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condition of things, and to render the picture and visible shape of the age eternally present to posterity? We do not know; the advent of such men is not a thing to be calculated upon. There are ages in the world's history politically momentous, yet inglorious—

'carent quia vate sacro.'

But the final culmination of a period is when great actions are crowned by a splendid record. Meanwhile within the last few years a school of poetry altogether novel has been springing up—a school which, taking the classical legends as its main theme, only occasionally and in lyrical fashion glances from thence at the thoughts which are most prevalent among the inquirers and workers of the age. Of this school Mr. Morris is the most powerful writer; but the most striking single passages have, we think, been composed by Mr. Swinburne, in that volume of as yet unfulfilled promise, the 'Atalanta in Calydon.' To these poets we may recur on some future occasion; but at present we must be silent about them. Nor can we say more concerning such a graceful minor poet as Mr. Barnes, in his Dorsetshire poems; nor of those very notable writers, who, like Dr. Newman and 'George Eliot,' have expressed in verse the superabundance of feeling and thought that remained to them after the greater fullness of their labours in prose.

A. R. Wallace

Review of Lyell

ART. III.—1. *Principles of Geology; or the Modern Changes of the Earth and its Inhabitants considered as illustrative of Geology.* By Sir Charles Lyell, Bart., M.A., F.R.S. Tenth and entirely revised Edition. London, 1867 (Vol. I.), 1868 (Vol. II.).

2. *Elements of Geology; or the Ancient Changes of the Earth and its Inhabitants, as illustrated by Geological Monuments.* By Sir Charles Lyell, Bart., F.R.S. Sixth Edition. London, 1865.

THE first edition of the 'Principles of Geology' appeared in 1830: the tenth edition was completed in 1868. In this period of thirty-eight years the work has grown to double its original bulk, and has besides given birth to two vigorous children, the 'Elements of Geology' and the 'Antiquity of Man.' These have reached, the one a sixth and the other a third edition, and are both of them bulky volumes, the former even surpassing in size the entire parent work at the time when it first came before the public. Translations of all these works into French and German, and even into the Russian language, have made them widely known over the whole civilised world.

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We believe we are correct in saying that no other work on geology has ever reached ten editions; and we may perhaps go further, and say that no purely scientific work, not specially educational or popular, has ever had so large a circulation during its author's life. As another distinctive character of this work, we may point out that in its whole scope and aim it stands entirely alone and without rivals. Books on geology, like books on almost every other branch of science, can be counted by the dozen and the score; but among them all there is not one that goes over the same ground as Sir Charles Lyell's great work. We have volumes on every branch of the subject, mineralogical, stratigraphical, and palæontological; we have 'Handbooks' and 'Manuals,' 'Treatises' and 'Introductions;' we have educational, systematic, picturesque, and theological Geology: but we have no other work whatever on the Modern changes of the Earth and its Inhabitants considered as the very foundations and principles of Geology. And yet the subject is one of the most wide and varied interest, as we hope to be able to convince our readers. It admits of description of the most marvellous natural phenomena, and discussions of the most curious nature into the past history of the earth and even of the solar system. If, therefore, Sir Charles Lyell has been permitted to retain undisputed possession of this wide and fertile field of research for so long a period, we must impute it to his having treated the subject so exhaustively, with such lucidity of argument and such a charm of style, as completely to satisfy both scientific readers and the educated public, and thus render competition hopeless. A book with such a history is certainly worthy of our attention. We propose, therefore, to lay before our readers in the first place a short sketch of its main purport, bearing in mind the state of scientific opinion at the date of its appearance; and then to discuss some of the matters of very great interest which first appear in this tenth edition and make it in many respects an entirely new work.

At the time when Sir Charles Lyell first came before the public, the standard work on Geology both in this country and throughout Europe, was Cuvier's 'Essay on the Theory of the Earth.' In 1827, a fifth edition of the English translation was published, and so late as 1830 a German translation appeared,—striking proofs of its wide popularity, due no less to the great name of its author than to the authoritative tone in which it was written, the beauty and clearness of its style, and to its being almost the only recent work that discussed, however briefly, the great questions of theoretical Geology.

In this essay, besides giving an abstract of his researches on fossil

fossil animals, Cuvier proposed to show how far the 'history of the revolutions of the globe' had been restored, and he believed that he had determined many parts of it 'in such a rigorous manner' that they would be 'regarded as points definitely fixed, and form an epoch in science.' He then proceeds to contrast the calm and peaceful aspect of the surface of the earth with the appearances discovered when we examine its interior. Here in the raised beds of shells, the fractured rocks, the inclined or even vertical stratification, we find abundant proofs 'that the surface of the globe has been broken up by revolutions and catastrophes.' The different character and constitution of successive strata, and the diverse organic remains found in them, showed that the nature of the ocean and the matters which it held in solution must again and again have changed, and that there must have been various successive irruptions of the sea over the land. He then goes on to prove that these irruptions and retreats of the sea have not been slow or gradual; 'but most of the catastrophes which have occasioned them have been sudden;' and he remarks that 'this is especially easy to be proved with regard to the last of these catastrophes: that which, by a twofold motion, has inundated and afterwards laid dry our present continents.' This proof is so remarkable that it deserves to be quoted entire:—

'In the northern regions it [the inundation] has left the carcasses of large quadrupeds, which became enveloped in the ice, and have thus been preserved even to our own times, with their skin, their hair, and their flesh. If they had not been frozen as soon as killed, they would have been decomposed by putrefaction. And, on the other hand, this eternal frost could not previously have occupied the places in which they have been seized by it, for they could not have lived in such a temperature. It was, therefore, at one and the same moment that these animals were destroyed, and the country which they inhabited became covered with ice. This event has been sudden, instantaneous, without any gradation: and what is so clearly demonstrated with respect to this last catastrophe, is not less so with reference to those which preceded it.'*

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* Cuvier was at this time acquainted with Playfair's 'Illustrations of the Huttonian Theory,' in which that author maintains that the ice-preserved rhinoceros and mammoth of Siberia inhabited that country at a time when the climate was very little different from what it is now. After showing the untenability of every other hypothesis, Playfair thus sums up:—'On the whole, therefore, no conclusion remains but that these bones have belonged to species of elephants, rhinoceros, &c., which inhabited the very countries where they are now buried, and which could endure the severity of the Siberian climate. The rhinoceros of the Wilui certainly lived on the confines of the Polar circle, and was exposed to the same cold when alive, by which, when dead, its body has been so long and so curiously preserved.'—(Playfair's Works, vol. i. p. 464.) This view, which is that universally held at the

This passage may be taken as a good example of the style and tone of the whole work, which then proceeds to show that *life* has not always existed upon the globe, and that 'it is easy for the observer to distinguish the point at which it has begun to deposit its productions.' The 'primitive mountains' are said to afford this evidence, and their 'sharp and bristling ridges and peaks are indications of the violent manner in which they have been elevated.' On the flanks of these mountains 'a sea without inhabitants' deposited schists, porphyries, sandstones, and limestones destitute of shells, and prepared materials for the mollusca and zoophytes which were presently to deposit upon these formations vast heaps of their shells and corals.

After giving a sketch of the changes now going on, and describing erratic blocks, alluviums and volcanoes, he concludes that 'it is in vain we search among the powers which now act at the surface of the earth for causes sufficient to produce the revolutions and catastrophes, the traces of which are exhibited in its crust.'

He is not less confident of the 'newness of the present continents,' of which he furnishes physical proofs:—

'It must,' he says, 'have been since the last elevation of the land above the sea, that precipices began to disintegrate and to form heaps of débris at their bases; that our rivers have begun to flow and to deposit alluvial matters; that our present vegetation has spread over the surface and has produced soil; that our cliffs began to be corroded by the sea; that our sand downs began to be thrown up by the wind, and that men have begun to spread themselves over the surface.'

He then shows that all these processes go on rapidly, and concludes:—

'that if anything in geology be established, it is that the surface of our globe has undergone a great and sudden revolution, the date of which cannot be referred to a much earlier period than five or six thousand years ago; that this revolution overwhelmed and caused to disappear the countries which were previously inhabited by man, and the species of animals now best known; that on the other hand it laid dry the bottom of the last sea, and formed of it the countries which are at the present day inhabited.'

We have thought it necessary to bring forward what Cuvier taught, as nearly as possible in his own words, or it would hardly be credited to what extent the theory of 'convulsions' and 'catastrophes' was really carried. These doctrines had held undisputed

the present day, and is a striking example of the logical acuteness of its author, was however far too simple for Cuvier, who preferred calling in the aid of a most awful and utterly unimaginable catastrophe, which, had it ever occurred, must have destroyed every living thing in a large portion of the Palæarctic region.

undisputed sway for nearly twenty years, and had been weighted by the authority of one of the greatest scientific names in Europe. The chief writers on Geology in France and England supported similar views, while the doctrines of Hutton and Playfair, so much in advance of their age, seemed to be utterly forgotten. It was at this juncture, when Cuvier was at the height of his fame, and his 'Theory of the Earth' was still being translated into foreign languages, that a hitherto unknown author, Mr. Lyell, had the audacity to strike at the very root of this theory, and to demonstrate by masterly reasoning and by a vast array of facts, that almost every portion of it was radically unsound. From the date of the completion of the 'Principles of Geology' there appeared no more English editions of the 'Theory of the Earth.'

