lands. Then come the torn pages of the Permian rocks (which count as the last of the Palæozoic) that preserve little of the land vestiges of their age. Only after a long interval of time does the history spread out generously again.

The Permian rocks record an age of harshness and desolation in the world's history. They mark the phase of transition from the Palæozoic age of fish and amphibia to the Mesozoic age of reptiles.

It must be borne in mind that great changes of climate have always been in progress, sometimes stimulating and sometimes checking life. Every species of living thing is always adapting itself more and more closely to its conditions, which are always changing. There is no finality in adaptation. There is a continuing urgency towards change.

We do, however, find certain creatures of a lowly type which early adapted themselves to widespread simple conditions so completely that they have never been greatly modified or exterminated or replaced. For example, there is a little shell-fish called *Lingula* fitted to an obscure sedentary life in warm seas. This genus has endured without conspicuous change throughout the entire geological record.

On the other hand, geologists show us collections of fossils in which one can trace modifications in only a few thousand years, as climate, food and enemies have changed.

About these changes of climate that are always in progress on the earth's surface some explanations are necessary here. They are not periodic changes; they are slow fluctuations between heat and cold. The reader must not think that because the sun and earth were once incandescent the climatic history of the world is a simple story of cooling down. The centre of the earth is certainly very hot to this day, but we feel nothing of that internal heat at the surface; the internal heat, except for volcanoes and hot springs, has not been perceptible at the surface since first the rocks grew solid. Even in the Azoic or Archæozoic Age there are traces in ice-worn rocks and the like of periods of intense cold. Such cold waves have always been going on everywhere, alternately with warmer conditions. And there have been periods of great wetness and periods of great dryness throughout the earth. They depend upon astronomical and terrestrial fluctuations of extreme complexity into which we will not enter here.

And, in accordance, we find from the Record in the Rocks that there have been long periods of expansion and multiplication when life flowed and abounded and varied, and harsh ages

when there was a great weeding out and disappearance of species, genera, and classes, and the learning of stern lessons by all that survived.

It is probable that the warm spells have been long relatively to the cold ages. Our world to-day seems to be emerging with fluctuations from a prolonged phase of adversity and extreme conditions. Half a million years ahead it may be a winterless world with trees and vegetation even in the polar circles. At present we have no certainty in such a forecast, but as knowledge increases it may be possible that our race will make its plans thousands of years ahead to meet the coming changes.

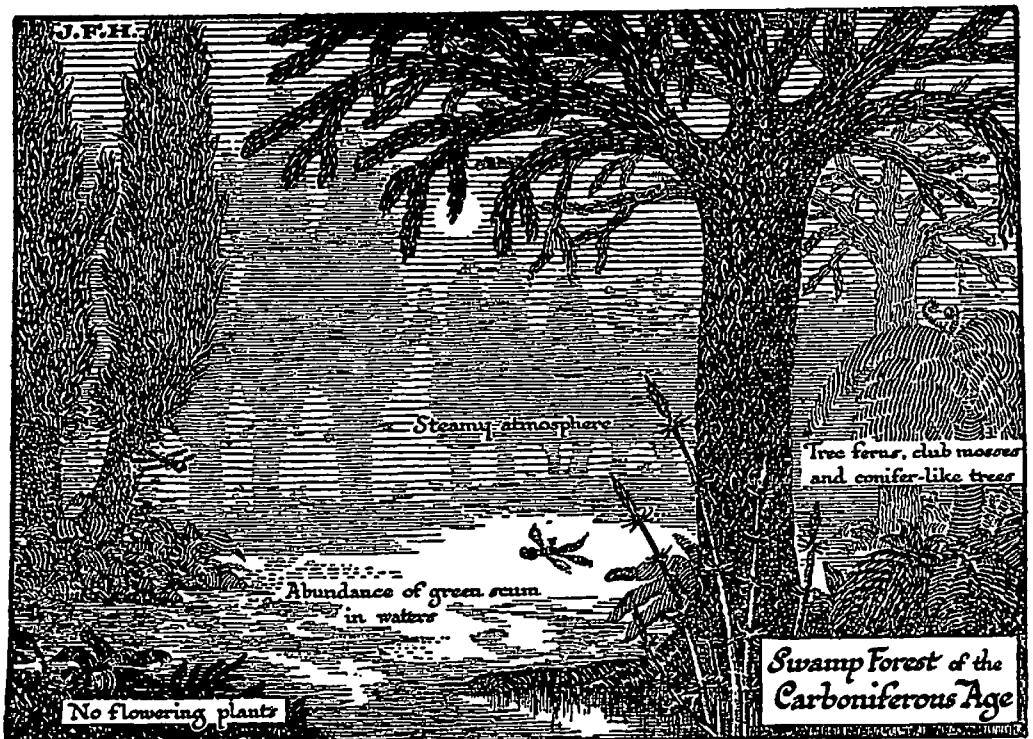


DIAGRAM OF LIFE IN THE LATER PALÆOZOIC AGE

Life is creeping out of the water. An insect, like a dragon-fly, is shown. There were amphibia like gigantic newts and salamanders, and even primitive reptiles in these swamps.

