W M Jack

IV.

The Five Gateways of Knowledge.

A Popular Work on the Five Senses.

By GEORGE WILSON, M.D. F.R.S.E.

Regius Professor of Technology in the University of Edinburgh.

Eighth Thousand. Foolscap 8vo, extra cloth, gilt leaves, 2*s.* 6*d.*; or on common paper, 1*s.*

NEARLY READY.

I.

Life of Dr George Wilson, F.R.S.E.

Late Regius Professor of Technology in the University of Edinburgh.

Author of "The Five Gateways of Knowledge," &c.

II.

Life of Edward Forbes, the Naturalist.

By GEORGE WILSON, M.D. and ARCHIBALD GEIKIE, F.G.S. of the Geological Survey.

MACMILLAN AND CO., LONDON AND CAMBRIDGE.

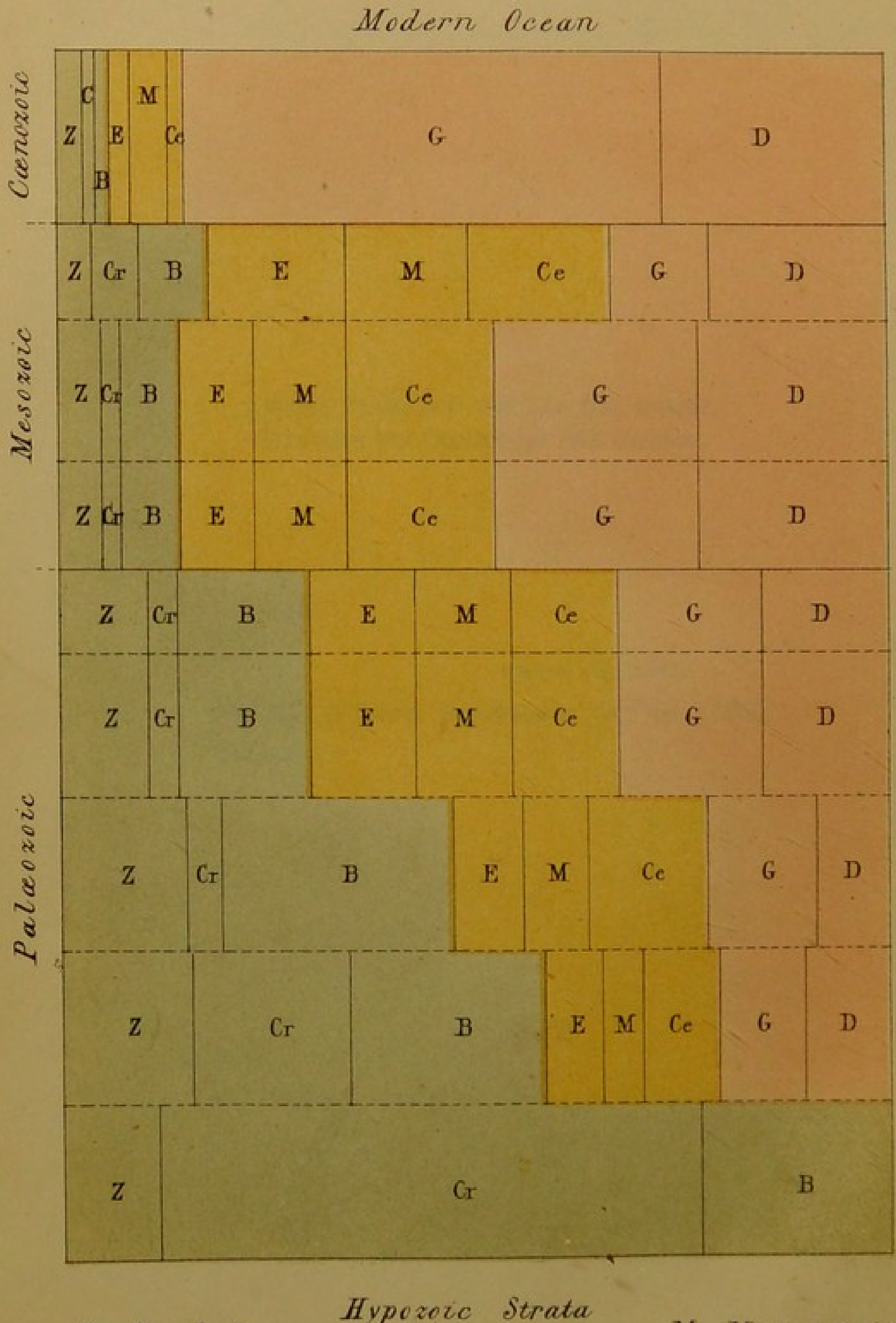
LIFE ON THE EARTH.

KNOWN UNTO GOD ARE ALL HIS WORKS,
FROM THE BEGINNING OF THE WORLD.

πάντα γὰρ οὔπω
Ἐκ Διὸς ἄνθρωποι γιγνώσκομεν, ἀλλ' ἔτι πολλὰ
Κέκρυπται.

SUCCESSIVE SYSTEMS OF MARINE INVERTEBRAL LIFE.

Fig. 6.



Z. *Zoophyta*
Cr. *Crustacea*
B. *Brachiopoda*
E. *Echinodermata*

M. *Monomyaria*
Ce. *Cephalopoda*
G. *Gasteropoda*
D. *Dimyaria*

LIFE ON THE EARTH

ITS

ORIGIN AND SUCCESSION.

BY

JOHN PHILLIPS, M.A. LL.D. F.R.S.

LATE PRESIDENT OF THE GEOLOGICAL SOCIETY OF LONDON, PROFESSOR OF GEOLOGY
IN THE UNIVERSITY OF OXFORD.

MACMILLAN AND CO.

Cambridge:

AND 23, HENRIETTA STREET, COVENT GARDEN,

London.

1860.

Cambridge:
PRINTED BY C. J. CLAY, M.A.
AT THE UNIVERSITY PRESS

TO THE HON. AND REV.

LATIMER NEVILLE, M.A.,

VICE-CHANCELLOR OF THE UNIVERSITY OF CAMBRIDGE,

THIS VOLUME

WHICH CONTAINS THE SUBSTANCE OF THE REDE LECTURE,

DELIVERED UNDER HIS AUSPICES IN MAY, 1860,

IS BY PERMISSION

MOST RESPECTFULLY DEDICATED.

ERRATA.

Page 106, line 10, *for* 'omitting the Chelonida. They' *read* omitting the Chelonida, they

— 216, — 5, *for* Αἰεὶ—ὑπέρμορον, *read* Αἰὲν—ὑπείροχον

PREFACE.

In the following pages, the three great divisions of Strata, and the three great portions of Geological Time, are termed Palæozoic, Mesozoic, and Cænozoic; these designations having fairly won their way, and being really preferable, while treating of the Succession of Life, to such titles as Primary, Secondary, and Tertiary, which express something more than the knowledge we actually possess, and something different from the idea we wish to convey.

While speaking of the Lower Palæozoic Strata and the beautiful system of Life which they contain —a system of the highest importance in the inquiry now on hand—I find it convenient to employ the combination of Siluro-Cambrian, or Cambro-Silurian, as the occasion suggests; and have pleasure in thus commemorating in my phrase the gigantic labours, sometimes independent, sometimes associated, but always successful, by which, first of all men, Murchison and Sedgwick laid open for us these deeply-buried monuments of the earliest Life on the Earth.

Under the title Cænozoic, I wish the reader to comprehend with me not only the Eocene, Meiocene, and Pleiocene of Lyell, but the whole series of Supra-cretaceous deposits; the latest geological age being chiefly distinguishable by the presence and activity of MAN, for whom the Book of the Strata, inscribed with the earlier Wonders of Nature, has been given to be opened with care and deciphered with reverence, by the help of comparison with the living inhabitants of the Land and Sea.

OXFORD,
Oct. 1860.

CONTENTS.

THEORIES AND OPINIONS.

LIFE ON THE EARTH.

MR VICE-CHANCELLOR,

THE subject which, by your command, I have the gratification of bringing before the notice of the University of Cambridge, is not offered as new, though, in consequence of being at the present time subjected to that scrutiny which always arises on the production of new evidence, it wears a somewhat novel aspect. For certainly the history of life is a theme which can never have been absent from the mind of a contemplative naturalist. It never can have been absent, because in all the classifications, in all the systems by which we vainly task ourselves to represent the divine idea of nature, we have invariably looked for a beginning, a progress, and a possible end. Standing by the stream of life, we have surveyed the variations in its course, and appealed to history and experience, for the data which might guide us to a right view of its incessant fluctuations, and its recurring uniformities. We have thus found all nature, organic and inorganic, to be harmoniously combined in mutual dependence; the worlds of matter and of life linked together by peculiar associations, which endure through long time amid varying phenomena, all suggestive of appointed succession and definite purpose. Perceiving that every one thing exists as part of a system, that all effects are parts of a series, and that the whole is compacted together and kept in perpetual movement by some determinate and general principles, we are constrained to believe that so perfect a plan must be permanent and subject to no material change. Nor is this inference much disturbed by the fact that in every stage we perceive vicissitudes from the greater to the less, and from the less to the greater: from the simple to the complex, and from the complex to the simple. For the changes which thus manifest themselves appear, by sufficient experience, to be often repeated in cycles of measurable duration, and governed by laws which appear of perpetual efficacy. Thus amidst all the diversity of nature nothing appears accidental, nothing indefinite, nothing unforeseen, and it is this consideration which makes the study of creation hopeful. We may never fathom the mystery of the origin of life or the inner constitution of matter, but every step we take in accordance with sound reason and reverent feeling brings us nearer to a better understanding of the problem, and is a step in the right direction. Let us, then, bring into view the facts discovered in relation to the Origin and Succession of Life on the Earth, not with the expectation that we can altogether penetrate the 'scheme of creation,' but to get a further insight into it, and a clearer perception of the appointed laws of nature, by the use of those senses with which the Almighty has endowed us. Let us hope that while we study the external world, and, perhaps in vain, strive to master its wonderful history, we shall at least enlarge and correct our ideas, and truly perform the part assigned to us in the large field of creation which we are enabled and invited to contemplate.

Nature, in a large sense, is the expression of a DIVINE IDEA, the harmonious whole of this world of matter and life. Man, included in this whole, is endowed with the sacred and wonderful power of standing in some degree apart, so as to observe the course, investigate the laws, and measure and direct the inexhaustible powers which surround him and penetrate him. The knowledge thus slowly gathered is contained in two great HUMAN IDEAS, the idea of *force*, as producing phenomena, and of *time* as determining the succession and duration of these. The ideas of *constant* force and *perpetual* time are suggested to us in various ways by the repeated occurrences of nature; *uniform measures* of force and time are obtained by observation of the earth's constant force of attraction toward its centre, and unchanging velocity of rotation on its axis. By comparing phenomena with uniform measures of force, and uniform measures of time, we obtain, or strive to obtain, for each natural effect, a correct numerical valuation in terms of the force employed and the time consumed in the production of the effect.

There are, or appear to be, different kinds of force, producing different kinds of effects—as magnetism and gravitation;—but they are often comparable, and capable of valuation under the one comprehensive idea of relative magnitude. Thus all natural effects known to us are measured or conceived to be measurable, by units of force, operating through units of space in units of time. And nature appears to us to be the sum of these effects combined into a 'System,' harmonious, mutually dependent, and preserved entire amidst an endless succession of limited vicissitudes. In expressing our conceptions of this well-adjusted 'System of Nature' we employ the term '*Laws;*' and the more comprehensive these are,—the higher the abstractions which they represent—the less do we conceive them to be variable; so that the most general laws which we reach or strive to reach, are conceived to be, like their Divine Author, independent of time and exempt from change.

ESSENTIAL CONDITIONS OF LIFE.

The Forces of Nature are constant; we do not conceive of them as beginning, or changing, or ending; the Laws of Nature appear to us invariable; but the forces and the laws are manifested only in relation to particular *conditions*. Thus in the case of life, regarded as a manifestation of forces according to laws, we find it to be limited to 'organic' structures composed of certain sorts, and certain combinations of matter[1]. Much of the matter which composes living bodies is capable of assuming the gaseous form, as Carbon, Hydrogen, Oxygen, Nitrogen. Other parts are capable of appearing in solution, as Phosphate of Lime, Carbonate of Lime, &c. All the substances named exist in nearly all plants and animals; and it appears, though we do not know how, necessary to the exhibition of vital phenomena, that they should be present—necessary, I mean, according to this actual plan of creation, the only one we are acquainted with, or can justly

[1] In modern language matter is said to be known to us only by effects cognizable by our senses; these effects are due to forces; matter is the seat of these forces; or, if we will, it is a collection of centres of force.

conceive of as possible. For though it may be urged, and cannot be doubted, that other elements, other forces, and other laws might be employed for other systems of life; that is a conjecture which may be useful when thinking of the possible inhabitants of other planets, as Mercury, or Jupiter, or Neptune, but is not suited to the Land, Sea, and Air, with which our History of Life is connected. Deprive the atmosphere of its carbonic acid,—plants disappear; let phosphate of lime be absent—not only vertebrate animals vanish, but a large part of both the animal and vegetable races would languish and become unproductive[1]. Without supposing oxygen or the other elements to be entirely absent, any material change in their relative quantity must greatly affect the relative abundance of different races of living beings whose dependence on these elements is different in degree.

Life is dependent on a continual loss and restoration of parts in its organic fabric. One great part in this process is maintained by the atmosphere, from which all plants and all animals draw supplies of gaseous elements suited to their constitution. Plants absorb the carbonic acid, which exists in the atmosphere to the extent of $\frac{1}{1000}$th part by weight,

[1] Phosphate of Lime occurs in so many animals, and in so many plants, in some part or other, as to be regarded by eminent writers as an invariable accompaniment of life.

and yield oxygén in return; while on the other hand, animals inspire this oxygen, and evolve in exchange carbonic acid. Thus appears a real and necessary relation between the atmosphere as it is, and the double system of life which is in operation. If we change the constitution of the atmosphere, all the relations in which it is so important must be changed also, and amongst the most obvious of these are the reciprocally dependent races of plants and animals. It has been conjectured by Brongniart, that the very rich series of vegetable forms, including many ferns, in the old carboniferous deposits, may have been favoured in their amazing growth, not only by high temperature and humid atmosphere, but by a greater proportion of carbonic acid in the air. Dr Daubeny has submitted this to a trial, in vessels properly supplied with a regulated artificial atmosphere, and the result is not unfavourable to the speculation.

Again, animal life depends upon the previous exercise of vegetable life; for ultimately all animals subsist upon plants, as these feed upon the atmosphere. Perhaps nothing is more surprising than the immense diversity of the forms and qualities of the plants, coupled with the almost equal dependence of all vegetative life upon the same atmosphere chemically everywhere almost identical. Upon this vast variety of plants, innumerable hosts of herbivorous animals feed, and they minister to the appetites of the Carnivora. It is conceivable that while the plants remain unchanged, the Herbivora might vary, or might become the prey of different flesh-eaters; but it is perhaps not conceivable that with such an atmosphere as ours, under such conditions as now obtain, there could be generally any great variation in the relative total amount of vital energy in plants, compared with animals. There seems also a high degree of permanence in the relation of Herbivora compared with Carnivora. Our marine Cetacea might be replaced by Enaliosaurians; our Gasteropoda by Crustacea; our fishes by Cephalopoda; but the researches of geology seem to shew that from the earliest periods, carnivora and herbivora, plants and animals, have been combined into the same general relations of mutual dependence as at present.

Subject to these conditions, life appears in all the habitable spaces of the land, sea and air, filling each with beings capable of enjoying their own existence, and of ministering to the bodily wants and intellectual longings of the one observing and reflecting being to whom God has committed the wonderful gift of thoughts which reach back beyond the origin of his race, and stretch forward to a brighter futurity.

In the elements of land, air, and water, both plants and animals are fitted to live by means of contrivances varied in almost every individual case, but always to be conceived of as elegant adaptations to some conditions of matter — adaptations to gravity, to force of wind, to depth of water, to degrees of light, to periodicity of seasons, and even to local and limited occurrences. Regard the eye which in its perfect state, as in man, is destined to feel the presence or absence of light, to distinguish the colours of the several rays, and to perceive the forms of the luminous surfaces. What is it but a triple photographic lens with six curved surfaces calculated for three different media; calculated for achromaticity and spherical aberration; provided with a variable self-adjusting aperture, and a variable self-adjusting focal length, adapted to something better and more sensitive than a collodion-plate—the beautifully expanded and guarded retina, which after the fraction of a second of time is ready to receive a new impression with undiminished energy. Regard the two eyes, the natural stereoscope, by whose beautiful joint action solids take their proper aspect, distance is estimated, and the landscape acquires that instructive composition which our artists delight to imitate.

Again, regard this wonderful organ, modified to suit the sunny flight of the eagle, the twilight mousing of the owl, the brousing of the ruminant, the nocturnal watch of the lion; the watery life of the whale, or the fish, where the different refractive power of the fluid in which they live is accompanied by modifications, not alike in each, but yet alike in the manifestation of intentional adaptation. Consider in the same point of view the large orbit of Ichthyosaurus with its broad circlet of sclerotic bones; or the reticulated lenses of the Trilobite; or finally, the black or red spots sensitive only to light in the Mollusca and Radiata; or scrutinize in the same way any other organ of sense, in the animals of every age, and inquire with the Psalmist:

> He who planted the ear, shall He not hear?
> He who made the eye, shall He not see?

Life runs always the same course of growth, decay and death, in the individual—always the same course of renewal by offspring, after a definite mode which varies with the different kinds of living beings. One of these modes seems to deserve separation from the rest, under the title of fissiparism, because in it the individual seems divided, and so the number of individuals multiplied. This obtains among the Polyparian Zoophyta, and may be paralleled among many plants, and artificially exemplified by cuttings.

But in general, there is the preparation of egg or seed, the development of these in connection with nutritive matter prepared in each, and the passage through several stages before the complete state of individual life is attained ; then recurs the separation of parts impressed with the wonderful power, and subject to the inconceivable restraint, of so acting on and being acted on by the elementary powers around, as to grow, reproduce and decay, in forms and through periods corresponding to those appointed for their ancestral races since time began.

INFLUENCE OF CLIMATE ON THE DISTRIBUTION OF LIFE.

Not the whole surface of the earth is occupied by living beings. Notwithstanding the perpetual struggle to diffuse their seed, plants do not cover all the regions of the land ; nor is the amazing fertility of many marine animals able to carry life into all parts of the sea. The geographical distribution of plants and animals, a subject of great richness and instruction, offers some general facts which must not be neglected in reasoning on the ancient forms of life which fill the stratified rocks.

Among the most influential of all the causes which limit the ranges of life is temperature. The annual mean temperature, the extremes of yearly and daily heat and cold, and the humidity of the atmosphere, in a good degree dependent on temperature, are conditions to which life in general, and special forms of life in particular, are adjusted.

For example, proceeding from the equator to the north, along the land in the new or the old world, we find the number of the forms of life continually grow less and less. According to an estimate of some date, if we count in the warm zones of Asia the plants which range northwards from the equator with a temperature of 80°, so as to reach the latitude where the annual mean temperature of 64° prevails, we shall find 4500 species; between 64° and 48° the number is reduced to 1500, while between 32° and 0° the total sinks to 500, till in Walden Island, lat. 80½ north, only ten species occur; and finally, the whole series becomes extinct.

So if we estimate the land mammalia of the Tropical zone at 800 species, the proportionate number for the Temperate zone is 200, and for the Polar zone twenty. But the reverse holds in regard to the Cetacea, which increase towards the Polar oceans.

It may be further observed that the earth seems to have the two extremes of life, the hot extreme in the deserts of Africa, the cold extreme toward either pole, and toward the summits of high mountains. The American Flora is richer than that of the old world. If 13000 be the number of phanerogamous plants in Tropical America, 4000 may be taken to represent the flora in the Temperate zone. If 2000 plants can be collected within a radius of ten miles in India, about 500 can be found in an equal space of the surface of England[1].

In Mr Watson's interesting work on the *Geographical Distribution of British Plants,* we find the Highland plants of Scotland grouped in three divisions according to elevation—1000 to 2000 ft., 2000 to 3000 ft. and 3000 to 4000 ft. above the sea. The numbers are :—

273 species—183 species—85 species
48 orders—38 orders—25 orders,

shewing clearly the reduction of vegetative energy with increased elevation.

Equally positive is the limitation fixed by climate upon the geographical range of the different natural groups of plants. Proceeding northward from the equator we pass through the fruitful equatorial region of the bananas and palms, the tropical zone of arborescent ferns and figs, the sub-tropical zone of

[1] Humboldt; Hooker, *Indian Flora;* Watson's *British Plants;* Balfour's *Class Book;* Somerville's *Phys. Geography,* Meyen, *Botanical Geography.*

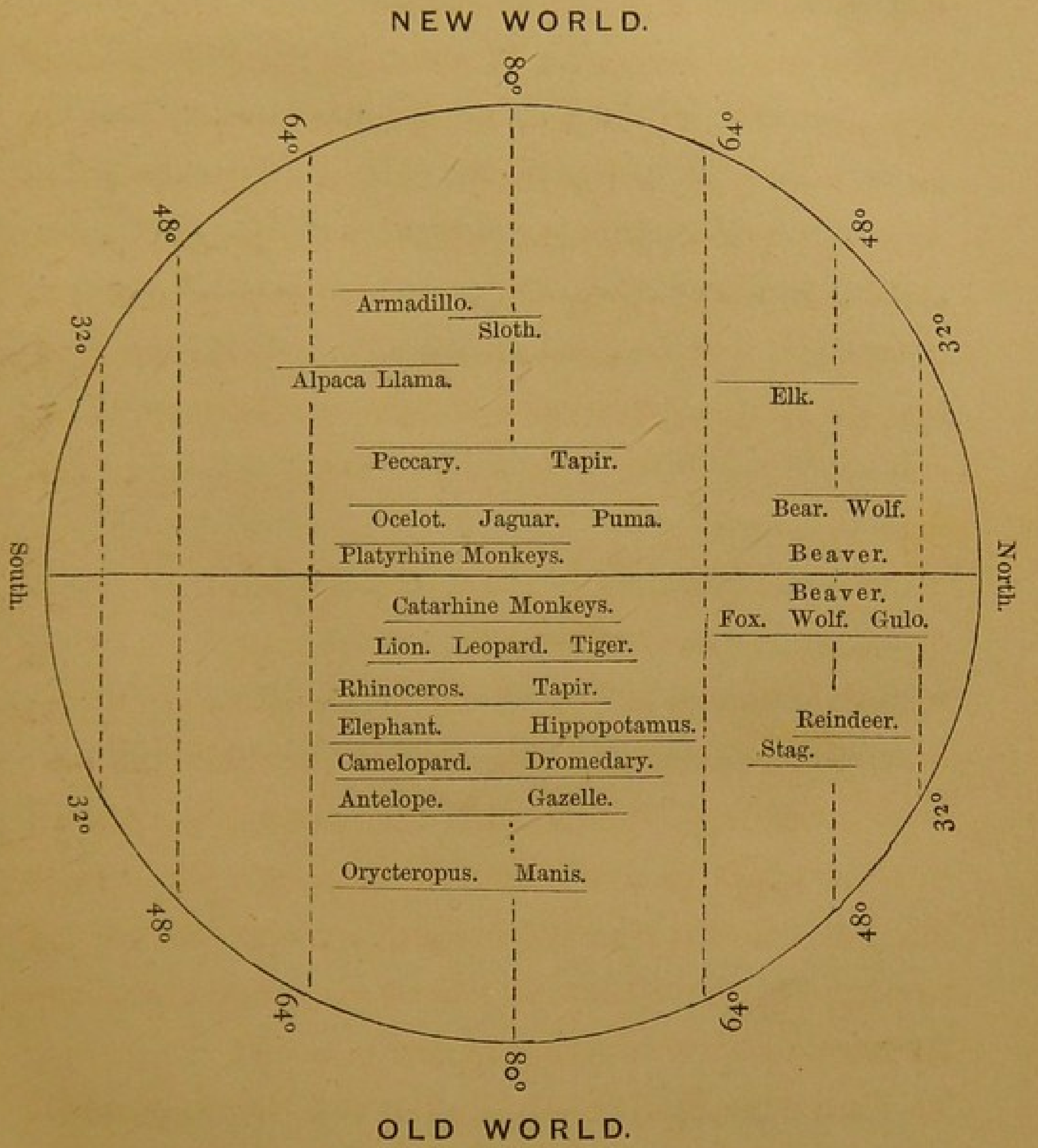
myrtles and laurels, the warm temperate zone of evergreen trees, the cold temperate zone of deciduous trees, the sub-arctic zone of pines, the arctic zone of rhododendra, and finally, the polar zone where the last relics of vegetable life expire[1].

The same succession of plants is found in ascending the lofty mountains of the equatorial zone, as Chimborazo in South America, and Popocatepetl in North America, whose summits have the polar climates, and their slopes the plants and animals of different latitudes. The ranges are equally definite on Etna, but there the palm zone is only at the very base; and on Mont Blanc, which has none of the lower and warmer zones.

In a diagram, Fig. 1, the distribution in latitude of several races of mammalia is traced by lines. If we regard the two halves of the circle divided by the central meridian as representing the old and new world, we shall find in each the same laws prevail for the same groups; though none of the species are the same in the two regions, except toward the north pole, where there is almost a connection of the two countries by islands and ice.

Thus the Platyrhine Monkeys of the new world are balanced by the Catarhine Quadrumana of the old world; the Feline races of Asia and Africa, the

[1] Humboldt.


NEW WORLD.
80°
64°
48°
32°
Armadillo.
Sloth.
Alpaca Llama.
Peccary.
Tapir.
Ocelot.
Jaguar.
Puma.
Platyrhine Monkeys.
Elk.
Bear.
Wolf.
Beaver.
South.
North.
Catarhine Monkeys.
Lion.
Leopard.
Tiger.
Rhinoceros.
Tapir.
Elephant.
Hippopotamus.
Camelopard.
Dromedary.
Antelope.
Gazelle.
Orycteropus.
Manis.
Beaver.
Fox.
Wolf.
Gulo.
Reindeer.
Stag.
OLD WORLD.

Lion and Leopard, are copied so to speak by the Puma and Jaguar of tropical America; the Tapir of Mexico mimics the congeneric animal of Sumatra; the Sloth, Armadillo, and Myrmecophaga of Brazil, find relatives in the Manis and Orycteropus of Asia and Africa.

These parallels might be extended by many examples from Struthious and other birds, and from Crocodiles and other reptiles, tending to shew in two large separated regions, two distinct but analogous groups of life, subject to similar limitations by climate.

In like manner, reef-making Corals in the sea, and the large molluscous families of Cones, Cowries, and Volutes, might be mentioned as characterizing the warmer waters; but a more curious and interesting law of distribution of marine life, is founded on investigation of the contents of the sea at different depths.

INFLUENCE OF DEPTH ON THE DISTRIBUTION OF LIFE IN THE SEA.

One example, the best known, is the Survey of the Ægean sea-depths by the late excellent naturalist, Edward Forbes. Dividing the depths from the surface to 230 fathoms into eight unequal zones, he finds the distribution of testaceous mollusca in them to be as under:

I.	0 to 2	2	147	735
II.	2 to 10	8	291	161
III.	10 to 20	10	124	124
IV.	20 to 35	15	142	91
V.	35 to 55	20	141	70
VI.	55 to 79	24	119	50
VII.	79 to 105	26	85	33
VIII.	105 to 230	125	66	6

The first column gives the zones in succession downwards.

The second gives the limits of the zone in depth by fathoms.

The third, the depth in thickness of each zone in fathoms.

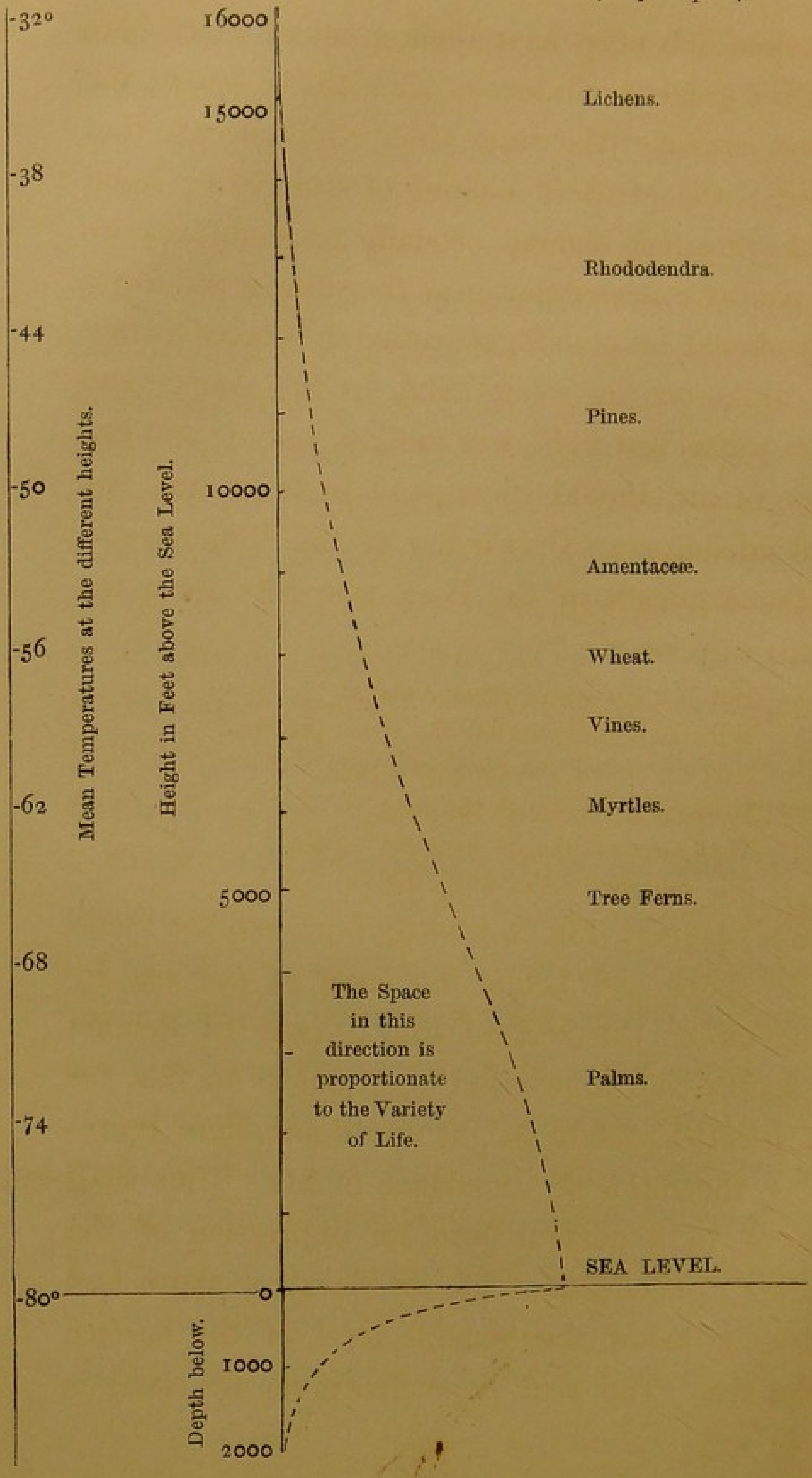
The fourth the number of species found in each zone.

The fifth is a column which I have calculated by dividing the fourth by the third, to shew the relative productiveness of each zone. (For the sake of avoiding decimals, the quotient is multiplied by 10.)

Thus it appears that the relative fertility of the several zones decreases downwards toward zero: and it is believed that at 300 fathoms life is extinct.

If we consider that at and near the surface of the sea all the influences favourable to both vegetable

FIG. 2, *to face* p. 17.



and animal life must have their greatest effect, here being the greatest mixture of air with the water; the greatest motion of the water, to give full effect to that mixture; the greatest amount of stimulating light, and the greatest change of daily temperature; we shall readily conceive that near the surface the forms of life should be both more varied and more abundant; while, on the other hand, in the deeper and calmer water, less light, less motion, less air and less change of air, should correspond to fewer and less varied inhabitants. Only a few of the Mollusca are, like the Argonaut of the Poet, who tilts along the Atlantic waves—

> But if a breath of danger sound,
> With sails quick-furled she dives profound,
> And far below the tempest's path
> In coral grots defies the foe,
> That never broke, in heaviest wrath,
> The sabbath of the deeps below.

In a Diagram, Fig. 2, we may represent the limits of life above and below the level of the sea by setting off on the vertical line a scale of heights and depths, and drawing at right angles to this, for each selected zone of height and depth, lines representing the ratios of abundance of life. Thus shall we have, in a general form, an expression of the apparent dependence of life on elevation above and depression below the general level of the surface of the sea. The real dependence on the land is ascertained by the temperatures placed opposite the several elevations.

PROVINCES OF LIFE.

We have been speaking of the climatal distribution of life-forms in general, and of the larger groups and families. The distribution of genera and of species seems to obey the same general laws of co-ordination to climate, elevation, and depth; but it also often suggests the dependence on existing purely local conditions, on ancient geological revolutions, or even on locality considered alone and without regard to conditions.

The great group of Ferns occurs in nearly all latitudes; *Arborescent Ferns*, excluded from cold and fluctuating climates, extend further to the south than to the north of the equator. Thus, Aspidium is arborescent on the shores of Auckland and Campbell, as far as $52\frac{1}{2}$ S. Lat.; Alsophila and Cybotium in Australia and Van Diemen; Cyathea and Dicksonia are conspicuous in the vegetation of New Zealand.

An example of the limitation of a race to terrestrial conditions is afforded by the Gorilla; that monstrous anthropoid animal of the eastern coast of Africa, whose residence seems limited by the forests which supply it with food.

On the contrary, it is to ancient geological revolutions that we must ascribe the detached aspect of the distribution of many plants and animals; these great changes having divided what was once a continuous area, and interrupted what was once a free communication between the regions in which the species occur. Thus we may comprehend the occurrence of Scandinavian plants in the mountains of Scotland, and the north of England; as Myosotis alpestris, on Micklefell 2400 ft. high, in Yorkshire; Cornus Suecica on the eastern moorland, and Trientalis Europæa, in the western part of the same county. We must suppose land once continuous between Scotland and Norway, and a climate more severe than the present. Under such circumstances the plants might spread southward; and afterwards, when the countries were divided and the climate became milder, they might remain in a few and especially cold or elevated situations[1].

In the same way we may attempt to explain the remarkable fact that not only a very considerable number of European plants is found in the Himalaya mountains, but also many of the accompanying birds.

The late Dr Royle long since called attention to this remarkable fact, and Dr Hooker, recently, has stated that no less than 222 species of *British* plants extend to India, and oblige us to look to a common

[1] E. Forbes, in *Memoirs of Geological Survey*, Vol. I.

origin for the species found in both these regions, and to seek for causes no longer in operation for their distribution over so extended an area[1]. It is remarkable that these 222 species include no less than 154 genera. Among them are the plants which flower in fields and meadows, in woods and wastes, in marshes and in water—trees and herbs, climbers and parasites, reproduce before us the familiar aspect of European vegetation. The water-plants include Ranunculus aquatilis, Nymphæa alba, Myriophyllum verticillatum, Hippuris vulgaris, Alisma plantago, Sagittaria sagittifolia, Butomus umbellatus, Acorus calamus, and several species of Potamogeton. East of Kumaoon, the European admixture of plants gives place to a Chinese and Malayan flora. West of the Himalaya, mountain-plants of the European type occur at several points, ideally connecting this range with the coasts of the Levant and the Black Sea, and really indicative of the anciently connected flora and the continuous means of communication.

Another inference from such facts is of equal importance. The species of plants thus shewn to be identical in the regions of the Himalaya and the Islands of the West, have retained their characters during all the time of the existence of each race; these characters have survived the chances of long

[1] *Flora Indica.* Introductory Essay, 108.

migration, have traversed large tracts without hybridism, and have been subject to various physical influences without suffering any sensible change. Ranunculus aquatilis in India and Britain every where retains the little nectary at the base of each petal, to mark the genus, still spreads its white blossoms on the water, and extends its filmy leaves beneath. Still Ranunculus lingua distinguishes itself by its leaves, and Ranunculus arvensis by its prickly seeds.

Instances of purely local species of plants are very common; sometimes defined by impassable boundaries—as broad oceans or crested mountains;—but not unfrequently contracted to small areas from a once wider distribution, or confined to such areas by the successful rivalry of other and more prosperous races. Thus the huge cypresses in the Sierra Nevada of Upper California, known to us as Wellingtonia[1], are now confined to a small district, and indeed rear their prodigious heads 400 ft. high, mostly in one valley, where they have lived for a thousand years and more near the head-waters of the Stanislaus and St Antonio rivers, lat. 38° N., long. 120° 10′ W.[2] So in the valley of the Cherwell, in Oxfordshire, the Fritillaria adorns but a few meadows,

[1] Sequoia Wellingtoniana is perhaps the right appellation.

