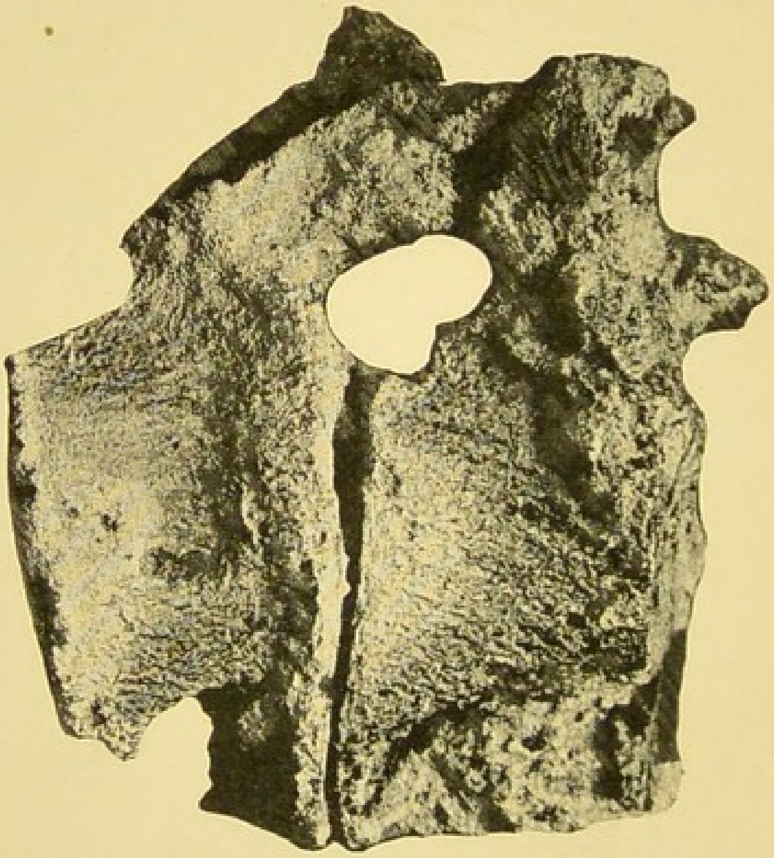
THE GEOLOGICAL EVIDENCES OF EVOLUTION

ANGELO HEILPRIN



IRON VERTEBRÆ OF FOSSIL MAN.

From a ferruginous sand-rock on Big Sarasota Bay, west coast of Florida (p. 86).

THE GEOLOGICAL EVIDENCES OF EVOLUTION.

BY

ANGELO HEILPRIN.

PROFESSOR OF INVERTEBRATE PALEONTOLOGY AT, AND CURATOR-IN-CHARGE OF, THE ACADEMY OF NATURAL SCIENCES OF PHILADELPHIA.

AUTHOR OF

"TOWN GEOLOGY: THE LESSON OF THE PHILADELPHIA ROCKS," "THE GEOGRAPHICAL AND GEOLOGICAL DISTRIBUTION OF ANIMALS" (INTERNATIONAL SCIENTIFIC SERIES), ETC.

PHILADELPHIA:

PUBLISHED BY THE AUTHOR.

ACADEMY OF NATURAL SCIENCES.

1888.

G469

TO MY DEAR PARENTS,

TO WHOSE LOVE FOR NATURE I OWE

WHAT LITTLE OF SCIENTIFIC KNOWLEDGE I POSSESS,

AND WHOSE KINDLY SYMPATHY WITH MY WORK

HAS BEEN THE SPUR TO MY LABORS,

THE FOLLOWING PAGES ARE AFFECTIONATELY INSCRIBED.

A. H.

WHILE much has been done toward popularizing the subject of Evolution, whether in the way of expounding the principles of the doctrine, or of gathering in the proofs in favor of it, there has not thus far appeared, to the knowledge of the author, any collective or consecutive statement of the evidence which geology and paleontology present in support of organic transmutation. With the view of partially filling this gap in the literature of Darwinism the author has prepared, at the request of many of his friends, the following pages, which represent, somewhat broadened, the substance of a Friday evening discourse delivered at the Academy of Natural Sciences of Philadelphia. Brief though the statement is, it is hoped that it may yet be of service to those to whom the more specialized material is not readily accessible.

A. H.

ACADEMY OF NATURAL SCIENCES,
Philadelphia, December, 1887.

THE GEOLOGICAL EVIDENCES

OF

EVOLUTION.

Just fifty years ago this year were planted the germs of a train of scientific speculation whose development was destined to mark an epoch in the history of science—to work a most profound revolution in the tendencies of modern thought. It was then that Charles Darwin first conceived the idea of investigating that mystery of mysteries, the origin of species, and it was then that he laid the foundation of that remarkable work which some twenty years later was destined to convulse the scientific world. Nearly thirty years have now elapsed since the "Origin of Species" first saw the light of day, and although in its infancy it met with but few adherents to its general proposition that all existing organic forms are but modifications of, or derivatives from, allied or previously existing forms, it numbers at the present day an equally small, or still smaller, number of opponents. It may safely be said that no broad scientific generalization, unless possibly it be that of the Correlation of Forces, ever met with such ready acceptance as did the doctrine of evolution or transformism. It is not my purpose to-night to discuss the status of evolution, which has long since passed from the realm of pure and simple theory, but to present to you such of the more salient facts bearing upon its proof, drawn from my own department of geology and paleontology, as will permit you to understand why the greater number of naturalists consider the doctrine as firmly established to-day as is the Copernican theory of planetary revolution, the theory of gravitation, or the undulatory theory of light.

Before entering into an analysis of this evidence, it will be well to understand what is meant by the term "evolution" as applied to organic beings. There is much misconception on this point, arising primarily from an erroneous interpretation of the relations which the different animal and vegetable organisms hold to one another. Evolution, in its more common acceptation—in the sense I propose treating of it to-night—signifies merely the evolving or production of new organic forms from forms more or less unlike themselves; it recognizes as the result of its action that all the varied animal and vegetable forms now inhabiting or covering the earth's surface are the descendants, through a long series of modifications or transformations, of a limited number of ancient types whose ancestry lies buried deep in the history of the world. As a corollary of this, which might be termed material evolution, we have an accompanying evolution of the mind, habit, and consciousness, but these important factors in sociology do not concern us this evening.

One of the most popular fallacies connected with evolution is the supposition that if all organic forms are mere derivatives of one another, no matter how unlike they may be, it follows that they occupy a serial position with reference to each other; in other words, it is conceived that if all the connecting forms were discovered, they would build up a continuous organic chain. Nothing could be further from the truth; evolution recognizes modification in the most divergent directions, and the tree of life that it restores is not a straight stem growing from a continuous apical bud, but a stem, or possibly even a limited number of stems, branching in varying directions. The bird, which, in our conception of structural organization, stands intermediate in rank between the reptile and mammal, appears to be a descendant of the former, the reptile, but the mammal, which immediately follows the bird, has little or no direct connection with it. One line or the other is a side line, and there can be no connection between the two except at their points of divergence.

Granting the truth of the doctrine of evolution, what is the nature of the proof that would be required of the geologist to establish its validity? He would be required to show, in the first place, that there has been a steady advance in the type of structural organization from first to last—not a necessary elimination of forms of low degree, but an overbalancing of these by forms of a more complicated or higher grade of structure. Evolution does not hold, as some opponents of the theory would lead us to suppose, that the progressive modification of individual organic forms need be, or indeed has been, one of continuous advance; it recognizes merely a general advance for the entire organic frame, while it admits of individual retardation or degeneration. Its progress or procession is the equivalent of the progress seen in the development of civilization; the united world advances, whereas individual tribes or nations remain at a standstill, or even degenerate and decay. Such is precisely the history of the organic development of our planet; new and more complicated organic types are being continually evolved, but side by side with these forms we still meet with those of a lower grade of organization, while still others, belonging to the earlier periods of the earth's history, have completely dropped out.

As a second proof of his position the geologist would be compelled to show the lines along which certain organic forms have developed; to speak more explicitly, he would be required to indicate a number of transitional types intermediate in their relations between forms otherwise apparently far removed from one another. These are the so-called "missing links." Furthermore, these missing links must appear at definite geological periods, and not promiscuously at all times and places. This is practically the sum total of the proof that would be required of the geologist, and I believe that I shall be able during the course of the evening to show to your entire satisfaction that he can furnish this proof, and furnish it in a most convincing manner.

I have placed before you a chart representing the different geological periods, beginning with the oldest at the bottom and ending with the newest on top. I have so arranged it that each vertical inch of its surface covers 2,000 feet thickness of deposit belonging to each of the several periods of time, the maxima of thickness occurring at any one part of the earth's surface having been selected.* You can thus determine for yourselves the relative values, as measured by the thickness of the several deposits, of the different periods of time, an important consideration in dealing with the life-histories of animal groups. Now, when we seek to investigate the life-histories of the different periods indicated on this chart, we are immediately struck by the very remarkable progression of the animal forms distinctive of those periods. Instead of meeting with a promiscuous association of animals of lowest and highest organization, we find a general advance in structural type from beginning to end. It is true, we cannot in all cases indicate that

* In the following table the relative thicknesses are expressed in feet, and the measure referred to in the text has necessarily been omitted.

	Epochs and Formations.	*Faunal Characters.*
CAINOZOIC OF TERTIARY.	POST-PLIOCENE. Glacial Period.	Man. Mammalia principally of living species. Mollusca exclusively recent.
	PLIOCENE, 3,000 feet.	Mammalia principally of recent genera —living species rare. Mollusca very modern.
	MIOCENE, 4,000 ft. OLIGOCENE, 8,000 ft.	Mammalia principally of living families; extinct genera numerous; species all extinct. Mollusca largely of recent species.
	EOCENE, 10,000 ft.	Mammalia with numerous extinct families and orders; all the species and most of the genera extinct. Modern type Shell-Fish.
	LARAMIE, 4,000 ft.	Passage Beds.
MESOZOIC OF SECONDARY.	CRETACEOUS, 12,000 ft. Chalk.	Dinosaurian (bird-like) Reptiles; Pterodactyls (flying Reptiles); toothed Birds; earliest Snake; bony Fishes; Crocodiles; Turtles; Ammonites.
	JURASSIC, 6,000 ft. Oolite. Lias.	Earliest Birds; giant Reptiles (Ichthyosaurs, Dinosaurs, Pterodactyls); Ammonites; Clam-and Snail-Shells very abundant; decline of Brachiopods; Butterfly.
	TRIAS, 5,000 ft. New Red Sandstone.	First Mammalian (Marsupial); 2-gilled Cephalopods (Cuttle-Fishes, Belemnites); reptiiian Foot-Prints.
PALEOZOIC OF PRIMARY.	PERMIAN, 5,000 ft.	Earliest true Reptiles.
	CARBONIFEROUS, 26,000 ft. Coal.	Earliest Amphibian (Labyrinthodont); extinction of Trilobites; first Cray-fish; Beetles; Cockroaches; Centipedes; Spiders.
	DEVONIAN, 18,000 ft. Old Red Sandstone.	Cartilaginous and Ganoid Fishes; earliest land (snail) and freshwater Shells; Shell-Fish abundant; decline of Trilobites; May-flies; Crab.
	SILURIAN, 33,000 ft.	Earliest Fish; the first Air-Breathers (Insect, Scorpion); Brachiopods and 4-gilled Cephalopods very abundant; Trilobites; Corals; Graptolites.
	CAMBRIAN, 24,000 ft.	Trilobites; Brachiopod Mollusks.
AZOIC.	ARCHÆAN, 30,000 ft. Huronian. Laurentian.	Eozoön (probably not a fossil.)
	PRIMEVAL.	Non-sedimentary.

a type of higher or more complicated organization invariably followed a lower type belonging to the same group, but as a general rule we note that there has been a steady advance in type structure. What is the nature of this advance, or the essence of the first required proof?

Looking at the animal kingdom broadly, and without attempting to destroy the perspective by inquiring into unnecessary details, we find that of the two great divisions into which that kingdom is divided, the backboned or vertebrate animals, like the fish, reptile, amphibian, and quadruped, and those without backbone, the Invertebrata, like the coral, starfish, crab, etc., only the latter is represented in the earliest period, the Cambrian, in which indisputable animal remains have been found. Not a vestige of any of the higher forms has here been met with. But let me warn you against this non-appearance. It is by no means impossible, or indeed unlikely, that backboned animals already lived during this period of time, and that their remains will still some day be discovered. The fact, however, that the Cambrian deposits have been so extensively studied, and that no such remains have yet been found, renders it more than probable that the animals of this class, if they existed at all, existed in very small numbers; and there can scarcely be a shadow of doubt that their real development followed that of the animals without backbone, whose remains are so numerously scattered through the rocks. And let me warn you further that the future finding of a few vertebrate remains in the Cambrian deposits will be no evidence against the doctrine of evolution—not until these remains will be found very much more numerously than there is a prospect of ever finding them.

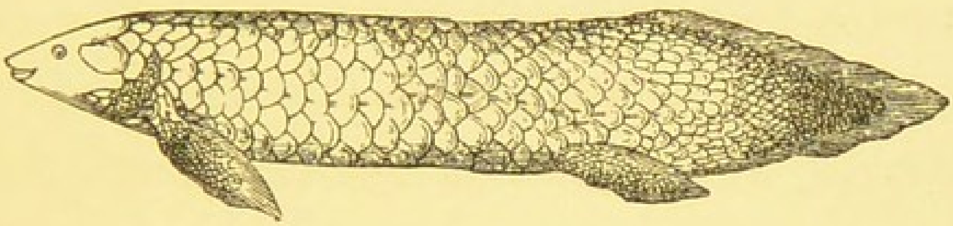
In the period succeeding the Cambrian, the Silurian, we find the first traces of backboned animals, —and what are they? The lowest members of the series, those which exhibit the least development of the sense organs—the fishes. These animals are numerically insignificant during this era, and appear only towards its close; in the period following, the Devonian, they become very abundant, so much so that this period has been aptly designated the "Age of Fishes." But neither here, nor in the period preceding, the Silurian, has there ever been found a vestige of an animal higher in the scale of organization than a fish. In the rocks of the Carboniferous period do the first of the more highly organized animals appear, but only in forms, as far as it is possible to determine from our knowledge of recent animal life, whose early existence is passed in an ichthyic or fish-condition. These are the amphibians, the group to which the frogs and toads, the newts and salamanders belong—animals, as we all know, and as we see exemplified in the tadpole, whose larval forms breathe the oxygen of the water by means of exposed gills, and which in their advanced or adult stage, develop true lungs, and thus approximate the reptilian condition. But we meet as yet with no true reptiles. These appear for the first time in the rocks of the succeeding period, the Permian.

We have now passed through about two-thirds of the known cycle of geological history, or completely through what is known as the Paleozoic period of time. In the Triassic period we have the first evidence of the existence of the highest animals, the mammals, and in the period following this, the Jurassic, of birds, an apparent contradiction to the order of appearance.

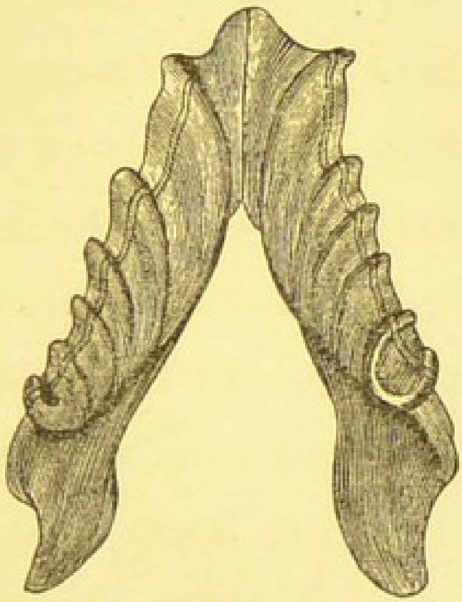
Let us here enter somewhat more closely into an examination of the order of appearance that has been outlined, and see what it signifies. I believe we shall find in its analysis both kinds of evolutionary proof that we are in search of. But in order to do this we must satisfy ourselves as to the relationships to one another of the different animal groups whose histories we have followed. What is a fish, what is an amphibian, and what is a reptile, and what relationship do these three groups bear to one another? I can in this place only briefly indicate the essential anatomical features of these groups. Beyond having the characters belonging to the Vertebrata in general, fishes may be described as cold-blooded, water-inhabiting animals, breathing by means of gills, having but two chambers to the heart, and rejoicing in a purely systemic circulation—*i. e.*, the arterialized or oxygenated blood instead of being returned to the heart before being finally distributed, is carried directly from the gills to the different parts of the body. The body, moreover, is provided with fins, which fins are supported by fin-rays. When we compare this general structure with that of an amphibian, such as a salamander or frog, we naturally find much difference. The frog breathes by means of lungs, is largely an inhabitant of the land, has three chambers to its heart, has a true pulmonary circulation—the blood being first returned from the lungs to the heart before it is finally distributed—and the body is destitute of fins and supporting fin-rays, Thus, there would appear to be but little connection between these two classes of animals. When, however, we inquire into the early history of the frog we find a very close connection, and one that proves the young frog to be more of a fish than anything else.

The familiar tadpole or fish-like form is an inhabitant of water, and like the fish it breathes water by means of gills; it has but two partitions to its heart, a non-pulmonary circulation precisely like that of the fish, and the body provided with fins, which are, however, destitute of fin-rays.

Leaving out certain differences in the osteological structure of the cranium, we might indeed say that almost the only striking character separating this larval amphibian from the fishes is the absence of fin-rays; but in whatever way we look upon it, the creature is much more a fish than anything else, and differs less from certain fishes than these do from each other. So that to all intents and purposes the frog is a dual creature—a fish in its young stage and something else afterwards. Why then, it might be asked, separate the amphibians from the fishes at all? The master mind of Professor Huxley has solved this question. The fishes and amphibians are but sub-groups of a single division, known to naturalists as the Ichthyopsida. I have thus far indicated to you only a one-sided relationship. The amphibians not only approach the fishes, but the fishes approach equally the amphibians. There exist a limited number of



1.



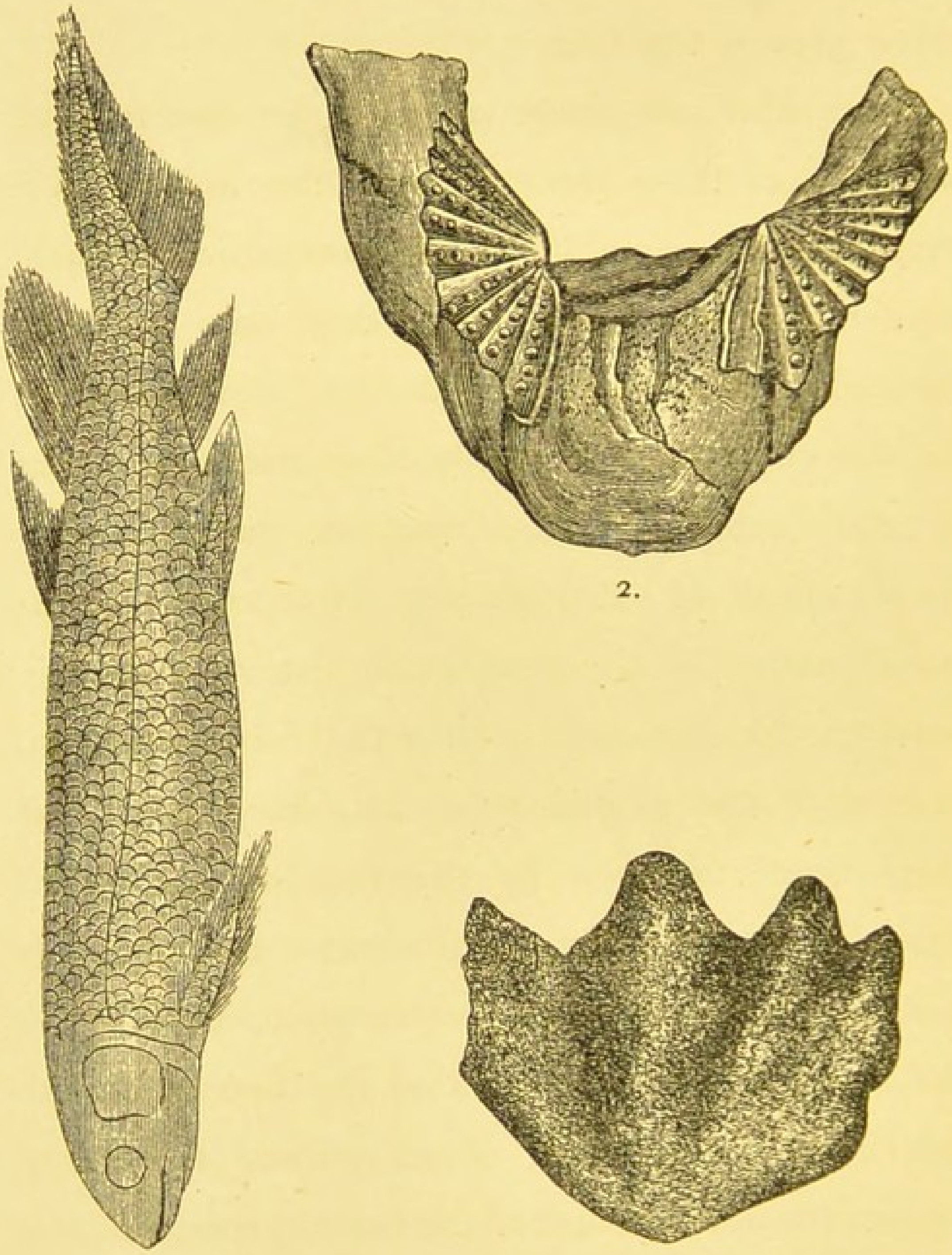
2.