CHAPTER 4

THE AGE OF REPTILES

§ 1

We know that for many millions of years the wetness and warmth, the shallow lagoon conditions, that made possible the vast accumulations of vegetable matter which, compressed and mummified, are now coal, prevailed over most of the world. There were some cold intervals, it is true; but they did not last long enough to destroy the growths. Then that long age of luxuriant low-grade vegetation drew to its end, and for a time life on the earth seems to have undergone a period of world-wide bleakness. That concludes what we may call Part I—and by far the longest Part—in the history of life on this planet.

When the story resumes again after this arrest at the end of the Palæozoic Era, we find life entering upon a fresh phase of richness and expansion. Vegetation has made great advances in the art of living out of water. While the Palæozoic plants of the coal-measures probably grew with swamp water flowing over their roots, the Mesozoic flora from its very outset included palm-like cycads and low-ground conifers that were distinctly land plants growing on soil above the water level.

The lower levels of the Mesozoic land were no doubt covered by great fern brakes and shrubby bush and a kind of jungle growth of trees. But there existed as yet no grass, no turf or greensward, and no flowering plants at all, great or small. Probably the Mesozoic was not an age of very brightly coloured vegetation. It must have had a flora green in the wet season and brown and purple in the dry. Probably it was not nearly so beautiful as are the woods and thickets of to-day. There were no gay flowers, no bright autumn tints, before the fall of the leaf, because there was as yet no fall of the leaf. And beyond the lower levels the world was still barren, still un-

clothed, still exposed without any mitigation to the wear and tear of the wind and rain.

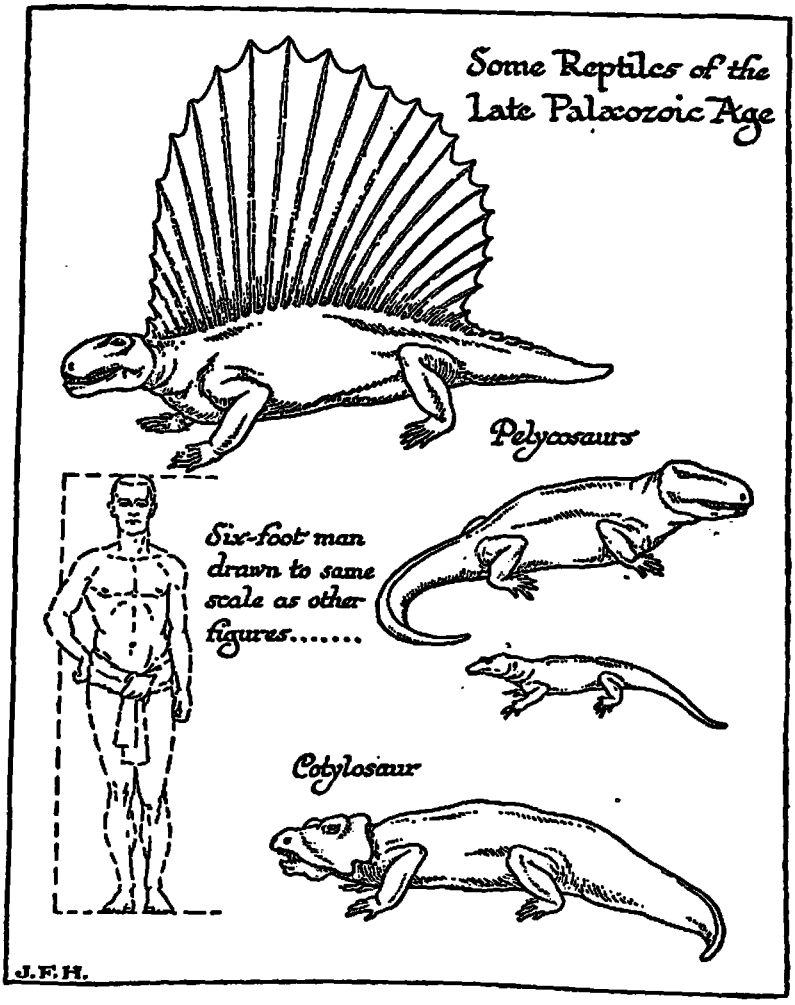
When one speaks of conifers in the Mesozoic the reader must not think of the pines and firs that clothe the high mountain slopes of our time. He must think of lowland evergreens. The mountains were still as bare and lifeless as ever. The only colour effects among the mountains were the colour effects of naked rock, such colours as make the landscape of Colorado so marvellous to-day.

