about the measure-relations of space in the infinitely small are not therefore superfluous questions.

If we suppose that bodies exist independently of position, the curvature is everywhere constant, and it then results from astronomical measurements that it cannot be different from zero; or at any rate its reciprocal must be an area in comparison with which the range of our telescopes may be neglected. But if this independence of bodies from position does not exist, we cannot draw conclusions from metric relations of the great, to those of the infinitely small; in that case the curvature at each point may have an arbitrary value in three directions, provided that the total curvature of every measurable portion of space does not differ sensibly from zero. Still more complicated relations may exist if we no longer suppose the linear element expressible as the square root of a quadric differential. Now it seems that the empirical notions on which the metrical determinations of space are founded, the notion of a solid body and of a ray of light, cease to be valid for the infinitely small. We are therefore quite at liberty to suppose that the metric relations of space in the infinitely small do not conform to the hypotheses of geometry; and we ought in fact to suppose it, if we can thereby obtain a simpler explanation of phenomena.

The question of the validity of the hypotheses of geometry in the infinitely small is bound up with the question of the ground of the metric relations of space. In this last question, which we may still regard as belonging to the doctrine of space, is found the application of the remark made above; that in a discrete manifoldness, the ground of its metric relations is given in the notion of it, while in a continuous manifoldness, this ground must come from outside. Either therefore the reality which underlies space must form a discrete manifoldness, or we must seek the ground of its metric relations outside it, in binding forces which act upon it.

The answer to these questions can only be got by starting from the conception of phenomena which has hitherto been justified by experience, and which Newton assumed as a foundation, and by making in this conception the successive changes required by facts which it cannot explain. Researches starting from general notions, like the investigation we have just made, can only be useful in preventing this work from being hampered by too narrow views, and progress in knowledge of the interdependence of things from being checked by traditional prejudices.

This leads us into the domain of another science, of physic, into which the object of this work does not allow us to go to-day.

Synopsis

PLAN ot the Inquiry:

I. Notion of an n-ply extended magnitude.
  § 1. Continuous and discrete manifoldnesses. Defined parts of a manifoldness are called Quanta. Division of the theory of continuous magnitude into the theories
   (1) Of mere region-relations, in which an independence of magnitudes from position is not assumed;
   (2) Of size-relations, in which such an independence must be assumed.
  § 2. Construction of the notion of a one-fold, two-fold, n-fold extended magnitude.
  § 3. Reduction of place-fixing in a given manifoldness to quantity-fixings. True character of an n-fold extended magnitude.

II. Measure-relations of which a manifoldness of n dimensions is capable on the assumption that lines have a length independent of position, and consequently that every line may be measured by every other.
  § 1. Expression for the line-element. Manifoldnesses to be called Flat in which the line-element is expressible as the square-root of a sum of squares of complete differentials.
  § 2. Investigation of the manifoldness of n-dimensions in which the line-element may be represented as the square root of a quadric differential. Measure of its deviation from flatness (curvature) at a given point in a given surface-direction. For the determination of its measure-relations it is allowable and sufficient that the curvature be arbitrarily given at every point in $n\frac{n-1}{2}$ surface directions.
  § 3. Geometric illustration.
  § 4. Flat manifoldnesses (in which the curvature is everywhere = 0) may be treated as a special case of manifoldnesses with constant curvature. These can also be defined as admitting an independence of n-fold extents in them from position (possibility of motion without stretching).
  § 5. Surfaces with constant curvature.

III. Application to Space.
  § 1. System of facts which suffice to determine the measure-relations of space assumed in geometry.
  § 2. How far is the validity of these empirical determinations probable beyond the limits of observation towards the infinitely great?
  § 3. How far towards the infinitely small? Connection of this question with the interpretation of nature.

THE DEVELOPMENT THEORY IN GERMANY*

III.

Chorology: or, the Geographical Distribution of Living Beings

THE importance of the theory of Evolution does not consist in its accounting for this or that particular fact, but in its explaining all biological facts collectively. It is found to be confirmed in every detail by the mode of distribution of the various organisms on the surface of the earth. This distribution had already been studied by Alexander von Humboldt and Fr. Schouw for plants, by Berghaus and Schmarda for animals. But previous to Darwin and Wallace, this study had produced only a collection of unsystematised facts; Haeckel has attempted to create out of it a special science under the name of *Chorology*.

