CHAPTER XXV

DISTRIBUTION OF ORGANISMS IN TIME AND SPACE

PART I. PALAEONTOLOGY

Introduction. Palaeontology is that portion of biological science that deals with organisms which once lived on the earth and are now found buried in it as *fossils.* A fossil is the rock-like remains of a former living organism. The word literally means something that is "dug up." Fossils are usually petrified teeth, bones, shells or wood. Soft parts, such as muscles and viscera, usually disintegrated too soon to become permanently recorded as fossils. Not all localities are favorable for such preservation. Pressure, elevation, foldings and erosion destroy fossils. Often they are discovered when a cut is made through a hill for a railroad or when uncovered by erosion. At rare intervals extensive deposits of fossils are discovered. It is, after all, remarkable that enough material has been recovered to make possible the science of Palaeontology, when one considers the very many conditions operating against the preservation and discovery of such specimens.

History of Palaeontology. Fossils were not unknown to the ancients. Aristotle thought they were examples of spontaneous generation taking place in the depths of the earth, and that such forms never had a chance to live on the surface. When hippopotamus bones were found in Sicily, Empedocles (450 B.C.) thought they indicated a great battle in ancient times between giants and Gods. Xenophanes of Colophon (500 B.C.) found fossil fish in rocks near ancient Syracuse and thought they had been caught in the rocks when these were under water. Nearly two thousand years later Leonardo da Vinci, a man of unusual common sense (or rather uncommon sense), urged that fossils were the remains of former living animals. In fact, Steno, professor of anatomy at Padua in 1669, compared the teeth of living sharks with similar fossil structures and asserted that they were identical. During the eighteenth century it was commonly believed that fossils were remains of animals that died in the great flood of Noah's time. For example, one specimen appeared to be the fossil skeleton of a child. This afterwards proved to be a large salamander.

It is said that Werner (1750–1817) first suggested that the relative age of different rock strata could be identified by their fossils. This method is employed today and is known as the "*Fossil Index.*" Werner also noted that fossils more nearly like existing living species occurred in more recent strata. Cuvier (Fig. 368), the distinguished comparative anatomist of France, studied fossils of Vertebrates unearthed near Paris. He asserted that they ought to be listed with living animals. He would not acknowledge that any living forms were descended from such ancestors and in attempting to account for their distribution claimed that there had been eight great successive catastrophes like the flood in Noah's time. Lamarck studied Invertebrates, showing, for example, that some fossil mollusks were similar to living forms and that some had long ago become extinct. This had a distant bearing on the theory of evolution which he developed. William Smith (1769–1839), an English surveyor, suggested that there had been a regular succession of layers of rock or strata.

FIG. 368. — Georges Cuvier.

In 1830, Charles Lyell (Fig. 369), an English geologist, published an epoch-making book in which he presented a new (and what is still held to be true) explanation of the history of the earth. He held that forces present today operated likewise in the past and that these forces not only brought about the changes in the earth's crust in the past but are doing so today; that it is a continuous process. Streams cut down continents, and transport material to new places. Changes in temperature, wind, waves, volcanoes and glaciers have long been at work. Animals died all along the line of time; they were later buried. This process took thousands upon thousands of years and in this period there was a succession of animal forms.

Estimating the Age of the Sedimentary Rocks. The history of the earth, back to remote times, is outlined in the stratified rocks, those on the surface being the newest and those at the bottom the oldest. Due to such agencies as earthquakes, the regularity of stratification is in many cases upset. The geologist has methods by which he *estimates* the total age of the entire strata of sedimentary rocks. This is done in three ways:

First. Estimating the age of the ocean. Considering the present salt concentration of seawater, the rate at which it is increasing, and assuming a "fresh-water" ocean to begin with, the conclusion is that oceans are about 100 million years old.

Second. Rate of sedimentation. Fossils are found only in the sedimentary rocks, the total thickness of which amounts to 75 miles. At the present rate of sedimentation, about 3000 million years would have been required to form these rocks.

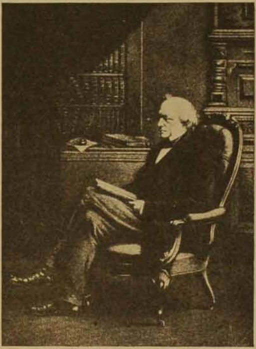

Fig. 369. — Charles Lyell, Geologist.

Third. Radioactivity. The rate at which radio-active uranium breaks down into helium and further into lead is determined. It is possible then to compute the length of time during which this disintegration has taken place and from this the age of the rocks in which these radio-active substances occur. Applying this method the conclusion is that some rocks are over 1000 million years old.

The geologist divides the portion of the earth's history with which he is concerned into great *Eras*, each of which is variously divided into *Periods*. He estimates a total length of time and then apportions a certain percentage of this to each era and period, determined by the thickness of the strata and other factors. The student can see that geologic time has not the precise character of time in human history. The periods are often named after localities where rich deposits of certain types of fossils have been found. The Cambrian Period, for example, is named after Cambria, the old Roman (Latin) name for Wales. *Fossils are found in the sedimentary rocks.*

Eras of Geologic Time. We will not discuss here the *early* formation of the planet, earth, since these questions belong to another field which might be called astronomical geology. Undoubtedly long ages were occupied in the work of sedimentation, during which many geologists recognize five *Eras*, first an older *Archeozoic* and later *Proterozoic*, these two comprising about 55% of geologic time, *according to Professor Schuchert*, who assumes that these ancient *Eras* existed for 275 million years. Geologists often combine both periods into the *Precambrian*. Following the Precambrian and extending down to the present, a period of 225 million years, are *three great Life Eras*. *Most of the fossils which give distinct evidence of plant and animal structure come from these strata. It is evident that the Life Eras comprise less than half of the estimated age of the sedimentary rocks.* Professor Schuchert truly says: " Any one wishing to be impressed with the immensity of *Geologic Time* should stand on the brink of the Grand Canyon in Arizona and reflect on how long it has taken the Colorado River to cut this nearly mile-deep gorge, the most beautiful and impressive in the world. He should also think of how long it has taken the seas to lay down this depth of *Paleozoic Strata* and the more than two miles of *Proterozoic* sediments beneath them. Having done all this, he should remind himself that after all, he has seen but a small part of the whole geologic column." The present tendency as noted above, is to increase Professor Schuchert's estimate of geologic time.