Amidst this spreading vegetation of the lower plains the reptiles were increasing mightily in multitude and variety. They were now in many cases absolutely land animals. There are numerous anatomical points of distinction between a reptile and an amphibian; they held good between such reptiles and amphibians as prevailed in the carboniferous time of the Upper Palæozoic; but the fundamental difference between reptiles and amphibians which matters in this history is that the amphibian must go back to the water to lay its eggs, and that in the early stages of its life it must live in and under water. The reptile, on the other hand, has cut out all the tadpole stages from its life cycle, or, to be more exact, its tadpole stages are got through before the young leave the egg case. The reptile has come out of the water altogether. Some had gone back to it again, just as the hippopotamus and the otter among mammals have gone back; but that is a further extension of the story, that is a detail and a complication, to which we cannot give much attention in this *Outline*.

In the Palæozoic Period, as we have said, life had not spread beyond the swampy river valleys and the borders of sea lagoons and the like; but in the Mesozoic life was growing ever more accustomed to the thinner medium of the air, was sweeping boldly up over the plains and towards the hill-sides. It is well for the student of human history and the human future to note that. If a disembodied intelligence with no knowledge of the future had come to earth and studied life during the Early Palæozoic Age, he might very reasonably have concluded that life was absolutely confined to the water, and that it could never spread over the land. It found a way. In the Later Palæozoic Period that visitant might have been equally sure that life could not go beyond the edge of a swamp. The Mesozoic Period would still have found him setting bounds to life far more limited than the bounds that are set to-day. And so to-day, though we mark how life and man are still limited to five miles of air and a depth of perhaps a mile or so of sea.

we must not conclude from that present limitation that life, through man, may not presently spread out and up and down to a range of living as yet inconceivable.