[2] Seemann, *Ann. Nat. Hist.* March, 1859.

and the Snow-flake is equally local. Gagea lutea is a rare plant of the Oxfordshire hills, yet it reappears in the Himalaya; Gentiana lutea is found on the high slopes of the Puy de Dôme, but it is deficient over the greater part of central France, and is rare even in the direction of the Alps till we reach the mountains where it occurs more frequently. Instances like these which have been now enumerated, seem to be satisfactory in proof that the actual distribution of any given species is the final result of many long periods of general effort to extend, and of some particular influences to restrain, its diffusion.

Remarkable examples are recorded by botanists of plants having sprung up unexpectedly in the course of cultivation, in spots where such had not been growing for very long periods. Perhaps the well-known case of the upspringing of white clover on the burnt surface of the heaths of Yorkshire, when lime has been added, is one of the most striking. The heath thus displaced has been growing there for many centuries; the little clover is rarely seen in the district; yet no sooner is the heath expelled and the calcareous element added, than it grows and covers the surface.

The distribution of particular groups of animals is quite as limited as that of plants, and this is true not only for land-animals but for the inhabitants of the sea and the free wanderers of the air. While some genera are of very wide occurrence in the sea, as the little Spirula, and the huge Physeter; while some birds pass from arctic to temperate, and from temperate to torrid zones, and some quadrupeds annually migrate over large breadths of land in quest of food, the far greater number appear to be restrained by necessity or limited by choice to narrow tracts and definite associations of life.

It is not by conformity of climate or physical conditions, or oceanic currents, that the few existing genera of Brachiopoda are now allowed representatives in almost all seas, for each particular species of these genera is usually limited to one small area, or zone of ocean. Rhynchonella psittacea to the circumpolar seas; Terebratula vitrea to the Mediterranean; and Waldheimia australis to the shore of New Holland[1].

Reptilia in a general sense depend for their distribution on favourable climate; but when we examine any certain group, as the Crocodilidæ, one species is found to belong to the Nile, another to the Ganges, a third to the North American rivers. Struthious birds wander over the dry lands of several

[1] See on questions of Distribution of Mollusca, Woodward's *Rudimentary Treatise on Recent and Fossil Shells*,—an excellent work.

parts of the world, but the Rhea is found in South America, the Ostrich in Africa and Arabia, the Cassowary in the Indian Islands, and the Emeu in Australia.

The Condor clings to the summits of the Cordillera, the Lammergeyer haunts the Alps—the Stork knoweth her abiding place. In a word, every living race of plants and animals exists in a province of space; over which by natural conditions it has been diffused, within which by natural conditions it has been restrained, and beyond which it only passes by a change of these conditions. Thus one place of origin is indicated for each species of plant and animal—one locality where it first appeared, whether it still remain there confined to a limited region, or have wandered far away, without losing its prominent characters, through length of time, change of conditions, mixture with other races, or any of the innumerable incidents of the 'struggle for existence.'

I have thus, Mr Vice-Chancellor, recapitulated some of the laws regarding the Conditions and Limitations of Life, which are commonly accepted among naturalists, and must be observed by geologists who desire to work out the problem of the succession of ancient created being. I propose them as the very reverse of novelties, and regard them as truths generally admitted. Here in Cambridge, I know that these and other great results of the contemplation of nature are well comprehended, since you have all long had the advantage of hearing them from the eloquent lips of the noblest of English Geologists, your pride and my pride—Professor Sedgwick. Assuming, then, definite limits and conditions for every living form; a definite local origin, and a longc-ontinued permanence of structure and habits for each species of plant and animal, I may now turn to the appointed purpose of this lecture, and trace the history of the changes of life in the ancient lands and seas.

TYPES OF LIFE STRUCTURE.

One of the most arduous of all the enterprises of science is the attempt to classify the variously allied objects of organic and inorganic nature, according to their prevalent structures and qualities—to place them in such relations to each other as they really have—to represent, in short, the *plan* of these parts of creation—according to the leading *ideas* of which it is, or seems to us to be, the expression. Not that so great a purpose was at first conceived by Aristotle and his followers, or even by Linnæus, or Cuvier; it was at first intended to group together things which resembled each other,—as crystals—herbs—trees;—residents in the water—animals of the land. Proceeding from such analogies to stricter inquiries, other and firmer divisions were founded on the organs of motion, prehension, food, respiration and circulation,—the organs of sense, and the internal arrangements of the nervous system. In the course of these inquiries we have detected, under many disguises, some general rules of structure and function —patterns or *types* so to speak to each of which a vast number of specific forms can be referred, as if they were so many examples of one general structure, modified in an almost infinite variety of ways to suit appointed habits of life. The general characters of agreement we often call *typical*, the special characters of difference are often called *adaptive*—terms which imply the recognition of law and modification, mind and choice—a Creator who works by rule, and who has provided for wonderful diversity in his works and for the persistence through them all of some firm general principles of construction, which can be traced out in their operation by the human mind-process of observation, comparison, and inference.

When reduced to the smallest number of great primary types, we find Plants to be ranked in two divisions:—

Phanerogamous or flowering and seed-bearing, and Cryptogamous or flowerless plants deficient of true seeds.

These may be again subdivided so as to make four great groups: viz.

Phanerogamous plants with stamens and pistils, spiral vessels, and seeds.	1. Dicotyledones. Embryo with two seed-lobes, stem growth outward, leaves reticulated, symmetry quinary or quaternary (as *Ranunculaceæ*, *Rosaceæ*, *Labiatæ*, *Coniferæ*). 2. Monocotyledones. Embryo with one seed-lobe, stem growth internal, leaves usually with parallel veins, symmetry ternary (as *Liliaceæ*, *Araceæ*, *Gramineæ*).
Cryptogamous plants, without flowers, true stamens, pistils, spiral vessels, or seeds.	3. Acrogens. Stem, with leaves and branches, mostly traversed by vessels (as *Filices*, *Lycopodiaceæ*, *Equisetaceæ*). 4. Thallogens. No distinct stem or leaves, or vessels, but cellular expansions (as *Lichenes*, *Algæ*, *Fungi*).

In like manner Animals may be collected in four great groups:—

I. Vertebrata. Brain protected by bony (or cartilaginous) case, and, proceeding from it, a nervous trunk carried along the upper side of a chain of articulated bones (vertebræ) or a corresponding cartilaginous axis. Symmetry bilateral.

II. Articulata. Body jointed or ringed across. A double nervous cord, ganglionated at intervals, proceeding along the body. Symmetry bilateral.

III. Mollusca. Body not jointed or ringed across: nervous cord encircling the alimentary canal, and ramifying through the body. Symmetry bilateral or spiral.

IV. Radiata. Nervous system absent or reduced to a ring round the alimentary canal with few radiating threads. Symmetry radiate round an axis.

There are some forms of plants and animals so slightly adapted to *special* purposes of life, as far as we have yet discovered, that life may be thought to reside in them only in a *general* form; the type of which—if that can be called typical which seems rather to be marked by absence of all but elementary organization—may be called cellular or rudimentary. This group, however, is but provisional, and will probably be hereafter better divided according as the nutritive and reproductive systems are more surely analysed by the microscope.

Under the great types of vegetable and animal structure which have been mentioned, naturalists find it convenient to adopt many classes, orders, families, genera, species and varieties. These are not so settled in any case as to be altogether free from change by fresh inquiries and discoveries: they have been augmented and modified by the discoveries of palæontology; which have filled several void spaces in the series of affinities, and illustrated modern types by ancient parallels.

The adherence of plants and animals to the several leading types is sufficient in most cases to leave no doubt of the place of each; the typical peculiarity influences all parts of their structure,—the leaves, flowers and fruit of a plant—the limbs, dermal covering, composition, colour and temperature of the blood in an animal. So that a single leaf will generally decide the place of a plant in the three great divisions—a single drop of circulating fluid, the eye, a bone, a shell or crust, that of an animal. As an exception among plants we may mention those of the family Smilaceæ which yield Sarsaparilla, whose leaves are veined with the net-work of Dicotyledones, but whose seeds are formed on the model of Monocotyledones. Among animals the Polyzoa or Bryozoa were long ranked as Radiate animals, and there is now a difference of opinion regarding the place of the conspicuous family of Echinodermata, which some place at the head of the Radiata, but others join with Annulose animals.

Each great type comprehends several considerable subdivisions, in each of which a reigning idea may often be traced in the structure, and exemplified in the function. These are again subdivided in a manner suggestive of other ideas. For example, Mammalia are separated from all other animals by their mode of rearing their young.

Among Mammalia quadrupedal motion on land appears to be the reigning idea, which determines the complete type; but the Cetacea, destined for aquatic life, are bipedal, and have their two legs altered to perform the work of pectoral fins, and the tail expanded to a propulsive instrument. Thus ideas are expressed which seem borrowed from fishes, to which in general form suited for easy motion in water the Cetaceans also correspond. So in early geological times we find Ichthyosaurus assuming that sort of conformity to fish-structure and form, which belongs to what Mac Leay calls *analogy*, while the real *affinity* of the whale is to ordinary Mammalia, and the real affinity of the Ichthyosaurus is to ordinary Reptilia.

In a different manner the quadrupedal mammal is modified for flight in the air. The Bat takes up the extended interdigital membrane, and the sternal keel, by *analogy* with birds—as in older periods of the world, the Pterodactyle spread its wings and worked its pectoral muscles under the same peculiarities[1]. Instances of this kind might be greatly multiplied, but these may be sufficient to shew that each great type or subtype of structure admits of variations of

[1] See the evidence of the sternal keel of Pterodactylus in the fine collection of Green Sand Fossils in the Cambridge Museum.

high importance, by adopting means, if we may so speak, to express the ideas which are prevalent in another division. Though each great type seems to have in a general sense one main destiny marked out for it by structure, place of residence, and habits, yet each of the three higher types (Mollusca, Articulata, Vertebrata) admits of modifications to suit some of them for watery, and others for aërial life; some for swimming, others for flying, some for climbing, others for burrowing into earth or wood or mud or stone. Thus every thing that lives, is especially constructed for its life[1], in conformity with general types which admit of much modification, to suit particular purposes.

ADAPTATIONS OF LIFE STRUCTURE.

Some idea may be formed of the rich variety of adaptations of animal structures to the conditions under which they are appointed to live by a mere enumeration of a few well-known cases, such as the following variations in respect of the powers of attachment or locomotion.

Life in water is maintained in objects which exhibit a vast diversity of forms and magnitudes, and

[1] La moindre facette d'os, la moindre apophyse a un caractère determiné, relatif à la classe, à l'ordre, au genre et à l'espèce auxquels elle appartient.—Cuvier, *Ossemens Fossiles*, Disc. prel.

various contrivances are employed to adapt them to the specific gravity of the liquid. Among those not so adjusted are a large portion of the shell-covered Mollusca, which by reason of the weight of the shell are for the most part collected on the beds of lakes, rivers or the sea. Within reach of the tidal agitation, where the water is well charged with air, several races of Mollusca *attach* themselves—as the young oyster by its lower shell fixes itself permanently and furnishes support to others. Anomia is attached by a sort of plug, Pinna and the young Mytilus by a byssus spun through the agency of a muscular organ called the foot, which in all the races mentioned loses its usual function of locomotion.

The attachment of Actinia by its broad base, and of Patella by its circular mantle, is not of so permanent a character. Perhaps this is also the case with the suspensional ligament of Lingula and Terebratula. More curious examples are furnished by the cusps for adhesion which cover the arms of Cephalopoda[1], both recent and fossil, and the sucking surfaces of Remora.

Flotation is accomplished in some of the marine races by very obvious contrivances. In the large Medusidæ whose figure is hemispherical, a steady position with the mouth downward is maintained by

[1] The *Polypus* of Aristotle and Homer.

the help of fringes dependent from the edge; in Physalia and Velella, an air-bladder is raised above the general mass and catches the wind; in Nautilus the complicated air-chambers of the shell with a pipe through them all, appears to be another and more remarkable contrivance, which belonged to the group through all geological time; the air-bladder of fishes has been often celebrated in this respect; and we may add the thick oily integument of the Cetacea which at once balances their heavy bones, maintains the heat of their bodies in the polar oceans, and gives the boat-like form which fits them for motion in water.

Swimming, though chiefly exhibited by the Articulated and Vertebrated divisions of animals, is sometimes exercised by the other types. Some of the Infusoria swim by the aid of cilia on the periphery, or about the mouth, others by altering the form of the body. Some of the Cephalopoda employ the hinder expansion of the body as well as the arms and hydraulic funnel, for motion. But it is in the Articulata with jointed feet and among the Vertebrata, that swimming by special organs arrives at the most curious and diversified excellence.

We may remark in regard to nearly all of these special organs that the general idea carried out in them is that of striking the water forcibly with an expanded organ, which can again be drawn through the water more slowly and with less surface to be again expanded and presented for a fresh effort.

Thus whales and fishes, the Triton and the young Frog, all work the expanded tail after the manner which men use in sculling a boat; while the beautiful boat-beetle (Notonecta) floating on his back rows himself with long jointed, flattened oars, fringed with stiff bristles. When he strikes for motion, the oars extend themselves, and the bristles catch the water and widen the instrument; but in returning the oar is bent, and turned edgeways, and the bristles pass easily through the liquid—*θαῦμα ἰδέσθαι*—a wonderful thing to behold.

The paddles of the Turtle and the pectoral fins of the Whale are instruments having the same general property of varying the extent of surface exposed to the water. A similar result is obtained by the very different contrivance of the webbed feet of the Swan and the Otter—and that remarkable organ for backward swimming or rather leaping in the water, the bending tail of the Lobster and Crawfish, which besides has its five plates endowed with lateral motion, so as to fold up into a small area.

It is interesting to observe this same structure in the Lobsters (Glyphia) of the ancient oolites, and to note in the Speeton clay and the London clay the flexible tail of the Crayfish (Palinurus), distinct from that of the true Astacidæ in those remote ages as it is still found to be in the corresponding groups living together in the ocean. Equally curious to notice in the Ichthyosaurus and Teleosaurus of the Lias the same principles of watery propulsion, by the tail and lateral paddles, as in the Fish, Turtles and Alligators of the present period. One general idea runs through the whole series, the propulsive power is worked by a system of leverage placed more or less retrally, aided by a directing power placed forward. If Plesiosaurus appear to be an exception, the anomaly may be regarded as compensated by the extension of the neck, for thus in fact the dynamic centre is really retral, as to the general figure, while the approximation of the paddles gives remarkable power of quick turning, suitable to its way of life.

Diving. The same backward position of the propulsive organs is even more remarkable in the case of the diving birds, such as Colymbus, Uria, Aptenodytes, whose general form resembles that given by mechanicians to ships constructed for swift motion, and suggests to every observer the idea of the solid of least resistance in water. The same peculiarities appear in a different manner in the very different group of diving insects, such as Dytiscus, Colymbetes, and Hydrophilus, and may be found again in some of the ciliated Infusoria like Trichoda anas. But nowhere does it reach so high a degree of perfection in air-breathing animals, as in the water-birds alluded to; in which if we examine the form of the head, the texture and arrangement of the feathers, and the elegant bony apparatus of the chest, admitting of much expansion and much contraction, we see how well, in every part, the whole living machine is fitted for its peculiar purpose, and calculated to follow with success even the fishes which glide so easily through their native element.

Boring into solid substances, by which, in contrast with all these cases, some marine tribes excavate for themselves a dwelling, which they can never leave, is accomplished by several quite different contrivances. Digging into sand is effected by some bivalve Mollusca, as Lutraria and Mya, by the action of the same muscular mass called a foot, which enables the Cockle to spring some distance, and the Unio to cut its way through the slime. Pholades bore into chalk and much harder limestone by turning round their body and its sharply serrated shelly covering on the pivot of the foot; Teredines in a similar manner destroy the substance of ships, and Limnoria terebrans, a Crustacean, eats its way into the wooden piles of harbours. So in early geological times, perforating Modiolæ and Pholades are traced by their work into the substance of coral, and Teredines are found to have rasped their way through the masses of drift wood in the Portland oolite, the Woburn sand, the Chalk and London clay.

Movements in air are accomplished by animals of the articulated and vertebrated types with a considerable variety of organization, curiously engrafted on the original structure by modification of some of its parts. If we consider the mechanism for flight in its completeness, the general idea appears to be the employment of two anterior limbs for rowing through the air by an expanded elastic wing, and employing some retral instrument for steerage. Thus the general arrangement is in a considerable degree the inverse of that employed for swimming. The wing or air-fin is in like manner distinct in principle of construction from the paddle or water-fin. Its anterior edge is always strongly fortified—by bones in Birds, by strong tracheal tubes in Insects—the surface is made flexible by feathers in Birds, by clear or scaly membranes in Insects. Thus a yielding blade is presented to the air, and this yielding is so managed in Birds as to be nothing anteriorly but great retrally, very little on the stroke, very great on the return. This is managed (1) by the tile-like arrangement of the feathers as a whole; for thus they are strongly compacted in one direction, and feeble in the other; (2) by the bending of the jointed wing to extend or reduce the surface, and increase or diminish the flexibility; and (3) by the construction of each effective wing-feather. For each of these is so made, both in regard to the axis of the plume, and in regard to the smaller elements of the feather, as to be strong in the direction in which the whole wing-arrangement is strong, and yielding in the direction in which the whole wing is yielding.

This remarkable concurrence of the individual strength of the feather in all its parts with the mechanical conditions of the problem is secured by the general shape and also by a change of the substance of the feather on the opposite faces; the upper convex face of the wing-feather having the compact quill-sheath *extended along it* to the very extremity and giving origin to the plume, while below it is a thick mass of cellular substance, not so covered, in which extension and contraction take place advantageously. This is exactly the arrangement indicated by the experiments of engineers, and the theories of mechanicians, for the employment of the least weight of such elastic materials in the production of the required result[1]; but no human hands could make an apparatus embodying so perfectly the abstract

[1] Hodgkinson and Fairbairn, in *Reports of the British Association*. Barlow, *On Strength of Materials*.

truths of mechanical science, nor could the human mind with the materials given have predicted by any theory the arrangement which is found to be so complete. Into the other wonders of the feather, its hollow quill basis, its implantation, the relation of the directions of its axis and plane to the axes and planes of the plumose elements I cannot now enter, though by this means the impression that the whole is an ingenious and profound piece of mechanism would surely be strengthened.

The scheme of feather structure and arrangement is altered in the tails of Birds to suit the very different mechanical purposes of that instrument—altered in the construction of the individual feathers—in the direction of their planes—in the resultant of their strength. Hence the resemblance of the steering-tails of the swift Falconidæ, and Hirundines, and Sternidæ—in contrast with the stiff prop of the Picidæ, and the almost extinction of the apparatus and suppression of the function in the acuminated tails of the Diving-birds. Every feather is altered when the work is different.

Among Insects the Lepidoptera, with their expanded wings, shew the same principle, differently carried out; what in human contrivances is called 'feathering the oar' being largely employed in nature; and in Coleoptera we may cite the curious doubling and cross-folding of the membranous wings under their waterproof horny elytra, as a singular and expressive example of a purely mechanical operation, performed on an organ for its conservation, more ingenious than the putting-up of a fan in its varnished case, or a parapluie into its oiled sheath.

The same mechanical principles may be traced in the wings of the Bat, carried out in practice in such a manner as to suit the Mammalian type of bones and dermal covering. The fluttering collapse of the soft skin of the Vespertilionidæ is however a much lower order of movement in air than the rapid sweep of the elastic feather-wing of the bird; nor need we suppose for the flying Lizards of the Mesozoic ages a very rapid or very sustained flight, notwithstanding the hollowness of their elongated digital bones, the carinated sternum, and the devotion of a large part of the muscular energy to the anterior limbs. But there is no reason whatever for comparing the Pterodactyle with such parachute-bearing Mammals as Petaurus, and Pteromys, and still less with the Lizard called Draco volans. The membranes extended between the limbs of the former creatures, and beyond the ribs of the latter, serve only to retard their fall, and thus to allow of their making longer leaps, especially among trees, just as the flying-fish makes long leaps by the sustaining power of its expanded pectoral fins. Pterodactylus, by its large and pointed wings, retractile neck and snapping long-toothed jaws, seems to realize all that can be supposed of a reptile accustomed to flap the air rather heavily not far above shallow waters, and occasionally to snatch from them fishes swimming near enough to the surface to come within reach.

Life in Trees presents us with a considerable variety of contrivances for holding to the surface, grasping the branches, or making incisions into the bark and wood. To say nothing of the sucker feet of Dipterous Insects, and the Gecko Lizard, we may remark on the prevalent idea of climbing and holding on by opposable fingers which appear among the Reptilia in Chamæleon, among the Birds in the Parrot and Woodpecker, and among the Mammalia in the whole race of the Quadrumana. Perhaps the prehensile tail of the Platyrhine Monkeys, and the suspensorial claws of the Sloth, may be quoted among the singular provisions of animals of the New World. It is even more curious to notice with respect to some of these climbing animals, the other adjustments which complete their equipment. Thus the feeding of the Woodpecker is provided for not only by its scansorial foot, its supporting tail, and its perforating beak, which makes the forests ring around. We have further to notice the singular piece of mechanism by which its long tongue is suddenly projected, and suddenly retracted, a mechanism of elastic bone, the hyoid or tongue-bone greatly lengthened backward, the horns turned upward in a groove of the cranium and planted in the right nostril. Inexplicable on any view but that of a wise co-ordination of the different parts of the structure to answer an appointed end. With this view in our minds we no longer wonder at the long spirally wrapped muscles which govern this elastic bone, or at the terminal armature of the tongue.

Nor under such an aspect are we confounded by the sudden outrush of the Chamæleon's tongue, which seizes instantly, by its moistened extremity, the fly so patiently watched; the result of a combined mechanism whereby the soft mass is straightened, directed, and shot forth like an arrow flying to its mark, and then retracted and folded within the jaws which otherwise could not have received it[1].

Life on land presents no less variety of appropriate adjustments, by which the general types of the Vertebrata and Articulata are made to answer a great diversity of requirements. To take examples from Mammalia. For pure motion what can be conceived more complete than the whole frame, and

[1] These peculiarities of the Woodpecker and Chamæleon and other animals were some of my pleasant studies of Natural History 30 years since.

especially the unidigital limbs of the horse? The predaceous habits of the Feline races are indicated by their sharp curved claws, retractile into sheaths; the Mole is strengthened for digging by the approximation of the scapulæ, and the outward-turned broad anterior feet; even for suspension during hybernation the Bat has a hooked finger prepared; and thus, to close this part of the subject, we find everywhere in rich profusion, what would be regarded as remarkable inventions, if they were due to human minds and hands, and which cannot be removed from the list of intelligent adaptations because they are frequent in nature, and are of higher perfection and greater beauty than any work of man.

On the whole it is evident that in the several great types of animals very similar mechanical functions are performed by means of organizations which depend on the type, and have only analogical resemblances in the different types.

In each great type the variations of the several organs may be such that, while the homologies are not to be doubted, the employment of the organs varies much. In some cases parts of the fabric dwindle to mere representatives, as the wing-bones of the Ostrich and the pelvic bones of the Whale; in others they die out altogether, as the hind-limbs of the Cetacea.

These gradations and modifications of the parts constituting a general type may be represented by one of three suppositions:—First, that the structure is what we see because that portion of the general type, and that state of the organ or constituent part of the type was *selected* as suitable for the life of the creature; Secondly, that the structure has become what it is by *degradation* from a fuller type through the reduction or suppression of certain parts by want of exercise of their functions; Thirdly, that the typical structure is *incompletely manifested* because some of the functions have been unexercised, and the organs which belong to them consequently remain undeveloped.

Each of these views may be thought to be so far founded on observation of nature as to be allowed in an hypothesis for comparison with more observations. The choice between them can only be justified by reference to phenomena, which by their number, consistency and critical character, may furnish a basis for sound judgment. Without such reference a choice no doubt will be often made, but it can then be little better than prejudice, and must be expected to differ in different persons, according to the previous training of their minds. It is consoling to believe that each may be connected, indeed will be connected, by minds accustomed

To look through Nature up to Nature's God,

with reverential thoughts of the GREAT MAKER. No sincere inquirer for truth will be likely to expect success in the search,

——————— unde queat res quæque creari,
Et quo quæque modo fiant, operâ sine Divōm;

and no one who has advanced so far in Philosophy as to have thought of one thing in relation to another will ever be satisfied with Laws which had no Author, Works which had no Maker, Co-ordinations which had no Designer. In this as in other cases,

An undevout philosopher is mad.

SYSTEM OF LIFE COEVAL WITH MAN.

The Living creation then, as we see it, is found to exist only in a fabric of certain sorts and certain combinations of matter, in the presence of the atmosphere, subject to continual loss and restoration of parts, suffering death in every individual, and renewed by birth of other individuals; adapted to the elements of water, land, and air; limited by temperature and physical conditions; called into being at certain points of origin, and spread over certain areas of occupation.

Thus the visible creation presents itself as a calculated whole; the parts co-ordinated; the conditions adjusted; the origin defined; and a long duration secured. Looking at it in this aspect we may conceive it to be all of one age—the result of one act of power and wisdom,—the expression of one will at one epoch of time, and in this sense employ for the whole the term, Creation, which admits of no explanation in human language, because it refers to an act of God's power, transcending all human thought and experience.

How completely the life of to-day represents the life of the earliest historic times, in the same countries, may be ascertained by the slightest examination of the books, sculptures and buried skeletons, which speak of those times. The Swallows, whose twittering disturbed Anacreon, still break the slumbers of the luxurious poets of our day, and still excite the wonder of naturalists by their long flight to Memphis[1]; the Ibis still wanders by Egyptian rivers; Philomela still charms us with her song of love; still clang the Cranes, and soar aloft the Eagles; still dance in air the summer-loving Flies as in the days of Homer; and still the Polypus and Sponge, and all the inhabitants of the sea, exhibit in the Mediterranean the peculiar properties noticed in them by Aristotle. Various as are the races of

[1] Anac. 12. 33.

horses, dogs, and cattle now, they seem to have been as various in the earlier times, and associated then as now with particular tracts of country and families of mankind[1]; nor even in regard to man do we find much change in the African, Caucasian, or Mongolian races, which seem to have been from remote antiquity separate, and still are distinguishable by the characters assigned to them in the pages of Ammianus Marcellinus and Herodotus, and in the ancient sculptures of Egypt.

The interval of time which has elapsed since the present races of created life came into being cannot be known by any kind of research practicable for mankind, unless Geology can solve the problem. As far as human experience goes—a few thousand years—there appears too little change in individual character, or in the combination of the whole series, to furnish any data for inferences touching the epoch of the 'creation.' If we are able to say these races of plants and animals were not eternal, nor the earliest of created things, but had predecessors and a date of origin, it is not Zoology, nor History, nor Tradition which tells us so; but Geology, which, agreeing with the authority of Scripture in the late date of man, and the races of beings associated with him, adds its own testimony of Pre-adamitic beings.

[1] Oppian. ΚΥΝΗΓ. I. 116.

If we take as the first of the problems to be examined on this subject, that which seems the most likely to be answered on satisfactory evidence, viz. the geological antiquity of the human race, we find clear though incomplete testimony leading to a sure and definite conclusion. Man and the works of man have been preserved in natural repositories of higher antiquity than all the mausoleums, and tumuli, and ὑπογαῖα; in caverns, peat-bogs, lacustrine and river-sediments, which derived their characteristic features from the operation of physical conditions long since passed away. Thus deep in the sediments of many of our British valleys left by the rivers in some earlier period, we find the canoe of the primitive inhabitant, hollowed by fire and rude stone chisels from the trunk of the native oak. In Caverns near Swansea, and near Narbonne, skeletons of the early people have been found; in those of Kent's hole and Brixham and Sicily, and deep in the gravel of Amiens and Abbeville, the flint instruments which served for rude workmen in wood, rude diggers of the ground, or rude warriors in the field. According to such observations as we can make these facts can only be explained by supposing a long period of time to have elapsed since their occurrence. To heap twenty or more feet of sediment over the buried canoes by the ordinary operation of a river like the Yorkshire

Aire, would require thousands of years; if it were not accumulated under the ordinary circumstances now in operation, but under different geographical conditions, this would perhaps require the hypothesis of still longer time. In the alluvial sediments of this same valley lie nearly complete skeletons of the extinct Hippopotamus major[1]; in another place jaws and horns of the deer, and hazel wood and nuts, some of them petrified[2]. Perhaps man was contemporary with this extinct Hippopotamus, which has also been found in the Peat deposits of Lancashire.

The gravel of Amiens and Abbeville appears to furnish evidence of higher antiquity for the flint implements found there, for they lie at the bottom of the deposit, 20 ft. or more in depth. The deposit is of fluviatile origin, but it is not in the bed of the actual valley. It lies in what must have been the course of the great floods of some earlier time, under other geographical conditions, before the actual river-channel was sunk to its present level. In this gravel have been found remains of Elephas primigenius, now extinct. Man may have been contemporary with that animal in Europe; nor will this appear a very startling inference, if we remember the discovery of the entire specimen covered with flesh and hair at the mouth of the Lena.

[1] *British Association Reports*, 1853. [2] *Phil. Mag.* 1827.

But how many soever of centuries we allow for the accumulation of the gravel, the filling of the caves, or the deposition of the alluvium, this period thus indicated is as nothing compared to those which have passed away before it began. In a general summary we may affirm that the human period of the earth's history is a very short one on the geological scale, the latest of all, and yet the most important, since independent of the interest conferred on it by the presence of our race, it is by evidence collected from this period that we are to judge of the earlier ages of nature.

If we put as our second question the geological antiquity of the races of plants and animals which are directly and specially associated with man, as the valuable Pomaceous Plants and Ruminant Animals, the answer is of the same kind. They are of recent date—their remains are found only in deposits near the surface, which belong to the existing order of physical conditions, the later effects of geological agencies. The creatures most useful to him appear to be of contemporaneous origin; and may be employed as marks of the human period, in cases where no traces of man or his works remain. The relation of this to earlier periods will appear in the following scale of geological time, the length of the periods being not perhaps exactly proportioned to the thick-

Geological Scale of Time.

		Periods.	Systems.	Life.
	10		Pleistocene.	Man.
			Pleiocene.	
1	9	Cænozoic.	Meiocene.	Placental Mammals.
			Eocene.	
2	8		Cretaceous.	
3	7	Mesozoic.	Oolitic.	Marsupial Mammals.
4	6		Triassic.	
5	5		Permian.	
6	4		Carboniferous.	Reptiles.
7	3	Palæozoic.	Devonian.	Land Plants. Fishes.
8	2			
9	1		Siluro-Cambrian.	Monomy. Echinod. Pterop. Heterop. Dimy. Gasterop. Annel. Polyzoa. Zooph. Brach. Crust.
10				

nesses of the systems of strata, but yet (as will be shewn hereafter) undoubtedly to some extent represented by them.

In this scale the total thickness of the Fossiliferous strata, down to the Lingula beds of Wales, is assumed to be 10 miles, 52800 ft. That is not the maximum thickness, which in Britain is supposed by Ramsay to be 72584 ft. In his estimate the Palæozoic beds are taken much above the average, and the Cænozoic beds much below the average of Europe. Morris gives the maximum numbers thus, Cænozoic 2830, Mesozoic 6170, Palæozoic 49460. D'Orbigny's general statement gives 21260 metres = 69750 ft., the Tertiary occupying 9842 ft., while in England they are supposed to be 2240. The figures on the left may be used to mark miles of depth, thickness of deposits, or periods of unknown duration, according to the purpose in view.

The Geological Scale of Time thus constituted by the succession of marine strata, is liable to the objection which applies to almost every scale of historical time, that it is not complete in any one region, no one oceanic basin having been yet discovered which has received marine sediments continuously through all geological periods. The remedy is the same as in ordinary history—the scales of different regions are combined by means of common terms, which in one district appear in the upper part of one series, and in another district in the lower part of another. Thus in several parts of England the Permian system is unconformed to the Coal series, but on the borders of the Staffordshire Coal-field it seems otherwise, and the sequence appears to be nearly complete. Again, the passage of the Permian strata into the Triassic group is more full in the south of Yorkshire than elsewhere, and the passage of the Trias into Lias is best exhibited (in England) in the Vale of the Severn. The uppermost chalk of Maestricht and the region of Bayonne softens the break which in England appears so decisive at the base of the Cæno-zoic strata; and thus, with few exceptions, by taking our data from different regions we acquire nearly but not quite a complete series of the strata of marine origin, and the means of accurately placing the monuments of the life which has passed away for ever.

SUCCESSIVE SYSTEMS OF LIFE.

Passing from the limited consideration of man and his works, and the animals and plants specially associated with him, to examine as a third problem how far into antiquity we can trace the forms of the numerous species of existing plants and animals, we find in deposits of old, but perhaps not prehistoric or at least prehuman date—peat bogs—subterranean forests—sea-beaches—lacustrine marls—river-sediments—many examples of the plants, shells, insects, birds and quadrupeds now existing, together with a few no longer living in the same regions, as the Wolf and Beaver in England, or not now living any where, as the Irish Elk, Rhinoceros, Hippopotamus major, Elephas primigenius, and large Lion. Below these, in the deposits called Pleistocene, the proportion of extinct species mixed with species still living increases. In the Pleiocene tertiaries it is great, still greater in the Meiocene, and quite predominant in the Eocene, below which, in all the Mesozoic and Palæozoic Strata, there is hardly a fossil specimen of a living species—though it is held by several writers that Terebratulina striata of the Cretaceous Strata is both fossil and living, and it is not possible to distinguish some forms of fossil and living Foraminifera[1].

With the exceptions already noted, if they be really such, the whole living creation, examined by species, as we understand this term, ceases below the Tertiary Strata. For this reason, to indicate the real affinity of their organic contents to the living creation, I have elsewhere called them *Cænozoic*.

The following table will illustrate this statement

[1] Auct. Ehrenberg, Jones, Parker.

by a few examples of living species selected from marine animals only[1].

	E. Spatangus purpureus.	A. Vermilia vermicularis.	Cr. Cancer pagurus.	P. Flustra membranacea.	B. Rhynchonella psittacea.	M. Pecten opercularis.	D. Cardium edule.	G. Aporrhais Pes Pelicani.	Cet. Balæna mysticetus.
In Modern Oceans	*	*	*	*	*	*	*	*	*
In Cænozoic Strata. Pleistocene	*	—	—	—	—	*	*	*	*
Pleiocene	*	*	*	*	*	*	*	*	—
Meiocene	—	—	—	—	—	—	—	—	—
Eocene	—	—	—	—	—	—	—	—	—
In Mesozoic Strata..................	—	—	—	—	—	—	—	—	—
In Palæozoic Strata	—	—	—	—	—	—	—	—	—

But if we examine the fossil and living races by *genera* instead of species, the result is different. For instance, some existing genera of Mollusca occur in the Mesozoic, and perhaps even in the Palæozoic Strata, though in these latter the genera Avicula, Modiola, Nucula, &c., among Conchifera, are by some writers thought to be distinguishable from their living analogues.

The subjoined table is meant to illustrate this

[1] The asterisk indicates in what deposits the living species occur. E. Echinodermata ; A. Annelida ; Cr. Crustacea ; P. Polyzoa or Bryozoa ; B. Brachiopoda ; M. Monomyaria ; D. Dimyaria ; G. Gasteropoda ; Cet. Cetacea.

statement by examples taken from the same classes as in the former table, with the exception of Fishes (F), which are here substituted for Cetacea.

	E. Cidaris.	A. Serpula.	Cr. Palinurus.	P. Cellepora.	B. Terebratula.	M. Pecten.	D. Nucula.	G. Nerita.	F. Lamna.
In modern Oceans	*	*	*	*	*	*	*	*	*
In Cænozoic Strata............	*	*	*	*	*	*	*	*	*
In Mesozoic Strata	*	*	*	*	*	*	*	*	*
In Palæozoic Strata	—	*	—	*	*	*	*	*	—

For comparison with the tables just given of species and genera still living traced backward in time, we may in like manner select species and genera living in the older strata, and trace them upward in the rocks, or forward in time, as in the following examples. There being no Fishes in the

	Z. Halysites catenularius.	E. Protaster Salteri.	A. Nereites Cambrensis.	Cr. Agnostus pisiformis.	P. Dictyonema sociale.	B. Lingula Davisii.	M. Ambonychia Triton.	D. Ctenodonta lævis.	G. Euomphalus Corndensis.	Cc. Orthoceras Avelinii.
In modern Oceans	—	—	—	—	—	—	—	—	—	—
In Cænozoic Strata	—	—	—	—	—	—	—	—	—	—
In Mesozoic Strata.........	—	—	—	—	—	—	—	—	—	—
In Palæozoic Strata	*	*	*	*	*	*	*	*	*	*

lower parts of the Palæozoic Strata, Zoophytes are introduced (Z) instead. We have added also a column for the Cephalopoda (Cc).

In the same manner we may select genera which occur in the older strata, and trace upward those which have the greatest range in the strata, in other words, the longest duration in time.