The *Life Eras* are first the ancient *Paleozoic*, followed by the *Mesozoic* and later by the *Cenozoic*. Each *Era* is subdivided into *Periods* characterized by fossils indicating the plant and animal life and presenting evidences of oceanic and continental changes as well as modifications in climate.

Geologic Time Table. The following table indicates how the geologist divides the great *Life Eras*.

GEOLOGIC TIME TABLE

Era	Duration Millions of Years 500–1000 (Estimate)	Periods	Characteristic Life Forms
Cenozoic	Three to five per cent	Quaternary Recent or Post-glacial Pleistocene or Glacial Tertiary Pliocene Miocene Oligocene Eocene (dawn)	Age of Man-Intelligence. Age of Mammals and Seed Plants: Birds and Fishes like present-day types: There was a great evolution of Mammals. The gigantic reptiles of the preceding age are gone, leaving types like present-day reptiles. Vast migrations during latter part of this Era. Then came glacial periods also.
Mesozoic	Five to ten per cent	Cretaceous (Upper) Comanchian (Lower Cretaceous) Jurassic Triassic	The great age of reptiles, dinosaurs; pterodactyls, ichthyosaurs. First Birds (toothed) and reptile-mammals. Plants, marine invertebrates and insects attain modern condition. Modern bony fishes have arrived.
Paleozoic	Fifteen to twenty-five per cent	Carboniferous *a.* Permian *b.* Pennsylvanian *c.* Mississippian Devonian Silurian Ordovician Cambrian	Amphibians the dominant land vertebrates; Great Coal Age. Swamps and dominance of Pteridophyte Plants and Pteridosperms. First insects and reptiles. Armored (archaic) fish abundant. Great invertebrate evolution. Many of these forms not persisting.
Proterozoic	?	Traces of fossils	These two Eras sometimes called the Precambrian.
Archeozoic	?-many-?	No fossils found	

The following summary is a brief commentary on the changes which took place as period succeeded period.

Precambrian. In the Proterozoic, calcareous Algae and even traces of Annelids have been found.

Paleozoic Era. *Cambrian.* All the phyla of invertebrate animals are represented but not necessarily by present-day forms. Crab-like animals called Trilobites, and Brachiopods, mollusk-like forms but with a dorsal and ventral shell, occur in great numbers. Gasteropods and Cephalopods began to increase.

Ordovician. The seas swarmed with a great variety of Invertebrates. There were reef-building corals and indications that fresh-water fishes had appeared.

Silurian. Great wealth of Invertebrates. Land plants appeared and also scorpions and some fresh-water fishes. The climate was warm and moist but large areas gradually become arid.

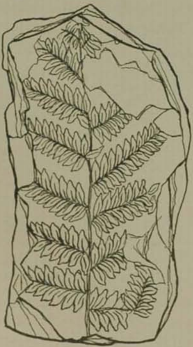

FIG. 370. — Fossil fern from carbonaceous shale.

Devonian. More green plants covered the land, the dominant Invertebrates decreased and fishes came into the ascendancy. Many sharks and large-headed lung fishes. There were large fern-like plants, lycopods. No insects as yet. The Amphibia emerged. The fresh waters contained many fishes.

Mississippian. The leading Invertebrates receded from their erstwhile dominant position. Great marine sharks, feeding on shelled forms, may have been responsible for this. Plant life advancing.

Pennsylvanian. The climate was warm and pleasant with abundant rains. Oceanic and continental changes formed great swamps. A wealth of spore-bearing plants and the spores scattered by rain and wind. There were ferns (Fig. 370), giant lycopods and horsetails and seed-bearing ferns, the like of which no longer exist, the so-called pteridosperms; cycads appeared and conifer-like forms but no modern conifers or flowering plants. There were many air-breathing land animals, snails, insects, amphibia and some evidences of reptilian life. Toward the close of this period the great forests of spore-bearing plants vanished to form the coal beds. There were many cockroaches, dragon flies, scorpions and spider-like forms. Gradually the climate became drier and colder, causing modifications in the plant and animal life. There were repeated mountain formations.

The seas contained many Invertebrates. The first land Vertebrates to appear were the Amphibia, the " leading " land Vertebrates from the late Devonian on into the Pennsylvanian. These Amphibians are called Stegocephalia (Armored head). Some of them were ten feet in length and they lived in and out of the water.

Permian. During this period, smaller forms of insects appeared in place of the larger ancient types. Metamorphosis was introduced as an adaptation to a dry climate. Many small types of reptiles appeared and Cycads, more adapted to a colder climate.

Mesozoic Era. This has been called the *Age of Reptiles.* They dominated as do now the birds and mammals. Giant herbivorous and carnivorous forms there were. Some types became adapted to marine life and others developed mechanisms for flight. Early in the *Triassic* there arose small reptile-like, egg-laying Mammals.

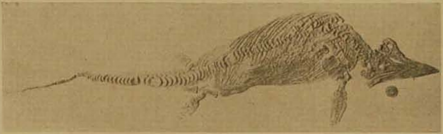

FIG. 371. — Ichthyosaur — Fish lizard. (From specimen at College of the City of New York. Photo by Stratford.)