The earliest known reptiles were beasts with great bellies

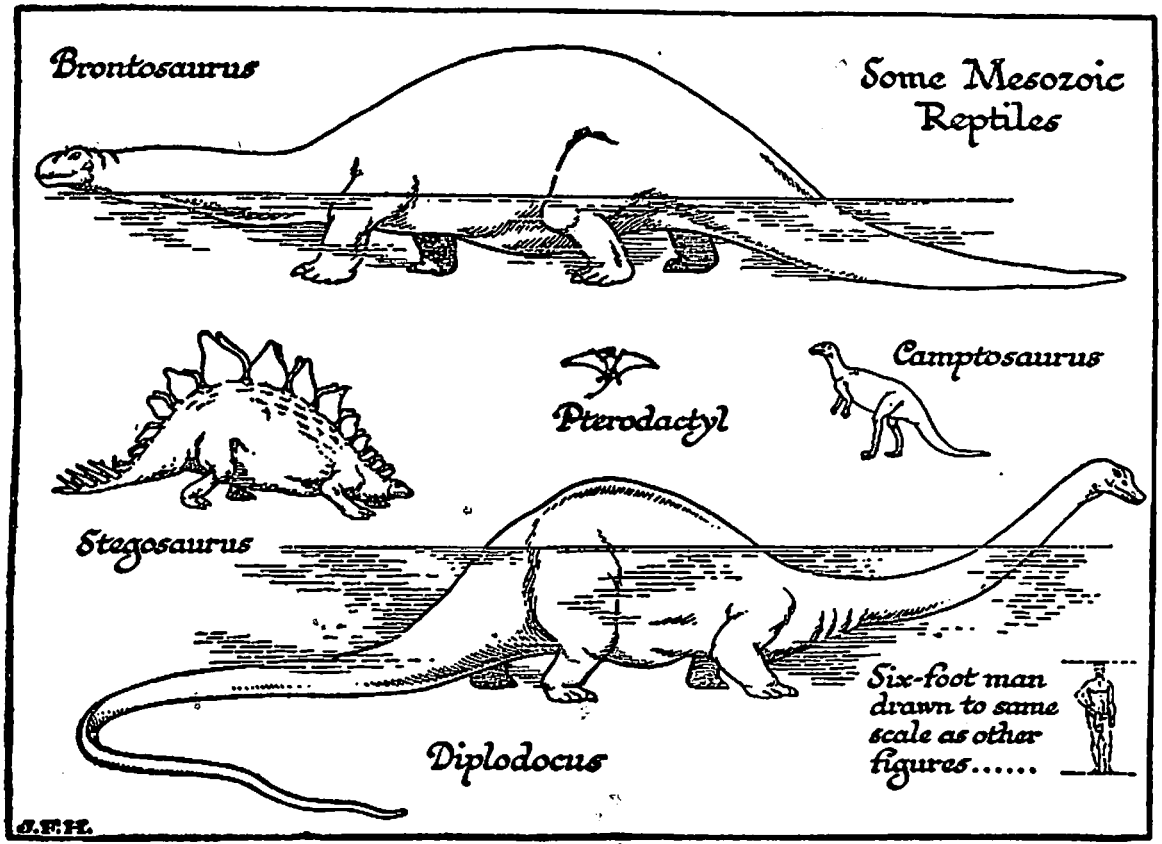


and not very powerful legs, very like their kindred amphibia. wallowing as the crocodile wallows to this day; but in the Mesozoic they soon began to stand up and go stoutly on all-fours, and several great sections of them began to balance themselves on tail and hind-legs, rather as the kangaroos do now, in order to release the fore-limbs for grasping food. The bones of one notable division of reptiles which retained a quadrupedal habit,

a division of which many remains have been found in South African and Russian Early Mesozoic deposits, display a number of characters which approach those of the mammalian skeleton and because of this resemblance to the mammals (beasts) this division is called the *Theromorpha* (beastlike). Another division was the crocodile branch, and another developed towards the tortoises and turtles. The *Plesiosaurs* and *Ichthyosaurs* were two groups which have left no living representatives; they were huge repitles, returning to a whale-like life in the sea. *Pliosaurus*, one of the largest Plesiosaurs, measured thirty feet from snout to tail tip—of which half was neck. The *Mosasaurs* were a third group of great porpoise-like marine lizards. But the largest and most diversified group of these Mesozoic reptiles was a varied group known as the *Dinosaurs*, many of which attained quite enormous proportions. In bigness these greater Dinosaurs have never been exceeded, although the sea can still show in the whales creatures as great. Some of these, and the largest among them, were herbivorous animals; they browsed on the rushy vegetation and among the ferns and bushes, or they stood up and grasped trees with their fore-legs while they devoured the foliage. Among the browsers, for example, was the *Diplodocus carnegii*, which measured eighty-four feet in length. The *Brachiosaurus* was still more colossal—it had a live weight of about 50 tons! Still larger bones are appearing. These great monsters had legs, and they are usually figured as standing up on them; but it is very doubtful if they could have supported their weight in this way out of water.

The bones end in cartilage: the joints are not very strong. Buoyed up by water or mud these monsters could have got along very well. The ordinary big Dinosaur has a bulky lower body and lower limbs, which were probably almost always submerged or floating. Neck, head and fore-limbs are much lighter in structure; these were probably kept out of water.

Another noteworthy type of Dinosaur was the *Triceratops*, a reptilian parallel of the hippopotamus, but with a rhinoceros-like horn. There were also a number of great flesh-eaters who preyed upon these herbivores. Of these, *Tyrannosaurus* seems almost the last word in "frightfulness" among living things. Some species of this genus measured forty feet from snout to tail. Apparently it carried this vast body kangaroo fashion on its tail and hind-legs. Probably it reared itself up. Some authorities even suppose that it leapt through the air. If so, it possessed muscles of a quite miraculous quality. A leaping elephant would be a far less astounding idea. Much more probably it


Some Mesozoic Reptiles
Brontosaurus
Pterodactyl
Camptosaurus
Stegosaurus
Diplodocus
Six-foot man drawn to same scale as other figures.....
G.F.H.

waded half submerged in pursuit of the herbivorous marsh saurians. It may have fought out its kills in channels and sheets of water like the Norfolk Broads or the Everglades of Florida.

§ 2

Dragons.