1. *Ceratodus Forsteri*, mud-fish of Australia. 2. Dental armature of same.

fishes, known as "mud-fishes," inhabitants of the waters of South America, Africa, and Australia, which depart from other fishes so widely as to be properly constituted into a distinct class of their own. They are provided, in addition to gills, with true lungs, by means of which they respire the oxygen of the air directly, and with which there stands in immediate relation a pulmonary circulation, operated by a heart with three chambers.

Having thus established the relationship existing between fishes and amphibians, it will be well to consider in how far this relationship also extends to the third group of cold-blooded animals, the reptiles. Manifestly, a reptile is most closely related to the amphibians, from which it differs primarily in never breathing by means of gills, and in having but a single articulation to the base of the skull, instead of the two seen in an amphibian. It may also be added that the amphibian has a naked skin, whereas nearly all reptiles are provided with scales or plates developed in the integument. In other important points of structure—such as the lungs, heart, and circulation—a reptile agrees essentially with an adult amphibian, and indeed more so than certain reptiles agree with one another. The amphibian is, in truth, an animal that binds the three groups together.

If we now ask ourselves what are the relative positions of these three groups, the answer is a very simple one. The amphibians are obviously higher than the fishes, since they pass from, or through, a fish stage to maturity; developing in the direction of the reptile, they naturally point to the latter as the superiors in the scale of organization. Recognizing this position, what is the nature of the geological history that they would be likely to tell? That the fishes appeared first, that the amphibians came next, and that these were followed by the reptiles, just as we have seen it actually to have been the case. It is a remarkable fact, and one most confirmatory of the doctrine of evolution, that the history of the individual development of an animal frequently repeats the development of the broad group which it represents. But geological evidence is not entirely satisfied with the evidence of succession, corresponding to the law of development, which I have



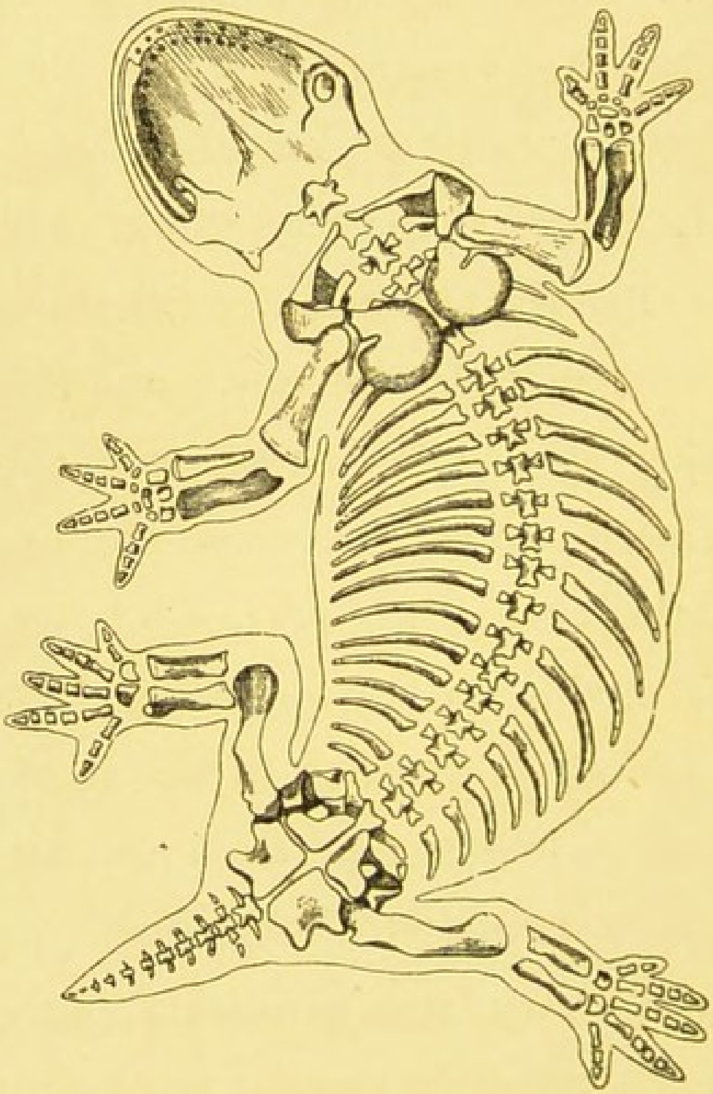
2.

1. 3.

1. *Dipterus Valenciennesi,* Devonian fish. 2. Dental armature of same.
3. Tooth of Ceratodus (Trias).

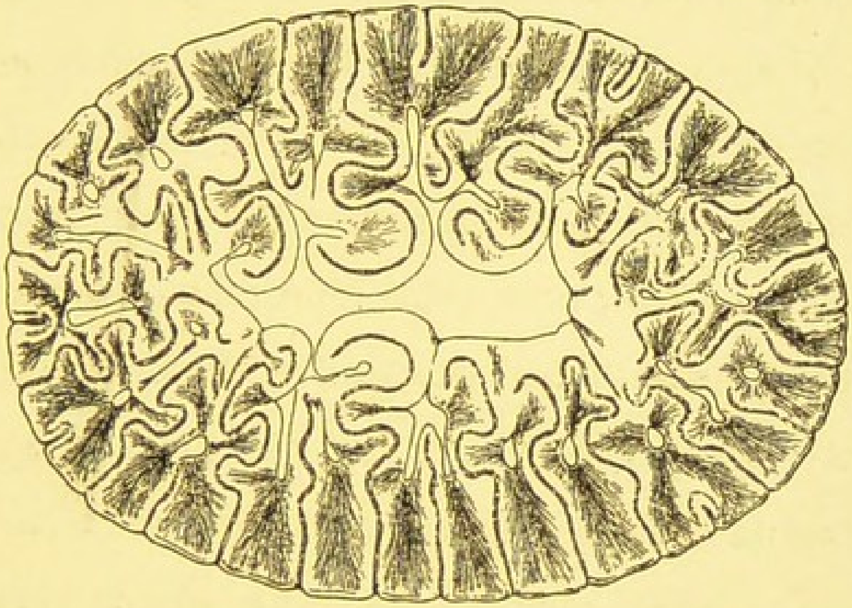
just given you; it must sooner or later show that in the period intervening between the first appearance of fishes and the earliest development of amphibians there existed a type of fish more closely related to the amphibian than the ordinary fishes—in other words, a connecting link more or less closely related to the mud-fishes. Such a form we find in Dipterus and its allies, fishes that belong to the Devonian period of time; and if any proof were further wanted indicating the antiquity of the existing group of lung-fishes, we have but to point to the occurrence of one of our modern genera, Ceratodus, already in the deposits of the Permian period. Ceratodus, in fact, represents the oldest living vertebrate type known to naturalists.

There is a remarkable structural peculiarity belonging to a very large number, if, indeed, not to the vast majority, of the earliest amphibians, which seems to distinguish them from all the modern members of the same group of animals. This is a singular labyrinthine infolding of the substance of the teeth, which has given to the group the name of the Labyrinthodontia. Now it is a surprising circumstance that many of the most ancient fishes, or those which preceded the labyrinthodonts in time,



Labyrinthodon Rütimeyeri, an early amphibian.

have this same peculiarity of structure, and at the present day we have still a form, the alligator-gar—one of the last remaining survivors of that ancient ichthyic group, the ganoids—which retains this peculiarity of dental structure. From what has already been said, I believe it will be admitted that we have the strongest kind of evidence to show that the amphibians have been developed from the fishes, and further, that one of the most striking

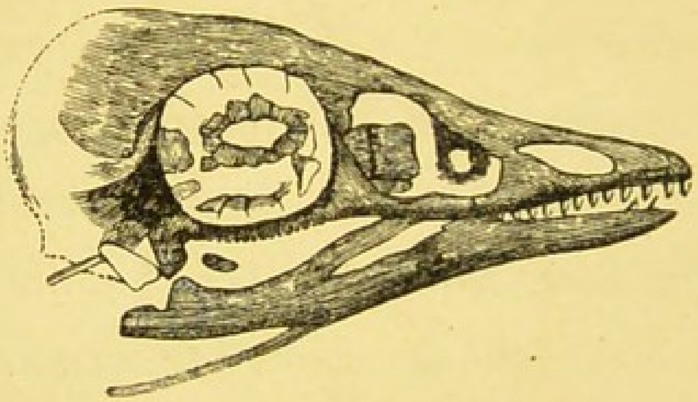


Section of labyrinthodont tooth.

characters of these most ancient amphibians is a character which had already been developed in that class of animals whose position is unmistakably below them in the scale of organization.

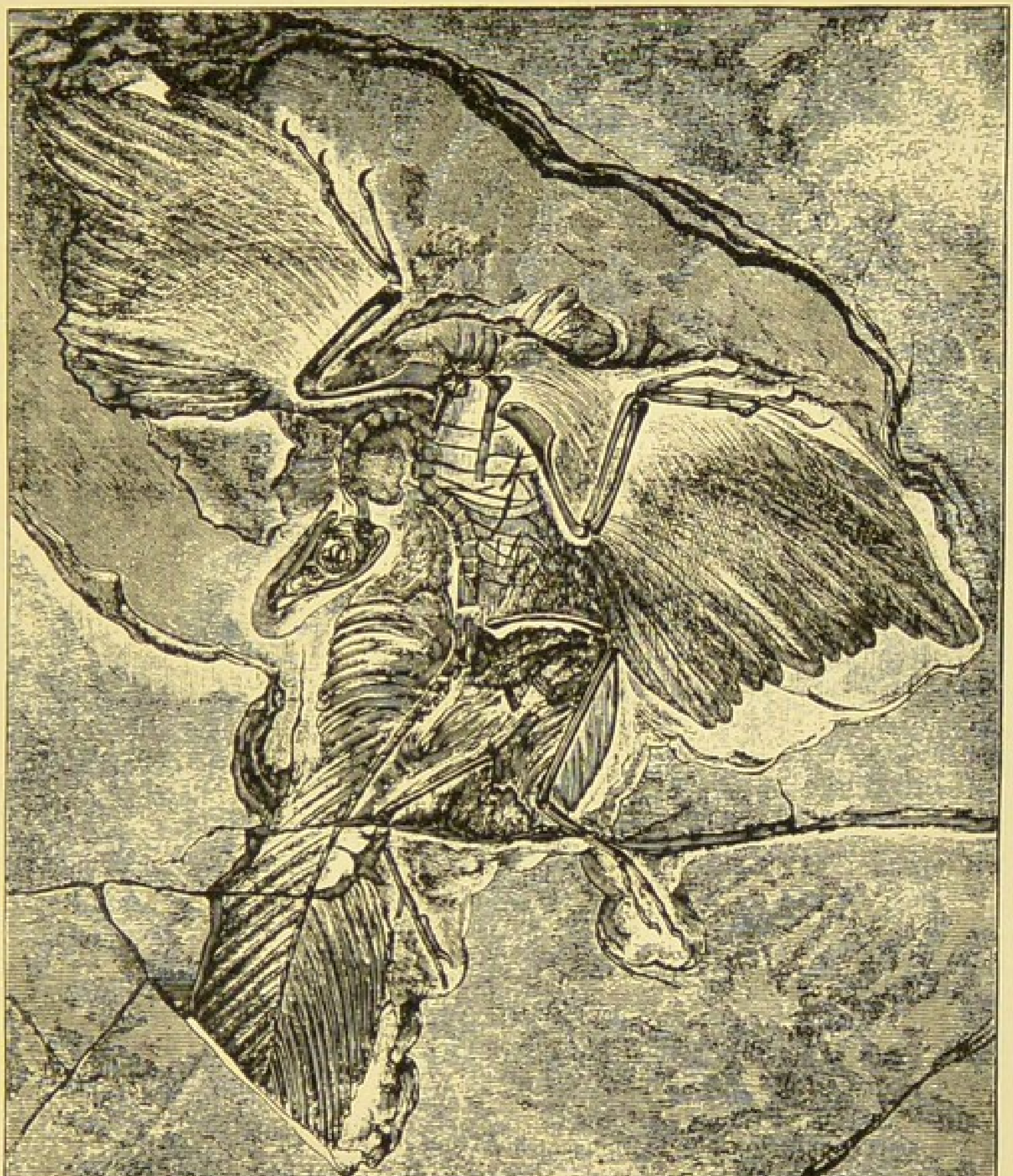
Passing now to a consideration of what some choose to call the rather anomalous appearance of birds and mammals in Mesozoic time—*i. e.*, the appearance first in time of the more highly organized group—I am compelled to ask, in what respect is this appearance anomalous? What special relation do these two groups hold to one another and to the animals that succeed them; and in accordance with what law should it be required that the order of appearance be reversed? Manifestly, only if it can be shown that the line of descent of the mammal passed through that of the bird; otherwise the two need bear no special relation to one another. What is the zoological position of the bird, and what that of the mammal? At first sight a bird appears to be most sharply defined, and absolutely isolated, from all other members of the great group of animals. And our conception of this isolation would probably have remained intact to the present day were it not for the very remarkable discoveries which the paleontologist has brought to light during the last half-century.

Briefly defined, a bird is a hot-blooded vertebrate animal, provided with feathers to its body, with a complete pulmonary circulation operated by a four-chambered heart, and with the anterior appendages so modified as to permit of navigation through the air; the mouth is destitute of teeth, a character which serves to separate it from the greater number of other vertebrate animals. This is our conception of a modern bird. But what has been its earlier history? I have placed before you the figure of a remarkable creature, known as the Archæopteryx, only two individuals of which have thus far been discovered. The first, now deposited in the British Museum, was found about twenty-five years ago, and the second some ten years since, and constitutes to-day one of the treasures of the museum of Berlin. They were both found in the lithographic-stone quarries of Solenhofen, Bavaria, and in deposits that by geologists are referred to the Jurassic period of time. This remarkable creature, which was of about the size of a raven, had a generally bird-like head, but differing from all modern birds, the head was supplied with true teeth in the extremities of both the upper and lower jaws, which teeth were implanted in distinct sockets, as in the more highly constituted reptiles. The body was provided with well-developed feathered wings, but again, departing from true birds, the rest of the body, except the tail and parts of the legs, appears to have been either largely



Head of the Berlin Archæopteryx.

naked, or but scantily clothed with feathers; the legs and feet were bird-like in structure, but in the hand and tail we have a remarkable combination of reptilian and avian characters. The latter, instead of being made up in principal part of feathers radiating from a greatly condensed vertebral axis, is prolonged into a long



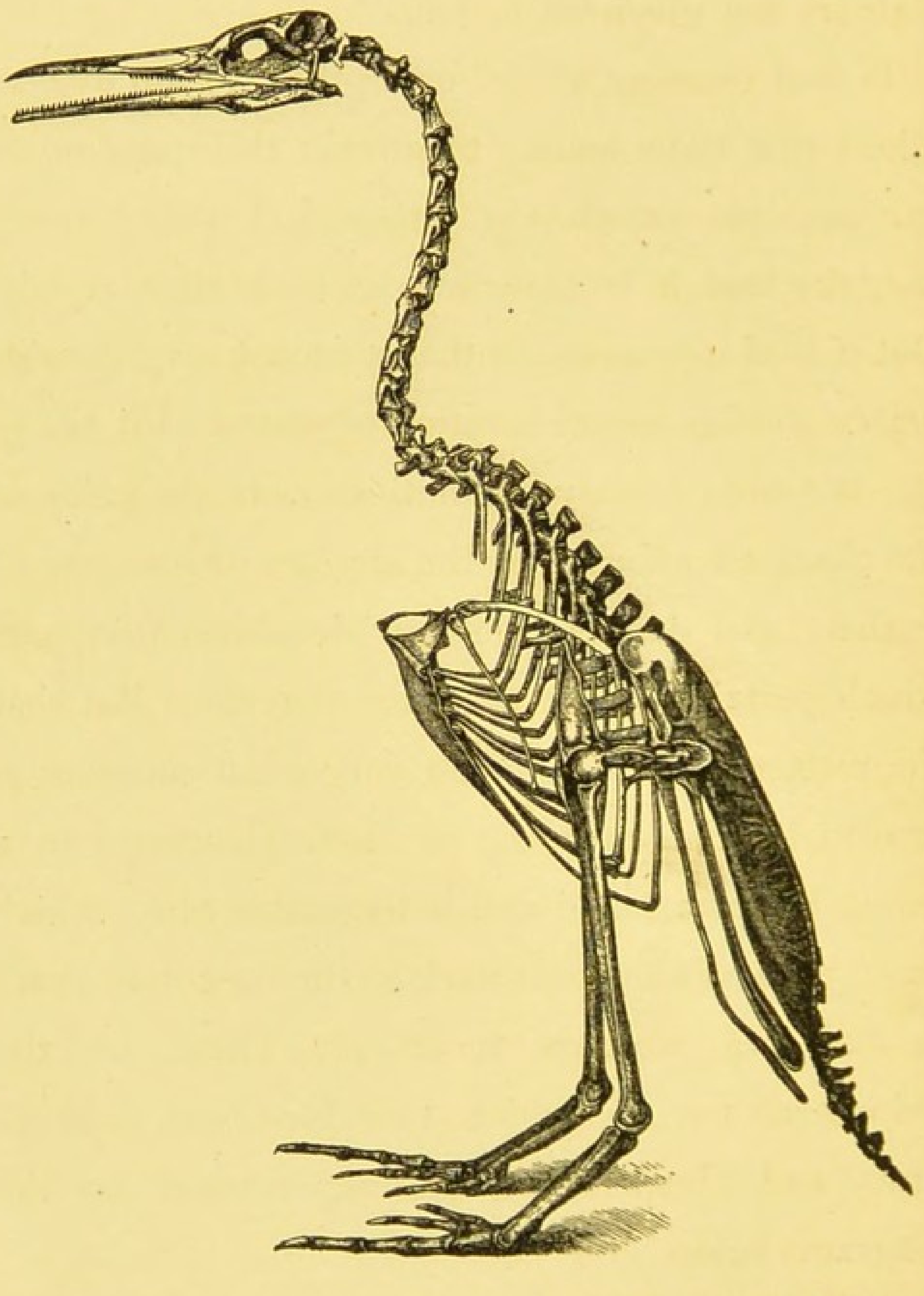
ARCHÆOPTERYX.

Specimen in the Berlin Museum.

succession of vertebræ, from two sides of which feathers are given off in pairs.