	Z. Zaphrentis.	E. Taxocrinus.	A. Spirorbis.	Cr. Calymene.	P. Ceriopora.	Br. Lingula.	M. Avicula.	D. Modiola.	G. Natica.	Cet. Nautilus.
In modern Oceans	—	—	*	—	—	*	*	*	*	*
In Cænozoic Strata............	—	—	*	—	—	*	*	*	*	*
In Mesozoic Strata	*	—	*	—	*	*	*	*	*	*
In Palæozoic Strata	*	*	*	*	*	*	*	*	*	*

Again, if we consider not genera but greater groups as families, their extension is greater, their antiquity higher; while some classes of the radiated and molluscous and articulated divisions occur in all the strata. Thus the general result is to shew that only one general plan of creation is to be traced in all the range of geological time, though the terms in which this plan is expressed vary from period to period. There is a succession of the forms of life to be traced in the strata; we shall shew hereafter that the relative proportions of the families, orders, and classes vary so as, in this limited sense, to justify our speaking of different systems or combinations of life; but they are all included in one general plan of the Omniscient mind, comprehending the past, the present, and the future.

Perhaps this subject may be yet further illustrated by means of tables shewing on the one hand the numerical distribution in time of some genera of marine animals now living and remarkably prevalent in the sea, and of others as abundant in the more ancient strata. In each case the relative abundance of species is intended to be shewn by the numerals corresponding to each period. I confine the illustrations to the Molluscous animals, because of their being the most uniformly plentiful in all periods, and to the British Islands, as affording the best or most convenient terms of comparison.

Numerous in a living state.

	Cardium.	Tellina.	Fusus.	Cerithium.	Murex.	Strombus.	Oliva.	Conus.	Pleurotoma.	Voluta.	Mitra.	Cypræa.
Recent	200	200	100	100	170	60	117	269	430	70	350	150
Cænozoic..	22	34	43	32	14	1	3	9	50	32	8	14
Mesozoic..	34	5	7	22	2	—	—	—	—	—	—	—
Palæozoic.	—	—	—	—	—	—	—	—	—	—	—	—

The numbers representing the several genera in the Cænozoic groups of strata would bear a much nearer proportion to those of the now living species if we had employed the data of Deshayes, and included European species. The analogy of the Cænozoic to the living marine fauna, and the contrast between these and the older systems of life are especially striking in regard to the Gasteropodous genera placed to the right.

Numerous in a fossil state.

	Orthis	Producta.	Spirifera.	Terebratula.	Trigonia.	Pholadomya.	Pleurotomaria.	Nerinæa.	Bellerophon.	Ammonites.	Belemnites.	Orthoceras.
Recent	—	—	—	1	1	1	—	—	—	—	—	—
Cænozoic..	—	—	—	2	—	1	—	—	—	—	—	—
Mesozoic ..	—	—	5	70	45	29	30	18	—	280	36	1
Palæozoic .	69	51	84	6	—	—	54	—	41	—	—	97

VARIETY OF THE FORMS OF LIFE IN SUCCESSIVE PERIODS.

If we select among the marine classes of animals those which are represented in all the great periods of Geology, count the number of species yet discovered in them in the British strata[1], and refer

[1] See Morris's excellent *Catalogue of British Fossils*, 2nd Edit.

them at present to only three great periods, we have the following result:

	Zoophyta.	Echinodermata.	Crustacea.	Brachiopoda.	Monomyaria.	Dimyaria.	Gasteropoda.	Cephalopoda.	Total.
Cænozoic ...	27	41	15	8	63	394	662	12	1222
Mesozoic ...	103	245	65	165	308	499	389	396	2170
Palæozoic ...	379	225	218	632	196	342	401	336	2729

The absolute number of marine species appears thus to be greatest in the Palæozoic Strata; but when the thickness of the deposits—which represents elapsed time—is taken into account, the variety of forms in a given thickness or given period of time is very much less.

For if we take account of the thickness according to the maximum scale for Britain proposed by Ramsay, on data collected by the Geological Survey, the following table may be constructed:—

	Total Species in 8 classes.	Maxim. Thickness.	Relative number of Species to 1000 ft.
Cænozoic Strata.........	1222	2240	545
Mesozoic Strata.........	2170	23190	164
Palæozoic Strata	2729	57154	41

The ratio thus found by dividing the number of species by the maximum thickness, represents the variety of life by the *relative number of species* to be expected *on an average* in searching a given thickness of strata in each of the great periods. Also since it is known that the species are not uniformly arranged through the deposits of each period, but occupy many distinct stages in each, we may say that *on the average,* they represent the *rate of change* in the forms of marine life, or the number of *different species* to be expected in searching successive equal thicknesses in each of these systems of strata. According to Morris's estimates of thickness (p. 52), the relative numbers would have been 432, 251, 59.

Had we instead of the figures which represent the thicknesses and number of species found in Britain employed the data given by D'Orbigny[1], counting all the species in all the classes of Mollusca and Radiata, viz.

	Species.	Thickness in metres.	Ratio.
Cænozoic............	6042	3000	201
Mesozoic	9064	6010	150
Palæozoic............	3180	12250	26

we should have nearly the same result as with Morris's numbers; a nearer approximation of the Mesozoic and Cænozoic ratios, but the same remarkable inferiority of the Palæozoic series.

[1] *Palæontologie et Geologie,* II.

Thus it appears certain that the *variety of life*, estimated by the marine tribes existing in a given period, is greater in the more recent periods; but the number of individuals, or the *abundance of life*, is not measured by the same proportions. Periods of extraordinary *abundance* alternate in every great series of strata with other periods of comparative *scarcity;* and though sometimes this may be explained by the well-known fact that red peroxide of iron in sedimentary strata is very unfavourable to marine invertebral life, while grey protoxidated rocks of the same series contain organic remains in abundance; and sometimes requires attention to the unequal conservative conditions, or originally unequal feeding circumstances of Calcareous, Argillaceous and Arenaceous sea-bottom; still it is a very impressive phenomenon in the continuously grey Cambrians and Silurians, in the continuously grey Carboniferous rocks, in the continuously protoxidated Oolitic strata, and in the almost uniform deposits of Lias, Oxford Clay, Kimmeridge Clay, Gault, London Clay and Barton Clay. An illustration is subjoined from the Lower Palæozoic Strata of Britain. Fig. 3.

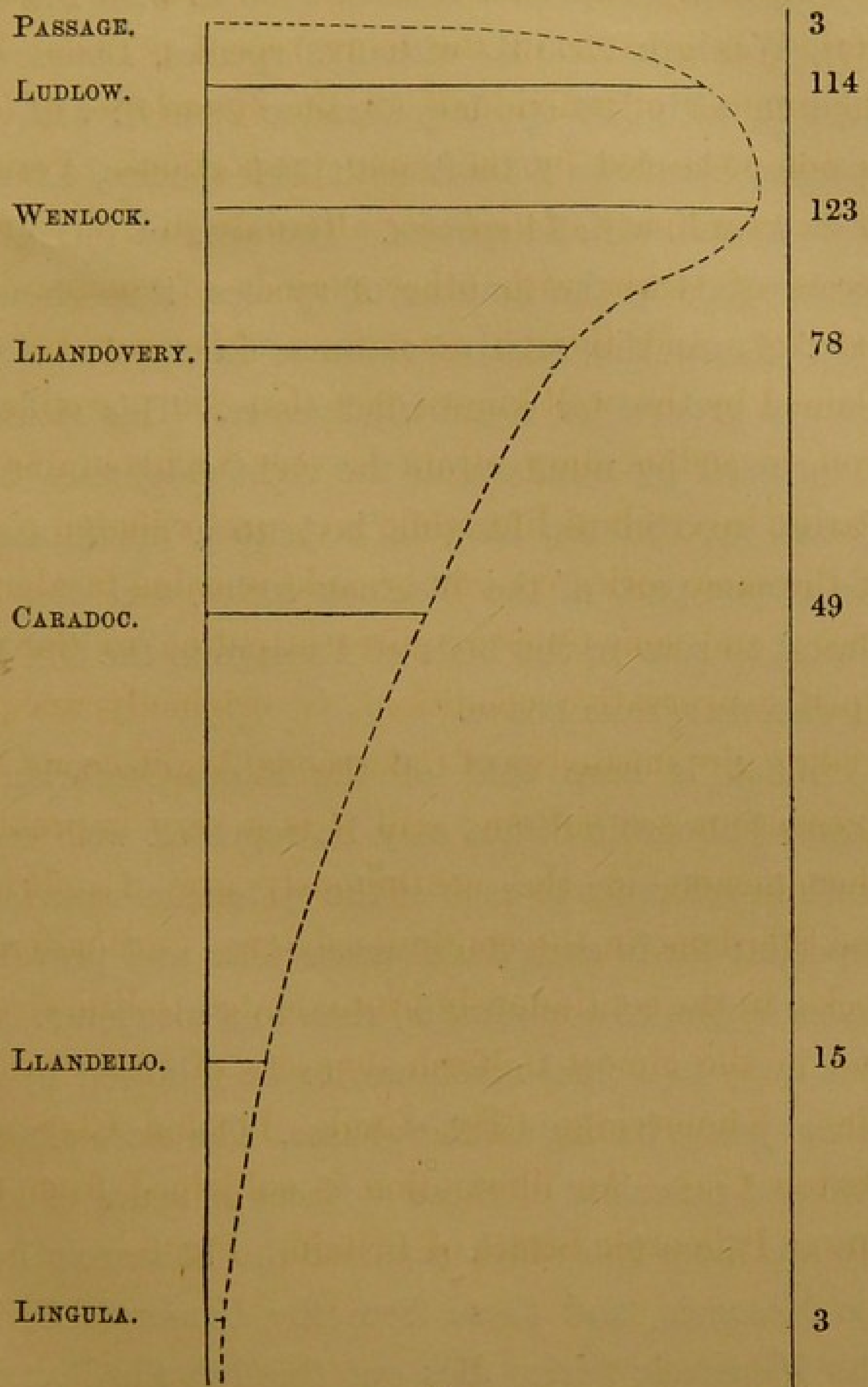

Passage.
Ludlow.
Wenlock.
Llandovery.
Caradoc.
Llandeilo.
Lingula.
3
114
123
78
49
15
3

Fig. 3.

In this diagram the Passage Beds are taken at 500 ft. with 13 species, Ludlow 2000 ft. with 228 species, Wenlock 2500 ft. with 322 species, Llandovery 2500 ft. with 196 species, Caradoc 6800 ft. with 335 species, Llandeilo 6800 ft. with 104 species, Lingula beds 4000 ft. with 14 species. The area of the spaces corresponds to the number of species, thus shewing at a glance the relative richness in species of the several groups for equal thicknesses. This richness (expressed by numbers on the right side) rises from almost zero in the Lingula beds to a maximum in the upper part of the Wenlock series, and dies out almost to zero in the beds of Passage to the Old Red Sandstone system above.

What is here said of the Siluro-Cambrian or Lower Palæozoic Strata may be repeated with equal truth in reference to each of the systems of associated deposits: for in each the characteristic and prevalent fauna begins at a minimum, rises to a maximum, and dies away to a final minimum, to be followed by another system having similar phases. The most remarkable and prevalent of these surfaces or zones of least life are those two which separate the Palæozoic from the Mesozoic, and these from the Cænozoic Series. The Palæozoic Series dies out through the Permian system, and the Mesozoic rises slowly in the Trias; so the Mesozoic Series dies away in the uppermost beds of the Cretaceous system, and the Cænozoic Series grows slowly through the lowest Eocene to a maximum in the later tertiaries.

A depression in the maximum occurs in the Palæozoic Series of Britain corresponding to the Devonian period, here so largely represented by peroxidated sediments; another in the Mesozoic period, in the uppermost Oolites, which are poor in comparison with the richer series of Oxford and Bath. These peculiarities are represented in the following diagram by a continuous curve, which corresponds to the numerical prevalence of life, and represents its rise and fall. Fig. 4.

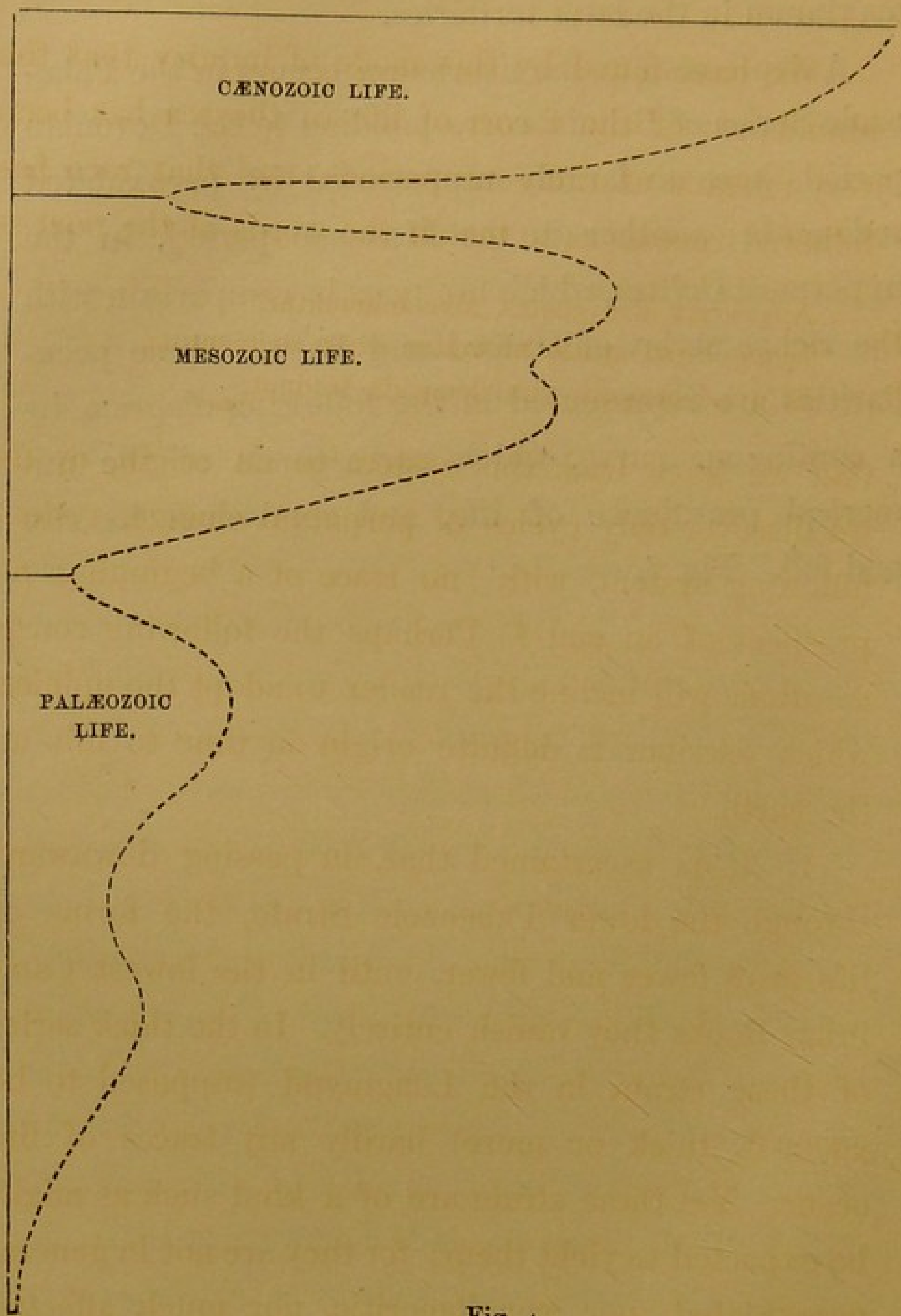


Fig. 4.

ORIGIN OF LIFE ON THE EARTH.

We have found by this mode of inquiry that the abundance of the forms of life in the sea has been very unequal at different periods, and that race has followed race so as to match the words of the poet—

> Augescunt aliæ gentes, aliæ minuuntur,
> Inque brevi spatio mutantur sæcla animantum,
> Et quasi cursores vitaï lampada tradunt.

Can we trace back this system to an origin, or do we discover only cycles of perpetual change, system following system, with 'no trace of a beginning, no prospect of an end'? Perhaps the following considerations will incline the reader to adopt the opinion which ascribes a definite origin in time to life on the earth.

1. It is ascertained that, in passing downward through the lower Palæozoic Strata, the forms of life grow fewer and fewer, until in the lowest Cambrian Rocks they vanish entirely. In the thick series of these strata in the Longmynd (supposed to be 20000 ft. thick or more) hardly any traces of life occur. Yet these strata are of a kind such as might be expected to yield them; for they are not in general peroxidated, nor conglomeritic, nor much affected by metamorphic action, nor so much confused by

slaty cleavage as to render the search for fossils ineffectual by any of these circumstances. The materials are fine-grained or arenaceous, with or without mica, in laminæ and beds quite distinct and of various thickness, by no means unlikely to retain impressions of a delicate nature, such as those left by Graptolites, or Mollusks, or Annulose crawlers. Indeed, one or two such traces are supposed to have been recognized, so that the almost total absence of the traces of life in this enormous series is best understood by the supposition that in these parts of the sea little or no life existed. But the same remark of the excessive rarity of life in the lower deposits is made in North America, in Norway, and in Bohemia, countries well searched for this very purpose, so that all our observations lead to the conviction that the lowest of all the strata are quite deficient of organic remains. The absence is general—it appears due to a general cause. Is it not probable that during these very early periods the ocean and its sediments were nearly devoid of plants and animals, and in the earliest time of all which is represented by sediments, quite deprived of such?

2. The variety of life in the sea continually augments from the lower Cambrian rocks upwards, in such a way as to leave no doubt of the richer fauna of the Llandeilo series being a part of the same

natural system as that of the Lingula flags below, and of the Caradoc beds above. Thus in tracing backward the series of Siluro-Cambrian life it appears to diminish, and disappear in a few forms, if not in a single form, before we reach the base of the strata. Thus we seem to have, as nearly as can be had, the evidence of the beginning of the earliest traceable life after the commencement of the earliest non-metamorphic strata.

3. In tracing downwards the various classes of marine animals, we find them to disappear separately at several successive zones of strata, so that for each class we have reason to think the origin in time is reached, or at least approached. Thus Fishes are not found below the Ludlow Rocks; Rhynchonella and Avicula hardly pass below Caradoc beds; Dimyaria and Cephalopoda grow very rare in the Llandeilo Rocks; and Lingula is almost the solitary occupant of the lowest laminæ of the fossiliferous beds of Wales.

No doubt it is open to any one to compare this approach to a Hypozoic Zero, with the reductions of life to a minimum above the Palæozoic and above the Mesozoic deposits; and to *suppose* that below the Palæozoics *were* other earlier strata and earlier systems of life, though they are now all lost in the general metamorphism which has produced the

Gneiss and Mica Schist. No one is likely to believe this however who attends seriously to the facts regarding the successive appearance of the classes, orders, families, genera and species, as we search the records of Geological time.

EARLIEST SYSTEMS OF LIFE.

The earliest system of life of which monuments remain is found in that very low part of the fossiliferous rocks of Wales, to which Professor Sedgwick first directed attention, now called the Lingula Zone. Perhaps the fossils of Bray, in the county of Wicklow, may belong to an older group of the strata, but this is assumed rather than proved. Of the two generic forms there discovered, Oldhamia may be a plant; Histioderma is an Annelid, probably of the Cephalobranchiate order. Taking our stand on the now well-explored Lingula Zone, but including in our Survey the forms just mentioned, we find the following characters of marine life, for no trace of terrestrial or of Fresh-water organization has been observed.

Zoophyta?	One genus.	Oldhamia, 2 species.
Annelida	2 genera.	Histioderma—Arenicolites—2 species.

Crustacea	7 genera.	Agnostus—Conocephalus—Ellipsocephalus — Hymenocaris — Olenus — Paradoxides — Protichniites — 11 species.
Polyzoa	One genus.	Dictyonema—1 species.
Brachiopoda	2 genera.	Lingula—Orthis. 3 species.

The list is taken from a valuable catalogue of the Lower Palæozoic Fossils of the British Isles, in Murchison's *Siluria*, Ed. II. 1859[1]. The Crustacea belong mostly to the great family of Trilobitidæ. Norway and North America yield each a series of the same general character. A larger number of species has been detected by M. Barrande in Bohemia, with the same general aspect. Individuals of the Oleni, Lingulæ and Oldhamiæ are abundant in certain layers, but a large portion of the strata of this 'Primordial' Zone is devoid of all traces of life.

Small as is this series of generic forms, we recognize representatives of each of the three great branches of the Invertebrata—there are carnivorous feeders as well as creatures nourished by cellular or vegetable food—and Fucoids are traced both in Norway and Malvern, in beds below the Oleni. In

[1] Three species of Oleni found by myself in the black shales of Malvern are included in this zone, though in the Catalogue referred to they are placed in the Caradoc formation. Murchison, however, assigns these black shales to the early date here adopted for them. *Siluria*, 45 et seq.

what sense a system of life restricted to these few and mostly small elements can be regarded as the ancestral type of the races now living in the sea,

——— gentis cunabula nostræ,

will perhaps appear as we proceed. Lingula is henceforward always present in every great group of strata till we reach the Tertiaries.

The next combination which attracts attention occurs in the superincumbent group of strata, called the Llandeilo formation. The following summary will be sufficient for our purpose:

Zoophyta.........	4 genera..........	4 species.
Annelida.........	5 „	7 „
Crustacea	16 „	34 „
Polyzoa	6 „	22 „
Brachiopoda ...	5 „	18 „
*Monomyaria ...	1 „	1 „
*Dimyaria	2 „	2 „
*Gasteropoda ...	3 „	3 „
*Heteropoda ...	1 „	2 „
*Pteropoda	2 „	6 „
*Cephalopoda ...	2 „	4 „

The classes of Invertebrata are now augmented to eleven: the new classes, all Molluscous, marked by the asterisk, being very poor in species, while the previously existing classes have become much more fertile.

The Annelida include both Cephalobranchiate and Dorsibranchiate tribes.

The Crustacea are nearly all Trilobites.

Among the Brachiopoda is no Rhynchonella or Terebratula.

The single Monomyarian is Ambonychia Triton, from Bird-hill, near Llandeilo, of the family Aviculaceæ.

The two Dimyarians are Ctenodonta lævis and Cucullella Anglica (of the family Arcadæ).

These two families stand near to one another in the methods of naturalists.

Among the characters of this period is the relative prevalence of Pteropod and Polyzoan species, and the absence of Echinodermata, if indeed the Haverfordwest Strata which yield Echinosphærites and Sphæronites, be rightly removed from this formation.

The Carnivorous tribes are augmented by the Cephalopoda, which henceforward are found to sustain a very important part in the economy of the sea, and in a less degree by the Pteropoda and Heteropoda.

A third combination may be examined in the Caradoc formation, which indeed is scarcely to be separated from the Llandeilo series, but is much richer in species.

*Amorphozoa ...	2 genera..........	3 species.
Zoophyta	11 ,, ...	23 ,,
*Echinodermata..	8 ,, ...	20 ,,

Annelida	6	genera	8	species.
Crustacea	28	,, ...	82*	,,
Polyzoa	9	,, ...	27	,,
Brachiopoda ...	12	,, ...	67	,,
Monomyaria ...	2	,, ...	7	,,
Dimyaria	10	,, ...	31	,,
Gasteropoda ...	10	,, ...	25	,,
Heteropoda......	1	,, ...	7	,,
Pteropoda	4	,, ...	7	,,
Cephalopoda ...	4	,, ...	26	,,

Two new classes, Amorphozoa and Echinodermata, appear among the lower groups of the Invertebrata. Crustacea ascend to a great predominance, both in number, variety, and magnitude, still belonging to the same divisions; Cephalopoda, Gasteropoda and Dimyaria grow to be numerous. Thus the aspect of the marine Fauna is greatly altered.

Brachiopoda abound, and now Rhynchonella, an existing genus, appears, but without Terebratula, which is also living. Among the Dimyaria, Pleurorhynchus is recorded, but Arcadæ and Mytilidæ are the predominant races, Aviculidæ still the only Monomyarian group. Among the Gasteropoda Murchisonia prevails. Orthoceras, comparatively rare in Llandeilo rocks, is here abundant. Star-fishes appear among Echinodermata.

The series of strata next above is regarded by Murchison as a transitional or intermediate group between the Caradoc and Wenlock formations, and receives from him the name of Llandovery Rocks. Hardly a single genus (Nidulites may perhaps be one exception), but as many as 71 out of 193 species seem to have been found exclusively in these deposits.

Plants. Fucoids.

Amorphozoa	2	genera	2	species.
Zoophyta	14	„	26	„
Echinodermata	5	„	6	„
Annelida	2	„	3	„
Crustacea	11	„	16	„
Polyzoa	3	„	5	„
Brachiopoda	13	„	69	„
Monomyaria	2	„	5	„
Dimyaria	8	„	13	„
Gasteropoda	13	„	26	„
Heteropoda	1	„	6	„
Pteropoda	3	„	3	„
Cephalopoda	5	„	13	„

We find in the Upper Silurian Strata the system of life unequally represented in the different parts of the series, most full in the Wenlock and Ludlow groups, and reduced almost to nothing in the uppermost beds. In the Wenlock group, which contains the principal calcareous mass of the Silurian Strata, we find:

Amorphozoa	3	genera.	3	species.
Zoophyta	29	„	66	„

Echinodermata	20 genera	34 species.
Annelida	4 "	6 "
Crustacea	16 "	36 "
Polyzoa	12 "	25 "
Brachiopoda ...	17 "	79 "
Monomyaria ...	2 "	12 "
Dimyaria	7 "	15 "
Gasteropoda ...	8 "	18 "
Heteropoda......	1 "	3 "
Pteropoda	2 "	3 "
Cephalopoda ...	3 "	22 "

The prevalence of Zoophyta is connected with the great abundance of limestone in this Zone, a circumstance less favourable to Crustaceans, though these are still numerous; all Entomostracous, mostly Trilobites. The Monomyarians are all Aviculoid, the Dimyarians mostly Arcaceæ and Mytilaceæ.

In the Ludlow Zone which follows, we have to remark a general analogy to the Caradoc deposits, both being for the most part arenaceous and muddy deposits, with only partial expansions of the calcareous element. Hence fewer Zoophyta and Echinodermata, more Monomyaria and Dimyaria, these bivalves being still of the same natural families. In the uppermost layer Land-plants and Fishes appear for the first time in the History of Life.

Plants probably terrestrial	1 genus 1	species.
marine ...	2 genera......5	"
Amorphozoa (none)		

Zoophyta	8	genera	10	species.
Echinodermata	11	„	17	„
Annelida	6	„	8	„
Crustacea	15	„	39	„
Polyzoa	1	„	1	„
Brachiopoda	10	„	30	„
Monomyaria	2	„	17	„
Dimyaria	10	„	41	„
Gasteropoda	10	„	27	„
Heteropoda	1	„	4	„
Pteropoda	3	„	4	„
Cephalopoda	5	„	30	„
! Fishes	5	„	7	„

The decline of the whole series is very marked in the Passage-beds, which yield only the following meagre list.

Plants probably terrestrial—Lycopodiaceæ ?

Crustacea	5	genera	11	species.
Brachiopoda	1	„	1	„
Gasteropoda	1	„	1	„
! Fishes	5	„	7	„

Of the few species here noted, three Fishes, the two Mollusks, and six of the Crustacea, are also found in the upper Ludlow beds, of which indeed these are merely the capping. This decline of the Silurian species may be compared with the dawn of the series in the Lingula Zone; the analogy of conditions is maintained by the Crustacea and Brachiopoda, but difference of time is marked by Gasteropoda and Fishes.

From the data thus collected we may compile one general table representing the numerical prevalence in time of each of the classes of Marine Invertebrata in the Lower Palæozoic Strata as at present known.

	Amorphozoa.	Foraminifera.	Zoophyta.	Echinodermata.	Annelida.	Crustacea.	Polyzoa.	Brachiopoda.	Monomyaria.	Dimyaria.	Gasteropoda.	Heteropoda.	Pteropoda.	Cephalopoda.
Passage Beds.	—	—	—	—	—	11	—	1	—	—	1	—	—	—
Ludlow.........	—	1	10	17	18	39	1	30	17	41	27	4	4	30
Wenlock	3	—	66	34	6	36	25	79	12	15	18	3	3	22
Llandovery ...	2	—	26	6	3	16	5	69	5	13	26	6	3	13
Caradoc	3	—	23	20	8	82	27	67	7	31	25	7	7	26
Llandeilo	—	—	4	—	7	34	22	18	1	2	3	2	6	4
Lingula	—	—	2?	—	2	11	1	3	—	—	—	—	—	—

By inspection of this table it appears that the earliest system of marine life contained a few examples of five great classes; viz. Zoophyta, Annelida, Crustacea, Polyzoa, Brachiopoda.

In the next period all the ordinary classes of Mollusca are added, in small numbers.

In the third period, Echinodermata appear, and perhaps Amorphozoa, for this seems, to me at least, still somewhat doubtful.

Thus excepting Cirripedia which up to this time have not been certainly recognized, all the important classes of Marine Invertebrata are traced into the Lower Palæozoic Strata, beginning in each case with few species and very few genera. The progress of the several classes is very unequal. Crustacea, relatively abundant in every stage, reach a maximum in the third period. Brachiopoda, also a very abundant group, reach the maximum in the fifth period with Zoophyta and Echinodermata, while the Monomyaria, Dimyaria, Gasteropoda, and Cephalopoda increase, though not uniformly, upwards to the sixth period. The seventh period is everywhere marked by a zone of sterility, the local extinction of most of the classes, and the introduction of a new order of sediments, brought by a new set of watery currents. Arranging the classes according to their priority of appearance, including Fishes, and giving to each in the successive strata a space proportioned to the number of species, we construct the scheme of proportionate life for the Lower Palæozoic Strata, represented in Fig. 5.

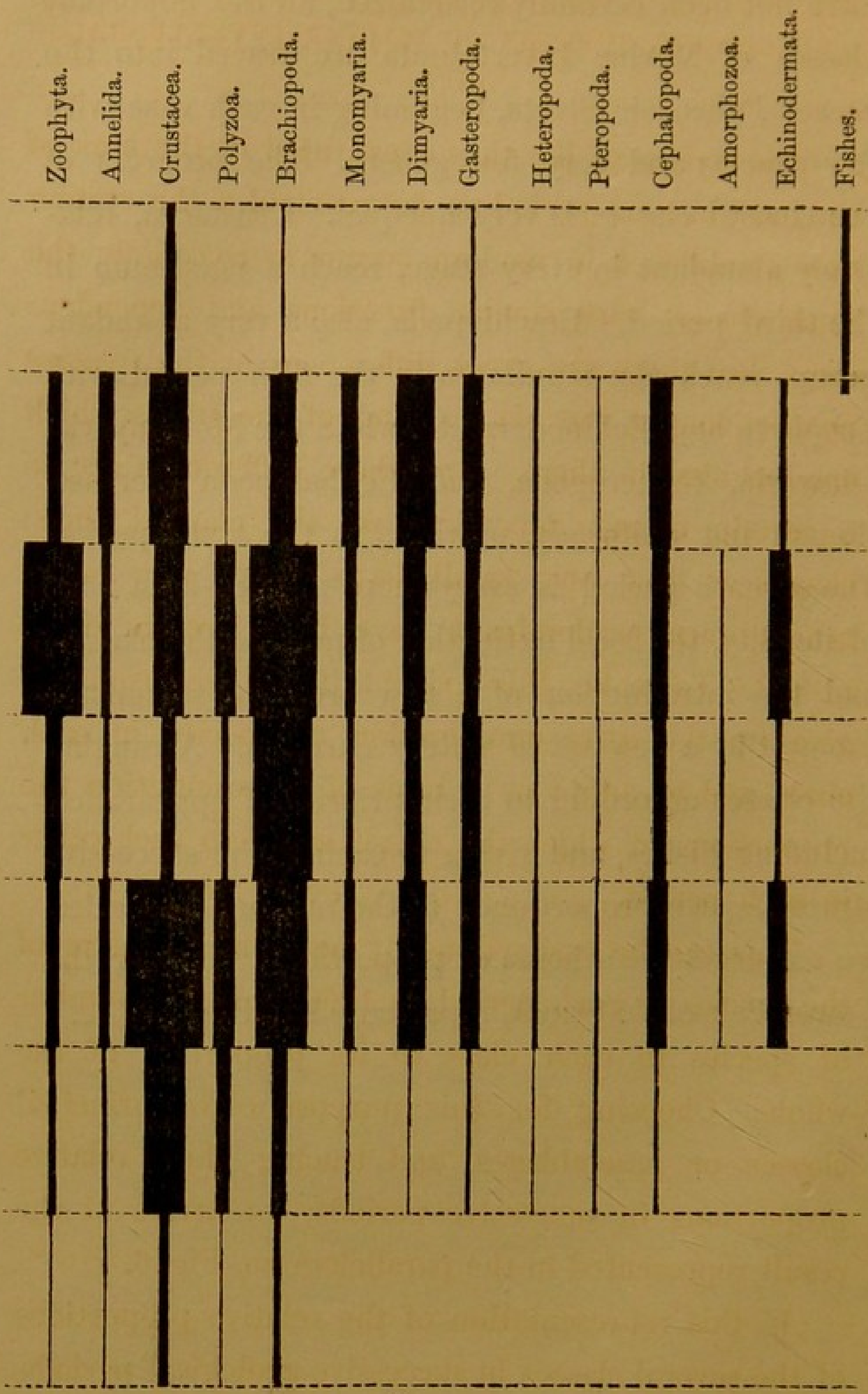

Zoophyta.
Annelida.
Crustacea.
Polyzoa.
Brachiopoda.
Monomyaria.
Dimyaria.
Gasteropoda.
Heteropoda.
Pteropoda.
Cephalopoda.
Amorphozoa.
Echinodermata.
Fishes.

Fig. 5.

SUCCESSIVE SYSTEMS OF MARINE INVERTEBRAL LIFE.

The system of life thus constituted in the seas of the most ancient period so far resembles the system now established in modern oceans as to contain the same classes with similar functions and dependencies. But there are great differences in the relative proportions of the classes, and of the tribes which are included in them. And these differences are to a certain extent dependent on the elapsed time; classes at first very small have grown very large, others once predominant have been greatly diminished. To make this evident it will be useful to give up the mere enumeration of species in each class, and to adopt as a basis of representation the proportions in which the classes stand to each other in each period.

This can be easily done by equating the sum of the species in each period to 1000, and the number of species in each class to its proportion of the whole. Choosing for this purpose eight principal classes or assemblages, and tracing their relative proportions in successive periods, we arrive at the result represented in the parallelogram, Fig. 6.

In this representation of the relative proportions of the several classes in successive geological periods, the arrangement is purposely made to shew by the blue tint those classes which suffer diminution with time, and by the red tint those which from small beginnings grow to great preponderance,—while the yellow tint is assigned to classes which scarcely appear in the early period, but swell out in the middle of the scale so as to equal or overmatch either of the other classes Thus appears in a striking light the great difference between the systems of oceanic life in earlier and later periods, the nature of this difference, and something of the method of variation which binds the whole into one plan, and connects the dawn of created life with this our breathing world.

In all the great periods the numerically prevalent life among the Invertebrata of the Sea appears in the Molluscous division[1].

In the three grand periods the order of prevalence is thus found.

Cænozoic Period ... *Gasteropoda*, Dimyaria, Monomyaria, Echinodermata, Zoophyta, Crustacea, Cephalopoda, Brachiopoda.

Mesozoic Period ... *Dimyaria*, Cephalopoda, Gasteropoda, Monomyaria, Echinodermata, Brachiopoda, Zoophyta, Crustacea.

[1] Only in the very earliest zone, Crustacea appear to predominate over Brachiopoda.

Palæozoic Period...*Brachiopoda*, Gasteropoda, Zoophyta, Dimyaria, Cephalopoda, Echinodermata, Crustacea, Monomyaria.

Taken in the order of their total numerical superiority, the classes range thus:

	Cænozoic.	Mesozoic.	Palæozoic.	Total.
Gasteropoda.........	662+	389	401	1452
Dimyaria............	394	499+	342	1235
Brachiopoda	8	165	632+	805
Cephalopoda	12	396+	336	744
Monomyaria	63	308+	196	567
Echinodermata ...	41	245+	225	511
Zoophyta............	27	103	379+	509
Crustacea	15	65	218+	298

The sign + is placed to the maximum number in each class, shewing that the maximum is attained in the

Cænozoic Period, by Gasteropoda.
Mesozoic Period, by Dimyaria, Cephalopoda, Monomyaria, Echinodermata.
Palæozoic Period, by Brachiopoda, Zoophyta, Crustacea.

These results afford but slight encouragement to the speculation of the inferiority of the earlier and superiority of the later systems, and of continual progress upward in the organization of animals. In proportion to the elapsed time the changes make progress, but these changes are not always in the sense of uninterrupted advance from inferior to superior forms.