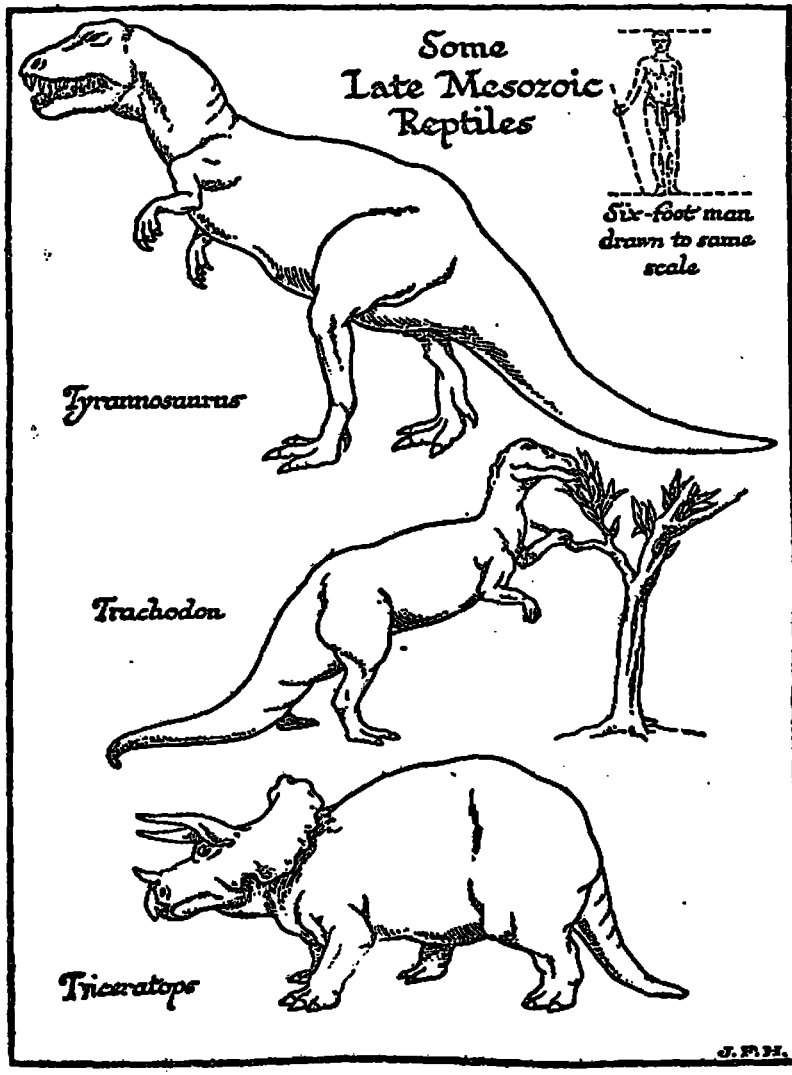
One special development of the dinosaurian type of reptile was a light, hopping, climbing group of creatures which developed a bat-like web between the fourth finger and the side of the body which was used in gliding from tree to tree after the fashion of the flying squirrels. These bat-lizards were the *Pterodactyls.* They are often described as *flying* reptiles, and pictures are drawn of Mesozoic scenery in which they are seen soaring and swooping about. But their breastbone has no keel such as the breastbone of a bird has for the attachment of muscles strong enough for long-sustained flying. They must have flitted about like bats. They must have had a grotesque resemblance to heraldic dragons, and they played the part of bat-like birds in the Mesozoic jungles. But bird-like through they were, they were not birds nor ancestors of birds. The structure of their wings was altogether different from that of birds. The structure of their wings was that of a hand with one long finger and a web; the wing of a bird is like an arm with feathers projecting from its hind edge. And these Pterodactyls, so far as we know, had no feathers. The feather is a very specialized skin structure which was developed only once in the evolution of life.

§ 3

The First Birds.

Far less prevalent at this time were certain other truly bird-like creatures, of which the earlier sorts also hopped and clambered and the later sorts skimmed and flew. These were at first—by all the standards of classification—Reptile. They developed into true birds as their reptilian scales became long and complicated fronds rather than scales, and so at last, by much spreading and splitting, feathers. Feathers are the distinctive covering of birds, and they give a power of resisting heat and cold far greater than that of any other integumentary covering except, perhaps, the thickest fur. At a very early stage this novel covering of feathers, this new heat-proof contrivance that life had chanced upon, enabled many species of

birds to invade a province for which the pterodactyl was ill equipped. They took to sea fishing—if, indeed, they did not begin with it—and spread to the north and south polewards beyond the temperature limits set to the true reptiles.



The earliest known bird (the *Archæopteryx*) had no beak; it had a row of teeth in a jaw like a reptile's. It had three claws at the forward corner of its wing. Its tail, too, was peculiar. All modern birds have their tail feathers set in a short compact

bony rump; the *Archæopteryx* had a long bony tail with a row of feathers along each side.

It is quite possible that most of the earliest birds did not fly at all, that there were birds before flying. They may have run, rather like hens, spreading their arms a little to balance and steer. But once the feathers developed, so light and strong, and so easy to spread, it was only a question of time before the wing began to carry the bird.

By the end of the Mesozoic, there were birds of many kinds—strong fliers, soarers, runners and divers with greatly reduced wings. One or two of these early birds had, it seems, retained the simple teeth of their reptilian ancestors.

