Bulletin # 22

The Dinosaurs of Wyoming

By

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The Wyoming Geological Survey

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BULLETIN XXII

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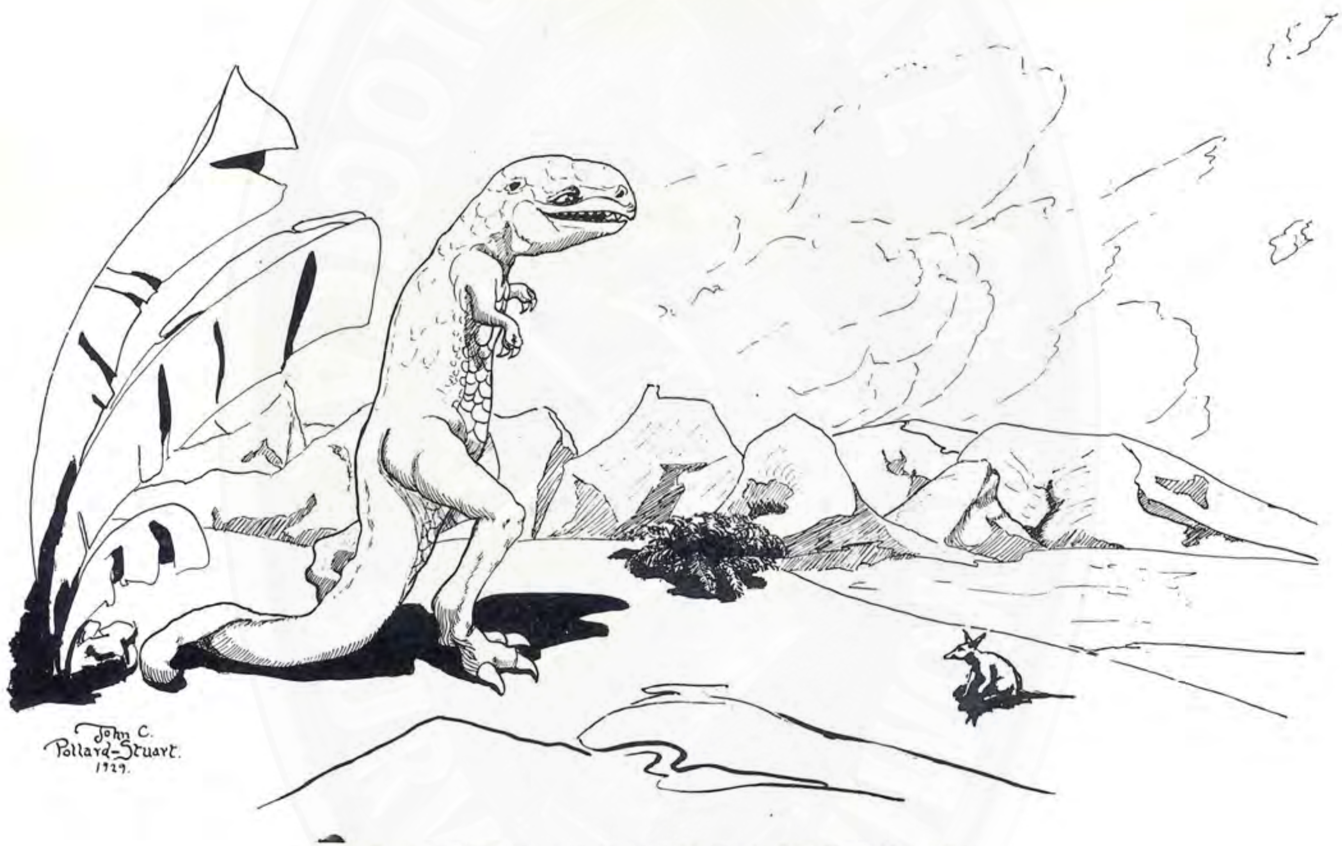
1930

Tragedy of the Mesozoic

All the elements of deep tragedy were present during the closing stages of the Age of Reptiles. The ponderous dinosaurian reptile, many feet long, and thousands of pounds in weight, was a failure. Mother Nature had, through millions of years, given the dinosaurs every chance to succeed in the development of a race, ancestral to later, higher forms. Experiment after experiment, yielding the curious and the bizarre, had all failed. One by one dinosaur groups had appeared, run their course, and disappeared in extinction. What more is needed in a successful tragic drama than the powerful pathos, inability of adjustment to changed environments, and certain disastrous end? The dinosaurian reptile, here depicted, was the last of his race, a sad hero of the Mesozoic.

Yet provident Nature had not been idle nor thoughtless, for way back in the Triassic Period, when the dinosaurs began their earthly course, the Mammals, derived from other reptiles, also had their beginning. They were dominated by reptiles of sea, land and air throughout the Age of Reptiles, and during the entire Mesozoic the Mammals remained small and inconspicuous; many of them doubtless arboreal in the Cretaceous days and living their lives remote from the dinosaurs. Others, resembling the rodents, lived in holes in the ground, or in crevices among the rocks.

