient here to indicate the more important ones as bearing upon distribution. These are that the Polar area was the centre of origination of all the successive phases of vegetation that have appeared on the globe, all being developed in the north; and that the development of flowering plants was enormously augmented by the introduction during the latter part of the secondary period of flower-feeding insects, which brought about cross-fertilisation.

It remains to allude briefly to the most important general works on distribution that have appeared since the foundation of this Association. Of these, the two which take the first rank are Prof. Alphonse de Candolle's "Géographie Botanique" and Mr. Wallace's "Geographical Distribution of Animals." Prof. de Candolle's work[1] appeared at a critical period, when the doctrine of evolution with natural selection had only just been announced, and before the great influence of geological and climatal changes on the dispersion of living species had been fully appreciated; nevertheless it is a great and truly philosophical work, replete with important facts, discussed with full knowledge, judgment, and scrupulous caution. Of its numerous valuable and novel features, two claim particular notice, namely, the chapters on the history of cultivated and introduced plants; and the further development of Humboldt's "Arithmeticæ Botanices," by taking into account the sums of temperatures as well as the maxima, minima, and means, in determining the amount of heat required to satisfy all the conditions of a plant's life, at the various periods of its existence, and especially the maturation of its seeds.

Of Mr. Wallace's great work, "The Geographical Distribution of Animals," I cannot speak with sufficient knowledge of the subject, and can only appreciate and echo the high praises accorded to it by zoologists for its scientific treatment of a vast subject.

The "Géographie Botanique" was followed by the late Dr. Grisebach's "Die Vegetation der Erde,"[2] which contains an admirable summary of the vegetation of the different regions of the globe as limited by their physical features, divested of all theoretical considerations.

For the largest treatment in outline of the whole subject of distribution, I must refer to the chapters of Darwin's "Origin of Species" which are devoted to it.

In reference to these and other works, very able and instructive discussions of the principles of geographical distribution are to be found in the presidential addresses delivered before the Linnean Society, in 1869, 1870, and 1872, by the veteran botanist, G. Bentham.

With Mr. Wallace's "Island Life" I must conclude this notice, and very fittingly, for besides presenting an admirable account of the origin and migrations of animals and vegetables in oceanic and continental islands, it contains a complete and comprehensive analysis of those past and present conditions of the globe, astronomical, geological, geographical, and biological, which have been the earlier and later directors and controllers of the ever-warring forces of organic nature. In this work Mr. Wallace independently advocates the view of the northern origin of both the faunas and floras of the world.

I conclude with the hope that I have made the subject of the distribution of organic life on the globe interesting to you as geographers, by showing on the one hand how much it owes its advance to the observations made and materials collected by geographical explorers, and on the other how greatly the student of distribution has, by the use he has made of these observations and materials, advanced the science of physical geography.

SECTION G

MECHANICAL SCIENCE

Opening Address by Sir W. Armstrong, C.B., D.C.L., LL.D., F.R.S., President of the Section

The astonishing progress which has been made in the construction and application of machinery during the half century which has elapsed since the nativity of the British Association for the Avancement of Science, is a theme which I might with much complacency adopt in this address, but instead of reviewing the past and exulting in our successes, it will be more profitable to look to the future and to dwell on our failures. It is but justice to say that by growing experience, by increasing facilities of manufacture, and by the exercise of much skill and ingenuity, we have succeeded in multiplying and expanding the applications of our chief motor, the steam-engine, to an extent that would have appeared incredible fifty years ago; but the

made either by the *Challenger* expedition or by the various "transit of Venus expeditions" that have recently visited this interesting island.

[1] "Flora Antarctica," pp. 230, 240. See also Moseley in *Journ.* Linn. Soc. Botany, vol. xv. p. 485, and "Observations on the Botany of Kerguelen's Island," by myself, in the *Philosophical Transactions*, vol. 168, p. 15.

[2] See "Outlines of the Distribution of Arctic Plants," *Transactions* of the Linnean Society, vol. xxiii. p. 257. Read June, 1860.

[3] *Proceedings* of the Royal Geographical Society, vol. xxii. p. 415 (1878)

[4] *Comptes rendus* of the International Congress of Geographical Science, which met in Paris in 1875, but apparently not published till 1877

[5] Address of the President delivered at the anniversary meeting of the Royal Society of London, November 30, 1878.

[1] Prof. Alph. de Candolle divides his subject into botanical geography and geographical botany; the distinction is obvious and sound, but the two expressions have been so long used and regarded as synonymous, and as embracing both branches, that they cannot now be limited each to one. Perhaps the terms topographical botany and geographical botany would prove more acceptable designations.

[2] Published in 1872. Translated into French under the title of "La Végétation du Globe," by P. de Tchihachef, Paris, 1875.