With the exception of the monocellular protozoa, which, on account of their simplicity, have been able to appear at the same time or at several times in different places; with the exception also of species which owe their origin to a hybrid or bastard generation, and which it has been possible to reproduce in different circumstances wherever the parent species have previously spread, it must be admitted that each of the other species has only been originated a single time and in a single place. But, once produced, they must, as a consequence of the struggle for existence, and in virtue of the laws of population, or rather of excess of population, tend to spread to the widest possible extent. Animals and plants migrate as well as man, both actively and passively.

In the case of animals, which have, more than plants, freedom of movement, active migration plays the principal part. The more easy locomotion is in the case of any species, the more rapidly is the species bound to spread. This is why birds and insects, furnished with wings, although referable to a less number of orders or natural groups than other animals, yet present a very great diversity of species slightly distinguishable from one another; this is to be ascribed to the fact that the facility with which they can move from place to place has subjected them to the modifying influences of the most varied localities. After birds and insects the swiftest runners among the denizens of the land, the best swimmers among the inhabitants of the water have been subject to the widest extension. With regard to animals which are fixed or immovable while being developed, corals, tubicolæ, tunicata, crinoids, &c., they usually enjoy during their youth so much of the power of movement as admits of their displacement. A great number of floating plants are also transported to great distances by water.

But the spread of a large number of plants and of certain animals can be explained only by a passive migration. The wind sweeps to great distances, sometimes over seas, eggs of small animals, seeds, and sometimes even minute organisms; this explains the well-known phenomena of showers of frogs. These eggs, these seeds, these small organisms, sometimes fall into the water, which transports them to still greater distances. Trunks of trees, which traverse the ocean under the direction of the currents, and those which the tempest hurls from the mountain tops, can carry with them, hidden in their interstices, in the moss or the parasitical plants with which they are covered, in the earth which adheres to their roots, innumerable germs to be developed in new regions. The icebergs of the polar sea have landed foxes and bears even on the shores of Iceland and Britain. Birds, insects, mammals which are removed, carry with them thousands of parasites, microscopic beings, eggs or germs. Man himself carries them about more abundantly still along with the varied materials he employs for his works and his industry.

The fact of the distribution of certain species which cannot be explained by migration, either active or passive, may be accounted for by geological facts. In consequence of the im-

* Continued from vol. vii. p. 434.

perceptible but unceasing change of the level of the seas, in consequence of the phenomena of subsidence and elevation of the land, lands at one time united have been divided, watercourses which communicated have been separated, thus accounting for the fact that fishes of the same species are found in different rivers, that islands are tenanted by the same mammals as the continents. England has been united to Europe at two different times; at a certain epoch our continent must have been united by land to N. America. The South-sea Islands are the remains of what was at one time a single land; so in the Indian Ocean land has at one time stretched along the South of Asia from Sunda to Africa; this great continent which Sclater has called *Lemuria*, on account of the apes which were peculiar to it, is probably the cradle where the human race was developed from the anthropoid apes. Mr. Wallace has proved that the Malay Archipelago consisted of two entirely different parts: one, comprehending Borneo, Java, and Sumatra, was united to Asia by the peninsula of Malacca, while the other, comprehending the Celebes, the Moluccas, New Guinea, the Salomon Isles, &c., was immediately attached to Australia.

Another cause which has favoured the dispersion of species all over the globe, was the uniformity of temperature which prevailed up to the tertiary geological period. Previous to the freezing of the polar regions, species found everywhere a climate equally warm and agreeable, favourable to migrations in all directions; since that period, on the contrary, a new difficulty of existence has arisen,—organisms have to undergo acclimatisation; those which have the power of adapting themselves to the lower temperature of regions at a distance from the equator, have been transformed by selection into new species; while those which have found such adaptation impossible, have been compelled, under pain of extinction, to remove to more favourable climates. When, at a later period, occurred that strange phenomenon—of which, as yet, no satisfactory explanation has been given—known as the Glacial Period, animals and plants were compelled to migrate anew; the living population of the earth, condensing itself between the tropics, a terrible struggle for existence took place between the old inhabitants of these regions and those that fled thither for refuge; many species were bound to disappear, while many new ones were originated. There is still another chorological phenomenon which is to be accounted for by the glacial period, viz., the resemblance of many of the inhabitants of mountains to those of the Polar regions; as those animals and those plants are not found the intermediate countries, it is absolutely necessary to suppose a migration which, considering the habits of these creatures, could only have taken place at the glacial epoch. It is probable that at this period the gentians, the saxifrages, the Polar hare and fox, inhabited the central part of Europe; but as the temperature rose, some of these creatures retired towards the north, while the remainder found a refuge upon the summits of the European mountains.