So at the close of the great Age of Reptiles—The Mesozoic—the stage was set for a great tragedy, the extinction of the Dinosaurs! The Mammal (on the right), inconsiderable in size, whether marsupial, multituberculate or just any Mesozoic Mammal, specializing in brain power, stands ready to assume, unafraid, a leadership of untold possibilities, which he and his kind later maintained throughout the Age of Mammals, the Cenozoic, and still maintain in the Age of Man.



An Upper Cretaceous Landscape in Wyoming, Millions of Years Ago.

Dedicated to

My Teacher in Paleontology

SAMUEL WENDELL WILLISTON

in Memory of

Our Many Fossil Hunts

in

WYOMING

The DINOSAURS *of Wyoming*

By

ROY L. MOODIE, Ph. D.,

Santa Monica, California

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INTRODUCTION

The interest that has been displayed in regard to the dinosaurs that formerly thrived in Wyoming prompted the publication of this bulletin. This interest is not surprising. Many million years ago the dinosaur family reached its maximum degree of development in or near the fresh water ponds and lakes that dotted the terrain we now call Wyoming.

It may seem strange to relate that no work has recently appeared in which an attempt is made to review the supremacy of Wyoming in bone and brawn development for all time. To rectify this outstanding omission Dr. Roy L. Moodie, the well-known paleontologist, anatomist and paleopathologist was prevailed upon to write this book under title of "THE DINOSAURS OF WYOMING."

Perhaps no savant was better qualified to undertake this important commission. As a hunter of dinosaur fossils, Dr. Moodie covered the most promising areas of Wyoming during the past 25 year period. Most of this work was done for leading museums and educational foundations. To many scholars and to those residents of Wyoming who came in contact with him during his research work Dr. Moodie's name and standing as a scientist needs no further introduction.

The composition of Dr. Moodie's manuscript is of the non-technical style, and being profusely illustrated with restorations of Wyoming material that now repose within the larger museums of the world, it is anticipated that this publication will prove to be unusually fascinating.

JOHN G. MARZEL,
State Geologist.

PREFACE

The subject of dinosaurs in general, and the dinosaurs of Wyoming in particular, has interested me since the spring of 1904, when for the first time I dropped off the train at Rawlins for a summer's work in the fossil beds of the Wind River Mountain area. I found the party waiting, ready to start in a light wagon equipped with the bows for a canvas cover—a common sight. We soon started on our drive to Lander, one hundred and fifty miles away—a full week's journey in those days. After that summer I spent several more seasons in the Wyoming fossil fields, either with Dr. S. W. Williston as companion or working under his directions.

In the many camps we had together Dr. Williston told me of his work at Como Bluffs, excavating dinosaur bones for Professor Marsh; a terribly lonely job during the early winter months of the late seventies. As an amateur dipterologist I had in my bag the second edition of Williston's Manual of North American Diptera. I shall never forget the keen pleasure derived from hearing the author tell how in his despair at not being allowed to write about dinosaurs, a form of activity which Professor Marsh reserved for himself, he had turned to the study of the Diptera, a study at which he became famous. But ever mingled in with other talk there was always that background of the huge, ungainly dinosaurian reptiles, making a unique appeal to our fancy. What were the dinosaurs? Where had they come from? Why had so many lived and left their bones in the area now called Wyoming? What was their manner of life? To what reptilian group were they related?

During the three years I spent in Williston's laboratory as Fellow in Vertebrate Paleontology at the University of Chicago, our discussions of dinosaurian affairs were of the greatest interest. In one of our daily searches for marine reptiles in Wyoming, especially the plesiosaurs, we one day came across a tangled lot of fossil bones, so broken and water worn that we couldn't tell what great group of vertebrates the fragments represented. We thought it might be a giant turtle. One interesting looking chunk was taken to camp, where in a red-water irrigation ditch Dr. Williston scrubbed off the crust of mud in which the specimen was caked. After he had cleaned it somewhat I heard him say: "By George, Moodie, that's a dinosaur, and whoever heard of a dinosaur in marine sediments? We must save every scrap of bone." The material was unlovely to look at, but we wrapped the scraps in newspaper and packed it for shipment. This material was the type of Stegopelta landerensis, the only dinosaur Williston ever named. He then turned this unwelcome "mess" over to me for description. Many were the weary hours I spent trying to find a "fit" in the broken bones. This was my initiation into vertebrate paleontology.

In later years when I began a study of the evidences of disease and injury in ancient times, the first specimen I studied was a fossil tumor, a haemangioma, involving two caudal backbones of a huge dinosaur which had been collected in the Como Beds of Wyoming by Dr. Williston.

