more distinct the details very faintly shown in the original. To the anatomist every bone or fragment of a bone is recognisable; while the unmistakable feathers, and the foot with the increasing number of joints from the inner to the outer toe, are sufficient to show that it is a true bird, notwithstanding its curiously elongated tail feathered on each side. In this specimen there is no sign of the head; but fortunately another specimen has recently been found, in which the skull is well preserved, and which shows that the beak was armed with teeth (Fig. 71). Later on, in the Cretaceous formation of Kansas, U.S.A., some well-preserved aquatic birds have been found. One is of large size (about 4 feet high), something like a diver, but with flat breast-bone, and therefore probably with rudimentary wings; another, much smaller, has long wing-bones and a deeply keeled sternum. The bony tail of these is not much longer than in living birds, but in both the beaks are toothed.

The main reason for the extreme rarity of bird-remains in the Mesozoic era is, that being so light in body and plumage they could very rarely be preserved. Those that died in or on the margins of rivers or lakes, or which fell into the water, would be at once devoured by the fishes or the aquatic or aerial reptiles which seem to have swarmed everywhere.

Concluding Remarks on Mesozoic Life-Development

The remarkable series of facts which have now been summarised, and which have been largely due to researches in North America, South Africa, and Europe during the last twenty or thirty years, are of such a nature that they seem to call for some cosmical explanation similar to that suggested to account for the vast development of cryptogamous vegetation towards the close of the Palæozoic era. The facts
are in many respects strikingly parallel. We find in the Carboniferous series of rocks a storing-up of vast masses of vegetable matter in the form of coal, which is unique in the whole past history of the earth, and this was at a time when the only land vertebrates were archaic forms of amphibians. Almost immediately after the deposit was completed true reptiles appeared all over the earth, and rapidly developed into that "Age of Reptiles" which is perhaps the greatest marvel of geological history. Birds and Mammalia also started into life, apparently branching off from some common stock with the reptiles. Then, during that blank in the record separating the Secondary from the Tertiary era, the whole of this vast teeming mass of reptilian life totally disappeared, with the two exceptions of the crocodiles and the tortoises, which have continued to maintain themselves till our own day, while true lizards and snakes, which are not known in earlier times, became the predominant forms of reptilian life. It was during the same blank period of the geological record that mammals and birds sprang into vigorous and diversified life, just as the reptiles had done during the blank between the Primary and Secondary eras. To complete the great series of life-changes (perhaps as a necessary preparation for them), plants underwent a similar transformation; the prominent Cryptogams, Conifers, and Cycads of the Secondary era gave way towards its close to higher flowering plants, which thenceforth took the first place, and now form probably fully 99 per cent of the whole mass of vegetation, with a variety of nourishing products, in foliage, fruit, and flower, never before available.

Now here we have a tremendous series of special developments of life-forms simultaneous in all parts of the earth, affecting both plants and animals, insects and vertebrates, whether living on land, in the water, or in the air, all contemporaneous in a general sense, and all determining the transition from a lower to a very much higher grade of organisation. Just as in the first such great step in advance from the "age of fishes" to the "age of reptiles" we see reason to connect it with the change from a more carbonised to a more oxygenated atmosphere, produced by the locking up of so much carbon in the great coal-fields of the world;
So, I think, the next great advance was due to a continuation of the same process by a different agency. Geologists have often remarked on the progressive increase in the proportion of limestone in the later than in the earlier formations. In our own country we see a remarkable abundance of limestone during the Secondary era, as shown in our Lias, Oolites, Portland stone, and Chalk rocks; and somewhat similar conditions seem to have prevailed in Europe, and to a less extent in North America. As limestone is generally a carbonate of lime, it locks up a considerable amount of carbon which might otherwise increase the quantity of carbonic acid in the atmosphere; and as lime, or its metallic base, calcium, must have formed a considerable portion of the original matter of the earth, solid or gaseous, the continued formation of limestone through combination with the carbonic acid of the atmosphere must have led to the constant diminution of that gas in the same way that the formation of coal reduced it.

It seems probable that when the earth's surface was in a greatly heated condition, and no land vegetation existed, the atmosphere contained a much larger proportion of carbon dioxide than at present, and that a continuous reduction of the amount has been going on, mainly through the extraction of carbon from the air by plants and from the water by marine animals and by chemical action. The superabundance of this gas during the early stages of the life-world facilitated the process of clothing the land with vegetation soon after it appeared above the waters; while its absorption by water was equally useful in rendering possible the growth of the calcareous framework or solid covering of so many marine animals.

With the progressive cooling of the earth and the increased area of land-surface, more and more of the atmospheric carbon became solidified and inactive, thus rendering both the air and the water better fitted for the purposes of the higher, warm-blooded, and more active forms of life. This process will, I think, enable us partially to understand the fundamental changes in life-development which characterised the three great geological areas; but it does not seem sufficient to explain the very sudden and complete changes
that occurred, and, more especially, the almost total extinc-
tion of the lower or earlier types just when they appear to
have reached their highest and most varied structure,
their greatest size of body, and their almost world-wide
distribution. Before attempting a solution of this difficult
problem an outline must be given of the latest, and in some
respects the most interesting, of the geological eras—the
Tertiary, or, as more frequently termed by geologists, the
Cainozoic.
Fig. 72.—Skeleton of *Phenacodus primavus*.

From the Lower Eocene of Wyoming, U.S.A. Body about 4 feet long. (P.M. Gyrle.)
The most primitive known ungulate mammal.
CHAPTER XII

LIFE OF THE TERTIARY PERIOD

Directly we pass from the Cretaceous into the lowest of the Tertiary deposits—the Eocene—we seem to be in a new world of life. Not only have the whole of the gigantic Dinosaurs and the accompanying swimming and flying reptiles totally disappeared, but they are replaced in every part of the world by Mammalia, which already exhibit indications of being the ancestors of hoofed animals, of Carnivora, and of Quadrupedal.

Order—Ungulata

In the Lower Eocene strata of North America and Europe, the sub-order Condylarthra is well represented. These were primitive, five-toed, hoofed animals which, Dr. A. Smith Woodward tells us, "might serve well for the ancestors of all later Ungulata." One of these, Phenacodus primum, was found in the Lower Eocene of Wyoming, U.S.A., and was about 4 feet long exclusive of the tail (see Fig. 72). Considering that this is one of the very earliest Tertiary mammals yet discovered, it is interesting to note its comparatively large size, its graceful form, its almost full series of teeth, and its large five-toed feet; affording the starting-point for diverging modification into several of the chief types of the higher mammalia. So perfectly organised an animal could only have been one of a long series of forms bridging over the great gulf between it and the small rat-like mammals of the Mesozoic period.

Another sub-order is the Amblypoda, of which the Coryphodon of Europe and North America is one of the best known. This was about 6 feet long, and was first
obtained from our London Clay. It had a heavy body, five-toed stumpy feet, and a complete set of 22 teeth in each jaw adapted for a vegetable diet; but no defensive tusks or horns. Other allied species were much smaller, and all were remarkable for a very small brain.

But a little later, in the Middle Eocene of North America, they developed into the most wonderful monsters that have ever lived upon the earth—the Dinocerata or “terrible-horned” beasts. These had greatly increased in size; they often had large tusks in the upper jaw; and horns of varied forms and sizes were developed on their heads. The tusks were sometimes protected by a bony flange projecting downwards from the lower jaw immediately behind it, as well shown in the figure here given of *Uintatherium ingens*. This animal must have been about 11 feet long and nearly 7 feet high; and if the six protuberances of the skull carried horns like our rhinoceroses, it must, indeed, have been a “terrible” beast. The imperfect skull of another species (Fig. 74) shows even larger the bony horncores presenting all the appearance of having carried some

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**Fig. 73.**—*Uintatherium ingens.*

kind of horns. This seems the more probable, as many of the species had no tusks, and in that case mere rounded bony protuberances would have been of little protective use. Figure 75 (on p. 222) represents the skeleton of one of the largest species without tusks. From the scale given, it must have been 11 or 12 feet long and nearly 8 feet high.

Professor Marsh informs us that these strange-horned animals have been found only in one Eocene lake-basin, in Wyoming, U.S.A. He says:

"These gigantic beasts, which nearly equalled the elephant in size, roamed in great numbers about the borders of the ancient tropical lake in which many of them were entombed. This lake-basin, now drained by the Green River, the main tributary of the Colorado, slowly filled up with sediment, but remained a lake so long that the deposits formed in it during Eocene time reached a vertical thickness of more than a mile. . . . At the present time this ancient lake-basin, now 6000 to 8000 feet above the sea, shows
evidence of a vast erosion, and probably more than one-half of the deposits once left in it have been washed away, mainly by the action of the Colorado River. What remains forms one of the most picturesque regions in the whole West, veritable *mauvaises*
terres, or bad lands, where slow denudation has carved out cliffs, peaks, and columns of the most fantastic shapes and colours. This same action has brought to light the remains of many extinct animals, and the bones of the Dinocerata, from their great size, naturally first attract the attention of the explorer.

As regards the mental powers of these strange animals, Professor Marsh says:

"The brain-cavity of Uintatherium is perhaps the most remarkable feature in this remarkable genus. It shows us that the brain was proportionately smaller than in any other known mammal, recent or fossil, and even less than in some reptiles. It is, in fact, the most reptilian brain in any known mammal. In *U. mirabile* (one of the large-tusked, horned species) it could apparently have been drawn through the neural canal of all the presacral vertebrae."
An equally strange monster has been found in Egypt, and forms a new sub-order, Barypoda. It is known from a very complete skull (Fig. 76, p. 223), which is remarkable for the very regular set of teeth, as well as for the wonderful horn-cores, two small at the back and two enormous ones projecting in front. The skull is nearly 3 feet long, and the larger horn-cores about 2½ feet; and as these certainly carried true horns they probably surpassed any of the Dinocerata. Large quantities of detached bones have also been obtained, sufficient to show that the creature was an ungulate of elephantine dimensions and altogether unique in appearance.

Order—Carnivora

These can also be traced back to middle or late Eocene times both in North America and Europe. They were moderate-sized animals, forming a distinct sub-order, Creodonta, the skeleton of one of which is shown in Fig. 77. They had flesh-eating teeth, but more like those of the carnivorous marsupials of Australia than of our living carnivores, with a type of skeleton showing considerable lightness and activity. Some of the species were as large as lions.

Some of the older remains in South America, called Sparassodonta, are believed to belong to the same or an allied sub-order. They occur in beds of Lower Miocene age in Patagonia; and Mr. Lydekker holds them to be "undoubtedly marsupials," allied to the Dasyuridæ of Australia. One of these has been named Prothylacinus, from the resemblance of its jaw to that of the Tasmanian wolf (Thylacinus australis). Other small species forming a distinct family, Microbiotheridæ, he also thinks were probably "minute polypodont marsupials of Australian type." ¹

¹ Geog. Hist. of Mammals, pp. 111-112. From these facts and others referred to in my preceding chapter, Mr. Lydekker thinks that "it is difficult to come to any other conclusion than that the ancestors of the Santa Crucian polypodont marsupials reached the country either by way of the Antarctic continent or by a land-bridge in a more northern part of the Pacific." To avoid a break of connection in the present exposition, I have briefly stated some of the difficulties in the way of such a theory in an Appendix to this chapter. The whole subject of the "Permanence of Oceanic and Continental Areas" is more fully discussed in my volumes on Darwinism and Island Life.
In the later (upper) beds of the Eocene formation and the Early or Middle Miocene, ancestral forms of many of our Mammalia have been found both in Europe and North America; but these are so numerous, and their affinities in some cases so obscure, that only a few of the prominent examples need be given. One of these, whose skeleton is
figured below (Fig. 78), belongs to the family Anthracotheriidae,

which has affinities with the pigs and the hippopotami, of which it seems to be an ancestral form. The fossil remains
Fig. 79. *Anoplotherium commun.*

Upper Eocene (Paris; also at Binstead, Isle of Wight). (From Nicholson’s Palaeontology.)

This animal was about the size of an ass, and was especially remarkable for its continuous set of 44 teeth, there being no gap in the series. No living mammal except man has this characteristic. It is supposed to have been a highly specialised early type which has left no direct descendants.

Fig. 80.—*Palaeotherium magnum.*

From the Upper Eocene of Paris and the Isle of Wight. (Nicholson’s Palaeontology.)

The numerous species of Palaeotherium were three-toed animals having resemblances to horses, tapirs, and llamas. The species here figured (as restored by Cuvier) was about the size of a horse, but it is now known that the neck was considerably longer than here shown.
of this group are found in deposits of Middle Tertiary age all over the northern hemisphere. They have two, three, or four separate toes, and teeth much like those of swine.