Is this creature a bird or reptile? I am free to admit that I am unable to answer this question to my absolute satisfaction, although I would probably say that it is more nearly bird than reptile. But if bird it is manifest that we must very considerably modify our conception of what a bird really is. We must modify our notions as to the value of the character afforded by the absence or presence of feathers, and deduct from our definition that part which pertains to the presence of teeth. But that the matter of teeth is of no very great moment is proved by the existence of these structures in a group of remarkable and indisputable birds, which have been discovered during the last few years in our own western territory. These are the Odontornithes, of which two members, Ichthyornis and Hesperornis, are represented on the diagrams before you.

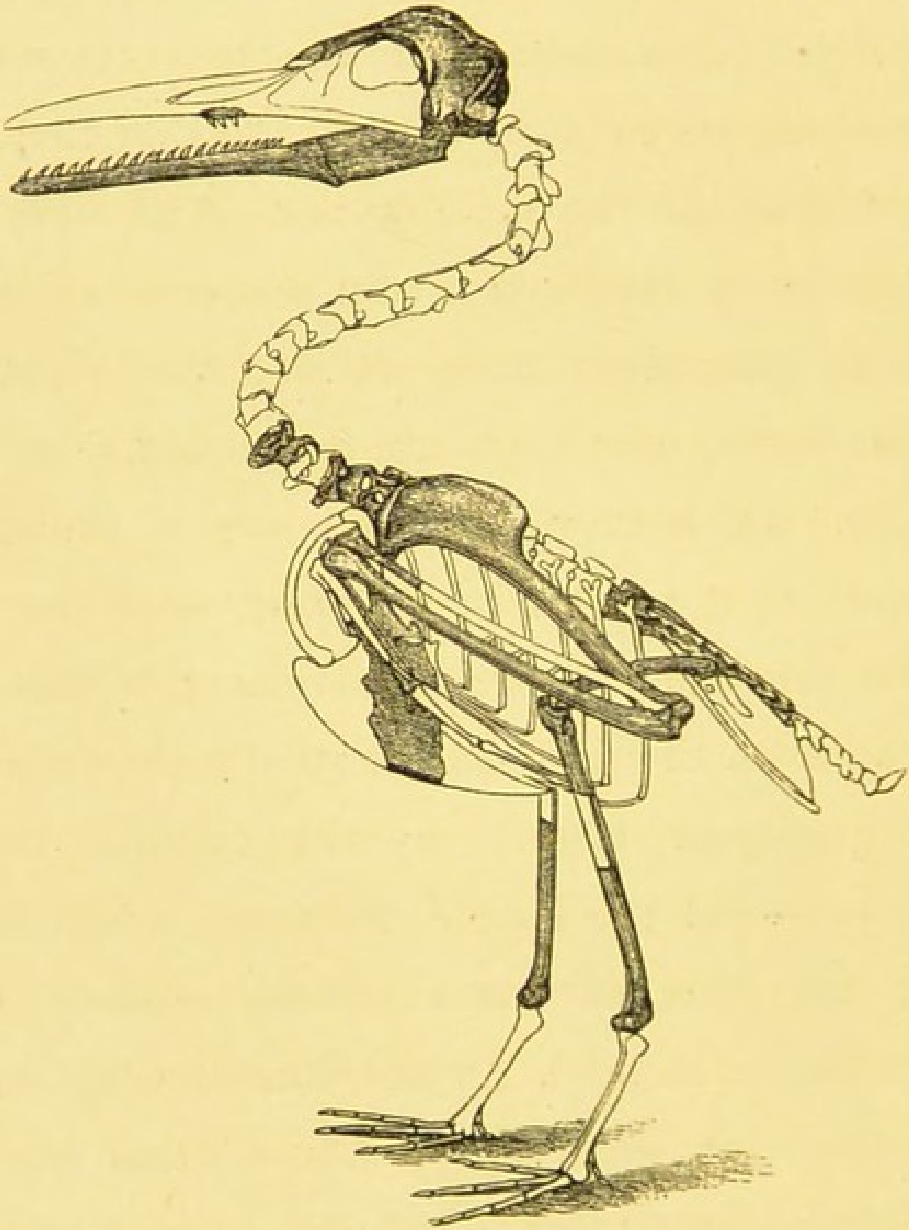
That these earliest birds were largely reptilian in character can, with the evidence before us,



Hesperornis regalis.—Specimen in the Peabody Museum, New Haven.

scarcely be gainsaid; and if it can be shown with equal force that many of the earlier reptiles possessed characters belonging to birds, have we not the right to assume that the two classes of animals are very closely related, and that they belong to one and the same stock? And since the modern birds have practically dropped all their reptilian characters, have we not the right to assume further that birds are descended from reptiles, of which they represent only a diverging group? Is it not merely a repetition of the tale that is furnished by the development of the amphibian from the fish—so beautifully shown, apart from geological history, by the tadpole before our eyes—and the reptile from the amphibian? It is true that we know of no modern bird which passes through an absolute reptilian stage, but does not embryology tell us that one of the primary structures separating birds from reptiles, the feather, is merely a modified scale, and that it originates as a true scale?

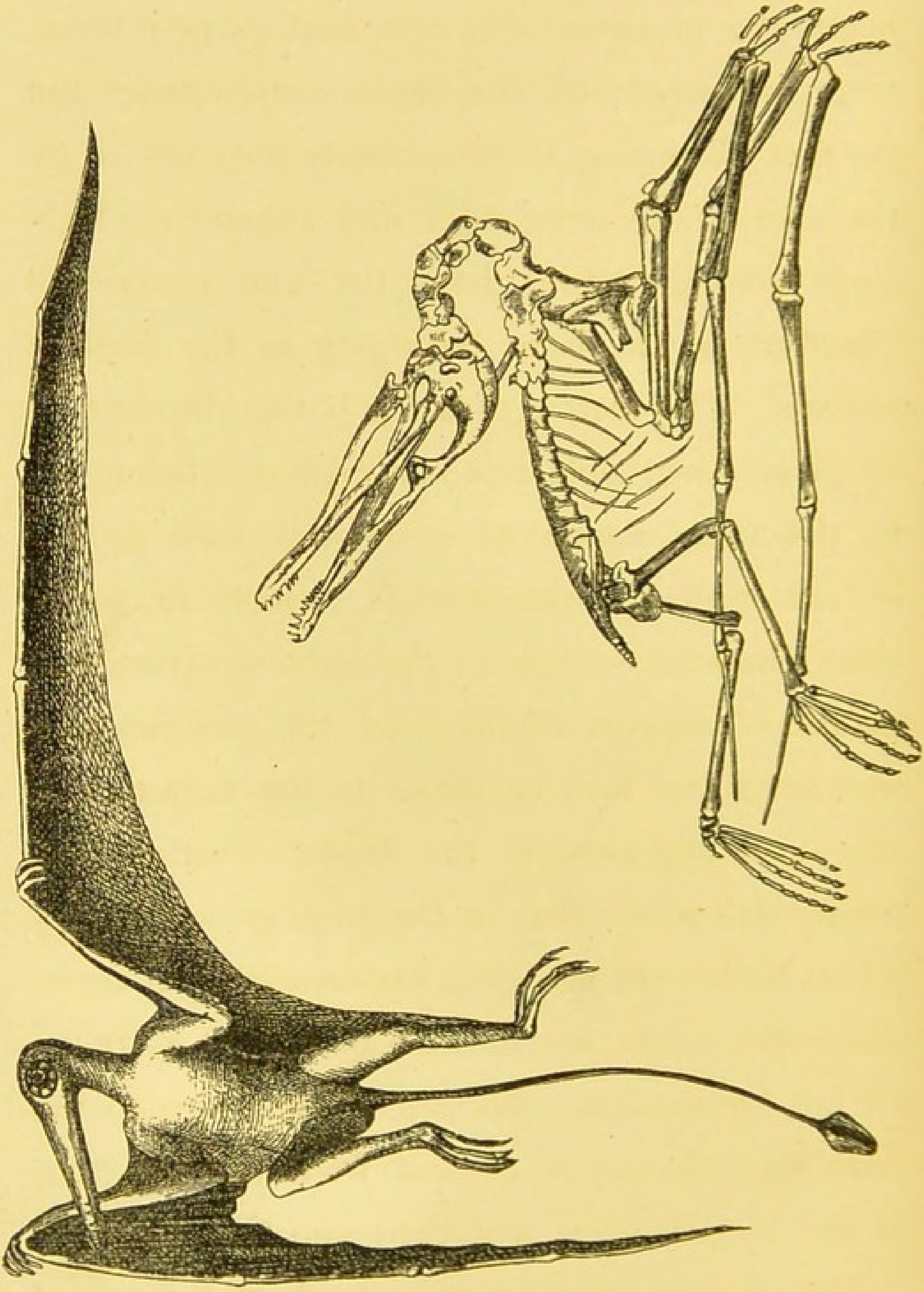
If the combination of the modern and ancient characters of birds approximates them so closely to reptiles, what indeed, it might be asked, are the



Ichthyornis victor.—Specimen in the Peabody Museum, New Haven.

fundamental characters which separate them from reptiles? We have still the four-chambered heart, the presence of wings, and certain structures connected with the hinder extremities. But the first distinction is immediately disposed of by the case of the crocodiles and alligators, which, alone among reptiles, have the four recognized chambers of the heart belonging to the highest animals. The matter of wings is also disposed of by those remarkable reptilian creatures belonging to the same epoch of geological time as the earliest bird, the pterodactyls, which in many other characters—such as the light structure and manner of support of the head, the presence of a well-developed keel or carina to the breast-bone, etc.—also approximate the birds. Furthermore, we are well aware that in the large group of struthious birds—the ostriches, cassowaries, and apteryxes—the wings are so little developed as to be all but functionless. We are hence driven to the remaining characters derived from the structure of the hind-quarters and their appendages.

The most careless observer is aware that a bird can at almost all times be distinguished from a

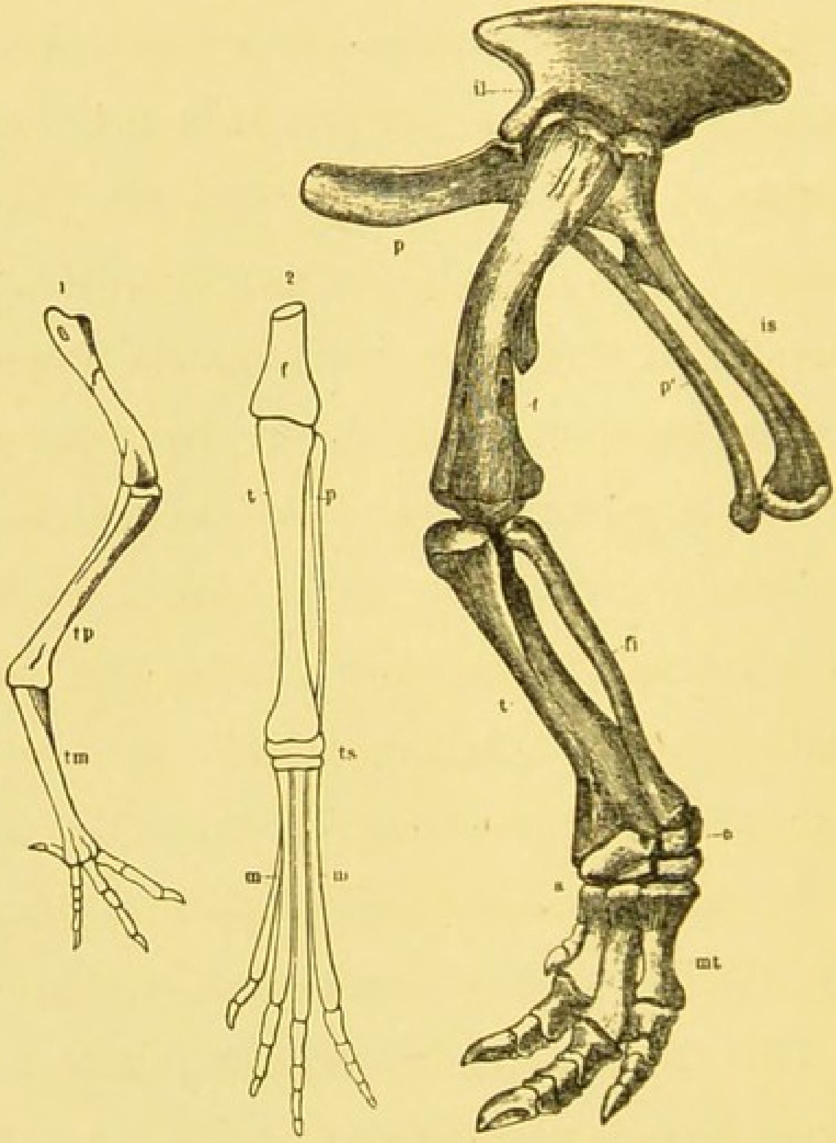


1. 2.

Pterodactyls.—1. *Rhamphorhynchus* (restored); 2. *Pterodactylus.*

reptile by its mode of progression—its elevation on the hinder extremities alone. But this mode of progression does not differ more from that of a reptile than does the method of a snake from that of a turtle, yet both are reptiles. It is in the relative disposition of the parts that we find the important difference. In all birds the pelvic girdle, which consists of the three bones recognized in man as the pubis, ischium, and ilium, has the pubis directed in a direction more or less parallel with that of the ischium; in other words, backward. In all reptiles, on the other hand, this bone is directed forward. Again, in all, or nearly all birds, there is a prominence, known as the cnemial crest, developed on the upper part of the tibia, for the attachment of the powerful muscles of the leg. This is wanting in reptiles; and further, there are certain peculiarities connected with the articulation of the foot to the leg in birds which almost immediately serve to distinguish these parts from the similar parts of reptiles. Have we any reptilian forms which at all meet the divergencies in character here brought out?

All of you who have visited our museum will remember the large animal, mounted on the east

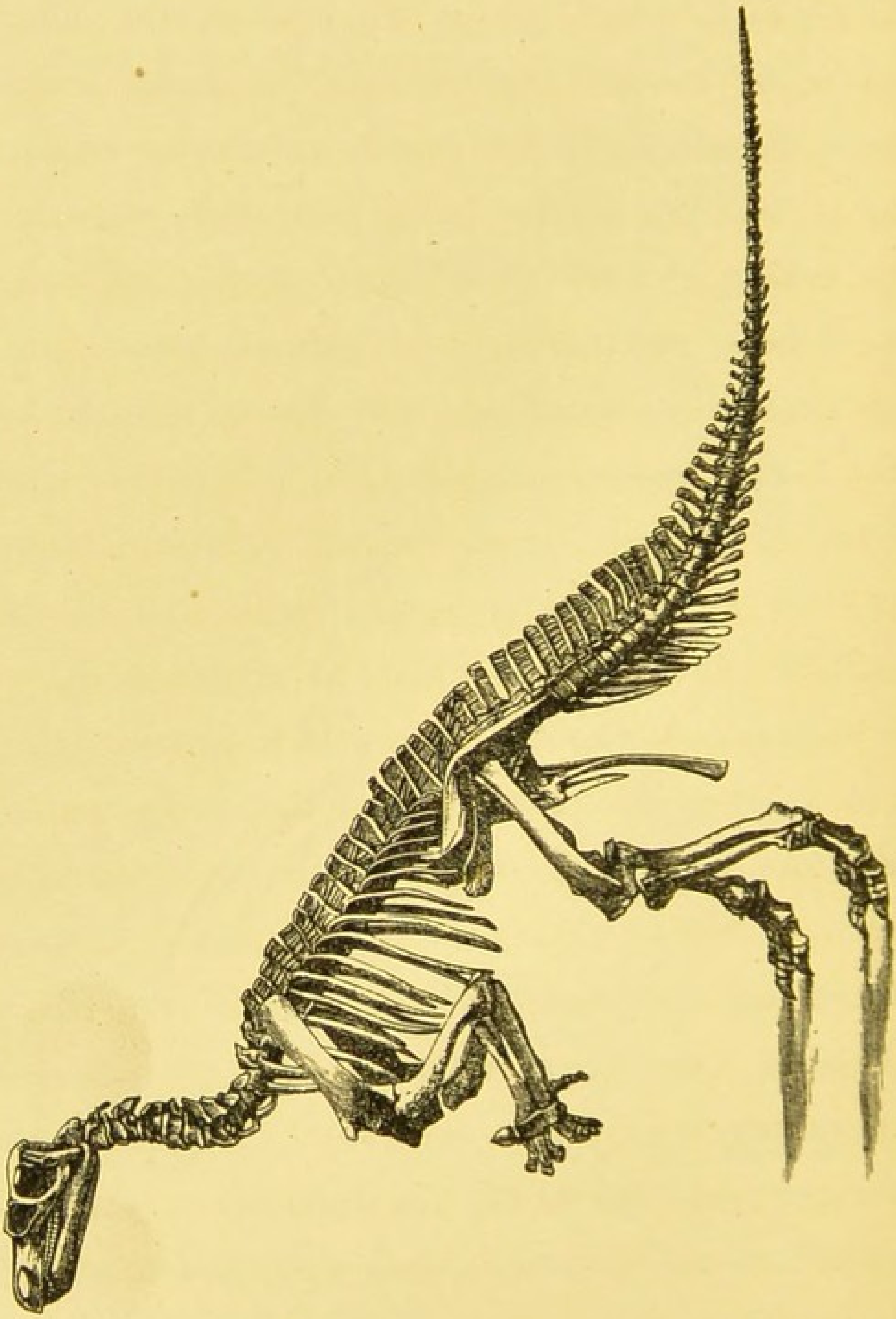


1. 2. 3.

1, Leg of a hen ; 2, of a hen-embryo ; 3, of a dinosaur (*Camptonotus*), showing disposition of pelvic bones.

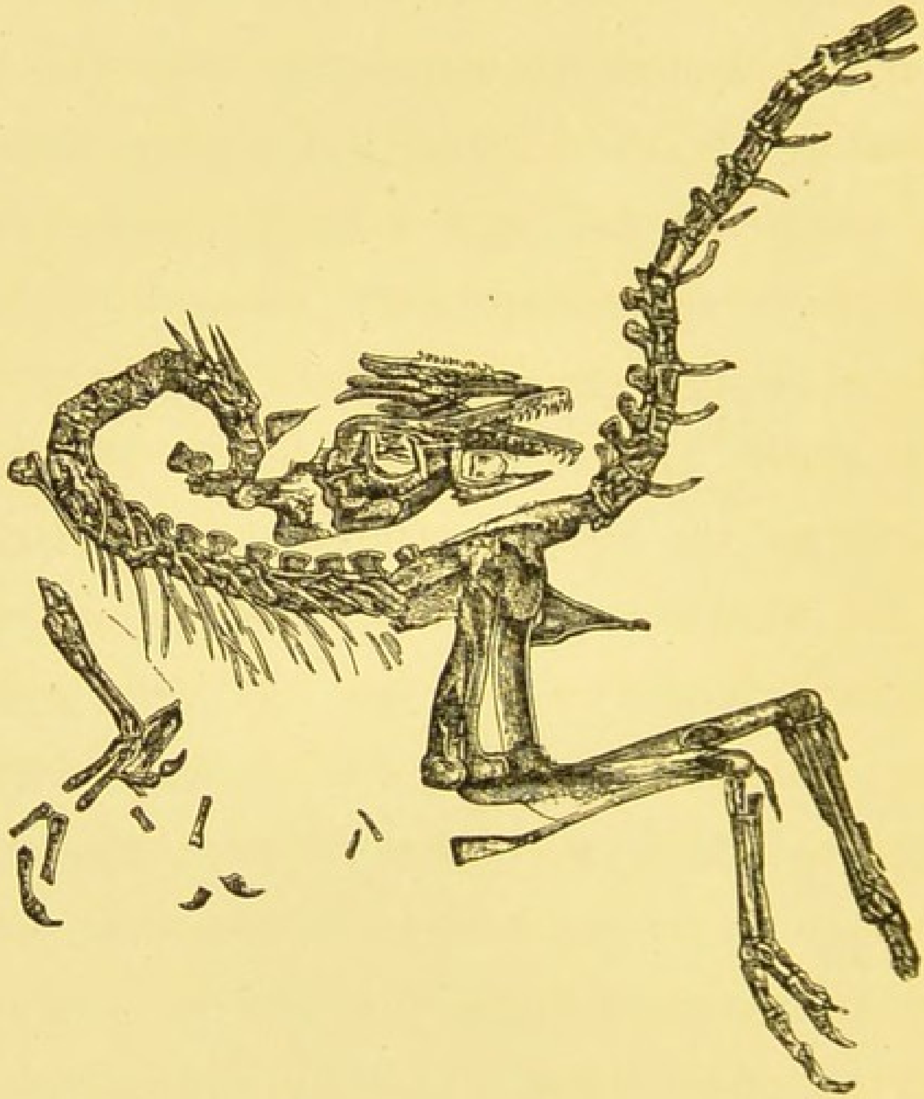
side, which was discovered on the Hopkins Farm, near Haddonfield, N. J., some thirty years ago.