These gave rise later to the suckling Mammals. The Stegocephalians disappeared in the Triassic. The Invertebrates characteristic of the Paleozoic disappeared. The early Mesozoic was the great Cycad Age.

Jurassic Period. Tree ferns, horse-tails, lycopods, cycads, ginkos and conifers formed the dominant vegetation, but the spore-bearing forms lost the ascendancy. Small frogs appeared and many types of reptiles. The Dinosaurs reached the maximum of their evolution and also marine reptiles, the Ichthyosaurs (Fig. 371) and aerial reptiles, called Pterodactyls. Archaeopteryx, the oldest bird ever found, was taken from the strata of the Jurassic.

Cretaceous. This period gets its name from chalk, which is characteristic of cretaceous deposits. These are made up of the calcareous skeletons of minute pelagic animals and plants prevalent in this period. Great ocean floods spread over the lands and there were marked changes in climate. Ichthyosaurs, Pterodactyls and Dinosaurs were on the decline. This is true of the Cycads also.

The last of the toothed birds, such as Hesperornis, appeared in the upper Cretaceous. During all this period the small, defenseless Mammals played a minor rôle. Flowering Plants were evident.

Cenozoic Era. This has been called the *Age of Mammals.* In the later *Eocene,* some Mammals (whales) became inhabitants of the sea. The little equine form, Eohippus, lived in this period. There were also toothless, flightless birds resembling the ostrich, but none of the ancient reptile types. The Mammals radiated out into the modern orders. Turtles, alligators and crocodiles attained their greatest development in the *Oligocene.* The climate was pleasant. In the *Miocene* the climate became cooler, mountain forming took place, and in some sections desert conditions prevailed. The *Miocene* has been called the Golden Age of Mammals. There were woody trees and shrubs resembling those of the present. Grasses (monocotyledons) appeared and played their part in the evolution of herbivorous mammals, such as horses.

In the *Pliocene,* elephant-like forms, the mastodons, evolved, 3-toed horses, llamas, giraffe-like camels, rhinoceroses, saber-toothed tigers, true cats, and in Asia, cattle, sheep and goats appeared. In South America that unique collection of ancient mammal types such as the tree sloths, ant-eaters, armadillos were left alone to develop. In the *Pleistocene,* the ground sloths appeared there. The true bears wandered over into North America from Asia. Africa was the scene of great activity in the evolution of its peculiar mammalian types which remain today, but are gradually being reduced by the onward march of human civilization.

Meaning of the Evidence. Invertebrates appeared long before Vertebrates, Fishes before Amphibia, Ferns before Flowering Plants, Reptiles before Birds and Mammals, etc. The lower strata contain generalized forms, the more superficial (later or younger) strata show more specialized forms. Many localities on the land have once been the floor of the sea. Corals are now found in fossil beds, hundreds of miles from the ocean. Tropical forms are found in localities that now have severe winters. North and South America were separated from Middle Eocene time to late Miocene. There are evidences of great migrations of animals in response to great climatic changes. Either the migration or the great environmental changes may have produced new species. Lull says: "The animals followed three great evolutionary lines, culminating in the Mollusks, the Arthropods and the Vertebrates;

of these the Cephalopods represent the final goal of molluscan evolution, the insects of arthropod evolution and the Mammals of vertebrate evolution."

Insect Evolution. The insects are supposed to have been derived from primitive Arthropods called *trilobites* (Fig. 184). They had amphibious habits, had a number of similar segments, and lived in the early Paleozoic Era. From this type also originated Crustacea and some of the Arachnida such as scorpions and the horseshoe crab, Limulus. The ancient insects were carnivorous and aquatic. During the late Permian and early Triassic there were few insects. Conditions had changed from a moist, warm climate to one cold and dry. Plant life was changing. Other types of animals responded to the change. Insects became more numerous in the lower Jurassic. The first Lepidoptera appeared in the middle Jurassic, and the first Hymenoptera in the upper Jurassic. These insects were plant eaters. In the Cretaceous appeared a wonderful development of Flowering Plants, and Lepidoptera and Hymenoptera associated with them. This proved to be of mutual advantage to both flower-visiting insects and the flowering plants and had a great deal to do with the rapid extension of these Spermatophytes. In the Tertiary, all the higher types of insects were well-established, social insects and parasitic forms as well. Lull says that the primary cause for the origin of insects from Trilobites was the great development of land flora and fauna in the Silurian and Devonian age of the Paleozoic Era. The profound change in climate in the Permian Period not only almost destroyed the Pteridophyte Flora, but introduced metamorphosis in insects by which they could survive inclemency of climate. The appearance of flowers in the Cretaceous is very important.

Life in the Carboniferous Periods. The Carboniferous division of the late Paleozoic comprises the Mississippian, Pennsylvanian and Permian Periods. During part of this period the climate was warm and moist. It was the great Coal Age during which the great Pteridophytes and Gymnosperms thrived. They were spore-bearing, rapid-growing and soft-wooded. These in turn were almost destroyed by the icy Permian climate. During the Mississippian, gigantic sharks were the dominant animals of the sea but not in the later periods.

Reptilian Evolution. The *Reptiles* probably originated from stegocephalian-like forms in the upper Carboniferous. The Permian furnished specimens of five out of the fifteen orders of Reptiles recognized by some authorities. From a short-legged, crawling, generalized type there developed cursorial, arboreal, aerial, fossorial, amphibious, aquatic and ambulatory types. This is an illustration of adaptive radiation. It also appears in the development of insects and was first clearly pointed out in the case of Mammals by Osborn. The Mesozoic has been called the Age of Reptiles, and America was the scene of their greatest developmental activity. Some were like modern crocodiles and turtles. There were great fish-lizards or Ichthyosaurs in an ocean which had no whales. There were also flying reptiles or Pterodactyls in the air which had no modern types of birds.