For example, Cephalopoda, by universal consent, stand at the head of the Molluscous kingdom of animals; but their origin is of the same date as that of the Mollusca generally: they rapidly rise to importance, but pass the maximum in the Mesozoic period, and are now but a small and scattered part of the inhabitants of the sea, enormously outnumbered by the inferior races of Gasteropoda and Dimyaria. Thus, starting from an equal basis, the superior class has lost in the 'struggle for existence.' But we must examine this subject on other occasions, after gathering additional data.

CHANGES IN MARINE ANIMALS WITH ELAPSED TIME.

The principal classes of marine fossil Invertebrata have now been traced from what seems to be their origin, to or beyond the epoch of their greatest prevalence. We have, in fact, taken the *census* of our marine inhabitants at several periods. It remains to examine them with reference to their structure and grade of organization in these periods; to compare, for instance, the Crustacea and Mollusca of one period with those of another, and thus to learn the *amount* of variation in this respect from period to period, and what is the *method* of variation. We may include in this inquiry Fishes, which to the extent of 736 species have been recorded in the British strata, Marine Reptiles, which are less numerous, and Cetacea, which are rare.

Amorphozoa offer in this respect little for remark. Belonging to the lowest grade of animal organization—by some naturalists of eminence counted among plants—Sponges are nowhere very abundant except in the Cretaceous Strata, where some forms occur much like existing tribes, and similarly furnished with siliceous spicula, and in some cases with a network of anastomozing fibres.

Foraminifera.—These minute cellular structures occur perhaps in most of the limestones and clays, but at present the greater number are quoted from the Upper Mesozoic and Cænozoic Strata. In general they correspond much and even remarkably to existing kinds. Some fossil groups, extremely variable in form, appear quite undistinguishable from recent examples; so that by this tribe of animals there appears a continuity of some specific forms from Mesozoic through Cænozoic to recent times[1].

Zoophyta.—The fossil groups are principally of the kinds which secrete the stony support known as Coral, and belong to the division of Zoantharia. With hardly an exception (Gorgonia?) the numerous

[1] Carpenter, *Proc. of Roy. Soc.* 1855—60. Jones and Parker, *Journal of the Geological Society of London*, 1860.

genera of the Palæozoic systems belong to this division; the same is true for the Mesozoic series; and even in the Cænozoic strata Alcyonoid Zoophyta are rare. Here, then, is one great order of Zoophyta continuous through the whole series. The genera change with the successive deposits, but there is one remarkable law of structure which is characteristic of period. The radiating plates of the Coral are in a young state pretty regular in number and in the mode of division. In all the Palæozoic Strata the primary or principal plates are four, or some multiple of four; in all the Mesozoic and Cænozoic Strata they are six, or some multiple of six. This striking generalization, due to Milne Edwards and the late Jules Haime, is thought to be subject to no more than solitary exceptions. It suggests the reflection that the persistence of characters which we observe in modern living nature was quite as remarkable in ancient organizations, and throws a heavy weight into the scale against the doctrine of the later forms of life being derived from earlier types, through natural variations integrated by time.

Echinodermata.—Six fossil groups represent this beautiful class of animals, viz. Crinoidea, Blastoidea, Cystoidea, Ophiuroidea, Asteroidea, Echinoidea. Of these, two are only known fossil (Blastoidea and Cystoidea), and they belong to the Palæozoic Strata.

Crinoidea are very rare in a living state, Echinoidea plentiful. Now 29 species of Crinoidea occur in the Lower Palæozoic, 15 in Middle Palæozoic, and 105 in Upper Palæozoic Strata. After this they grow comparatively rare, though still 29 species occur in Mesozoic Strata, and 5 in the Cænozoic series. One recent species! On the other hand, Echinoidea are represented in the Palæozoic series by 12 species, in the Mesozoic by 173, and in the Cænozoic by 25.

All the Echinoidea of the Palæozoic series belong to the regular division, with the openings of the alimentary canal opposite (E. endocyclida). The same group occurs in the Mesozoic Series, but in addition we have a second equally large group with these openings not opposite (E. exocyclida), and this is continued in the modern ocean.

The Echinoidea of the Palæozoic Series have such peculiarities in the series of plates and pores as to claim to be enrolled in separate families (Palæchinidæ and Archæocidaridæ), or even to constitute an order (Perischoechinoidea) equal to that of the Echinoidea.

The contrasts which have thus been stated between the Palæozoic and later forms of Radiated Animals may be represented in the following tabular view; where the word Neozoic is used to include Mesozoic and Cænozoic ages.

	PALÆOZOIC.		NEOZOIC.	
	Quadripartita.	ZOOPHYTA.	Sexpartita.	
	BLASTOIDEA. Inarticulata. CYSTOIDEA.	CRINOIDEA.	Articulata.	
Palæchinidæ. Archæocidaridæ.	Endocyclida.	ECHINOIDEA.	Endocyclida. Exocyclida.	Cidaridæ, &c. Echinidæ, &c.

Annelida.—In the modern seas we find two great groups, Cephalobranchiate and Dorsibranchiate Annelida. The same two orders exist in the Lower Palæozoic Strata, sometimes containing species of very large dimensions, and they seem to have been, as now, mostly prevalent on muddy shores.

Cirripedia.—These beautiful animals are not recognized in Palæozoic Strata.

Crustacea.—Dividing them into two groups we find one (Entomostraca) extremely prevalent in the Palæozoic periods; the other (Malacostraca) not yet certainly discovered therein.

Among the Entomostraca the large groups of Trilobitidæ and Eurypteridæ are peculiar to the Palæozoic ages.

The relations to time which thus appear among the Articulata are represented in the following Table.

	PALÆOZOIC.	NEOZOIC.
ANNELIDA.	Cephalobranchiata. Dorsibranchiata. }	{ Cephalobranchiata. Dorsibranchiata.
		CIRRIPEDIA.
CRUSTACEA.	Trilobitidæ. Eurypteridæ. } Entomostraca.	{ Entomostraca. Malacostraca.

Polyzoa, or *Bryozoa*.—These abnormal, often compound mollusks, in their mode of growth and membranous or stony parts much resembling Zoophyta, occur in all the groups of Strata, and excepting Reteporidæ, which are almost confined to Palæozoic Strata, their families are pretty equally diffused.

Tunicata, another somewhat less abnormal group, not covered by shell, is not recognized in a fossil state.

Brachiopoda abound in the Strata, and are scattered through the modern Seas in somewhat greater numbers than was formerly supposed, when dredging at considerable depths was not practised. They are rare in the Cænozoic Strata. Of nearly forty genera and subgenera upwards of twenty appear limited to the Palæozoic Series; only two are mentioned among the Cænozoic fossils of Britain; but twelve at least occur in various modern oceans. The families of Spiriferidæ, Orthidæ, and Productidæ are confined to the Palæozoic Strata; Terebratulidæ, Rhynchonellidæ, Craniadæ, Discinidæ, and Lingulidæ may be regarded as of all periods; Lingula, Discina, Crania, Rhynchonella, Thecidium, Argiope, Terebratella, Waldheimia, Terebratulina, Terebratula, are both fossil and recent. Of these, Terebratula, Rhynchonella, Crania, Discina, Lingula, pass through all the great periods of Geology and still exist, with peculiarities of structure and association very like those which belonged to them in the earliest periods. For example, the Lingulæ of every age always shew almost exactly equal, delicate, depressed, nearly smooth or slightly striated valves, accuminated at the beaks. The shells of Terebratulæ of every age manifest the beautiful punctation to which Dr Carpenter called attention, and are usually smooth; while, in marked contrast with its associate through the immensity of time, Rhynchonella is deficient of this punctation, and is commonly ridged in radiating folds.

If we place before us a series of Lingulæ according to their antiquity, and include the recent species, we remark the absence of the genus from the British Tertiaries, and the abundance of it in Palæozoic ages, the greater comparative breadth of some of the older species (Lingula Davisii, L. granulata), the more elliptical contour of particular examples (L. elliptica from the Carboniferous rocks, L. Beanii from the Inferior Oolite), but upon the whole a uniformity from one end of the series to the other, which suggests very strongly the idea of very narrow limits imposed on the tendency to variety in this genus of mollusks.

If we take in like manner a series of Terebratulæ, such as T. hastata, from the oldest known forms in Devonian and Carboniferous rocks, T. elongata of the Permian, T. punctata of the Lias, T. ornithocephala of the Inferior Oolite and Fullers' Earth Rocks, and T. digona of the Great Oolite, or another series such as T. sacculus of the Carboniferous, T. sufflata of the Permian, T. perovalis of the Fullers' Earth, T. intermedia of the Cornbrash, T. biplicata of the Green Sand, T. semiglobosa of the Chalk, T. grandis of the Crag, and T. vitrea of the existing ocean,—illustrate each largely by examples with sinuated or even margins, more or less prominent beaks, greater or smaller foramina, we shall be amazed at the small amount of real differences which divide these species so far—how very far!—removed from one another in order of time. If we try on a mingled series of Terebratulæ of all ages the sharpest powers of our differentiating naturalists, the same result may happen to them as has happened to older palæontologists,—to confound species differing in age from the Devonian Limestones to the Upper Green Sand; from the Chalk to the Bath Oolite; from the Lias to the Mountain Limestone. Little difference appears between T. striata of the Chalk and T. caput serpentis of the Sea, nor is T. fimbria of the Inferior Oolite very unlike the recent T. Australis.

If we choose among Rhynchonellæ a series such as

R. decemplicata, Silurian; R. anisodenta, Devonian; R. pleurodon, Carboniferous; R. variabilis, Lias; R. tetraedra, Marlstone; R. media, Fullers' Earth; R. obsoleta, Great Oolite; R. inconstans, Kimmeridge Clay;—

or compare

R. Wilsoni of the Silurians; R. concinna of the Oolite; R. octoplicata of the Chalk; with R. psittacea of the Norwegian Seas;

we shall perceive how very small is the amount of change which all the lapse of time has witnessed in the forms of what seem to be among the most variable as well as the most numerous of fossil shells.

Rudista are not known below the Cretaceous Series.

Monomyaria.—Classing these in four great families, Aviculidæ, Pectinidæ, Limidæ, and Ostreidæ, which are all found both fossil and recent, we remark in the first place the constancy of the general characters of each. Thus Ostreidæ shew always rudely laminated shells; Pectinidæ and Limidæ are nearly equivalvular, neat, and radiated; the former nearly equilateral, the latter more oblique; but in this respect yielding to the Aviculidæ, which are more frequently smooth externally, and pearly within, and have very unequal valves. No true oysters occur below the Mesozoic strata. Pecten and Lima are not known below the Carboniferous Limestone; Aviculidæ belong to every geological age.

Dimyaria.—Two great divisions constitute this large group of shells. To the Asiphonida, which approach nearest to Monomyaria, and include three marine groups, Mytilidæ, Arcadæ, Trigoniadæ, and one freshwater group, Unionidæ, belong nearly all the equivalved bivalves of the Lower Palæozoic, and the larger portion of those found in the Upper Palæozoic formations. They are numerous in the later strata, and excepting Trigoniadæ still remain so. The larger group of Siphonida begins to be plentiful in the Oolitic and Cretaceous rocks, and is much more abundant in the tertiary strata and existing oceans.

Two conspicuous fossil genera, Trigonia and Pholadomya, are represented by one living species to each. The former is confined in a fossil state to Mesozoic Strata, and in a recent state to the Australian shore; the latter, a constant companion in Mesozoic Strata, is found also in the Eocene beds, and has been discovered living off the Island of Tortosa. The recent species is in each case judged to be distinct from the fossils. What strong affinities, however, obtain in each case between the fossil and the living races will appear by attending to the form, surface ornament, commissure of valves, hinge, umbones, and muscular impressions.

Pholadomya in every age preserves a striking conformity of characters—radiating ribs on a part of the surfaces, usually swollen at intervals by prominent laminæ of growth, a thin tumid oblong shell, prominent beaks, gaping posterior end, obscure hinge-teeth. The recent species differs but slightly from fossils which might be selected from the Oolites.

Trigonia exhibits more diversity of form and ornament, but preserves the essential characters; a thick shell, ribbed or tuberculated with beaks bending toward the posterior side, which is angular, and bears a prominent ligament often preserved in the fossils. Internally the shell is nacreous, with deep muscular impressions; the hinge-teeth are strong, radiating, and transversely striated. If we place in the order of their existence the following species of Trigonia, we shall perceive at once the general affinity and the special diversity which runs through this genus. The recent species is the only one with ridges radiating from the beak over all the surface.

Recent............	Trig. pectinata.
Chalk	T. sulcata.
Cretaceous	T. dædalea.
	T. clavellata.
Oolitic	T. costata.
	T. striata.
Lias	T. literata.

Pteropoda.—These floating mollusks are few in the stratified deposits of every age; more frequent in the sea. Conularia, Theca, and Pterotheca, belong to the Palæozoic Strata; Hyalæa, Cleodora, and Cuvieria, are both recent and tertiary.

Heteropoda.—The symmetrically convolute Bellerophon, and its allies Cyrtolites and Porcellia, are confined to Palæozoic Strata. The recent Carinariæ are represented by one tertiary Italian fossil.

Gasteropoda.—The marine kinds—all breathing by gills and freely swimming in their embryonic state by help of two ciliated fins, retractile with the body into a convolute shell—grow by constant laws of development into shells of various forms, usually spiral, though examples occur in which this character is insensible (e.g. Patella). The most numerous order both in the recent and fossil state receives the title of Prosobranchiata, from the anterior position of the gills. This character cannot be recognized in fossils, but the forms of the shells are always sufficient to identify the order. It may be divided into two suborders: Holostomata with entire aperture to the shell, Siphonostomata with the aperture notched or canaliculate. The former are for the most part feeders on vegetables, the latter, for the most part carnivorous. The late Mr Dillwyn remarked the prevalence of the siphonostomatous shells in the Tertiary Strata, and the extreme rarity of them in older strata. This curious generalization is found to be of much importance in general views regarding the succession of Molluscous life.

No siphonostomatous shell has yet been found in the Palæozoic Strata. If we place the Mesozoic fossil shells, formerly called Rostellaria (now Alaria), and Cerithium, in the holostomatous division—as Morris and Woodward do—there will remain but few exceptions to the rule that the Palæozoic and Mesozoic Gasteropoda belong to the herbivorous division. Euomphalus and Murchisonia are Palæozoic; Alaria and Nerinæa, Mesozoic. The function of the Carnivora was in the earliest of these periods principally exercised by Cephalopoda; in the later period Fishes and Reptiles were effective as allies, or opponents.

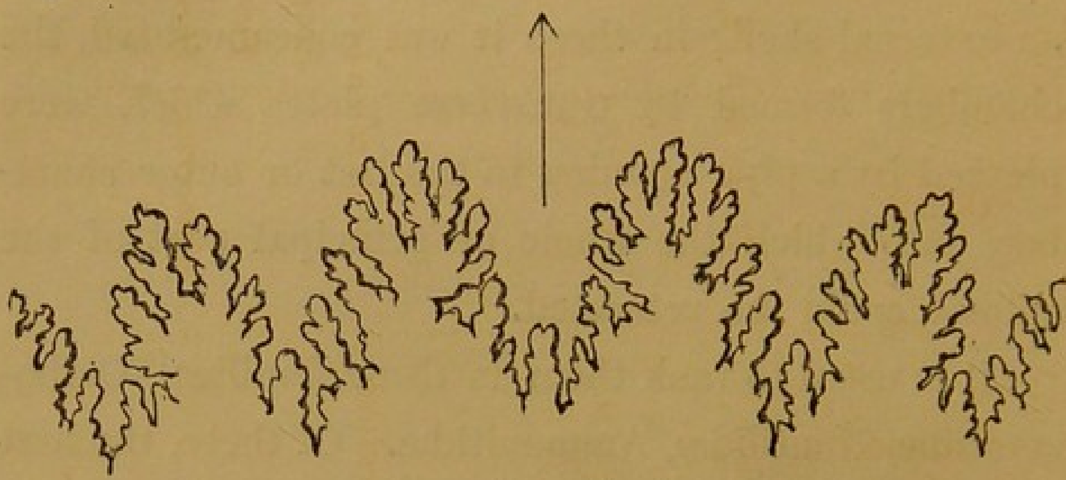
Cephalopoda, among the most abundant as well as highest in organization of all the fossil mollusca, are much less numerous in the modern than they were in the older periods. If we class them by the organs usually called arms or feet, as Octopod, Decapod, and Polypod, we find no trace of the first in the Strata of the British Isles, though Argonauta is fossil in the Italian Tertiaries. Decapod fossil genera more or less allied to the recent Loligo, which includes a long horny pen; to the recent Sepia, which contains a broad calcareous plate, thickly fibrous in front, concave behind, and ending in a solid apex; and to the fossil Belemnite, which is of a long conical figure, concave and chambered in front, fibrous behind, and sometimes mucronated. These are all absent from the Palæozoic Strata, and Belemnites, by far the most numerous group, are peculiar to the Oolitic and Cretaceous formations. The recent genera have an ink-bag containing black pigment; this organ is recognized in several of the fossil races, filled with the fossil ink, which retains its good colour, and has been successfully employed in drawings.

The Polypod genera were (unlike all those previously mentioned except Argonauta) protected by an external shell; in these it was concamerated, the chambers formed by transverse plates which were pierced by a pipe opening to the last or outer chamber, into which the whole or principal part of the animal could be retracted.

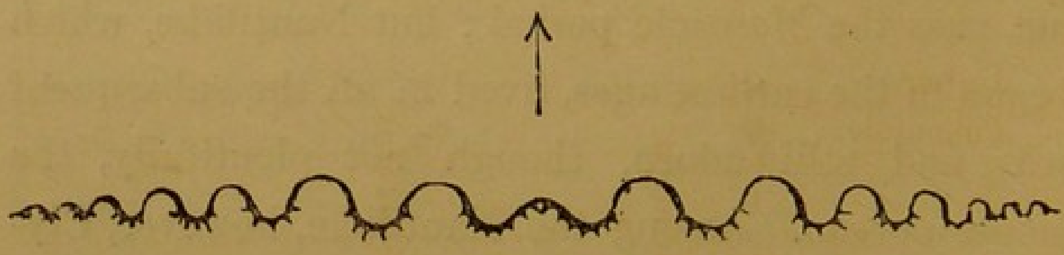
It is usual to rank them in three families—Orthoceratidæ, Nautilidæ, Ammonitidæ. Of these, the first did not pass[1] the Palæozoic period; Ammonitidæ did not pass the Mesozoic period; but Nautilidæ, which began in the earliest ages, lived in all the subsequent seas, and still adorn, though not plentifully, the modern ocean. Among the Nautilidæ, however, Clymenia ceased before the close of the Palæozoic age. The geological range of the Ammonitidæ is still more

[1] Unless in the single case of the Triassic beds of Saint Cassian, which contain what seem to be Orthoceratites, and also very peculiar Ammonitidæ having the numerous gradually diminishing lobes of Ceratites, with the highly ramified sutures of the Oolitic Ammonites.

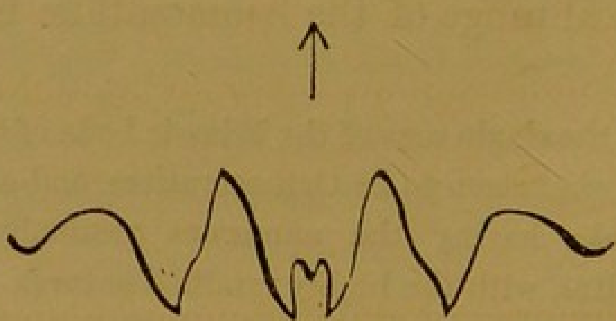
curious, for the earliest group, Goniatites, ceases with the upper Palæozoic Strata; Ceratites occurs in Muschelkalk, but does not enter the Lias; Ammonites begins at some height in the Lias, and dies out before reaching the upper Chalk, being accompanied in decline by Hamites, Scaphites, Turrilites and Baculites. These distributions appear in the following Table.



Ammonites sublævis.



Ceratites nodosus.



Goniatites striatus.

Recent.			Nautilus.				
Cænozoic.			Nautilus.				
Cretaceous.	Belemnites.		Nautilus.	Ammonites.	Scaphites.	Turrilites.	Hamites.
Oolitic.	Belemnites.		Nautilus.	Ammonites.			Ancyloceras.
Triassic.			Nautilus.	Ceratites.			
Upper Palæozoic.	Orthoceras.	Clymenia.	Nautilus.	Goniatites.			
Middle Palæozoic.	Orthoceras.	Clymenia.		Goniatites.			
Lower Palæozoic.	Orthoceras.						

Having so limited a total range in time, but including some hundreds of well-marked specific forms, and being widely diffused in geographical space, Ammonites furnish to the Palæontologist admirable data for fixing the chronological succession of the secondary strata, in cases when these strata are not continuously traceable. Taking some well-known forms, including Ceratites, and placing them in the order of their superposition, we obtain the following series of geological epochs in the great Mesozoic Period.

No Ammonites or Ceratites or Goniatites in Cænozoic Strata.

Cretaceous Period			Amm. Rhotomagensis	Lower Chalk.
			A. varians	Upper Green Sand.
			A. auritus	Gault.
			A. Deshaysii	Lower Green Sand.
Jurassic Period.	Upper Oolitic Age		A. giganteus	Portland Oolite.
			A. biplex	Kimmeridge Clay.
	Middle Oolitic Age		A. vertebralis	Oxford Oolite, and below.
			A. calloviensis	Kelloways Rock.
	Lower Oolitic Age	Great Oolite.	A. macrocephalus	Cornbrash, and below.
			A. gracilis	Great Oolite.
		Inferior Oolite.	A. Parkinsoni	Inf. Oolite upper part.
			A. Humphreysianus	Inf. Oolite middle part.
			A. Murchisonæ	Inf. Oolite lower part.
			A. Jurensis	Sand.
	Liassic Age		A. bifrons	Upper Lias.
			A. Conybeari	Lias Limestone.
			A. planorbis	Lowest Lias.
Triassic Period			Ceratites nodosus	Muschelkalk.

No Ammonites or Ceratites in the Palæozoic Strata.

Fishes commencing, as already stated, in the upper Silurian Strata, become from that point highly important in geological history—more important than even their numerous remains at first seem to indicate; for though teeth, scales, and fin-rays of these animals are not scarce in the strata, these, the most conservable of the hard parts of fishes, are scattered irregularly, and, until studied after the method of Agassiz, give but slight information. Under the hands of this great naturalist and his disciples, Egerton and Enniskillen, we have seen the history of fossil fishes grow to embrace many hundreds of distinct forms, very interesting in physiology, always very valuable in geological reasoning. The method of Agassiz is no doubt in some degree conventional, and specially framed for the study of fossils, yet the characters derived from the dermal covering are always of high value in the classification of the vertebrata, and specially influential in fishes.

Two great orders of fishes have enamelled scales e.g. Placoid and Ganoid Fishes—the latter have enamel externally, bone internally for each scale, and the scales so closely packed as to constitute a real dermo-skeleton. These orders occur in all the strata above the Silurians, and still exist: they are the only orders which occur in the Palæozoic rocks; in the existing ocean and in the Tertiary Strata they are comparatively the least abundant.

Two other orders have horny scales, neither bony nor enamelled—viz. Cycloid and Ctenoid Fishes; and these, beginning their courses with the Mesozoic Strata, constitute by far the largest portion of the existing race of fishes. Here again we perceive the strong contrast between the Palæozoic and Neozoic inhabitants.

Existing marine Fishes have tails formed on different models, as the forked tail of the Salmon, the rounded tail of the Wrasse, the elongate pointed tail of the Conger, and the unequally lobed tail of the Shark. The three former tails may be called regular or symmetrical, the latter unsymmetrical; or if we please, the fishes possessing the former may be called Homocercal, while the latter may be called Heterocercal. In existing nature the Homocercal fishes are by far the most numerous; they are plentiful in Cænozoic and Mesozoic Strata, but they are unknown in the Palæozoic rocks, where Heterocercal fishes alone occur. This is the more remarkable because both in the Palæozoic and Mesozoic rocks Ganoid fishes abound; still Palæozoic races are all heterocercal, Mesozoic are mostly homocercal. In all periods Placoid fishes were heterocercal.

The group of Placoid Fishes is the only one which has existed through all geological periods to the present day; it includes a large range and gradation of structure, so that while some races may probably be regarded as of the highest type in the class, others (if we include Myxine) can only just claim to be vertebrata. The fossil races belong generally to the higher types. The skeleton being cartilaginous or mainly so, it often happens that the vertebral column is not preserved: indeed very frequently only a few scattered teeth and fin-rays remain to attest the existence and magnitude of these ancient mostly shark-like creatures. Singular to say, one group of these fishes, represented in a living state by one Australian species (Cestracion Philippi), has been traced through all these periods (except Cænozoic) by its teeth and fin-rays, abounding in Palæozoic and Mesozoic ages; while, on the other hand, the ordinary sharks of the modern seas are represented in the Tertiary strata plentifully, in the Mesozoic sparingly, in the Palæozoic not at all. The Cestraciontidæ have, besides pointed teeth in front, some very large and broad behind, not pointed but suited for crushing and grinding hard and solid substances, such as shell-covered Mollusca, Crustacea, Echinodermata, or even Ganoid fishes[1].

Reptilia according to Owen[2] may be arranged in thirteen orders, of which five, viz. I. Batrachia (Frogs),

[1] Buckland, *Br. Tr.* Pl. 41.

[2] *Reports of British Association*, 1859.

II. Chelonida (Turtles), III. Ophidia (Snakes), IV. Lacertilia (Lizards), and V. Crocodilia (Crocodiles), are both recent and fossil; and eight, viz. VI. Deinosauria, VII. Thecodontia, VIII. Pterosauria, IX. Anomodontia, X. Sauropterygia, XI. Ichthyopterygia, XII. Labyrinthodontia, XIII. Ganocephala are only found in a fossil state. Among the marine tribes are some of the Chelonida, all the fossil Ichthyopterygia, Sauropterygia, some of the Crocodilia and Lacertilia, possibly the Thecodontia[1], omitting the Chelonida. They stand in the following order of time:

Mososaurus.........Chalk.
Leiodon ....Chalk.
Pleiosaurus.........Kimmeridge Clay.
Cetiosaurus.........Great Oolite and upwards to Wealden.
Teleosaurus.........Lias and upwards to Chalk.
Ichthyosaurus......Lias and upwards to Chalk.
Plesiosaurus ......Bone Bed, Aust, and upwards to Chalk.
Stagonolepis[2] ......Triassic Sandstone of Elgin.
Thecodontosaurus. Conglomerate, Bristol.

It will be seen hereafter that Terrestrial and Freshwater Reptilia appear to be of higher antiquity than the marine tribes yet discovered. Remains of Chelonida appear to be about of the same antiquity as the marine Saurians; they occur in the Red

[1] The fossil Crocodilia may perhaps have visited rivers and the land; their legs might allow of this, and their feet are not unsuitable.

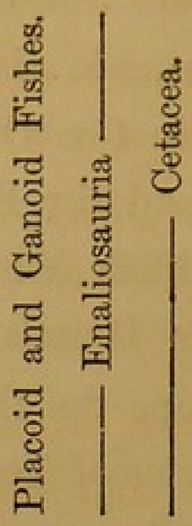
[2] Huxley, *Geol. Soc. Journal*, 1859.

Sandstone of Lochmaben in Dumfriesshire, with various undetermined Ichnites.

Cetacea appear to be totally absent from any of the deposits older than the Tertiary Strata, a circumstance more remarkable since the discovery of terrestrial Mammalia in the Oolitic Strata of Purbeck and Stonesfield, and the Bone-bed of Würtemberg. The Crag of Suffolk (Pleiocene) is the oldest tertiary deposit in our Islands containing Cetacea. In no district of Europe do they reach downward even to the earliest series of Tertiary Strata. Above this D'Orbigny counts four genera in the Parisian, seven in the Falunian, five in the sub-Apennine strata —fifteen, the maximum, in the modern seas. In a general point of view, the Cetacea, Great Reptiles, and Great Fishes,

Cænozoic	Cetacea,
Mesozoic	Great Reptiles,
Palæozoic	Placoid and Ganoid Fishes,

may be regarded as successively the dominant races of the Sea, the Cetacea taking up the functions which had been exercised by the Enaliosaurians. The earlier races of Cestraciont Fishes, with their crushing teeth, may be thought very well suited to such food as the shelly Mollusca, the strongly-walled Encrinites, and the cuirassed Crustacea of the early periods might furnish; and when their influence declined in the Tertiary Seas, the skates and rays, furnished with a suitable pavement of teeth, may be supposed to have assumed some of their duties.



FRESHWATER LIFE.

The stratified rocks on which we base the general scale of elapsed time being marine, and the occurrence of freshwater deposits among such being necessarily limited, it is not surprising that our history of freshwater life is marked by many lacunæ. Rather may we be surprised that the nature of the movements of the earth in ancient times was such that marine deposits were covered by lakes, or estuaries, at several epochs, and sometimes for long periods of time. In the following brief catalogue, suited to the British Isles, we find what may be termed Freshwater zones in all the great systems of Strata.

Cænozoic Period..	Postglacial shelly marls, &c. Preglacial shelly marls, &c. Alternating freshwater and marine Strata of the Isle of Wight.
Mesozoic Period ...	The deposits of the Weald of Sussex. The deposits of Whitby and Scarborough.
Palæozoic Period ...	The Coal-formation. The Upper part of the Old Red Sandstone of Ireland.

And besides, there are several cases of the intermixture of land-plants and insects and sea-shells, only to be explained by the flowing of currents from the land, as at Stonesfield, Westbury Cliff, &c.

The forms of life in the Fresh waters of the Earth differ from those in the Sea in all cases; but the difference can seldom be traced to any physiological necessity, arising from the difference of the fluids. Amorphozoa, Zoophyta, Mollusca, Annelida, Crustacea, Fishes, Reptiles and Mammalia, occur in both, under shapes not indeed identical, but fashioned on the same general models. The salmon migrates from one water to the other, and experiments appear to shew that by long continuance of favourable circumstances other fishes and some Mollusca might be made to exchange elements, or to subsist for a time in brackish water, a fluid of intermediate character. But, on a large scale, the provisions of nature keep separate the denizens of lakes and rivers from those of the lagoons, bays, and currents of the sea.

This fact, which is observed in all countries, is connected with another of much significance, the comparative fewness of the freshwater races, and their great affinity over large tracts of the earth. Unionidæ and Cycladæ are the prevailing family of Dimyarian Mollusks; Paludinadæ and Limnæadæ, reinforced by Ancylus, Melania, Neritina, &c. the most frequent of Gasteropoda. How these freshwater genera have been so widely diffused as in fact we find them; how some particular species have become common to so many rivers and lakes, are questions of much interest. For as neither the animals nor their ova could pass through the salt water, and retain vitality, we must ascribe to changes in physical geography and the accidents of mixed occupation of a country, the transference from one river to another, of the germs of life; or regard the existing fresh waters, now unconnected, as formerly somehow connected; or suppose a creation of the same species or the same genera at many separate points. Rejecting this last, we may venture to prefer, as a general explanation, the transfer of the germs of life by natural events, specially by birds carrying spawn from one river to another, even as now we are transferring by experimental means the Crawfish, the Trout, and other valued creatures, to rivers which have never yet been visited by them.

The results arrived at by tracing some of the successive groups of freshwater life, from the earliest date to their eventual distribution, are very instructive in regard to what may, with reference to human ideas, be termed the Theory of Creation. Taking first the molluscous classes and remembering that Brachiopoda and Monomyaria are absent from fresh waters, we may fix our attention on the Dimyarian family of Unionidæ and Cycladæ. They occur fossil according to the following scale:

Cænozoic—		Unio, and Cyclas, not very plentiful, with Gasteropoda and land-plants.
Mesozoic —	Wealden......	Unio and Cyclas, with Cyprides and Gasteropoda and land-plants.
,,	Purbeck	Unio and Cyclas, with Cyprides and Gasteropoda and land-plants (Cycadaceæ).
,,	Yorkshire Oolitic.	Unio not common, with land-plants (Cycadaceæ, &c.)
Palæozoic—	Coal-formations.	Unio, several species, common, with land-plants, Lepidodendron, &c. Cyprides, &c.
,,	Upper Old Red.	Unio, in one locality, with Ferns.

Here we have the remarkable fact of decided affinity in the successive groups of freshwater bivalves, through the vast series of deposits which extends from the Devonian rocks to the present ocean —similar forms, similar accompaniments, and similar exclusions of other forms, such as Brachiopoda, Monomyaria, &c. So that the law of segregation (if we may use this term) which separates the few freshwater from the many marine races, operates now as it did operate in the Palæozoic ages, and similar races are subjected to its influence. During all this time Unionidæ have maintained their characteristic structure and associations. Taking next the Gasteropoda we remark in living nature two groups, one separating air from water by means of gills like fishes, the other breathing air by lungs. Of the former, the living examples cluster round the genera, Paludina, Valvata, Ancylus, Neritina, the former are represented by Planorbis, Limnæa, Physa, Melania. In a fossil state these forms are recognized at several stages, but not at so early a period as the Dimyarians. They are not known to occur below the Purbeck Strata.

Cænozoic...Paludina, Neritina, Planorbis, Physa, Limnæa, Melania, &c. several zones in the Fluvio-marines of the Isle of Wight.

Wealden ...Paludina, Melania, Melanopsis.

Purbeck ...Paludina, Valvata, Melania, Physa, Limnæa, Planorbis.

The freshwater Mollusca altogether appear of later origin than the marine tribes, and the Gasteropoda appear to be of later origin than the Dimyaria, in fresh waters as well as in the sea. If we compare the fossil and living Paludinæ, Physæ, Limnææ and Planorbes, we are struck by the great resemblance in each case; Physa in each case has the sinistral spire, Planorbis is discoidally depressed, Paludina rises in tumid whorls, Limnæa extends from a large aperture to an acute point. Here again is the evidence of long duration of even slight peculiarities, persistence of type, and restraint of variation.

If in either of these cases—the Unionidæ—the Paludinadæ—the Limnæadæ—Planorbes—Physæ, &c.,—the modern forms are derived from the ancient, we have the full measure of the whole variation—the differentials of change are all integrated by time, and we behold the sum—how little! But if not so, if the modern and ancient species have sprung from different branches of a stem still older than either, how much stronger, if possible, is this decisive testimony against the doctrine of indefinite change through time and circumstance! Circumstances have varied, ages have passed away, and yet every generic group exhibits at every step the same essential characters, and many of the little peculiarities, such as eroded beaks, plications on the surface, reflexions of the lip, carinations of the whorls, which cannot be consistent with accumulated tendencies to change.

If in the same spirit we look at the few Insects, Crustaceans and Reptilia, the only other freshwater groups which occur at several stages in the series of strata, very similar results appear, much resemblance in the components of the several groups from whatever age we take the examples, and much adherence to generic, or family type. The series of freshwater Reptiles considered in this respect offers the largest variations, but the structure of some of the earlier forms, even in regard to the limbs, is too uncertain to allow of a satisfactory view of their history. True Crocodiles with vertebræ concave in front, occur above the Chalk[1]; Crocodilians with biconcave vertebræ—an indication of aquatic, but not necessarily of marine life—are frequent in the Oolites and Lias[2], and are found in the Trias[3], with a Lacertian fossil[4]. Batrachians with deciduous gills are mostly of Tertiary date[5], but allies of the Menopoma and Triton appear in the Coal Strata, and in Strata above them[6]. Freshwater Chelonians are recognized in the Strata of Purbeck and in Tertiary deposits.

[1] Croc. Harsingsiæ.
[2] Teleosaurus and Steneosaurus.
[3] The Stagonolepis of Elgin.
[4] Rhynchosaurus of Shropshire.
[5] In the *Paper Coal* of the Rhine.
[6] Archegosaurus—Labyrinthodon.

TERRESTRIAL LIFE.

The information afforded by freshwater deposits, and the effects of freshwater currents flowing into the sea, is strongly reflected in the history of the ancient land. As the stream flows down from its parent mountains, gathering air and penetrated by light, it soon begins to swarm with infusoria, feeding among the immersed and marginal vegetation; Planorbes, Limnæadæ, Cycladæ, appear in its sparkling or quiescent water; Gammarinæ and Daphniæ, Insects and Argyronetæ, furnish delicate diet to the watchful Trout; and thus race follows race, till finally Unionidæ prevail and occupy the bed of the current as it slowly winds toward the estuary, which, itself almost deserted, divides the fluviatile from the oceanic worlds of life.

When in the Coal-formation we find an abundance of Unionidæ, often buried in colonies as they lived, in layers of fine sediment, alternating with Coal Strata, accumulated towards the margin of the sea, we may easily connect in imagination this marshy savannah with rivers descending from the interior, and suppose on their banks many races of animals whose remains, if rare, may nevertheless occur to diligent search on favourable occasions.