Many books and papers have been written about dinosaurs. A list of the titles alone would fill many printed pages, but we are constantly learning something new about the dinosaurs and we will not learn the complete story for a long time to come. There are doubtless hundreds of dinosaurs still embedded in the rocks of Wyoming, some of which will come to light and add new knowledge.

The list of books, memoirs and papers on dinosaurs given below, is not a complete compilation of the printed works on Wyoming dinosaurs, but it gives a clue to the readily available sources of information from which the interested student can read further to the limit of paleontological information. Many important and interesting publications written in foreign languages are omitted. Dinosaurs have lived in every continent on the globe, and everywhere they attract attention, and someone has written something interesting about them everywhere.

Dinosaurs, the world around, are reptiles of the Mesozoic; that middle era of geological time between the Paleozoic and the Cenozoic. Although dinosaurians are known from the first period of this era—the Triassic—yet we never found a single scrap of a dinosaur in the massive Red Beds (Permian and Triassic) which are so conspicuous a figure of the landscape along the eastern foothills of the Wind River Mountains. The dinosaurs of Wyoming are all Cretaceous and Comanchean, covering a large period of time reckoned in millions of years. The Como Beds of the Lower Cretaceous, known also as the Morrison Formation or Atlantosaurus Beds, yield the greatest number of dinosaurs, as will be told later on.

I am under obligations to Professor R. S. Lull, Professor of Paleontology at Yale University for the loan of cuts illustrating **Stegosaurus,** the most grotesque vertebrate the world has ever seen.

Mr. Barnum Brown, of the American Museum of Natural History, has aided the work greatly and has permitted the use of some of his illustrations.

The National Geographic Society has cooperated by furnishing electrotypes of certain figures which appeared in their "Magazine."

The American Museum of Natural History has granted the use of figures which have appeared in "Natural History."

The Los Angeles Museum has given the use of twenty half-tone and zinc blocks.

I am further indebted to various persons whose writings have been used as sources of information on dinosaurs, for which credit is given in each case.

Mr. John G. Marzel, State Geologist, suggested the subject and scope of this volume, and made its preparation possible.

ROY L. MOODIE.

Santa Monica
July, 1929
California

CHAPTER I.

What Are the Dinosaurs?

The Dinosaurs are known to us today chiefly from their fossilized bones often of a surprisingly large size. Two dinosaur mummies, found in Wyoming, and the dinosaur eggs found recently in the Gobi Desert reveal the nature of the skin and the method of reproduction. A careful study of all this material, in comparison with other vertebrates living and extinct, shows us that the Dinosaurs are reptiles. The reptiles living today are the lizards, snakes, turtles and crocodiles, as well as other similar forms. The Dinosaurs belong to none of these, though resembling the lizards more strongly in appearance than any other of recent reptiles; yet the dinosaurs are not lizards. They are a group apart; a group which has been extinct for millions of years.

Ranging in size from the common barnyard fowl up to huge creatures eighty feet long or twenty-five feet high, with a weight of many tons; the dinosaurs exhibit a high diversity of structure and form, although the dinosaur structure is apparent in all. By their form the reptiles of the dinosaurian group can be divided into four or five types, determined by their feeding habits as suggested by the structure of the skeletal parts. The groups are all found in Wyoming, with the exception of the smaller, active creatures which are found elsewhere in the Triassic Red Beds. Although these beds occur in Wyoming not a fragment of a dinosaur has ever been found in these deposits.

Few areas of equal extent anywhere throughout the world have yielded such enormous numbers of the Mesozoic Dinosaurs as has the State of Wyoming. Nowhere are conditions more favorable for the collection of huge fossilized bones as exist in this state. During the past half century many of these ancient relics have been quarried and have found their resting places in distant museums throughout the world, where museums are fostered.

Since the dinosaurs are of a long past time the various kinds are known to the scientific world by strange jaw-breaking words, for which there are no common equivalents, so we must use such terms as we can in discussing the nature of these ancient reptiles. Terms such as Sauropoda, Theropoda, Ornithopoda or Predentata are not so formidable as others which scientists have used when discussing the dinosaurs. Many of these terms are explained in the **glossary.**

The word **dinosaur** itself means **terrible reptile,** though some members of the group are not at all terrible, either in appearance or nature. Many dinosaurs are ornamented with odd-looking spines and plates, horns and various excresences not found in other vertebrates. Some dinosaurs walked on four feet; some on two, with the fore legs very diminutive; some had long tails flattened for swimming and it is said that some of the smaller, hollow-limbed creatures were semi-arboreal, resembling the flying squirrels of today.