Dinosaurs. Certain reptiles called *Dinosaurs* were the dominant land vertebrates from the middle Triassic to the close of the Cretaceous. They ranged in size from about that of a cat to forms vastly larger than the elephant. The bodies of many were short and stocky, their legs were long and unlike modern quadruped reptiles, these walked or ran on their hind legs, the tail acting as a balancing organ as in the kangaroo. The early forms were much like modern lizards. But from this type many diverse forms developed; some of great size; some carnivorous, some herbivorous; some protected with a bony armor; some quadrupeds, and some bipeds.

Tyrannosaurus (Fig. 372). The "Tyrant Saurian" (Osborn) represents the extreme development of carnivorous Dinosaurs. It was forty-seven feet long. The head was over four feet long, its great jaws had teeth from three to six inches long, and the toes were armed with sharp curved claws, six or eight inches in length. The head was twenty feet above ground when the animal stood up. The bend of the knee was six feet above the ground. Its forelimbs were small and it moved about on its hind limbs, and was *digitigrade*, like an ostrich. Its movements were slow and ponderous, hard to start, and difficult to stop. Its brain was small. It was one of the largest carnivorous animals that ever lived.

Brontosaurus, called the "Thunder Saurian" by Professor Marsh, was a great amphibious Dinosaur. Its skeleton was discovered near Medicine Bow, Wyoming, in 1898. A specimen sixty-six feet, eight inches long, was placed on exhibition at the American Museum of Natural History in New York, in 1905. Its estimated weight was 38 tons. It had a long, thick tail, a long neck, a short body and solid, heavy, pillar-like limbs. Its head was comparatively small. It probably ate soft plants and lived in shallow waters, rich in plant life, crawling out upon the land to lay eggs. Matthew appropriately names it, the "Leviathan of the Shallows."

The duck-billed Dinosaur, *Trachodon*, was over sixteen feet high when standing. It was herbivorous and the mouth was expanded into a broad duck-bill, covered with a horny sheath. The teeth totaled over 2000 in both jaws. The American Museum of Natural History in New York was fortunate in obtaining a rare specimen in which the skin has been preserved. The animal had

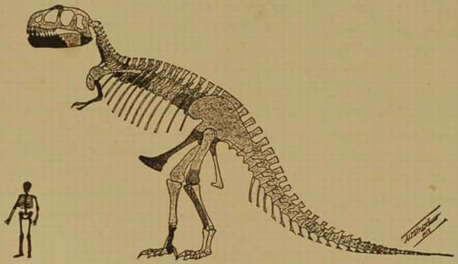

FIG. 372. — Tyrannosaurus rex. Compare with human skeleton at left. (American Museum of Natural History.)

apparently died a natural death and the soft parts, instead of decaying, were preserved for a time by desiccation in the hot sun, until petrifaction preserved it as a fossil mummy.

During the Upper Cretaceous period and near the close of the age of Reptiles, the climate of northern North America was similar to that prevailing now in Southern California. Plant fossils indicate the existence of fig trees, palms and the horsetail. With the close of the Mesozoic, the dominant position long maintained by the Dinosaur reptiles was lost. No trace of them appears in the Tertiary. They had thrived for millions of years. It is a great life cycle with its period of humble birth, its morning of youth, the noontime of its glory and its evening of death. Lull ascribes extinction to great elevation of land areas, the draining of great inland seas and the restriction of old haunts.

Evolution of Birds. Huxley has called Birds, "glorified reptiles," a simile justified by the results of embryological and anatomical comparisons. The origin of Birds from Reptiles is buried in obscurity. *Archaeopteryx* is the earliest known bird, found in the upper Jurassic and contemporary with early Dinosaurs. A description has already been given. It is not amiss here to recall the teeth in both jaws, the three-clawed fingers of the hand, and the long tail with a row of feathers on each side. *Hesperonis* was discovered in the Cretaceous of Kansas. It was about four and one half feet long. It could not fly, but had long powerful hind limbs and was probably an excellent diver and swimmer. It possessed teeth. *Ichthyornis* was much like our modern gulls and possessed the power of flight. It was smaller but had teeth. It was in most respects like modern birds. The birds of the next era, Cenozoic, were even more like modern birds.

Evolution of Mammals. Mammals are regarded as having arisen from small reptiles called *Cynodonts* found in the Triassic Period of the Mesozoic. The teeth of these reptile-mammals are divided into incisors, canines and molars, as is characteristic of the Mammals. It is claimed by some that the early mammals first appeared in South Africa. The increasing dryness of the climate and formation of dry land acted as stimuli to the development of a speedy form.

Mammals and birds were held in check during the Age of Reptiles. But they managed to survive and to assume a dominating position in the Cenozoic. They had developed a very important mechanism by which the body could maintain a constant temperature fairly well. This was later improved upon so that the maintenance of constant temperature enabled higher forms to exist, despite considerable changes in the temperature of the surrounding medium. The duck-bill and spiny anteater (Echidna) of Australia are considered survivors of early reptile-mammals. These two forms are oviparous, but higher mammals appeared and produced living young. Near the end of the Mesozoic pouched animals or Marsupials migrated in great numbers to Australia. Before any *higher* mammals had developed, the AustraKan Region had become isolated from South America and the Marsupials were destined to continue for ages in a quiet environment in which there was little evolution.

Evolution of Horse. It is impossible in this brief review to study the palaeontological history of all forms of Mammals. The history of the horse is one of the most complete studies in this field. The wild horses found on our western plains were not immediately indigenous to America. They were *feral* (escaped from domestication) descendants of domestic horses brought to this country from Europe by early expeditions, such as those of the Spanish. In many of these expeditions the human members perished, but the horses roamed the wilderness, left offspring and so spread. A more ancient history of the horse has been painstakingly investigated. It has been traced back by a series of stages to the lower Eocene, early in the Cenozoic Era. The scene of great activity in its development was in America. (1) *Eohippus* (Fig. 373), found in the lower Eocene, was about a foot high. The forefoot had four toes and the hind foot had three toes and each had a vestige of an additional toe.