When plants or animals migrate to new regions, they are subjected to new conditions of existence to which they must adapt themselves. The new climate, new food, relations with new organisms, all this obliges the emigrants to submit to modifications under pain of annihilation, and, as a consequence, to form new varieties or new species; it is in these circumstances, in fact, that natural selection acts with the greatest intensity. In ordinary circumstances, individuals which have changed breed with individuals who have not changed, and the products of such crossings have a tendency to revert to the primitive type; but when a migration has taken place, when modified individuals are separated from others by mountains or by seas, they can no longer interbreed, and this isolation insures the preservation of the newly acquired forms. It is of course evident that these considerations apply only to species in which the sexes are separate.

There still remain three other chorological phenomena which furnish an important proof of the truth of the evolution theory. There is first the likeness of form, the family resemblance which exists among the local species characteristic of each region, and the extinct and fossil species of the same region; in the second the no less striking family resemblance which exists among the inhabitants of certain groups of those of the neighbouring continents, whence the population of these islands must have come; and lastly, the special character presented by the collective fauna and flora of the islands. All the facts adduced by Darwin, Wallace,* and Moritz Wagner,† as well as all those other facts which geographical and topographical dispersion of organisms present to us are simply and completely explained by the theory of selection and migration, while it would be impossible to explain them without it.

* "Malay Archipelago."
† The "Darwinian Theory and the Law of Migration of Organisms" Leipzig, 1868).

Palæontology

Thanks to the theory of evolution, the natural classification of animals and plants, which was previously only a record of names for arranging the different forms in an artificial order, or a record of facts expressing summarily the degree of resemblance among them, tends to become the genealogical tree of organisms. In order to construct it the student has only to combine the data furnished by the three parallel developments referred to above—the palæontological development, the embryological development, and the systematic development in the order of perfection or of comparative anatomy. The writer in the *Revue Scientifique* here gives a table presenting a view of the geological and palæontological doctrines of Haeckel. Between the stages generally admitted by geologists, Haeckel intercalates others which he calls inferior or intermediate stages in relation to the superior stages. Haeckel accepts completely the system of gradual and continuous evolution as propounded by Lyell, and rejects the system of sudden catastrophes which has been advocated by Cuvier and his disciples. He places the probable appearance of man in the Miocene, and his certain existence in the Pliocene. Many attempts have been made to determine approximately how many thousand years each geological period has lasted; these conjectures are principally framed on the relative thickness of the different beds. The total thickness of the Archæolithic or Primordial beds, in which Haeckel includes the Laurentian, Cambrian, and Silurian, is 70,000 ft.; that of the Primary, from the Devonian to the Permian, 42,000 ft.; that of the Secondary, 15,000 ft.; that of the Tertiary, 3,000 ft.; while the thickness of the beds of the "Anthropolithic" or Quaternary age is only from 500 to 700 ft. From these figures, the following relative duration of the successive ages may be deduced:—

Primordial Age . . .	53·6
Primary ,, . . .	32·1
Secondary ,, . . .	11·5
Tertiary ,, . . .	2·3
Quaternary ,, . . .	0·5

Thus the Primordial age has existed longer than the other four put together. As to the number of centuries or of millenniums necessary for the deposition of one bed only one foot thick, that depends on circumstances so variable that it is impossible to give any measure: it is longer in the depths of mid-ocean, in the beds of very long rivers, in lakes which receive no affluents; it is shorter on the sea-margins, at the mouths of great rivers whose course is long and straight, in lakes which receive many tributary streams. It results from such considerations that every estimate of the duration of a geological epoch must be relative.

It will be necessary, moreover, to take into consideration, elevations and depressions of the ground, which, according to Haeckel, will be alternative, and will correspond to the mineralogical and palæontological differences which exist between two systems of beds and between two formations of these systems. When a certain region, after having remained for many thousand centuries beneath the water, emerges for a certain time, and is again submerged, it will be readily admitted that the bed which is deposited after such an interval ought to present characteristics different from those of the lower bed: for time is bound to accomplish change of all organic and inorganic conditions. This theory has been disputed by Huxley, who finds it inconsistent with the existence of a large number of beds, in which are found united organic forms, holding a middle place between those of adjacent formations; the English naturalist adduces, for example, the beds of Saint Cassian, in which are found mingled the forms of the primary and secondary formations.