Instead of that hasty and superficial view of natural causes now acting, which led Cuvier and so many other writers to the conclusion that they were totally inadequate to explain the phenomena of geology, Mr. Lyell investigated them with the most painstaking minuteness, applied the tests of survey and measurement, and showed that, taking into consideration the element of long periods of time, they were, in almost every case, fully adequate to explain those phenomena. He showed at the same time, that violent and convulsionary action, vast débâcles and sudden upheavals, would not at all account for the observed facts. That if we descended from vague general comparisons, and studied in detail all the appearances presented by the crust of the earth, we found everywhere proofs of slow and continuous action, everywhere the minutest correspondence with what was now taking place, if we but took the trouble to learn what that really was. He showed that modern volcanoes had poured out equally vast masses of melted rock, which had covered equally extensive areas with any ancient volcano; that strata were now forming, comparable in extent and mass to any ancient strata; that organic remains were being preserved in them, just as in the older formations: that the land was almost everywhere rising or sinking as of old; that valleys were being excavated and mountains upheaved; that earthquake-shocks were producing faults; that vegetation was now preparing future coal-beds; that limestones, crystalline, metamorphic, and igneous rocks, were still being formed; and that, given time, and the intermittent or continuous action of the causes we can now trace in operation, and all the contortions and fractures of strata, and every other phenomenon supposed to necessitate catastrophes and cataclysms, may be again and again produced.

The views advocated with so much talent have steadily gained wider and wider acceptance, and have led to considerable modification in the doctrines held by those who have most consistently opposed them. The 'Convulsionists' of the present day, are very different from those of the time of Cuvier.

There is one objection made to the doctrines of the 'Uniformitarians,' as the followers of Sir Charles Lyell have been termed, which appears very plausible, but which rests upon a misconception of what those doctrines really are. It is said, that it is unphilosophical and almost absurd to believe, that in our little experience of a few hundred or at most a few thousand years, we can have witnessed all forms and degrees of the action of natural forces; that we have no right to take the historical period as a fair sample of all past geological ages; and that as a mere matter of probability we ought to expect to find proofs of greater earthquakes, more violent eruptions, more sudden upheavals, and more destructive floods, having occurred during the vast æons of past time. Now this argument is perfectly sound if it limits itself to the strict laws of probability and average, and no Uniformitarian would deny the possibility and even the probability of their having been *some* greater convulsions in past geological ages than have ever been experienced during the historical period. But the Convulsionists do not confine themselves to this. They maintain that, *as a rule*, all the great natural forces tending to modify the surface of the earth, were more powerful and worked on a larger scale than they do now, and that there has been a steady if not an uniform decrease in those forces from the earliest epochs to the present day. The Uniformitarians demand proofs of any such decrease of energy; and Sir Charles Lyell's book is in great part a critical examination of all these supposed proofs, and a more or less vigorous demonstration of their fallaciousness. His doctrine is simply that of real against imaginary causes, and he only denies catastrophes and convulsions to have been the course of nature in early times, because he finds that forces analogous both in kind and degree to those of existing nature are quite competent to explain all the phenomena.

We will now proceed to a consideration of the many interesting additions to this tenth edition of the 'Principles of Geology'; and some of these will serve to show how willing the author is to admit a former condition of the world very different from its present state, whenever there is direct evidence of such a change, and whenever causes which are known to have been in operation, seem adequate to have produced it.

In the first volume we find, besides many smaller additions, that five entire chapters have been added or re-written. These are,

are, Chapter IX. which treats of the progressive development of organic life, and will be better considered when we come to the new matter in the second volume; and Chapters X. to XIV. which discuss in great detail geological vicissitudes of climate and their probable causes, and are so exceedingly interesting as to deserve our attentive consideration.

One of the earliest and most striking deductions from the study of fossils, was, that the climate of former ages was warmer than that of the present day; and this was held to support the hypothesis of the primeval fusion of our planet. It was tacitly assumed that all the facts went to show a greater heat in the more ancient than in the comparatively modern epochs; and the scarcity or total absence of organic remains in the most ancient formations, was supposed to be due to the earth having then just solidified and begun to cool down, without being yet in a fit condition to support animal or vegetable life. This very simple hypothesis received its first shock when the existence of a former glacial epoch was demonstrated, and a more accurate study of all the indications of climate in past ages seemed to imply alternations of temperature rather than a regularly progressive decrease of heat. Proofs of a very warm climate in high northern latitudes, during the early and middle tertiary epochs were next discovered, while there seemed to be no satisfactory evidence that it was still warmer in the remotest palæozoic times. Then came the calculations of the physicists, who demonstrated that very soon after the crust of the earth had solidified, the climate of the surface would cease to be affected in any perceptible degree by the temperature of the interior, however high that might be; and it was at length perceived that the problem was a far more complicated one than had been at first imagined. Of late years our knowledge of the structure, affinities, and distribution of fossil animals and plants has immensely increased; the relation of existing organisms to climate has been more accurately studied; terrestrial and astronomical causes of change of climate have been inquired into, and we are enabled to approach this difficult question, with a full appreciation of its difficulty, if not with much confidence in our ability to solve it.

One of the most startling geological revelations of modern days is the demonstration, that at so comparatively recent a period as the Miocene a temperate climate prevailed within the Arctic circle, and poplars, planes, and lime-trees grew within twelve degrees of the pole. Beds of fossil-plants of this epoch have been found in Iceland, on the Mackenzie River in North Canada, in Banksland, in North Greenland, and in Spitzbergen. A hundred and forty-four species of flowering plants and nine ferns have

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been described by Professor Heer. Seventy-eight of these were probably trees, and fifty shrubs. There were no less than thirty-one Coniferæ, among which were four species of *Sequoia*, allied to the gigantic Wellingtonias of California (a group which was abundant in Miocene times), and three of these were also inhabitants of Central Europe. Species of *Thujopsis* and *Salisburia*, genera now found only in Japan, inhabited Spitzbergen and North Greenland, along with beeches, oaks, planes, poplars, maples, walnuts, limes, hazels, and even a magnolia. Among the shrubs were buckthorn, holly, dogwood, and hawthorn; while ivy and vines twined round the forest trees, and large broad-leaved ferns grew beneath their shade. Many of the limes, planes, and oaks had very large leaves, and the tulip-trees and maples bore large fruits; in some cases even the flowers are preserved, and the specimens are so abundant and so perfect, that it is impossible to escape the conclusion that all the plants grew upon the spot, and that the climate must have been at the very least as mild as that of the South of England at the present day. Yet in North Greenland an enormous glacier now covers the whole country, leaving only a narrow strip of land free from ice in summer, and no woody vegetation but a few dwarf willows can exist.

Here, then, we have absolute proof that the warm climate which characterised the Miocene epoch in the north temperate zone extended into the Arctic regions; and it is Professor Heer's opinion that forests might then have flourished at the North Pole itself. But although this is by far the most striking and the most satisfactory case, it is not the only indication of a mild Arctic climate in past ages. Ammonites, Belemnites, and an Icthyosaurus, have been found in Oolitic rocks about 77° N.—animals which we are almost certain could not have inhabited a frozen sea. Coal and characteristic coal-fossils have been found about the same latitudes. Again, in the oldest of all the formations which produce sufficient organic remains to afford any indications of climate—the Silurian—Encrinites, Corals, and Mollusca have been discovered in the Arctic regions, and seem unmistakeably to indicate a warm and open sea where there is now an almost perpetually frozen ocean.

Besides these indications of warm or temperate climates in past ages, extending sometimes far into the Arctic regions, the opinion has of late years been steadily gaining ground among geologists that there are also very satisfactory proofs of cold intervals or glacial epochs intercalated among them. In the same Miocene formation in which we find such abundant remains of the luxuriant sub-tropical fauna and flora that pervaded Central Europe,

Europe, there occurs south of the Alps a series of beds containing immense angular blocks of serpentine and greenstone, sometimes striated and polished, and thus exactly resembling those which occur in true glacial drift. The geological position of these beds is indisputable, since they rest upon Lower Miocene strata and are covered by an Upper Miocene shell-bearing formation; and Sir Charles Lyell admits, after close personal examination, that no other hypothesis than ice-action is at present tenable. Again, in the Eocene formation north of the Alps is an immense series of beds of sandstone and shale entirely devoid of all organic remains but fuci, and some of which contain angular blocks varying in size from 10 to 100 feet in diameter. These facts clearly point to deposit by icebergs in a cold sea.

Still further back in the Cretaceous period, isolated blocks of greenstone and syenite, often with granitic sand attached, found in the white chalk of the south of England, is held to indicate the action of ice, and to imply a cool climate somewhere near. It is now admitted that chalk is a deep-sea formation, and some of the stones found, weighing from thirty to forty pounds, cannot be accounted for by any other means of transport than floating icebergs.