A great deal has been said and written about the weight of the larger dinosaurs especially; some saying that the larger sauropods attained a weight of forty tons. Such estimates are wrong since they are based on the weight of the fossilized bones when a single thigh bone may weigh several hundred pounds, being to all essential purposes rock. Such erroneous estimates fail to take into consideration the provisions nature has made to lighten the ponderous skeleton of these huge reptiles. Extensive excavations into the backbone joints for muscular attachments reduce the amount of bone to a great degree, and since the backbone represents the greater part of the weight these hollows are important. The huge limb-bones are not solid but contain many spaces. Even under the microscope the dinosaur bone is filled with spaces and the amount of solid bone is small. Such spaces are to be sure filled with body fluids during life, heavy of course, but not of such weight as solid bone would be. Taking these factors into consideration it seems probable that a dinosaur sixty feet long and fifteen feet high did not weigh over 10,000 pounds, or about five tons. This weight is not excessive for such dinosaurs as **Diplodocus, Brontosaurus** or **Camarasaurus,** reptiles from the Como Beds of Colorado and Wyoming, but the estimate may be too small.

If this estimate is correct then it seems probable that the sauropod dinosaurs were amphibious, living and possibly feeding in rivers, lakes and swamps of the Mesozoic. Many writers have depicted these animals submerged or feeding along the edges of water where the aquatic plants were abundant enough to furnish food for their huge bodies. The languid actions of these huge animals was doubtless repeated in their slow digestion, so that a meal every few days would suffice. It seems almost incredible that the small head of the sauropod dinosaurs could take in sufficient food materials to nourish that great bulk.

If one asks to what age the dinosaurs attained it might be said that several hundred, or even a thousand, years might have been lived in their slow, ponderous way. It may be possible that the carnivorous and more active forms did not live so long. We have no information from the dinosaurian fossils themselves, but may base an estimate on analogy with modern reptiles. The flesh-eating dinosaurs had no known enemies, but were themselves enemies to the plant eaters. Injuries on certain fossilized dinosaur bones show this to have been true. The small mammals which lived with them may have eaten their eggs, but of formidable enemies they had none.

CHAPTER II

The Geological Age of the Dinosaurs

Dinosaurs are often called "the rulers of the Mesozoic." This does not mean that they actually **ruled** all other animals, but simply means that they were the dominant vertebrates of the land areas, as the winged dragons, the pterodactyls, ruled the air, and as the large marine reptiles, the mosasaurs and plesiosaurs, were the largest and most numerous vertebrates of the Mesozoic seas. Dinosaurs were never adapted to either the air or the seas—they lived on land or in fresh water.

The term Mesozoic means **middle life,** and refers to those three geological periods, the Triassic, Jurassic and Cretaceous, during which the dinosaurs lived. Figure 1 shows the relative position of the Mesozoic. The era opens with the Triassic, a time of great vertebrate development. When the Mesozoic begins the earth had already existed for 85 per cent of its duration, assuming the age of the earth to be 500,000,000 years. The Mesozoic endured for 11 per cent of the earth's history, a matter of several million years. Thus we see that
2 while the dinosaurs really existed a long while ago, yet from the standpoint of earth age, they are relatively modern animals.

The Mesozoic witnessed the origin of the birds, some of them with teeth, indicating a reptilian ancestry, and the mammals, which were all small throughout the Mesozoic, taking on size only after the Age of Mammals, the Cenozoic, had begun. Turtles, lizards and crocodiles existed along with the **dinosaurs,** and often left their remains in the same beds, such as the Como Beds of Wyoming.

FIG. 1.—DIAGRAM ILLUSTRATING NORTH AMERICAN HISTORICAL GEOLOGY

The Mesozoic Era, the Age of Reptiles, which witnessed the life of the dinosaurs, is near the top.

The rivers on the earth have always carried mud, sand and gravel to the sea, which, in settling, have spread out in layers over the sea bottoms or in lakes, rivers and swamps. Remains of various forms of life, such as shells and bones, accumulated after death in these layers, where the hard parts were preserved as fossils. In time, these sediments consolidated into hard rock and have been elevated above the sea level.

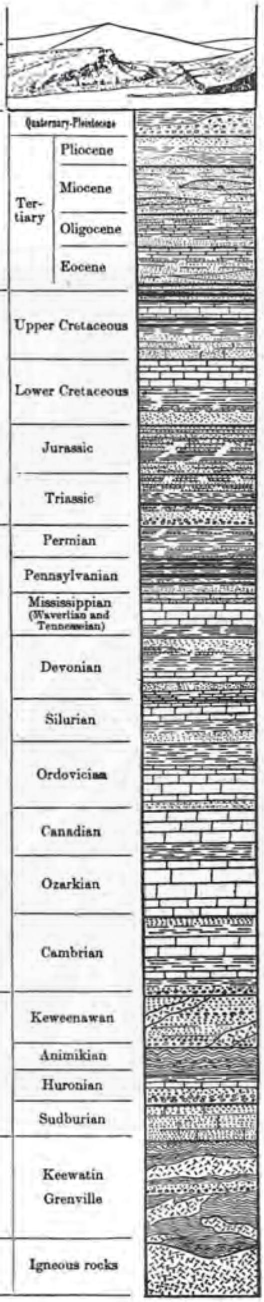
The geologist studies these ancient deposits, which now form a large part of the earth's surface, and from the nature of the sediments and from the life remains or fossils, that they contain, he is able to reconstruct much of the past history of the earth.