It is certain that even yet our knowledge of palæontology is very imperfect, and far from enabling us to write, with anything like exactness, the history of the production of organic species. We know with what difficulties this study is surrounded. The fossil remains of the most remote ages appear to have been destroyed by the great heat of the lower beds in which they were deposited. *Eozoon Canadense* is the only fossil which has hitherto been found in the formations of the Laurentian period; while the beds of carbon and of crystallised lime (graphite and marble) give us the assurance that in them have existed animal and vegetable petrifactions. Another difficulty lies in the fact that hitherto the field of geological exploration has been very restricted. Outside of England, Germany, and France, very few formations have been seriously studied; almost the only successful explorations have been in railway-cuttings. One indication of what may be discovered elsewhere is furnished by the remarkable petrifactions which have resulted from some researches prosecuted in Africa and Asia, in the neighbourhood of the Cape, and on the Himalayas: forms have been discovered which fill up important gaps in palæontological classification. It must be remembered also that only the hard and solid parts of organisms have been preserved, that entire forms, such as the Medusæ, shell-less molluscs, many articulata, nearly all worms, could leave no trace behind. The most important parts of plants, the flowers, have completely disappeared. Moreover, terrestrial organisms have been petrified only in accidental instances, where they have fallen into the water and been covered with mud; it is not to be wondered at then if the number of fossils of this kind is relatively much less considerable than that of those kinds which have inhabited the sea or fresh water. This explains also the apparently strange fact that of many fossil mammals, especially those of the secondary, we recognise only the lower jaw. This arises from the fact that that bone is easily separated from the dead body; while the rest swims on the surface of the water and is carried to the bank, the jaw falls to the bottom, and is buried in the mud, where it is petrified. The traces of those which have been found in different beds of sandstone, and especially in the red sandstone of Connecticut, belong to organisms whose bodies are entirely unknown to us, and prove that we are far from possessing remains of all actual forms. What gives us reason to think that an immense number must remain unknown is the fact that of those whose fossil remains we possess, only one or two examples have come to light. It is only ten years since a bird of the highest importance was discovered in the Jura; till then no intermediate form was known between the birds proper and reptiles, which are, nevertheless, the class most closely related to the former. Now this fossil bird, which possesses the tail, not of an ordinary bird, but of a lizard, confirms the hypothesis that birds are descended from the saurians. A couple of small teeth which have been found in the Keuper of the Trias are, up to the present, the only proof that mammals have existed from the Triassic period, and that they did not appear only in the Jurassic period, as was previously believed.

Fortunately we are able to supplement the insufficient data of palæontology by those of embryology, since individual development is, as it were, a reproduction or recapitulation brief and rapid, by means of heredity and adaptation of the development of species. Embryology is especially valuable for the light which it throws on the more ancient forms of the primordial period; by it alone do we learn that these primitive forms must have been simple cells, similar to eggs; that these cells, by their segmentation, their conformation, and their division of labour, have given birth to the infinite variety of the most complicated organisms.

To the valuable data respecting the relations of organisms furnished by palæontology and embryology must be added those derived from comparative anatomy. When organisms, whose exterior is very different, resemble each other in their interior construction, we may conclude with certainty that this resemblance is due to heredity, while the differences are a result of adaptation. If, for example, we compare the limbs or extremities of different mammifers, the arm of man, the wing of the bat, the anterior members of the mole adapted for digging, those of other mammifers made for leaping, climbing, or running; if we consider, besides, that in all these members variously formed, the same bones are found, equal in number, in the same place, disposed in the same manner, are we not forced to admit the close relationship of organisms? This homology can be explained only by heredity, by descent from common ancestors. And to go still further, if we find in the wing of the bird, in the anterior members of reptiles and amphibia, the same bones as in the arms of man, or in the anterior limbs of other mammifers, can we not affirm with certainty the common descent of all these vertebrate animals?