Another family, the Anoplotheridae, contains a variety of animals which seem to be ancestral forms of the ruminants. The genus Anoplotherium (Fig. 79) was one of the most remarkable of these in having a full and continuous set of teeth without any gaps, like that of the Arsinoitherium already figured.

An allied family, Oreoodontidae, somewhat nearer to ruminants, but with four-toed feet, were very abundant in North America in Miocene times. They were remotely allied to deer and camels, and were called by Dr. Leidy "ruminating hogs." They seem to have occupied the place of all these animals, six genera and over twenty species having been described, some of which survived till the early Pliocene.

The family Palæotheridae was also abundant during the same period in Europe, and less so in North America. As shown in the restoration in Fig. 80, it somewhat resembled the tapir; but other genera are more like horses, and show a series of gradations in the feet towards those of the horse-tribe, as shown by Huxley's figures reproduced in my Darwinism.

The Origin of Elephants

Till quite recently one of the unsolved problems of palæontology was how to explain the development of the Proboscidea or elephant tribe from other hoofed animals. Hitherto extinct species of these huge beasts had been found in a fossil state as far back as the Miocene (or Middle Tertiary) in various parts of Europe, Asia, and North America; one species, the mammoth, being found ice-preserved in Arctic Siberia in great quantities. Some of these were somewhat larger than existing elephants, and several had enormously large or strangely curved tusks; but, with the exception of Dinotherium, which had the lower jaw and tusks bent downwards, and Tetrabelodon, with elongated jaws and nearly straight tusks, none were very different from the living types and gave no clue to their
line of descent. But less than ten years ago a number of fossils have been obtained from the Middle and Higher Eocene beds of the Fayoum district of Egypt, which give the long-hoped-for missing link connecting the elephants with other ungulates.

The most primitive form now discovered was about the size of a very large dog, and its skull does not differ very strikingly from those of other primitive ungulates. It has, however, some slight peculiarities which show a connection with the Proboscidea. These are that the nasal opening is near the end of the snout, indicating, probably, the rudiment of a proboscis; the back of the skull is also thickened and contains small air-chambers, the first step towards the very large air-chambers of the elephant's skull, whose purpose is to afford sufficient surface for the powerful muscles which support the weight of the tusks and trunk. The teeth show two short tusks in front in the upper jaw in the same position as the tusks of elephants, while the lower jaw or chin is lengthened out and has two incisor teeth projecting forward. The molar teeth show the beginning of the special characters which distinguish the huge grinding teeth of the elephants. This creature was named *Mæritherium lyonsi*; and its remains have been found in great abundance along with those of both land and sea animals, showing that they were deposited in what was then the estuary of the Nile, though now far inland.

Somewhat later, in the Upper Eocene, another group of animals, the Palæomastodons, have been found, showing a considerable advance (see Diagram, Fig. 82). They vary in size from a little larger than the preceding to that of a small elephant. The skull is very much modified in the direction
of some of the later forms. After these come the Tetrap-
belodons from the Miocene beds of France and North

Recent

Pleistocene

ELEPHAS

(short chin)

Upper Pliocene

Lower Pliocene

TETRABELODON

[LONGIROSTRIS STAGE]

(shortening chin)

Upper Miocene

Middle Miocene

TETRABELODON

[ANGUSTIDENS STAGE]

(long chin)

Lower Miocene

Upper Oligocene

Migration from Africa

into Europe - Asia

Lower Oligocene?

Upper Eocene

PALAEOmastodon

(lengthening chin)

Middle Eocene

MOERITHERIUM

(short chin)

Lower Eocene

Fig. 82.—Diagrams showing increase of size and alteration in

form of skull and teeth of the Proboscidea since Eocene

time. (B.M. Guide.)
America, and the Pliocene of Germany. These were more like elephants in their general form, though their greatly elongated lower jaws, bearing incisor teeth, seem to be developing in another direction. In Tetrabelodon longirostris, however, we see the lower jaw shortened and the incisor teeth greatly reduced in size; thus leading on to the true elephants, in which these teeth disappear.

The skeleton of Tetrabelodon angustidens (Fig. 83) shows the lower tusks shorter than the uppers, but in the specimen mounted in the Paris Museum, and photographed in Sir Ray Lankester’s Extinct Animals, both are of the same length, and the upper pair curve slightly downwards on each side of the lower pair; and they are thus shown in the suggested appearance of the living animal, here reproduced from his book. (Fig. 84.) The trunk could not therefore have hung down as in the modern elephants, and it seems hardly likely that with such tusks a trunk would have been developed. If a short one had been formed it would probably have been for the purpose of drinking and for pushing food into the mouth sideways. It is most interesting to see how the difficulty was overcome. In the next stage both pairs of tusks have become straightened out, the lower ones much reduced in length and the chin also somewhat shortened. That this process went on step by step is indicated by the Mastodons, which are elephants with a simpler form of teeth, and a pair of tusks like all living and recently extinct elephants (see Fig. 85). But when very young the American Mastodon had a pair of short tusks in the lower jaw, which soon fell out. In the character of its teeth generally, the Mastodon agrees with Tetrabelodon (which was originally classed as a Mastodon); and there are Indian extinct species which show other stages in the reduction of the lower jaw.

We have here, therefore, a most remarkable and very rare phenomenon, in which we are able to see progressive evolution upon what seems to be a wrong track which, if carried farther, might be disastrous. Usually, in such cases, the too much developed or injuriously developed form simply dies out, and its place is supplied by some lower or less modified species which can be more easily moulded in the
Fig. 83.—Skeleton of *Tetralophon angustidens*.
From the Middle Eocene of Sansain, France. (R. M. Grube.)

Fig. 84.—Probable Appearance of *Tetralophon angustidens*.
(From Sir Ray Lankester's Extinct Animals.)
right direction: But here (owing probably to some exceptionally favourable conditions), after first lengthening both lower jaw and lower tusks to keep pace with the upper ones, a reversal of the process occurs, reducing first the lower tusks, then the lower jaw, till these tusks completely disappeared and the lower jaw was reduced to the most useful dimensions in co-ordination with a greatly lengthened and more powerful trunk. Although

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**Fig. 85.—Skeleton of *Mastodon americanus***

From the Pleistocene of Missouri, U.S.A. Length, 20 feet; height, 9½ feet

(B M. Gudge)

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in this case the gaps are still rather large, there can be no doubt that we have here obtained a view of the line of development of the most remarkable land mammals now living from a small generalised ungulate mammal, as indisputable and as striking as that of the horses from the little five-toed Eohippus of the American Eocene.

It may be here mentioned that the huge American Mastodon has been found in the same deposits with stone arrow-heads, and was undoubtedly hunted by early man;
as was also the huge mammoth whose beautifully curved tusks form its chief distinction from the living Indian elephant (Fig. 86). This species is abundant in the frozen mud at the mouths of the Siberian rivers; and in some cases the whole body is preserved entire, as in an ice-house, and the flesh has been sometimes roasted and eaten by the natives. Remains of skeletons have been found in our own country and over a large part of Northern Europe and Asia; while its portrait has been drawn from life by
Life of Tertiary Period

Prehistoric man, either upon the tusks themselves or upon the flat portions of the horns of reindeer which he hunted for food.

Tertiary Mammals of South America and Australia

No part of the world has so many distinct groups of Mammalia peculiar to it as South America, among which the most remarkable are the sloths and the armadillos; and all of them are found fossil in the middle or late Tertiary or the Pleistocene, from Brazil to Patagonia, and are often represented by strange forms of gigantic size. Some account of these will now be given. Darwin was one of the first collectors of these fossils on his voyage in the Beagle, and during the last twenty or thirty years numerous travellers and residents, especially in Argentina, have more thoroughly explored the deposits of the pampas of various ages. Their great richness and importance may be indicated by the following enumeration of the chief orders of Mammalia represented in them.

Of the Primates (or monkeys), all the remains are of the peculiar American families Cebidae and Hapalidae, with one extinct genus of the former. Bats (the order Chiroptera) are abundant, with several peculiar genera. The Insectivora are very rare in South America, but a fossil has been found supposed to belong to the peculiar West Indian family Solenodontidae. The Carnivora are chiefly represented by fossils of the American family Procyonidae (comprising the raccoons and coati-mundis), of which several extinct genera have been obtained. The hoofed animals (Ungulata), which, from their great abundance in a living state in every part of the world, and their habit of living together in great herds often of many thousands, have been most frequently preserved in a fossil state, are here represented not only by all the chief forms that still inhabit the country, but also by some which are now only found in other continents, as well as by many which are altogether extinct. Among the former the most interesting are true horses of the genus Equus, as well as two peculiar genera of ancestral Equidae, distinct from those so abundant in North America. There are also several ancestral forms of the Llama tribe, one of which,
Macrauchenia patachonica, was as large as a camel; and there are others so distinct as to form a separate family, Proterotheriidae.
Another sub-order, Astrapotheria, were more massive animals, some of which equalled the rhinoceros in size. They consist of two distinct genera, only found in the Patagonian deposits of Mid-Tertiary age.\footnote{A Geographical History of Mammals, R. Lydekker, F.R.S., etc., 1896, p. 81.}

Still more remarkable is another group—the Toxodontia—sometimes exceeding the rhinoceros in bulk, but with teeth which approached those of the Rodentia; of these there are various forms, which are grouped in three distinct families. The skeleton of one of the largest species of this sub-order is shown in Fig. 87. Yet another distinct sub-order, Pyrotheria, which in its teeth somewhat resembled the extinct European Dinotherium, and which had a large pair of tusks in the lower jaw, is found in the earlier Tertiary strata of Santa Cruz in Patagonia. The elephants also had a representative among these strange monsters in the form of a species of Mastodon, a genus also found in North America.

The very numerous and peculiar South American rodents commonly called cavies, including the familiar guinea-pig, are well represented among these fossils, and there are many extinct forms. Most of these are of moderate size, but one, Megamys, said to be allied to the viscachas, is far larger than any living rodent, about equalling an ox in size.

Perhaps more remarkable than any of the preceding are the extinct Edentata which abound in all these deposits. The entire order is peculiar to America, with the exception of the scaly ant-eater of Asia and the aard-vark of South Africa, and there is some doubt whether these last really belong to the same order. The living American edentates comprise three families, generally known as sloths, ant-eaters, and armadillos, each forming a well-marked group and all with a fair number of distinct species. But besides these, two extinct families are known, the Glyptodontidae and the Megatheriidae, the former being giant armadillos, the latter equally gigantic terrestrial sloths. Both of these lived from the Miocene period almost to our own time, and they are especially abundant in Pliocene and Pleistocene deposits. Some of the extinct forms of armadillo were very much larger than any now living; but it is among the Glyptodons, which had a continuous shield over the whole body, that the
largest species occurred, the shell being often 6 or 8 feet long. The skeleton of one of these is represented by Fig. 88. One of the most recent (Daedicus) was 12 feet long.
Fig. 89.—**Probable Appearance of the Giant Ground-Sloth**  
*Megatherium giganteum*.  
As large as an elephant. Found in the Pleistocene gravels of South America.  
(From Sir Ray Lankester’s Extinct Animals, p. 172.)

Fig. 90.—*Mylodon robustus*.  
From the Pleistocene of South America. (Nicholson’s Palaeontology).
of which 5 feet consisted of the massive armoured tail, which latter is believed to have borne a number of movable horns. The earlier fossil species were of much smaller size, and, though far more abundant in the south, a few of them have been found in the Pliocene deposits of Texas.

The extinct ground-sloths are even more remarkable, since they were intermediate in structure between the living sloths and the ant-eaters, but adapted for a different mode of life. Almost all are of large, and many of gigantic size. The Megatherium, which was discovered more than a century ago, was one of the largest, the skeleton (represented by a cast in the British Museum) being 18 feet long. Their massive bones show enormous strength, and they no doubt were able to uproot trees, by standing erect on the huge spreading hind feet and grasping the stem with their powerful arms, in order to feed upon the foliage, as shown in the illustration (Fig. 89). The jaw-bones are lengthened out, indicating extended lips and probably a prehensile tongue with which they could strip off the leaves. An allied genus, Mylodon, which is somewhat smaller, has been found also in Kentucky in beds of the same age, the Pleistocene.

What renders these creatures so interesting is, that they survived till a very recent period and that they were contemporaneous with man. Both human bones and stone implements have been found in such close association with the bones or skeletons of these extinct sloths that they have been long held to have lived together. But a more complete proof of this was obtained in 1897. In a cavern in Patagonia, in a dry powdery deposit on the floor, many broken bones of a species of Mylodon were found; and also several pieces of skin of the same animal showing marks of tools. Bones of many other extinct animals were found there, as well as implements of stone and bone, remains of fires, and bones of man himself. Among the other animal remains were those of an extinct ancestral horse, and on some of the bones there were found shrivelled remains of sinews and flesh.