The rocks in the earth's crust give evidence also of the physical conditions under which they were formed, and apparently the physical processes, such as erosion and weathering, have not changed throughout all geological time. The life on the earth, however, is constantly varying, owing to change of environment, and species after species sooner or later die out to be replaced by other forms of life. Rocks of similar age therefore contain similar species of fossils. Dinosaur history occupied only a small part of geologic history, although existing for millions of years.

If all the sedimentary rocks of past ages had been accumulated in their greatest thickness at one place they would form a succession of strata over 40 miles in height.

—After Dr. R. S. Bassler.

DIAGRAMMATIC SECTION OF EARTH'S CRUST



ERAS OF GEOLOGIC TIME WITH CHARACTERISTIC LIFE			CHARACTERISTIC ROCKS WITH MAXIMUM THICKNESS
PSYCHOZOIC ERA (Recent) Age of man			Alluvial deposits in rivers, etc.
CENOZOIC ERA (Modern life) Age of mammals and modern plants	Quaternary-Pleistocene		Shale, sand, and gravel
	Tertiary	Pliocene	5,000 feet clay, shale, gravel, and sandstone
		Miocene	14,000 feet shales, sandstones, and limestone
		Oligocene	6,000 feet shales, sandstone, and limestone
		Eocene	8,000 feet limestone, sandstone, and coal
MESOZOIC ERA (Medieval life) Age of reptiles	Upper Cretaceous		20,000 feet sandstone, shale, limestone, and coal beds
	Lower Cretaceous		20,000 feet limestone, shale, and sandstone
	Jurassic		10,000 feet sandstone and shale
	Triassic		15,000 feet sandstone, shale, and coal beds
PALEOZOIC ERA (Ancient life) Age of higher invertebrate animals	Permian		7,000 feet sandstone and shale
	Pennsylvanian		10,000 feet sandstone, shale, and coal beds
	Mississippian (Waverlian and Tennesseian)		4,500 feet shale and limestone
	Devonian		12,000 feet limestone, sandstone, and shale
	Silurian		6,000 feet sandstone, shale, and limestone
	Ordovician		6,000 feet sandstone, limestone, and shale
	Canadian		4,000 feet limestone and shale
	Ozarkian		6,500 feet massive limestone
	Cambrian		18,000 feet quartzite, sandstone, shale, and limestone
PROTEROZOIC ERA (Primitive life) Age of primitive plants (algæ) and invertebrate animals	Keweenawan		30,000 feet conglomerate and sandstone with lava flows
	Animikian		14,000 feet banded slates and cherts with iron ore
	Huronian		10,000 feet glacial conglomerates, quartzite, and limestone
	Sudburian		20,000 feet of white quartzite
ARCHEOZOIC ERA (Primal life) Age of unicellular life	Keewatin Grenville		100,000 feet sedimentary schist and gneiss with lava flows; slates, conglomerates, and limestone
PRIMITIVE CRUST	Igneous rocks		Granite and other igneous rocks

CHAPTER III

Their Origin and Distribution Throughout the World

Wyoming dinosaurs are immigrants, as were the early human inhabitants. They came into the state, found it a good place to live, millions of years ago, even as it is today, and they stayed to leave their bones for future seekers of the truth. The probable routes by which they came into the state are shown in the two accompanying maps (Figures 2 and 3).

No one knows where the dinosaurs originated, or from what preceding group of reptiles they took their origin. Some scientists maintain that the carnivorous dinosaurs—the Theropoda—arose from a separate ancestral group than the amphibious group—the Sauropoda. That means that the Dinosauria were polyphyletic and not a natural group of reptiles at all. Triassic dinosaurs were so well differentiated during the opening stages of the Mesozoic that we feel sure that the ancestors of these dinosaurian reptiles must have lived in the closing period of the Paleozoic—the Permian, whose red rocks show that similar, arid conditions prevailed throughout a long period of time. Triassic dinosaurs do not occur in Wyoming, but elsewhere we know them as small, active, carnivorous forms, showing some relationships with other Triassic reptiles, especially those called the phytosaurians—crocodile-like animals.

The maps (Figures 2 and 3) show a very wide distribution of dinosaurian forms throughout the world. Practically every continent has yielded their bones. Since these maps were made great discoveries have been made in Asia.