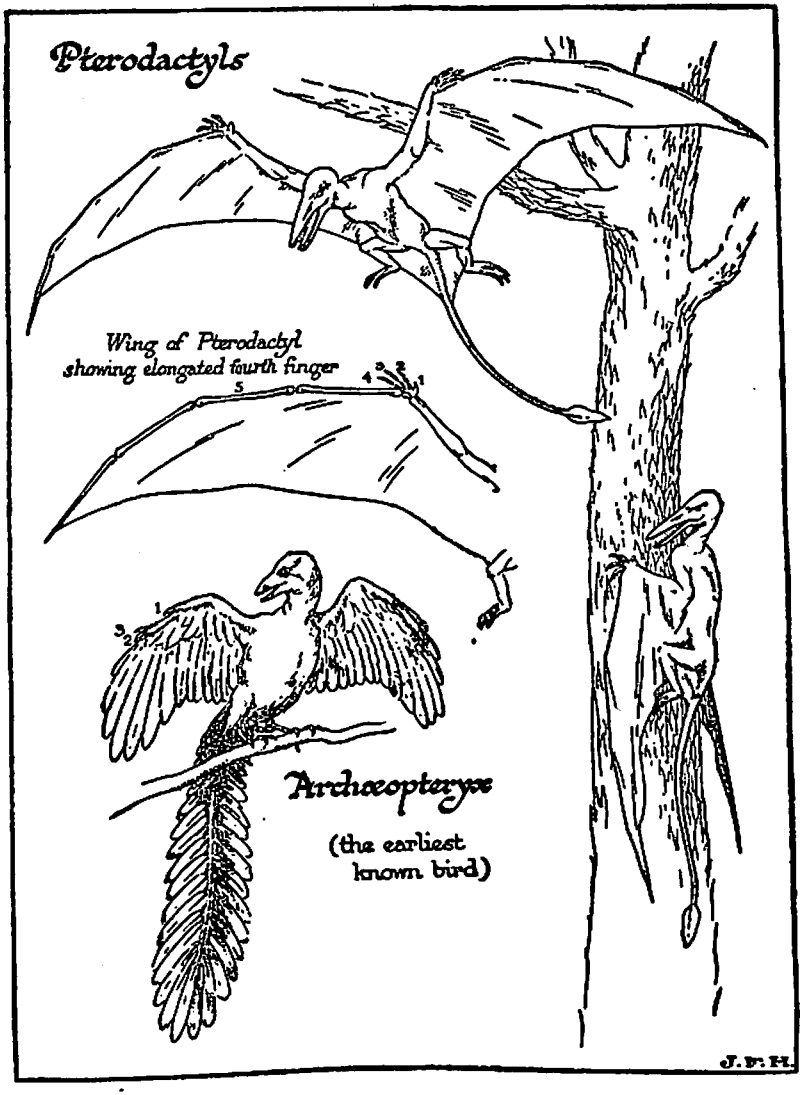
§ 4

An Age of Hardship and Death.

This great period of Mesozoic life, this second volume of the book of life, is indeed an amazing story of reptilian life proliferating and developing. But the most striking thing of all the story remains to be told. Right up to the latest Mesozoic rocks we find all these reptilian orders we have enumerated still flourishing unchallenged. There is no hint of an enemy or competitor to them in the relics we find of their world. Then the record is broken. We do not know how long a time the break represents; many pages may be missing here, pages that may represent some great cataclysmal change of terrestrial conditions. When next we find abundant traces of the land plants and the land animals of the earth, this great multitude of reptile species had gone. For the most part they have left no descendants. They have been "wiped out." The pterodactyls have gone absolutely; of the plesiosaurs and ichthyosaurs none is alive; the mosasaurs have gone; of the lizards a few remain, the monitors of the Dutch East Indies being the largest; all the multitude and diversity of the dinosaurs have vanished. Only the crocodiles and the turtles and tortoises carry on in any quantity into later times. The place of all these types in the spectacle of the world that the Cenozoic fossils presently unfold to us is taken by other animals not closely related to the Mesozoic reptiles and certainly not descended from any of their ruling types. A new kind of life is in possession of the world.

This apparently abrupt ending-up of the reptiles is, beyond all question, the most striking revolution in the whole history

of the earth before the coming of mankind. It is probably connected with the close of a vast period of equable warm conditions and the onset of a new austerer age, in which the winters



were bitterer and the summers brief but hot. The Mesozoic life, animal and vegetable alike, was adapted to warm conditions and capable of little resistance to cold. The new life, on the other hand, was before all things capable of resisting great changes of temperature.