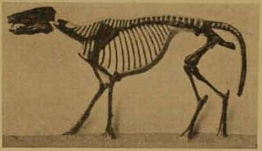

FIG. 373. — Eohippus, the little horse of the lower Eocene. (Am. Mus. Nat. Hist.)

The molar teeth had short crowns. The skull was small and the face and lower jaw were short. Fossil remains of these horses have been found in North America and Europe, but the latter disappeared toward the end of the Eocene. (2) *Mesohippus*, found in the Oligocene, was about eighteen inches tall. It has only three toes on each foot. The middle toe on each foot was longer than the others. It was similar in appearance to Eohippus, but the cusps on the teeth were united in ridges. It probably fed on juicy grass or leaves as Eohippus had done. (3) *Merychippus* was found in the Miocene and was about three feet high. All four feet had three toes as a rule, but the middle (third) was distinctly longer and the second and fourth well above the ground. The molar teeth had quite long crowns and the upper surface was worn down to a surface in which ridges of enamel alternated with dentine. The lower jaw was heavier. It crushed the green vegetation on which it fed. The face was longer.

There were many horses during the Miocene in western North America. The single middle toe was functioning more and more, while the toes lateral to it were becoming useless. This made possible swifter movements over the plains and was an important measure of defense. It is believed that North America and Asia were separated during part of the Tertiary but again united during the Pliocene.

(4) *Pliohippus.* This horse was about the same size as Merychippus. The two lateral toes had become further reduced. So Pliohippus was functionally a one-toed horse. The teeth had long crowns. (5) Equus, the fossil horse of the Pleistocene, was very much like the modern horse. It was five feet or more in height.

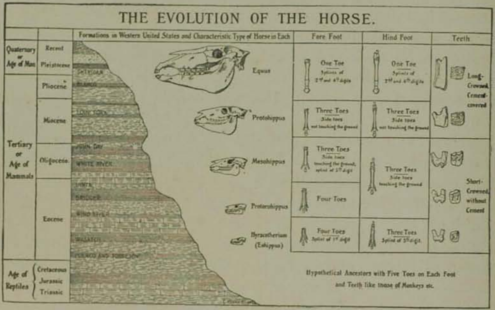

FIG. 374. — Evolution of the Horse. From an exhibit in the American Museum of Natural History. (Courtesy A. M. N. H.)

There was but one toe on each foot. The animal ran on its toes. The upper surface of the long crowned teeth presented an admirable mechanism for grinding its characteristic food. The face and the lower jaw were long.

The horses of the Pleistocene were descendants of Pliohippus. Some made their way northwest via the land bridge across Behring Sea to Asia and Europe and others wandered into South America across an Isthmus of Panama. But all the American horses died out. When Eohippus lived in America, the climate was humid and this little animal lived on marshy ground. Later the climate changed. The air became dry, and hard plains were formed so that one-toed forms were better suited to these conditions. The succulent vegetation changed to dried grass, and the change in teeth and form of skull were adapted to this (Fig. 374).

Evolution of Camel. The history of the Camel shows that its ancestor, *Protylopus*, was about the size of a rabbit and lived in North America. The front feet had four distinct, useful toes. The first was not represented. The hind feet had two toes. This animal occurs in the late Eocene. From it sprang three lines of descendants. Two of these have disappeared. The third line lived in North America until late Pliocene or Pleistocene, when it migrated to South America and Asia and Africa. The llama is a representative of the South American line. The Asiatic and African line is represented by the dromedary, or one-humped camel, and also the two-humped form. These have been domesticated for thousands of years. There are no other wild forms.

Evolution of Elephant. The evolution of the Elephant can be clearly traced from the late Eocene onwards. The fossil remains of a form named *Moeritherium* were found near Cairo, Egypt. This animal was probably about three and one half feet high. The Mastodons lived in the Pliocene and Pleistocene and were not in the same immediate line of ancestry as modern elephants. They ranged from Europe across Asia to Alaska and south through the United States but did not reach South America. They fed on twigs of evergreen trees. Remains have been found in swamps in several of the states, *i.e.*, New York, Indiana, Ohio. *Elephas primigenius* (Fig. 375), the hairy or woolly Mammoth, closely related to the living Asiatic elephant, was provided with long black hair and thick brown wool, enabling it to survive Arctic cold. It could withstand the rigors of an ice age. Frozen specimens have been taken from the ice in Siberia. One was discovered in 1799, and another in 1901. These animals were known to prehistoric man. Primitive artists made drawings of the Mammoth on the walls of caves. Mammoths flourished in the Pliocene and

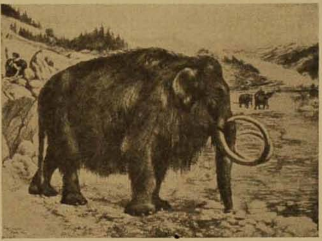

FIG. 375. — Elephas primigenius. After Osborn. From a painting by Charles Knight. (Courtesy Am. Mus. Nat. Hist.)

Pleistocene. They have been extinct for thousands of years. The only living representatives of the elephant group are the Indian and African species. *Elephas africanus* (Fig. 279), is larger, has enormous ears and longer tusks. Its ivory is more highly prized than that of the Indian elephant.

Appearance of Man. The Miocene was a period of great mammalian development. Climatic and earth changes took place in the Pliocene. Old land bridges disappeared and new ones were formed. Migrations of animals consequently took place so far as possible. Of all the forms, this was more possible in the case of Birds and Mammals. Man is thought to have appeared in this age. With the Pleistocene, during which the rise or elevation of the continents continued, the age of ice began. There were long periods of bitter cold alternating with short periods of warmer climate. Many kinds of animals were destroyed. Man was able to withstand the rigors of these long, terrible ages. The icy cold gradually receded further and further north and the Age of Reason and Intelligence and what is known as Human History finally began.