We have no more indications of cold till we reach the Permian or Magnesian Limestone period, at which time Professor Ramsay has almost demonstrated the intercalation of a glacial epoch. A red unstratified marl occurs frequently in Worcestershire, Shropshire, and other parts of England containing angular fragments of various rocks, some half a ton in weight, and many of them polished and striated. They lie confusedly, just as do the rocks and pebbles in the boulder drift, and many of the blocks must have come from the mountains of Wales, twenty, thirty, or fifty miles distant. All this is so exactly characteristic of ice-action at the present day and in the recent glacial epoch, that we are compelled, however unwillingly, to admit that so far back as the Permian our seas were at times actually colder than they are now. Earlier still, in the Devonian, many geologists see evidences of ice-action in the conglomerates containing blocks and pebbles, some of which are polished and striated; and even in the still more ancient Cambrian strata some indications of a similar nature have been traced; but even if we neglect these more doubtful cases, we have sufficient evidence to give us a completely new idea of the past history of our globe. Instead of the regular increase of temperature in past ages which early geological and cosmical theories took for granted, we find proofs of alternations of warm and cold periods far back into the Palæozoic epoch, and no proof that the climate which produced the coal-plants was any warmer than that

that of the comparatively recent Miocene flora. Where we had expected to find a marked contrast between the old and the existing world, we discover on a more extended survey a close resemblance; and this resemblance extends in some cases to physical details of climate, which we might have supposed would leave no permanent record on the leaves of the great stone book, but which are so curious and instructive as to deserve more attention than has been given to them. In some of the older rocks small hemispherical impressions are found, which exactly resemble the marks left on a surface of fine sandy mud by a shower of rain. Circular pits of various sizes are thus formed, with a somewhat raised rim, and they are often all a little deeper on one side, showing the direction of the wind when the drops fell which produced them. Fine specimens of these rain-prints were obtained by Sir Charles Lyell from the mud-flats of the Bay of Fundy, in Nova Scotia, where in summer the sun dries and hardens the surface so rapidly that the succeeding tide covers them over with a layer of sediments, and thus effectually preserves them. A cake of this dried mud can be split, and will sometimes show the rain-marks and their casts on two opposite surfaces. Now the markings on certain Triassic and Carboniferous shales of North America correspond in the minutest particulars to these recent rain-prints, and even agree with them in the average size and depth of the pits; so that we learn, not only that rain fell in those early times, but that the general atmospheric conditions were so similar, that the size of the drops was about the same as they are now, that the sun shone out afterwards and hardened the surface, and that within a few hours the tide flowed gently over that ancient shore and deposited its preserving layer of sediment. There is a stratum of Triassic shales in New Jersey which preserves layer upon layer of these rain-prints, and among them Mr. Redfield, the well-known meteorologist, has detected curious indented subangular impressions which exactly correspond to the marks produced by a storm of angular *hail;* a most curious corroborative proof of the striking similarity of our present climates to those of the most ancient geological periods.

The evidence we have here briefly sketched, of alternations of cold as well as of warm climates, far into the remotest past of which Geology gives us any knowledge, and the proof it offers us, that in the enormous lapse of ages between the Carboniferous and the Miocene epochs there was no clearly-marked decrease of temperature, seems quite incompatible with the notion of the climate of our globe having been affected even in the earliest times by internal heat derived from a central fluid mass. The geological evidence of climate in the remotest epochs of the earth's earth's history gives absolutely no support to the view of its having ever been in an intensely-heated molten condition. Many attempts have been made to account for the alternations of climate about a mean condition somewhat warmer than that which we now enjoy. It has been supposed that the solar system passes through regions of space of higher and lower temperature. But this view has received very little support, for not only is it entirely beyond proof, but the astronomical and physical difficulties in the way of its reception are enormous. True to his great principle of seeking, in the present condition of the earth, for a clue to its past history, Sir Charles Lyell, in former editions, put forth a very beautiful theory of past changes of climate having been mainly due to a different distribution of land and sea from that which now exists. Many striking facts show that this is a real and efficient cause of abnormal climate. Cumberland House, in North America, has the same latitude as our city of York, but its mean temperature is the freezing point; Newfoundland, about the latitude of Paris, has the same mean temperature as Stockholm and St. Petersburg; while Ireland, in the latitude of frozen Labrador, has a uniform climate whose mean is the same as that of New York in the latitude of Naples. Turning to the Southern hemisphere, we find that in the island of South Georgia, in the same latitude as Yorkshire, the perpetual snows descend to the level of the sea, there are no trees or shrubs, and even at midsummer the heat rarely rises ten degrees above the freezing point. Yet at Terra del Fuego, in the same latitude, and only 800 miles further west, the snow-line is 3000 to 4000 feet high, the slopes of the hills are covered with forests, and in summer there are abundance of gay flowers, which are visited by humming birds! Now, all these striking differences, and many others equally curious, are known to be due to the distribution of sea and land. Water is an equaliser of temperature. Warm currents are continually flowing towards the poles, cold currents towards the equator. Land surfaces within or near the tropics produce heat, near the poles cold. High mountains always produce cold; and this cold or heat is carried by prevalent winds to adjacent and even sometimes to far distant lands. Thus, the winds that blow direct from Australia to New Zealand, 1500 miles distant, melt the snow on the Southern Alps of the middle island and produce floods, a fact which shows how much the climate of those islands might be modified, either by a south-eastern extension of Australia, or by a submergence which should lay its hot plains and deserts under water. In the former case the glaciers might almost disappear; in the latter (especially if an extension of antarctic land occurred at the same time towards

towards New Zealand) they might descend to the sea, and so deteriorate the climate as to render the island uninhabitable. The direction taken by icebergs greatly affects temperature, and this must depend on the direction of ocean currents, which are themselves dependent on the distribution of the land. The south-westerly winds which prevail in the temperate zones are an important factor in determining climate. They cause the western coasts of the great northern and southern continents to be so much milder and more uniform in temperature than the eastern, and we can scarcely doubt that if an archipelago of broken land occupied the place of these continents, the whole region would enjoy a more genial climate than any portion of it does now.

The present distribution of land and sea upon the globe is exceedingly irregular and unsymmetrical. The eastern hemisphere contains twice as much land as the western—the northern more than twice as much as the southern. But what shows the irregularity in a more striking manner is the fact that the globe can be divided into two hemispheres, one of which shall have about eight times as much water as land, while in the other the land and water shall be about equal, and of the latter hemisphere the British isles form the centre or pole. Now, as it is certain that much which is now land has very recently been sea, and as every spot which is now land has at some time been sea; and yet further, as we know that changes from land to sea, and from sea to land, have taken place over and over again at almost every part of the surface, we may feel pretty sure that many other equally abnormal distributions of land and sea have occurred during past ages, and that hardly any peculiarity of distribution is impossible. Yet, without any very extravagant supposition, we may see how very great changes of climate might be brought about. At present the oceans have free communication over the whole globe; the warm waters of the equator can penetrate to the poles, while the accumulated ice of the Arctic regions is melted by the warm southern currents. But suppose the Arctic and north temperate seas were ever completely, or almost enclosed by land—as might easily happen by a comparatively limited elevation of the sea bottom between Greenland, Iceland, and the Orkneys, and at the entrance to Davis' Straits—would not the ice of each successive winter accumulate so as to form a vast ice-cap which would inevitably produce a glacial epoch over the whole north temperate zone. If, on the other hand, the polar regions were as free from land as the Atlantic Ocean is now, and if almost all the highest land were situated within forty-five degrees of the equator,—which it might very easily be since those limits include considerably more than two-thirds of the whole surface of the globe,—

globe,—it is certain that no ice would ever be formed at sea, and that islands within ten or twelve degrees of the pole might enjoy a climate as mild as the south of Ireland or the warmest parts of New Zealand. The differences of temperature of places in the same latitude at the present day fully warrant this belief.

Changes of distribution of sea and land are therefore a sufficient cause for any changes of climate of which we have geological evidence. That changes of the required amount must certainly have occurred at various epochs of past time is also certain; yet Sir C. Lyell himself furnishes us with a very strong argument against these changes having been the sole cause of those variations of climate of which we have such clear evidence, although they may have been always an important, and perhaps an essential, collateral agent in their production. This argument depends on the fact that the depth of the oceans is much greater than the height of the continents. It has been calculated that the mean height of the whole land of the globe above the sea-level is only 1000 feet, while the mean depth of the oceans is 15,000 feet. Now, as there are mountain ranges of 20,000 feet and upwards, and many extensive plateaux of 8000 and 10,000 feet, it follows that a very large portion of the surface of the land cannot be much more than 500 feet high, so that a sinking of a hundred fathoms would convert a vast extent of land into sea. Again, all the shallow seas are near land, while the remoter portions of the great oceans are enormously deep, so that an elevation of 1000 or 2000 feet would only produce new land adjacent to existing land; while to change the ocean beds into dry land would require a continuous elevation of 15,000 or 20,000 feet. It follows from this, that while local changes of land and sea may be frequent and comparatively rapid, those greater changes which would result in the complete submergence of continents and elevation of the deepest ocean beds, can only be the work of long periods of time, comparable at least to the age of entire geological formations. When, therefore, we find evidence of great change of climate in the same formation, such as the glacial epochs of the Eocene, Miocene, and Newer Pliocene formations, which seem to have been immediately preceded and followed by warm or temperate periods, it may be argued that we can hardly impute such changes entirely to modifications in the distribution of sea and land, of which we have in most cases no evidence. But, on the other hand, it may be urged—and the argument is a very forcible one—that, as we know that Newer Pliocene strata in Sicily have been raised to a height of 3000 feet above the sea, and the still later glacial drifts in the British Islands to more than 2000 feet, it is evident that such an amount of of change is possible in a very limited portion of geological time as to be capable of producing important modifications of climate. A subsidence of no greater amount than the elevations now referred to would depress the Isthmus of Panama and a large portion of Nicaragua to the depth of a thousand feet below the sea-level, so that the Gulf Stream might pass entirely into the Pacific ; and it is a very curious circumstance that quite recently it has been ascertained by Dr. Gunther that no less than 57 species of true marine fishes are found on both the Atlantic and Pacific coasts of Central America out of 173 species known to inhabit those waters.* These species, Dr. Gunther remarks, are absolutely identical, and present no local modifications whatever, so that we are almost driven to the conclusion that there has really been a temporary connexion between the two oceans at a very recent period. The Mollusca, it is true, show no such striking identity of species, but this is not difficult to explain when we consider how comparatively limited are their means of dispersal, and how completely their existence is dependent on local conditions, which might not be favourable on the shores or in the bed of the interoceanic channel.