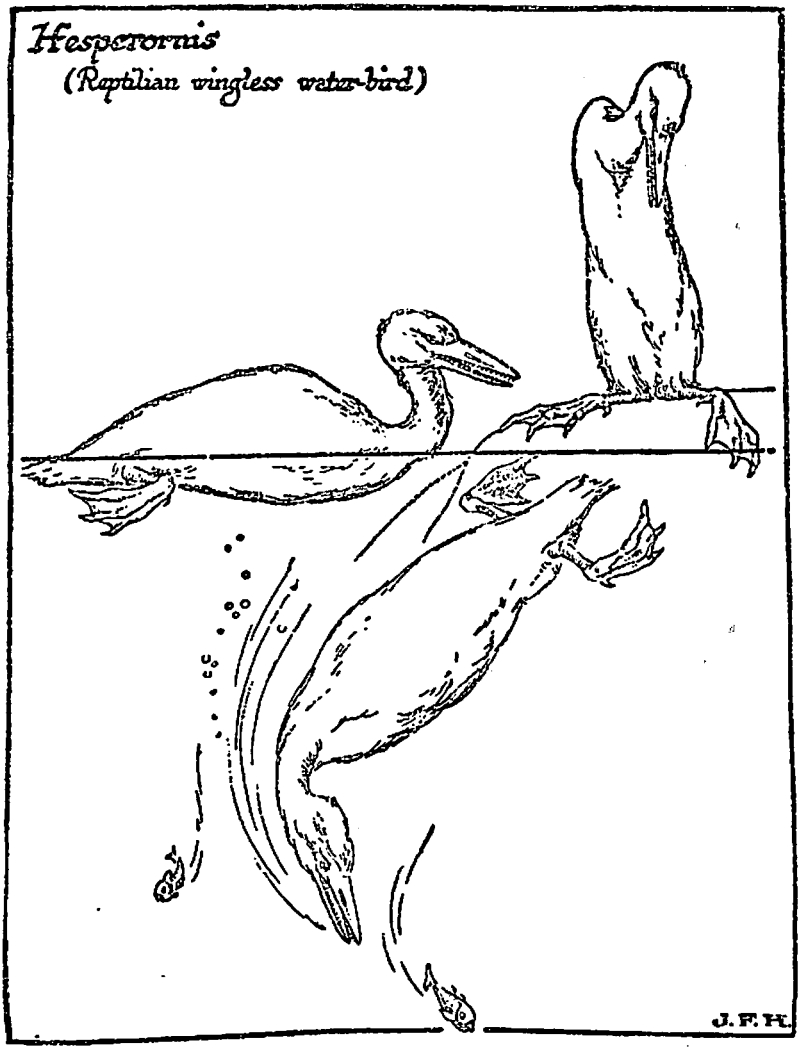
It was not only that the Reptiles as such had no fur nor feathers to equalize temperature conditions, but that the structure of the Reptilian heart is also not adapted to the maintenance of a high temperature against surrounding cold.

Whatever it was that led to the extinction of the Mesozoic reptiles, it was probably some very far-reaching change indeed, for the life of the seas did at the same time undergo a similar catastrophic alteration. The crescendo and ending of the Reptiles on land was paralleled by the crescendo and ending of the Ammonites, a division of creatures like squids with coiled shells which swarmed in those ancient seas. Most people are familiar with their huge coiling shells, sometimes two feet or more in diameter. All through the rocky record of this Mesozoic Period there is a vast multitude and variety of these Ammonites; there are hundreds of species, and towards the end of the Mesozoic Period they increased in diversity and produced exaggerated types. When the record resumes these too have gone. They have left no remnant at all. So far as the reptiles are concerned, people may, perhaps, be inclined to argue that they were exterminated because the Mammals that replaced them, competed with them, and were more fitted to survive; but nothing of the sort can be true of the Ammonites, because to this day their place has not been taken. Simply they are gone. Unknown conditions made it possible for them to live in the Mesozoic seas, and then some unknown change, some jolt in the orderly succession of days and seasons, made life impossible for them. No genus of Ammonite survives to-day of all that vast variety, but there still exists one isolated genus very closely related to the Ammonites, the Pearly Nautilus. It is found, it is to be noted, in the warm waters of the Indian and Pacific Oceans.

And as for the Mammals competing with and ousting the less fit reptiles, a struggle of which people talk at times, there is not a scrap of evidence of any such direct competition. To judge by the Record of the Rocks as we know it to-day, there is much more reason for believing that first the reptiles in some inexplicable way perished, and then that later on, after a very hard time for all life upon the earth, the mammals, as conditions became more genial again, developed and spread to fill the vacant world.