PART II. GEOGRAPHICAL DISTRIBUTION

Introduction. Living things occur everywhere — in the tropics; in arctic regions; on mountain summits; in valleys; in deserts; in ocean water; in brackish waters; in fresh waters; in caves; in rock crevices; in top soil; in the air. But fauna and flora are not evenly distributed. Africa has the gorilla, the chimpanzee and elephant, while Brazil, with conditions similar to those of Africa, has none of them but possesses the tapir, the sloth and New World monkeys. Why is not the tiger a native of America? Why are the Marsupials the prevailing Mammals of Australia?

According to the geographic distribution of animals, the earth's surface has been divided into zoogeographical regions, each characterized by an assemblage of forms peculiar to that region. Some of the forms are found in more than one region, but nevertheless the following distinct districts appear to be clearly indicated.

Zoological Regions. *A. Palaearctic Region.* This consists of Europe; Africa, north of the Sahara Desert; Asia, north of the Himalayas; Japan, etc.

B. Nearctic Region, consisting of North America and Greenland.

Let us discuss these two regions. Great groups of Mammals are represented here. Many forms found in both are closely related although differing in details. Examples of such similar forms are the bears, wild cats, foxes, hares and deer. Many trees are found common to both. They, of all the regions, are the most similar, and some students join them, forming the *Holarctic* region. It seems best to subdivide the Holarctic into the Palaearctic and Nearctic because of minor but distinct differences between the related forms occupying these regions of the earth. For example, the opossum, skunk, raccoon and rattlesnake are peculiarly North American forms.

C. Neotropical Region. This consists of tropical North America, Central America, West Indies, South America, etc. This region is represented by a great number of forms peculiar to it. For example, the jaguar, llama, peccary, tapir, sloth, armadillo, opossum and New World monkeys with prehensile tails. There are no native oxen, sheep or antelopes.

D. Ethiopian Region, consisting of Africa, south of the Sahara Desert, Madagascar and Mauritius. The characteristic animals of this region are the gorilla, chimpanzee, baboon, lemur, African elephant, hippopotamus, rhinoceros, zebra, giraffe, antelope, lion leopard and ostrich. Some are native *only* in this region.

E. Oriental Region. India, south of the Himalayas, Burma, Siam, Southern China, Sumatra, Java, Borneo and the Philippines. Typical animals of this region are the orang-utan; gibbon; tigers; jungle fowl, the ancestor of domestic fowls; the Indian elephant; the Indian tapir and rhinoceroses peculiar to this district.

F. Australian Region. Australia, Tasmania, Papua and New Guinea. Sometimes New Zealand is included with Australia. This region is unique because of an almost total absence of higher Mammals, the Eutheria. It is the home of Marsupials. The monotremes are still found there. It has its own characteristic snakes, lizards and birds. New Zealand is characterized as being the home of wingless birds and the lizard-like Rhyncocephalia, peculiar only to this island. The higher animals are few and small.

G. Polynesian Region. This region consists of the oceanic islands of the Pacific such as Fiji, Society Islands, Hawaiian Islands and Samoa. These islands are volcanic in origin, having been formed by relatively abrupt eruptions. The surrounding waters are very deep. The shores are often fringed with coral reefs. Darwin has said that the characteristic vegetation is herbaceous forms of large size such as bananas and palms. There is an absence on these islands of amphibia and terrestrial land mammals.

Peculiarities of Distribution. Now, although it is evident that the above-named regions have their own peculiar fauna and flora, yet we find many examples of similar forms occupying different regions. How can we account for the vagaries of geographical distribution? We can, for example, accept the belief in special creation as an explanation. According to this idea, when the earth was created, its different regions were stocked with the various plants and animals now found in them, and forms occurring there today are lineal descendants of the forms first placed therein. This explanation is satisfactory to one who simply accepts it and goes no further. But it will not satisfy the student who begins to investigate. It becomes less satisfactory as the investigation proceeds. After all, it will be noted in the brief discussion that follows, that a *creation* or *beginning* is not denied, in fact it is a necessary part of the natural explanation of geographical distribution. To one who studies the problem, the special creation belief is truly a vagary, a vast puzzle, expressive of the whims of a creator. On the other hand, one who grasps the full significance of the problem moves to a higher plane wherein he sees evidences of the operation of great natural processes, the handiwork and instruments of a truly sublime Creative Force.

We find diverse types occupying territory which as far as climate and other conditions are concerned are equally fitted for both. Darwin says: "If we compare large tracts of land in Australia, South Africa and western South America between latitudes 25 and 35 degrees, we shall find parts extremely similar in all their conditions, yet it would be impossible to point out three faunas and floras more utterly dissimilar." "Or again, we may compare the productions of South America south of latitude 35 degrees with those north of latitude 25 degrees, which consequently are separated by a space of ten degrees of latitude, and are exposed to considerably different conditions; yet they are incomparably more closely related to each other than they are to the productions of Australia or Africa under nearly the same climate."

Explanations of Distribution. The student of geographical distribution takes into account, as Bartholomew says, all available knowledge of plant and animal life and assumes that a process of evolution has taken place. He finds that the information furnished by the geologist as to changes in the earth's surface during geologic time and in the physical conditions is essential to an understanding of distribution. He assumes that this form and that form first appeared in centers of origin, *i.e.*, that they evolved in particular regions from which they migrated in various directions and that their present distribution was determined by barriers of one sort or another. Once having arrived at points far distant from their origin, they were prevented from returning to their original home or there might have been no necessity for so doing. This process has gone on for a long period of time, so long that the human mind cannot grasp any adequate conception of it.