It is now generally admitted that during the glacial epoch a considerable part of northern Europe was submerged, admitting of the southward passage of the cold and iceberg-laden water of the Arctic seas. Add to this the undoubted recent submergence of the Sahara, and the very probable divergence of the Gulf-stream,—and we have three distinct changes in the distribution of land and sea probably occurring about the last epoch of excessive cold. Each of them is admitted to be capable of producing a very considerable effect on climate, and it does not seem improbable that the three combined would have had so powerful an effect, that if their occurrence were really synchronous they might well have proved a sufficient cause for the glacial epoch.

For some years past great attention has been paid to the question of what effect astronomical causes may have had upon climate, and Mr. James Croll has published a series of able papers on almost every phase of this subject. The thirteenth chapter of the 'Principles' is devoted to a discussion of the facts and arguments of Mr. Croll and others on this interesting problem, which is connected with some of the boldest speculations of modern science.

The earth in its revolution round the sun describes an ellipse, differing very little from a circle. The excentricity of this

* 'Transactions of the Zoological Society of London,' vol. vi. p. 397 (1868).

ellipse

ellipse varies slowly and irregularly, and it may in the course of ages approach very nearly to a circle, or become very perceptibly elongated. The excentricity cannot however exceed certain limits, which are pretty accurately known. When the excentricity is least, the difference between the earth's perihelion (or least) distance from the sun, and its aphelion (or greatest) distance is about half a million of miles; when greatest the same difference may amount to 14 millions. At present the difference is about 3 millions of miles. The total quantity of heat received by the earth from the sun in each revolution is inversely proportional to the length of the minor axis of the ellipse, and this varies so little for all changes of excentricity, that the extreme possible differences of total annual heat due to this cause alone are as 1000 to 1003, or so small as to have no perceptible effect upon climate.

But the obliquity of the ecliptic, leading to the difference of seasons and the long polar day and night, materially affects this result, because the two hemispheres will be differently acted upon by an extreme degree of excentricity according as their summer or winter occurs at perihelion or aphelion. If the north pole is turned away from the sun when the earth's distance is at a maximum, the winters will not only be colder but also longer than they would be if the earth were at its minimum distance; while at the same time the southern hemisphere will have shorter and milder winters. Now, the procession of the equinoxes, combined with the revolution of the apsides, cause all these changes to be gone through in about 21,000 years, so that if at any given period winter in the northern hemisphere occurs at aphelion, in 10,500 years afterwards it will occur at perihelion, and at the end of the full period of 21,000 years will occur again in aphelion. It has been stated that the change of excentricity is irregular, but it is also very slow; so that several complete revolutions of the equinoxes may occur during a period of great excentricity, and the question is to discover whether these alternations of very long and cold with very short and mild winters, at intervals of about 10,500 years during periods of great excentricity, will account for the glacial epochs which seem to have occurred, as it were suddenly, in the midst of warmer periods.

The heat derived from the sun varies as the square of the distance, and it is calculated that when winter occurs in aphelion during an extreme excentricity, that hemisphere will be receiving one-fifth less heat than it does now when the excentricity is very small. It is therefore supposed that all the moisture in high latitudes would fall as snow instead of rain, and would accumulate to such an extent that the heat of summer, although very great

great (but of short duration), would be insufficient to melt it. The power of the sun in summer would, it is said, be diminished by the quantity of fog and cloud produced by the action of so much melting snow and ice. Thus the snow would accumulate year by year till a sheet of glacier ice covered all the high lands, and even descended over much of the plains, as we know it did during the glacial epoch.

At the same time the opposite hemisphere, enjoying a short and mild winter, would have little snow, and the long moderately warm summer would soon melt it and thus lead to an almost perpetual spring near the poles, while the temperate zone, Mr. Croll thinks, would enjoy a perpetual summer. Thus would be produced a condition of things similar to that of the carboniferous epoch, when there was a warm, moist, and equable climate throughout temperate and even Arctic latitudes. These results are supported by a great array of calculation of temperatures, which are, to say the least, of very doubtful value, as it is impossible to determine how far they would be modified by terrestrial conditions. A striking example of the preponderating influence of terrestrial over astronomical causes in determining climate is afforded by the present state of the earth. The excentricity is now 3 millions of miles, and we are to that extent nearer to the sun in winter than in summer, while the southern hemisphere is so much farther from the sun in winter. The difference is one-thirtieth of the mean distance, and the whole earth ought therefore to be one-fifteenth warmer in December than in June. But exactly the reverse is found to be the case, and the whole earth is really colder in December, owing to the greater masses of land in northern than in southern regions. According to calculation, the northern hemisphere ought to be warmer in winter and colder in summer than the southern, since the earth is in that phase of procession which ought, according to Mr. Croll, to produce some approximation to a perpetual spring in the north temperate zone; but the reverse is again the fact, as shown by the following mean temperatures given by Dove:—

Northern Hemisphere ..	Summer, 70°·9 ..	Winter, 48°·9 ..	Difference, 22°·0
Southern Hemisphere	„ 59·5	„ 53·6	„ 5·9

Here we see that the southern hemisphere, taken as a whole, approaches to the perpetual spring which ought to occur in the northern, and there is little doubt that if the great mass of lofty antarctic land were to be submerged and the same quantity raised near the tropic of Capricorn, this would actually exist in all the south temperate zone. Now, when we find that not only does our present amount of excentricity produce absolutely no perceptible

perceptible effect on our climate, but that the real differences of the two hemispheres are in an exactly opposite direction and of a very considerable amount, and when we know that this effect is produced solely by terrestrial causes, we must feel very doubtful whether an excentricity three or four times as great might not also have been often partially neutralised by similar causes.

Mr. Croll has calculated a table of the amount of excentricity for the last million of years, for the purpose of seeing how far the probable date of the glacial epoch could be determined. He finds that there was about three times the present excentricity 100,000 years ago; three and a half times 200,000 and 210,000 years ago; and nearly as much 850,000 years ago. Mr. Croll was at first disposed to place the glacial epoch at the remotest of these dates, and Sir Charles Lyell thinks that the more recent periods do not afford time for those changes in physical geography and in organic life of which we have proof. Since then, however, Mr. Croll has changed his opinion, and thinks that the middle period, or 200,000 years ago, is quite as far back as we can place the date of the glacial epoch, while 850,000 years ago will mark the Miocene glacial epoch. His reasons for this change of opinion will introduce us to some of the most curious speculations of modern geology.

Taking the glacial epoch at about 800,000 years back as a basis, Sir C. Lyell has calculated, by the proportionate change in the forms of life, the approximate age of the entire geological series. He puts the Eocene at 60 millions of years back, the Carboniferous at 160 millions, and the Cambrian at 240 millions of years. Now Sir William Thomson, of Edinburgh, has argued, and Mr. Croll thinks demonstrated, that it is absolutely impossible that the existing order of things on our globe can go so far back, because the sun is emitting heat at such a rate that no conceivable agency could have maintained it the required number of years.

It may be fairly doubted, however, whether our knowledge of the forces of the universe is at present so accurate or so complete as to enable us to speculate with any chance of arriving at the truth, on such tremendous problems as the age of the sun and the sources of its light and heat. Even among physicists and mathematicians there are radical differences of opinion on these questions, and Professor Challis has published a paper on the 'Source and Maintenance of the Sun's Heat,'* in which he directly opposes Sir W. Thomson's views, and maintains that the light and heat of the sun are due to the dynamical action of different orders of vibrations of the ether upon each other; and

* 'Philosophical Magazine,' 1863, p. 460.

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he seems to think that they are closely related to the force of gravitation and are equally inexhaustible. When such great men as these disagree, the geologist may take heart, and pursue his researches into the past history of our globe, unchecked by the dread of overdrawing his account at the bank of time.

But although we may feel satisfied that the physicists have not yet quite settled the antiquity of the sun, and thus placed a limit to the age of the earth and the other planets, recent geological investigations of a very definite character do seem to show that the time required for the past changes of the earth has sometimes been over-estimated. Sir Charles Lyell has given a full account of the enormous quantity of sediment brought down by the Ganges and the Mississippi, and has calculated at what rate the deltas of these rivers have been formed, and how vast an extent of new strata they may be building up at the bottom of the ocean. But these and similar statistics have been made use of in a still more instructive manner by Mr. Croll and Mr. Geikie, as a means of proving the unexpected rapidity of sub-aërial denudation, not only in forming valleys and mountains, but in steadily and surely lowering the surface of whole continents. This subject deserves our attentive consideration, since it appears to afford one of the most reliable measures of geological time.