Investigations conducted by scientists from the University of Berlin over the years 1909-1912, in East Africa, from which at a cost of $58,000.00 two hundred and fifty tons of fossils, in 1,050 cases, were secured, showing the presence of these reptiles. The dinosaurs indicated in these collections represent forms very similar to those known from Wyoming. Although no complete skeletons were found, enough material was secured to enable the museum to mount four great sauropods, two small carnivorous and one armored dinosaur. Among the dinosaur bones found at Tendaguru, Africa, was one leg bone, a femur, which measured nine feet in length. It is the largest animal bone ever found anywhere. This huge size is thought to indicate a great age for the individual, possibly 1,000 years, for reptile bones continue to grow throughout life. The size of the entire creature must have been appalling, requiring 1,000 pounds of food at a meal, which sluggishly digested, possibly lasted the individual several days. It seems probable that many of these African dinosaurs were mired in the mud and were overtaken by the tides. One dino-

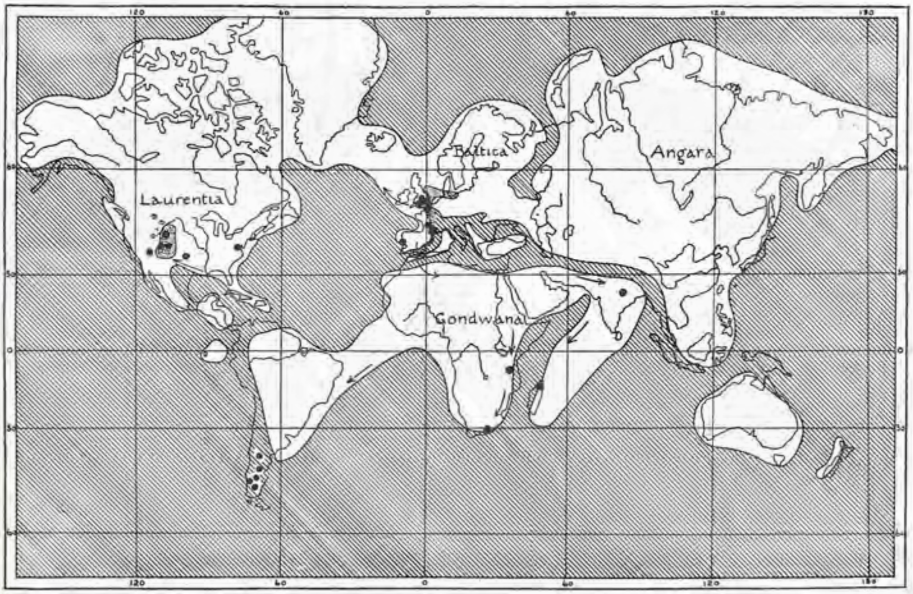


FIGURE 2.

Map showing the chief localities and probable routes of migration of the large quadrupedal, amphibious Dinosaurs—the Sauropoda. Based upon Professor Schuchert's late upper Jurassic map of North America and de Lapparent's map of similar formations for the rest of the world. The heavy round dots show the positions of localities where sauropod bones have been found, and the arrows show the general trend of migratory paths.—Courtesy of Professor R. S. Lull.

saur bone, thickly encrusted with oyster shells, shows the sea was near, and the huge bone had been washed into salt water. The evidences seem to show that the sauropod dinosaurs inhabited low, marshy ground, with numerous lakes and rivers where they would be relatively free from attacks by the carnivorous reptiles.

Coming nearer home, there is a fine collection of Cretaceous dinosaurs in the Canadian Museum at Ottawa, where the fossils secured by the Geological Survey are stored. These specimens have been described in numerous papers by L. M. Lambe, C. M. Sternberg, W. A. Parks and others. Within recent years expeditions led by Barnum Brown during seven seasons, 1909-1915, have secured for the American Museum of Natural History a most remarkable series of beaked dinosaurs whose characters are dealt with in a series of papers by Mr. Brown in the Bulletin of the Museum. Collecting these dinosaurs has proven no easy task, and the conditions met, and some of the results secured in the Canadian explorations are discussed by Brown in his paper listed in the bibliography at the end of this book.* Dr. Matthew remarks (loc. cit., p. 544):

> "In addition to all the various kinds of dinosaurs, the Red Deer River has yielded a fine series of fossil turtles, crocodiles, and other remains of less interesting extinct animals. But it is and will continue to be famous as the greatest dinosaur locality in the world, the source of half the American Museum's dinosaur collections and of many choice skeletons that are, or will be, the pride of various other institutions."

The South American dinosaurs are not well known, but the skeletal remains described indicate sauropodous, plant-feeding reptiles and carnivorous forms, related to the dinosaurs of Wyoming. Mr. Riggs, while collecting fossil mammals in Patagonia for the Field Museum of Natural History, found dinosaur bones of large size which had been assembled many years before for shipment, and had been abandoned, by the unknown collectors, with all their tools.

The dinosaurs of the central Asiatic area, especially the Gobi Desert, show a close counterpart of the dinosaurs of Wyoming, and are of the amphibious, sauropod, carnivorous, ceratopsian (horned), iguanodont types. Osborn regards central Asia as the point of origin and the center of radiation of the giant dinosaurs, from which the reptiles migrated to all of the other, connected, land masses during Mesozoic times. Most remarkable of all was the discovery of dinosaur "eggs," the like of which had never been known before. These Asiatic dinosaurs are now being studied.