The Hadrosaurus, as it is called, is the representative of a large group of reptiles, the dinosaurs, or terrible reptiles, many of whose members depart just in that much from other reptiles as is indicated by the above characters supposed to belong to birds. In other words, we have here both small and giant animals, whose progression was either largely, or mainly, effected by the hinder appendages alone; in which the pubic bone of the pelvis was directed backward, more or less in a direction parallel with that of the ischium; in which the tibia was provided with a well-developed cnemial crest; and in which, finally, the ankle-joint of the foot and the disposition of the toes were in accordance with the disposition seen in birds. Many of these animals, furthermore, had the pneumatic character of the bones of birds, ensuring a certain amount of lightness to an otherwise ponderous frame. These singular creatures, one of which, the Iguanodon, is represented in the diagram before you, first appeared in the Triassic age, or in the period immediately



Iguanodon Bernissartensis.—Specimen in the Brussels Museum.

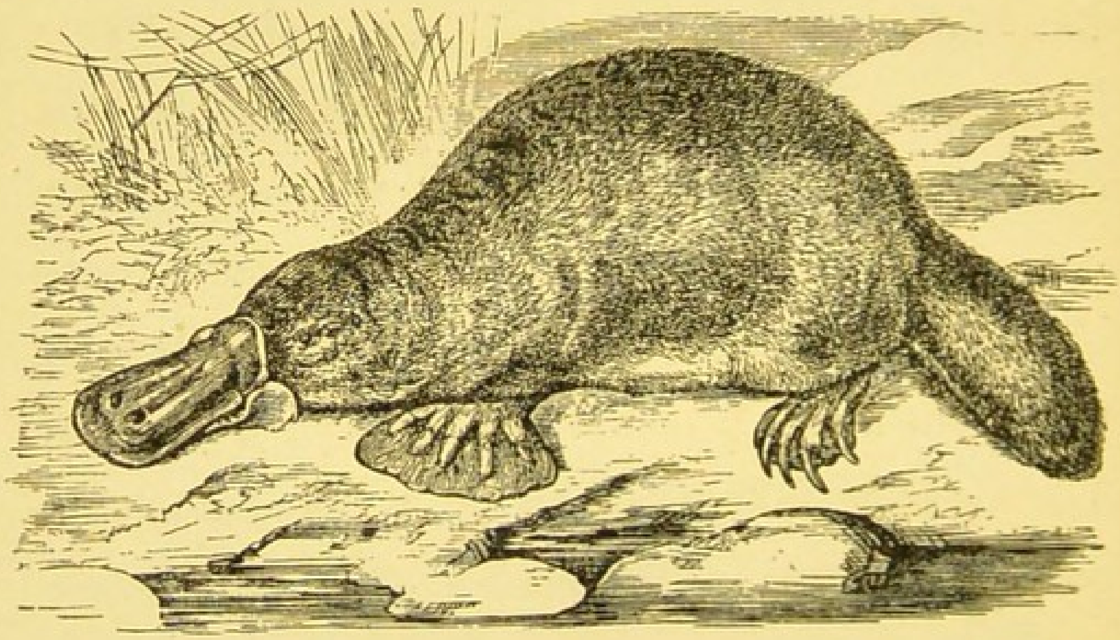
preceding the advent of the earliest known bird, Archæopteryx, although they do not acquire any special development until the period following, the Jurassic. It is to them that we owe those remarkable foot-tracks which have made the red-sandstone of the Connecticut Valley famous, and which for full half a century after their discovery were unhesitatingly referred to giant birds of a type thought to be more or less identical with that of the ostrich. So singularly striking are the bird characters of these reptiles, that for many years they have been looked upon by many naturalists as the stock whence the non-flying or ostrich-like birds have been derived—the pterodactyls, or winged reptiles, furnishing the line to the winged or flying birds—and, indeed, it has been thought that very nearly the exact type could be pointed out which gave departure to the birds. This has been indicated by Professor Huxley to be near to Compsognathus. However correct or incorrect this determination may be, there can be no doubt in the face of the evidence before us, as coming from the side of both reptile and bird, that the two classes of animals are simply modifications of the same stock,



Compsognathus longipes.

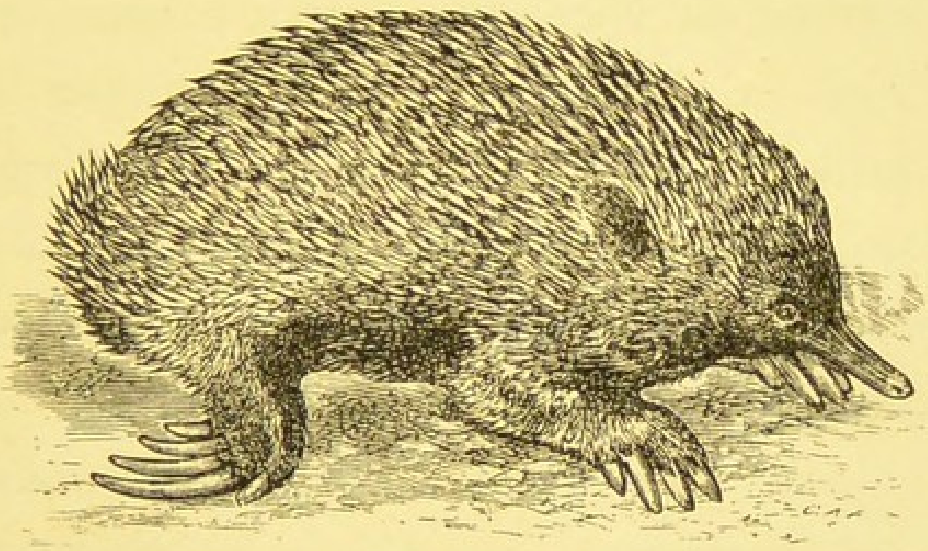
and that the one (the bird) is a derivative of the other (reptile). The zoological relationship clearly points to the nature of this derivation, which the geological evidence amply and fully confirms.

Were the Mammalia in any way specially connected in their zoological relationship with birds, we should naturally expect to find them appear in succession to the birds. The vertebrate line would then be an absolutely successive one. But this relationship does not exist. For a long time zoologists have held to the opinion that these highest animals were more nearly related to the reptiles than to any other class of the Vertebrata, but the evidence supporting this conclusion was all but the very weakest. The fundamental conception of a mammalian departs so widely from that of any other representative of the great series to which it belongs, that an actual comparison between it and the nearest forms appears almost impossible. But recent researches have thrown new light upon the problem. That most obvious distinction separating the Mammalia from all other animals—namely, that they bring forth their young alive, and that the young is nourished directly from the parent—has generally been considered an impassable obstacle in the way of correlating these animals with animals lower in the scale of organization than themselves. It is barely three years since we had the startling announcement, made



Australian duck-bill (*Ornithorhynchus*).

independently by two investigators, and through observation on two distinct animals, that at least two of the mammalian types, the duck-bill and the echidna, instead of developing their young in the normal manner of the animals of their class, bring them forth within the egg, and that the early development of the egg corresponds with the development of the egg of the reptile. This is one of the most extraordinary discoveries made in zoology during the last decade, and so remarkable is it, that when a similar announcement was made some sixty years ago, and by



Spiny hedgehog (*Echidna*).

one of the most eminent of naturalists living at the time, it met with absolute unbelief.

The evidence bearing upon the inter-relationship of mammals and reptiles is rapidly accumulating, and it will probably not be long ere we will be able to point to the connecting form between the two. From the existing evidence before us we are safe in concluding that the line of descent of these animals is direct from a reptilian stock; and this being admitted, there is no anomaly in the fact that the mammals appeared before the birds. Both birds and mammals are divergent modifications from a common axial stock. It is certainly an interesting feature bearing upon the reptilian relationship of the Mammalia that the earliest reptilian forms, those of the Permian period, are the only animals which possess the remarkable dental characters of the Mammalia. These, as is well known, have the teeth divided into three series—incisors, canines, and molars—a structure unknown among other living animals. But in the reptiles of the Permian period, which may perhaps be looked upon as the ancestral stock whence the Mammalia were derived, the same dental feature is presented.

II.

We have thus followed the succession of the higher groups of animals through geological time, and find that this succession is one that is in perfect harmony with structural relationship. Had we no other evidence to offer in favor of evolution than that which I have laid before you as coming from fishes, amphibians, reptiles, and birds, this evidence, in my mind, would of itself be amply sufficient to prove the position. But there is no lack of other evidence, and evidence fully as strong, and, if possible, still stronger than that which I have given you. Thus, if we trace the histories of the primary and secondary groups of the larger divisions of the animal kingdom, we meet with a repetition of much the same order of appearance. The fishes, for example, are represented in the oldest formations exclusively by such forms as betray a comparatively low grade of organization; these are the sharks and ganoids, in which the vertebral column remains largely in the embryonic condition, becoming only partially ossified in most cases. The lung-fishes, which are a direct modification of the ganoid type, representing, however, a considerable amount of specialization in the development of a respiratory apparatus adapted to breathing directly the oxygen of the atmosphere, appear considerably later, possibly in the Carboniferous period, but are already preceded by an intermediate type, that of the dipteroid ganoid. The more highly organized fishes, the teleosts, or bony fishes, appear for the first time, as far as we know, in the deposits of the Cretaceous period, and may consequently be looked upon as a comparatively modern group;

but even here we find that this highest group was immediately preceded in time by a type of ganoid-plated fishes, the Leptolepidæ, which in so far partake of the characters of both ganoid and teleost as to have induced naturalists to place them alternately now in the one group, now in the other.

When we cast a broad glance over the existing fish fauna of the globe, and compare it with that of the earlier geological periods, we find that it differs, not only in the introduction of types of a higher grade of organization, but in the actual elimination of the lower structural forms. The ganoids, for example, which are numbered by hundreds of species in the interval between the Devonian and Jurassic periods, are practically extinct at the present day, numbering but a mere handful of species. A somewhat similar, although less marked, elimination is also distinctive of the selachians (sharks, rays). We thus find a complete rotation marking the succession of these animals. Evolution or transformism is the expression of necessity for a change; hence, the rotation of forms. Among the amphibians, reptiles, and birds, likewise, we observe that the older forms are very different from those now living, but the difference becomes less and less marked as we approach the present day. The same holds equally true with the mammals, whose earliest representatives are again forms of a very low grade of organization. These are the marsupials of the Triassic and Jurassic periods, forms more or less closely allied to some of the lowly types inhabiting the Australian continent.

The chart before you indicates the rise and fall of this highest order of animals. It will be seen that they date their first appearance from the Triassic period, where, however, there are but three or four genera, and a barely larger number of individuals, represented. One of these, and the first species described, is on the table before you, known as Dromatherium. A further development takes place in the Jurassic period, when a broad hiatus follows. No mammalian remains have thus far been discovered in any indisputable Cretaceous deposit, and I may at once confess my inability to satisfactorily account for this non-appearance. But I feel perfectly safe in prophesying that they will yet be found, and were I as sure of many other things generally considered positive as I am of this one, I could remain satisfied.

In the first stage of the Tertiary period, known as the Eocene, we meet with the earliest of the placental mammals, or those forms in which direct union is established between the young and parent during the process of development. From this period, it might be said, dates the origin of our modern fauna. It will be seen from the chart before you that only about one-half of the existing orders of quadrupeds are represented in the Eocene period; these are the marsupials, insectivores, rodents, whales, hoofed-animals, bats, lemurs, and possibly even monkeys. In addition to these there are a number of orders which have no living representatives at the present day. In the Miocene, or middle Tertiary period, there are superadded the edentates, or toothless animals, the carnivores, sirenians, elephants, and true monkeys. *Per contra*, the special Eocene orders to which reference has just been made, have completely disappeared, so that in the Miocene period only those orders of quadrupeds are represented which have living representatives in our existing fauna. But it must not be construed from this that there is a true faunal identity; this only appears in the most recent or Post-Pliocene period.

From the beginning of the Tertiary period to the present day there is a steadily progressive approximation to modern type-structures, but this approximation is a very gradual one. This will appear clear to you when it is stated that, with barely a single exception, not only are all the Eocene species and genera of mammals different from those of the present day, but even the families are very largely different; furthermore, there are a number of orders indicated which have no representation in the modern fauna. The only known living types of mammals which are generically represented in the Eocene period are two genera of bats—Vespertilio and Vesperugo—and the opossum (Didelphys). In the Miocene period the faunal difference is measurably lessened by the elimination of the special orders which belong to the period preceding, and by the introduction of a considerable number of modern genera, such as the porcupine, beaver, squirrel, rabbit, tapir, rhinoceros, hippopotamus, hog, deer, giraffe, elephant, cat, dog, and hyena. The families, moreover, are very largely identical with existing ones, so that in its entirety the Miocene fauna may in a broad way be looked upon as distinctly modern. The species of this period are, however, all, or nearly all, distinct from those now living. In the period following, the Pliocene, there is a still further approximation to the modern fauna in the introduction of an additional number of existing types—such as the sheep, goats, and oxen, the bear and camel, and among monkeys, the macaques. Indeed, the greater number of the genera are identical with the genera of to-day, and even a limited number of living species appear for the first time. One of these is the common hippopotamus, which, consequently, represents about the oldest type of existing quadrupeds. In the Post-Pliocene period the correspondence between the existing and extinct faunas is still further increased through the large preponderance of recent species. On the border-line of this and the preceding period we meet with the earliest unequivocal remains of man himself.

The correspondence between the recent and extinct mammalian faunas may be conveniently summarized as follows:

Post-Pliocene period.

Mammalia principally of living species.

Pliocene period.

Mammalia principally of recent genera—living species rare.

Miocene period.

Mammalia principally of living families—extinct genera numerous; species extinct.

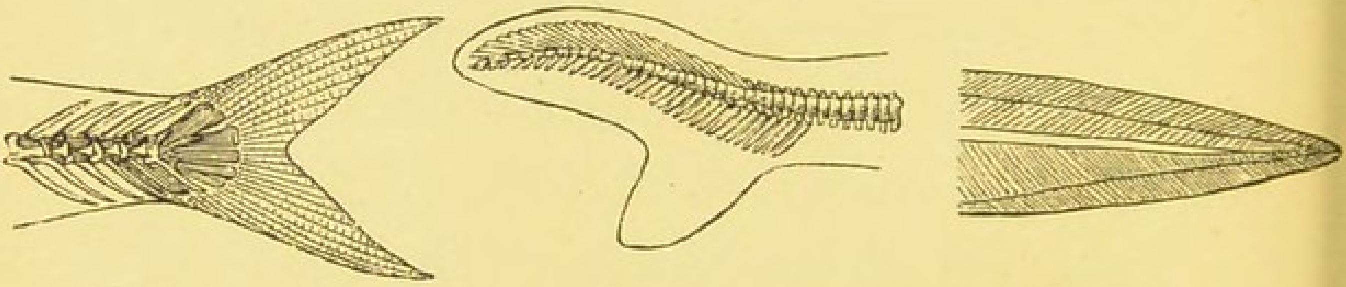
Eocene period.

Mammalia with numerous extinct families and orders. With two or three exceptions, all the genera extinct. Species all extinct.

I appeal to the facts before you, and ask, Could there be a more beautiful demonstration of the rise and fall of a fauna tending in the direction of general succession? Do we not see in the wreck of the past faunas the roots of the fauna of our own day, and can we close our eyes to the evidence of development that is here presented to us? A skeptical mind may, however, still urge that this is but a fortuitous succession, and that we have failed to bring forward proof of such transformism as will permit us to see that the modern groups which succeed the more ancient ones are necessarily developed from these. But proof in this direction is by no means wanting. When we trace back the histories of some of our existing groups of animals we find that the characters by which they are defined become less and less marked, until they are almost completely lost, when the group as such disappears. In other words, the specialized animals of to-day, or rather their representatives, become more and more generalized as we trace them back in geological time. Thus, the Carnivora lose much of the true type of carnivore structure in the early part of the Miocene period, and by almost insensible modifications pass off into a group of animals, their immediate forerunners in the Eocene period—the Creodonta—which combine about equally the characters of the Carnivora with those of the Insectivora. Thus, the Creodonta stand intermediate between two of our modern groups which are seemingly very far removed from one another. In the same way, if we take some of the more prominent families of the Carnivora, the bears and dogs, for example, we find that their special structural features likewise disappear—the bears becoming less and less bears, and the dogs less and less distinctively dogs, until we meet with an animal, the Amphicyon, which is about as much the one as the other. Similarly, the cats become less and less cat-like, and they can be traced down to animals which on the one side link them to the civets, and on the other, to the dogs.

Again, the large group of the lemurs, those singular representatives of the Quadrumana which impress such a distinct individuality upon the fauna of Madagascar, become less and less lemurine the farther back we trace them, approximating very closely to the type of insectivore structure. So complete is this approximation that the most experienced zoologists are at a loss to determine in many cases whether certain ancient types are in reality lemurs or insectivores. Other animal groups likewise converge toward this same group of the Insectivora, which (or certain immediate allies) are now considered to represent the stem from which most of the existing placental mammals have been developed. We thus see how unstable are the characters which have been formulated toward the proper delimitation of animal groups. The beautiful classification of Cuvier, which was founded on the assumption that the living organisms represented are the only types known to nature, is no longer applicable in the sense it was intended by its illustrious promulgator, and it is vain to plead the individuality or want of convergence of animal groups.

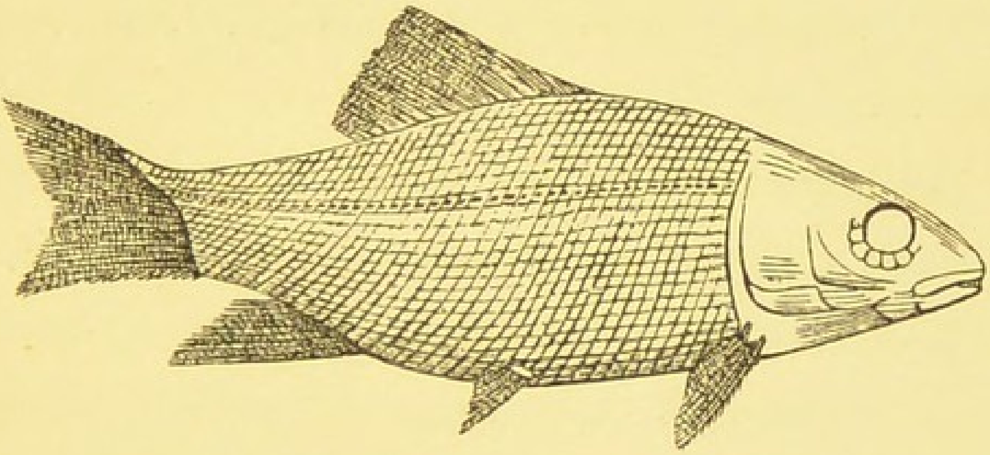
But let us press the inquiry still further, and



1. 2. 3.