It is evident that all the sediment, sand, and gravel carried by a river to the sea must come from some part of the surface drained by that river, and when the quantity of solid matter and the area of the river-basin are known, it is easy to calculate the average depth annually taken from the surface. In many cases the quantity of solid matter carried down by rivers has been accurately determined, and the following are some of the results given by Mr. Geikie:—

The Ganges has its basin lowered $\frac{1}{2358}$ of a foot per annum.
The Mississippi ,, ,, ,, $\frac{1}{6000}$,, ,, ,,
The Hoang-ho ,, ,, ,, $\frac{1}{1464}$,, ,, ,,
The Rhone ,, ,, ,, $\frac{1}{1528}$,, ,, ,,

In other words, in about 1500 years the whole basins of the Hoang-ho and the Rhone will be lowered a foot; in 15,000 years, 10 feet; and in 1,500,000 years, 1000 feet. But the mean height of Europe is only about 670 feet, so that if other rivers carry down as much sediment as the Rhone, in little more than a million years Europe will be planed down to the level of the sea. Of course as the surface becomes lower, the denuding and carrying power would be less, and this would greatly lengthen the process; but on the other hand, large tracts of the basins of all large rivers are alluvial flats, and are subject to occasional overflowings. These are all raised rather than lowered, and therefore imply a greatly increased

increased action on the sloping surfaces. Again, wherever there are lakes, as in the Rhone basin, an immense quantity of the sediment goes to fill up the lake, and this has to be added to the quantity brought down to the sea, and goes to increase the action on the hills and slopes. We must consider further, that the denuding action goes on with exceeding irregularity; in some parts the surface wears away rapidly, in others it remains unchanged for thousands of years. Solid rock-surfaces retaining glacial striæ and loose moraines still remaining in Welsh valleys sufficiently indicate how local and partial is the denuding action. But this only proves how powerful it must be in other places,—how valleys must be deepened, how precipices must be eaten away (as is often indicated by the taluses at their feet), how chalk and limestone must be dissolved, and how sand, gravel, and the less tenacious clays must be rapidly carried down by every shower of rain and every tiny brooklet. If in two or three thousand years the average surface of a country is lowered a foot, then certainly the definite lines and limited surfaces, where denudation is most active, must be lowered ten or perhaps fifty feet; and in 80,000 years, the very lowest of the periods that can be assigned since the close of the glacial epoch, changes of surface must have been produced that would be measured by hundreds of feet; and in the much vaster period adopted by Sir Charles Lyell, by thousands.

It must, we think, be admitted that this actual measurement of the quantity of matter conveyed away from the surface of a country by its rivers at the present day is a very powerful, though not perhaps a conclusive, argument against adopting the epoch of 850,000 years ago as the date of the glacial period; and at first sight it seems equally strong against that of 210,000 or 80,000 years. We must consider, however, that a considerable portion of the matter carried down by rivers consists of loose materials, through which they and their numerous tributaries cut their channels; and if such loose materials were scarce, the quantity of denuded matter would be very much diminished. The well-known black-water rivers of South America bring down exceedingly little sediment, and the amount of denudation effected in the vast granite district of the Upper Rio Negro must be almost infinitesimal. Among the mountains of Wales and Scotland we often see streams which even in floods have clear brown waters, and hardly bring down any sediment, while others are heavily charged with earth, gravel, and stones. Now, every subsidence of a country beneath the sea will tend to fill the lower valleys with such loose materials, which will furnish afterwards a large portion of the sediment carried down by the rivers. Such subsidences

sidences and elevations have perhaps occurred many times since the glacial epoch; unequal subsidences will have sometimes altered the level of valleys and diminished the carrying power of rivers; and we can hardly solve this question of the rate of denudation satisfactorily till we find a river-basin which contains no gravel, drift, or loose soil already deposited in it, and, by determining the quantity of matter it carries away annually, get some notion of the amount of average rock-formations denuded by sub-aërial action. We are inclined to think that this would be found to be a very small fraction of that given by most of the rivers which have already been measured.

If this view of the case is correct, it will follow that the enormously rapid rate of denudation going on now is only rendered possible by recent submergence of the land, especially during the last glacial epoch, when vast deposits of gravel, drift, and clay were formed in the valleys and lowlands, and even to the height of several thousand feet on the mountains. The quantity of matter now carried away by our rivers is therefore no measure of the rate at which solid rock formations can be denuded, or whole continents eaten away. To determine this we require measures of the sediment carried away from purely intertropical river-basins, whose sources do not descend from snowy mountains. Such rivers as the San Francisco and the Tocantins in Brazil would perhaps serve for this purpose, although from the abundance of the tropical rains there can be little doubt that they must possess more denuding power than the rivers of temperate latitudes; unless the powerful agency of frost in loosening and decomposing rocks should balance the effect of the tropical rainy seasons.

It may however be argued, that no measure of the rate of destruction of our continents can be obtained by a study of denudation alone, because the subterranean elevating forces must always on the whole have fully balanced the degrading forces, and are probably still doing so. But though the mean height of a continent may be kept stationary, or may even be increased by the action of subterranean forces, this will actually assist the denuding power, by loosening rocks, causing mountain slides, raising and inclining alluvial deposits, and altering the slope of valleys. The form of the surface will therefore be continually more and more changed, and the existing rate of denudation on the most moderate estimate, shows that the amount of this alteration of the surface would be enormous in the course of hundreds of thousands of years.

We have been able to glance only at a few of the more important considerations that enter into the difficult questions of geological

geological climates and geological time. The subject is now being discussed so vigorously and studied so carefully that we may soon hope to arrive at more definite results than have hitherto been possible. The impression produced by our own study of the subject may be expressed in the following propositions:—

1. That geology affords no evidence in support of the view that, on the whole, the more ancient were hotter than the more recent climates. The Palæozoic age may have been, for anything we know to the contrary, less tropical than the Tertiary.

2. That the present climate of the globe, and especially of the northern hemisphere, is abnormal; and this can be clearly traced to the very abnormal distribution of land and water that now obtains.

3. That the main vicissitudes of geological climate, and especially the alternations of warm and cold climates of which we have distinct evidence, have been to some extent due to regularly recurring astronomical causes, whose effects were, however, profoundly modified, or sometimes entirely neutralised, by terrestrial changes of surface acting in conjunction with, or in opposition to them.

4. That the date of the glacial epoch may not have been earlier than some portion of the latest period of great excentricity (from 80,000 to 250,000 years back), and was probably due, in great part, to its coincidence with one or more of the very important changes of physical geography (the subsidence of the Sahara, of the Isthmus of Panama, and the communication of the Arctic Ocean with the Baltic), which are known to have occurred somewhere about the same time.

We have dwelt at so much length on one of the important subjects first discussed in detail in the tenth edition of the 'Principles of Geology,' that we must pass over the new and valuable matter in the eight interesting chapters on Etna and other volcanoes, and on the general phenomena of earthquakes and of elevation and subsidence of land, in order to give some account of what will always be considered the great distinguishing feature of this edition,—the adoption in its main outlines, if not in all its details, of Mr. Darwin's theory of the Origin of Species.

In all previous editions of his work Sir Charles Lyell had strenuously opposed the theories of transmutation or development put forth by Lamarck, or by the author of the 'Vestiges of Creation,' and had endeavoured to show that they were unsupported by facts. True, however, to his grand principle of explaining the former history of the earth by a reference to the phenomena sidences and elevations have perhaps occurred many times since the glacial epoch; unequal subsidences will have sometimes altered the level of valleys and diminished the carrying power of rivers; and we can hardly solve this question of the rate of denudation satisfactorily till we find a river-basin which contains no gravel, drift, or loose soil already deposited in it, and, by determining the quantity of matter it carries away annually, get some notion of the amount of average rock-formations denuded by sub-aërial action. We are inclined to think that this would be found to be a very small fraction of that given by most of the rivers which have already been measured.

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more than thirty years, and during the issue of nine editions of his work, Sir Charles Lyell had been constantly quoted as the greatest and most authoritative opponent of 'transmutation:' a doctrine which he had, in fact, very strongly condemned. In his tenth edition he re-writes the whole of this portion of his book, and gives in his adhesion to a theory which to superficial readers will appear hardly distinguishable from that which he had all his life so unmistakably opposed. The history of science hardly presents so striking an instance of youthfulness of mind in advanced life as is shown by this abandonment of opinions so long held and so powerfully advocated; and if we bear in mind the extreme caution, combined with the ardent love of truth, which characterise every work which our author has produced, we shall be convinced that so great a change was not decided on without long and anxious deliberation, and that the views now adopted must indeed be supported by arguments of overwhelming force. If for no other reason than that Sir Charles Lyell in his tenth edition has adopted it, the theory of Mr. Darwin deserves an attentive and respectful consideration from every earnest seeker after truth.