Remains of dinosaurs have long been known from England where the paleontologist Sir Richard Owen proposed the name Dinosauria. While English dinosaurs represent the same groups as occur in the State of Wyoming there is no considerable deposit where complete material may be had. A large, bipedal, plant-eating dinosaur, named **Iguanodon**, known only from scraps, was soon to become famous.

* See also W. D. Matthew, 1920. Canadian Dinosaurs. Natural History, XX., 536-544 (illustrated).

About fifty years ago a wonderful find of dinosaurs was made near Brussels, Belgium, in a coal mine in a village called Bernissart. The skeletons of no less than twenty-two huge Iguanodont dinosaurs were found complete, embedded in a fairly soft, clay-like rock. The authorities of the National Museum at Brussels, Belgium, took charge of the place and carefully removed the skeletons to the Museum, where seven of the skeletons were cleaned of rock and mounted as one of the most attractive dinosaur exhibits in Europe.

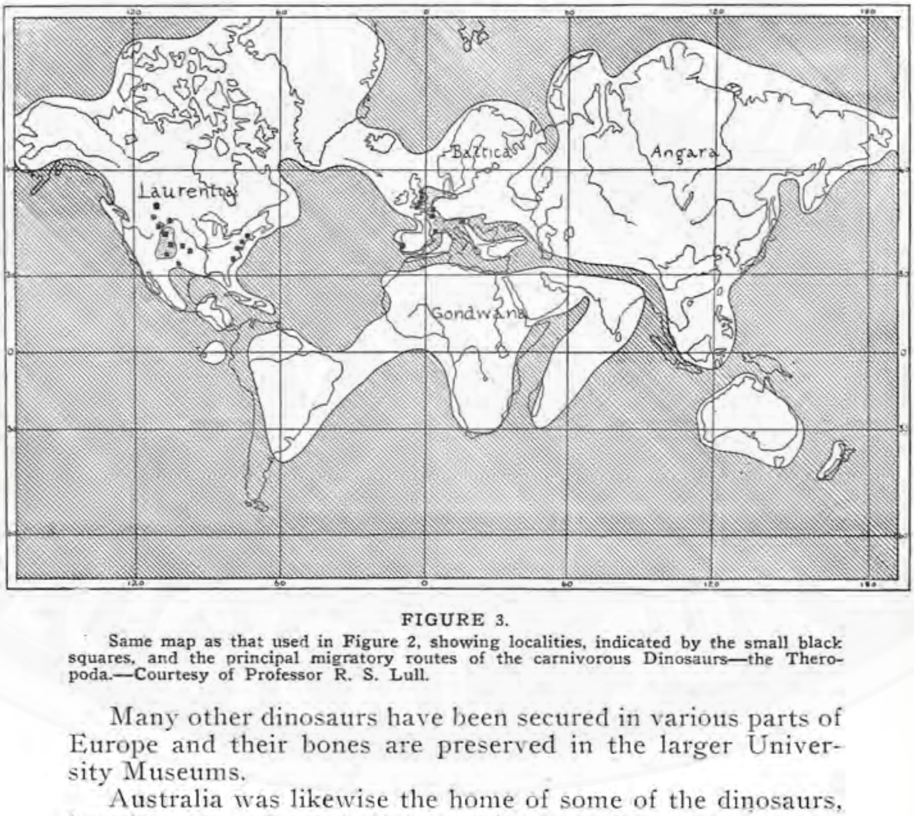


FIGURE 3.

Same map as that used in Figure 2, showing localities, indicated by the small black squares, and the principal migratory routes of the carnivorous Dinosaurs—the Theropoda.—Courtesy of Professor R. S. Lull.

Many other dinosaurs have been secured in various parts of Europe and their bones are preserved in the larger University Museums.

Australia was likewise the home of some of the dinosaurs, but they are so far only indicated by fragmentary remains.

The geographical distribution of the dinosaurs depended upon their finding favorable living conditions. Professor R. S. Lull says:

> "In order to comprehend the remarkable geographical distribution of the dinosaurs, it is necessary to investigate the character of their various habitats, the conditions they were

forced to meet and the marvelous degree of adaptation to the environment which they underwent.

"I imagine the conditions which gave to the dinosaurs their initial evolutionary trend were such as are thought to have prevailed, beginning in the Permian, throughout Triassic time. This is well shown in the region now known as the Connecticut valley. The older notion of the estuarine origin of these deposits has been abandoned in favor of the idea that they were of terrestrial origin, the climatic conditions being those of semi-aridity with areas here and there which were subject to inundations occurring in times of torrential rains such as are observed to-day under similar climatic conditions in different portions of our globe. This lends color to the view that the early dinosaurs were truly terrestrial types, with marked cursorial adaptation, indicated in the free, bipedal stride and compact, bird-like foot which is shown by the fossil footprints.