Allied forms are found in older deposits, as far back as the Miocene, but these are all of smaller size. They probably ranged all over South America, and the two genera Megatherium and Mylodon occur also in the most recent
deposits of the southern United States. The numerous skeletons in the pampas of Argentina are usually found on

the borders of old lakes and rivers, in the positions in which they died. They are supposed to have perished in the mud or quagmires while attempting to reach the water for drink
during dry seasons, great droughts being prevalent in the
district; but when these large animals lived there must have
been much more woody vegetation than there is now.
During the voyage of the Beagle, Darwin collected a large
quantity of these interesting fossils, as described in his
Naturalist's Voyage round the World (chap. v.). The skeleton
and outline figure of a Mylodon shown in Fig. 90 was 11
feet in total length, but other species were larger.

A remarkable extinct genus, Scelidotherium, of which the
complete skeleton is shown in Fig. 91, was about 10 feet long,
and has less massive limbs than the Megatherium or Mylodon,
and more elongated jaws. In some respects it approached
the ant-eaters, and was probably, like them, terrestrial in its
habits. About twelve distinct genera of these ground-sloths
are now known, comprising a large number of species.
They ranged all over South America and into the warmer
parts of North America, and before the immigration of the
horse and the sabre-toothed tiger in Pleistocene times, they
must have constituted the larger and more important portion
of the mammalian fauna of South America.

Extinct Mammals of Australia

The existing Australian mammals, although of varied form
and structure, are almost all marsupials, the only exceptions
being the aerial bats, and small rodents allied to rats, which
latter might have entered the country by means of floating
timber or trees from the nearest islands. These two orders
are therefore of little importance geographically, although by
counting the species it may be made to appear that the
higher mammals (Placentalia) are nearly as numerous as the
lower (Marsupialia). The wild dog, or dingo, is also apparently
indigenous, but it may have been introduced by early man,
as may some of the rodents. It is unfortunate that the
deposits of Tertiary age in Australia seem to be very scanty,
except recent gravels and alluvial muds, and none of these
have produced fossils of Mammalia except in caves and
dried-up lakes, which are all classed as of Pleistocene age.
These, however, are very productive in animal remains
which are extremely interesting.

They consist of many living species, but with them
numbers of extinct forms, some of gigantic size, but all undoubtedly allied to those living in Australia to-day. Thus, bones of kangaroos are found ranging in size from that of the smallest living species up to that of a donkey, and sometimes of very distinct forms and proportions. But

![Image of skull]

**Fig. 92.—Skull of an Extinct Marsupial, Diprotodon australis.** From the Pleistocene of Queensland and South Australia. With a man’s skull, to show comparative size. (B.M. Guide.)

with these have been found a huge wombat, the size of a large rhinoceros, of which the skull is here represented (Fig. 92). The complete skeleton has been quite recently obtained from Lake Callabonna in South Australia. It is found to be 12 feet long measured along the vertebrae, and 6 feet 2½ inches high.

![Image of skull]

**Fig. 93.—Skull of Thylacoleo carnifex.** From the Pleistocene of Australia. One-fifth nat. size. (B.M. Guide.)
As it has been found in various parts of the continent, it was probably abundant. Another smaller animal of somewhat similar form was the Nototherium, which was found in Queensland, together with the Diprotodon, about fifty years ago. A large phalanger was also found, which Professor Owen called the pouchled lion (Thylacoleo carnifex), but it is doubtful whether it was carnivorous (see Fig. 93). True carnivorous marsupials allied to the “Tasmanian wolf” (Thylacinus) and the Tasmanian devil (Sarcophilus) are also found.

How and when the marsupials first entered Australia has always been a puzzle to biologists, because the only non-Australian family, the opossums, are not closely allied to any of the Australian forms, and it is the opossums only which have been found in the European Early Tertiaries. But recent discoveries in South America have at length thrown some light on the question, since the Santa Cruz beds of Patagonia (Middle Tertiary) have produced several animals whose teeth so closely resemble those of the Tasmanian Thylacinus that Mr. Lydekker has no doubt about their being true marsupials allied to the Dasyuridae. There is also, in the same beds, another distinct family of small mammals—the Microbiotheridae of Dr. Ameghino—which, from a careful study of their dentition, are also considered by Mr. Lydekker to be “polyprotodont marsupials of an Australian type.”

But even more important is the discovery of living marsupials of the Australian rather than the American type in the very heart of the South American fauna. In 1863 a small mouse-like animal of doubtful affinities was captured in Ecuador. But in 1895 a larger species of the same genus was obtained from Bogota; and it was then seen that they belonged to a group of which large numbers of fossil remains had been found in the Santa Cruz beds. By a comparison of these remains of various allied forms with the specimens of those now living, it seems no longer possible to doubt that marsupials of Australian type have existed in South America in Middle or Late Tertiary times, and that some of them survive to-day in the equatorial Andes, where their small size has probably saved them from extinction. Of these latter, Mr. Lydekker says: “In the

1 A Geographical History of Mammals, p. 109.
skeleton the lower jaw exhibits the usual inflexion of the angle; and the pelvis carries marsupial bones. A small pouch is present in the female." These small marsupials have been named Caenolestes, while their fossil allies are so numerous and varied that they have to be classed in three families—Abderitidae, Epanorthidae, and Garzoniidae. This is only mentioned here to show the large quantity of materials upon which these conclusions are founded.

Teachings of Pleistocene Mammalia

For the purpose of the present work it is not necessary to go into further details as to the development of the higher forms of life, except to call attention to some other cases of the sudden dying out of great numbers of the more developed species or groups during the most recent geological period—the Pleistocene.

It has already been shown how, in temperate South America, the huge sloths and armadillos, the giant llamas, the strange Toxodontia, and the early forms of horses all disappeared at a comparatively recent epoch. In North America a similar phenomenon occurred. Two extinct lions; a number of raccoons and allied forms, including several extinct genera; six extinct species of horses; two tapirs; two genera of peccaries; a llama and a camel; several extinct bison, sheep, and deer; two elephants and two mastodons, and four genera of the wonderful terrestrial sloths, ranged over the whole country as far north as Oregon and the Great Lakes in quite recent times; while four genera of the great ground-sloths have been found as far north as Pennsylvania.

This remarkable assemblage of large Mammalia at a period so recent as to be coeval with that of man, is most extraordinary; while that the whole series should have disappeared before historical times is considered by most geologists to be almost mysterious. At an earlier period, especially during the Miocene (Middle Tertiary), North America was also wonderfully rich in Mammalia, including not only the ancestors of existing types, but many now quite extinct. At this time there were several kinds of monkeys allied to South American forms; numerous extinct Carnivora, including the great sabre-toothed tiger, Machæro-
dus; several ancestral horses, including the European Anchitherium; several ancestral rhinoceroses, the huge horned Brontotheriidae, the Oreodontidae, and many ancestral swine. Almost all these became extinct at the end of the Miocene age.

In Europe we find very similar phenomena. During the Pleistocene age, the great Irish elk, the cave-lion and the sabre-toothed tiger, cave-bears and hyænas, rhinoceroses, hippopotami and elephants, extinct species of deer, antelopes, sheep and cattle, were abundant over a large part of Europe (many even reaching our own country), and rapidly became extinct; and what renders this more difficult to explain is, that all of these and many others, with numerous ancestral forms, had inhabited Europe throughout the Pliocene and some even in Miocene times.

These very interesting changes in the northern hemisphere are paralleled and completed in far-distant Australia. In caves and surface deposits of recent formation a whole series of fossil remains have been found, all of the marsupial order, and most of them of extinct species and even extinct genera. But what is more extraordinary is, that several of them were larger than any now living, while some were as gigantic as the huge ground-sloths and armadillos of the Pampas. There were numerous kangaroos, some much larger than any living, including species allied to the tree-kangaroos of New Guinea; a Phascolomys (wombat) as large as a donkey; the Diprotodon, a thick-limbed animal nearly as large as an elephant, but allied both to the kangaroos and the phalangers. Equally remarkable was the Thylacoleo carnifex, nearly as large as a lion and with remarkable teeth (Fig. 93, p. 240). The very peculiar Nototherium, allied to the wombats, was nearly as large as a rhinoceros; and several others imperfectly known indicate that they were of larger size than their nearest living allies.

A number of very similar facts are presented by recently extinct birds. The Moas of New Zealand were of various sizes, but the largest was 8½ feet high when standing naturally, but when raising its body and neck to the fullest extent it would have perhaps reached to a height of 12 feet.

In Madagascar also there was a huge bird, the Aepyornis,
which was probably larger than the largest of the Moas, and whose egg, frequently found in sand-hills, sometimes measures 3 feet by 2½ feet in circumference, and will hold more than two gallons. It is almost certain that these huge birds were all coeval with early man, and in the case of the Moas this has been completely proved by finding their bones in ancient native cooking ovens. It is probable, therefore, that their final extinction was due to human agency.

**Probable Cause of Extinction of the Pleistocene Mammalia**

The complete extinction of many of the largest Mammalia, which were abundant in almost all parts of the world in Pleistocene times, has not yet received a wholly satisfactory explanation. The fact that the phenomenon is so near to our own era renders it more striking than similar occurrences in remote ages. With the one exception of the glacial epoch, there has been very little modification of the earth's surface since the close of the Tertiary era; and in several cases species which undoubtedly survived that event have since become extinct. This great climatic catastrophe did undoubtedly produce extensive migration of Mammalia; but, owing to the fact that the ice-sheet had very definite limits, and that numbers of large mammals were merely driven southward, it is not held to be a sufficient cause for so general a destruction of the larger forms of life.

Another circumstance that puts the glacial epoch out of court as a sufficient explanation of the widespread extinction is that in two very remote parts of the earth, both enjoying a warm or even a sub-tropical climate—Australia on the one hand, and Brazil to Argentina on the other,—exactly the same phenomena have occurred, and, so far as all the geological evidence shows, within the same general limits of time.

It is no doubt the case that at each of the dividing lines of the Tertiary era—that is, in passing from the Eocene to the Miocene, or from the latter to the Pliocene, and thence to the Pleistocene—many large Mammalia have also become extinct. But in these cases a much greater lapse of time can be assumed, as well as larger changes in the physical conditions, such as extension of land or water, climate, vegetation, etc., which, combined with the special disabilities of
very large animals, are sufficient to account for the facts. It may be well here to state again the causes which lead to the extinction of large animals rather than small ones, as given in my Darwinism (p. 394) more than twenty years ago, and also in my Geographical Distribution of Animals, i. p. 157 (1876):

"In the first place, animals of great bulk require a proportionate supply of food, and any adverse change of conditions would affect them more seriously than it would affect smaller animals. In the next place, the extreme specialisation of many of these large animals would render it less easy for them to become modified in any new direction required by the changed conditions. Still more important, perhaps, is the fact that very large animals always increase slowly as compared with small ones—the elephant producing a single young one every three years, while a rabbit may have a litter of seven or eight young two or three times a year. Now the probability of useful variations will be in direct proportion to the population of the species, and, as the smaller animals are not only many hundred times more numerous than the largest, but also increase perhaps a hundred times as rapidly, they are able to become quickly modified by variation and natural selection, while the large and bulky species, being unable to vary quickly enough, are obliged to succumb in the struggle for existence."

To these reasons we may add that very large animals are less rapid in their motions, and thus less able to escape from enemies or from many kinds of danger. The late Professor O. Marsh, of Yale University, has well observed:

"In every vigorous primitive type which was destined to survive many geological changes, there seems to have been a tendency to throw off lateral branches, which became highly specialised, and soon died out because they were unable to adapt themselves to new conditions. . . . The whole narrow path of the Susillus (hog) type, throughout the entire series of the American Tertiaries, is strewn with the remains of such ambitious offshoots, many of them attaining the size of a rhinoceros; while the typical pig, with an obstinacy never lost, has held on in spite of catastrophes and evolution, and still lives in America to-day."

We may also remember that it is still more widely spread over the Old World, under the various forms of the hog-family (Suidæ), than it is in America, under the closely allied peccary type (Dicotylidæ).
That this is a true cause of the more frequent passing away of the largest animal types in all geological epochs there can be no doubt, but it certainly will not alone explain the dying out of so many of the very largest Mammalia and birds during a period of such limited duration as is the Pleistocene (or Quaternary) age, and under conditions which were certainly not very different from those under which they had been developed and had lived in many cases down to the historical period.