The statement is often made that Darwin has only revived the theory of Lamarck under a new name, and although the mere fact, that so cautious and acute a thinker as Sir Charles Lyell sees in them the wide difference between truth and error, is almost a sufficient answer to this accusation, it may be as well to point out briefly in what the difference consists. The theory of Lamarck was, that there were two causes tending to effect changes in animal and vegetable forms,—the influence of external conditions leading in animals to changes of habits, which in time modify their form and structure, and the tendency to progressive development. The first is a real cause, but one quite inadequate, as is best seen in its application to plants; for although the constant running of an antelope in endeavouring to escape from its enemies may be supposed to increase the length of its legs and the rapidity of their motion, we can see no such reason why one plant should acquire the power of climbing, and another that of floating at the surface of the water, or why a herb should acquire the woody trunk of a tree. Again, we have no shadow of an explanation given us of the complicated adjustments of the parts of organisms, of the stamens to the pistils of plants, of the teeth and claws to the stomach of animals, of the colours of animals to the purposes of concealment, of flowers to the insects that fertilise them. We are now referred to the second cause of change—the tendency to progressive improvement. But this is a purely imaginary one. Its exist-

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ence is not demonstrated; we are not told how or whence it arises, or how it can act, nor are we able to form any clear conception of a power capable of producing such a result as the progressive improvement of all the varied forms of life, except through the intervention of a variety of subsidiary laws and actions. Such a supposed *tendency* is as vague and as useless as it would be to impute all life and all its forms to the action of a 'vital principle,' or an 'organising fluid.' It is evident, therefore, that Lamarck was unable to give any intelligible explanation of nature.

Darwin, on the other hand, is at all events clear and intelligible. He calls in the aid of no 'tendencies' or 'principles,' which he does not clearly explain, and he supports every position by an appeal to the facts of nature. More than this, he appeals to *all* the facts, and applies his theory to the explanation of the most varied and the most complicated phenomena; and he is ready to give up his whole system if one fact can be found absolutely irreconcileable with it.

Mr. Darwin's theory is based on a very few groups of observed facts, and on one demonstrable principle. The first group of facts is the *variability* of all organisms descended from the same parents; a variability not confined to external form or colour, but extending to every part of the structure, and even to constitutional and mental characteristics. This variability is found to be one of the most universal facts in nature. It is not common or general only, but absolutely universal. Every one knows from his own experience that no two individuals of a family, whether human or animal, are absolutely alike, but no one knows the large amount, or the infinite phases of this variability, but the naturalist or the breeder.

The fact of universal and all pervading variability being proved, it is next shown that every kind of variation can be accumulated, by the simple process of choosing from a great number of individuals those which possess any given variation in a marked degree, and breeding from these. It is found that in the next generation, the offspring do not, as might perhaps have been supposed, cease to vary further in the same direction, but generally vary from their parents as a centre in every direction, and if a large number of individuals are produced, a considerable increase of the first variation may be obtained. For example, the wild jungle cock (*Gallus bankiva*) has an average size about equal to that of our smaller kinds of domestic poultry, and out of thousands or millions of individuals none are ever so large as the 'Shanghae,' or so small as the 'Bantam' breeds. Yet these are descended from the same race, made permanently larger or smaller

smaller by the process above described. In pigeons, the bill, the feet, the wings, and the tail have been altered in size and form to an extent nowhere seen in the original wild stock, and Mr. Darwin has shown that the bones and internal organs are capable of modification to an equal extent. The power of accumulating every kind of variation is therefore proved, and this is the very corner-stone of the theory, and that which best distinguishes it from all hypotheses of transmutation or development that have preceded it.

Another fact of importance is, that all living things have the capacity of increasing in a geometrical ratio. If a pair produce ten young ones once during their lives, and these breed at a year old, there will be nearly 20 millions produced in ten years. Many animals, and most plants, have far greater powers of increase than this, and even the slowest breeding of all, the elephant, would in 500 years increase from a single pair to 15 millions. But we know that in any country once stocked with animals and plants, the number of individuals may fluctuate slightly, but never regularly increases. Taking an average of all the species, it certainly remains nearly stationary. It follows, therefore, that the deaths every year are almost exactly equal to the births. If the number of sparrows in England is on the average half a million, and if a million young ones are hatched every year, then before the next year a million sparrows must die. So in a forest of oaks, the number of trees cannot increase on the same space of ground, yet millions of acorns are dropped annually, and would all become oak-trees under favourable conditions, but all must die before maturity till an oak falls and leaves room for some of them. Now when, according to our supposition, a million sparrows die every year, what is it that determines which individuals die and which survive? We know that wild animals die of diseases, of hunger, of cold, by the attacks of enemies, and perhaps from other causes. Will it be the healthy or the sickly that will die of disease,—the strong or the weak that will die of hunger,—the well feathered or the poorly feathered that will die of cold,—the active and wary or the slow and careless that will be killed by enemies? We can only answer these questions one way. We are as sure of the average result, as we are that an Insurance Company, which charged the ordinary rates to all people with consumption and heart-disease would soon be bankrupt; and we may well express it by the term—'survival of the fittest,'* a term which states the absolute fact, that those

* This term was first used by Mr. Herbert Spencer in his remarkable work, 'The Principles of Biology,' and its more general adoption would alone answer some of the popular objections to Mr. Darwin's theory.

best

best adapted to survive do survive, and those least adapted die. This is Mr. Darwin's celebrated theory of 'Natural Selection,' but which is more properly a self-evident principle or axiom. Having been led to it by the analogy of the choosing or selecting by man of certain varieties to continue the breed, while others were neglected or destroyed, he personified the various natural causes which led to the preservation of the half million, and the death of the million, and termed them 'natural selection.' But people are continually forgetting that the term is an analogical one, and object over and over again that 'selection' implies a selecter; whereas if they would take pains to understand the thing, instead of puzzling over the mere term, they would see that the preservation of those best fitted to live, was as much the secondary result of the powers of nature as is the arrangement of sand and pebbles by water, or the selecting of leaves to be drifted into heaps by the wind, while the stones and sticks are left behind.

Fully bearing in mind these great and demonstrable facts—the universal variability of all organisms and of all their parts,—the possibility of accumulating these variations in definite directions—the enormous reproductive powers of all living things; and the mortality equal to the births,—and lastly the necessary survival of the fittest—we shall be able to see, that the changes in external nature animate and inanimate continually going on, must produce indirect effects vastly greater and more important than any which, as Lamarck supposed, they can produce by their direct action on individuals or species.

Let us take first the differences of colour in animals. These are absolutely inexplicable on Lamarck's theory, for we do not find that any change of conditions produces definite changes of colour, still less does it produce the varied spots, lines, bands, and patches of colour that occur in animals. Neither have the motions of animals, their desires, or their food been proved to produce any definite effects on their colours. But we know that colour is the most variable of all an animal's characters, and yet in a state of nature colour as a rule is very constant in each species. Mr. Darwin has shown, however, that colour is often intimately associated with other constitutional peculiarities. In Virginia the paint root (*Lachnanthes tinctoria*) is eaten by pigs, and makes their hoofs drop off. But black pigs are uninjured by it. Consequently, in places where this plant is abundant the farmers never keep any but black pigs, as no others can be raised except in confinement. Here we have a beautiful illustration of the mode of action of 'natural selection.' The pigs of Virginia are not all born black any more than in other countries,

but

but those of all other colours soon die, and therefore in a state of nature a black race would be produced; and from the powerful action of the law of hereditary descent there can be little doubt that in time the litters would consist almost entirely of black pigs. If after this had happened it were first discovered that white or brown pigs could not live in the district, we should have a striking example of adaptation; but the adaptation would evidently be an adjustment brought about by the simple law of 'natural selection' or 'survival of the fittest,' and the rigid extermination of all individuals not adapted to the surrounding conditions. It can be easily seen that in this case 'natural selection' does not imply a personal selector, since exactly the same result must happen whether the farmer kills off the white pigs himself and turns the black ones loose, or turns out all together.

This case, although curious, is by no means isolated. White terriers suffer most from distemper, and white chickens from the gapes. In Sicily the *Hypericum crispum* is poisonous to white sheep alone. White horses suffer severely from eating honey-dewed vetches, while chestnuts and bays are uninjured. Purple plums in North America are subject to a disease from which green and yellow plums are free. Again, the white pigeons of a flock are the first to fall victims to the kite. White rabbits of a very hardy kind have been turned loose but fail to maintain themselves, and black fowls on the west coast of Ireland are picked off by sea-eagles. Here we have the explanation of the otherwise puzzling fact, that white quadrupeds and birds are so rare in nature, although abundant among all domesticated animals; and the explanation is all the more satisfactory because it accounts for the exception to the rule, in the case of many arctic birds and quadrupeds as well as of sea birds, for to these the white colour is a protection instead of a danger. Now this same principle will apply to structural and constitutional peculiarities and to habits. Man can accumulate variations either in the root, the leaf, the flower, or the fruit of plants, their colour, odour, or taste; in the size, swiftness, or scent of dogs; he can alter the bill, the feet, the tail, or the habits of pigeons; can increase the milk of the cow or the fat of the pig; can alter the length of ear in the rabbit and of horns in the bull, or can attend to two or even more of these points at once. In like manner the law of 'survival of the fittest,' by simply determining which out of the immense surplus annually born shall be the parents of the next generation, must lead to the modification of every part of an animal's organization that affects its welfare,—that is to say, sooner or later of its whole organization. So long as the changes of of land and sea of which geology assures us, and their concomitant changes of climate, of soil, and of vegetation, and of the distribution of animal forms, are going on, each species in turn must be exposed to new conditions and new dangers, must have to live upon new food, or to struggle with new enemies. Those whose organization is sufficiently flexible to furnish in each generation favourable variations, will become adapted to the new conditions and will appear as the new or representative species of the naturalist; such as could not vary quickly enough would die out, and furnish the extinct species whose remains the palæontologist disentombs.