By such scrupulous attention to the contents of Ironstone nodules at Coalbrook Dale Mr Anstice discovered two species of Coleoptera (Curculionidæ), and a Neuropterous Insect (Corydalis)[1]. But the most remarkable illustration of the utility of this kind of hopeful search is afforded by the discovery of a landshell, allied to if not identical with Pupa, in the interior of a fossil tree (Sigillaria), in the Coal-formation of Nova Scotia, by Sir C. Lyell and Dr Dawson. Remains of Land Reptiles (Dendrerpeton and Hylonomus), and a Chilognathous Myriapod (Xylobius). An airbreathing Gasteropod of a modern genus, airbreathing Reptiles, Insects of two recognized orders, and a Myriapod, these suggest and indeed imply the existence of many more forms of terrestrial animals so as to constitute a Fauna of the Carboniferous age. Precarboniferous we might perhaps say, for plants of the family (Lepidodendra) with which these insects and reptiles and shells are associated occur in earlier strata, being first noticed in the uppermost bands of the Silurian system.

Terrestrial plants are scattered at intervals through most of the Marine Strata, above the Silurian Rocks, thus indicating the force and frequency of affluents from the land. They were collected in considerable quantity in estuarine and lacustrine deposits of the Carboniferous and Oolitic eras, and in lagoons of salt water, as at Stonesfield, having been,

[1] Prestwich, *On Coalbrook Dale Coalfield, Geol. Trans.*

perhaps, blown into these latter situations with Neuropterous and Coleopterous Insects, among the latter, Buprestidæ and Curculionidæ. In the Palæozoic ages are no Cycadaceæ; in the Neozoic no Lepidodendra; Ferns abound in several of the deposits in and above the Upper Devonian Strata.

In the lowest beds of the Lias and passage-beds from the Trias, Insects have been collected at the Cliffs of Aust, Westbury and Wainlode, and at several other places in the Vale of the Severn, probably blown into shallow salt water, a common circumstance on the coasts. Others occur more abundantly in the Vale of Wardour and Purbeck[1]. The census of the fossil orders of Insects runs thus:

Cænozoic...Coleoptera (Copris, Donacia, Harpalus,) in Pleistocene beds, at Mundsley, Norfolk.
(In France most of the Orders of Insects are found in freshwater beds at Aix in Provence).
Mesozoic ...Purbeck beds, Coleoptera, Neuroptera, Orthoptera, Homoptera, Diptera.
Oolite of Stonesfield, Coleoptera, Neuroptera.
Lias of Severn Vale, Coleoptera, Neuroptera, Orthoptera, Homoptera, Diptera.
Palæozoic...Coal-formation, Coleoptera, Neuroptera.

Terrestrial Saurian Reptiles acquired extraordinary magnitude in the Oolitic period, and exhibit as

[1] Brodie, *On Fossil Insects.* Westwood has determined many of the orders and genera.

high a grade of organization in Megalosaurus and Iguanodon as the aquatic Crocodilians, of the same ages, Teleosaurus, Steneosaurus, Cetiosaurus and their allies. The earliest traces of Land Saurians are those already alluded to as found in the Nova Scotia coal-field, one of which is supposed to be of Lacertian, the other of Ganocephalic affinity. Perhaps in regard to most of the Saurian fossils we may prudently wait for further information before confidently assigning them to marine, fluviatile, or terrestrial life. Ichthyosaurus is no doubt truly marine, Megalosaurus truly terrestrial; regarding many others we may reserve an opinion.

Of fossil birds our evidence is mostly in footsteps, sometimes, as in Connecticut[1] and near Hastings[2], of such extraordinary magnitude as to match the stride of the Moa of New Zealand. In general the footprints are of the Cursorial order of Birds; marks of their movements are found in the sandy shores of the Permian, Triassic, and Oolitic Seas.

Mammalia of the Marsupial order appear to have the priority in time. The most ancient fossils of this kind yet traced are the small insectivorous teeth found in the Trias of Würtemburg[3]. Next

[1] Hitchcock, *Mem. American Academy*, Vol. III.

[2] Beckles, *Journal of Geol. Soc.*

[3] Lyell, *Elem. of Geol.* p. 343.

come the Insectivora of Stonesfield, which in part belong to the Marsupialia[1], and one, the latest of the discoveries there, the Stereognathus Ooliticus, which belongs to an artiodactylous order[2]. Next come the Insectivora and Rodentia of Purbeck[3], also in part Marsupial. Then as far as yet discovered a blank follows; there is no Mammal known of the Cretaceous period, but the Tertiary Strata reveal several successive groups. The whole series stands thus, if we include more than the British Fauna:

Pleistocene and Pleiocene. Full series of orders of mammalia.
Meiocene...Pachydermata and other families.
Eocene......Pachydermatous prevail.
Purbeck ...Marsupial Insectivora, Rodentia.
Stonesfield..Marsupial Insectivora, Artiodactylous genus.
Trias.........Marsupial Insectivora.

ANTIQUITY OF THE EARTH.

Geologists have been much censured for vainly endeavouring to assign measures of time to the seemingly vague and shadowy ages of the Trilobites and Belemnites; nor have they escaped censure for

[1] Buckland, *Bridgewater Treatise* and Owen, *Brit. Foss. Mammalia.*

[2] See for the latest Classification of Mammalia the *Rede Lecture* by Prof. Owen, 1859.

[3] The capital discovery of Mr Beckles.

countenancing speculations which assign to the human race a period very much longer than that hitherto adopted on historical grounds. They deserve no rebuke, however, for the endeavour to force their way into the citadel of natural truth, if they undertake the siege after a sufficient survey of the difficulties of the enterprise, which in this case are not slight. Let any one acquainted with the modern aspect of Astronomy, consider well the nature of that problem which, omitting all previous cosmical changes, would count the years since the planet became a terraqueous globe—let him then look at the Mosaic narrative, and be satisfied with the truth, that 'In the beginning God created the heavens and the Earth,' for no measures of time conceivable by man will reach back to that remote epoch in the history of our solar system. That, however, is the starting-point of physical geography, for then began the movements and changes in land, water, and air, which it is the business of geology to register and interpret. As already explained, the gift of life on this earth is limited by conditions within which alone it is possible: until these conditions were attained—that is to say, arrived at in the pre-ordained course of nature—the earth might be well described by the words 'without form, and void.' For the rocky monuments of this period, which we have endeavoured to trace, the terms 'Azoic' and 'Hypozoic' have been suggested. Thus arises the second great epoch in geological chronology—the epoch of Life on the Earth—the starting-point of Palæontology. How shall we proceed to collect evidence which may bring that remote event into a scale of solar time? What natural phenomena can be found, so much alike in all past periods of time, and so related to years and cycles of years, as to be safely employed in estimating, not only the relative antiquity of the several races of plants and animals, but the absolute antiquity of the earliest inhabitants of the earth?

The Geological Scale of Time is founded on the series of the strata deposited in the ancient sea; if the forces tending to produce such deposits have always been productive of equal effects in equal times, the thicknesses of the strata are exact measures of the times; the thickness added in a certain historical time to the modern sea-bed, will bear the same proportion to the total thickness which has been added in geological time as the historical time ascertained to the geological time required. This view of the uniformity of natural effects, in the strict terms here assigned, is perhaps held by none of the followers of Hutton, however nearly some expressions of the eminent author of the *Principles of Geology* may seem to approach it. It cannot be held consistently by any speculator who is unprepared with proof, that the conditions under which the laws of nature operate have always been the same; not indeed at each moment of time or at each point of space, but when a cycle of time or the average of such cycles is taken as the unit of proportion, and the area of the globe is the field of experiment. Now this proof requires that the proportion of land and water and atmosphere should be always cyclically the same, the land equally elevated, the water equally deep—that terrestrial climate should on the whole have been unchanged—atmospheric precipitations always equal in total effect—the surface of the globe always equally destructible,—besides other conditions on which equality in the rate of deposition of sediments depends. Still, in spite of all these difficulties, the short measure of modern physical effects in a given time is the only standard to be applied to the immensity of past duration.

They who reject the uniformity of natural effects, as a principle of computation of past geological time, do so on the ground that the earth has gone through a series of different conditions since it became a terraqueous globe; that the effect of such different conditions may be perfectly seen in different parts of the globe at present, giving to one quarter more rapid waste of the land and more rapid accumulation in the sea; that some of these changes of conditions can be traced to vast and ancient movements in the crust of the earth, perhaps the accumulated consequence of slow variation in the condition of the interior, but certainly productive of great derangement of rate in the accumulation of earthy sediments at the surface. In the full announcement of this view of the earth being subject to great disturbance from within,—disturbance growing less and less with time—no one has been more explicit than Leibnitz, who conceived the idea of a globe once fluid with heat, then slowly cooling, changing its dimensions, and breaking up its surface in confusion; 'donec, quiescentibus causis atque equilibratis, consistentior emergeret rerum status.' The two theoretical views thus strongly contrasted may be represented by a few letters—any known natural effect or amount of work performed (E), is a product of the power operating (P), and the time consumed (T), or $E = PT$. If P can be determined, T becomes known. If P is assumed with uncertainty, as by the Uniformitarians, T is equally uncertain. The really useful problem then is to find the limits of the power, which can only be done by a knowledge of the law according to which the conditions influencing its value depend. Such a law is supposed to be discoverable in the decreasing temperature of the surface of the globe; with this decrease the disturbances from the interior are supposed to diminish, and the action of the atmosphere to be more and more approaching to a uniform rate. I propose to consider the computations which may be founded on these different views.

Nothing can be simpler in aspect than the problem of the age of the stratified crust of the globe on the Uniformitarian hypothesis. We have only to find out the rate of accumulation of sediment in the sea—the thickness of deposits produced in a year, or century, or some long historic period—and apply this measure or rate to the ancient deposits. This modern rate of progress of deposits is very unequal; great along some shores, which thus are stretching outwardly to contract the domain of the sea, insensible on others, especially where sea-currents sweep the coast and carry away the sediments to other situations. But so it was in ancient times, for none of our strata have more than a limited range, and some of those that are most extensive may be reasonably thought to have acquired their large breadths by oceanic currents which disturbed and redistributed sediments over areas greater than those of original deposition.

The distance to which fine sediments brought by rivers are carried in the ocean is found much to exceed the expectation of scientific navigators. The fine sediments of the Maranon were still discoverable by Sabine at the discoloured surface of the sea 300 miles from the mouth, so that in fact even the deep central valleys and gulphs of the Atlantic may be receiving sediments from the Western Chains of America, mixed with, perhaps alternating with other particles from the interior of Africa. The extent of modern oceanic deposits may thus be admitted as equal to that of the ancient Strata; if so, the Uniformitarian calculation becomes of easy application.

Take any large surface of the land, which yields to the atmospheric agency unequally in different parts, because granite, limestone, and sandstone, are unequally acted on by rains, and frosts, and carbonic acid; observe and measure what is carried away by one or more rivers from this surface to the sea in one year. Assume this to be a fair average for the whole surface of the land, and, to save trouble, suppose the whole of the sediment to be spread out on the sea-bed, over an area equal to that from which it was derived. The thickness wasted from the land, in one year, is thus the same as that added to the sea-bed in one year. Divide by this thickness the measured thickness of the sedimentary strata, the result is the number of Uniformitarian years employed in depositing the strata, if the materials were all derived in this manner from atmospheric waste of the land, as some suppose.

For example, the Ganges, which drains 300,000 square miles of plains, hills, and mountains, containing a great variety of rocky and earthy masses, delivers annually to the Bay of Bengal 6,368,077,440 cubic feet of sediment, which is equal to $\frac{1}{111}$th of an inch in a year. The maximum thickness of the strata is supposed to be about 72,000 feet = 864,000 inches, and dividing this by $\frac{1}{111}$th we have the calculated antiquity of the base of the stratified rocks = 95,904,000 years. But here two things are to be allowed for. The thickness of the old strata is taken at a maximum, and the new deposit is supposed to spread over a much larger space of sea-bed than it really does, so that the period found is something too large. On the other hand, the Ganges carries very much more sediment than some other great rivers,—nearly twenty times as much as the Rhine;—it has the character of tropical or excessive effect, and on this account the period may be much too short.

In whatever way we try the question of the antiquity of the fossiliferous strata, whatever class of phenomena we bring under examination, the results are always the same, always indicative of periods too vast, and we must add too vague, for conception. If for the purpose of arriving at more definite ideas we select from the pile of strata some part whose origin is clear, and whose formation was continuous, the time still comes out enormous. The Coal-formation, in South Wales, is 12,000 feet thick, and through a great part of its thickness there, gives proof after proof that this whole series of strata was deposited bed by bed at or nearly at the level of the sea; the estuarine alveus continually sinking, and continually receiving additions of fresh sediment. Many beds of Coal, amounting to one hundred and twenty feet in thickness, alternate with these sediments. Not a single bed of limestone occurs in the series; towards the bottom are marine shells, above only freshwater shells and land-plants; the whole mass agreeing with the facts of estuarine accumulation at the mouth of a great river. If the growth of the sediment were at the same rate as the waste of the land, $12{,}000 \times 12 \times 111 =$ the years employed in the production of the sediments $= 15{,}984{,}000$ years.

But there are circumstances in the Coal-formation which greatly modify this result. It is evidently a deposit in quiet water—quiet as compared with the agitation of the open ocean. In such a case the addition of sediment would not follow the law of open sea-deposits but rather that of lakes, and so the strata would be for the most part accumulated in a sort of delta, or along a limited range of coast-line. The Coal-field of South Wales is connected by the character and succession of the Strata with those of the Forest of Dean, Kingswood, and Somersetshire. This gives a length of 125 miles and a maximum breadth of 50, which may be assumed to have been one great deposit, on the southern side of one line of coast. If the 6250 square miles thus calculated were all deposited from the spoils of one great river equal to the Ganges, something less than half an inch would be deposited in a year, and 12,000 feet in 333,000 years.

If we vary the computation by taking what may be thought a fairer basis of comparison, and suppose a stream equal to the great Indian river to have produced the Wealden deposits—3000 square miles and 1000 feet thick—twelve thousand years would accomplish the work, but the Wealden deposits probably extended to more than four times the area, though with a less average thickness.

But the sea also attacks the land, often very strenuously, and along the vast line which it beats with restless energy, many parts of the coast yield much, all yield something, to the watery hammers. The rate at which the sea wastes the land depends on the nature of the coast, and the force and direction of the currents. A cliff of shale or glacial detritus falls away very rapidly in consequence of the decay of its base. On the coasts of Yorkshire the fertile lands of Holderness have lost from this cause $2\frac{1}{4}$ yards per annum, during the whole period since it has been carefully noted. So the feeble shores of Norfolk, Suffolk and Essex have suffered enormous loss. The picturesque cliffs of the southern coast of England, from Dover to Devonshire included, composed of chalk, sand, sandstone, and indurated clays, are suffering rapid displacement. Look at the many arched rocks and island-peaks in the Purbeck beds about Lulworth; contemplate the Chalk Needles of the Isle of Wight; consider the vast heap of pebbles in the Chesil bank; climb the sliding Lias cliffs of Charmouth; everywhere signs of recent, daily, destruction. Stand on the high ridge of the chalk where it fronts the sea in Warburrow Bay; mark the incomplete ring of the fortifications which sheltered British or Saxon warriors,—incomplete because since that comparatively modern date the sea has reclaimed a part of his ancient domain,—and you will have a true idea of the real recession of our island boundary. Measure on the lofty summit of Golden Cap, near Lyme Regis, the fissures prepared for many yards to yield at once along the precipitous face; look at the Preventive stations on the cliffs at Lulworth and in sight of Kimmeridge which threaten to fall, and must soon be removed; see this, which is a fair specimen of the average waste of English coasts, and specially of the south coast, before adopting an estimate of the rate of annual loss. In his recent work, *On the Origin of Species,* Mr Darwin assumes the rate of waste for the Wealden coast to be one inch in a century; I should have preferred, and do prefer, an estimate of one inch in a year, that is to say, one hundred times as great, and I suppose that by most observers this will be thought too low an estimate for all but the most invincible coasts. Still the effect of all this violence of the waves on the production of materials for the sea to deposit in new strata is not great, compared to the powerful action of the atmosphere on the broad surfaces of the land.

For example, assume an extravagantly high rate of waste, such as that on the coasts of England, which certainly cannot equal 1 foot in a year; apply it to the whole of the sea-coasts of the world; assume these to be equal to four circuits of the globe, that is to say, 100,000 miles in extent, and 100 feet high. The annual waste will be $\frac{100000 \times 100 \times 1}{5280^2} = 0{\cdot}4$ cubic miles of sediment. The area of the land being as before assumed equal to the area of new deposits, we have 50,000,000 sq. miles covered $\frac{1}{2000}$th inch deep with these spoils won by the sea from the land. The quantity of sediment derived from cliffs, although computed on exaggerated data, being so very much less than that obtained by the universal waste of the surface of the land, may be neglected in future calculations.

Keeping still the same purpose in view, the attainment of some probable estimate of the time which was consumed in the production of some definite part, if not the whole, of our stratified deposits, we may take as a new basis of computation the rate of growth and duration of life of some races of fossil plants and animals. Thus at several stages in the Coal-formation of Yorkshire and Derbyshire occur beds of shale some inches or one foot in thickness which are full of Unionidæ. The area over which these shells in their peculiar beds can be traced is sometimes as much as 40 miles long in one direction, parallel to the edge of the coal-field; the breadth is considerable, may be as great, indeed, but can be proved for a few miles. They have not been spread over this area by drifting, but by natural distribution of the young, as we see happen in the lower parts of rivers approaching the sea and the beds of lakes. Modern Unionidæ live some years. Suppose only the period of one life, say five years, to have passed during the distribution of the species over the area, and that during this period one foot of shale was accumulated, we have the years consumed in depositing the strata of this coal-field, 3000 to 5000 ft. thick; =15,000 to 25,000 years. But several layers of the shells lie in the thickness of one foot. In the same coal-field, near the base, we find one or more thin beds of shale and calcareous balls, abounding in Goniatites Listeri, and some other marine shells. These Goniatites are of every magnitude, from the youngest not larger than mustard-seed, to specimens three inches in diameter. This fact leads to an inference of the same order, and indicates a period only to be expressed in tens of thousands of years.

These inferences apply only to the rate of accumulation of shales; we cannot adopt the same estimates for the sandstones, which may have been more rapidly, or for the coal-beds which may have been more slowly aggregated. For these latter deposits, fortunately, Liebig and modern agricultural Chemistry have supplied a different and independent basis of computation.

It is now very generally admitted that our coal-strata are derived from the accumulation of trees, and other kinds of plants, on or very near to the places of their growth; at all events the greater part can have been moved but small distances. Plants after their germination draw from the atmosphere the Carbon which is fixed in their tissues, and combined with Oxygen, Hydrogen, and in some cases Nitrogen, constitutes the main part of their substance. The chemical composition of the atmosphere is everywhere nearly the same; the stimulus of light which is the great determinant of the chemical processes in plants, and which specially governs the absorption of carbonic acid by them, acts with much equality on the various races of plants. Hence much equality in the amount of Carbon taken from the atmosphere, and fixed in the substance of plants in a given time. Liebig has found that the annual product of Carbon fixed in plants so different as Fir-wood, Hay, Beet-roots, and Straw, is the same in weight, for the same extent of ground. This quantity is about 1000 Hessian lbs. for 40,000 square feet of surface[1]; in English weight and measure 10 lbs. for 244 square feet.

Supposing the whole of this quantity to be stored up year by year, and converted to Anthracite, the variety of Coal richest in Carbon, such as occurs in South Wales and North America, it would amount to about one inch in 170 years. If converted to ordinary Coal, with about 75 per cent. of Carbon, it would yield one inch in 127·5 years. In South Wales

[1] *Organic Chemistry*, 1840.

the total thickness of Coal, some beds being Anthracitic and some ordinary Coal, is 120 feet. To produce this thickness of ordinary Coal, by vegetables growing on the spot, would require $120 \times 12 \times 127{\cdot}5 = 183{,}600$ years. The same thickness of Anthracitic Coal would require $120 \times 12 \times 170 = 244{,}800$ years. Add to either of these periods the lowest number of years found for the deposition of the sediments in the same coal-field, 333,000, and we have as the probable length of time required for the production of the Strata of Coal, Sandstone, Shale, and Ironstone in South Wales, half a million of years.

If now we turn to the Leibnitzian Theory, and apply it to the same problems, we must first settle the limits of the atmospheric power to waste the surface in the early geological periods. This limit at the origin of the oceans needs not to be inquired into; there would indeed be a mighty power in action—perpetually falling floods—the fountains of heaven—wasting a hot and friable surface[1]. Coming down to the base of the Palæozoic System, and adopting as high a limit for the temperature of the surface of the globe as might be possible to suit the races of Mollusca and Crustacea then coming into view, we may allow 20° higher mean temperature than at present. From this point it must be

[1] Babbage. Ninth *Bridgewater Treatise.*

supposed to have declined to the actual condition, and with the depression of temperature the atmospheric wasting power to have declined also, and in a more rapid progression. For the quantity of moisture sustained in air of different temperatures freely in contact with water diminishes more rapidly than the temperatures[1]; so that if we take 56° for the present mean temperature of the surface of the earth, and suppose it to have been formerly 76°, the quantity of moisture held up by the atmosphere formerly may be taken at nearly double that now supported in it.

This being the case, and the causes of rain and vicissitudes of seasons the same in kind, we may admit the atmospheric power in wasting the earth's surface to have been double what it is now, and that from that time to the present it has sunk in geometrical progression. Under these conditions the time consumed in the production of the same total effect as that already stated, under the actual powers of the atmosphere, could not be so little as two-thirds of that computed on the hypothesis of uniform action, viz. 63,936,000 years.

But according to the same hypothesis the action of the sea and atmosphere in early times must have been more effective than at present, because of the

[1] It varies in geometrical proportion to the temperature.

greater frequency, or greater violence, of movements in the crust of the earth: for thus it would yield more easily to the assaults of the waves and atmospheric vicissitudes. During the earlier periods, land rising through the waves was subject to more rapid erosion by the sea and the atmosphere; short æras of enormous waste productive of conglomerates, longer periods of strong action yielding large masses of sandstone, still longer periods of more equable decay producing more extended beds of clay since indurated to shale and slate.

During the same periods land was sunk in one tract as well as raised in another, perhaps to as great a depth here as the elevation there; while it was sinking, fresh edges were exposed to the sea, and thus the waste was quickened. How are these effects to be calculated? Strictly they cannot be. But, as an illustration, let us suppose that by these operations the resisting power of the rocky masses of the earth's crust was weaker than at present—only one-half as great—so that combining this ratio to resist with that already allowed for the power to destroy, we shall have the earlier atmospheric waste effectively four times as great as at present. This allowed, we shall find the whole time, as given by the Uniformitarian hypothesis, cannot be reduced to so little as $\frac{2}{5}$, or 38,000,000 years.

The same hypothesis applied to the formation of the Coal Strata leads to very similar results. Higher mean temperature, a greater quantity of moisture, a larger dose of carbonic acid in the air,—these things must be allowed to have been active in accelerating the growth of the plants in Palæozoic ages. If it is conceivable that the growth was then twice as rapid as now, that only halves the immense period already assigned by the calculation; and besides it takes no account of the probably serious objection that very rapid growth under these conditions would be in some degree balanced by very rapid decay and dissipation of the constituent elements of the plants.

From all that has been said we may learn that by no hypothesis founded on probability, or consistent even in a small degree with actual phenomena, and the course of natural events, can we assign for the deposition of the fossiliferous strata so short a period as that last mentioned. It is rather to be supposed very much longer, if reduction of temperature is to be taken as the mainly influential condition of deviation from uniform action. For if this reduction of temperature were taken at 20° it must have required ages of ages to be accomplished by the excess of radiation into space over the heat received from the sun; the period may not elude calculation, but it lies quite beyond the power of the mind to contemplate with steadiness.

Abandoning all further attempts to determine the probable antiquity of the Strata, and the several races of Life, in measures of solar time, we may refer to some more limited trials to assign a date to the origin of the present physical aspect of nature—the present action of the sea on its coasts, and of the rivers on their beds. In the speculations of De Luc concerning natural chronometers this period is described as posterior to the existence of our continents, and as having a fixed chronology; it is now regarded as the latest of the Pleistocene periods; in the northern zones of the world it is the Postglacial period; and it includes, according to all observation and opinion, the age of the human race.

Herodotus, the first author who ventured an estimate of this kind, was naturally conducted to it by his inquiries regarding the ancient history of Egypt. This fertile country, 'the gift of the Nile,' offered him, in the real and fabulous narrative of its governors, a long series of centuries of elapsed time, and in the periodical floods and corresponding rise of its surface and growth of its delta, natural chronometers by which in some degree to check the traditions of the priests.

The conclusion of Herodotus does not however directly apply to the land of Egypt. The statement is to the effect that if the Nile were turned into the Arabian gulf, that part of the sea would be filled up by sediments in 20,000 years; indeed, according to his own opinion, in 10,000 years. Such being the present tendency of the river to deposit sediment, he justly concluded that, in the long lapse of earlier time, the Nile may have filled up the greater Egyptian gulf which lay in its course.

De Luc, one of the most ingenious and laborious geologists at the close of the last century and the commencement of the present, devoted much attention to those operations of the sea and rivers which promised to afford some measures of effect applicable to the problems of past time. The growth of new land on the sea-shore, the waste of the old surfaces by the waves, the filling up of lakes and the wearing away of valleys,—these, diligently studied, led him to the general conclusion that the actual state of our continents is not ancient; that it is not very long since they were given to the dominion of men; that not many ages have elapsed since the continental parts of our globe were abandoned by the ocean.

The *limited* growth of new lands—still yearly on the increase by deposition of sediment—the *small extent* to which lakes have been filled up by the rivers which enter them, and the *truncation* of hills sloping to the sea by cliffs not far from the point where the slope once met the sea-level, may be mentioned as data of this kind. Undoubtedly they all tend to convince us of the comparatively short period of time which has elapsed since the sea began to waste, or to be filled up, and the rivers began to wear away the upper parts and to fill up the lower parts of the valleys; but it is difficult to translate this conclusion into centuries or thousands of years. Perhaps such a case as that of the Derwent River flowing into the Lake of the same name in Cumberland, and augmenting year by year the mass of sediments at the upper end, may be found worthy of special attention, because of the abundance of rains on the slaty mountains around, the shortness of the course of the river, and the very slight degree in which cultivation, quarrying, and mining, have, till within a few years, altered the natural character of the surface. The requisite measures of the lake, the delta, and the sediment brought by the river, would present no great difficulty.

Perhaps it may be sufficient to take one example, the best at present known, to which computation has been applied, for determining the number of years in which a river has been running and excavating for itself a channel in rocks of one definite character. This example is found in the recession of the Falls of Niagara[1].

The river St Lawrence, in traversing the space of 32 miles between Lake Erie and Lake Ontario, has a fall of 330 feet. The general floor of the whole country is limestone resting on shale; the limestone appears in the stream, covered in the banks on each side by alluvial sand from 10 to 140 feet thick for the first 25 miles. At this point the great Falls occur; the river being precipitated over the solid and projecting rock of limestone, in one tremendous cascade 158 to 164 feet deep, into the subjacent shale, which is deeply excavated below the general level of the channel, and also worn into a recess forty feet within a perpendicular line dropped from the limestone edge of the cataract. Below this point the river flows in the deep chasm which it has worn for itself, seven miles, to Queenstown and Lake Ontario.

The Falls recede, not regularly, but by sudden steps, in proportion as the subjacent shale is worn away, and leaves the crown of limestone unsupported. In the course of forty years they have thus receded fifty yards. Adopting this as the rate of recession for the whole of the channel below the Falls, we have 9856 years for the time which has elapsed

[1] Lyell, *Principles of Geology*, I. 277.

since the epoch when the Falls began their backward progress from Lake Ontario.

This epoch, however, is not of necessity the same as that of the origin of the river action, which may have gone on for some unknown time previously. It does not then give us the desired information of the length of the Postglacial period, or the date, as De Luc might have expressed it, of the birth of our continents. But it seems to point in the same direction as all the other natural chronometers, and to compress within a few thousand years the later part of the Pleistocene Period, when the main features of the Land, the Rivers and Lakes, and Plains and Mountains, had been finally redeemed from the power of the sea, and peopled by the now existing races of plants and animals.

CHANGES OF CLIMATE.

Few inferences have obtained a more general assent among geologists than that which affirms the change of climate during the progress of life on the globe. The evidence on which reliance has been placed has been sometimes adopted on light grounds, sometimes rejected for fresh and better testimony; but the conviction of almost every writer has been deliberately recorded in favour of the prevalence of much higher temperatures during early geological periods in the northern zones of the earth, varied by at least one great interval of remarkable cold in later times. Before proceeding to consider *how* such variations of climate might be possible, it will be useful to collect some points of the evidence which may be regarded as establishing the fact of their having *really* taken place.

There is only one kind of evidence—that to be obtained from organic remains; and as in existing nature some groups are more definitely related to and indicative of climate than others, so in the fossil world. In some modern genera and families the species are distributed over different latitudes; some being intra-tropical, others extra-tropical, some in the temperate, others in the arctic zones.

Such genera and families can only be employed in arguments on ancient climate, where they contain species which are both recent and fossil, and this occurs only in the Cænozoic Strata. But there are other fossil genera, families, and even larger natural groups, which on proper questioning yield satisfactory answers in regard to the main characters of the climate to which they were appointed, whether on land or in the sea.

To take our first examples from the vegetable kingdom, we may inquire what climate is indicated by the characteristic forms of land-plants buried in the Coal-formation. Ferns are usually in fragments, distributed by water on the successive surfaces of deposition. It can seldom be ascertained whether they belonged to arborescent or repent kinds, but two or three species of the former division under the title of Caulopteris are recognized in the Coal-measures. The great abundance of Ferns is a further and good argument for great warmth and dampness. If Lepidodendra belong to the natural order of Lycopodiaceæ, their extraordinary size may be held to demand the extreme of the conditions favourable to that race, heat and moisture; if they include strong analogies to Araucariæ, that is an indication in the same direction. Sigillariæ, now commonly placed among the Gymnospermous Phanerogamia, near Cycadaceæ, have also been thought allied to Cacteaceæ, and to Tree-ferns, and thus follow on the same side as their companions the Lepidodendra.

Calamites, no longer referred to Equisetaceæ, but with Asterophyllites classed among Coniferæ, give no independent testimony to climate; but a few Palms (Flabellaria, Palmacites, Trigonocarpum), and Musaceæ (Musocarpum), concur with the Tree-ferns in requiring for the low shores of early time, where now extend the coal-deposits of America and Europe, a mean temperature of 64°, which is 16° above that now experienced in the centre of the Coal-basin of Scotland, 20° higher than that of the Coal-field of Michigan, and not less than 30° above that of the northern part of Newfoundland, to which the American Coal-basin extends.

Again, in the Oolitic period, we find Ferns still the prevalent vegetation, with gigantic Equiseta, and stems and fronds of Zamioid and Cycadeoid plants and Pandanaceæ, all indications of an equally warm climate, prevalent as far north as Yorkshire and Bornholm. Thus a difference of 16° or more appears in favour of the ancient temperature.

In Cænozoic Strata, the natural orders of Cucurbitaceæ, Anonaceæ, and Nipadaceæ in the London basin, and Palmaceæ in that of Paris, carry on the inference to times nearer our own; but there is reason to suspect the influence of drift—like that of the modern gulf-stream—in transporting the numerous fruits now found in the clay of Sheppey[1].

Coral growing into masses comparable to modern reefs affords a valuable illustration of marine climate at several geological epochs; for reefs having this origin, whether rising perpendicularly in the waters, or accumulated under the influence of sea-currents, are confined in modern nature to a limited breadth on either side of the equator. The Corals which fall

[1] Bowerbank, *Fossil Fruits and Seeds of Sheppey*.

under this designation in the West Indian Archipelago are for the most part not of the same species as those which occur in the Indian and Pacific Oceans, and thus the argument acquires a generality and independence of specific forms and peculiarities; which suits it for application to the extinct races, and the earlier reefs constructed often by different genera, in the Silurian, Carboniferous, and Oolitic periods.

Keeping in mind that light, warmth, and proximity to the surface of pure sea-water, are essentials for the life of the reef-making animals, we shall understand the complete segregation of these remains from the great mass of argillaceous and arenaceous sediments in the several formations. The limestones of Wenlock and Aymestry, of Plymouth, of Mendip, Flintshire, Derbyshire, and Yorkshire, all of Palæozoic ages and full of Coral-beds and bands of corals in place and attitude of growth, appear to be little else than the accumulations of Polypean and Crinoidal reliquiæ, augmented by the shells and other exuviæ of the sea-animals naturally attracted to the growing calcareous accretion. Each of these limestones indicates an interval of rest in the accumulation of sediments, a pause of the depression of the sea-bed[1].

[1] *Memoirs of Malvern* in *Memoirs of Geological Survey*, II. 1.

The Crinoidea mentioned in connexion with the Coral-reefs may perhaps be quoted independently as favouring the opinion of a prevalent high temperature in these northern regions in the Palæozoic periods, for the living Pentacrinite, very similar to the fossil groups in the London Clay and Mesozoic Strata, has been found only in the West Indian Seas. If we look at a map of isothermal lines, it will appear that a mean temperature like that to be inferred for the land of the Coal-measures from the evidence of Plants, ought to be assigned to the sea of the same period from the evidence of the Marine Radiata.

This inference, according to discoveries in the northern parts of America, would seem to carry the warmth of ancient times very much beyond the experience of geologists in Europe—even to the shores of the Arctic Sea—where mean temperatures below that of congelation now prevail.

The Mollusca of Tertiary Strata in Europe may sometimes be appealed to for evidence of the former connexion of the basins in which they were collected with the ocean, in such a manner as to allow of at least occasional communication; so that Voluta, Conus, Cypræa, Nautilus, &c. might be introduced among the fossils of the basins of London and Paris. But in earlier geological periods, evidence of this kind is very faint; and a very large proportion of the fossil shells of all orders must be passed over as yielding no sufficient data for a sound conclusion. If we may trust to the few species of the recent genus Nautilus, as indicative of a warm climate, and include all the fossil groups in the same inference, the conclusion already obtained as to the Palæozoic and Mesozoic seas of the north temperate zone would be confirmed.

With much confidence we may appeal to the class of Reptiles for proof of the warm climates of the land, sea, and fresh water of the whole Mesozoic period, for this whole class, as represented in modern times, has such a dependence on temperature as to diminish rapidly in number and dwindle to small size beyond the tropics, and to require special provisions for enduring the winter cold. Not that it seems necessary to suppose, for their comfortable life, a climate heated above ordinary temperatures, in the same proportion that their magnitude exceeds that of recent species. The living Crocodilia are confined to rivers which open into warm seas, and their own geographical range does not pass the isothermal of 64° mean annual temperature. Within this range are most of the races of Serpents and Batrachians on land, and of Turtles in the sea; except that now and then some species wander beyond their usual bounds; as we may perhaps suppose the marine Turtles and Saurians of the Mesozoic and Cainozoic periods occasionally to have done. In migrations of this kind it is difficult to assign the limits; individuals may arrive and live, where the race would soon perish in the struggle with unfavourable natural conditions.

In the earlier Tertiary periods, the excessive predominance of Pachydermatous Genera, allied to Tapir, Rhinoceros, Hippopotamus, Elephas, and the occurrence of their remains in old lakes and marshes, &c. seem to require the hypothesis of their having lived through long ages in the latitudes of Paris, the Rhine-land, and England. Granting that they indicate a warmer climate then prevailing, we may confirm it by the remains of Serpents and Monkeys found in the London clay at Kyson near Ipswich[1]. But in the later Tertiary epochs, the frequent mixture of Rhinoceros and Hippopotamus and Elephant with Horse, Ox, Deer, Wolf, Bear and other quadrupeds, whose relatives are found in various climates, and are known by experience to prosper in the climates now prevalent where their remains occur, renders inferences as to climate from them too vague and indecisive to be trusted. With these mixed land quadrupeds lie in several situations, in old Pleistocene lakes, shells

[1] Owen in *British Fossil Mammalia.*

of the land and fresh waters, which are identical with those now living in the same neighbourhood, unmixed with any from latitudes further south, or further north ; so that here we have a decisive test, and must admit in these cases that the climate was nearly the same as now. This applies to the Postglacial period, in some part of which we place the commencement of the History of Man.

The Glacial period itself—marked over a great part of the north temperate zone in America and Europe, by marine deposits heaped over what had been dry land—covering sometimes the lacustrine and peaty layers of that earlier (Preglacial) land,—this period was one of considerable refrigeration, within the large areas mentioned, for the shells found in the deposits are of the colder arctic types; and the deposits are found to be consistent with the idea of icebergs floating in deep water over all but the mountainous tracts, (these being covered with ice and snow, the source of glaciers and icebergs,) and not consistent with any other probable condition of things.

Thus we have one well-marked period, at least, of considerably greater cold in the northern temperate regions, succeeding many periods of greater warmth in these same regions. It has been supposed that toward the close of the Palæozoic period, a very early glacial sea was spread round several of our

British and Scottish mountains, and that the remarkable conglomerate of the Malvern and Abberley hills, now supposed to be of Permian age, is due to the floating and stranding of icebergs along the edge of the sea which washed the Longmynd, Abberley, and Malvern hills[1]; and a more comprehensive conjecture was once proposed by Agassiz, that the ancient climate was subject to several sudden depressions, coincident with great destructions of life, followed by some rise of temperature, and a renewal of life.