Different types of tail-structure.—1. Homocercal (modern form). 2. Heterocercal (ancient form). 3. Diphycercal (primitive form).

within a narrower sphere. I have thus far treated of the relations of the different higher groups of animals, the limitations of which may not be very clear to the non-scientific mind. But where, the skeptical mind may ask, are the proofs of individual variation, of variation in special organic structures? I will attempt to lay before you some of these, and take my first illustration from the class of fishes. In the vast majority of the ordinary bony fishes, as is well known, the tail is nearly equally divided into two lobes, and is said

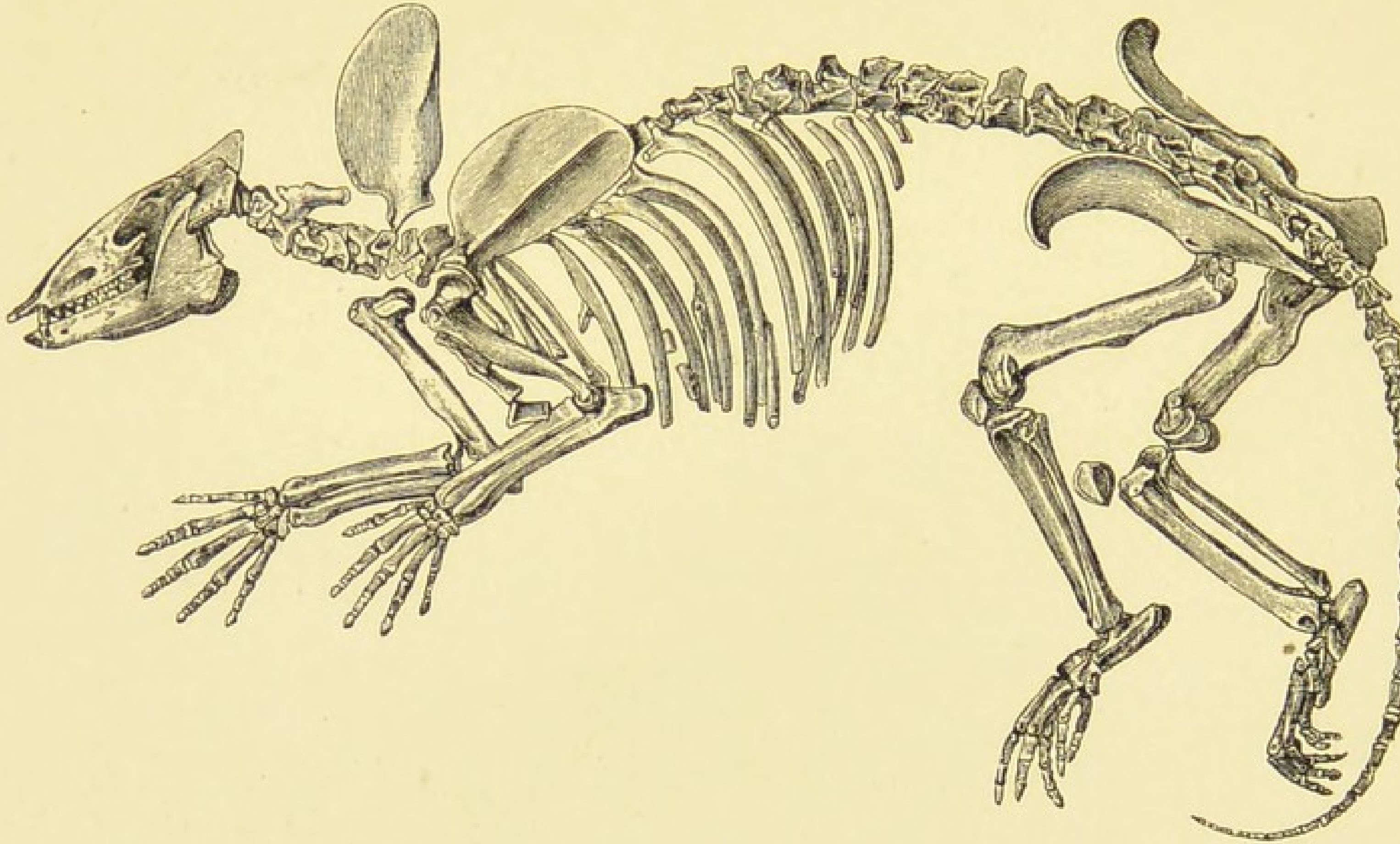


Semionotus leptocephalus.—Ganoid fish from the Lias of Germany.

to be *homocercal.* In sharks and rays, as representatives of the cartilaginous fishes, on the other hand, the tail is typically unequally lobed, and is said to be *heterocercal.* This, as might have been expected, seeing that the sharks represent a comparatively low ichthyic type, is also the case with the earliest fishes, with both sharks and ganoids, and not till an intermediate middle period do we find a tendency on the part of the tail toward homocercality. A large proportion of the Jurassic ganoids are provided with the modern form of tail, and these, again, are preceded by a form, Semionotus, in which the tail is of a distinctively transitional character.

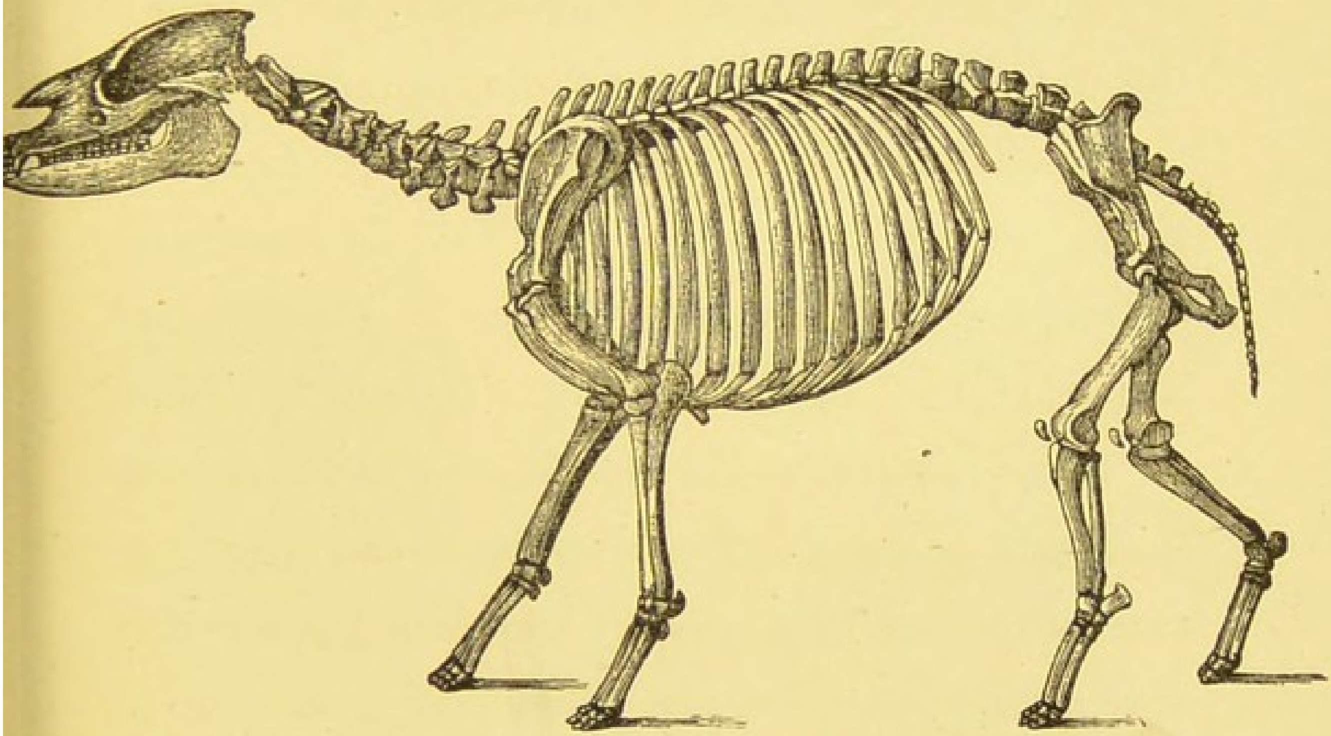
As pertaining to the group of reptiles I can present to you an equally beautiful and conclusive case of the modification of special structures. The crocodiles represent a fairly ancient group of reptiles, beginning with the Triassic period of time; the recent genera date from the period of the chalk. In their history they present a remarkable series of developmental changes. In the modern crocodiles, and in those of the later Cretaceous period, two series of bones belonging to the roof of the mouth, known as the palatines and pterygoids, are so disposed as to form the boundaries of the posterior nostrils; in the crocodiles that preceded these, or those of the early Cretaceous and Jurassic periods, only the palatines are produced to form these nares; and in the still earlier and earliest forms, those of the Triassic period, neither the one bone nor the other is concerned in the structure of the parts in question. Correlatively with these changes other modifications, scarcely less significant, mark the rise of this very remarkable animal group. Thus, the earlier crocodilian forms retain a primitive character in the biconcave form of the vertebræ—a structure belonging primarily to the lowest group of vertebrates, the fishes. This structure is replaced in the Cretaceous period by the cup-and-ball, or procœlous vertebra, which is also the type of the Tertiary and modern forms.

Other instances of similar variation and progression could readily be cited, but my limited time will only permit me to dwell upon a few very striking cases drawn from the class of mammals. The history of the horse furnishes, perhaps, the most complete series of structural modifications which permit us to trace the ancestry of an animal in very nearly its minutest details. The chart before you indicates these modifications in a series of horse-like animals which carries the line of descent of our modern animal back to the Eocene period, and to an animal so very different, that were it known by itself alone, it would be classified by zoologists, not only as a species distinct from the modern horse, but as a distinct genus, representing an entirely different family, and even a wholly different sub-order. The connecting ties, however, absolutely establish the serial line of progression, and indelibly mark the pedigree. The history of the European horse is almost as complete as that of the American, but remarkable though it may appear on any but an evolutionary hypothesis, its first ancestral forms include an animal different from any of the earlier equine progenitors of the New World, and one that holds equal claim to



Phenacodus (Lower Eocene). Progenitor of the American horse. Specimen in the possession of Prof. E. D. Cope, Philadelphia.

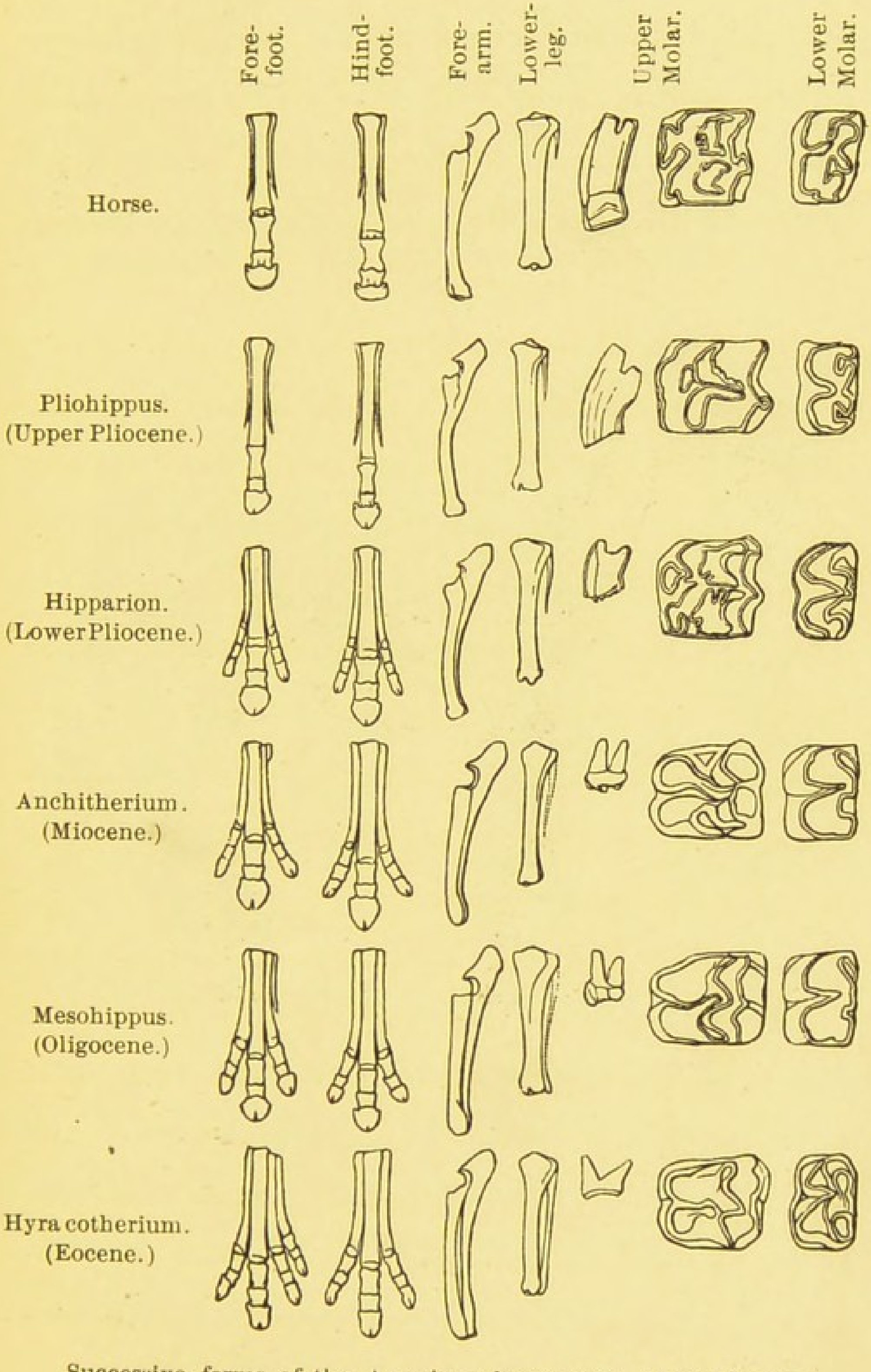
being the true progenitor of the tapir and tapir-oid animals. This is the Palæotherium, several species of which, ranging in size between the



Palæotherium. Ancestral form of the European horse (Lower Tertiary of the Paris Basin).

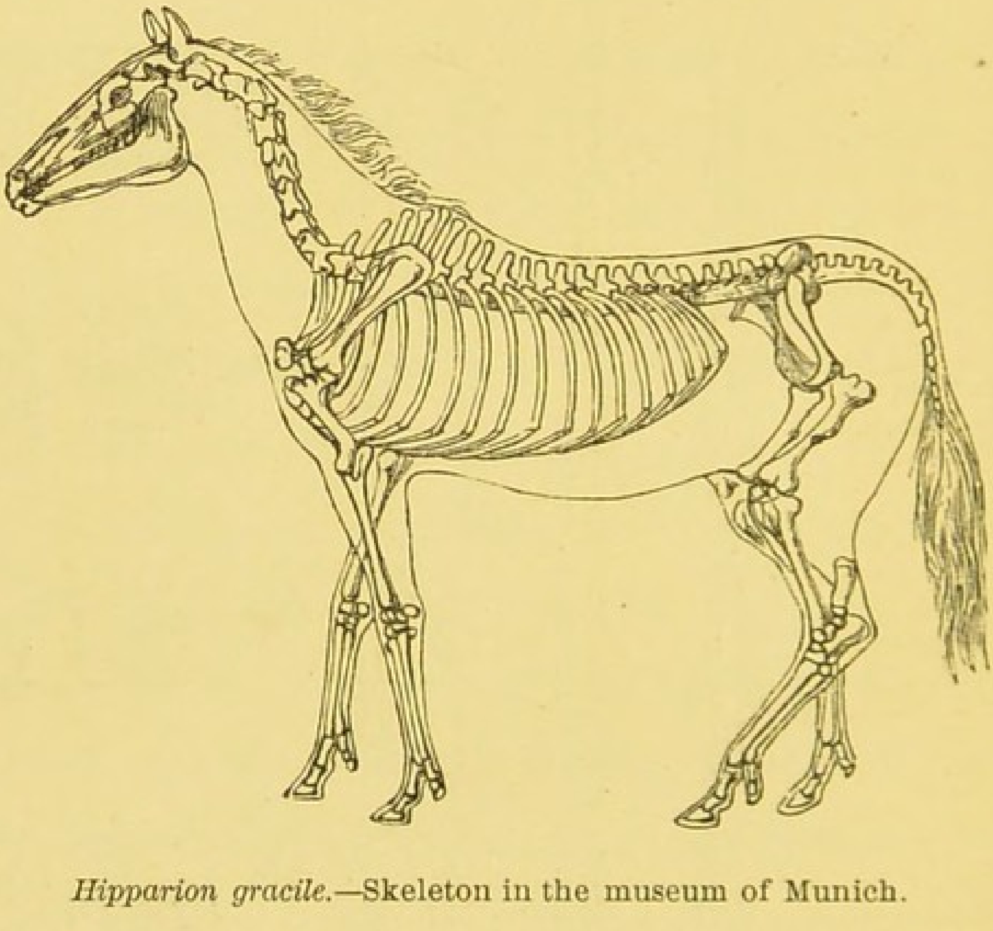
deer and horse, have been described, and whose remains from the early Tertiary strata of the Paris Basin furnished the material for one of the classic memoirs of the illustrious Cuvier.