Here we have at all events a real and a powerful cause in action, and one which is accurately defined, and has been copiously illustrated by observation and experiment. No occult powers are postulated, but instead of them demonstrable groups of facts; and Mr. Darwin has developed his theory so fully and has shown it to be in accordance with such a vast mass and variety of phenomena which on any other hypothesis are unintelligible, that it has commanded very general acceptance, especially among geologists with whose general doctrines it so well harmonizes. Yet geology has furnished perhaps the most formidable or at least the most often quoted objections to it; but these objections are of a nature to weigh more with the public than with men of science, since they depend in a great measure upon the assumption that our knowledge of the past history of the earth is tolerably complete. Mr. Darwin, however, lays great stress upon the extreme imperfection of the geological record itself, and the very small portion of that record which we have yet brought to light. This was fully established by Sir Charles Lyell even in his first edition, but as the subject is an important one and very commonly misunderstood, it will be as well to give a short sketch of it.

The first consideration is, that as the ocean covers by far the larger portion of the globe, and has, as long as our continents have retained their present outlines, received much of their preservable organic remains, we are at once precluded from ever obtaining a sight of a large portion of the record. On the land itself we only get a glimpse of its interior here and there: in valleys, in railway cuttings, or in quarries, mines, and wells, and only in a few of the more civilised parts of the globe. But even in the places where we have access to the strata formed at any former period of the earth's history, we know that those strata will not contain anything like a consecutive record of the animals and vegetables that lived in its vicinity. As long as the surface at that spot was dry land, few or no organisms could be be preserved, except at the mouth of some large river which might carry down their remains and cover them with sediment. But when the strata thus formed came to be raised up again above the waters, they would be exposed to the action of the waves and in most cases be eaten away and redistributed on the sea-bottom. Only when a long-continued subsidence had allowed strata of great thickness to be formed, and when the subsequent elevation was so rapid or the situation was so favourable that they could resist the denuding action of the sea, would fossiliferous strata ever rise above the surface. We might, therefore, anticipate, that between the formation of any given beds and others of different composition lying upon them, there would often elapse vast and unknown intervals of time, allowing for a complete change in animal and vegetable life; and this is exactly what geologists find. In the infancy of the science it was supposed that this indicated a catastrophe by which hundreds of species were destroyed, and a sudden creation of hundreds of new ones. Now it is universally admitted to prove only a vast lapse of time.

But even under the most favourable conditions different groups of animals will be very unequally preserved. Shelly molluscs will, perhaps, be abundant; corals sometimes equally so; crustacea and fishes, being easily decomposed, more rare; terrestrial reptiles and mammals still scarcer; and flying birds and insects the scarcest of all. All soft creatures, naked molluscs, zoophytes, medusæ, and the more delicate insects, will never be preserved at all. Bearing these various facts in mind, how rash it must be to conclude that because we do not find the remains of any group of animals in certain strata, those animals nowhere existed on the globe at that time! It seems almost too absurd to hold any such opinion; yet this is really the essence of the most common argument against Mr. Darwin's views. 'Where,' it is said, 'are the intermediate forms connecting distinct groups of animals which must have existed if your theory is true?' The sufficient answer to this objection is, that the chances against any particular intermediate type being found are so nearly infinite, that we need not expect to find it; but that numerous intermediate types have been discovered, and their number steadily increases with the process of geological investigation. Professor Owen has repeatedly declared that one of the chief characteristics of extinct animals is to be more generalised in structure than existing species, and this is exactly what we should expect if the one has descended and diverged from the other. Cuvier considered the ruminants and the pachyderms as two most distinct orders of mammals; but Owen and others

others have now demonstrated that there once existed a variety of genera and species connecting, by almost imperceptible grades, such widely different animals as the pig and the camel. Scarcely a more isolated group than the genus *Equus* (comprising the horses, asses, and zebras) can be found among living quadrupeds; but through the intermediation of three fossil genera it is connected by a regular series of forms to the Eocene *Palæotherium*, itself allied to the existing tapir and rhinoceros. The recent researches of M. Gaudry in the Miocene strata of Greece have furnished much new evidence in the same direction. He has discovered the group of the *Simocyonidæ*, intermediate between bears and wolves; the genus *Hyænictis*, which connects the hyænas with the civets; the *Ancylotherium*, which is allied both to the extinct mastodon and to the living pangolin or scaly ant-eater; and the *Helladotherium*, which connects the giraffes with the deer and antelopes. Between reptiles and fishes an intermediate type has been found in the *Archegosaurus* of the coal formation, and the Triassic *Labyrinthodon* combined characters of the Batrachia with those of crocodiles, lizards, and ganoid fishes. Even the birds, the most wonderfully-isolated of all existing orders of animals and the most rarely preserved in a fossil state, yet furnish evidence of a former connection with reptiles. The Oolitic *Archæopteryx*, in its long tail and some other characters, approaches the reptiles much more nearly than does any existing bird; and the *Compsognathus*, an extraordinary reptile from the same formation and allied to the Dinosaurians, according to Professor Huxley approaches birds even more than the *Archæopteryx* does reptiles. Now, in the face of these undoubted facts (and hundreds less conspicuous but equally important are known to palæontologists), it cannot fairly be maintained that the absence of intermediate types is a valid objection to Mr. Darwin's views.

But now another objection is raised. It is said that in strata where a group of animals first appears we often find a great abundance of distinct species and very highly organized types, such as the abundance of Lower Silurian trilobites and cephalopods, of Devonian fishes, of Carboniferous ferns and coniferæ, of Liassic reptiles, and of Eocene mammals. 'Why,' it is asked, 'do we not find traces of the slow growth and development of these groups through successive formations, instead of finding them, as it were, bursting at once into vigorous life?' This is, no doubt, a serious objection, as long as we consider the change from one formation to another to have been effected by catastrophes and convulsions rather than by slow changes during vast periods of time. But a full appreciation of the imperfection of the

the geological record, and of the almost unimaginable succession of years that may have intervened between the Eocene and the Cretaceous or between the Devonian and Silurian formations, will enable us to understand how an important group like the fishes or the reptiles may for ages have existed on the earth while their fossil remains were either not preserved or have not yet been discovered by us, and then seem to appear at once in a state of high development. Sir Charles Lyell furnishes us with an excellent illustration of the inconclusiveness of all such reasoning by giving a table * showing the dates at which the different groups of Vertebrata were discovered in successively earlier formations. For twenty years the *Palæotherium* and other Eocene mammalia were held to have been the first warm-blooded Vertebrates that appeared upon the globe, and their variety and high organization were such as entirely to oppose all ideas of their development from lower forms. But in 1818 the Stonesfield mammals were discovered far back in the Lower Oolite, and in 1847 in the Upper Trias, nearly at the commencement of the secondary formations. Birds were not found in the Lower Eocene till 1839. Nineteen years later they were discovered in the Upper Greensand, and so recently as 1863 in the Oolite. Reptiles are nowhere abundant below the Lias, but a single specimen had proved their existence in the Permian formation so long back as the year 1710. In 1844, however, they were found in the coal formation, and there show evident signs of an earlier and more generalised organization. Fishes have steadily advanced in age with increasing research. Before 1793 they were not known to be older than the Permian age, but in that year they were detected in the Mountain Limestone; in 1828 in the Devonian; in 1840 in the Upper Ludlow beds; and in 1859 in the Lower Ludlow beds of the Upper Silurian formation.

These facts all point to the imperfection of our knowledge, and should teach us that the absence of a group of animals or plants can never be inferred from the fact of our not having yet found any of its remains. Quite recently the *Eozoon Canadense* has been discovered in the lowest of all known strata, far below what have always been considered as the Primary and Azoic beds of European geologists; and only last year an endogenous land plant, the *Eophyton*, was discovered in the Cambrian strata of Sweden, proving the existence of land vegetation of a highly-organized type at that early epoch.

With this mass of evidence, all tending in one direction, we

* 'Elements of Geology,' 6th ed. p. 583.

can

can scarcely deny the fairness of Mr. Darwin's assumption that not only is the geological record imperfect, but we only have fragments of the last volume of it: an unknown series of preceding volumes having been lost or destroyed. In other words, he believes that before the Cambrian and Laurentian rocks were deposited there was life upon the globe; and we know that a number of formations which may have contained the relics of that life must have been ground down to form those early stratified rocks, while others, equally ancient, have probably been so metamorphosed by heat as to have lost all trace of their original structure. It is certain that, if the world has been in existence long enough, and denudation, upheaval, and subsidence have always gone on, the earlier formations must have been so lost; and if we find a convergence backward of all forms of life towards simpler and more generalised types, and if we lose, one after another, the higher and more specialised groups (as we certainly do), then we have a right to claim a sufficiency of past time, wherein to lose successively all but the very lowest forms of life, and to follow out our converging lines of existence till they meet in the same remote point. For this the known formations will not suffice; and Mr. Darwin claims, as a reasonable assumption, an earlier series, which have left no recognisable proofs of their existence, but which, nevertheless, modern geologists are not disposed to deny him.