What we are seeking for is a cause which has been in action over the whole earth during the period in question, and which was adequate to produce the observed result. When the problem is stated in this way the answer is very obvious. It is, moreover, a solution which has often been suggested, though generally to be rejected as inadequate. It has been so with myself, but why I can hardly say. In his Antiquity of Man (4th ed., 1873, p. 418), Sir Charles Lyell says:

"That the growing power of man may have lent its aid as the destroying cause of many Pleistocene species must, however, be granted; yet, before the introduction of fire-arms, or even the use of improved weapons of stone, it seems more wonderful that the aborigines were able to hold their own against the cave-lion, hyena, and wild bull, and to cope with such enemies, than that they failed to bring about their extinction."

Looking at the whole subject again, with the much larger body of facts at our command, I am convinced that the above somewhat enigmatic passage really gives the clue to the whole problem, and that the rapidity of the extinction of so many large Mammalia is actually due to man's agency, acting in co-operation with those general causes which at the culmination of each geological era has led to the extinction of the larger, the most specialised, or the most strangely modified forms. The reason why this has not been seen to be a sufficient explanation of the phenomena is, I think, due to two circumstances. Ever since the fact of the antiquity of man was first accepted by European geologists only half a century ago, each fresh discovery tending to extend that antiquity has been met with the same incredulity and opposition as did the first discovery of flint weapons by
Boucher de Perthes in the gravels near Amiens. It has been thought necessary to minimise each fresh item of evidence, or in many cases to reject it altogether, on the plea of imperfect observation. Thus the full weight of the ever-accumulating facts has never been adequately recognised, because each new writer has been afraid to incur the stigma of credulity, and therefore usually limited himself to such facts as he had himself observed, or could quote from his best-known contemporaries. On the other hand, the old idea that man was the latest product of nature (or of evolution) still makes itself felt in the attempt to escape from any evidence proving man's coexistence with such extinct species as would imply greater antiquity. In the chapter on The Antiquity of Man in North America (in my Natural Selection and Tropical Nature) I have given numerous examples of both these states of mind. And what makes them so specially unreasonable is, that all evolutionists are satisfied that the common ancestor of man and the anthropoid apes must date back to the Miocene, if not to the Eocene period; so that the real mystery is, not that the works or the remains of ancestral man are found throughout the Pleistocene period, but that they are not also found throughout the Pliocene, and also in some Miocene deposits. There is not, as often assumed, one "missing link" to be discovered, but at least a score such links, adequately to fill the gap between man and apes; and their non-discovery is now one of the strongest proofs of the imperfection of the geological record.

When we find, as we do, that, with the one exception of Australia, proofs of man's coexistence with all the great extinct Pleistocene Mammalia are sufficiently clear, while that the Australians are equally ancient is proved by their forming so well-marked and unique a race, the fact that man should everywhere have helped to exterminate the various huge quadrupeds, whose flesh would be a highly valued food, almost becomes a certainty. The following passage from one of our best authorities, Mr. R. Lydekker, F.R.S., puts the whole case in a very clear light, though he does not definitely accept the conclusion which I hold to be now well established. He says:
"From the northern half of the Old World have disappeared the mammoth, the elasmothere (a very peculiar, huge rhinoceros, whose skull was more than three feet long), the woolly and other rhinoceroses, the sabre-toothed tigers, etc.; North America has lost the megalonyx and the Ohio mastodon; from South America, the glyptodonts, mylodons, the megalothere, and the macrauchenia have been swept away; while Australia no longer possesses the diprotodon and various gigantic species of kangaroos and wombats. In the northern hemisphere this impoverishment of the fauna has been very generally attributed to the effects of the glacial period, but, although this may have been a partial cause, it can hardly be the only one. The mammoth, for instance, certainly lived during a considerable portion of the glacial epoch, and if it survived thus far, why should it disappear at the close? Moreover, all the European mastodons and the southern elephant (Elephas meridionalis) died out before the incoming of glacial conditions; and the same is true of all the extinct elephants and mastodons of Southern Asia. Further, a large number of English geologists believe the brick earths of the Thames valley, which contain remains of rhinoceroses and elephants in abundance, to be of post-glacial age. As regards the southern hemisphere, it can hardly be contended that glacial conditions prevailed there at the same time as in the northern half of the world.

"It is thus evident that, though a very great number of large mammals were exterminated (perhaps partly by the aid of human agency) at the close of the Pleistocene period, when the group had attained its maximum development as regards the bodily size of its members, yet other large forms had been steadily dying out in previous epochs. And it would seem that there must be some general, deep-seated cause affecting the life of a species with which we are at present unacquainted. Indeed, as there is a term to the life of an individual, what is more natural than that there should also be one to the existence of a species. It still remains indeed, to account for the fact that the larger Pleistocene mammals had no successors in the greater part of the world, but perhaps is in some way connected with the advent of man."

It is sometimes thought that early man, with only the rudest weapons, would be powerless against large and often well-armed mammals. But this, I think, is quite a mistake. No weapon is more effective for this purpose than the spear, of various kinds, when large numbers of hunters attack a single animal; and when made of tough wood, with the point hardened by fire and well sharpened, it is as effective

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1 Lydekker's Geographical History of Mammals, p. 18.
as when metal heads are used. Bamboo, too, abundant in almost all warm countries, forms a very deadly spear when cut obliquely at the point. The way in which even a man-eating tiger is killed by this means in Java is described in my Malay Archipelago (p. 82). Such a method would doubtless have been adopted even by Palæolithic man, and would have been effective against any of the larger animals of the Pleistocene age.

It is therefore certain, that, so soon as man possessed weapons and the use of fire, his power of intelligent combination would have rendered him fully able to kill or capture any animal that has ever lived upon the earth; and as the flesh, bones, hair, horns, or skins would have been of use to him, he would certainly have done so even had he not the additional incentive that in many cases the animals were destructive to his crops or dangerous to his children or to himself. The numbers he would be able to destroy, especially of the young, would be an important factor in the extermination of many of the larger species.

There remains, however, the question, well put by Mr. Lydekker, whether there is not some general deep-seated cause affecting the life of species, and serving to explain, if only partially, the successive dying out of numbers of large animals involving a complete change in the preponderant types of organic life at certain epochs; and to this question and some others allied to it a separate chapter must be devoted.

APPENDIX

THE THEORY OF CONTINENTAL EXTENSIONS

Most writers consider that the facts given on p. 224 go to prove the existence of a direct land-connection between South America and Australia in Early or Middle Tertiary times. This, however, seems to me to be highly improbable for reasons given at full in my Island Life. Its supposed necessity depends on the assumption that the geological record is fairly complete, even as regards these small mammals, and that their not being yet discovered in the northern continents proves that they never existed there. But the extreme rarity of the small Secondary Mammalia, though they have been found scattered over the whole northern hemisphere, and the limited
area in South America in which these Tertiary marsupials have been found, taken in connection with the enormous areas of geologically unexplored land in Asia and Australia, should make us very cautious in assuming such vast and physically improbable changes of land and sea at such a comparatively recent epoch. The theory of land-connection also introduces enormous difficulties of various kinds which it is well briefly to consider. If we suppose an absolute land-connection in order to allow the marsupial type to have entered Australia from temperate South America, we have to face the incredible fact, that of the whole varied mammalian fauna of the latter country this one group only was transmitted. In these same deposits there are found ancestral hoofed animals of small size (Pyrotherium); numerous rodents allied to cavies and porcupines; a host of Edentata allied to sloths, ant-eaters, and armadillos. These, taken altogether, are many times more numerous than the marsupials; they were more varied in structure and mode of life; and it is almost incredible that not one representative of these somewhat higher forms should have reached the new country, or having reached it should have all died out, while the inferior group alone survived. Then, again, we know that birds and insects must have abounded in South America at the same period, while the whole 7000 miles of connecting land must have been well clothed with vegetation to support the varied life that must have existed upon it during the period of immigration. Yet no indication of a direct transference or interchange of these numerous forms of life in any adequate amount is found in either Australia or South Temperate America. We can hardly suppose such an enormous extent of land to have been raised above the ocean; that it should have become sufficiently stocked with life to serve as a bridge (7000 miles long!), and that a few very small marsupials only should have crossed it; that it then sank as rapidly as it had been formed; with the one result of stocking Australia with marsupials, while its other forms of life—plants, birds, insects, molluscs—show an unmistakable derivation from the Asiatic continent and islands. A careful examination of a large globe or South Polar map, with a consideration of the diagram of the proportionate height of land and depth of ocean at p. 345 of my Darwinism, together with the argument founded upon it, will, I think, convince my readers that difficulties in geographical distribution cannot be satisfactorily explained by such wildly improbable hypotheses. If the facts are carefully examined, it will be found, as I have shown for the supposed "Atlantis" and "Lemuria," that such hypothetical changes of sea and land always create more serious difficulties than those which they are supposed to explain. People never seem to consider what such an explanation really means. They never follow out in imagination, step by
step, the formation of any such enormous connecting lands between existing continents in accordance with what we know of the rate of elevation and depression of land, and the corresponding organic changes that must ensue. They seem to forget that such a vast and complete change of position of sea and land is not really known ever to have occurred.

Let us consider for a moment what the supposed land-connection between South America and Australia really implies. The distance is more than half as much again as the whole length of the South American continent, and 1000 miles farther than from Southampton to the Cape. This alone should surely give us pause. But unless we go as far south as the Antarctic circle, the depth of the intervening ocean is about two miles; and until we get near New Zealand there is not a single intervening island. There are here none of the indications we expect to find of any geologically recent depression of land on a vast scale. Of course we may suppose the connection to have been along a great circle within ten degrees of the South Pole, but that will not greatly shorten the distance, while we have not a particle of evidence for such a vast change of climate in Mid-Tertiary times as would be required to render such a route possible. But the mere physical difficulties are equally great. All land elevation or depression of which we have geological evidence has been exceedingly gradual, very limited in extent, and always balanced by adjacent opposite movements. Such movements appear to be slow creeping undulations passing over continental plateaux and their immediately adjacent submarine extensions. Sometimes the depressions seem to have taken the form of basins; but we cannot conceive of any elevation of continental dimensions, or depression of oceanic character as to depth and area, without the complementary movement to complete the undulation. A continental extension between South America and Australia would almost necessarily imply a subsidence of one or both of those countries over an equal area and to an equal depth; and, so far as I am aware, no geological evidence has been adduced of any such vast changes having occurred at so recent a period in either continent. I believe it can now be truly said that no stratigraphical geologist accepts the theory of frequent interchanges of continental and oceanic areas, which are so hastily claimed by palæontologists and biologists to be necessary in order to overcome each apparent difficulty in the distribution of living or extinct organisms, and this notwithstanding the number of such difficulties which later discoveries have shown to be non-existent.
CHAPTER XIII

SOME EXTENSIONS OF DARWIN'S THEORY

DURING the fifty years that have elapsed since the Darwinian theory was first adequately, though not exhaustively, set forth, it has been subject to more than the usual amount of objection and misapprehension both by ignorant and learned critics, by old-fashioned field-naturalists, and by the newer schools of physiological specialists. Most of these objections have been shown to be fallacious by some of the most eminent students of evolution both here and on the Continent; but a few still remain as stumbling-blocks to many earnest readers, and, as they are continually adduced as being serious difficulties to the acceptance of natural selection as a sufficient explanation of the origin of species, I propose to give a short statement of what seem to me the three objections that most require an answer at the present time. They are the following:—

1. How can the beginnings of new organs be explained?
2. How can the exact co-ordination of variations, needed to produce any beneficial result, be effected with sufficient rapidity and certainty?
3. How is it that excessive developments of bulk, weapons, ornaments, or colours, far beyond any utilitarian requirements, have been so frequently produced?

These three objections are of increasing degrees of importance. The first is, in my opinion, wholly speculative and of no value, inasmuch as it applies to what happened in the earlier stages of evolution, of which we have a minimum of knowledge. The second is of somewhat more importance; for, though in the great majority of cases of adaptation the ordinary well-known facts of variation and survival would
amply suffice, yet there are conceivable cases in which they might be insufficient, and these cases are now explained by a very interesting combination of the effects of acquired modifications of the individual with the selection of congenital variations. The third is, I think, somewhat more important, as indicating a real deficiency in the theory, as originally stated, but which is now well supplied by an extension of that theory from the body itself to the reproductive germs from which its parts are developed. I will, therefore, endeavour to explain in as simple a manner as possible how these three objections have been overcome.

(1) The Beginnings of Organs

The objection that the first slight beginnings of new organs would be useless, and that they could not be preserved and increased by natural selection, was one of the most frequent in the early stages of the discussion of the theory, and was answered by Darwin himself in the later editions of his book. But the objection still continues to be made, and owing to the great mass of controversial literature continually issued from the press many of the objectors do not see the replies made to them; there is therefore still room for a somewhat more general answer, which will apply not only to certain individual cases, but to all. The most general and therefore the best answer I have yet seen given is that of Professor E. B. Poulton in his recently published Essays on Evolution. He says:

"Organs are rarely formed anew in an animal, but they are formed by the modification of pre-existing organs; so that, instead of having one beginning for each organ, we have to push the beginning further and further back, and find that a single origin accounts for several successive organs, or at any rate several functions, instead of one."