Admitting that such great changes have happened in the climate of our north temperate zones, how are they to be accounted for?

If in agreement with the conclusions of Herschel[2] we admit the earth's orbit to be only in a small degree variable, and so the sun's influence nearly constant; and decline to accept the hypothesis of Poisson[3] that the solar system in its wandering through space has encountered various temperatures; we shall find our power of explaining the great differences of climate, on the same area in ancient and modern times, reduced to estimating the effect of variations proper to the planet. It has been sup-

[1] See *Memoirs of the Geological Survey*, II. 1 for my description of this conglomerate. Professor Ramsay is the author of the hypothesis referred to.

[2] *Geological Transactions*, Ser. 2, Vol. II.

[3] Whewell in *Reports of British Association*, 1835.

posed that the mass of the Earth has grown *altogether colder*, since the earliest times, by radiation of its heat into and beyond the cold starry spaces of the universe. It has been conjectured that the Earth's axis has been displaced, so that parts once under the more direct action of the sun have lost much of his beneficent influence; and it has been thought that the differences in question might arise from a different distribution of land and water, which is a known cause of considerable inequality of temperature in the same latitudes.

In considering this subject we may remark that inequalities of temperature in the same parallel of latitude may be observed when an area of water is compared with a surface of land; and when land varies in elevation, and the nature of its surface. Sir Charles Lyell has founded on these facts the supposition that if a tract of land, equal to and of the same form as our existing continents and islands and rising to the same height, were collected round the poles, while the equatorial zones were occupied by an encircling sea, the whole earth would be cooler than it is now. There is no doubt that this would be the case, but it happens not to agree with the observed facts regarding the glacial deposits, for these require deep ocean over much of what is now land in circumpolar zones.

On the other hand, he supposes that if all the land, similarly shaped, were collected along the equator, while the poles were overflowed, the whole earth would be warmer than it is now. This appears somewhat doubtful; for though the equatorial regions of land might gather more heat from the sun, and the polar regions receive more warmth by oceanic communications, still these polar surfaces of warmed water might lose more heat by radiation into space than equal surfaces of snowy land; and thus the whole ocean might be cooler, as well as more equal in temperature. Whatever changes we suppose possible in the distribution of land and sea must fall short of these extreme suppositions, which besides do not so well match the phenomena of any geological period, as to prevent our turning to other causes of change—not in the temperature of the whole surface of the globe, but in the climates of particular parts, still following the guidance of Lyell.

Of these two are very prominent; the flowing of oceanic currents, and the course of the winds; and to these a great and real influence is justly attributed, in heating some parts of the earth above the average, and in cooling other parts below it. Thus the well-known broad and constant stream which flows from the Gulf of Florida up the North Atlantic, carries a vast body of warmed water from the tropical shores of North America, to the Arctic circle, the North Cape of Scandinavia, and the icy shores of Spitzbergen. Along the line of this current the isothermal lines are inflected to the northward, beyond the points which they reach in the midst of the continents of Asia and America 10, 15, and even 20 degrees; in other words the northern parts of Europe have their winter climate in particular so mitigated by the aid brought to them over 2000 miles of sea, as to make the yearly average of temperature higher by 10° or 15° than places in the corresponding latitudes in the United States. Conceive that by some movement of the solid earth-crust, this current were entirely prevented from flowing up the Atlantic, then 10° or 15° would be lost to the climate; suppose other unfavourable circumstances arising from the new distribution of land and water, such as a cold current from the north; perpetual snows would gather on the mountains of Scotland, Cumberland, Wales, and Ireland; glaciers would be formed in suitable situations; icebergs would be floating on the sea; Arctic shells might be encouraged in growth, and the phenomena of the glacial period be repeated[1].

It appears from these considerations, that by a change of the oceanic currents, quite within geological probability, the warmest meridional band in the

[1] Hopkins in *Geol. Soc. Journal*, Vol. VIII.

northern hemisphere might lose its singular advantages of climate, so that glaciers might spread over its valleys now fertile of corn. Changes in the earth's physical features will account for a local augmentation of cold, and explain to us the glacial epoch, the phenomena of the boulder drift, and the Arctic fauna which accompanies it. Can we by processes of the same order, taken in another direction, account for the opposite effect of greater heat in the same regions in earlier times?

The hypothesis of Sir C. Lyell already alluded to, which attributes change of climate to an alteration in the distribution of land and water, though apparently not of much efficacy in exalting the mean temperature of the whole surface of the globe, opens beyond doubt a source of real power to change the local climate of any part, and especially to augment the warmth of a tract lying far from the equator. We see this to be strikingly the fact in the case of the gulf-stream running up the Atlantic; and in a less degree in the bending of the isothermals northward to Behring's Strait. The maximum effect of such currents, according to the present arrangement of land and water, is seen in the beneficial action of the gulf-stream on the western coasts of the British Islands and Norway: and unless we can imagine a position of the continents more favourable for the distribution of water warmed between the tropics, we must conclude that no material elevation of mean temperature can be effected by means of oceanic currents, beyond that imparted by the gulf-stream and winds which blow in the same direction.

What appears to be the most favourable distribution of land and water for the diffusion of heat, is neither an equatorial nor a polar position of large continents; nor indeed of large continents at all, but low islands scattered over the area of the globe, amidst large breadths of water[1]. By this means the watery communications being everywhere easy, the whole ocean would acquire the greatest uniformity of which it is capable, the lands would partake in this equality, and the general temperature would be something exalted by the absence of the cooling effect on the atmosphere of the lofty mountain-ridges, for these intercept and mix the aerial currents, and chill the winds which cross their snowy tops and afterwards traverse the lower ground. The thermometric range of mean temperature on the surface of the earth (the Pole not being in the coldest zone) is about 100° Fahr.; that of the sea, where most warmed by the Atlantic currents, even to the Pole, probably not above 80° Fahr.

[1] Prof. Hennessy has suggested a similar view of the subject. *Atlantis*, Jan. 1859.

In the following Table the temperatures according to latitudes are represented (1) for the whole Northern Hemisphere, (2) for the warmest band of water up the Atlantic[1], (3) the difference of these or the warming influence exerted by the sea-currents and winds.

Pole.	I.	II.	III.
80°	—	—	—
70	17°	36°	19°
60	30	46	16
50	41	54	13
40	56	62	6
30	68	68	0
20	76	76	0
10	79	79	0
0	79	79	0

As already observed the temperatures, even in the warm North Atlantic band, are not high enough to suit the case of the Coral growths in Palæozoic and Mesozoic ages, which demand in lat. 60° about 34°, in addition to the average temperature, or 18° above the highest observed temperature.

To meet this necessity we may suppose a more effective distribution of the equatorial temperature into the basins of the North. We may further suppose, for the sake of calculation, the average result

[1] From Dove's *Maps of Temperature.*

for each zone of latitude to be an increase of warmth proportioned to the difference of area between that zone and the equatorial zone. On this supposition the following calculation is made[1].

The addition to mean temperature in lat. 60° being taken at 30°, the scale of augmentations for the whole series of latitudes will be nearly as in Col. I., and, the equatorial temperature remaining the same, the temperature for each latitude up to 70° will be as in Col. II.

Pole.	I.	II.
80°	—	—
70	39°	56°
60	30	60
50	22	63
40	14	70
30	8	76
20	4	80
10	1	80
0	0	80

These temperatures would meet the geological requirement; but it seems very doubtful whether there is enough of probability about the hypotheses on which they are founded, to meet the two objections which follow. 1. The augmentation, here attri-

[1] The formula is merely this. Augmentation $= A$ (rad. − cos. lat.).

buted to a considerable part at least of the hemisphere, is twice as great in amount as in the most favourable example now to be found on any part of the globe. 2. The average temperature of the whole area affected must be augmented by about 13°. Though neither of these conditions may be accepted as very probable, we can hardly avoid believing the varying distribution of land and water to be an important element in a just explanation of ancient high climate in northern zones.

There is indeed a further consideration which deserves much attention. One characteristic of the climates not very far from the equator is the small range of the annual temperature, only a few degrees being the full amount of vicissitude in this respect through the year. Some weight must be allowed to this in forming our scale of required additional temperature; perhaps a considerable weight. Under the conditions assumed in the last calculation the whole of the oceanic temperatures would become remarkable for very small variations from one part of the year to another; and thus one characteristic requisite in the life of the plants and animals of the warm regions being perfectly fulfilled, it seems very probable that so high an average temperature as that assumed might not be required. If we allow full force to this idea, and conceive the equatorial temperature to be lowered (as it would be) by an effective distribution of part of its warmth by currents directed toward the poles, the difficulty would be much reduced.

For those who are not satisfied with the probability of the explanation just examined, another hypothesis is ready, the displacement of the axis of the earth. Though this is refused by the proper authorities, the astronomers, it may be worth while to mention that the centre of gravity of the earth cannot be regarded as having been always absolutely fixed when we remember the irregular distribution of the axes of elevation of different periods, the very considerable mass of the elevated mountain-chains, and the great amount of subsidence by which the areas of deposition have been affected at different times. But if the centre of gravity of the earth be allowed to be thus inconstant in position, the axis of rotation must be subject to change from the same cause. Such minute variations, however, would be of small efficacy in regard to the matter in hand, if we are to judge by the actual distribution of the masses of elevated land, and the direction of the depths of the sea. Even if we could place an extra load on one meridian between the pole and the equator, and thus cause an angular deviation of the axis, this is a process requiring long perseverance and many repetitions in the economy of nature to produce a sensible effect[1].

Passing without remark conjectures regarding the limits of the precession of the equinoxes, and the obliquity of the ecliptic, and estimates of the variation of the diameter of the earth's orbit, by which it has been attempted to meet the difficulties of ancient geological climate, a few words may be added regarding one speculation which has justly received more serious consideration. The interior temperature of the earth is observed to augment sensibly as we descend; the figure of the earth indicates original fluidity; the lowest rocks agree with the opinion that great heat has been an essential agent in giving to them their present appearance. The earth is hotter within than at the surface; receives a current of heat from the interior, and dissipates it into space; grows cooler, and has been always growing cooler, from the earliest times. Why not suppose the greater surface-heat of early times to have been caused by the then greater and nearer influence of the interior much heated masses? The influence of such a flow of heat outward to all parts of the surface, independent of latitude, is exactly of such a kind

[1] Col. Sir H. James has attributed a great effect to this cause, *Athenæum*, Sept. 1860. Remarks have followed by Professor Airy, Professor Jukes, and Professor Hennessy, which agree with the views expressed in this work.

as our problem seems to require. What are the objections to it?

Two, principally. First. The rate of increase of temperature, as we go downward, is proportioned to the quantity of heat flowing out and influencing the climate by increase of sensible or thermometric temperature. To augment by 10°, 20°, or 30° the existing temperature of the surface would require an augmentation of heat from the surface downward, in the same proportion as the measure of warmth to be communicated (say 10°) to the measure of warmth (say $\frac{1}{20}$th of a degree) actually communicated. In the case supposed, 200 times as great as now, the heat of boiling water would be attained at about 50 feet of depth! How under such circumstances could the Mollusca and other creatures live in the sea, or plants grow on the land?

Secondly. The rate of cooling of the earth by radiation into space is so slow at present, that to reduce the actual effect (say $\frac{1}{20}$th of a degree) to half that amount would require, according to the calculation of Poisson, the period of one hundred thousand millions of years[1]. In earlier times, the flow of heat outward being much greater, the rate of cooling would have been much more rapid; still the period of time which must have elapsed in the

[1] Hopkins, *Address to Geol. Soc.* 1851.

reduction of the surface temperature by only 10° is so vast and even inconceivable, that the adoption of the hypothesis to that extent seems to require something more than courage. But even ten degrees of added warmth in lat. 60° would not be sufficient to meet the case of the Corals in the sea, or the Palms, Ferns, or Cycadaceæ on the land.

These objections have been urged as fatal to the opinion that the internal heat of the earth, now hardly sensible among the elements of surface climate, was formerly a real and efficient, if not the principal, cause of the superior mean temperature of the sea and lands in extra-tropical countries. They have even been urged by geologists, who accept the same heat as real and very influential in that general metamorphosis of the lowest rocks, which is observed in every country, and in those disturbances of the strata, which are equally universal, and of various ages. It appears to me, however, that in these objections one thing is forgotten—the state of the atmospheric mantle which envelopes the terraqueous globe, mitigates solar heat and stellar radiation, and, like the clothing of a steam cylinder, prevents excessive waste of the warmth treasured within. For nothing can be advanced to justify the supposition that this important element in the economy of nature was always of the same total weight, always identical in chemical composition, and always on the average charged to the same degree with aqueous vapour. On the contrary, to take an example which appears decisive, from the accumulation of the Coal Strata, there is good reason to adopt positively the opinion that the chemical constitution (if that may be termed a chemical constitution which is only a mechanical mixture) of the atmosphere has been greatly altered. For if the Carbon, fixed in the thick and extensive beds of coal since the Palæozoic ages, were again restored to the atmosphere from which it was taken, the weight of Carbonic acid now in the atmosphere ($\frac{1}{1000}$th part) would be more than doubled. Those who think the proportion of the three main constituents of the atmosphere must ever have been as they are now, may if they please double also the Oxygen and Nitrogen, and thus augment the total barometric pressure of the early Palæozoic ages to 60 inches! But without adopting such an extreme view, there is really no reason to limit our theory of the ancient atmosphere in respect of Oxygen or Nitrogen any more than in regard to Carbonic acid. The whole atmosphere may have weighed more; if so its measured depth must have been greater, and its effect in restraining the waste of heat, and, what is equally important, in reducing the extremes of climatal difference, also greater.

Moreover, a warmer atmosphere, whether of greater total mass or not, would hold more moisture in suspension, and thus the tendency to equalize temperatures might probably be augmented, both by the transport of aqueous vapour to the coolest parts, and by the wider canopy of clouds which are well known to be effective in preventing the wasteful radiation of heat from the surface of the earth. Thus all these inquiries—into the greater *diffusion of warmth* over the surface by oceanic currents—the *greater flow of heat* from the interior of the earth, and the *greater resistance to the escape and waste* of this heat, by the surrounding atmosphere—concur in shewing that causes really founded in nature, and still operating, may be appealed to for solution of the interesting questions regarding ancient climate. Neither perhaps is fully sufficient singly to explain the phenomena, but they are of a nature to be combined without improbability into a general and satisfactory solution of the problem.

PHYSICAL ASPECTS OF THE EARTH.

The rich variety of the earth's surface, as it is now possessed by man, is the legacy of many long ages of busy nature, labouring to upheave the mountains, and depress the seas, and carefully storing up the treasures of those distant years for the enjoyment of the present period. No Coal-fields, to last even a single century, are now growing at the mouths of our rivers; no metallic veins are spreading through the rocks that we can explore; no great catastrophe breaks down the barriers of seas, or opens picturesque glens through the ridges of the mountains. Yet the forces whose accumulated effects seem to us so mighty are still alive, and still give proof of their power to make further change in the condition of the globe.

If we trace back the physical history of the parts of the earth best known to us, we shall be surprised at the permanence of many of the great features of the land and sea; where these have changed we can often clearly see the mode and almost the mechanism of change, and not unfrequently discover somewhat of the effect of these variations on the distribution of ancient life, its mutation and discontinuity.

The German Ocean is what remains of a wider Tertiary Sea, which spread over a large part of the country north of the Carpathians, extending eastward across the plains of Southern Russia, and north of the Caucasus, but probably closed to the westward. The Mediterranean of the Tertiary ages stretched northward up the Adriatic gulf, to include the basin of the Po; eastward and southward into Syria, Egypt and Africa, and communicated with the Atlantic by a strait, where now is the valley of the Garonne and the basin of Bordeaux. The Black Sea was connected to a long gulf up the vale of the Danube. Land stood up in this large tract of ocean only in small islands or much ramified masses, where now appear the mountains in the centre of France, in Germany, on the borders of Bohemia and Moravia, in the Hartz, and Carpathians. The British Isles formed almost a complete western boundary, while small points and narrow ridges of land marked the rising Alps and Apennines, and the mountains of Dalmatia and Croatia.

In a far earlier period, after the deposition of the Carboniferous Strata, many of the great features of the British Isles and Scandinavia had been firmly fixed by the axes of elevation which range north-eastward from Ireland, through Scotland to the Norwegian Alps, and eastward along the south of Ireland and the south of England, through Belgium, and across the Valley of the Rhine; this last tract was afterwards sunk again and partly covered up by secondary and tertiary deposits, but the former was never again wholly submerged.

But in the still earlier Cambro-Silurian period, the broad ocean flowed over nearly every part of the area now occupied by land in the whole of the northern zones, most probably here and there diversified by primitive islands, whose situation, however, and constitution are merely conjectural, till we arrive at the series of Wenlock rocks in the Malvern hills. Here is proof of land situated where now is the ridge of the Worcester Beacon; land from which fell, into the sea of that period, rocky fragments precisely the same in nature as the variable Syenites of that ridge; fell into tranquil and slightly agitated water of small depth, and were there cemented together with Corals, Crinoids, Shells and Trilobites, a venerable and interesting mark of the ancient limit of the old and populous sea, against the old perhaps uninhabited land. Accustomed, in this way, to regard the northern seas of our time as the shrunk and ramified remainders of wider tracts of ocean, and the lands as amplified by comparatively modern desiccation round primitive peaks and ridges, we naturally turn to consider whether the forms of life in the sea manifest any special affinity to the fossils of the neighbouring tracts from which it has withdrawn; and in what degree the plants and animals which now cover the land are related to those which occupied smaller spaces in the same regions.

Taking for a favourable illustration the Germanic Ocean, and comparing its Mollusca with those of the adjoining Pleiocene Crag, on the eastern coast of

England, Deshayes found about 40 per cent. of the Crag shells identical with living species, and of these nearly all occur in the neighbouring ocean[1]. In like manner, the Tertiary fossils of the sub-Apennine region of Italy are successfully compared with those of the modern epoch, yielding, according to Deshayes, 41·8 per cent. of living species, a large proportion of them from the neighbouring seas[2]. By observations of this kind, the Tertiary Series is linked in easy harmony with the actual period; but if we make the same kind of comparison of the Tertiary with preceding Mollusca, but little of direct affinity can be traced; and the same remark applies to the common bound-

[1] See Lyell's *Principles of Geology;* Wood, in *Pal. Soc. Memoirs.*

[2] 'From the copious fauna which now tenants the Mediterranean waters, a series of changes may be traced, through older sea-beds of the same area, far back into bygone ages. Nowhere do we find better illustration than here of the nature of the changes which a fauna may undergo in time: the evidence is consecutive. It is possible, however, that the Mediterranean series, recent and fossil, may be imperfect, and that the *earliest* periods of our European marine fauna are not represented there. A comparison of the contents of the older Italian deposits, and their equivalents containing the remains of the existing Atlantic species of Testacea, with those of the Faluns of Bordeaux and Touraine, suggests the probability that in these last we have an earlier stage still in the history of our fauna, referable to the time when the Mediterranean depression had not yet been opened to the Atlantic waters.'—Forbes and Godwin-Austen, *Nat. Hist. of European Seas,* 1859.

ary of the Mesozoic and Palæozoic Deposits, not many closely related forms passing the limits in either case. The present age is in fact a part of the great Cænozoic period.

The attention of Linnæus was drawn to the other question regarding the succession of forms on the land, and in the *Amœnitates Academicæ*, which contain some essays from his own hand, and many contributed by his pupils, we find an interesting discourse on the subject of the extension of life from the centres of mountainous districts[1]. It is easy to find examples of parallel forms of Mammalia now living, with some of the Tertiary quadrupeds once denizens of the same regions, or regions formerly connected by land; the affinities thus traced being feebler in proportion to the antiquity of the earlier forms. Thus, in England the Beaver is extinct, but yet lives in Germany; our Red Deer is apparently the same as some Pleistocene fossils, and very similar to others of earlier date; and our European Wolf is found in the ossiferous caverns of England, Germany and France. Sometimes, without this close affinity, a considerable resemblance is found between special tribes now living and others fossil in the same region. In a part of the Continent of America this is remarkable, among the Edentata, which though

[1] De telluris orbis incremento.

not quite confined to that region, are more plentiful there than elsewhere, and are successors of fossil races also found almost exclusively in that country. Thus the fossil Megatherium has been compared with the Sloth, the Glyptodon with the Armadillo; nor does the enormous bulk of the fossils hinder the reception of them into the same natural families. The same lands then have been in successive periods peopled by analogous races, and thus we have manifested 'a wonderful relationship on the same continent between the dead and the living[1].' Still this succession of similar forms is limited to Cænozoic ages.

One other example must suffice. The marsupial peculiarity of Australian Mammalia is not of modern date; the Australian caves contain evidence of the same character in the races whose remains are there preserved. The peculiarity indeed is of far earlier origin, for it occurs in the Eocene deposits of the basin of Paris, in the Lacustrine deposits over the upper Oolite in Purbeck, in the lagoon of the great Oolite at Stonesfield, and probably in the Trias of

[1] Darwin. This author does not suppose the living Edentata of the same region to be the dwarfed descendants of these monstrous beasts, but speaks of some others, their contemporaries in time and companions in the same caverns, which may be regarded as the progenitors of the living species.

Würtemberg. In respect of the Stonesfield fossils, this is not the only evidence presented by that curious deposit of similarity of Mesozoic life in the north, and Cænozoic life in the antipodal region of the south. It extends to other groups, both of the land and sea, and almost justifies the notion of some affinity even in the systems of life. For just as at Stonesfield, so in Australia, small insectivorous marsupial mammals are associated with Cycadaceous Plants and Ferns; as now in the seas surrounding Australia, Terebratula and Rhynchonella, Trigonia and Cucullæa, consort with Turtles and the Cestraciont Sharks, near reefs of Coral, and rivers tenanted by Gavialian Crocodiles, so at Stonesfield in the older time, similar animals in similar combination.

What does this teach us? Are we looking upon two partially similar but really separate creations suited to partially similar conditions in very different periods of time? Or is the life-system of the modern Australian land and sea truly derived in some of its components by descent with modification from the older periods of the world, and preserved to this our day, notwithstanding displacement over half the circumference of the globe, and all the vicissitudes of an immensity of time?

Whoever has the courage to adopt the latter view, must accept with it the obvious inference that in all the countless ages which have rolled away since the branches of Zamia were blown into the lagoon of Stonesfield, the amount of organic change has been small in each group of plants and animals; that a similar amount of change affected the unlike inhabitants of land and sea; that Mollusca and Sharks, and Turtles and Crocodiles, have all been modified by differences of a small description in passing from Oolitic to modern times, while not only hosts of Ammonites and Belemnites have perished in the experiment, but many new forms, as Oliva, Mitra, Triton, Struthiolaria, unknown in the earlier period, have come into view in the latter! But let it be adopted. What follows? These small differences then, accomplished in all that prodigious range of elapsed time, under all that variety of physical changes and removals, these are all the mutations which have been possible under the constant tendency of hereditary descent to perpetuate similar forms with modification.

One of these genera, that of Trigonia, is known to be in the fossil state rich in species; supposing them to have all come from one original typical form, the differences which they shew in strata of the same system, deposited within the same grand period, and under much similarity of conditions, argues a facility in giving variations; let this operation be supposed to be continued in the interval between the epoch of Stonesfield and that of Australia, and the effects summed by natural selection, the result is the modern Trigonia, scarcely differing more in appearance from the fossil species than they differ one from another.

But if not so derived, by continual descent, but sprung from separate contemporaneous branches of one stem of life, arriving at a given standard of excellence at such enormously different epochs, how should it happen that Plants and Quadrupeds on land, Sharks and Mollusks in the sea, should in each of these two cases pass with equal advance along the streams of change, moving in one case so fast, in the other so slow? But if the branches sprang at different times and led to these similar results, would this double origin in time, for several similar forms, in similar associations, fit with the hypothesis of continual development?

THEORIES AND OPINIONS.

FORMED STONES.

THREE centuries have glided by since Bernard Palissy, the philosophic potter of Xaintonge, revived the ancient opinion of Herodotus[1] and Pythagoras[2], and wrote the simple words,

'Je t'ay monstré plusieurs coquilles reduites en pierre.'

France may well be proud of him, for he was among the first who ever uttered in modern Europe sensible remarks on the subject of Palæontology[3], and they fell on incredulous ears.

Two centuries only remove us from Agostino Scilla[4], the worthy Italian painter, who strove to dissipate false speculations regarding petrified marine exuviæ, by excellent drawings of recent and fossil teeth, Echinida and shells, from the Tertiary Strata of Messina and Malta. What these false speculations were, is too well known to the readers of our earliest English authors, Plot, Llwydd, Lister, Ray, and Wood-

[1] *Euterpe*, 12. [2] Ovid, *Metam.*

[3] The first of Palissy's Essays is dated 1557; the complete work 1580; Gessner's work, De omni rerum fossilium genere, &c., was printed at Zurich in 1565.

[4] La vana speculazione disingannata. Earliest Edition, 1670.

ward, who consumed the latter part of the seventeenth century in wrangling about 'formed stones,' 'plastic forces,' and 'lusus naturæ.'

The learned Dr Robert Plot, the first Keeper of the Ashmolean Museum in Oxford, in that valuable Natural History of Oxfordshire (1677), which was the model for many goodly volumes in other counties of England, after carefully describing many Ophiomorphites, Ostracites, Belemnites, and Cockles lying in their stony sepulchres, is brought to consider the great question then so much controverted in the world.

'Whether the stones we find in the form of shell-fish, be *lapides sui generis*, naturally produced by some extraordinary plastic virtue latent in the earth or quarries where they are to be found? Or whether they rather owe their form and figuration to the shells of the fishes they represent, brought to the places where they are now found by a deluge, earthquake, or some other such means, and there being filled with mud, clay, and petrifying juices, have in tract of time been turned into stones, as we now find them, still retaining the same shape on the whole, with the same lineations, sutures, eminences, cavities, orifices, points, that they had whilst they were shells.

'In the handling whereof' (he tells us), 'though I intend not any peremptory decision, but a friendly debate; yet having according to the wishes and advice of those eminent virtuosi, Mr Hook and Mr Ray, made some considerable collections of these kind of things, and observed many particulars and circumstances concerning them; upon mature consideration, I must confess I am inclined rather to the opinion of Mr Lister, that they are *lapides sui generis;* than to theirs, that they are thus formed in an animal mould. The latter opinion appearing at present to be pressed with far more and more insuperable difficulties than the former. For they that hold these stones were thus formed in the shells of fishes, must suppose either with Steno, that they were brought hither by the Deluge in the days of Noah; or by some other more particular and perhaps national flood, such as the Ogygean or Deucalionian in Greece, than either of which there is nothing more improbable.'

His argument against the Noachian origin of the figured stones is very complete; first, that it was not universal, but confined to the continent of Asia; and next, that if it were universal it could not have produced the effects which require to be explained, whether it were occasioned by rain, or the breaking up of the sea, and whether it were violent or gradual.

CATACLYSMS.

Sufficient as they were, and satisfactory as they ought to have been, these arguments against the diluvial origin of the 'figured stones,' did not prevent the adoption of it by many writers who had gained the right faith in regard to their nature and origin. Woodward, the great founder of the Chair, which has been so worthily filled by Mitchell and Sedgwick, who ransacked the British Islands for fossils, and devoted all his mind to "observation of the present state of the earth, and of the site and condition of the marine bodies which are lodged in and upon it," adopts the hypothesis which Plot rejected, to account for phenomena which that author had not rightly valued. His *Natural History of the Earth* (1695), contains these propositions and reflections:

1. 'That the marine bodies were borne forth of the sea by the universal deluge; and that upon the return of the water back again from off the earth, they were left behind at land.'

2. 'That during the time of the deluge, whilst the water was out upon and covered the terrestrial globe, all the stone and marble of the antediluvian earth; all the metals of it; all mineral concretions; and in a word all fossils whatever that had before

obtained any solidity, were totally dissolved, and their constituent corpuscles all disjoined, their cohesion perfectly ceasing. That the said corpuscles of these solid fossils, together with the corpuscles of those which were not before solid, such as sand, earth and the like; as also all animal bodies and parts of animals, bones, teeth, shells, vegetables and parts of vegetables, trees, shrubs, herbs; and to be short, all bodies whatsoever, that were either upon the earth or that constituted the mass of it, if not quite down to the abyss, yet at least to the greatest depths we ever dig; all these were assumed up promiscuously into the water, and bodies in it, and made up one common confused mass.'

3. 'That at length all the mass that was thus borne up in the water, was again precipitated and subsided toward the bottom—according to the laws of gravity—forming the strata, including the organic fossils according to their specific gravity.'

He then goes on to explain the solidification of the strata, their original parallelism, their subsequent dislocation by a force from within, and the production by this means of the irregularities of the surface of the earth, and makes these explanations on the whole:

'Here was, we see, a mighty revolution; and that attended with accidents very strange and amazing; the most horrible and portentous catastrophe that nature ever yet saw; an elegant, orderly, and habitable earth, quite unhinged, shattered all to pieces, and turned into a heap of ruins: convulsions so exorbitant and unruly; a change so exceedingly great and violent, that the very representation alone is enough to startle and shock a man.'

ALL LIFE DERIVED FROM THE SEA.

By degrees, however, the great truth fixed by geology, that we stand on the dried bed of the ancient sea, began to influence the ingenious writers who followed close upon Plot and Scheuchzer. Among these De Maillet, in the singular work called '*Telliamed*,' (his own name reversed,) is conspicuous for the perverse resolution with which he follows out the evil consequences of an 'inappropriate idea[1]' on this subject. Believing that the old sea-beds were laid dry by the retirement and diminution of the water, about three feet in a thousand years, he feels no hesitation in deriving all the plants and animals of the land from prior productions of like nature in the sea, though at present circumstances may fail which contributed formerly to spontaneous

[1] See Whewell's *Inductive Sciences* for examples of 'appropriate ideas.'

generation, and that the earth is reduced to ordinary propagation.

> Jamque adeo fracta est ætas, ecfœtaque tellus
> Vix animalia parva creat, quæ cuncta creavit
> Sæcla, deditque ferarum ingentia corpora partu.

The germs of life he supposes to be everywhere provided through the universe—in air, food, water—ready to be developed into species by the warmth of the sun, in water or mud disposed to fecundity, so that all life has proceeded from the sea. Whether this constitution of things be ascribed to laws of nature or the design of the Creator, he regards with indifference, being satisfied that such a condition of things is real.

The difficulty of the change from watery life to aërial life, he regards lightly.

'A hundred millions of individuals must have perished, without being able to assume the new habit of life, but it is enough if two have survived the trial, to give permanence to the race.'

Here is one example of the process:

'It may have happened, as indeed we know it often does happen, that flying-fishes fell into brambles or pastures, from which it was impossible to return to the sea by the effort which brought them from it, and that in this state they acquired a greater power of flight. Their large fins, no longer bathed by the waters of the sea, divided and opened in drying; the separated fin-rays prolonged themselves, and became covered with barbs, or to speak exactly, the membranes which had previously held them together were metamorphosed. The barb formed of these separated pellicles, lengthened itself; the skin gradually covered itself with a down of the same colour, and this down increased. The subventral fins, which, as well as the large fins, assisted their *promenade* in the sea, became feet, and served them for *walking* on the earth. Some other small changes took place in their shape. The beak and neck of some were lengthened, of others shortened; and so of the other parts of the body. But still the conformity of the original figure remains on the whole; and it is and always will be easy to recognize.'

So much for the origin of Birds! By processes equally easy and satisfactory, the sea is shewn to be the parent of quadrupeds and men.

GERMS OF LIFE.

Buffon adopted similar views as to the derivation of the forms of life, and was followed by one greatly superior in real knowledge of nature, who has given to the dreams of De Maillet a regular form and delusive symmetry[1].

Lamarck supposes all the phenomena of life may be accounted for upon electro-chemical principles, and that the higher and more intelligent races of animals may have been gradually formed by the plastic power of nature, out of the smallest and simplest. By nature, we are to understand a certain order of causes and effects, constituted by the will of the Supreme Author of all things, and appointed to produce all the phenomena of the material world. In obedience to this secondary power he supposes that the attractive force of matter is sufficient to produce small portions of gelatinous substance, capable of being acted on by these powerful agents, caloric and electricity, and that when thus acted on they exhibit vital energies; in other words, that caloric and electricity acting on appropriate dead matter may convert it into living organic matter. Further, that the modifying influence of circumstances has caused these indefinite organic living masses to be extended into various animal forms; that first were produced the more simple, from these, by methods of reproduction, aided by the continued action of the same vital fluids and under the influence of changed circumstances

[1] *Philosophie Zoologique* and *Introduction to Animaux sans Vertèbres.*

and acquired habits and desires, other different and superior races of animals may have been formed.

In this hypothesis we have three assumptions:

First, that some of the inferior tribes of plants and animals are producible by the agency of caloric and electricity from dead matter, and that locomotion in some of these is accomplished by the external influence of these exciting fluids, and not by the inherent power of the creature.

Secondly, that the organic beings thus originating are capable of indefinite change of form and structure from the force of external circumstances.

Thirdly, that new habits of life are acquired with the new structures; that individual desires or longings have influence in the further development; and that the acquisition and exercise of the senses, instinct, reason, hope and fear, memory of the past, and expectation of the future, is a part of this stupendous chain of metamorphism with a tendency to progressive improvement.

Neither of these assumptions is proved, or rendered probable; but rather becomes less and less acceptable the more we consider the illustrations suggested by the author, which are scarcely less surprising than the instance already quoted from *Telliamed.*

The foundation in truth for this hypothesis is the unquestionable power of adaptation which living creatures possess, through exercise of the organs of life, by which *some change* is possible in structure and some change in function also, the new qualities being in *some degree* transmitted to the descendants.

There is no need to mention in detail the views of other and later continental writers, for none have been more ingenious, more plausible, or more explicit; nor has the proof which is wanting to sustain the propositions of Lamarck been supplied by his followers in any country.

The speculations of Lamarck have met with a full and fair examination in Lyell's *Principles of Geology*, leading to a deliberate rejection of the hypothesis, and a decisive affirmation of the reality of species in nature. The following is his recapitulation of the result of the inquiry.

'For the reasons therefore detailed in this and the two preceding chapters, we may draw the following inferences in regard to the reality of *species* in nature:

'1. That there is a capacity in all species to accommodate themselves, to a certain extent, to a change of external circumstances, this extent varying greatly, according to the species.

'2. When the change of situation which they can endure is great, it is usually attended by some modification of the form, colour, size, structure, or other particulars; but the mutations thus superinduced are governed by constant laws, and the capability of so varying forms part of the specific character.

'3. Some acquired peculiarities of form, structure, and instinct are transmissible to the offspring; but these consist of such qualities and attributes only as are intimately related to the natural wants and propensities of the species.

'4. The entire variation from the original type, which any given kind of change can produce, may usually be effected in a brief period of time, after which no farther deviation can be attained by continuing to alter the circumstances, though ever so gradually; indefinite divergence, either in the way of improvement or deterioration, being prevented, and the least possible excess beyond the definite limits being fatal to the existence of the individual.

'5. The intermixture of the distinct species is guarded against by the aversion of the individuals composing them to sexual union, or by the sterility of the mule offspring. It does not appear that true hybrid races have ever been perpetuated for several generations, even by the assistance of man; for the cases usually cited relate to the crossing of mules with individuals of pure species, and not to the intermixture of hybrid with hybrid.

'6. From the above considerations, it appears that species have a real existence in nature; and that each was endowed, at the time of its creation, with the attributes and organization by which it is now distinguished[1].'

STRATA IDENTIFIED BY ORGANIC REMAINS.

The discovery by William Smith of the successive stages of the stratification of Britain, each containing the remains of the organic beings then living in the waters or distributed through their agency, each stratum having been in succession the bed of the sea, gave the basis of a true Palæontology, and a true history of the succession of life on the globe. Almost every geologist and naturalist who has read this history by the light of these discoveries has arrived at the conclusion that many separate acts of creation are required to explain the successive appearances of the various races of animals and plants. In a few instances, of late years, the attempt has been made to adapt the hypothesis of Lamarck to the facts of Geology, and to combine two really distinct ideas—to derive all the observed variety of organization from one or a few original germs, by steps continually ascending on the whole to higher

[1] *Principles of Geology*, Book III. conclusion of Chap. IV.

grades and greater perfection *as a physiological problem;* and to shew that in the buried worlds of life this continual expansion of the general fundamental form, with a continual tendency to higher and higher development, can be placed in evidence as *a matter of history.* It is important to keep this distinction in mind.

DEVELOPMENT.