To those who accept the doctrine of the development of all organisms from pre-existing species by variation and survival of the fittest, the group of insects offers some most suggestive illustrations of the extreme remoteness of the origin of life upon our globe. Taking into consideration their strange metamorphoses, the isolation of the various groups, their complex and highly specialised structure, and their wonderfully diversified forms, no class of animals more impresses us with the immensity of the time required for their development. Yet when we go back as far as the period of the Lias, we find a number of the most highly-organized groups,—as Elateridæ and Carabidæ among the beetles, Gryllidæ among the Orthoptera, and Dragon-flies among the Neuroptera, already in existence. Still more extraordinary, in the remote carboniferous epoch, the insects that haunted the fern-groves and Sigillaria swamps were still of forms that can in some cases be classed in existing families, such as cockroaches, crickets, white ants, and such extremely specialised forms of beetles as Curculionidæ and Scarabæidæ! If the development theory be true, these facts compel us to the conclusion that the ages since the carboniferous formation, vast though they are, can only

only be a small fraction of the whole period during which these complicated forms have been slowly evolved from the simpler Annulosa.

In adopting the views of Mr. Darwin, Sir Charles Lyell carries them out to their legitimate results, and does not shrink from the logical necessity, of the derivation of man from the lower animals; and he has written a very interesting chapter on the 'Origin and Distribution of Man.' Into this subject, however, we cannot now enter, except to remark briefly on some aspects of the question which all who have hitherto written upon it seem to have neglected.

It would certainly appear in the highest degree improbable, that the whole animal kingdom from the lowest zoophytes up to the horse, the dog, and the ape, should have been developed by the simple action of natural laws, and that the animal man, so absolutely identical with them in all the main features and many of the details of his organization, should have been formed in some quite other unknown way. But if the researches of geologists and the investigations of anatomists should ever demonstrate that he was derived from the lower animals in the same way that they have been derived from each other, we shall not be thereby debarred from believing, or from proving, that his intellectual capacities and his moral nature were not wholly developed by the same process. Neither natural selection nor the more general theory of evolution can give any account whatever of the origin of sensational or conscious life. They may teach us how, by chemical, electrical, or higher natural laws, the organized body can be built up, can grow, can reproduce its like; but those laws and that growth cannot even be conceived as endowing the newly-arranged atoms with consciousness. But the moral and higher intellectual nature of man is as unique a phenomenon as was conscious life on its first appearance in the world, and the one is almost as difficult to conceive as originating by any law of evolution as the other. We may even go further, and maintain that there are certain purely physical characteristics of the human race which are not explicable on the theory of variation and survival of the fittest. The brain, the organs of speech, the hand, and the external form of man, offer some special difficulties in this respect, to which we will briefly direct attention.

In the brain of the lowest savages, and, as far as we yet know, of the pre-historic races, we have an organ so little inferior in size and complexity to that of the highest types (such as the average European), that we must believe it capable, under a similar process of gradual development during the space of two or three thousand years, of producing equal average results. But the mental requirements of the lowest savages, such as the Australians or the Andaman islanders, are very little above those of many animals. The higher moral faculties and those of pure intellect and refined emotion are useless to them, are rarely if ever manifested, and have no relation to their wants, desires, or well-being. How, then, was an organ developed so far beyond the needs of its possessor? Natural selection could only have endowed the savage with a brain a little superior to that of an ape, whereas he actually possesses one but very little inferior to that of the average members of our learned societies.

Again, what a wonderful organ is the hand of man;* of what marvels of delicacy is it capable, and how greatly it assists in his education and mental development! The whole circle of the arts and sciences are ultimately dependent on our possession of this organ, without which we could hardly have become truly human. This hand is equally perfect in the lowest savage, but he has no need for so fine an instrument, and can no more fully utilise it than he could use without instruction a complete set of joiner's tools. But, stranger still, this marvellous instrument was foreshadowed and prepared in the Quadrumana; and any person, who will watch how one of these animals uses its hands, will at once perceive that it possesses an organ far beyond its needs. The separate fingers and the thumb are never fully utilised, and objects are grasped so clumsily, as to show that a much less specialised organ of prehension would have served its purpose quite as well; and if this be so, it could never have been produced through the agency of natural selection alone.

We have further to ask—How did man acquire his erect posture, his delicate yet expressive features, the marvellous beauty and symmetry of his whole external form;—a form which stands alone, in many respects more distinct from that of all the higher animals than they are from each other? Those who have lived much among savages know that even the lowest races of mankind, if healthy and well fed, exhibit the human form in its complete symmetry and perfection. They all have the soft smooth skin absolutely free from any hairy covering on the dorsal line, where all other mammalia from the Marsupials up to the Anthropoid apes have it most densely and strongly developed. What use can we conceive to have been derived from this exquisite beauty and symmetry and this smooth bare skin, both so very widely removed from his nearest allies? And if these modifications were of no physical use to him—or if, as appears almost certain in the case of the naked skin, they were at first a positive disadvantage—we know that they could not have been produced by natural selection. Yet we can well understand that

* See the admirable volume on the 'Hand,' by the late Sir Charles Bell, in the Bridgwater Treatise.

both

both these characters were essential to the proper development of the perfect human being. The supreme beauty of our form and countenance has probably been the source of all our æsthetic ideas and emotions, which could hardly have arisen had we retained the shape and features of an erect gorilla; and our naked skin, necessitating the use of clothing, has at once stimulated our intellect, and by developing the feeling of personal modesty may have profoundly affected our moral nature.

The same line of argument may be used in connexion with the structural and mental organs of human speech, since that faculty can hardly have been physically useful to the lowest class of savages; and if not, the delicate arrangements of nerves and muscles for its production could not have been developed and co-ordinated by natural selection. This view is supported by the fact that, among the lowest savages with the least copious vocabularies, the capacity of uttering a variety of distinct articulate sounds, and of applying to them an almost infinite amount of modulation and inflection, is not in any way inferior to that of the higher races. An instrument has been developed in advance of the needs of its possessor.

This subject is a vast one, and would require volumes for its proper elucidation, but enough, we think, has now been said, to indicate the possibility of a new stand-point for those who cannot accept the theory of evolution as expressing the whole truth in regard to the origin of man. While admitting to the full extent the agency of the same great laws of organic development in the origin of the human race as in the origin of all organized beings, there yet seems to be evidence of a Power which has guided the action of those laws in definite directions and for special ends. And so far from this view being out of harmony with the teachings of science, it has a striking analogy with what is now taking place in the world, and is thus strictly uniformitarian in character. Man himself guides and modifies nature for special ends. The laws of evolution alone would perhaps never have produced a grain so well adapted to his uses as wheat; such fruits as the seedless banana, and the bread-fruit; such animals as the Guernsey milch-cow, or the London dray-horse. Yet these so closely resemble the unaided productions of nature, that we may well imagine a being who had mastered the laws of development of organic forms through past ages, refusing to believe that any new power had been concerned in their production, and scornfully rejecting the theory that in these few cases a distinct intelligence had directed the action of the laws of variation, multiplication, and survival, for his own purposes. We know, however, that this

this has been done; and we must therefore admit the possibility, that in the development of the human race, a Higher Intelligence has guided the same laws for nobler ends.

Such, we believe, is the direction in which we shall find the true reconciliation of Science with Theology on this most momentous problem. Let us fearlessly admit that the mind of man (itself the living proof of a supreme mind) is able to trace, and to a considerable extent has traced, the laws by means of which the organic no less than the inorganic world has been developed. But let us not shut our eyes to the evidence that an Overruling Intelligence has watched over the action of those laws, so directing variations and so determining their accumulation, as finally to produce an organization sufficiently perfect to admit of, and even to aid in, the indefinite advancement of our mental and moral nature.

ART. IV.—*English Statesmen since the Peace of* 1815. By J. E. Kebbel, M.A. London, 1868.

WE have so long been accustomed to Parliamentary Government, to regard it as an indisputable and exceptional blessing, to be proud of it and proud of ourselves for having it, and to look down with a kind of Pharisaic compassion and contempt upon all nations which have it not,—that it will actually startle most of us to be asked to consider whether it has not accompanying evils to which we have been resolutely blind, and whether we do not pay a price for it of which we have never dreamed; and it sounds like disloyal heresy and lese-patriotism to suggest a doubt whether it is really so great a good after all, and a suspicion that it may be fast growing into a mischief. Yet something very like this is becoming the dim sentiment of numbers, and the half-confessed belief of a few; and both the vague thought and the definite conviction can find much justification in a close observation of our political progress and position. That we shall ever abandon our cherished system of government by party and legislation by a popular assembly, it is of course idle to fancy, and would be a grave error probably to desire; but it is something to take an impartial and searching view of its real working, and perhaps when once the country has fairly realised its mischiefs and its dangers, it may not be indisposed to listen to suggestions designed to mitigate the one and to avert the other. Therefore let us sit down for a few moments and count the cost.

What Parliament was to us in the days of our forefathers, what it