He then goes on to show that the four limbs of vertebrates have been again and again modified, for running, for climbing, for burrowing, for swimming, or for flying, and that their first appearance goes back to Palæozoic times in the paired fins of early fishes, while their actual origin must have been much farther back, in creatures whose skeleton was not sufficiently solidified to be preserved.
There is, however, a more general explanation even than this, and one that applies to what has always been held to be the most difficult of all—that of the origin of the organs of sense.

The various sensations by which we come into relation with the external world—sight, hearing, smell, taste, and touch—are really all specialisations of the last and most general, that of material contact. We hear by means of a certain range of air-waves acting on a specially constructed vibrating organ; we smell by the contact of excessively minute particles, or actual molecules, given off by certain substances; we taste by the action of soluble matter in food on the papillæ of the tongue; and we see by the impact of ether-vibrations on the retina; and as other ether-vibrations produce sensations of cold or warmth, or, when in excess, acute pain, in every part of the body, the modern view, that matter and ether are fundamentally connected if not identical, seems not unreasonable.

Now, as all our organs of sense, however complex, are built up from the protoplasm which constitutes the material of all living organisms, and as all animals, however simple, exhibit reactions which seem to imply that they have the rudiments of most, if not all of our senses, we may conclude that just in proportion as they have advanced in complexity of organisation, so have special parts of their bodies become adapted to receive, and their nervous system to respond to, the various contacts with the outer world which produce what we term sensations. There is therefore, probably, no point in the whole enormous length of the chain of being, from ourselves back to the simple one-celled Amœba, in which the rudiments of our five senses did not exist, although no separate organs may be detected. Just as its whole body serves alternately as outside or inside, as skin or as stomach, as limbs or as lips, so may every part of it receive a slightly different sensation from a touch outside or a touch inside, from an air-vibration or from an ether-vibration, from those emanations which affect us as noxious odours or disgusting tastes. But if this view is a sound one, as I think it will be admitted that it is, how absurd is it to ask, “How did the eye or the ear begin?” They began in the potentiality of that
marvellous substance, protoplasm, and they were rendered possible when that substance was endowed with the mysterious organising power we term life. First the cell was produced; and, from the continued subdivision of the cell at each subdivision taking a slightly different form and function, numerous one-celled animals were formed; and a little later the union of many cells of diverse forms and functions led to the endless multicellular creatures, constituting the entire world of life.

Thus every substance and every organ came into existence when required by the organism under the law of perpetual variation and survival of the fittest, only limited by the potentialities of living protoplasm. And if the higher sense-organs were so produced, how much easier was the production of such superficial appendages as horns and tusks, scales and feathers, as they were required. Horns, for instance, are either dermal or osseous outgrowths or a combination of both. In the very earliest known vertebrates, the fishes of the Silurian formation, we find the skin more or less covered with tubercles, or plates, or spines. Here we have the rudiments of all those dermal or osseous outgrowths which continue in endless modifications through the countless ages that have elapsed down to our own times. They appear and disappear, as they are useful or useless, on various parts of the body, as that body changes in form and in structure, and modifications of its external covering are needed. Hence the infinite variety in nature—a variety which, were it not so familiar, would be beyond the wildest flights of imagination to suggest as possible developments from an apparently simple protoplasmic cell. The idea, therefore, that there were, or could be, at any successive periods, anything of the nature of the abrupt beginning of completely new organs which had nothing analogous in preceding generations is quite unsupported by what is known of the progressive development of all structures through slight modification of those which preceded them. The objection as to the beginnings of new organs is a purely imaginary one, which entirely falls to pieces in view of the whole known process of development from the simplest cell (though in reality no cell is simple) to ever higher and more complex aggregations of cells, till we come to Mammalia and to man.
(2) The Co-ordination of Variations

The next difficulty, one which Herbert Spencer laid much stress on, is, that every variation, to be of any use to a species, requires a number of concurrent variations, often in different parts of the body, and these, it is said, cannot be left to chance. Herbert Spencer discussed this point at great length in his Factors of Organic Evolution; and, as one of the illustrative cases, he takes the giraffe, whose enormously long neck and forelegs, he thinks, would have required so many concurrent variations that we cannot suppose them to have occurred through ordinary variation. He therefore argues that the inherited effects of use and disuse are the only causes which could have brought it about; and Darwin himself appears to have thought that such inheritance did actually occur.

The points which Spencer mainly dwells upon are as follows: The increased length and massiveness of the neck would require increased size and strength of the chest with its bones and muscles to bear the additional weight, and also great additions to the strength of the forelegs to carry such a burden. Again, as the hind-legs have remained short, the whole body is at a different angle from what it was before the change from the ordinary antelope-type, and this would require a different shape in the articulating joints of the hips and some change in the muscles; and this would be the more important as the hind- and forelegs now have unequal angular motions when galloping, involving changed co-ordination in all the connected parts, any failure in which would diminish speed and thus be fatal to the varying individuals. Even the blood-vessels and nerves of these various parts would require modifications exactly adapted to the change in the other parts; and he urges that any individuals in which all these necessary variations did not take place simultaneously, would be at a disadvantage and would not survive. To do his argument justice, I will quote one of his most forcible paragraphs.

"The immense change in the ratio of fore-quarters to hind-quarters would make requisite a corresponding change of ratio in the appliances carrying on the nutrition of the two. The entire
vascular system, arterial and venous, would have to undergo successive unbuildings and rebuildings to make its channels everywhere adequate to the local requirements, since any want of adjustment in the blood-supply to this or that set of muscles would entail incapacity, failure of speed, and loss of life. Moreover, the nerves supplying the various sets of muscles would have to be appropriately changed, as well as the central nervous tracts from which they issued. Can we suppose that all these appropriate changes, too, would be, step by step, simultaneously made by fortunate spontaneous variations occurring along with all the other fortunate spontaneous variations? Considering how immense must be the number of these required changes, added to the changes above enumerated, the chances against any adequate readjustments fortuitously arising must be infinity to one."

Now, this seems very forcible, and has, no doubt, convinced many readers. Yet the argument is entirely fallacious, because it is founded on the tacit assumption that the number of the varying individuals is very small, and that the amount of coincident variation is also both small and rare. It is further founded on the assumption that the time allowed for the production of any sufficient change to be of use is also small. But I have shown in the early chapters of this book (and much more fully in my Darwinism) that all these assumptions are the very reverse of the known facts. The numbers of varying individuals in any *dominant* species (and it is only these which become modified into new species) is to be counted by millions; and as the whole number can, as regards any needed modification, be divided into two halves — those which possess the special quality required above or below the average — it may be said that nearly half the total number vary favourably, and about one-fourth of the whole number in a very large degree. Again, it has been shown that the number of coincident variations are very great, since they are always present when only a dozen or twenty individuals are compared; but nature deals with thousands and millions of individuals. Yet, again, we know that changes of the environment are always very slow as measured by years or generations, since not a single new species is known to have come into existence during the whole of the Pleistocene period; and as fresh variations occur in every generation, almost any character, with all its co-ordinated
structures, would be considerably modified in a hundred or a thousand generations, and we have no absolute knowledge that any great change would be required in less time than this.¹

Objectors always forget that a dominant species has become so because it is sufficiently adapted to its whole environment, not only at any one time or to any average of conditions, but to the most extreme adverse conditions which have occurred during the thousands or millions of years of its existence as a species. This implies that, for all ordinary conditions and all such adverse changes as occur but once in a century or a millennium, the species has a surplus of adaptability which allows it to keep up its immense population in the midst of countless competitors and enemies. Examples of such thoroughly well-adapted species were the American bison and passenger pigeon, whose populations a century ago were to be counted by millions and thousands of millions, which they were fully able to maintain against all enemies and competitors then in existence. But civilised man has so modified and devastated the whole organic environment in a single century as to bring about an extermination which the slow changes of nature would almost certainly not have effected in a thousand or even a million of centuries. This happened because the changes were different in kind, as well

¹ A very familiar fact will, I think, show that a large amount of co-ordinated variability in different directions does actually occur. First-rate bowlers and wicket-keepers, as well as first-rate batters, are not common in proportion to the whole population of cricket-players. Each one of these requires a special set of co-ordinated faculties—good eyesight, accurate perception of distance and of time, with extremely rapid and accurate response of all the muscles concerned in the operations each has to perform. If all the special variations required to produce such individuals were set forth by a good physiologist in the detailed and forcible manner of the passage quoted from Spencer about the giraffe, it would seem impossible that good cricketers should ever arise from the average family types. Yet they certainly do so arise. And just as cricketers are chosen, not by external characters, but by the results of actual work, so nature selects, not by special characters or faculties, but by that combination of characters which gives the greatest chance of survival in the complex, fluctuating environment in which each creature lives. The species thus becomes adapted, first to resist one danger, then another; first to one aspect of the ever-changing environment, then to another; till during successive generations it becomes so perfectly adapted to a long series of more or less injurious conditions, that, under all ordinary conditions, it possesses a surplus of adaptation. And as this complete adaptation is as often exhibited in colour and marking as in structure, it is proved that the transmission of the effects of use and disuse are not essential to the most complex adaptations.
as in rapidity, from any of nature's changes during the whole period of the development of existing species.

But although I feel confident that the known amount of variation would amply suffice for the adaptation of any dominant species to a normally changing environment, I admit that there are conceivable cases in which changes may have been so great and so comparatively rapid as to endanger the existence even of some of those species which had attained to a dominant position; such, for instance, as the opening of a land passage for very powerful new Carnivora into another continent or extensive area (as appears to have occurred with Africa in Tertiary times), in which case it is quite possible that such an animal as the American bison might have been first reduced in numbers, and, for want of any sufficiently rapid development of new means of protection, be ultimately destroyed.

But a few years ago an idea occurred independently to three biologists, of a self-acting principle in nature which would be of such assistance to any species in danger of extermination as, in some cases at all events, would enable it to become adapted to the new conditions. It would, in fact, increase the powers of natural selection, as above explained, to a degree which might sometimes make all the difference between life and death to a certain number of species. It depends upon the well-known fact that the use of any limb or organ strengthens or increases the growth of that part or organ. On this fact depends all training for athletics or games; and it is alleged by some trainers that any one, however weak naturally, can have his strength very greatly increased by systematic but carefully graded exercise. If, therefore, the survival of any animal in presence of a new enemy or unaccustomed danger depends upon increased powers of running, or jumping, or tree-climbing, or swimming, then, during the process of eliminating those individuals who were the worst in these respects, all the remainder would have to exercise their powers to the utmost, and would, in the act of doing so, increase their power of escaping the danger. Thus a considerable number would become capable of surviving, year after year, to a normal old age, and during this whole period would, year by year,
have fresh descendants, and of these only the very best, the most gifted naturally, would survive. The increased adaptation during the life of the individual would not be transmitted, but the quality of being improvable during life would be transmitted, and thus additional time and a considerably increased population would give more materials for natural selection to act upon. With this help the species might become so rapidly improved that the danger from the new environment would be overcome, and a new type might be produced which would continue to be a dominant one under the new conditions.\(^1\)

Now, while it must be admitted, that under certain conditions, and with certain classes of adaptations, the normal effects of natural selection would be facilitated by the aid of individual adaptation through use of organs, yet its effect is greatly limited by the fact that it will not apply to several classes of adaptations which are quite unaffected by use or exercise. Such are the \textit{colours} of innumerable species, which are in the highest degree adaptive, either as protecting them from enemies, as a warning of hidden danger (stings, etc.), as recognition-marks for young or for wanderers, or by mimicry of protected groups. Here the \textit{use} is simply being seen or not seen, neither of which can affect the colour of the object. Again, nothing is more vitally important to many animals than the form, size, and structure

\(^1\) As many readers are ignorant of the extreme adaptability of many parts of the body, not only during an individual life, but in a much shorter period, I will here give an illustrative fact. A friend of mine was the resident physician of a large county lunatic asylum. During his rounds one morning, attended by one of his assistants and a warder, he stopped to converse with a male patient who was only insane on one point and whose conversation was very interesting. Suddenly the man sprang up and struck a violent blow at the doctor's neck with a large sharpened nail, and almost completely severed the carotid artery. The warder seized the man, the assistant gave the alarm, while my friend sat down and pressed his finger on the proper spot to stop the violent flow of blood, which would otherwise have quickly produced coma and death. Other doctors soon applied proper pressure, and a competent surgeon was sent for, who, however, did not arrive for more than an hour. The artery was then tied up and the patient got to bed. He told me of this himself about two years afterwards, and, on my inquiry how the functions of the great artery had been renewed, he assured me that nothing but its permanent stoppage was possible, that numerous small anastomosing branches enlarged under the pressure and after a few months carried the whole current of blood that had before been carried by the great artery, without any pain, and that at the time of speaking he was quite as well as before the accident. Such a fact as this really answers almost the whole of Herbert Spencer's argument which I have quoted at p. 256.
of the teeth, which are wonderfully varied throughout the whole of the vertebrate sub-kingdom. Yet the more or less use of the teeth cannot be shown to have any tendency to change their form or structure in the special ways in which they have been again and again changed, though it might possibly have induced growth and increased size. Yet again, the scales or plates of reptiles, the feathers of birds, and the hairy covering of mammals, have never been shown to have their special textures, shapes, or density modified by the mere act of use. One common error is that cold produces length and density of hair, heat the reverse; but the purely tropical monkey-tribe are, as a rule, quite as well clothed with dense fur as most of the temperate or arctic mammals, while no birds are more luxuriantly feather-clad than those of the tropics. Neither is it certain that increased gazing improves the eyes, or loud noises the ears, or increased eating the stomach; so that we must conclude that this aid to the powers of natural selection is very partial in its action, and that it has no claim to the important position sometimes given it.