The modifications here referred to are primarily the greater or less differentiation of the elements of the foot and leg (fore and aft). In the modern horse there is but a single toe to each foot, which is supported by a single metapodial (cannon-bone), but in the more ancient horse-like animals the feet were polydactyl in character, being furnished with three, four, or even five toes. This is seemingly a broad difference, and it might reasonably be supposed that there must exist strong grounds for uniting animals that appear so widely removed from one another. The *rationale* of our classification is the fact that between the earliest horse-like animals and the modern horse we have a series of transitional forms which show almost every grade of foot structure leading from polydactylism to monodactylism, the toes undergoing gradual reduction in number, and (excepting the single toe that is retained) growing smaller in size as we proceed from the more ancient to the more modern forms. This gradation is beautifully



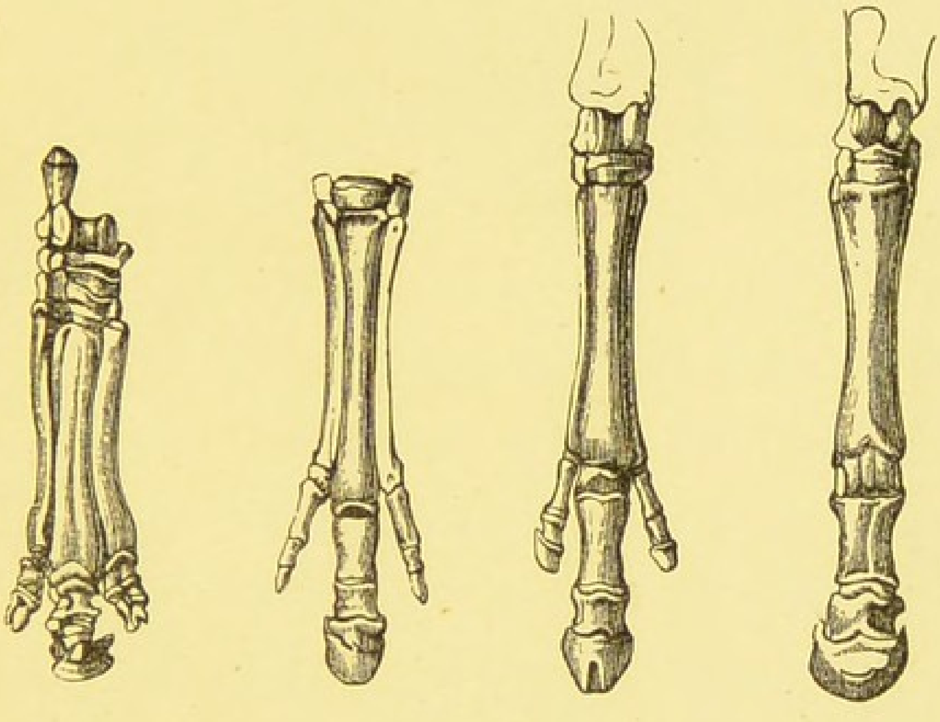
Successive forms of the American horse type. (After Marsh.)

illustrated in the chart before you, where the supernumerary, and to an extent functionless, toes of the Eocene Hyracotherium, which is followed by the less and less distinctively polydactyl



Hipparion gracile.—Skeleton in the museum of Munich.

forms of the Oligocene, Miocene, and early Pliocene periods, are seen to be represented in the later Pliocene Pliohippus and the recent horse (Equus) by a simple pair of "splints" attached to the cannon-bone. Beyond the Hyracotherium we have still a full five-toed animal, the Phenacodus, which is now generally recognized as the earliest known progenitor of the horse tribe. Correlatively with the progressive changes in the structure of the foot, there are equally well-

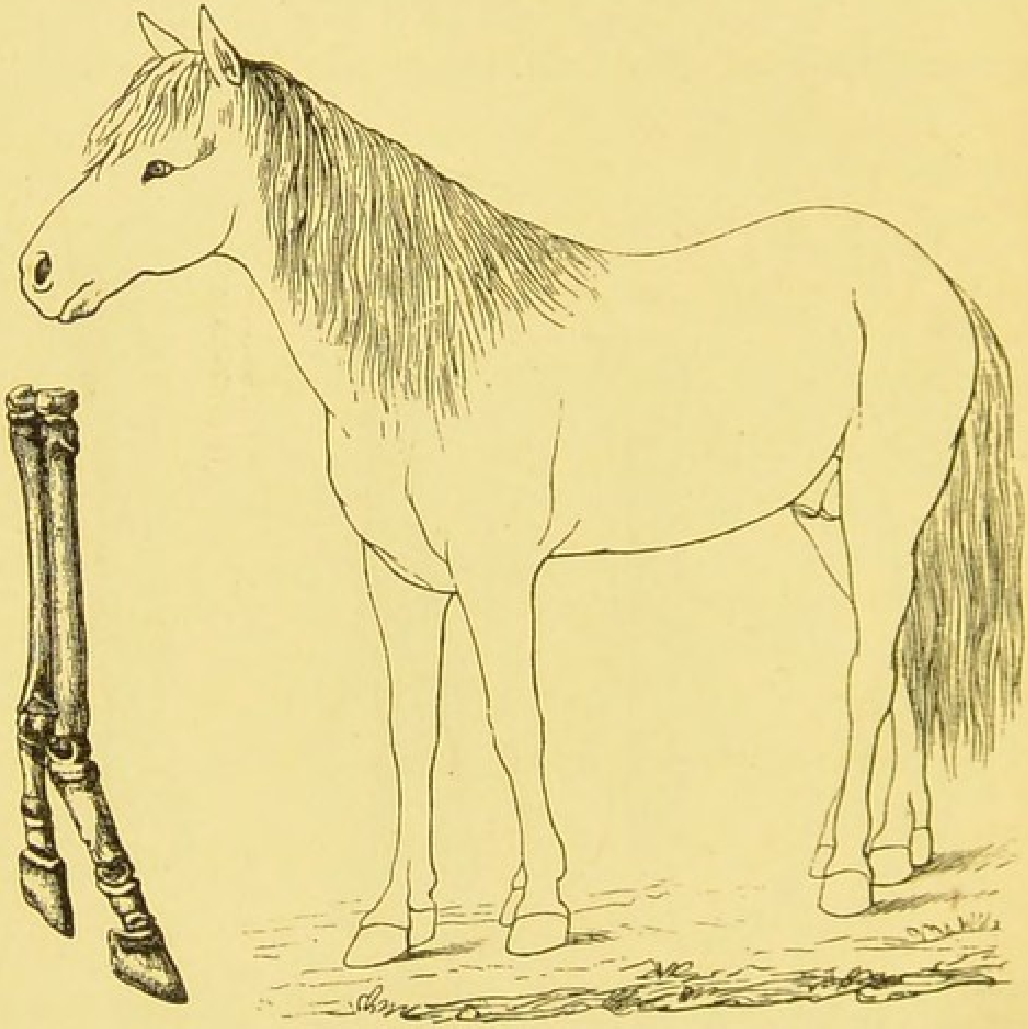


1. 2. 3. 4.

Successive stages in the development of the European horse.—1. Palæotherium (Eocene); 2. Anchitherium (Miocene); 3. Hipparion (Pliocene); 4. Equus (modern).

marked modifications in the disposition of the bones of the arm and leg, and in the form and complexity of the grinding teeth, which are also illustrated on the chart before you.

That some of these modifications belong as well to the horse as a specific animal as they do to the horse as a tribe, is conclusively shown



Recent didactyl horse. (After Marsh.)

by the circumstance that we even now occasionally meet with living horses possessed of more than one toe to the foot, and, indeed, it has been affirmed—although the statement still lacks full confirmation—that the embryo horse is polydactyl. These are important facts bearing upon the developmental history of the animal.

The cameline animals, especially those of the New World, present a connecting series or chain almost as complete as that which has been established for the horse. The existing animals of this group, in common with other ruminants, have the bones of the middle-foot (the metapodials) united into a single "cannon-bone," as in the deer, but they differ strikingly from all other members of the broad group which they represent in possessing a pair of incisor teeth in the upper jaw. By some naturalists the absence of superior cutting teeth in the ruminants has been supposed to stand in direct connection with the development of horns, but just in what manner has not been definitely determined. It is, however, an interesting circumstance, that the cameline forms, almost alone among ruminants, are entirely destitute of horns, while they possess the peculiar dental character above referred to.

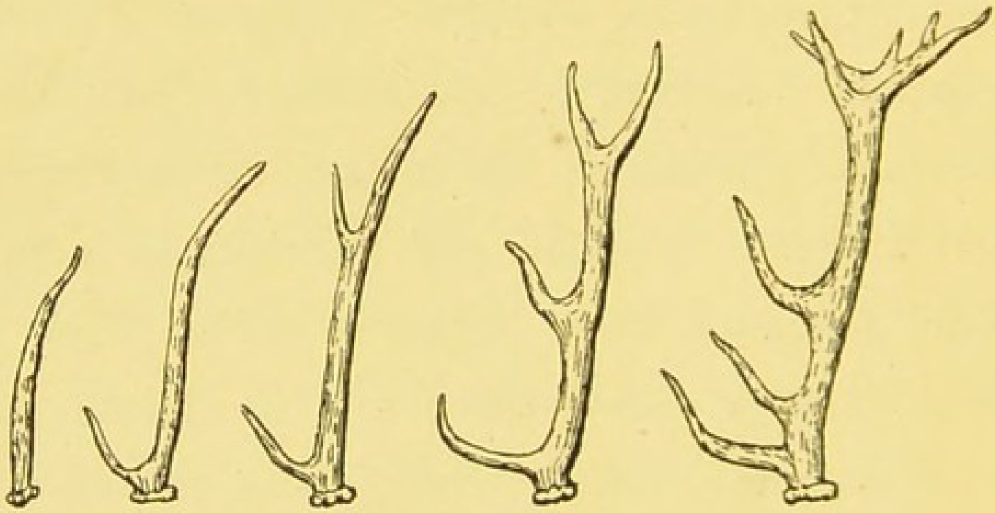
In following back the ancestral line of these hornless ruminants we can detect a series of very remarkable and gradual modifications which connect the modern animal with animal forms very unlike itself. Thus, in one of the earliest members of the cameline series, the Oligocene or Miocene Poëbrotherium, whose species appear to have had the slender and graceful proportions of the modern gazelles, the metapodial bones were distinct, and the mouth was furnished with a complete series of incisor teeth. This distinguishing dental character is retained in the succeeding Protolabis (Middle Miocene), but whether or not the metapodials were united into a single cannon-bone is still unknown. In the Upper Miocene Procamelus, whose forms ranged in size intermediate between the sheep and camel, the incisor teeth have been reduced to the normal number found in the camels, although the premolars still conform to the formula $\frac{4}{4}$, instead of $\frac{3}{2}$, which distinguishes the genus Camelus. An intermediate position between Procamelus and

Camelus is held by the Pliocene genus Pliauchenia, which possesses but three premolars in the lower jaw, while nearly the extreme term of reduction in this part of the dental series is found in the late Pliocene and recent llamas (Auchenia), which retain but two premolars in the upper jaw and a single one in the lower jaw. Finally, in the nearly contemporary genus Holomeniscus, which embraced animal forms fully equalling the camel in size, and ranging from Oregon to the valley of Mexico, there is but a single premolar left to each side of either jaw.

The eliminative development that has here been traced corresponds very closely with the conditions presented by the living animal in passing from its embryonic to its adult condition. Thus, in the fœtal condition of probably all ruminants the metapodial bones are distinct, as in the early Poëbrotherium; moreover, the animals are provided with cutting teeth in the upper jaw, in the manner of their ancient progenitors. Professor Cope, who has given close attention to the study of the development of the cameline race, further shows that very young camels have the additional premolar of Pliauchenia, and that this tooth is shed at an early period, very rarely persisting for any length of time. Similarly, the anterior premolar of the normal camel is found in the young llama, but it is dropped long before the animal attains maturity.

The investigation of the causes which have wrought these remarkable changes in the animal frame constitutes more properly a part of zoological or physiological inquiry, and I can but briefly refer to the modifications as resulting primarily from the interaction of mechanical forces. The use and disuse of parts must necessarily have a direct bearing upon their ultimate development, and similarly the manner of use must largely influence the manner of growth of such parts. These are conditions known to us in our every day experience but, owing to the very limited time over which our direct observation extends, we are generally able to detect only minor changes, and miss the grander effects which are dependent upon the action of time. The swift-footed animal, which in the process of rapid locomotion elevates the body so as to weight it principally upon the extremities of the toes, leads the way to the gradual disuse of those toes which, in the required position, are no longer able to give support to the body; hence, a consequent degeneration, and the formation of those apparently "accessory" and more or less functionless toes which we see in the hog and many other animals. Similarly, the necessity for a rigid frame combined with lightness would tend to bring about a consolidation of those bones, like the metapodials, whose independent action may now no longer be required. The character of the food supply, necessitating definite methods in the way of eating or mastication, must have a direct effect upon the masticating apparatus, and conduce toward the formation of the special dental structures which are distinctive of the different animal groups.

Perhaps no more beautiful illustration of the special modification of a certain organ or structure can be found than that exemplified in the development of the deer's horn. Everyone is aware that in our ordinary deer with branched antlers the process of growth is a regular and successive one. Before the first shedding we have a single



Successive stages in the development of the stag's antler. (After Gaudry.)

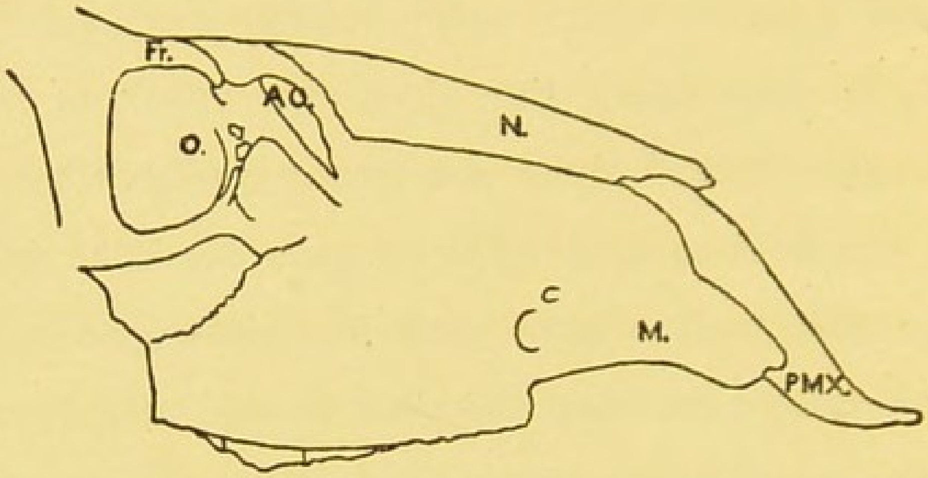
solid horn; after this shedding a single tine is developed; then a second, and a third, until we have the complicated structure of the typical antler. Now, precisely this system of progression can be traced in the geological history of these animals. In the early cervine animals of the Middle Miocene period, as has been so clearly stated by Prof. Boyd Dawkins, the horn is a simple

1. 2. 3. 4. 5.

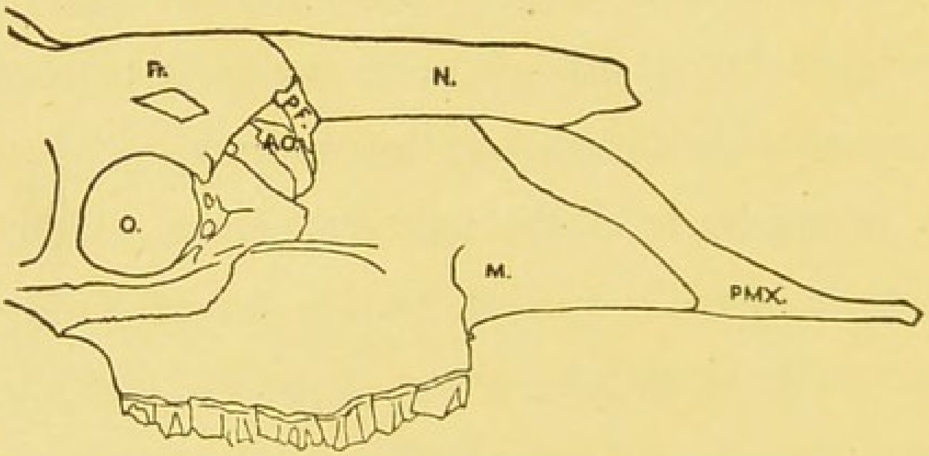
Stages in the geological development of the deer's antler. 1 (*Dicrocerus*), Miocene; 2, Upper Miocene; 3, Pliocene; 4, 5 (5, *Cervus Sedgwickii*), Newer Pliocene.

forked crown; in the Upper Miocene it becomes more complex, but is still small and erect, as in the roe; in the Pliocene it becomes larger and longer, and altogether more complex and differentiated, some forms, such as the Cervus dicranios of Nesti, having the most complicated antlers known either in the living or fossil state. Seeing this steady progression in the complication of the antler, it might naturally be expected that were we to trace this development backward we should gradually come upon a zero of complication, and that eventually the horn would completely disappear. And this is precisely what we find to be the case. The earliest cervine animals, or those of the Lower Miocene period, are absolutely hornless, and the series is thus made complete. The question naturally arises: Are these earliest hornless forerunners of the true deer deer or antelopes? The fundamental distinction between these two groups of animals lies in the fact that the horns of the antelope are hollow, instead of solid, as in the deer, simple, instead of branched, and that they are not periodically shed. But if there are no horns present, how are we to determine, in the absence of these distinguishing characters, the actual position of the animal under consideration? This is a problem that does not admit of ready solution; indeed, there is a strong probability that the hornless animals of the Lower Miocene period were ancestral to both deer and antelopes, a dual development starting out, just as we have seen to be the case with many other animals, in diverging directions. The high probability of this dual development is forced upon us, apart from all other considerations, by the remarkable case of the prong-horn of the western plains, which is a hollow-horned ruminant, to all intents and purposes a true antelope, yet with divided horns, whose sheaths are periodically shed, in the manner of the shedding of the horns of the deer.

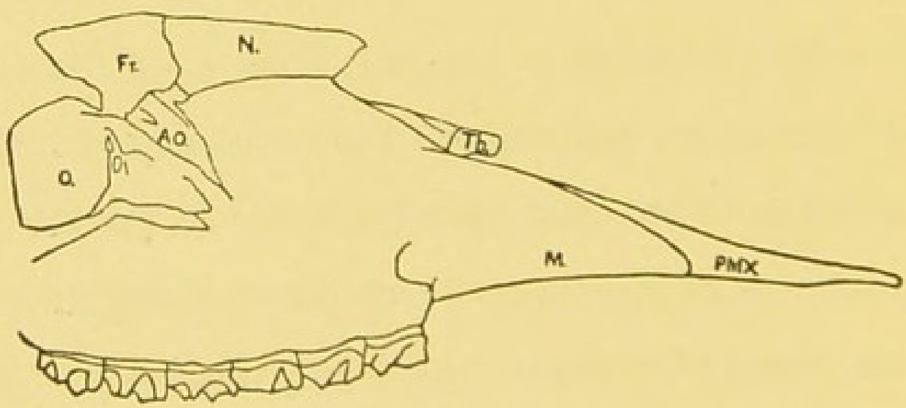
The deer have quite recently furnished one of the most interesting examples of a connecting form, or so-called missing link, in an animal exhumed from the swamps of northern New Jersey, which stands intermediate between the stag and elk. This relation is made clear by the figures of the skulls of the three species which are placed before you.



I.



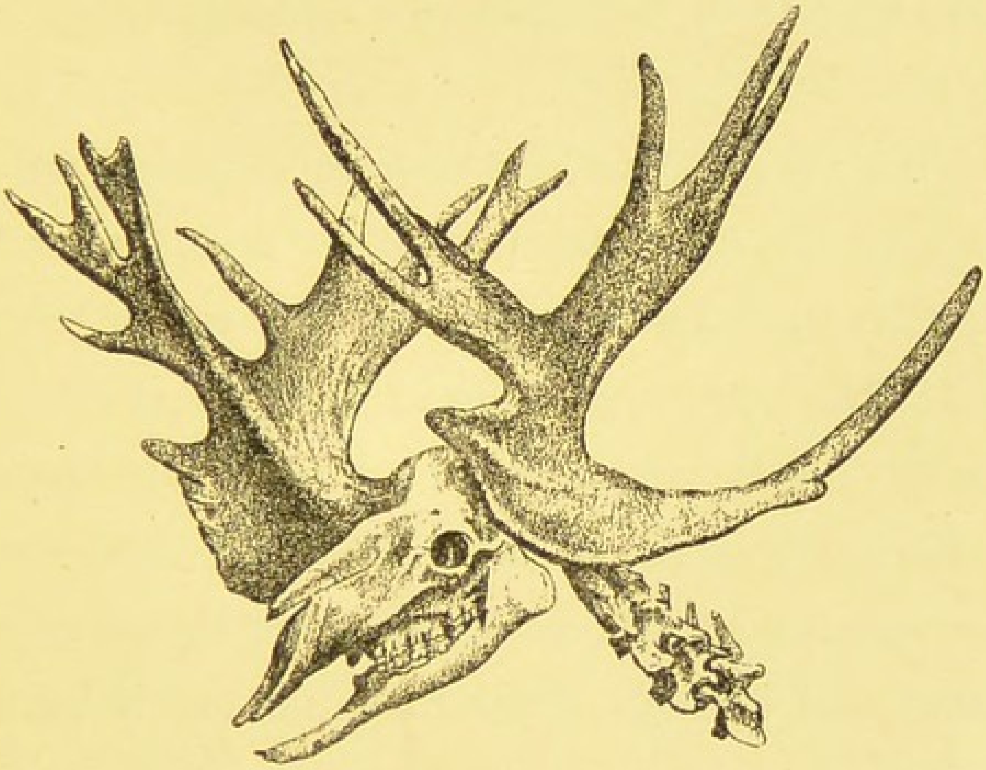
2.



3.

1, Skull of the Canada stag; 2, of *Cervalces Americanus;* 3, of the elk. (After Scott.)