The author of the *Vestiges of Creation* placed before the English reader some sketches of the aspect of the animated world in successive geological ages, and has proposed in relation to the vegetable and animal kingdoms a full hypothesis of development to fit the gradation from the simple Lichen and Animalcule respectively up to the highest order of Dicotyledonous trees and the Mammalia. He attributes a great amount of change to the necessary effect of variations in the physical conditions which are influential on life: this change being progressive from lower to higher grades, and unlimited except by the range of physical conditions.

'While the external forms of the various vertebrate animals are so different, the whole are, after all, variations of a fundamental plan, which can be traced as a basis through the whole, the variations being merely modifications of that plan to suit the particular conditions in which each particular animal has been designed to live. Starting from the primeval germ, which is the representative of a particular order of full-grown animals, we find all others to be merely advances from that type, with the extension of endowments and modification of forms which are required in each particular case: each form, also, retaining a strong affinity to that which precedes it, and tending to impress its own features on that which succeeds.

'The various organic forms of our world are bound up in one—a fundamental unity pervades and embraces them all, collecting them, from the humblest lichen up to the highest mammifer, in one system, the whole creation of which must have depended upon one law or decree of the Almighty, though it did not all come forth at one time. The idea of a separate creation for each must appear totally inadmissible. The single fact of abortive or rudimentary organs condemns it; for these, on such a supposition, could be regarded in no other light than as blemishes or blunders, the thing of all others most irreconcileable with that idea of Almighty Perfection which a general view of nature so irresistibly conveys. On the other hand, when the organic creation is admitted to have been effected by a general law, we see nothing in these abortive parts but harmless peculiarities of development, and interesting evidences of the manner in which the Divine Author has been pleased to work.

'The whole train of animated beings, from the simplest and oldest up to the highest and most recent, are thus to be regarded as a series of *advances of the principle of development,* which have depended upon external physical circumstances to which the resulting animals are appropriate. I contemplate the whole phenomena,' he says, 'as having been in the first place arranged in the councils of the Divine Wisdom, to take place, not only upon this sphere, but upon all the others in space, under necessary modifications, and as being carried on, from first to last, here and elsewhere, under immediate favour of the creative will or energy. We are drawn to the supposition that the first step in the creation of life upon this planet was *a chemico-electric operation, by which simple germinal vesicles were produced.*' After this it is suggested, 'as an hypothesis already countenanced by much that is ascertained, and likely to be further sanctioned by much that remains to be known, that the first step was *an advance under favour of peculiar conditions, from the simplest forms of being, to the next more complicated, and this through the medium of the ordinary process of generation.*'

I am relieved from the necessity of pointing out on how slight a basis these bold assumptions are rashly poised, by the opportunity of referring to the full and complete examination of the whole argument, in the *Discourse on the Studies of the University of Cambridge,* by Professor Sedgwick. In this luminous treatise, the hypothesis of development has been met at every point, on physiological and geological evidence; palæontology has been surveyed from a high point of view; the latest discoveries of Forbes, Falconer, and Owen, bearing on the subject, have been ascertained; and the true succession of physical phenomena has been traced through the long periods of time embraced by geology. From this large investigation, the general conclusion is that 'Geology, not seen through the mists of any theory, but taken as a plain succession of monuments and facts, offers one firm cumulative argument against the hypothesis of development[1].'

CONSTANCY OF SPECIES.

It is curious to contrast with these views of the unlimited mutability of species, the conclusions of an anatomist and naturalist, who is so little fettered by ordinary formulæ, as to admit in the genus Homo,

[1] *Studies of the University of Cambridge.* Preface, p. cxxviii. edit. 5.

sixteen distinct species. In discussing the geographical distribution of these families of men, and the animals associated with them, M. Charles Desmoulins[1] takes occasion to affirm in the strongest manner the constancy of specific forms, unimpaired by time and physical changes:

'In future it will be vain to contest the inalterability of species, by means of the thousand and one suppositions suggested by ignorance or deception. For example, the carp and the barbel, which differ much less one from the other than a Negro and a Frenchman, have the central parts of their nervous system, different in number, differently arranged and shaped. Evidently cold, heat, light, obscurity, exercise, repose, more or less food, &c. have had no influence on that.

'A single objection has been offered to the certainty of these results, and this objection is merely a supposition. It is supposed that the actual diversity of species depends on an alteration of primitive forms, either by climate, or by the crossing of allied species, which would thus have multiplied differences, which were afterwards strengthened by time, so that the actual species would be for the most part only accidental varieties rendered definite, one knows not how.

[1] *Hist. Nat. des Races Humaines*, 1826.

'These assertions are purely gratuitous. At the present time such deviations are not producible even by means of art, and it is known by examination of the fossils of the later formations, as well as by the comparison of the most ancient examples with their living analogues, that the forms remain unalterable.'

So Agassiz, after that complete survey of Fossil Fishes, which has earned him the perpetual gratitude of geologists, says on the question of the diversity of species due to development: 'We must necessarily rise to a higher cause, and recognize more powerful influences, exercising on the whole of nature a more direct action, if one wishes not always to move in a vicious circle. For my part, I am convinced that species have been created successively at different epochs; and that the changes which they have suffered during a geological period are but of secondary importance, and depend only on their greater or less fecundity, and on migrations subordinated to the influences of the period.'

On the same side must be ranked the great authority of Cuvier,

—— clarum et venerabile nomen.

'There is no proof that all the differences which now distinguish organized beings are of such a nature as to have been produced by circumstances. All that has been advanced on this subject is hypothetical;

experience appears to shew on the contrary, that, in the actual state of the globe, varieties are restrained within rather narrow limits, and as far back as we ascend into antiquity we see that these limits were the same then as now.

'We are therefore obliged to admit certain forms, which have been perpetuated since the origin of things without exceeding these limits; and all the beings which appertain to one of these forms constitute what is called a species. Varieties are the accidental subdivisions of the species.

'Generation being the only means of knowing the limits to which varieties can extend, a species may be defined, as comprising the individuals, descended one from another or from common parents, and those which resemble them as much as they resemble each other.

'These forms do not produce or change themselves; life supposes their existence; it can only be kindled in organizations ready prepared for it; and the most profound meditations, as well as the most delicate observations, reach no further than to the mystery of the pre-existence of germs.'

PRIMITIVE TYPES.

The illustrious author of the *Systema Naturæ* permitted his accurate and richly stored mind sometimes to wander into general contemplation of the origin of the large series of living beings which he had subjected to classification. Perhaps no man who ever lived was more entitled to pronounce an opinion on the affinities and sequences of the hosts of 'specific' forms which he had characterized. His Natural Orders of Plants are among the most real and consistent groups yet assembled; many of his divisions of plants and animals are the clearest and most satisfactory. What was the deliberate opinion of this gifted man? I take it from the 13th and best edition of his great work, 1767. It applies to plants only.

'Suppose that in the beginning the Almighty proceeded from the simple to the compound; from few to many; and thus from a primary vegetable principle, created so many different plants as there are *natural orders*. Then that He mixed these orders of plants in generation, so that as many plants should arise as now are distinct *genera*. Next that nature mixed these generic plants, by ambigenous generations (which change not the structure of the flower), and multiplied them into species, as many as possible, excluding however hybrids, as sterile.'

Without too minutely criticising the distinction here drawn between the work of the Almighty, and the performance of nature,—which apparently may be held to mean independent permanency of genus, and dependent mutability of species—we remark in this passage the recognition of general 'primary types,' the 'struggle for existence' and the final 'limitation of species,' which have often been appealed to in later speculations.

DISTINCTION OF SPECIES.

Ever since the days of Linnæus the tendency of naturalists has been toward a nicer discrimination of species and a more thorough appreciation of the affinities which constitute natural assemblages. The former analytical process has been pushed very far in Botany, Zoology and Palæontology, so that what Linnæus and his immediate followers regarded as mere varieties have since been freely admitted to rank as 'good' species. This decision in regard to the majority of plants and animals has been quite independent of and without any reference to proof of the descent of the objects from a common parentage which is the original ground of specific identity, or from different parents which should constitute specific difference. In the case of a very large majority of the living invertebrata, no proof of this sort has been looked for; a definite peculiarity of structure, however slight, if often repeated, so as to appear to be hereditary, has seldom been rejected as a *specific character;* even colour and magnitude are not despised in this analysis.

But in Palæontology the list of species is even less satisfactory. For here the question of descent is seldom to be insisted on at all; very often we have only the knowledge of one age of the fossils, sometimes only one specimen—occasionally only the surface of that. For the purpose of diminishing these sources of error, and of determining in regard to each species the two most important parts of its history, viz.

1. Its geographical province, the area which it occupies, in one stratum or in several strata;
2. Its geological range in differents parts of this area;

nothing is so effectual as those monographs of particular well selected districts, which are founded on accurate observations of the localities of fossils, and of the conditions under which they are observed. But these observations lose all their value if the species of fossils be not precisely and certainly determined, and this amidst the conflict of classifications, and unequal estimates of specific agreements and differences, is a condition of success not always easy to be secured. If for example we wish to trace the geographical province or geological range of a common shell like Spirifera striata, we find two difficulties—one practical—arising from the want of an adequate public collection, to which reference might always be made, for foreign as well as British fossils, for varieties of race, and examples of the young and the aged, and of stunted, deformed, or gigantic growth. The best figures and the best descriptions will never suffice for determining specific distinctions in particular cases of very variable groups. This practical difficulty, of becoming perfectly acquainted with the accepted nomenclature, is aggravated by the cloud of theoretical obscurity which has been for some time condensing round the origin and character of species. Are the groups which we call species united by characters which vary only within definable limits? Are these limits of variation for a given species constant for all the area of its province, and for all the period of its geological range? Palæontologists generally answer in the affirmative, and the type-specimens in our Museums appear to confirm it. But if instead of these selections to exemplify differences we make large collections to illustrate agreements, the species (so-called) seem to lose their distinctness, and a second, or even a third or fourth group of forms may be fairly united to the first, before arriving at a real circumscription available for space and for time.

This process, in the careful hands of Mr Davidson, has already reduced the number of species in several groups of Brachiopoda; and augmented the geographical area of the groups. When fully carried out, I expect it will be found that the Brachiopoda of the Carboniferous limestones, so remarkably allied over all Europe, have a much larger agreement with those of North America than is at present allowed in our Catalogues.

In this process of reducing the admitted number of species we are following in the track of great botanists like Bentham and Hooker, whose researches in modern nature have brought them into view of similar difficulties.

But what if, as naturalists of no mean fame have told us, the limits we thus draw round species are arbitrary functions of our own minds, not real boundaries set by nature; limits which are not chosen alike by different minds, nor surely and firmly retained by the same mind, at different times? If such an opinion, whether true or not, were accepted by physiologists from a survey of existing nature, how would it affect our view of the succession of life on the globe? Those who maintain it to be true, usually assume some hypothesis which involves the operation of long time, and thus brings the question within the judgment of Geology.

NATURAL SELECTION.

Moved by such considerations, an eminent naturalist and geologist of our day has quitted the high road of the *Systema Naturæ,* and is seeking for the history of species[1] by a path which takes the same general direction as that already explored by Lamarck toward the primitive germs and primordial forms of life. Nature, he affirms, in successive generations gives varieties; these in the struggle for existence have unequal fortune, those most adapted to the circumstances of the time and place prosper, and give origin to descendants which run the same risks, and under the same principle of 'natural selection' acquire more and more the character of distinctness and of superiority. Following out these ideas, he has arrived at results which are thus expressed:

'Although much remains obscure, and will long remain obscure, I can entertain no doubt, after the most deliberate study and most dispassionate judgment of which I am capable, that the view which most naturalists entertain, and which I formerly entertained, namely, that each species has been independently created, is erroneous. I am fully convinced that species are not immutable; but that those belonging to what are called the same genera

[1] Darwin, *Origin of Species,* 1859.

are lineal descendants of some other and generally extinct species, in the same way as the acknowledged varieties of any one species are the descendants of that species. Furthermore, I am convinced that natural selection has been the main but not the exclusive means of modification.'

If asked how far he extends the doctrine of the mutability of species, he replies:

'The question is difficult to answer, because the more distinct the forms are which we may consider, by so much the arguments fall away in force. But some arguments of the greatest weight extend very far. All the members of whole classes can be connected together by chains of affinities, and all can be classified on the same principle, in groups subordinate to groups. Fossil remains sometimes tend to fill up very wide intervals between existing orders. Organs in a rudimentary condition plainly show that an early progenitor had the organs in a fully developed state; and this in some instances necessarily implies an enormous amount of modification in the descendants. Throughout whole classes various structures are formed on the same pattern, and at an embryonic age the species closely resemble each other. Therefore I cannot doubt that the theory of descent with modification embraces all the members of the same class. I believe that animals have descended from at most only four or five progenitors, and plants from an equal or lesser number.

'Analogy would lead me one step further, namely, to the belief that all animals and plants have descended from one prototype. But analogy may be a deceitful guide. Nevertheless all living things have much in common, in their chemical composition, their germinal vesicles, their cellular structure, and their laws of growth and reproduction. We see this even in so trifling a circumstance as that the same poison often similarly affects plants and animals; or that the poison secreted by the gall-fly produces monstrous growths on the wild rose or oak-tree. Therefore I should infer from analogy that probably all the organic beings which have ever lived on this earth have descended from some one primordial form into which life was first breathed.

'As all the living forms of life are the lineal descendants of those which lived long before the Silurian epoch, we may feel certain that the ordinary succession by generation has never once been broken, and that no cataclysm has desolated the whole world. Hence we may look with some confidence to a secure future of equally inappreciable length. And as natural selection works solely by and for the good of each being, all corporeal and mental endowments will tend to progress toward perfection.

'It is interesting to contemplate an entangled bank, clothed with many plants of many kinds, with birds singing on the bushes, with various insects flitting about, and with worms crawling through the damp earth, and to reflect that these elaborately constructed forms, so different from each other, and dependent on each other in so complex a manner, have all been produced by laws acting around us. These laws, taken in the largest sense, being growth with reproduction; inheritance which is almost implied by reproduction; variability from the indirect and direct action of the external conditions of life, and from use and disuse; a ratio of increase so high as to lead to a struggle for life, and as a consequence to natural selection, entailing divergence of character, and the extinction of less improved forms. Thus, from the war of nature, from famine and death, the most exalted object which we are capable of conceiving, namely, the production of the higher animals, directly follows. There is grandeur in this view of life, with its several powers having been originally breathed into a few forms or into one; and that, whilst this planet has gone cycling on according to the fixed law of gravity, from so simple a beginning endless forms most beautiful and most wonderful have been, and are being, evolved[1].'

[1] Professor Sedgwick has communicated to the Cambridge Philosophical Society an examination of the evidence bearing on

GENERAL REFLECTIONS.

These various speculations on the subject of Fossil plants and animals, and the origin and progress of life, may perhaps, to the student of exact science, appear little more than the chase of a phantom, a wandering after unattainable truth. There is, however, something seductive in the problem of the origin of life, and one who has entered on this charmed path, will seldom leave it without reluctance. Vain and ill-judged as are some of these attempts, they ought perhaps not to be visited with the heavy condemnation which sometimes has been heaped upon them. Men may have mistaken views about the diluvial catastrophe; false conceptions regarding electricity as the agent of imparting life; wrong notions about the nature of atoms, and yet not reason, at least intentionally, as 'atheists', denying the incessant watchfulness of God over the arrangements which he has appointed. It is hard to believe this of any serious thinker, even of Lucretius, however strongly he may contend for the regular operation of natural laws, in opposition to the capricious meddling of those monstrous personifications of human passions,

the Darwinian hypothesis, not less searching than that formerly directed by the same hand into the doctrine contained in the work entitled *Vestiges of Creation*, and with the same result, a decided rejection of the hypothesis.

which were accepted for deity by the 'too superstitious' men of Athens and Rome. Erroneous opinions have but their day, and are, perhaps, less mischievous than the indolence which acquiesces in dull and incurious conformity with whatever may reign for the moment. Truth, or what appears such to human reason, operating on real facts and just inferences, this is the end of scientific research; while we seek it, let us not be too much troubled if some run in courses wide of our own, and ask questions we think not likely to be answered. If we do not ourselves believe the origin of created life to be discoverable by a creature limited to the observation of sensible phenomena, why should we restrain the enterprise of those who, vainly striving after something that is unattainable or fabulous, may yet win much that is accessible, valuable and real?

According to most of the hypotheses we have been considering, the forms, structures and habits of life, which we now circumscribe by specific characters, however distinct these may seem to be, are only constant for this moment, slowly varying through this period, as they have varied in preceding periods, possibly then at a greater rate than now. The forms that now are have had a long series of progenitors, gradually changing from the earliest times; many of the earlier races of a great common stock having died out, while others came into view; the whole theatre of life always full of action, but the actors continually changing, however slow the process of change.

But, as already observed, the evidence of most value for deciding the probability of such a progressive change in the forms of life is to be furnished by geology. That it does not furnish good evidence in favour of gradual and indefinite change is perhaps generally allowed; but that it does furnish evidence of interrupted and limited change, and that the changes mark steps of progress, is a prevalent opinion. It is the opinion of Mr Darwin, that if the record of life in the fossiliferous strata were complete, those changes which now appear interrupted and sudden would be found to have been continuous, and the progress by steps would become an inclined plane of easy ascent. This incompleteness he assumes to be enormous; so much so that the traces of whole periods of immense duration, including the first period, are lost; what we possess being merely fragments of the record, which indeed never was complete, owing to the character of some kinds of deposits. Thus we must not expect to be able to arrange the fossil remains in a real however broken series, since the true order and descent may be, and for the most part is, irrecoverably lost.

Surely this imperfection of the geological record is overrated. With the exceptions of the two great breaks at the close of the Palæozoic and Mesozoic periods, the series of strata is nearly if not quite complete, the series of life almost equally so. Not indeed in one small tract or in one section; but on a comparison of different tracts and several sections. For example, the marine series of Devonian life cannot be found in the districts of Wales or Scotland, but must be collected in Devonshire, Bohemia, Russia and America. When so gathered it fills very nearly if not entirely the whole interval between the Upper Silurian and the Carboniferous Fauna. So in England the marine intermediaries of the Oolitic and Cretaceous ages are not given: but the Neocomian Strata supply the want. We have no Meiocene Strata in England, but their place is marked in France and America.

Even the great breaks alluded to are bridged. The Permian series of life contains some Mesozoic interpolations; and the Lias contains reliquiæ of some Palæozoic genera. The upper chalk of Maestricht and the South of France extends toward the Tertiaries the reign of the Upper Mesozoic beds.

On the whole, it appears that there exist ample materials for testing any hypothesis of the sequence of life which includes the marine races; and that there is much ground for believing, in regard to the chasms which do exist in the series of freshwater and terrestrial races, that if filled, they would not lead to other inferences than such as appear consistent with the records of the sea. If the monuments of the earlier life of the globe are essential witnesses, but too few and independent for a satisfactory test of a given hypothesis of the sequence of life, it is unfortunately ineligible for admission among accepted truths.

Caloric, electricity, chemical action, are all influential on life; elevating and depressing it, carrying it on or bringing it to a close, according to the measure and mode of application of these powers of nature. Employed as they are in the current of life, and at every moment acting on and being acted on by it, nothing has seemed easier to speculation than to conceive these agencies so operating on appropriate matter as to *make* the vital machine which could not be kept in motion without them. The only thing wanting is the due co-ordination of these powers, in the appropriate matter. Here unfortunately is the difficulty—*due co-ordination* of independent powers in matter *rightly adapted* implies the directing mind of the Master of power and matter. The formula is imperfect—

We start, for LIFE is wanting there!

Given, however, the appropriate matter, and the stroke of life upon it, what have we—no living thing—but vitalized matter. Capable of what? Self-development? Into what simple organic form? The answer seems to have been an Infusory Animalculum, before the scrutiny of the microscope had shewn the real complexity of most of these children of unknown fathers, the transition stages of others, the definite course of life of all. At present the first hopeful product of the cryptogamy of electricity and carburetted moisture would be a fertile cell, for cells are the ultimate term of the mechanical analysis of organic beings.

Given then a cell with walls; composed of carbon, hydrogen and oxygen; capable of self-division and so of increasing in number. Let it be born in the sea according to Telliamed, or, in moisture, or slime, according to Lamarck, or if it suit better the following phenomena, in the air. What follows? An aggregation of cells. Plant or animal? Perhaps neither, but a living being, capable not of moving, but of being moved, says Lamarck, by the external powers influential on life, like Volvox. What next? Reproduction of other Volvoces by self-division, or the growth of new individuals within the parent.

Here the process, so far as our knowledge and observation go, at present, must stop—the aggregate of cells breaks up into smaller aggregates, or is resolved into solitary cells again, and our little circle of discovery is completed.

Given, therefore, something more; a current of water guided by cilia through the mass; removal and renewal of cells; addition of a new substance to line the canals, in forms determined by these currents; the growth of germs capable of being separated and going through the same series of events; in short a sponge, for the possession of which Botany and Zoology have had a long conflict, and which seems placed at the very lowest limit of specific life.

What is the next step, or rather leap, is hard to say; for if we go to the minute Foraminifera, that is a group of aggregated and perforated cells, with cilia, which helps us very little or not at all in the advancement of animalization; but if we ascend *per saltum* to the Zoophyta most allied to Spongiadæ, and claim affinity with Alcyonium, we require the large postulates of freely moving polypi, with eight arms round the contractile mouth, a complete digestive cavity, and ova of definite character.

Then again is another hiatus between the Alcyonidæ and the Mollusca, which neither fossil nor recent life can fill; and thus in what seem to be the first and easiest steps we can imagine, nothing but postulate upon postulate will bring us on our way. But postulates in the sense here used are equivalent to special endowments, not in the least easier to conceive of than separate creations; for what are these but endowments, and has not every special structure its appropriate germ and mode of growth?

If it is not possible in the existing ocean, among the innumerable and variable radiated, amorphozoan, and foraminiferous animals, to construct one chain of easily graduated life, from the fertile cell to the prolific ovarium and digestive stomach, it must be quite in vain to look for such evidence in the fossil state. In the face of the assumptions requisite to imagine such a chain, we cannot venture to adopt it as a probable hypothesis, and thus the idea of one general oceanic germ of life, whether we like it or not, must be abandoned. Reasoning of the same kind will convince us that to derive by any probable steps any one great division of the animal kingdom from another, involves too much of hazardous assumption to be adopted by a prudent inquirer.

Take therefore the hypothesis in an easier shape, and accept as primary structures in general forms all the great invertebral divisions which reside in water; let us suppose them capable of indefinite variation, and inquire what is the geological evidence

P 2

in proof of each later group being derived from some earlier one by descent with modification. Take the least incomplete series of forms, viz. the Mollusca, and undoubtedly the most favourable of all the marine groups for the application of hypothesis.

The earliest known Mollusk is the Brachiopod Lingula; which, as already observed, recurs in all the systems of strata, and is still living. It gives no generic branches. The next earliest are the Dimyarian genera, Ctenodonta and Cucullella, which cannot be regarded as descended from any conceivable Brachiopod, or accepted as progenitors of Modiola, Orthonota, Cardiola or Pleurorhynchus; still less of their Monomyarian companions, Ambonychia, Avicula and Pterinea. It is inconceivable that from these or any thing like them could be derived the Gasteropod, Euomphali, Loxonemæ, &c., or that the Heteropod Bellerophon, the Pteropod Theca, or the Cephalopod Orthoceras, are consanguineous, any one of them with any other. All these great classes then are *according to the evidence* equally aboriginal, though not of equal antiquity.

Without bringing in similar results from the other invertebral classes we may boldly affirm that the later series of Cambro-Silurian life cannot possibly be derived from the earlier series, according to the evidence preserved to us; but on the contrary requires absolutely the admission of separate stemmata, certainly for every principal group, apparently and probably so for every genus or natural assemblage of much resembling forms with similar structures.

The explanation offered by most palæontologists is that these several stemmata are of independent origin, separate creations in fact, using this term to indicate a process unknown to us, by which the Creator has provided for the appearance of new forms and structures at definite times, and in certain places, which it is in the province of palæontology to search out. The explanation offered in the hypothesis of Mr Darwin, is that the groups of life which appear to be and really are distinct, in the Cambro-Silurian rocks, are not aboriginal forms; but derived from progenitors of far earlier date, belonging to few types or to one; the original form, and the transition forms being unknown to us.

Now they are not unknown to us by any impossibility of being preserved, for the strata of the Cambro-Silurian series are of a kind in which organic remains of great delicacy are often preserved, and indeed such are preserved in these very strata; and by the hypothesis the life-structures which are lost must have only gradually differed in their nature from those which are preserved. It follows, therefore, that the earlier living progenitors of the Cambro-Silurian series, not only lived long before but must have lived somewhere else. But as in all the known examples of this series of strata, wherever found, we have everywhere animals of the same general type, and nowhere the traces of earlier progenitors, it is clear that everywhere we are required by the hypothesis to look somewhere else; which may fairly be interpreted to signify, that the hypothesis everywhere fails in the first and most important step. How is it conceivable that the second stage should be everywhere preserved, but the first nowhere?

This difficulty occurs again and again, not only at the great breaks of the series of strata accompanied with much disturbance and change of sea-bed, but during the ordinary and least interrupted accumulations of deposit, for example, in the Silurian and Oolitic systems, in each of which new families and genera, new types of structure in short, make their appearance frequently at definite stages, and always compel the hypothesis to the same answer—look elsewhere for the progenitor—the father is never buried with his children.

Is there not at the base of all these hypotheses of one continuously branching stream of variable life, some trace of the common errors of assuming that to be true without limits, which is acknowledged to be true in a restricted sense; of employing infinite time to integrate quantities which are subject to no law of varying magnitude; and of assigning a resultant to unknown and inconstant directions? Do we not find the 'mutability of species' illustrated by examples of *limited* change, effected by the *directing* agency of man; and then what stands for an inference that *unlimited* changes have been effected or are in progress by the *undirected* combination of external conditions? Are we sure that varieties which are given by nature in successive generations, can be *summed in one direction* by the variable preponderant of a number of *concomitant variable* conditions of life? Can we remove 'natural selection' from the large synonymy of 'chance,' except by giving to one of the variable conditions of which it is the sum, direction, definite value or effect? Is it not the one acknowledged possession by every species of an inherent tendency to propagate its like? Would not the effect of this one constant among any number of variables without law, be to preserve the characters of the species for ever? And if 'natural selection' were regarded as giving direction to these variables, in combination with that constant tendency, what would be the final result but that which has always been recognized, viz. a species varying within limits which are to be sought out by experience? But, finally, if Natural Selection be thus gifted with the power of continually acting for the good of its subject,—encouraging it, or rather compelling it to continual advancement,—

Αἰεὶ ἀριστεύειν καὶ ὑπέρμορον ἔμμεναι ἄλλων,

how is this beneficent personification to be separated from an ever watchful providence; which once brought into view sheds a new light over the whole picture of causes and effects?

It may be thought that, while professing to keep to the old and safe method of reasoning on known causes and ascertained effects, we deviate from this principle in regard to the origin of life, and introduce an unknown cause for phenomena not understood, by calling to our aid an act of 'creation.' Be it so, let the word stand for a confession of our ignorance of the way in which the governing mind has in this case acted upon matter; we are equally ignorant in every other instance which brings us face to face with the idea of forces not manifested in acts. We see the stream of life flowing onward in a determined course, in harmony with the recognized forces of nature, and yielding a great amount of enjoyment, and a wonderful diversity of beautiful and instructive phenomena, in which MIND speaks to mind. Life through many long periods has been manifested in a countless host of varying structures, all circumscribed by one general plan, each appointed to a definite place, and limited to an appointed duration. On the whole the earth has been thus more and more covered by the associated life of plants and animals, filling all habitable space with beings capable of enjoying their own existence or ministering to the enjoyment of others; till finally, after long preparation, a being was created capable of the wonderful power of measuring and weighing all the world of matter and space which surrounds him, of treasuring up the past history of all the forms of life, and of considering his own relation to the whole. When he surveys this vast and co-ordinated system, and inquires into its history and origin, can he be at a loss to decide whether it be a work of Divine thought and wisdom, or the fortunate offspring of a few atoms of matter, warmed by the *anima mundi*, a spark of electricity, or an accidental ray of sunshine?

INDEX.

D.

E.

F.

CAMBRIDGE: PRINTED AT THE UNIVERSITY PRESS.

SELECT LIST OF

New Works and New Editions

PUBLISHED BY

MACMILLAN AND CO.

CAMBRIDGE,

AND 23, HENRIETTA STREET, COVENT GARDEN, LONDON, W.C.

ONE SHILLING MONTHLY,

MACMILLAN'S MAGAZINE.

EDITED BY DAVID MASSON.

VOLUMES I. AND II. ARE NOW READY,

Handsomely bound in extra cloth, price 7s. 6d. each.

AMONG THE CONTRIBUTORS TO THE VOLUMES ARE

THE AUTHOR OF "TOM BROWN'S SCHOOL DAYS."
THE AUTHOR OF "JOHN HALIFAX."

THE REV. F. D. MAURICE.
R. MONCKTON MILNES, M.P.
THE REV. J. W. BLAKESLEY.
HENRY KINGSLEY.
F. LUSHINGTON.
ALEXANDER SMITH.
AURELIO SAFFI.
&c.

ALFRED TENNYSON.
PROFESSOR HUXLEY.
G. S. VENABLES.
PROFESSOR ANSTED.
J. M. LUDLOW.
HERBERT COLERIDGE.
REV. J. Ll. DAVIES.
&c.

12.11.60.
2,000 post.

POPULAR WORKS FOR THE YOUNG.

PRICE FIVE SHILLINGS EACH.

Tom Brown's School-Days. By AN OLD BOY.
With a new Preface. Seventh Edition. Fcap. 8vo. 5*s.*

"Those manly, honest thoughts, expressed in plain words, will, we trust, long find an echo in thousands of English hearts."—QUARTERLY REVIEW.

Our Year. A Child's Book in Prose and Rhyme.
By the Author of "John Halifax." With numerous Illustrations by CLARENCE DOBELL. Royal 16mo. cloth, gilt leaves, 5*s.*

"Just the book we could wish to see in the hands of every child . . . written in such an easy, chatty, kindly manner."—ENGLISH CHURCHMAN.

Mr. Kingsley's Heroes, or Greek Fairy Tales for my Children. New Edition, with Illustrations.
Royal 16mo. cloth, gilt leaves, 5*s.*

"A welcome and delightful volume, for the stories are prose poems both as to matter and manner."—ECLECTIC REVIEW.

Ruth and Her Friends. A Story for Girls.
With Frontispiece. Third Edition.
Royal 16mo, cloth, gilt leaves, 5*s.*

"The tone is so thoroughly healthy, that we augur the happiest results from its wide diffusion."—THE FREEMAN.

POPULAR WORKS FOR THE YOUNG—*Continued.*

Days of Old: Stories from Old English History for the Young.

By the Author of "RUTH AND HER FRIENDS." With Frontispiece. Royal 16mo. cloth, gilt leaves, 5*s*.

"*A delightful little book, full of interest and instruction . . . fine feeling, dramatic weight, and descriptive power in the stories.*"—LITERARY GAZETTE.

Agnes Hopetoun's Schools and Holidays: the Experience of a Little Girl.

By Mrs. OLIPHANT (Author of "Margaret Maitland"). With Frontispiece. Royal 16mo. cloth, gilt leaves, 5*s*.

"*One of Mrs. Oliphant's gentle, thoughtful stories. . . . described with exquisite reality . . . teaching the young pure and good lessons.*"—JOHN BULL.

Little Estella, and other Tales for the Young.

With Frontispiece. Royal 16mo. cloth, gilt leaves, 5*s*.

"*Very pretty, pure in conception, and simply, gracefully related . . . genuine story telling.*"—DAILY NEWS.

David, King of Israel. A History for the Young.

By J. WRIGHT. With Illustrations.

Royal 16mo. cloth, gilt leaves, 5*s*.

"*An excellent book . . . well conceived, and well worked out.*"—LITERARY CHURCHMAN.

My First Journal: a Book for Children.

By GEORGIANA M. CRAIK, Author of "Lost and Won." With Frontispiece. Royal 16mo. cloth, gilt leaves. 4*s*. 6*d*.

"*True to Nature and to a fine kind of nature . . . the style is simple and graceful . . . a work of Art, clever and healthy toned.*"—GLOBE.

THE RECOLLECTIONS OF GEOFFRY HAMLYN.

By HENRY KINGSLEY, Esq.

Second Edition. Crown 8vo. cloth, 6*s.*

Mr. Henry Kingsley has written a work that keeps up its interest from the first page to the last,—it is full of vigorous stirring life, and though an eager reader may be prompted to skip intervening digressions and details, hurrying on to see what comes of it all, he will, nevertheless, be pretty sure to return and read dutifully all the skipped passages after his main anxiety has been allayed. The descriptions of Australian life in the early colonial days are marked by an unmistakeable touch of reality and personal experience . . . . . Mr. Henry Kingsley has written a book which the public will be more inclined to read than to criticise, and we commend them to each other."—ATHENÆUM.

THE ITALIAN WAR OF 1848-9,

And the Last Italian Poet. By the late HENRY LUSHINGTON, Chief Secretary to the Government of Malta. With a Biographical Preface by G. STOVIN VENABLES.

Crown 8vo. cloth, 6*s.* 6*d.*

"*As the writer warms with his subject, he reaches a very uncommon and characteristic degree of excellence. The narrative becomes lively and graphic, and the language is full of eloquence. Perhaps the most difficult of all literary tasks —the task of giving historical unity, dignity, and interest, to events so recent as to be still encumbered with all the details with which newspapers invest them—has never been more successfully discharged. . . . Mr. Lushington, in a very short compass, shows the true nature and sequence of the event, and gives to the whole story of the struggle and defeat of Italy a degree of unity and dramatic interest which not one newspaper reader in ten thousand ever supposed it to possess.*"—SATURDAY REVIEW.

SCOURING OF THE WHITE HORSE.

By the Author of "TOM BROWN'S SCHOOL DAYS." With numerous Illustrations by RICHARD DOYLE. Eighth Thousand. Imp. 16mo. printed on toned paper, gilt leaves. 8*s.* 6*d.*

"*The execution is excellent. . . . Like Tom Brown's School Days, the White Horse gives the reader a feeling of gratitude and personal esteem towards the author. The author could not have a better style, nor a better temper, nor a more excellent artist than Mr. Doyle to adorn his book.*"—SATURDAY REVIEW.

EDITED BY W. G. CLARK, M.A.

Public Orator in the University of Cambridge.

George Brimley's Essays. With Portrait.

Second Edition. Fcap. 8vo. cloth. 5*s.*

"*One of the most delightful and precious volumes of criticism that has appeared in these days. . . . To every cultivated reader they will disclose the wonderful clearness of perception, the delicacy of feeling, the pure taste, and the remarkably firm and decisive judgment which are the characteristics of all Mr. Brimley's writings on subjects that really penetrated and fully possessed his nature.*"—NONCONFORMIST.

MEMOIR OF THE REV. GEORGE WAGNER,

Late of St. Stephen's, Brighton.

By J. N. Simpkinson, M.A., Rector of Brington, Northampton.' Second Edition. Crown 8vo. cloth, 9*s*.

"*A deeply interesting picture of the life of one of a class of men who are indeed the salt of this land.*"—Morning Herald.

BY FRANCIS MORSE, M.A.

Incumbent of St. John's, Ladywood, Birmingham.

Working for God. And other Practical Sermons. Second Edition. Fcap. 8vo. 5*s*.

"*For soundness of doctrine, lucidity of style, and above all for their practical teaching, these sermons will commend themselves.*"—John Bull.

"*There is much earnest, practical teaching in this volume.*"—English Churchman.

BY THE REV. J. LLEWELYN DAVIES, M.A.

Rector of Christ Church, St. Marylebone, late Fellow of Trinity College, Cambridge.

The Work of Christ; or the World reconciled to God. Sermons Preached at Christ Church, St. Marylebone. With a Preface on the Atonement Controversy. Fcap. 8vo. cloth, 6*s*.

BY THE REV. D. J. VAUGHAN, M.A.,

Vicar of St. Martin's, Leicester, late Fellow of Trinity College, Cambridge.

Sermons on the Resurrection. With a Preface. Fcap. 8vo. cloth, price 3*s*.

Contents:

BY W. WHEWELL, D.D.

Master of Trinity College, Cambridge.

The Platonic Dialogues for English Readers.

Two Vols. Crown 8vo. cloth, 14*s.*

"*So readable is this book that no young lady need be deterred from undertaking it: and we are much mistaken if there be not fair readers who will think, as Lady Jane Grey did, that hunting or other female sport is but a shadow compared with the pleasure there is to be found in Plato. The main questions which the Greek master and his disciples discuss are not simply for these in Moral Philosophy schools; they are questions real and practical, which concern Englishmen in public and private life, or their sisters or wives who are busy in lowly and aristocratic households.*"—ATHENÆUM.

THE REPUBLIC OF PLATO.

A New Translation into English.

With an Analysis and Notes. By J. LL. DAVIES, M.A., and D. J. VAUGHAN, M.A., Fellows of Trinity College, Cambridge. SECOND EDITION.