SCIENTIFIC SERIALS

Ocean Highways, May.—The first paper in this number is an article on Mexico, by Mr. Maurice Kingsley, accompanied by a map showing the course of the Vera Cruz and Mexico Railway. This is followed by a very interesting article on "Railway Communication between London and Calcutta," with a map showing the proposed line from Ostende, by Vienna, Constantinople, Diabeker, Herat, Cabul, Lahore, Delhi, Cawnpore, and Calcutta. By this route the land journey would amount to 6,336 miles, with only 73 miles of sea, which could be accomplished in 214 hours, or about 9 days; while by the present shortest route, the sea-journey amounts to 3,941 miles, and the time taken is 492 hours, or upwards of 20 days. Dr. Robert Brown contributes a paper entitled "A Cruise with the Whalers in Baffin's Bay," which is followed by "Notes on Mr. Stanley's Work," by Capt. R. F. Burton, in which that gentleman points out several things in Stanley's book that he thinks are capable of amendment. Burton thinks Stanley "wants only study and discipline, to make him a first-rate traveller." This is followed by a very valuable paper on "The Steppes to the North of Bokhara," by A. Vámbéry. Then follow the usual reviews, notes, reports of societies, &c.

SOCIETIES AND ACADEMIES

LONDON

Chemical Society, May 1.—Dr. Odling, F.R.S., president, in the chair.—Dr. H. Sprengel, "On a new class of explosives," gave an account of some new explosives consisting of two liquids inexplosive by themselves, but which when mixed and fired with a detonating charge are as effective as nitroglycerine.—Prof. Abel of the Royal Arsenal, Woolwich, drew attention to the great difference produced by variations in the mechanical state of the explosive.—On Zirconia, by Mr. J. B. Hannay.—On Pyrogallate of lead and lead salts, by Mr. W. H. Deering.

Royal Horticultural Society, April 16.—General meeting, Sir Coutts Lindsay, Bart., in the chair. The Rev. M. J. Berkeley commented on the plants exhibited, and remarked that the unused archways of railways might be profitably employed for the production of mushrooms.—Mr. W. A. Lindsay (the secretary) enumerated the concessions which the Council had made for this year to Her Majesty's commissioners for the Exhibition, including a passage-way across the gardens: the society would receive in return the sum of 1000*l*.—Scientific committee—Prof. Westwood, F.L.S., in the chair. The Rev. M. J. Berkeley commented on an article in the recent number of the journal of the Royal Agricultural Society on the injury suffered by horses fed upon mouldy oats. There was an evident error with respect to the fungus figured as *Aspergillum* (sic) which was clearly the common bread-mould *Ascophora Mucedo*. With respect to the diseased coffee-plants from Natal brought forward at the last meeting he was disposed to think that climatic conditions were the cause, of their malady. The differences between the summer and winter temperatures had been too slight to check the growth of the coffee trees. There are often three flowerings instead of one, or at all events two. It seemed on the whole probable that growth was over-estimated, and that, consequently, when the drought came, the plants were unable to support it. There was a minute immature black fungus, which might be referred to *Depazea*, on the twigs. Prof. Thiselton Dyer read a letter addressed to Dr. Hooker from Dr. Henderson in charge of the Calcutta Botanic Garden, describing the disease of the opium poppy. This appeared to be favoured by moist weather, and the plants affected were infested with *Peronospora arborescens*, and also with a fungus (which Mr. Berkeley identified as *Macrosporium cheiranthi*, a peculiar form of *Cladosporium herbarum*.) The places attacked were black, and the disease progressed from below, upwards. If the plant has not flowered when attacked, it never does so; but if it is on the point of flowering, the sepals, petals, and stamens, do not drop off as they would do in healthy plants. The effect of guano, even in very small quantities, was remarkable in increasing the crop.

Institution of Civil Engineers, April 29.—Mr. T. Hawksley, president, in the chair.—"On the Rigi Railway," by Dr. William Pole, F.R.S., M. Inst. C.E. The object of this railway was to convey passengers to the top of the Rigi, a mountain near Lucerne, from which there was a view so celebrated as to attract large numbers of visitors in the summer months. The line commenced at Vitznau, on the Lake of Lucerne, and was about four miles long. The works are mostly formed by cutting and benching on the rocky slope of the mountain. There was but one short tunnel, and only one iron bridge over a ravine. The gauge was 4 feet 8½ inches.

GLASGOW

Geological Society, April 10.—Mr. John Young, vice-president, in the chair.—The chairman exhibited a specimen