In the stag, it will be observed, the skull is high, and shows but little of that anterior attenuation which is such a distinctive feature of the skull of the elk. The nasal bones (N) of the former, again, are remarkably long when compared with the sim-

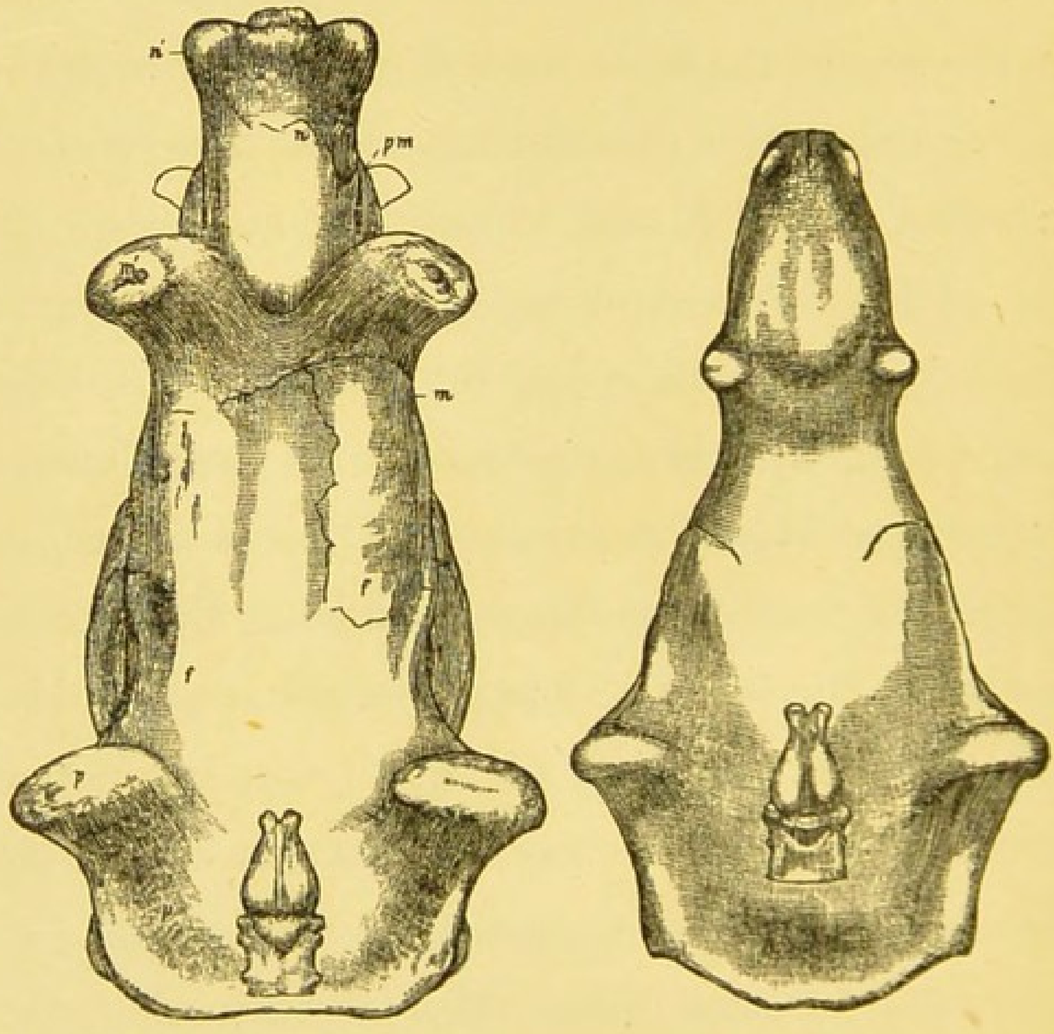


Head of *Cervalces Americanus.*—Specimen in the Museum of Princeton College.

ilar bones of the latter, and the premaxillaries (PMX), instead of being projected forward along the horizontal plane of the base of the skull, are deflected sharply downward. In all these points, it will be seen, the newly discovered form (Cervalces) holds an intermediate position. The skull exhibits a partial attenuation anteriorly, the premaxillaries are directed about equally downward and forward, and the nasal bones are measurably contracted in size. The horns likewise furnish characters which further serve to establish this dual relationship.

There is still one phase of development which remains to be considered—the development of intellect or brain force. Although seemingly an intangible subject, geology affords evidence in regard to it fully as important as that which attaches to the development of bone or muscle. No absolute relationship has as yet been determined to exist between the size of the brain and mental capacity, the latter being largely, or even principally, dependent upon the quality of the brain material, but, in a general way, it may be admitted that the larger the brain in proportion to the body, the greater will be the amount of brain force generated by it. Using this most legitimate standard as a basis for comparison, we are brought to an astonishing result when a study is made of the brains of the earlier animals, the outlines of many of which have been as perfectly preserved as the casts of the interiors of shells. From this study it appears that all the Tertiary mammals had comparatively small brains, and that there has been a gradual increase in the size of the brain mass from the earlier to the later parts of this period, the increase being almost wholly confined to the cerebral hemispheres. In the earlier forms—indeed, until late in the Tertiary—the hemispheres left the cerebellum entirely uncovered, and the olfactory lobes were correspondingly largely developed. The brain was, in fact, more nearly reptilian in character than mammalian. The series of diagrams before you illustrate the development of the brain in certain mammals of the Tertiary period more or less closely connected in their ordinal relations.

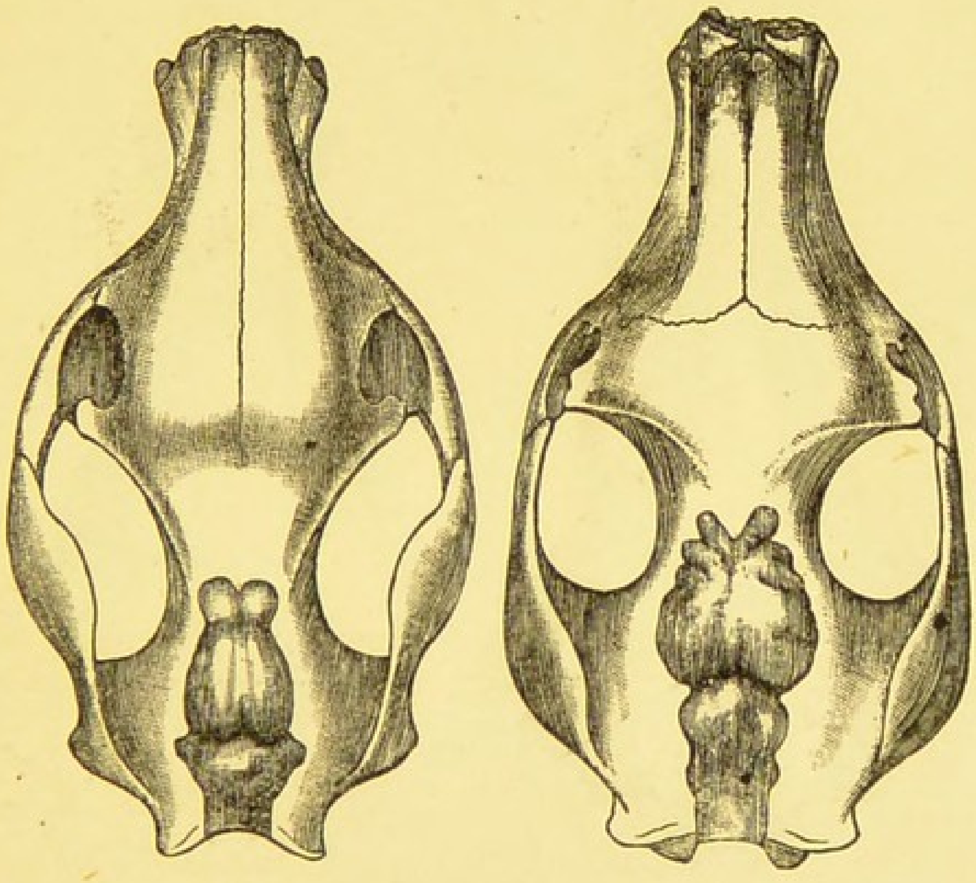
It will be seen from these figures that the relative size of the brain in the older mammalian types was small when compared with that of the forms which successively followed them. In some of the Dinocerata, which were by far the largest of the Eocene Mammalia, nearly equalling the elephant in size, the brain was so small that it could have been passed through the neural arches of the lumbar or



1. 2.

1, Skull of *Tinoceras* (*Uintatherium*) *ingens*, with brain cast in position; 2, of *Dinoceras laticeps*. Middle Eocene. (After Marsh.)

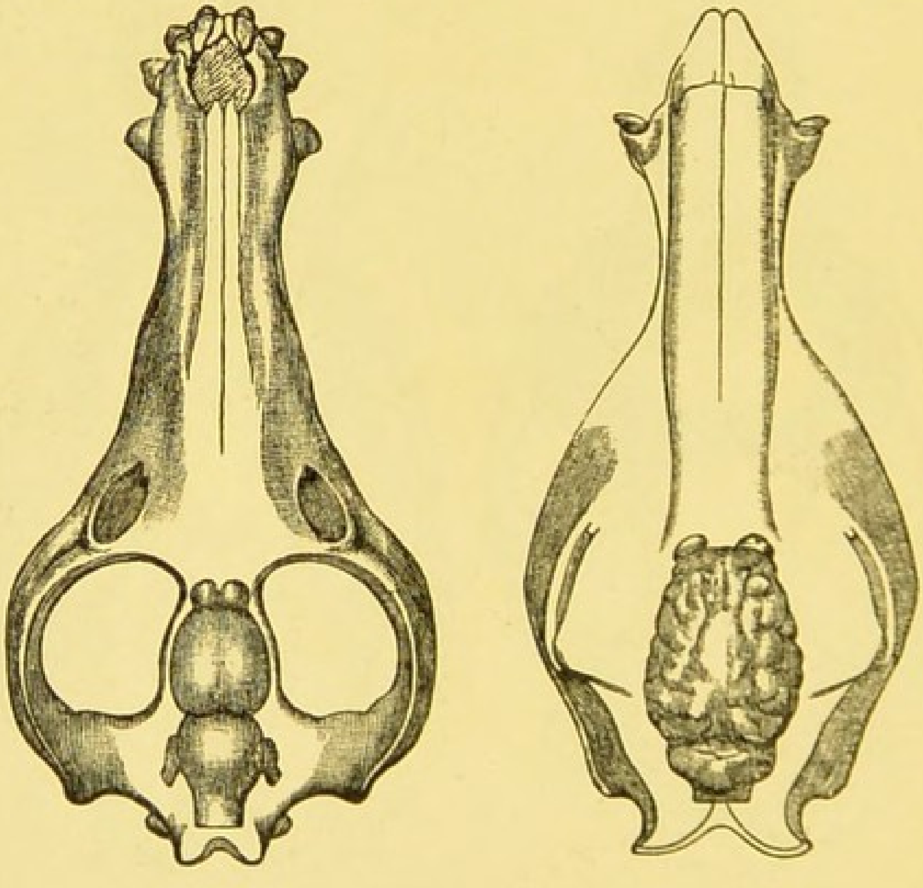
sacral vertebræ! In relative size this diminutive brain, which is proportionately the smallest brain known among mammals, whether recent or fossil, is surpassed by the brains of many reptiles. Hoplophoneus oreodontis, one of the sabre-toothed cats, although of about the size of a panther, had a brain no larger than that of the domestic cat. The peculiar sulci or gyri seen



3. 4.

3, Skull of *Limnohyus robustus* (tapiroid), Middle Eocene; 4, *Amynodon advenus* (rhinoceros), Upper Eocene. (After Marsh.)

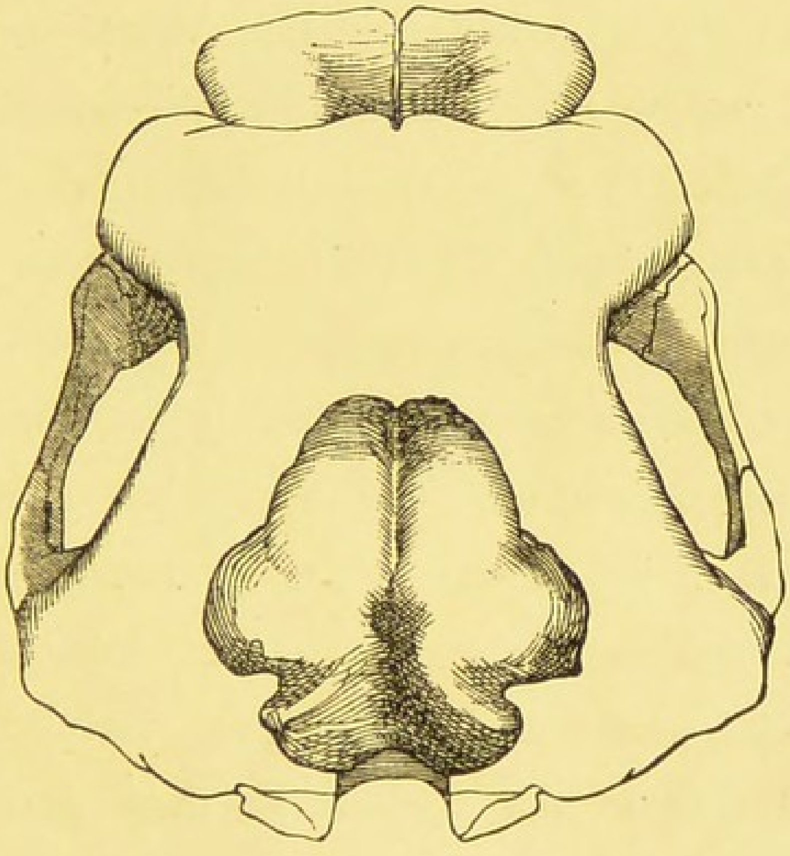
on the dorsal aspect of the brains of modern mammals were also largely absent in the earlier forms, or were disposed longitudinally, instead of transversely, as we find them in the lowest of recent placental mammals—the rodents, edentates, and insectivores. The same law of cerebral development which is here indicated for the Mammalia is also applicable to reptiles



5. 6.

5, Skull of *Elotherium crassum*, Miocene; 6, *Platygonus compressus* (peccary), Pliocene. (After Marsh.)

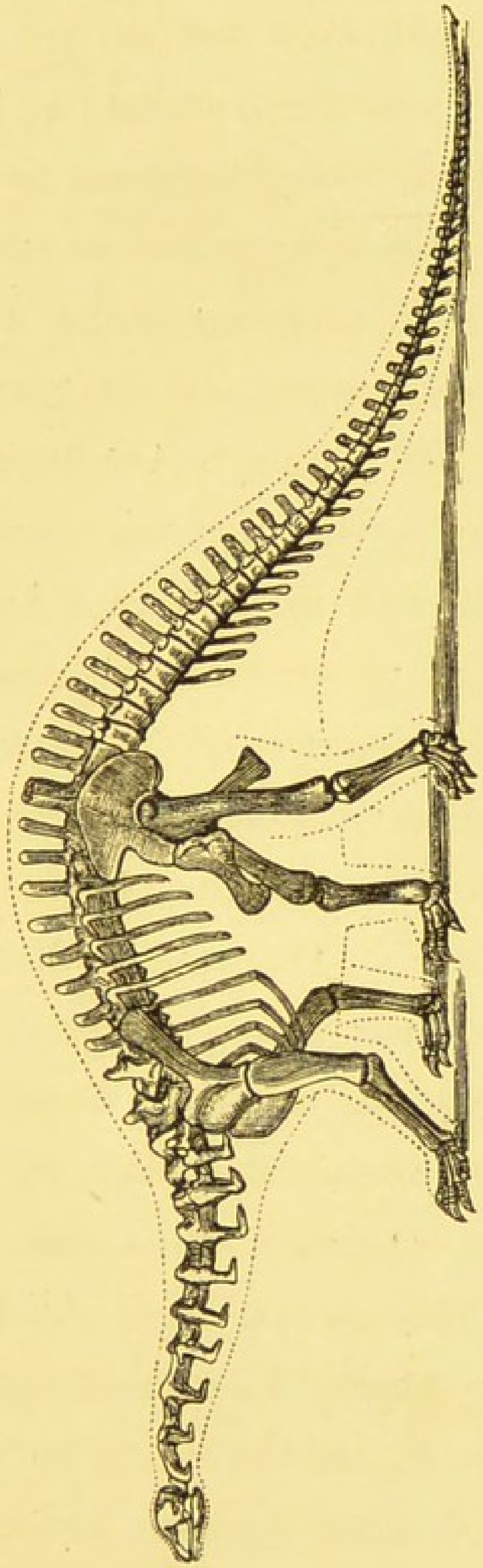
and birds, and in probably equal degree. I have placed before you a drawing of one of the largest of the dinosaurian reptiles, the Jurassic Brontosaurus, an animal measuring probably fifty feet in length, yet in which the weight of the entire skull does not appear to have exceeded that of the fourth vertebra of the neck.



7.

7, Skull of *Mastodon Americanus*, Pliocene and Post-Pliocene. (After Marsh.)

Before dismissing this part of my subject I must direct your attention to one phase of the inquiry which is as well geographic as it is geologic in its scope. It is a familiar fact that the different parts of the earth's surface are to-day characterized by distinct faunal associations. Thus, we recognize a South American fauna as distinguished from an African, a Eurasiatic fauna as distinguished from an African or Australian, and so on. Now if, as is contended by the upholders of organic evolution, our existing faunas have been developed from their immediate faunal antecedents, we must have some indication or foreshadowing in the latest geological formations of the faunal characters which, in a broad way, serve to distinguish the several zoogeographical regions. And this is precisely what we find. You have already learned that in the earlier Tertiary periods of mammalian history the existing animal forms were almost wholly different from the forms of to-day, and that they became less and less



Brontosaurus excelsus.—Jurassic dinosaur from Wyoming. (After Marsh.)

different as we approached the modern era. But with this distinctness there appears to have been more of a general correspondence between the faunas of the different parts of the earth's surface, so that the zoogeographical boundaries which we now recognize could at best be only partially drawn. It is only in the Post-Pliocene, or latest Tertiary, period that the approximation between the past and recent faunas has been so far established as to permit us to trace clearly the existing zoogeographical relations, and to state that the modern fauna has been sketched out in place. Thus, in the Australian Post-Pliocene marsupials Diprotodon, Nototherium, Thylacoleo, and their allies, we have the fore-runners of the various marsupial forms that now characterize the continental fauna; in the giant birds Palapteryx, Dinornis, Mionornis, etc., from New Zealand, Dromæornis from Australia, and Æpyornis from Madagascar, the forerunners of the wingless apteryx and the struthious birds from the same or neighboring regions; and in the giant

South-American edentates, Glyptodon, Megatherium, Mylodon, and their allies, the representative, if not the ancestral, forms of the existing sloth, armadillo, and ant-eater.

III.

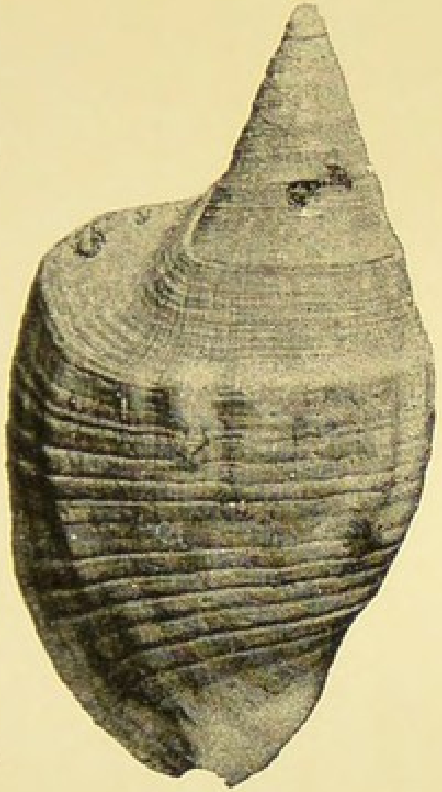
There has been much speculation, and no less controversy, during recent years, concerning the birthplace and origin of man, and I don't know that we are any nearer the solution of these questions than we were immediately after the publication of Mr. Darwin's "Origin of Species," nearly thirty years ago. That man is a descendant of some two-legged and two-armed creature much like himself, although less hominine both in the development of his intellectual faculties and the structure of his bodily frame, there is little reason to doubt, but science has thus far failed to make known this earliest and much looked for preadamite. I am not prepared to share the enthusiasm of certain French archæologists who recognize in a number of very ancient "chips" or "flints" the handiwork of apes, and in these last the missing progenitorial tribe (Anthropopithecus); for although the reputed facts may be true—and I am far from denying that they are true—some further evidence is needed before they can be confidently accepted as facts pure and simple. Nor can I fully appreciate the evidence which carries his antiquity back to the earlier portion of the Tertiary epoch. I fail to find satisfactory proof of man's belongings having been found in deposits very much (if at all) older than the Post-Pliocene, although not unlikely some such will yet be discovered of far more ancient date; but a sharp line must be drawn between actualities and probabilities.