(3) Germinal Selection, an Important Extension of the Theory of Natural Selection

Although I was at first inclined to accept Darwin's view of the influence of female choice in determining the development of ornamental colour or appendages in the males, yet, when he had adduced his wonderful array of facts bearing upon the question in the Descent of Man, the evidence for any such effective choice appeared so very scanty, and the effects imputed to it so amazingly improbable, that I felt certain that some other cause was at work. In my Tropical Nature (1878) and in my Darwinism (1889) I treated the subject at considerable length, adducing many facts to prove that, even in birds, the colours and ornamental plumes of the males were not in themselves attractive, but served merely as signs of sexual maturity and vigour. In the case of insects, especially in butterflies, where the phenomena of colour, and to some extent of ornament, are strikingly similar to those of birds, the conception of a deliberate aesthetic choice, by the females, of the details of colour,
marking, and shape of wings, seemed almost unthinkable, and was supported by even less evidence than in the case of birds.

After long consideration of the question in all its bearings, and taking account of the various suggestions that had been made by competent observers, I arrived at certain conclusions which I stated as follows:

"The various causes of colour in the animal world are, molecular and chemical change of the substance of their integuments, or the action upon it of heat, light, or moisture. Colour is also produced by the interference of light in superposed transparent lamellæ or by excessively fine surface striae. These elementary conditions for the production of colour are found everywhere in the surface-structures of animals, so that its presence must be looked upon as normal, its absence exceptional.

"Colours are fixed or modified in animals by natural selection for various purposes: obscure or imitative colours for concealment; gaudy colours as a warning; and special markings either for easy recognition by strayed individuals or by young, or to divert attack from a vital part, as in the large brilliantly marked wings of some butterflies and moths.

"Colours are produced or intensified by processes of development, either where the integument or its appendages undergo great extension or change of form, or where there is a surplus of vital energy, as in male animals generally, more especially at the breeding season."¹

Now the idea here suggested, of all these strange and beautiful developments of plumage, of ornaments, or of colour being primarily due to surplus vitality and growth-power in dominant species, and especially in the males, seems a fairly adequate solution of the problem. For the individuals which possessed it in the highest degree would survive longest, would have most offspring who were equally or even more highly gifted; and thus there would arise a continually increasing vitality which would be partly expended in the further development of those ornaments and plumes which are its result and outward manifestation. The varying conditions of existence would determine the particular part of the body at which such accessory orna-

¹ Natural Selection and Tropical Nature (new ed., 1895), pp. 391-392. For full details see Darwinism, chap. x. (1901).
ments might arise, usually, no doubt, directed by utility to
the species. Thus the glorious train of the peacock might
have begun in mere density of plumage covering a vital
part and one specially subject to attack by birds or beasts
of prey, and, once started, these plumes would continue to
increase in number and size, as being an outlet for vital
energy, till at last they became so enormously lengthened
as to become dangerous by their weight being a check to
speed in running or agility in taking flight. This is already
the case with the peacock, which has some difficulty in
rising from the ground and flies very heavily. Its enemies
in India are tigers and all the larger members of the cat-
tribe, and when any of these approach its feeding-grounds
it takes alarm and at once flies up to the lower branches of
large trees. In the Argus-pearl it is the secondary
wing-feathers that are exceedingly long and broad, so as to
be almost as much a hindrance to strong or rapid flight as
is the train of the peacock; and in both birds these orna-
tmental plumes have evidently reached the utmost dimensions
compatible with the safety of the species.

There can also be little doubt that in many of the birds-
of-paradise and of the humming-birds, in the enormous crest
of the umbrella-bird, in the huge beaks of the hornbills and
the toucans, in the lengthy neck and legs of the flamingos
and the herons, these various ornamental or useful append-
ages have reached or even overpassed the maximum of
utility. In another class of animals we have the same
phenomenon. The expansion of the wings in butterflies
and moths reaches a maximum in several distinct families—
the Papilionidae, the Morphidae, the Bombyces, and the Noctuæ,
in all of which it is sometimes from nine to ten inches.
Here, again, we seem to find a tendency to development
in size, which has gone on from age to age, till limits have
been reached to exceed which threatens the existence of the
species.

The progressive development of many groups of animals
affords curious illustrations of this continuous increase in
bulk, or in the size of particular organs, till they have
actually overpassed the line of permanent safety, and under
the first adverse conditions have led to extinction. Both
reptiles and mammals originated in creatures of small size which gradually increased in bulk, in certain types, till they suddenly became exterminated. In the former class the increase was apparently rapid, till the hugest land-animals that ever lived appeared upon the earth—the Dinosauria of the Jurassic and Cretaceous periods, already described. Many of them also developed strange horns and teeth; and these, too, when they reached their maximum, also suddenly disappeared. Flying reptiles—the Pterodactyles—also began as small animals and continually increased, till those of the period of our Chalk attained the greatest dimensions ever reached by a flying creature, and then the whole group became extinct at a time when a higher type, the birds, were rapidly developing.

With mammals the case is even more striking, all the earliest forms of the Secondary age being quite small; while in the Tertiary period they began to increase in size and to develop into a great variety of types of structure; till, in an age just previous to our own, such exceedingly diverse groups as the marsupials, the sloths, the elephants, the camels, and the deer, all reached their maximum of size and variety of strange forms, the most developed of which then became extinct. Others of a lower and more generalised type, but equally bulky, had successively disappeared at the termination of each subdivision of the Tertiary age. It is here that we can trace the specialisation and increase in size of the horse-tribe and of the deer; the latter passing from a hornless state to one of simple horns, gradually increasing in size and complexity of branching, till they culminated in the great Irish elk, which was the contemporary of the mammoth and man in our own country.

Dr. A. S. Woodward, keeper of Geology in the British Museum, discussed this curious phenomenon in his presidential address to the Geological Section of the British Association in 1909; and a few extracts will show how widespread are these facts, and the great interest they have excited. After sketching out the whole course of animal development, and showing how universal is the law (much emphasised by Darwin), that the higher form of one group never developed from similar forms of a preceding lower
type, but that both arose from an early, more generalised type, he says:

"To have proved, for example, that flying reptiles did not pass into birds or bats, that hoofed Dinosaurs did not change into hoofed mammals, and that Ichthyosaurs did not become porpoises, and to have shown that all these later animals were mere mimics of their predecessors, originating independently from a higher yet generalised stock, is a remarkable achievement."

Then comes a reference to the subject we are now discussing:

"Still more significant, however, is the discovery, that towards the end of their career through geological time, totally different races of animals repeatedly exhibit certain peculiar features which can only be described as infallible marks of old age. The growth to a very large size is one of these marks, as we observe in the giant Pterodactyls of the Cretaceous period, the colossal Dinosaurs of the Upper Jurassic and Cretaceous, and the large mammals of the Pleistocene and the present day. It is not, of course, all the members of a race that increase in size; some remain small until the end, and they generally survive long after the others are extinct.

"Another frequent mark of old age in races was first discussed and clearly pointed out by Professor C. E. Beecher of Yale. It is the tendency of all animals with skeletons to produce a superfluity of dead matter, which accumulates in the form of spines or bosses as soon as the race they represent has reached its prime and begins to be on the down grade. Among familiar instances may be mentioned the curiously spiny Graptolites at the end of the Silurian, the horned Pariasaurians at the beginning of the Trias, the armour-plated and horned Dinosaurs at the end of the Cretaceous, and the cattle or deer of modern Tertiary times. . . . The growth of these excrescences, both in relative size and complication, was continual and persistent until the climax was reached and the extreme forms died out . . .

"It appears, indeed, that when some part of an animal (whether an excrescence or a normal structure) began to grow relatively large in successive generations during geological time, it often acquired some mysterious impetus by which it continued to increase long after it had reached the serviceable limit. The unwieldy antlers of the extinct Sedgwick's deer and Irish deer (Fig. 95), for example, must have been impediments rather than useful weapons. The excessive enlargement of the upper canine teeth in the sabre-toothed tigers (Machærodon and its allies) must also eventually have hindered rather than aided the capture and eating of prey."  

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1 The species Machærodon neogenus, the skull of which is shewn in Fig. 94, appears to have had the largest canines of any species of the genus; and we are
Dr. Woodward further remarks:

"The curious gradual elongation of the face in the Oligocene and Miocene Mastodonts can only be regarded as another illustration of the same phenomenon. In successive generations of these animals the limbs seem to have grown continually longer, while the neck remained short, so that the head necessarily became more and more elongated to crop the vegetation on the ground. A limit to mechanical efficiency was eventually reached, and then there survived only those members of the group in which the attenuated mandibles became shortened, leaving the modified face to act as a proboscis. The elephants thus arose as a kind of afterthought from a group of quadrupeds that were rapidly approaching their doom." (See figures in last chapter, p. 229.)

This last is a specially interesting case, because it is the only one in which, without change of general environment or apparently of habits, a highly developed animal has retraced its latest steps, and then advanced in a new line of development, leading to the wonderful trunk and the enormous tusks of the modern elephant, as explained in Chapter XII. That these have now attained the maximum of useful growth is indicated by the fact that among the extinct forms are those in which they are developed to an unwieldy size, as in Elephas ganesa of North-West India, whose slightly curved tusks, sometimes nearly 10 feet long, must have put an enormous strain upon the neck, and the mammoth, whose greatly curved tusks were almost equally heavy.

Excessive Development of Lower Animals before Extinction

My friend Professor Judd has called my attention to the fact that many of the lower forms of life exhibited similar phenomena. The Trilobites (primitive crustaceans) which were extremely abundant in the Palæozoic rocks, in their last stages "developed strange knobs and spikes on their shells, so that they seemed to be trying experiments in excessive variation."

told by Mesers. Nicholson and Lydekker (Manual of Palæontology, ii. p. 1445). The upper carnassial tooth (the fourth premolar) "has four distinct lobes, and is thus the most complex example of this type of tooth known." The canines were about 9 inches long (more than half the length of the whole skull), and very unequally in proportion. It became extinct in South America in the Pleistocene epoch, about the same time as the last of the European species.
Fig. 94. — *Machærodus neogæus* (Sabre-Toothed Tiger).
From the Pleistocene of Buenos Ayres. One-eighth nat. size. (Nicholson's Paleontology)

Fig. 95.—Skeleton of Giant Deer (*Cervus giganteus*). (B.M. Guide.)
From a peat-bog in Ireland. One-thirtieth nat. size.
Figs. 96, 97 show typical forms of Trilobites (so called from their three-lobed bodies), while at a later period, when the whole group was approaching extinction, it produced spined forms like that shown in Fig 98.

**Eccentric forms of Ammonites**

At a later period the wonderfully rich and varied Ammonites show still more curious changes. Beginning in the Devonian formation they increased in variety of form and structure all through the succeeding formations, till they finally died out in the Cretaceous. The two species figured overleaf from the Trias (Figs 99, 100) may be taken as typical; but the variations in surface pattern are almost infinite. Visitors to Weymouth or Lyme Regis may find such in abundance under Lias cliffs, or in the former place along the shores of the backwater.

As time went on Ammonites increased in size, till in the Chalk formation specimens two or three feet diameter are
not uncommon. One of the largest English specimens in the British Museum (Natural History) was found at Rottingdean, near Brighton, and is 3 feet 8 inches across; but the

![Fig. 99. *Ceratites nodosus*. Trias.](image)

![Fig. 100. *Trachyceras aon*. Trias.](image)

largest known is an allied species from the Upper Chalk of Westphalia, and has the enormous diameter of 6 feet 8 inches.