Nothing is known of the causes of this revolution in terrestrial conditions. In a previous section it has been said that if the pole of the earth were square to the plane of its orbit there would be no change of the seasons. Suppose now that in the

earlier part of the world's history the earth's equator was not inclined or inclined very little to the orbit, then there would be just those equable conditions the fauna and flora of the



Mesozoic Period seem to indicate. Suppose, however, that some unknown cause tilted the axis of rotation to its present obliquity. At once all over the earth would come the alternation of summer and winter, heat and cold, and life would have to adapt itself afresh or die. The Reptiles perished for the most part, the Ammonites and a great variety of other creatures certainly

perished, and only slowly was the abundance of life restored. But no one has ever been able to suggest a force that could suddenly twist our spinning world in that fashion. We do not know what jars and jolts the solar system may have suffered in the past. We are left guessing. Some huge dark projectile from outer space may have come hurtling through the planets and deflected or even struck our world and turned the whole course of evolution into a new direction.

Little projectiles of that sort are always striking us. They come flying into our atmosphere and catch fire with the heat of their rush through the air and burn—the shooting stars. Most of these meteors are burnt to nothing before they reach the ground, but many have reached and continue to reach the earth. Some in our museums are several yards in diameter.

Perhaps once one was big enough to produce a change such as we have supposed.

But this is a lapse into pure speculation. Let us return to our facts.

§ 5

The First Appearance of Fur and Feathers.

Were there mammals in the Mesozoic Period?

No doubt there were, but they were small, obscure and rare, and palæontology has very little to tell about them. Patiently and steadily the geologists gather fresh evidence and reason out completer conclusions. At any time some new deposit may reveal fossils that will illuminate this question. Certainly either mammals, or the ancestors of the mammals, must have lived throughout the Mesozoic Period. In the very opening chapter of the Mesozoic volume of the Record there were those Theromorph Reptiles to which we have already alluded, and in the later Mesozoic a number of small jaw-bones are found, entirely mammalian in character.

But there is not a scrap, not a bone, to suggest that there lived any Mesozoic mammal which could look a dinosaur in the face. The Mesozoic mammals or mammal-like reptiles—for we do not know clearly which they were—seem to have been all obscure little beasts of the size of mice and rats, more like a downtrodden order of reptiles than a distinct class; probably they still laid eggs and were developing only slowly their distinctive covering of hair. They lived away from big waters, and perhaps in the desolate uplands, as marmots do now; probably they lived there beyond the pursuit of the

carnivorous dinosaurs. Some, perhaps, went on all-fours, some chiefly went on their hind-legs and clambered with their fore-limbs. They became fossils only so occasionally that chance has not yet revealed a single complete skeleton in the whole long record of the Mesozoic rocks by which to check these guesses.

These little Theromorphs, these ancestral mammals, developed hair. Hairs, like feathers, are long and elaborately specialized scales. Hair is, perhaps, the clue to the salvation of the early mammals. Leading lives upon the margin of existence, away from the marshes and the warmth, they developed an outer covering only second in its warmth-holding (or heat-resisting) powers to the down and feathers of the Arctic sea-birds. And so the mammals, like the birds, held out through the age of hardship between the Mesozoic and Cenozoic Ages, to which most of the true reptiles succumbed.

All the main characteristics of the flora and sea and land fauna that disappeared with the end of the Mesozoic Age were such as were adapted to an equable climate and to shallow and swampy regions. But, in the case of their Cenozoic successors, both hair and feathers gave a *power of resistance to variable temperatures* such as no reptile possessed, and with it they gave a range far greater than any animal had hitherto attained.

The range of life of the Lower Palæozoic Period was confined to warm water.

The range of life of the Upper Palæozoic Period was mainly confined to warm water or to warm swamps and wet ground.

The range of life of the Mesozoic Period as we know it was largely confined to water and fairly low-lying valley regions under equable conditions.

But in each of these periods there were types involuntarily extending the range of life beyond the prevailing limits; and when ages of extreme conditions prevailed, it was these marginal types which survived to inherit the depopulated world.

That, perhaps, is the most general statement we can make about the story of the geological record; it is a story of widening range. Classes, genera, and species of animals appear and disappear, but the range widens. It widens always. Life has never had so great a range as it has to-day. Life to-day, in the form of man, goes higher in the air than it has ever done before; man's geographical range is from pole to pole, he goes under the water in submarines, he sounds the cold, lifeless darkness of the deepest seas, he burrows into virgin levels of the rocks, and in thought and knowledge he pierces to the centre of the