In our own country the finding of the "most ancient remains" of man has from time to time been reported, but I am not aware that in any case these remains can be proved to be older than the remains found in different parts of Europe; indeed, in most cases they appear to be much younger. The implements from the "Trenton" gravels of the Delaware, if actually belonging there, would seem to indicate an antiquity dating from the glacial epoch, and probably nothing beyond this can be definitely located. The famous Calaveras skull, from the auriferous gravels of California, is still too much involved in obscurity to permit of its being used in positive evidence; nor can much dependence be placed upon the calculations which have been made to determine the age of the man of Florida, which was discovered by Pourtalès upwards of thirty years ago. I have the pleasure to lay before you this evening two human vertebræ, which I obtained two winters ago from a semi-compact ferruginous sandstone on Sarasota Bay (west coast of Florida), and which our distinguished President, Prof. Joseph

Leidy, has kindly determined for me to be probably the last dorsal and first lumbar. The vertebræ, it will be observed, are of iron, there having been a complete substitution of the bony material by iron-hydroxide (limonite), but with an absolute retention of the structure distinctive of bone. Many of the other bones of the skeleton were still associated with these vertebræ, but with limited facilities at my command I was only able to procure these two fragments. How old they may be I am not prepared to say; unfortunately, their geological position was such as not to permit of a clear determination of this point. Apart from the cast of an unknown form of coral found in a neighboring and similarly placed stratum, paleontology furnishes no clue to the solution of this interesting problem. But that the age is very great, the condition of fossilization fully proves; and I think it may be safely held that the vertebræ in question represent the most ancient, or very nearly the most ancient, remains of man that have thus far been discovered. But beyond this it would be dangerous to venture.

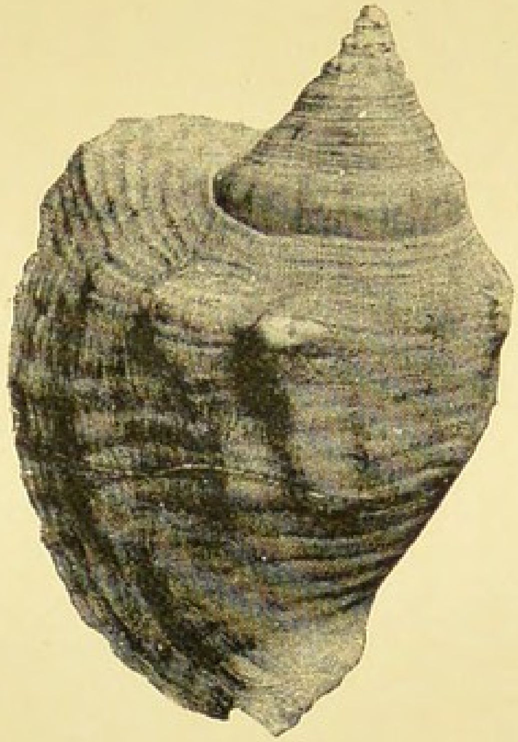
We have thus far confined our attention exclusively to a consideration of the higher groups of animals, the Vertebrata. The lower or invertebrate animals present equally striking proofs of modification and transformism, but the limited time at my command will permit me to bring before you only one or two special cases, drawn from the class of Mollusca, with which my own investigations are connected. If the doctrine of evolution holds true, it stands to reason that, as in the case of higher animals, the existing fauna must be foreshadowed in the fauna of a period immediately preceding; this connection cannot generally be established, owing probably to migrations and intermixtures of different faunas, as depending upon changes in the physical condition of the surroundings. In the sheltered region of the Gulf of Mexico, however, a fauna appears to have been developing in place for probably hundreds of thousands of years, so that the unequivocal ancestors of many of the living forms can be found in the fossil remains that preceded them. I have brought before you several such forms, which it was my pleasure to discover two winters ago in the interior wilds of the peninsula of Florida.

One of these you will readily recognize as a wing-shell, of the type of the large pink conch which is found on so many of our mantel tops; I have named the species, in honor of the distinguished President of this Academy, *Strombus Leidyi*. Alongside of it I have placed the stromb most nearly related to it in the recent fauna, *Strombus accipitrinus*, an inhabitant of the Floridian and West Indian coasts. In comparing the two together it will be seen that the principal distinguishing characters lie in the particular form of the wing, and in the tuberculation of the body-whorl or chamber, but these differences are so well marked as to obscure at first sight the relationship. In the majority of the fossil forms the wing is more or less evenly crescentic in outline, whereas in the recent species it is markedly quadrangular in its upper moiety, so much so that in extreme specimens the outline is wholly different from that seen in the fossil. But *Strombus Leidyi* shows a pronounced tendency to vary in the direction of *S. accipitrinus*, and conversely the latter, in this regard, seems to vary equally in the direction of the former, so that we have an almost perfect gradation established between the extreme wing-structures seen in the one species and the other, or between the almost perfectly crescentic outline and that which exhibits the greatest quadrangulation. In a similar manner the very prominent tubercles seen in the recent species, which are represented by elongated nodes in the fossil, are more or less lost in some individuals, although they at all times appear more prominent than in the

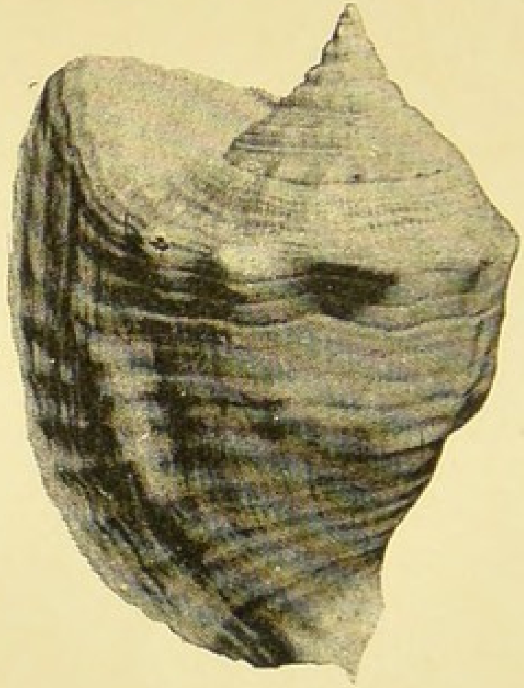


I

1*a*



2



2*a*

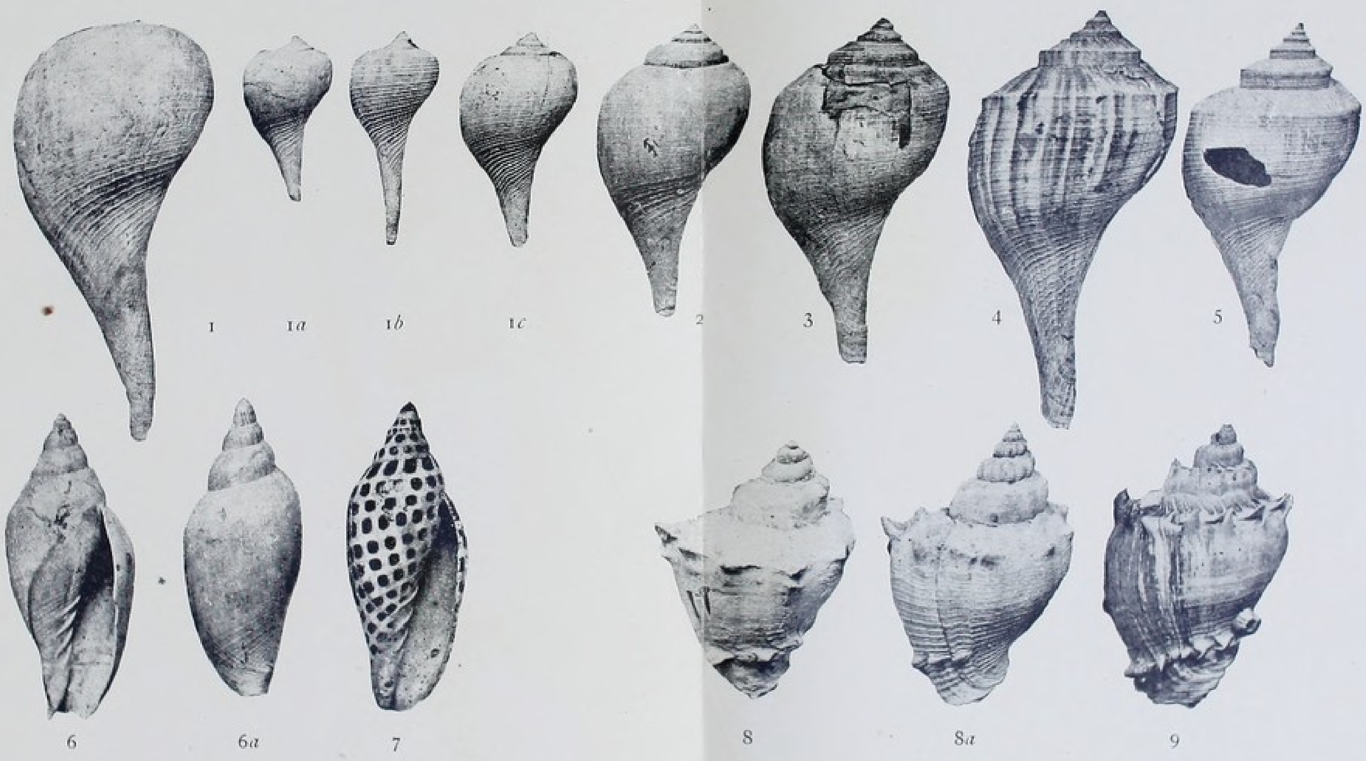
1, 1a, Strombus Leidyi (1, typical), Pliocene. 2, 2a, Strombus accipitrinus (2a, typical), recent.

fossil; on the other hand, the nodose ribs of the fossil frequently tend in the direction of tuberculation, thus again bridging the interval between the two species. We have step by step all the intervening gaps filled in between the two species, and in such a manner as to leave no doubt concerning the interrelationship of the forms in question. It is interesting to note in this connection that no individuals of the recent form occur in the deposits containing the fossil species, which, as an inhabitant of the seas immediately preceding the present one, may very reasonably be looked upon as the immediate progenitor of the stromb of the modern Gulf.

In the case of the other two forms which I have brought before you, the fossil crown-conch (*Melongena subcoronata*) and volute (*Voluta Floridana*), we have similar or analogous details of structure which unite them with their living representatives (*Melongena corona, Voluta Junonia*). Thus, the first-named is distinguished from the common crown-conch of the Gulf by several well-marked characters, of which the deficiency in the number of tubercles to the different whorls, and the horizontal position occupied by them, are especially apparent. The tubercles are also more compact, and do not show the foliaceous or scaly character which they exhibit in the living species. But while these differences in structure readily serve to distinguish the typical or most abundant forms of the two species, they in a measure fail when some of the less typical forms are taken by way of comparison. Thus, a tendency toward increase or duplication in the number of tubercles is here and there apparent in the fossil form, while, *per contra*, a tendency toward deficiency is not exactly rare in the recent species. Similarly, the tubercles or nodes of the fossil, which in the typical forms stand out nearly horizontally from the shoulder of the shell, or have but a moderate inclination, are occasionally more nearly directed in the position occupied by the tubercles of *M. corona*; conversely, in many of the less typical forms of the latter there is a close approximation to the condition found in *M. subcoronata.* In this manner the two species are inseparably bound together. As in the case of the stromb, so in this instance also, no trace (or at best but a doubtful one) of the recent Melongena has been found in the deposits containing the fossil; nor, on the other hand, have any traces of the latter been found in the modern seas, so that we may here also plausibly assume that the one form is the forerunner and probable progenitor of the other.

The fossil volute differs slightly in outline from the rare living species of the coast, and is further distinguished from it by its more acute apex, and the greater prominence of the costal ornamentation on the apical portion of the shell. These differences, although not very great, nor seemingly of much consequence, are yet persistent, and as such may be considered of sufficient value to characterize a distinct species. But despite these differences it is impossible not to observe the very close connection which unites the two forms, and I must admit that on first finding the fossil I almost unhesitatingly referred it to the recent species (*Voluta Junonia*), and only after a careful comparison of actual specimens of the two species was I able to discern the permanent differences between the forms in question. Yet so fully convinced was I of the ancestral relation binding together the two that I did not hesitate, even in the absence of all color-markings, to pronounce the one as the all-probable progenitor of the other. Other specimens that have since come to me prove the correctness of my surmise, since these very clearly show the peculiar and beautiful color-markings which belong to *Voluta Junonia*.

I also place before you two series of conch-shells of the group to which the pear-conchs (Fulgur and Sycotypus) of the New Jersey coast

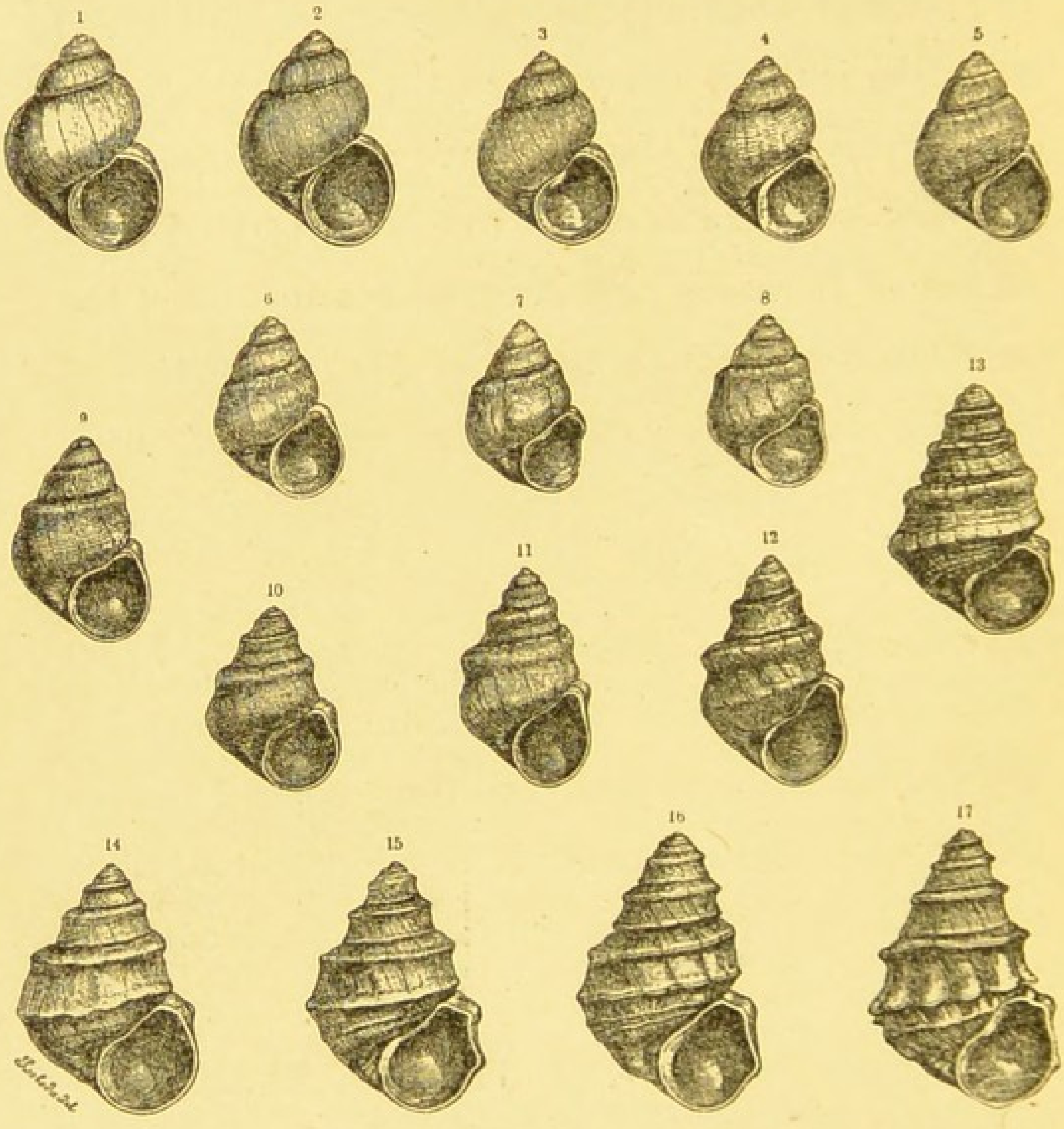


1-5, Series connecting Fulgur pyrum with Fulgur canaliculatus. 1, 1a, b and c, Fulgur pyrum. 2, F. excavatus. 3, F pyriformis. 4, F. plagosus 5, F. canaliculatus. 6, 6a, Voluta Floridana 7, V. Junonia 8, 8a, Melongena subcoronata. 9, M. corona.

belong, which the fossil fauna of Florida has permitted me to complete. They range back in time from the present era to the Miocene, or possibly even a still older, period, and comprise each some four or five hitherto described species and two or three new forms which are now for the first time brought to light. In other words, they represent some six or seven distinct species of systematists, yet so closely do they grade one into the other that it is impossible to define the individual limits, and they may be properly considered to represent one true or varying type. Is not this a remarkable instance of specific variation and origination, or is it merely a matter of blind coincidence?

It might very naturally be contended that in assuming the Pliocene fossils here represented to be the ancestral forms of some of the living species the assumption is in the nature of a thing taken for granted, and that no reasonable proof has been presented indicating the necessary changes from the extinct to the recent faunas. And were no further evidence presented than that which is embodied in the three shells under consideration, the objection taken would be allowed full weight. But when it can be shown, as can very readily be done in the present instance, that the Pliocene Floridian fauna, which is in geological time the fauna immediately preceding the present one, already embraces many of the forms that are now living, and a host of others that are strictly representative of, although not identical with, living forms; and further, that some of the forms, as the strombs, exhibit a remarkable tendency to variation or convergent modification, the objection loses all force, since it is distinctly opposed to the interpretation of fact and common sense. Manifestly, paleontology can offer no direct testimony to transmutation beyond that which a common-sense interpretation of facts will allow. But the evidence is approximately of the same nature as that which permits us to interpret a very large proportion of the phenomena about us without our being able to perceive the workings of such phenomena.

I cannot conclude this chapter on molluscan variation without referring to the very remarkable discoveries which have been made during the last few years in some of the later Tertiary lake basins of Germany and Austria, bearing upon the modification, through time, of the characters of certain well-known freshwater genera of mollusks. The so-called "Paludina beds" of Slavonia, which date from about the middle Tertiary period, will best illustrate my purpose. From these deposits, which run continuously from what are known as the "lower" to the "upper Paludina beds," and whose physical development appears to have been practically unbroken, Prof. Neumayr, of Vienna, has brought to light a number of forms, eight or more, of Paludina, which differ so materially from one another that to the casual observer they appear like so many distinct species; and as such have they actually been described. But it has been shown that the divergences through which the different forms have been brought about are clearly continuous and



Successive varietal and specific forms of Paludina from the Tertiary "Paludina-beds" of Slavonia. (After Neumayr.)

progressive; in other words, that the modification is a gradual one, leading up from the oldest found form of the basal series to the newest from the top bed. This is one of the completest cases of transformism known in the animal kingdom.

I have now submitted to you such of the evidences bearing upon evolution as it appeared to me would most readily appeal to a quick understanding and an unprejudiced mind. It is, however, but a tithe of the evidence which geology offers, and but a mere figment of that which pertains to zoology. If the facts that I have placed before you are true, and are properly interpreted, they must be held to be conclusive in favor of evolution; if they mean nothing, then science is a delusion and a snare, and we will be compelled to begin anew our conception of the universe, since the greater number of the recognized truths of astronomy, of chemistry, and of physics are based on facts identical in character with those which I have adduced from geology and paleontology.