It is an interesting fact that the very earliest Ammonites

![Fig. 101. *Cricoceras emerici*. Cretaceous.](image)

![Fig. 102. *Heteroceras emerici*. Cretaceous.](image)

were straight, and gradually became closely coiled. This form was maintained almost constant throughout the vast periods of the Mesozoic age, till towards the end, when the whole race was about to die out, they seemed to try to go back to their original form, which some almost reached (Fig.
105), while others, as Professor Judd remarks (in a letter), "before finally disappearing, twisted and untwisted themselves, and as it were wriggled themselves into extraordinary

![Fig. 103. — Macroscaphites ivanii. Cretaceous.](image)

![Fig. 104. — Hamites rotundus. Cretaceous.](image)

![Fig. 105. — Ptychoceras emericanum. Cretaceous.](image)

![Fig. 106. — Ancyloceras matheronianum. Gault. Late Ammonites. (From Nicholson's Palæontology.)](image)

shapes, in the last throes of dissolution." These strange forms (Figs. 96-106) are reproduced from Nicholson's Palæontology, and there are many others.
Special Features in the Development of Vertebrates

Another remarkable fact dwelt upon in Dr. Woodward's address is the remarkably small brains of those early types of vertebrates which were not destined to survive. The most striking cases are those of the Mesozoic reptiles and the Early Tertiary ungulate mammals, which both increased to such an enormous bulk, yet retained throughout an almost ludicrously small brain, as described in the last chapter. The same was the case to a somewhat less extent with the carnivorous mammals, the Creodonta and Sparassodonta of the Early Tertiaries both of the eastern and western hemispheres. These were sometimes as large as lions or bears, and had equally well developed canine teeth, but very small brains; and they all died out in Eocene or Early Miocene times, giving way to small ancestral forms of our modern carnivores, which then increased in size and developed larger brains, culminating in the highly intelligent fox and dog, cat and leopard, of our own day.

Yet another singular feature of some of the more highly developed vertebrates is the partial or total loss of teeth. This is well shown in the camels, which have only a pair of incisors in the upper jaw; while the whole vast family of the deer, cattle, and sheep have a completely toothless pad in the front of the upper jaws. This is apparently better adapted for rapid browsing of grass and low herbage—which is stored up in the paunch for rumination when at rest; and the absence of teeth as a defence is compensated by the possession of horns in a great variety of form and structure.

Even more remarkable is the total loss of teeth by modern birds, although the early types of birds possessed them. The bill, however, is often a very effective piercing or tearing weapon; and their strongly grasping claws and hooked bill render the birds of prey almost as powerful and destructive as the smaller members of the cat-tribe. This partial or total disappearance of the teeth has no doubt been helped on by the same principle which led to the persistent increase of useless appendages till checked by natural selection or till it led to the extinction of the entire race.
Germinal Selection

The numerous and varied phenomena which have been merely sketched in outline in the present chapter receive an approximate explanation by Professor Weismann's theory of germinal selection, which he first published in 1896. He appears to have been led to it by feeling the difficulty of explaining many of these phenomena by the "natural selection" of Darwin; but to have laid more stress on those of Section 2 of the present chapter than those of Section 3. He had in 1892 published his elaborate volume on The Germ-Plasm a Theory of Heredity, to which this later theory is a logical sequel.

During the last quarter of a century many striking discoveries have been made in what may be termed the mechanism of growth and reproduction; each successive advance in microscopic power and methods of observation have brought to light whole worlds of complex structure and purposive transformations in what was before looked upon as structureless cells or corpuscles. Some attempt will be made in a later chapter to discuss these primary life-phenomena; here it is only necessary to show briefly how Weismann's new theory helps us to understand the facts of life-development we have been dealing with. For this purpose I cannot do better than quote Professor Lloyd Morgan's very clear statement of the theory. He says:

"The additional factor which Dr. Weismann suggests is what he terms 'germinal selection.' This, briefly stated, is as follows:—There is a competition for nutriment among those parts of the germ named determinants, from which the several organs or groups of organs are developed. In this competition the stronger determinants get the best of it, and are further developed at the expense of the weaker determinants, which are starved, and tend to dwindle and eventually disappear. The suggestion is interesting, but one wellnigh impossible to test by observation. If accepted as a factor, it would serve to account for the inordinate growth of certain structures, such as the exuberance of some secondary sexual characters, and for the existence of determinate variations, that is to say, variations along special or particular lines of adaptation."

It may be well to give here Weismann's own definition

1 Habit and Instinct, p. 310.
of what he means by "determinants," as quoted by Professor J. Arthur Thomson in his fine volume on Heredity (p. 435):

"'I assume,' Weismann says, 'that the germ-plasm consists of a large number of different parts, each of which stands in a definite relation to particular cells or kinds of cells in the organism to be developed—that is, they are "primary constituents" in the sense that their co-operation in the production of a particular part of the organism is indispensable, the part being determined both as to its existence and its nature by the predestined particles of the germ-plasm. I therefore call these Determinants, and the parts of the complete organism which they determine Determinates.'”

Professor Thomson continues thus:

"But how many determinants are to be postulated in any given case? Weismann supposes that every independently variable and independently heritable character is represented in the germ-plasm by a determinant. A lock of white hair among the dark may reappear at the same place for several generations; it is difficult to interpret such facts of particulate inheritance except on the theory that the germ-plasm is built up of a large number of different determinants. It may be pointed out that almost all biologists who have tried to form a conception of the ultimate structure of living matter have been led to the assumption—expressed in very varied phraseology—of ultimate protoplasmic units which have the power of growth and division. It is in no way peculiar to Weismann to imagine biophors and to credit them with the powers of growing and dividing."

I quote these passages because Professor Thomson is thoroughly acquainted, not only with all Weismann's works, having himself translated some of them, but also with the work of other European and American writers on this very difficult problem; and he arrives at the conclusion, that Weismann's theory is the most carefully and logically worked out, and that some such conception is essential for a comprehension of the wonderfully complex phenomena of heredity. He also quite agrees with the conception that as these vital elements of the germ-plasm grow and multiply during the life of the organism, they must be nourished by fluids derived from it, and that there must be slight differences between them in size and vigour, and a struggle for existence in which the most vigorous survive. These

more vigorous *determinants* will lead to more vigorous
growth of the special part or organ they *determine*—hair,
horns, ornaments, etc.,—and wherever this increase is *useful*,
or even not hurtful, to the species, it will go on increasing,
generation after generation, by the survival of more and
more vigorous determinants.

* There is therefore both an internal and an external
struggle for existence affecting all the special parts—organs,
ornaments, etc.—of every living thing. With regard to the
more important structures, such as the limbs, the organs of
vision and hearing, the teeth, stomach, heart, lungs, etc., on
which the very existence of the individual as well as of the
species depends, survival of the fittest in due co-ordination
with all other parts of the body will continually check any
tendency to unbalanced development, and thus, generation
by generation, suppress the tendency of the more vigorous
determinants to increase the growth and vigour of its special
determinates, by elimination of the individuals which exhibit
such unbalanced growth. But in the case of appendages,
ornaments, or brilliant colours, which may begin as a mere
outlet for superfluous vital energy in dominant races, and
then be selected and utilised for purposes of recognition,
warning, imitative concealment, or for combat among males,
there will not be the same danger to the very existence of
the adult animal. It will, however, often happen that the
increase through germinal selection will continue beyond
the point of absolute utility to the individual; between
which and the point of effective hurtfulness there may be a
considerable margin. In this way we have a quite intelligible
explanation of the enormous development of feathers or
•decorative plumes in so many birds, enormous horns in deer
and antelopes, huge tusks in elephants, and huge canine
teeth in other quadrupeds. This view is supported by the
suggestive fact, that many of these appendages are retained
only for a short period, during the breeding season, when
vigour is greatest and food most abundant, and when
therefore they are least injurious.

Again, when acting in an opposite direction, the theory
serves to explain the rapid dwindling and final disappearance
of some useless organs, which mere disuse is hardly sufficient
to explain; such are the lost hind limbs of whales, the rudimentary wings of the Apteryx, the toothless beak of birds, etc. In such cases, after natural selection had reduced the part to a rudimental condition, any regrowth would be injurious, and thus determinants of increased vigour would be suppressed by the non-survival of the adult, leaving the weaker determinants to be crowded out by the competition of those of adjacent parts, the increased development of which was advantageous.

By this very ingenious, but, though speculative, highly probable hypothesis, extending the sphere of competition for nourishment and survival of the fittest from the organism as a whole to some of its elementary vital units, Professor Weismann has, I think, overcome the one real difficulty in the interpretation of the external forms of living things, in all their marvellous details, in terms of normal variation and survival of the fittest. We have here that "mysterious impetus" to increase beyond the useful limit which Dr. Woodward has referred to in his address already quoted, and which is also a cause of the extinction of species to which Mr. Lydekker referred us, as quoted towards the end of the preceding chapter.

Illustrative Cases of Extreme Development

Two examples of this extreme development have not, I think, yet been noticed in this connection. The wonderful long and perfectly straight spirally twisted tusk of the strange Cetaceous mammal, the narwhal, is formed by an extreme development, in the male only, of one of a pair of teeth in the upper jaw. All other teeth are rudimentary, as is the right tooth of the pair of which the left forms the tusk, often 7 or 8 feet long, and formed of a very fine, heavy ivory. The use of this is completely unknown, for though two males have been seen playing together, apparently, with their tusks, they do not fight, and their food, being small Crustacea and other marine animals, can have no relation to this weapon. We may, however, suppose that the tusk was originally developed as a defence against some enemy, when the narwhal itself was smaller, and had a wider range beyond the Arctic seas which it now inhabits; and when the enemy had become extinct this strange weapon went on
increasing through the law of germinal selection, and has thus become useless to the existing animal.

The other case is that of the equally remarkable Babirusa of the islands of Celebes and Buru, in which the canines of the males are so developed as to be useless for fighting (see Fig. 107). Here, too, there can be little doubt that the tusks were originally of the same type as in the wild boar, and were used for both attack and defence; but the ancestral form having been long isolated in a country where there were no enemies of importance, natural selection ceased to preserve them in their original useful form, and the initial curvature became increased by germinal selection, while natural selection only checked such developments as would be injurious to the individuals which exhibited them.

A Wider Application of the Principle of Germ-Selection

But it seems to me that the principle here suggested has a still higher importance, inasmuch as it has been the normal means of adding to and intensifying that endless variety of form, that strange luxuriance of outgrowths, and that exquisite beauty of marking and brilliancy of colour,
that render the world of life an inexpressible delight to all
who have been led to observe, to appreciate, or to study it.
It is through the action of some such internal selecting
agency that we owe much of what we must call the
charming eccentricity of nature—of those exuberances of
growth which cause the nature-lover to perpetually exclaim,
“What can be the use of this?” In the birds-of-paradise
we had long known of the tail-feathers, the breast-shields,
the masses of plumage from under the wings, the crests, the
neck-tippets, all in wonderful variety of shape and colour.
Then, in the island of Batchian I obtained a bird in which
from the bend of the wing (corresponding to our wrist) there
spring two slender and flexible white feathers on each side
standing out from the wing during flight, whence it has
been termed the standard-winged bird-of-paradise. Again,
a few years ago, there was discovered in the mountains of
German New Guinea another quite new type, in which,
from the corner of each eye, a long plume arises more than
twice the length of the bird’s body, and having, on one side
only of the midrib, a series of leaf-shaped thin horny plates
of a beautiful light-blue colour on the upper surface,
contrasting in a striking manner with the purple black,
ocrhre yellow, and rusty red of the rest of the plumage.

In the comparatively small number of birds-of-paradise
now known, we have a series of strange ornamental plumes
which in their shape, their size, their colours, and their point
of origin on the bird, exhibit more variety than is found in
any other family of birds, or perhaps in all other known
birds; and we can now better explain this by the assistance
of Weismann’s law in a highly dominant group inhabiting
a region which is strikingly deficient in animals which are
inimical to bird-life in a densely forest-clad country.

To this same principle we must, I think, impute that
superfluity of dazzling colour in many birds, but more especi-
ally in many insects, in which it so often seems to go far
beyond usefulness for purposes of recognition, or as a warning,
or a distracting dazzle to an attacking enemy.

Even in the vegetable kingdom this same law may have
acted in the production of enormous masses of flowers or of
fruits, far beyond the needful purpose of perpetuating the
species; and probably also of those examples of excessive brilliancy of colour, as in the intense blues of many gentians, the vivid scarlet of the Cardinal lobelia, or the glistening yellow of many of our buttercups. It is quite possible, therefore, that to this principle of "germinal selection" we owe some of the most exquisite refinements of beauty amid the endless variety of form and colour both of the animal and the vegetable world.