Let us consider a few examples, illustrative of the above.

Effect of Barriers. The Himalaya Mountains extend more or less east and west, north of the equator. They act as a barrier separating Palaearctic Fauna from Oriental Fauna. The country south of the Himalayas is tropical. On the other hand, the mountain ranges of Western United States extend north and south parallel with the Pacific coast line. These do not act as barriers, which separate distinctly different faunas, as is accomplished by the Himalayas.

Peculiarities of American Faunas. A study of the Mammals of South America reveals two natural groups. One group consists of such forms as the sloths and armadilloes, the tree anteater, flat-nosed monkeys, marmosets, chinchillas and tree porcupines, peculiarly South American forms. The other group consists of forms such as the tapir, peccary (a wild pig), llama, many kinds of deer, cats, wolves, rabbits and rats. The animals of the second group, though now South American species and peculiar to it, are nevertheless allied to similar North American species. The first-named group has practically no representatives in North America, with the possible exception of the Canadian porcupine. They are peculiarly South American types. How can we explain this problem?

In the Miocene period of the Cenozoic Era, North and South America were not connected as they are now by the Isthmus of Panama. Fossil records inform us of the prevailing faunas in each region. The Mammals of North and South America in those days were entirely different. Later on, in the Miocene Period, the Isthmus of Panama was formed by elevation, and thus a land bridge made possible migrations of the peculiar South American forms northward and of North American forms southward. The fossil record of the geologic strata of that time gives evidence that this migration took place. It attained its height in the Pleistocene. At that time, however, began the great glacial epochs. During the periods of great cold, both regions lost most of their Mammals. Cold exterminated practically all the forms which had invaded North America from the south. The northern visitors to the south fared better, however. Many of them successfully competed with the native South American forms. The northerners did not retain all their original specific characters, and so today we find in South America two groups of Mammals peculiar to it. One group is peculiarly South American and always has been. It is the older of the two. The other resembles North American types, somewhat modified, due to long sojourn in the south.

Professor W. B. Scott states that North America and Asia have been connected and disconnected many times where Bering Sea and Strait now are. Many migrations in both directions across this land bridge took place, as is shown by the fossil record. Many American forms were derived from the Old World. Some have been here so long that they are considerably different from their Old World relatives. Others, however, are very similar to Old World types. They are regarded as recent immigrations to America. It appears that the present separation of North America and Asia took place recently, so far as geological time is measured. The American bears are forms derived by immigration from the Old World. The musk ox, now limited to America, only recently became extinct in Siberia, but once lived as far west as Great Britain, which at the time was connected with the neighboring mainland across the Channel.

Similar Forms at Widely Separated High Altitudes. Why is it that on the summits of mountains far distant from each other we find similar forms although the faunas at the base of these widely separated mountains are different? Examination shows that the mountain-top forms are arctic types, similar to forms living in a belt below the poles. Darwin explained the peculiar distribution as follows. Long ago the circumpolar belt was occupied by arctic types. The glacial periods came in the Pleistocene. As the wave of ice moved south, the southern forms moved further south and the arctic types moved south behind them. The mountains to the south became covered with ice and the arctic types occupied the country at the lower altitudes. As the glacial period gave way to a warmer climate, the arctic forms then present in the temperate regions of North America and in central Europe as far south as the Alps and the Pyrenees could take two courses. First: they could travel northward again to the circumpolar belt which their ancestors had occupied. Some apparently did this. Second: others could ascend the mountain slopes, as the warmer climate continued, to an altitude where arctic conditions prevail — and there they have remained marooned, as it were, until the present.

Island Faunas. Let us consider the problems peculiar to island distribution. Two types of islands are recognized.

1. *Continental Islands.* Continental Islands at one time were undoubtedly connected with the nearest mainland which they resemble in geological structure. If the separation has taken place within recent geological time and passage back and forth is comparatively easy, then we find great similarities in fauna and flora as for example that of the British Isles and the neighboring mainland. If such islands have been isolated from the nearest mainland for long periods of geologic time by a wide, deep gulf, then the island fauna is likely to be peculiarly unique. Long isolation from the competition characteristic of the vast stretches of a continent does not stimulate such marked modifications and evolution of new types. This is illustrated by the fauna of Australia. The typical mammalian population was marsupial at the time the first civilized men arrived. There were different marsupial types, such as rodent-like forms, carnivorous forms, some herbivorous, some insect eaters, but there were no eutherians except a species of dog, which had apparently been recently introduced. There are evidences that Australia has been separated from the nearest continent since the Mesozoic. During the long, long ages of isolation and in the absence of marked changes in conditions, there was no stimulus to the evolution of the higher orders of mammals.

2. *Oceanic Islands* are located at great distances from the nearest mainland. They are the peaks of submerged volcanic mountains. The surrounding waters are very deep. They are fringed or covered with coral formations. They usually have fewer kinds of

living organisms than similar continental areas. Darwin states that although New Zealand is 780 miles long, yet it has only about the same number of different flowering plants as a *very much smaller area* in England. It is also true that species occupying oceanic islands are peculiar to that locality. Furthermore, entire classes of continental land forms are often absent from oceanic islands. Let us consider some particular islands in more detail.

The Galapagos Islands form a group of five large islands and ten smaller islands located about 600 miles west of Ecuador. They are separated from each other by channels of deep water, swift currents, a number of miles apart. In structure and other respects these islands are similar to the Cape Verde Islands off the coast of Africa. But the faunas are entirely different. The fauna of the Galapagos group is distinctly American and that of the Cape Verde Islands is distinctly African.