8vo. cloth, 10*s.* 6*d.*

"*So eloquent and correct a version will, we trust, induce many to become students of the Republic. . . The whole book is scholarlike and able.*"—GUARDIAN.

"*Free, nervous, idiomatic English, such as will fascinate the reader.*"—NONCONFORMIST.

BY GEORGE WILSON, M.D., F.R.S.E.,

Regius Professor of Technology in the University of Edinburgh; and Director of the Industrial Museum of Scotland.

Seventh Thousand.

1. The Five Gateways of Knowledge.

A Popular Work on the Five Senses. In fcap. 8vo. cloth, with gilt leaves, 2*s.* 6*d.* PEOPLE'S EDITION, in ornamental stiff covers, 1*s.*

"*Dr. Wilson unites poetic with scientific faculty, and this union gives a charm to all he writes. In the little volume before us he has described the Five Senses in language so popular that a child may comprehend the meaning, so suggestive that philosophers will read it with pleasure.*"—LEADER.

2. The Progress of the Telegraph.

Fcap. 8vo. 1*s.*

"*Most interesting and instructive . . . at once scientific and popular, religious and technical; a worthy companion to the 'Gateways of Knowledge.'*"—LITERARY CHURCHMAN.

THE WORKS OF

WILLIAM ARCHER BUTLER, M.A.,

Late Professor of Moral Philosophy in the University of Dublin.

FIVE VOLUMES 8vo. *UNIFORMLY PRINTED AND BOUND.*

"*A man of glowing genius and diversified accomplishments, whose remains fill these five brilliant volumes.*"—EDINBURGH REVIEW.

SOLD SEPARATELY AS FOLLOWS.

1. Sermons, Doctrinal and Practical. FIRST SERIES. Edited by the Very Rev. THOS. WOODWARD, M.A., Dean of Down. With a Memoir and Portrait. Fifth Edition. 8vo. cloth, 12*s*.

"*Present a richer combination of the qualities for Sermons of the first class than any we have met with in any living writer.*"—BRITISH QUARTERLY REVIEW.

2. Sermons, Doctrinal and Practical. SECOND SERIES. Edited by J. A. JEREMIE, D.D., Regius Professor of Divinity in the University of Cambridge. Third Edition. 8vo. cloth, 10*s*. 6*d*.

"*They are marked by the same originality and vigour of expression, the same richness of imagery and illustration, the same large views and catholic spirit, and the same depth and fervour of devotional feeling, which so remarkably distinguished the preceding Series, and which rendered it a most valuable accession to our theological literature.*"—From DR. JEREMIE'S PREFACE.

3. Letters on Romanism, in Reply to DR. NEWMAN'S Essay on Development. Edited by the Very Rev. THOMAS WOODWARD, M.A., Dean of Down. SECOND EDITION. Revised by the Ven. ARCHDEACON HARDWICK. 8vo. cloth, 10*s*. 6*d*.

"*Deserve to be considered the most remarkable proofs of the Author's indomitable energy and power of concentration.*"—EDINBURGH REVIEW.

4. Lectures on the History of Ancient Philosophy. Edited from the Author's MSS., with Notes, by WILLIAM HEPWORTH THOMPSON, M.A., Regius Professor of Greek in the University of Cambridge. 2 vols. 8vo., £1 5*s*.

"*Of the dialectic and physics of Plato they are the only exposition at once full, accurate, and popular, with which I am acquainted: being far more accurate than the French, and incomparably more popular than the German treatises on these departments of the Platonic philosophy.*"—From PROF. THOMPSON'S PREFACE.

THIRD EDITION.

Lectures to Ladies on Practical Subjects. Crown 8vo. 7*s*. 6*d*.

By F. D. MAURICE, CHARLES KINGSLEY, J. LL. DAVIES, ARCHDEACON ALLEN, DEAN TRENCH, PROFESSOR BREWER, DR. GEORGE JOHNSON, DR. SIEVEKING, DR. CHAMBERS, F. J. STEPHEN, ESQ. and TOM TAYLOR, ESQ.

CONTENTS:—Plan of Female Colleges—The College and the Hospital—The Country Parish—Overwork and Anxiety—Dispensaries—District Visiting—Influence of Occupation on Health—Law as it affects the Poor—Everyday Work of Ladies—Teaching by Words—Sanitary Law—Workhouse Visiting.

"*We scarcely know a volume containing more sterling good sense, or a finer expression of modern intelligence on social subjects.*"—CHAMBERS' JOURNAL.

BY BROOKE FOSS WESTCOTT, M.A.,

Author of "History of the New Testament Canon," &c.

Characteristics of the Gospel Miracles. Sermons preached before the University of Cambridge. With Notes.

Crown 8vo. cloth, 4*s*. 6*d*.

"*An earnest exhibition of important and exalted truth.*"—JOURNAL OF SAC. LITERATURE.

BY C. A. SWAINSON, M.A.

Principal of the Theological College, and Prebendary of Chichester.

1. The Authority of the New Testament; the Conviction of Righteousness, and other Lectures delivered before the University of Cambridge. 8vo. cloth, 12*s*.

"*These remarkable Lectures deal with most engrossing subjects in an honest and vigorous spirit. The religious topics which are now uppermost in the mind of the thoughtful classes among us, and which are fundamental to the Christian, are here grappled with, we gladly acknowledge, in a courageous, straightforward way. The reader is led to think healthily and calmly. . . . Our readers will do well to obtain the book and read it all, there is so much in it of abiding value.*"—LITERARY CHURCHMAN.

2. The Creeds of the Church. In their Relations to the Word of God and the Conscience of the Christian. 8vo. cloth, 9*s*.

3. A Handbook to Butler's Analogy. With a few Notes. 1*s*. 6*d*.

BY JULIUS CHARLES HARE, M.A.,

Sometime Archdeacon of Lewes, Rector of Herstmonceux, Chaplain in Ordinary to the Queen, and formerly Fellow and Tutor of Trinity College, Cambridge.

NINE VOLS. 8*vo. UNIFORMLY PRINTED AND BOUND.*

1. Charges to the Clergy of the Archdeaconry of Lewes. During 1840 to 1854, with Notes on the Principal Events affecting the Church during that period. And an Introduction, explanatory of his position in the Church, with reference to the Parties which divide it.
3 vols. 8vo. cloth, £1 11*s*. 6*d*.

2. Miscellaneous Pamphlets on some of the Leading Questions agitated in the Church during the years 1845 to 1851.
8vo. cloth, 12*s*.

3. Vindication of Luther against his recent English Assailants. Second Edition. 8vo. cloth, 7*s*.

4. The Mission of the Comforter. With Notes. Second Edition. 8vo. cloth, 12*s*.

5. The Victory of Faith. Second Edition. 8vo. cloth, 5*s*.

6. Parish Sermons. Second Series. 8vo. cloth, 12*s*.

7. Sermons preacht on Particular Occasions. 8vo. 12*s*.

The two following books are included among the collected Charges, but are published separately for purchasers of the rest.

Charges to the Clergy of the Archdeaconry of Lewes. Delivered in the years 1843, 1845, 1846. Never before published. With an Introduction, explanatory of his position in the Church, with reference to the Parties that divide it. 8vo. cloth, 6*s*. 6*d*.

The Contest with Rome. A Charge, delivered in 1851. With Notes, especially in answer to Dr. Newman on the Position of Catholics in England. Second Edition. 8vo. cloth, 10*s*. 6*d*.

BY JOHN McLEOD CAMPBELL,

Formerly Minister of Row.

The Nature of the Atonement, and its Relation to Remission of Sins and Eternal Life.

8vo. cloth, 10*s.* 6*d.*

"*This is a remarkable book, as indicating the mode in which a devout and intellectual mind has found its way, almost unassisted, out of the extreme Lutheran and Calvinistic views of the Atonement into a healthier atmosphere of doctrine. . . . We cannot assent to all the positions laid down by this writer, but he is entitled to be spoken respectfully of, both because of his evident earnestness and reality, and the tender mode in which he deals with the opinions of others from whom he feels compelled to differ.*"—LITERARY CHURCHMAN.

BY THE RIGHT REV. G. E. LYNCH COTTON, D.D.,

Lord Bishop of Calcutta and Metropolitan of India.

Sermons and Addresses delivered in Marlborough College, during Six Years.

Crown 8vo. cloth, price 10*s.* 6*d.*

"*We can heartily recommend this volume as a most suitable present for a youth, or for family reading; wherever there are young persons, the teaching of these discourses will be admirable.*"—LITERARY CHURCHMAN.

Sermons: Chiefly connected with Public Events in 1854.

Fcap. 8vo. cloth, 3*s.*

"*A volume of which we can speak with high admiration.*"

CHRISTIAN REMEMBRANCER.

Charge delivered to the Clergy of Calcutta at his Primary Visitation in September, 1859. 8vo. 2*s.* 6*d.*

BY JOHN HAMILTON, Esq. (of St. Ernan's,) M.A.,

St. John's College, Cambridge.

On Truth and Error: Thoughts, in Prose and Verse, on the Principles of Truth, and the Causes and Effects of Error.

Crown 8vo. Cheap Edition, cloth, 5*s.*

"*A very genuine, thoughtful, and interesting book, the work of a man of honest mind and pure heart; one who has felt the pressure of religious difficulties, who has thought for himself on the matters of which he doubted, and who has patiently and piously worked his way to conclusions which he now reverently but fearlessly utters to the world.*"—NONCONFORMIST.

BY CHARLES KINGSLEY, M.A.

Chaplain in Ordinary to the Queen, Rector of Eversley, and Regius Professor of Modern History in the University of Cambridge.

1. Two Years Ago. Third Edition. Crown 8vo. cloth, 6*s*.

"*Genial, large hearted, humorous, with a quick eye and a keen relish alike for what is beautiful in nature and for what is genuine, strong, and earnest in man.*"—GUARDIAN.

2. "Westward Ho!" or the Voyages and Adventures of Sir Amyas Leigh, Knight, of Borrough, in the County of Devon, in the reign of Her most Glorious Majesty Queen Elizabeth. New Edition. Crown 8vo. cloth, 6*s*.

"*Almost the best historical novel to our mind of the day.*"—FRAZER'S MAGAZINE.

3. The Heroes: Greek Fairy Tales for my Children. New and Cheaper Edition, with Eight Illustrations. Royal 16mo. beautifully printed on toned paper, gilt edges, 5*s*.

"*We doubt not they will be read by many a youth with an enchained interest almost as strong as the links which bound Andromeda to her rock.*"—BRITISH QUARTERLY.

4. Glaucus; or, the Wonders of the Shore. A Companion for the Sea-side. Containing Coloured Illustrations of the Objects mentioned in the Work. Fourth Edition. Beautifully printed and bound in cloth, gilt leaves. 7*s*. 6*d*.

"*Its pages sparkle with life, they open up a thousand sources of unanticipated pleasure, and combine amusement with instruction in a very happy and unwonted degree.*"—ECLECTIC REVIEW.

5 Phaethon; or, Loose Thoughts for Loose Thinkers. Third Edition. Crown 8vo. boards, 2*s*.

6. Alexandria and Her Schools. Four Lectures delivered at the Philosophical Institution, Edinburgh. With a Preface Crown 8vo. cloth, 5*s*.

WORKS BY C. J. VAUGHAN, D.D.

Late Head Master of Harrow School.

1. **Notes for Lectures on Confirmation.** With Suitable Prayers. Third Edition. Fcap. 8vo. limp cloth, red leaves, 1*s*. 6*d*.

"*A comprehensive, earnest, and useful manual.*"—English Churchman.

"*Commends itself at once by its simplicity and by its logical arrangement. Not overloaded with a multitude of points, and it brings those which are introduced before the mind in lucid order and in natural sequence. It will prove, as it is well to be, extensively useful.*"—The Press.

2. **St. Paul's Epistle to the Romans.** The Greek Text with English Notes. 8vo. cloth, 7*s*. 6*d*.

"*For educated young men this commentary seems to fill a gap hitherto unfilled. We find in it a careful elucidation of the meaning of phrases by parallel passages from St. Paul himself, with a nearly continuous paraphrase and explanation by which the very difficult connexion of the argument of the Epistle, with its countless digressions and ellipses and abrupt breaks, is pointedly brought out. An educated lad, who thought for himself, would learn more of the real meaning of St. Paul's words by thoroughly thinking out the suggestive exposition of them here supplied, than by any amount of study bestowed upon more elaborate and erudite works. . . As a whole, Dr. Vaughan appears to us to have given to the world a valuable book of original and careful and earnest thought bestowed on the accomplishment of a work which will be of much service, and which is much needed.*"—Guardian.

3. **Memorials of Harrow Sundays.** A Selection of Sermons preached in the School Chapel. With a View of the Interior of the Chapel.
Second Edition. Crown 8vo. cloth, red leaves, 10*s*. 6*d*.

4. **Epiphany, Lent, and Easter.** A Selection of Expository Sermons. Crown 8vo. cloth, red leaves. 7*s*. 6*d*.

"*Each exposition has been prepared upon a careful revision of the whole passage . . . and the extreme reverence and care with which the author handles Holy Writ, are the highest guarantees of success. Replete with thought, scholarship, earnestness, and all the elements of usefulness.*"—Literary Gazette.

5. **Revision of the Liturgy.** Five Discourses. With an Introduction. I. Absolution. II. Regeneration. III. The Athanasian Creed. IV. Burial Service. V. Holy Orders.
Crown 8vo. cloth, red leaves (1860), 117 pp. 4*s*. 6*d*.

"*The large-hearted and philosophical spirit in which Dr. Vaughan has handled the specific doctrines of controversy point him out as eminently fitted to deal with the first principles of the question.*"—John Bull.

BY THE VENBLE. ARCHDEACON HARDWICK.

Christ and other Masters: A Historical Inquiry into some of the chief Parallelisms and Contrasts between Christianity and the Religious Systems of the Ancient World.

Part III. Religions of China, America, and Oceanica.
Part IV. Religions of Egypt and Medo-Persia.

In 8vo. cloth, 7*s*. 6*d*. each.

"*Never was so difficult and complicated a subject as the history of Pagan religion handled so ably, and at the same time rendered so lucid and attractive.*" —COLONIAL CHURCH CHRONICLE.

BY THOMAS RAWSON BIRKS, M.A.,

Rector of Kelshall, Examining Chaplain to the Lord Bishop of Carlisle; Author of "The Life of the Rev. E. Bickersteth."

The Difficulties of Belief, in connexion with the Creation and the Fall. Crown 8vo. cloth, 4*s*. 6*d*.

"*A profound and masterly essay.*"—ECLECTIC.

"*His arguments are original, and carefully and logically elaborated. We may add that they are distinguished by a marked sobriety and reverence for the Word of God.*"—RECORD.

BY THE VERY REV. R. C. TRENCH, D.D.,

Dean of Westminster.

1. Synonyms of the New Testament.

Fourth Edition. Fcap. 8vo. cloth, 5*s*.

2. Hulsean Lectures for 1845—46.

CONTENTS. 1.—The Fitness of Holy Scripture for unfolding the Spiritual Life of Man. 2.—Christ the Desire of all Nations; or the Unconscious Prophecies of Heathendom.

Fourth Edition. Fcap. 8vo. cloth, 5*s*.

3. Sermons Preached before the University of Cambridge. Fcap. 8vo. cloth, 2*s*. 6*d*.

BY DAVID MASSON, M.A.,

Professor of English Literature in University College, London.

1. Life of John Milton, narrated in connexion with the Political, Ecclesiastical, and Literary History of his Time. VOL. I. 8vo. With Portraits. 18*s.*

"*Mr. Masson's Life of Milton has many sterling merits . . . his industry is immense; his zeal unflagging; his special knowledge of Milton's life and times extraordinary . . . . with a zeal and industry which we cannot sufficiently commend, he has not only availed himself of the biographical stores collected by his predecessors, but imparted to them an aspect of novelty by his skilful re-arrangement.*"—EDINBURGH REVIEW. *April*, 1860.

2. British Novelists and their Styles: Being a Critical Sketch of the History of British Prose Fiction. Crown 8vo. cloth, 7*s.* 6*d.*

"*A work eminently calculated to win popularity, both by the soundness of its doctrine and the skill of its art.*"—THE PRESS.

3. Essays, Biographical and Critical: chiefly on English Poets. 8vo. cloth, 12*s.* 6*d.*

CONTENTS.

I. Shakespeare and Goethe.—II. Milton's Youth.—III. The Three Devils: Luther's, Milton's, and Goethe's.—IV. Dryden, and the Literature of the Restoration.—V. Dean Swift.—VI. Chatterton: a Story of the Year 1770.—VII. Wordsworth.—VIII. Scottish Influence on British Literature.—IX. Theories of Poetry.—X. Prose and Verse: De Quincey.

"*Distinguished by a remarkable power of analysis, a clear statement of the actual facts on which speculation is based, and an appropriate beauty of language. These Essays should be popular with serious men.*"—THE ATHENÆUM.

THE ILIAD OF HOMER.

TRANSLATED INTO ENGLISH VERSE.

By I. C. WRIGHT, M.A., Translator of "Dante," late Fellow of Magdalen College, Oxford. Books I.—VI. Crown 8vo. 5*s.*

"*We know of no edition of the 'sovran poet' from which an English reader can derive on the whole so complete an impression of the immortal Epos.*"—DAILY NEWS.

THE WORKS OF

FREDERICK DENISON MAURICE, M.A.,

Incumbent of St. Peter's, St. Marylebone.

What is Revelation? With Letters on Mr. Mansel's Bampton Lectures. 10*s*. 6*d*.

Sequel to the Inquiry, "What is Revelation?" With Letters on Mr. Mansel's Strictures. 6*s*.

Exposition of the Holy Scriptures:
- (1.) The Patriarchs and Lawgivers. 6*s*.
- (2.) The Prophets and Kings. 10*s*. 6*d*.
- (3.) The Gospel of St. John. 10*s*. 6*d*.
- (4.) The Epistles of St. John. 7*s*. 6*d*.

Exposition of the Ordinary Services of the Prayer Book: 5*s*. 6*d*.

Ecclesiastical History. 10*s*. 6*d*.

The Doctrine of Sacrifice. 7*s*. 6*d*.

Theological Essays. Second Edition. 10*s*. 6*d*.

The Religions of the World. Third Edition. 5*s*.

Learning and Working. 5*s*.

The Indian Crisis. Five Sermons. 2*s*. 6*d*.

The Sabbath, and other Sermons. 2*s*. 6*d*.

Law on the Fable of the Bees. 4*s*. 6*d*.

The Worship of the Church. A Witness for the Redemption of the World. 1*s*.

The Word "Eternal" and the Punishment of the Wicked. Third Edition. 1*s*.

The Name Protestant, and the English Bishopric at Jerusalem. Second Edition. 3*s*.

The Duty of a Protestant in the Oxford Election. 1847. 1*s*.

The Case of Queen's College, London. 1*s*. 6*d*.

Death and Life. In Memoriam C.B.M. 1*s*.

Administrative Reform. 3*d*.

MANUALS FOR THEOLOGICAL STUDENTS,

UNIFORMLY PRINTED AND BOUND.

This Series of Theological Manuals has been published with the aim of supplying books concise, comprehensive, and accurate, convenient for the Student and yet interesting to the general reader.

I.

Introduction to the Study of the Gospels. By BROOKE FOSS WESTCOTT, M.A. formerly Fellow of Trinity College, Cambridge. Crown 8vo. cloth, 10*s*. 6*d*.

"*The worth of Mr. Westcott's volume for the spiritual interpretation of the Gospels is greater than we can readily express even by the most grateful and approving words. It presents with an unparalleled completeness—the characteristic of the book everywhere being this completeness—wholeness of view, comprehensiveness of representation, the fruits of sacred learning.*"—NONCONFORMIST.

II.

A General View of the History of the Canon of the New Testament during the FIRST FOUR CENTURIES. By BROOKE FOSS WESTCOTT, M.A.

Crown 8vo. cloth, 12*s*. 6*d*.

The Author is one of those who are teaching us that it is possible to rifle the storehouses of German theology, without bearing away the taint of their atmosphere: and to recognise the value of their accumulated treasures, and even track the vagaries of their theoretic ingenuity, without abandoning in the pursuit the clear sight and sound feeling of English common sense . . . . It is by far the best and most complete book of the kind; and we should be glad to see it well placed on the lists of our examining chaplains."—GUARDIAN.

"*Learned, dispassionate, discriminating, worthy of his subject, and the present state of Christian Literature in relation to it.*"—BRITISH QUARTERLY.

"*To the student in Theology it will prove an admirable Text-Book: and to all others who have any curiosity on the subject it will be satisfactory as one of the most useful and instructive pieces of history which the records of the Church supply.*"—LONDON QUARTERLY.

THEOLOGICAL MANUALS—continued.

III.

History of the Christian Church, during the Middle Ages and the Reformation (A.D. 590–1600).

By the Venerable CHARLES HARDWICK, Archdeacon of Ely.

2 vols. crown 8vo. 10*s*. 6*d*. each.

Vol. I. History of the Church to the Excommunication of Luther. With Four Maps.

Vol. II. History of the Reformation.

Each Volume may be had separately.

"*Full in references and authority, systematic and formal in division, with enough of life in the style to counteract the dryness inseparable from its brevity, and exhibiting the results rather than the principles of investigation.* MR. HARDWICK *is to be congratulated on the successful achievement of a difficult task.*" —CHRISTIAN REMEMBRANCER.

"*He has bestowed patient and extensive reading on the collection of his materials; he has selected them with judgment; and he presents them in an equable and compact style.*"—SPECTATOR.

"*To a good method and good materials* MR. HARDWICK *adds that great virtue, a perfectly transparent style. We did not expect to find great literary qualities in such a manual, but we* have *found them; we should be satisfied in this respect with conciseness and intelligibility; but while this book has both, it is also elegant, highly finished, and highly interesting.*"—NONCONFORMIST.

IV.

History of the Book of Common Prayer,

together with a Rationale of the several Offices. By FRANCIS PROCTER, M.A., Vicar of Witton, Norfolk, formerly Fellow of St. Catharine's College, Cambridge. Fourth Edition, revised and enlarged. Crown 8vo. cloth, 10*s*. 6*d*.

"MR. PROCTER'S 'History of the Book of Common Prayer' *is by far the best commentary extant . . . . . . Not only do the present illustrations embrace the whole range of original sources indicated by* MR. PALMER, *but* MR. PROCTER *compares the present Book of Common Prayer with the Scotch and American forms; and he frequently sets out in full the Sarum Offices. As a manual of extensive information, historical and ritual, imbued with sound Church principles, we are entirely satisfied with* MR. PROCTER'S *important volume.*"

CHRISTIAN REMEMBRANCER.

"*It is indeed a complete and fairly-written history of the Liturgy; and from the dispassionate way in which disputed points are touched on, will prove to many troubled consciences what ought to be known to them, viz.:—that they may, without fear of compromising the principles of evangelical truth, give their assent and consent to the contents of the Book of Common Prayer.* MR. PROCTER *has done a great service to the Church by this admirable digest.*"

CHURCH OF ENGLAND QUARTERLY.

MR. CORNWALL SIMEON'S

Stray Notes on Fishing and Natural History, With Illustrations. 7*s*. 6*d*.

"*Written in a hearty and sportsmanlike spirit, breathing freshly of the river side and abounding in quaint and piquant anecdote . . . . sound practical information, at once profitable to the tyro and entertaining to the proficient.*" —LITERARY GAZETTE.

"*As pleasant a volume of its kind as any that has appeared since 'White's History of Selborne.*"—JOHN BULL.

"*Excellent and thoroughly practical, just what the amateur needs.*"—ERA.

"*If this remarkably agreeable work does not rival in popularity the celebrated 'White's Selborne,' it will not be because it does not deserve it . . . the mind is almost satiated with a repletion of strange facts and good things.*"—FIELD, July 28, 1860.

"*What is to be said is said briefly and well . . . one of the most sensible and amusing of a class of books welcome always.*"—EXAMINER, Sept. 8, 1860.

MR. WESTLAND MARSTON'S NOVEL

"A Lady in Her Own Right." 10*s*. 6*d*.

"*A perfect masterpiece of chaste and delicate conception, couched in spirited and eloquent language, abounding in poetical fancies. . . . Seldom have we met with anything more beautiful, perfect, or fascinating than the heroine of this work.*" LEADER.

Artist and Craftsman. A Novel. 10*s*. 6*d*.

"*There are many beauties which we might have pointed out, but we prefer counselling our readers to read the book and discover for themselves.*"—LITERARY GAZETTE.

Blanche Lisle, and other Poems. By CECIL HOME. 4*s*. 6*d*.

"*The writer has music and meaning in his lines and stanzas, which, in the selection of diction and gracefulness of cadence, have seldom been excelled.*"—LEADER, June 2, 1860.

"*Far above most of the fugitive poetry which it is our lot to review . . . full of a true poet's imagination.*"—JOHN BULL.

MACMILLAN AND CO.'S

Class Books for Colleges and Schools.

I. ARITHMETIC AND ALGEBRA.

Arithmetic. For the use of Schools. By BARNARD SMITH, M.A. New Edition (1860). 348 pp. Answers to all the Questions. Crown 8vo. 4*s*. 6*d*.

Key to the above. Crown 8vo. 8*s*. 6*d*. Second Edition thoroughly Revised. [*In the Press.*

Arithmetic and Algebra in their Principles and Applications. With numerous Examples, systematically arranged. By BARNARD SMITH, M.A. Seventh Edition (1860), 696 pp. Crown 8vo. 10*s*. 6*d*.

Exercises in Arithmetic. By BARNARD SMITH, M.A. Part I. 48 pp. (1860). Crown 8vo. 1*s*. [Part II. *Nearly ready.*

Arithmetic in Theory and Practice. For Advanced Pupils. By J. BROOK SMITH, M.A. Part First. 164 pp. (1860). Crown 8vo. 3*s*. 6*d*.

A Short Manual of Arithmetic. By C. W. UNDERWOOD, M.A. 96 pp. (1860). Fcp. 8vo. 2*s*. 6*d*.

Algebra. For the use of Colleges and Schools. By I. TODHUNTER, M.A. Second Edition. Crown 8vo. 516 pp. (1860). 7*s*. 6*d*.

II. TRIGONOMETRY.

Introduction to Plane Trigonometry. For the use of Schools. By J. C. SNOWBALL, M.A. Second Edition (1847). 8vo. 5*s*.

Plane Trigonometry. For Schools and Colleges. By I. TODHUNTER, M.A. 272 pp. (1859). Crown 8vo. 5*s*.

Spherical Trigonometry. For Colleges and Schools. By I. TODHUNTER, M.A. 112 pp. (1859). Crown 8vo. 4*s*. 6*d*.

Plane Trigonometry. With a numerous Collection of Examples. By R. D. BEASLEY, M.A. 106 pp. (1858). Crown 8vo. 3*s*. 6*d*.

Plane and Spherical Trigonometry. With the Construction and Use of Tables of Logarithms. By J. C. SNOWBALL, M.A. Ninth Edition, 240 pp. (1857). Crown 8vo. 7*s*. 6*d*.

III. MECHANICS AND HYDROSTATICS.

Elementary Treatise on Mechanics. With a Collection of Examples. By S. PARKINSON, B.D. Second Edition. [*In the Press.*

Elementary Course of Mechanics and Hydrostatics. By J. C. SNOWBALL, M.A. Fourth Edition. 110 pp. (1851). Crown 8vo. 5*s*.

MECHANICS AND HYDROSTATICS—*continued.*

Elementary Hydrostatics. With numerous Examples and Solutions. By J. B. PHEAR, M.A. Second Edition. 156 pp. (1857). Crown 8vo. 5*s.* 6*d.*

Analytical Statics. With numerous Examples. By I. TODHUNTER, M.A. Second Edition. 330 pp. (1858). Crown 8vo. 10*s.* 6*d.*

Dynamics of a Particle. With numerous Examples. By P. G. TAIT, M.A. and W. J. STEELE, M.A. 304 pp. (1856). Crown 8vo. 10*s.* 6*d.*

A Treatise on Dynamics. By W. P. WILSON, M.A. 176 pp. (1850). 8vo. 9*s.* 6*d.*

IV. ASTRONOMY AND OPTICS.

Plane Astronomy. Including Explanations of Celestial Phenomena and Instruments. By A. R. GRANT, M.A. 128 pp. (1850). 8vo. 6*s.*

Elementary Treatise on the Lunar Theory. By H. GODFRAY, M.A. Second Edition. 119 pp. (1859). Crown 8vo. 5*s.* 6*d.*

A Treatise on Optics. By S. PARKINSON, B.D. 304 pp. (1859). Crown 8vo. 10*s.* 6*d.*

V. GEOMETRY AND CONIC SECTIONS.

Geometrical Treatise on Conic Sections. With a Collection of Examples. By W. H. DREW, M.A. 121 pp. (1857). 4*s.* 6*d.*

Plane Co-ordinate Geometry as applied to the Straight Line and the Conic Sections. By I. TODHUNTER, M.A. Second Edition. 316 pp. (1858). Crown 8vo. 10*s.* 6*d.*

Elementary Treatise on Conic Sections and Algebraic Geometry. By G. H. PUCKLE, M.A. Second Edition. 264 pp. (1856). Crown 8vo. 7*s.* 6*d.*

Examples of Analytical Geometry of Three Dimensions. With the Results. Collected by I. TODHUNTÈR, M.A. 76 pp. (1858). Crown 8vo. 4*s.*

VI. DIFFERENTIAL AND INTEGRAL CALCULUS.

The Differential Calculus. With numerous Examples. By I. TODHUNTER, M.A. Third Edition. 404 pp. (1860). Crown 8vo. 10*s.* 6*d.*

The Integral Calculus, and its Applications. With numerous Examples. By I. TODHUNTER, M.A. 268 pp. (1857). Crown 8vo. 10*s.* 6*d.*

A Treatise on Differential Equations. By GEORGE BOOLE, D.C.L. 486 pp. (1859). Crown 8vo. 14*s.*

A Treatise on the Calculus of Finite Differences. By GEORGE BOOLE, D.C.L. 248 pp. (1840). Crown 8vo. 10*s.* 6*d.*

VII. PROBLEMS AND EXAMPLES.

A Collection of Mathematical Problems and Examples. With Answers. By H. A. Morgan, M.A. 190 pp. (1858). Crown 8vo. *6s. 6d.*

Senate-House Mathematical Problems. With Solutions—

1848-51. By FERRERS and JACKSON. 8vo. *15s. 6d.*
1848-51. (Riders.) By JAMESON. 8vo. *7s. 6d.*
1854. By WALTON and MACKENZIE. 8vo. *10s. 6d.*
1857. By CAMPION and WALTON. 8vo. *8s. 6d.*
1860. By ROUTH and WATSON. Crown 8vo. *7s. 6d.*

VIII. LATIN.

Help to Latin Grammar; or, the Form and Use of Words in Latin. With Progressive Exercises. By Josiah Wright, M.A. 175 pp. (1855). Crown 8vo. *4s. 6d.*

The Seven Kings of Rome. A First Latin Reading Book. By Josiah Wright, M.A. Second Edition. 138 pp. (1857). Fcap. 8vo. *3s.*

Vocabulary and Exercises on "The Seven Kings." By Josiah Wright, M.A. 94 pp. (1857). Fcap. 8vo. *2s. 6d.*

A First Latin Construing Book. By E. Thring, M.A. 104 pp. (1855). Fcap. 8vo. *2s. 6d.*

Rules for the Quantity of Syllables in Latin. 10 pp. (1858). Crown 8vo. *1s.*

Theory of Conditional Sentences in Latin and Greek. By R. Horton Smith, M.A. 30 pp. (1859). 8vo. *2s. 6d.*

Sallust.—Catilina and Jugurtha. With English Notes. For Schools. By Charles Merivale, B.D. Second Edition, 172 pp. (1858). Fcap. 8vo. *4s. 6d.*

Catilina and Jugurtha may be had separately, price *2s. 6d.* each.

Juvenal. For Schools. With English Notes and an Index. By J. E. Mayor, M.A. 464 pp. (1853). Crown 8vo. *10s. 6d.*

IX. GREEK.

Hellenica; a First Greek Reading Book. Being a History of Greece, taken from Diodorus and Thucydides. By Josiah Wright, M.A. Second Edition. 150 pp. (1857). Fcap. 8vo. *3s. 6d.*

Demosthenes on the Crown. With English Notes. By B. Drake, M.A. Second Edition, to which is prefixed Æschines against Ctesiphon. With English Notes. (1860). Fcap. 8vo *5s.*

Demosthenes on the Crown. Translated by J. P. Norris, M.A. (1850). Crown 8vo. *3s.*

GREEK—*continued.*

Thucydides. Book VI. With English Notes and an Index. By P. FROST, Jun. M.A. 110 pp. (1854). 8vo. 7*s.* 6*d.*

Æschylus. The Eumenides. With English Notes and Translation. By B. DRAKE, M.A. 144 pp. (1853). 8vo. 7*s.* 6*d.*

St. Paul's Epistle to the Romans: With Notes. By CHARLES JOHN VAUGHAN, D.D. 157 pp. (1859). 8vo. 7*s.* 6*d.*

X. ENGLISH GRAMMAR.

The Child's English Grammar. By E. THRING, M.A. Demy 18mo. New Edition. (1857). 1*s.*

Elements of Grammar taught in English. By E. THRING, M.A. Third Edition. 136 pp. (1860). Demy 18mo. 2*s.*

Materials for a Grammar of the Modern English Language. By G. H. PARMINTER, M.A. 220 pp. (1856). Fcap. 8vo. 3*s.* 6*d.*

XI. RELIGIOUS.

History of the Christian Church during the Middle Ages. By ARCHDEACON HARDWICK. 482 pp. (1853). With Maps. Crown 8vo. cloth. 10*s.* 6*d.*

History of the Christian Church during the Reformation. By ARCHDEACON HARDWICK. 459 pp. (1850). Crown 8vo. cloth. 10*s.* 6*d.*

History of the Book of Common Prayer. By FRANCIS PROCTER, M.A. 464 pp. (1860). Fourth Edition. Crown 8vo. cloth. 10*s.* 6*d.*

History of the Canon of the New Testament during the First Four Centuries. By BROOK FOSS WESTCOTT, M.A. 594 pp. (1855). Crown 8vo. cloth. 12*s.* 6*d.*

Introduction to the Study of the Gospels. By BROOKE FOSS WESTCOTT, M.A. (1860). Crown 8vo. cloth. 10*s.* 6*d.*

The Church Catechism Illustrated and Explained. By ARTHUR RAMSAY, M.A. 204 pp. (1854). 18mo. cloth. 3*s.* 6*d.*

Notes for Lectures on Confirmation: With Suitable Prayers. By C. J. VAUGHAN, D.D. Third Edition. 70 pp. (1859). Fcap. 8vo. 1*s.* 6*d.*

Hand-Book to Butler's Analogy. By C. A. SWAINSON, M.A. 55 pp. (1856). Crown 8vo. 1*s.* 6*d.*

History of the Christian Church during the First Three Centuries, and the Reformation in England. By WILLIAM SIMPSON, M.A. 307 pp. (1857). Fcap. 8vo. cloth. 5*s.*

Analysis of Paley's Evidences of Christianity. By CHARLES H. CROSSE, M.A. 115 pp. (1855). 18mo. 3*s.* 6*d.*

ANNOUNCEMENTS.

I.

On the Origin and Succession of Life on the Earth. By JOHN PHILLIPS, M.A. F.R.S. F.G.S., Reader in Geology in the University of Oxford, and Rede Lecturer in the University of Cambridge, &c. With Illustrations. Crown 8vo.

II.

Life of Edward Forbes, THE NATURALIST. By GEORGE WILSON, M.D., late Professor of Technology in the University of Edinburgh, and ARCHIBALD GEIKIE, F.G.S., of the Geological Survey.

III.

Introduction to the Study and Use of the Psalms. By the Rev. J. F. THRUPP, Author of "An Investigation into the Topography, &c. of Ancient Jerusalem," &c. 2 vols. 8vo.

IV.

Rays of Sunlight for Dark Days: A Book of Selections for the Suffering. Royal 32mo. elegantly printed,

V.

An Elementary Treatise on Quaternions. With numerous Examples. By P. G. TAIT, M.A., Professor of Natural Philosophy in the University of Edinburgh.

VI.

A Treatise on the Dynamics of a Rigid Body. By E. J. ROUTH, M.A., and C. A. SMITH, B.A., Fellows of St. Peter's College, Cambridge.

VII.

A Treatise on Geometry of Three Dimensions. By PERCIVAL FROST, M.A., St. John's College, and JOSEPH WOLSTENHOLME, M.A., Christ's College, Cambridge.

VIII.

An Elementary Treatise on Statics. By GEORGE RAWLINSON, M.A., late Professor of Natural Philosophy in Elphinstone Institution, Bombay, formerly of Emmanuel College, Cambridge.

IX.

A Treatise on Trilinear Co-ordinates. By N. M. FERRERS, M.A., Fellow and Mathematical Lecturer of Gonville and Caius College.

R. CLAY, PRINTER, BREAD STREET HILL.

k