We may also owe to it the superabundant production of sap which enabled the early colonists of America to make almost unlimited quantities of sugar from the "sugar maple." Each tree will yield about four pounds of sugar yearly from about thirty gallons of sap; and it is stated by Lindley that a tree will yield this quantity for forty years without being at all injured; and large quantities of such sugar are still made for home consumption, the molasses produced from it being said to be superior in flavour to that from the sugar-cane. Here surely is a very remarkable case of an excessive surplus product which is of great use to man, and, so far as we can see, to man only. The same phenomenon of a surplus product is presented by the Para rubber-trees (Siphonia, many species), from which, at the proper season, large quantities of the precious sap can be withdrawn annually for very long periods, without injuring the trees or producing a diminution of the supply. There are also many other useful vegetable products, among those referred to in our fifteenth chapter, to which the same remark will apply; and it seems probable that we owe the whole of these, and many others not yet discovered in the vast unexplored tropical forests, to this far-reaching principle of "germinal selection."

General Conclusions as to Life-Development

Before quitting the subject of the course of development of the entire world of life as shown by the geological record, to which the present chapter is in a measure supplementary, it will be well to say something as to its broader features from the point of view adopted in this work. This is, that beyond all the phenomena of nature and their immediate causes and laws there is Mind and Purpose; and that the
ultimate purpose is (so far as we can discern) the development of mankind for an enduring spiritual existence. With this object in view it would be important to supply all possible aids that a material world can give for the training and education of man’s higher intellectual, moral, and aesthetic nature. If this view is the true one, we may look upon our Universe, in all its parts and during its whole existence, as slowly but surely marching onwards to a predestined end; and this involves the further conception, that now that man has been developed, that he is in full possession of this earth, and that upon his proper use of it his adequate preparation for the future life depends, then a great responsibility is placed upon him for the way in which he deals with this his great heritage from all the ages, not only as regards himself and his fellows of the present generation, but towards the unknown multitude of future generations that are to succeed him.

All of us who are led to believe that there must be a being or beings high and powerful enough to have been the real cause of the material cosmos with its products life and mind, can hardly escape from the old and much-derided view, that this world of ours is the best of all possible worlds calculated to bring about this result. And if the best for its special purpose, then the whole course of life-development was the best; then also every step in that development and every outcome of it which we find in the living things which are our contemporaries are also the best—are here for a purpose in some way connected with us; and if in our blind ignorance or prejudice we destroy them before we have earnestly endeavoured to learn the lesson they are intended to teach us, we and our successors will be the losers—morally, intellectually, and perhaps even physically.

Already in the progress of this work I have dwelt upon the marvellous variety of the useful or beautiful products of the vegetable and animal kingdoms far beyond their own uses, as indicating a development for the service of man. This variety and beauty, even the strangeness, the ugliness, and the unexpectedness we find everywhere in nature, are, and therefore were intended to be, an important factor in our mental development; for they excite in us admiration, wonder, and curiosity—the three emotions which stimulate
first our attention, then our determination to learn the how and the why, which are the basis of observation and experiment and therefore of all science and all philosophy. These considerations should lead us to look upon all the works of nature, animate or inanimate, as invested with a certain sanctity, to be used by us but not abused, and never to be recklessly destroyed or defaced. To pollute a spring or a river, to exterminate a bird or beast, should be treated as moral offences and as social crimes; while all who profess religion or sincerely believe in the Deity—the designer and maker of this world and of every living thing—should, one would have thought, have placed this among the first of their forbidden sins, since to deface or destroy that which has been brought into existence for the use and enjoyment, the education and elevation of the human race, is a direct denial of the wisdom and goodness of the Creator, about which they so loudly and persistently prate and preach.

Yet during the past century, which has seen those great advances in the knowledge of Nature of which we are so proud, there has been no corresponding development of a love or reverence for her works; so that never before has there been such widespread ravage of the earth's surface by destruction of native vegetation and with it of much animal life, and such wholesale defacement of the earth by mineral workings and by pouring into our streams and rivers the refuse of manufactories and of cities; and this has been done by all the greatest nations claiming the first place for civilisation and religion! And what is worse, the greater part of this waste and devastation has been and is being carried on, not for any good or worthy purpose, but in the interest of personal greed and avarice; so that in every case, while wealth has increased in the hands of the few, millions are still living without the bare necessaries for a healthy or a decent life, thousands dying yearly of actual starvation, and other thousands being slowly or suddenly destroyed by hideous diseases or accidents, directly caused in this cruel race for wealth, and in almost every case easily preventable. Yet they are not prevented, solely because to do so would somewhat diminish the profits of the capitalists and legislators who are directly responsible for this almost world-wide
defacement and destruction, and virtual massacre of the ignorant and defenceless workers.

The nineteenth century saw the rise, the development, and the culmination of these crimes against God and man. Let us hope that the twentieth century will see the rise of a truer religion, a purer Christianity; that the conscience of our rulers will no longer permit a single man, woman, or child to have its life shortened or destroyed by any preventable cause, however profitable the present system may be to their employers; that no one shall be allowed to accumulate wealth by the labour of others unless and until every labourer shall have received sufficient, not only for a bare subsistence, but for all the reasonable comforts and enjoyments of life, including ample recreation and provision for a restful and happy old age. Briefly, the support of the labourers without any injury to health or shortening of life should be a first charge upon the products of labour. Every kind of labour that will not bear this charge is immoral and is unworthy of a civilised community.

The Teaching of the Geological Record

But this is a digression. Let us now return to a consideration of the main features of the course of life-development.

The first point to which our attention may be directed is, that the necessary dependence of animal life upon vegetation is the cause of some of the most prominent and perhaps the most puzzling features of the early life-world as presented to us by the geological record. In the Palæozoic age we already meet with a very abundant and very varied aquatic life, in which all the great classes of the animal kingdom — sponges, zoophytes, echinoderms, worms, Mollusca, and vertebrates — were already fully differentiated from each other as we now find them, and existed in considerable variety and in great numbers. It is quite possible that the seas and oceans of those remote ages were nearly as full of life as they are now, though the forms of life were less varied and generally of a lower type. But, at the same time, the animal life of the land was very scanty, the only vertebrates that occupied it being a few Amphibia
and archaic reptiles. There were, however, a considerable number of primitive centipedes, spiders, Crustacea, and even true insects, the latter having already become specialised into several of our existing orders. All these occur either in the Coal formation of Europe or the Devonian rocks of North America, which seems to imply that when land-vegetation first began to cover the earth a very long period elapsed before any correspondingly abundant animal life was developed; and this was what we should expect, because it would be necessary for the former to become thoroughly established and developed into a sufficient variety of forms well adapted to all the different conditions of soil and climate, in order that they might be able to resist the attacks of the larger plant-feeding animals, as well as the myriads of insects when these appeared. So far as we can judge, the vegetable kingdom was left to develop freely during the enormous series of ages comprised in the Devonian, Carboniferous, and Permian formations, to which we must add the gap between the latter and the Triassic — the first of the Secondary formations. By that time the whole earth had probably become more or less forest-clad, but with vegetation of a low type mostly allied to our ferns and horse-tails, with some of the earliest ancestral forms of pines and cycads.

In the succeeding Secondary era the same general type of vegetation prevailed till near its close; but it was then everywhere subject to the attacks of large plant-devouring reptiles, and under this new environment it must necessarily have started on new lines of evolution tending towards those higher flowering plants which, throughout the Tertiary period, became the dominant type of vegetation. It seems probable that throughout the ages animal and vegetable life acted and reacted on each other. The earliest luxuriant land-vegetation, that which formed the great coal-fields of the earth, was probably adapted to the physical environment alone, almost uninfluenced by the scanty animal life. Then reptiles and mammals were differentiated; but the former increased more rapidly, being perhaps better fitted to live upon the early vegetation and to survive in the heavy carbonated atmosphere. This in turn became more varied and
better adapted to resist their attacks; and when the new type had become well established it quickly replaced the earlier forms; and the highly specialised reptiles, unable to obtain sufficient nourishment from it, and being also subject to the attacks of Carnivora of increasing power, and perhaps to some adverse climatic changes, quickly disappeared. Then came the turn of the Mammalia, the birds, and the more specialised insects, which, during this vast period, had been slowly developing into varied but always rather diminutive forms, the birds and mammals feeding probably on insects, roots, and seeds; but, in proportion as the reptiles disappeared, they were ready to branch out in various directions, occupying the many places in nature left vacant by these animals, and thus initiated that wonderfully varied mammalian life which throughout the whole Tertiary period occupied the earth's surface as completely, and almost as exclusively, as the reptiles had done during the middle ages of geological time.

The reactions of insects and flowers are universally admitted, as are those between birds and fruits; but the broader aspect of this reaction between animal and plant life as a whole has not, I think, received much attention. It does, however, seem to throw a glimmer of light on the very puzzling facts of the vast development of Secondary reptilian life, the apparent arrest of development of mammals during the whole vast period, and the rapid and abundant outgrowths of the higher types both of plants and of Mammalia in the Tertiary age.

The complete metamorphosis, broadly speaking, of both plant and animal life, on passing from the former to the latter epoch, is most startling. Such a change was, however, absolutely essential, not only for the production of the higher Mammalia and intellectual man, but also to provide for the infinitely varied needs of man's material, moral, and aesthetic development. The immensely varied plant-group of phanerogams has served to unlock for his service the myriad potentialities which lay hidden in protoplasm—the mysterious physical basis of all life. To this vast series of herbs and shrubs and forest-trees he owes most of the charms, the delicacies, and the refinements of his existence—almost all
his fruits, most of his scents and savours, together with a large part of the delight he experiences in mountain and valley, forest, copse, and flower-spangled meadow, which everywhere adorn his earthly dwelling-place.

To this we must add the infinitely varied uses to man of domestic animals, all supplied by the higher Mammalia or birds, while no single reptile has ever occupied or seems able to occupy the same place. We can only speculate on the part these have played in man's full development, but it must have been a great and an important one. The caring for cattle and sheep, the use of milk, butter, and cheese, and the weaving of wool and preparation of leather, must have all tended to raise him from the status of a beast of prey to that of the civilised being to whom some animals at all events became helpers and friends. And this elevation was carried a step further when the horse and the dog became the companions of his daily life, while fowls, pigeons, and various singing-birds added new pleasures and occupations to his home. That such creatures should have been slowly evolved so as to reach their full development at the very time when he became able to profit by them must surely be accepted as additional evidence of a foreseeing mind which, from the first dawn of life in the vegetable and animal cells, so directed and organised that life, in all its myriad forms, as, in the far-off future, to provide all that was most essential for the growth and development of man's spiritual nature.

In furtherance of this object it would be necessary to put a definite bar to the persistence of a lower type which might have prevented or seriously checked the development of the higher forms destined to succeed them; and this seems to have been done in the case of the Mesozoic reptiles by endowing them with such a limited amount of intelligent vitality as would not lead to its automatic increase under the stress of a long course of development, though accompanied by continual change of conditions and enormous increase in size. Hence the "ridiculously small brains" (as they have been termed) of these huge and varied animals. We may learn from this phenomenon, and the parallel case of the huge Dinocerata among the Tertiary mammals, that development of a varied form and structure
through the struggle for existence does not necessarily lead to an increase in intelligence or in the size and complexity of its organ the brain, as has been generally assumed to be the case.

If, as John Hunter, T. H. Huxley, and other eminent thinkers have declared, "life is the cause, not the consequence, of organisation," so we may believe that mind is the cause, not the consequence, of brain development. The first implies that there is a cause of life independent of the organism through which it is manifested, and this cause must itself be persistent—eternal—life, any other supposition being essentially unthinkable. And if we must posit an eternal Life as the cause of life, we must equally posit an eternal Mind as the cause of mind. And once accept this as the irreducible minimum of a rational belief on these two great questions, then the whole of the argument in this volume falls into logical sequence.

Life as a cause of organisation is as clearly manifested and as much a necessity in the plant as in the animal; but they are plainly different kinds (or degrees) of life. So there are undoubtedly different degrees and probably also different kinds of mind in various grades of animal life. And as the life-giver must be supposed to cause the due amount and kind of life to flow or be drawn into each organism from the universe of life in which it lives, so the mind-giver, in like manner, enables each class or order of animals to obtain the amount of mind requisite for its place in nature, and to organise a brain such as is required for the manifestation of that limited amount of mind and no more.

Thus and thus only, as it seems to me, can we understand the raison d'être of these small-brained animals. They were outgrowths of the great tree of life for a temporary purpose, to keep down the coarser vegetation, to supply animal food for the larger Carnivora, and thus give time for higher forms to obtain a secure foothold and a sufficient amount of varied form and structure, from which they could, when better conditions prevailed, at once start on those wonderful diverging lines of advance which have resulted in the perfected and glorious life-world in the midst of which we live, or ought to live.