Certain observations regarding Galapagos Island forms are illuminating. Although the fauna is fundamentally American, yet it is peculiarly Galapagos Islands, secondarily. Sea birds that can successfully navigate great stretches of ocean ways are about the same there as on the mainland. But the land birds, such as finches (Fig. 376), though showing basic similarities to mainland forms are Galapagos Island species. These small birds cannot easily travel over the long distance between Ecuador and the Islands. In some way, long ages ago, their ancestors from South America landed here, and here they have remained, and *isolation* under different general conditions and on special islands has provoked modifications that have produced peculiar types. The birds named cannot *easily* pass from island to island. When the original South American visitors arrived, they became isolated on separate islands and the evolution of special island varieties has taken place. We can understand why each island should have its own peculiar type. The Galapagos Islands are known to possess a unique type of tortoise, a very large form which has given its name to the islands. It is peculiarly a land form and cannot pass from island to island. Hence we can understand why each island, until recently (*i.e.*, before the islands had been visited by men), had its own particular variety of land tortoise. Fossil remains found on the mainland indicate that the present-day tortoises of the Galapagos Islands were derived from mainland forms. There are two kinds of large and related lizards resident here. One is a marine type. This can easily pass from island to island and there is little differentiation between them. On the other hand, there is a terrestrial type probably derived from the same ancestral form as the marine type. But the land lizards cannot move readily from island to island, so we find that each island has its own type.

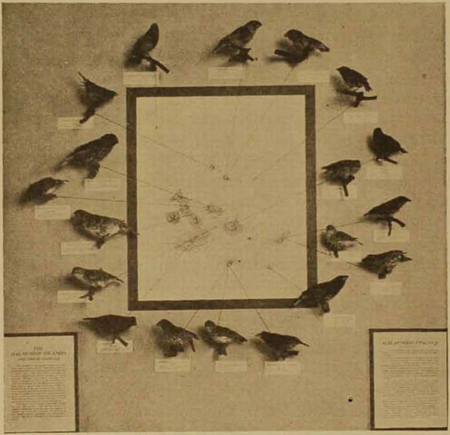

Photo of exhibit in American Museum of Natural History.

Fig. 376. — Distribution of Galapagos Island Finches. The islands probably received their original population from South America. Evolution of species peculiar to the islands is indicated. Darwin wrote: "—seeing this gradation and diversity of structure in one small intimately related group of birds, one might really fancy that from an original paucity of birds in this archipelago, one species had been taken and modified for different ends. — we seem to be brought somewhat near to that great fact — the first appearance of new beings on the earth." From — *The Voyage of the Beagle.*

The question arises as to how oceanic islands became populated; how the original visitors were able to survive such long ocean voyages.

Transportation over the Ocean. In the "Origin of Species," Darwin, in his discussion of Geographical Distribution, gives an account of many actual experiments which show that seeds can survive long contact with sea water. He indicates possible methods by which animals can be transported over seas. They may be transported in driftwood. Often collections of débris, forming natural rafts, break away from shores of rivers and are carried away possibly hundreds of miles. Insects and birds, favored by gales, have successfully traveled across many leagues of ocean. The chances against mammalian transportation are great. It has been noted that whereas oceanic islands do not possess native land mammals, yet bats related to the nearest mainland forms are found in them. Wingless insects are peculiar to long isolated oceanic islands. They are probably descendants of accidentally introduced winged visitors.

Amphibians are never endemic forms in oceanic islands although they thrive there when introduced. Sea water is very injurious to them and they cannot survive long immersion in it. There is a notable absence of gales in the region of the Galapagos Islands. There have been few accidental visitors for a long period. However, the Bermuda Islands are about the same distance off the North American Coast, and a number of North American forms are found there which are similar to the mainland types. The problem of transportation is easier, and mainland visitors are more numerous. The Bermudas lie in the pathway of storms from the West Indies and from the southern states and these gales would help the transportation of the types found in the islands.

Conclusion. The present-day distribution of plants and animals is explained by natural forces and conditions. We have evidence that types had their beginning in certain centers of evolution from which they migrated in various directions. They were separated by various barriers, some of which arose after the procession of forms had passed on. Subsequent generations were changed by the new conditions which appeared as time went on. In 1883 the Island of Krakatoa in Sunda Strait between Java and Sumatra was the scene of a great volcanic eruption in which the plants and animals were practically all destroyed. Yet by 1920, there were over 500 species established there again and they are just such forms as are found in the near-by larger islands.

The most widely distributed forms are those most independent of barriers. Examples are powerful flying forms and Man and the forms transported intentionally or accidentally by him.

Analysis of fossil records indicates that the ancestors of certain existent types evolved in a center of origin which may be far removed from present-day distribution. There is evidence that migration in various directions took place. The place of origin may not today possess any representative of present-day descendants. Independent geological evidence throws light on the course of distribution and the reason for it. Examples — the horse, camel and llama.

The organic forms occupying a continental island are related to those of the mainland with which the island was once connected. In many cases geological evidence indicates the former connection. If islands are relatively near the mainland, as, for example, the British Isles, the fauna and flora are very similar in the two localities.

If, however, the continental island has been separated from the mainland for a long period of time by a wide, deep gulf, then although the animals in each appear to have been derived from the same stock, yet the island forms are endemic and also very primitive and possibly in some respects degenerate, having undergone little evolution during the long period of isolation. Examples — fauna of Madagascar, New Zealand and Australia.

The organic forms resident on oceanic islands, which are volcanic in origin, are peculiar and endemic but are fundamentally related to forms found on the nearest mainland from which their ancestors could have been accidentally carried by gales. Insects and birds would have been carried along by air currents, but terrestrial types on floating fragments. Long periods of isolation would account for the development of endemic characteristics. Terrestrial vertebrates, and especially mammals, are not likely to be thus transported, and are poorly represented. Amphibians to which sea water is toxic are not found. Example — fauna of Galapagos and Hawaiian Islands.

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