"Huene derives the Theropoda and Parasuchia from one stem, the supposition being that the distinguishing characteristics were developed during the oldest Trias through adaptation. Increasing aridity of climate would render it necessary for an animal to go farther afield for water and possibly for food and thereby place a premium on good powers of locomotion, so that selection would be very active in weeding out the unfit or inadaptable lines. This locomotor adaptation in the quadrupedal stage is beautifully shown in the Parasuchian genus **Stegomus** from the Connecticut valley Trias, evidently a persistent type which, possibly because of the retention of armor, remained a quadruped though long of limb and with the greater portion of the weight borne on the hinder extremities. **Stegomus**, I imagine, though belonging, morphologically, to a very different race, represents a stage in the adaptation of the dinosaurs which was reached early in the Trias.

"Many modern lizards are amazingly swift of movement, but their journeys are brief and the rapidly moving types are small. It is a well known fact that a number of lizards, when startled, rise on the hinder limbs and run with a truly bipedal gait. It is significant that the bipedal lizards, so far as my knowledge goes, are all found in semi-arid climates—Australia, Southwestern United States. This tendency toward bipedalism, with a consequent profound alteration of the hind limbs and pelvis, both in bone and musculature, seems therefore to have developed to meet the need of greater range of movement necessitated by increasing aridity, and was the prime factor in the early evolution of the dinosaurian race.

"So strongly was this feature impressed, that the main lines of dinosaurian evolution, whether plant or animal feeders, were cursorial terrestrial types, though, as new conditions arose, or were met with during their forced migrations, aberrant types of marvelous complexity and range of specialization developed. These aberrant forms, from the fact that their remains were more readily preserved, are the ones best known to us and have colored our whole conception of the dinosaurian race.

"When the plant-feeding Orthopoda arose we do not know. **Nanosaurus** is known from the upper Trias of Colorado, while in the possibly contemporaneous beds of the Connecticut valley there have been found many footprints which Lull has shown to belong to plant-feeding types of general proportions not unlike those of their theropod allies, but differing mainly in the feebly prehensile character of the little, blunt-toed manus, the imprint of which is sometimes seen. The Theropoda, on the other hand, had a strong, grasping hallux, as a rule rotated to the rear of the foot so as to be in opposition to the other toes, and a manus with powerful claws, which had already sacrificed fully the function of locomotion to that of prehension. The Orthopoda could give rise to secondarily quadrupedal forms, the Stegosauria, the Ceratopsia; the Theropoda, on the other hand, had cast the die in favor of absolute bipedalism and stalked on upon the hind limbs to the end of their career.

"While both small and large forms prevailed at the close of the Trias, the differentiation, if we except the character of the pubis, is largely owing to opposite habits, acquired apparently in the remote Trias, very early in the dinosaurian evolution.

"The carnivores, as has been said, are relatively conservative in their evolution, except for the differentiation into the greater megalosauroid forms and the lesser compsognathoid types. The Theropoda were evidently the most mobile of all dinosaurs, free to migrate wherever other creatures lived which could possibly be utilized for prey, for not only do we find them the world over, with the exception of Asia. . . ."

CHAPTER IV

Historical Account of the Discovery of Dinosaurs in Wyoming

It is, of course, not possible to state the day, nor the month, and not even the year in which dinosaur bones were found in Wyoming, for such a discovery could only follow a realization of what dinosaurs are. In the early days, up to 1870, no one had the slightest idea that dinosaurs ever existed in Wyoming, because dinosaurs themselves were unknown in America, although Sir Richard Owen in England had already proposed the name Dinosauria. A discovery of dinosaurs anywhere could only be made by one with scientific training, although one without such training could have called attention to some of the queer things which later turned out to be dinosaurs.

Many people have queer notions about the nature of petrified objects. Centuries ago petrified sharks' teeth were called **glossopetrae or fossil tongues.** A piece of red and light striped chalcedony was **petrified bacon.** A coiled fossil shell was a **petrified snake.**

It may be that the primitive inhabitants of Wyoming, the Indians, had seen the huge dinosaur bone fragments weathered out of the cliffs in southern Wyoming, but if they thought of them at all, it was merely that they were queer looking rocks, somewhat different looking than the other rocks.

As a knowledge of the nature of fossil animals grew, the significance of the scraps and fragments of bone was realized. I do not suppose for an instant that the Mexican sheep herder who made the foundations of his cabin out of weathered dinosaur bones, realized that he was using the bones of giants. He would have been greatly surprised if anyone had told him of it, and probably would have considered it an untruth. Dinosaurs were outside of his line of thought. Yet the Bone Cabin Quarry yielded the American Museum of Natural History many scores of dinosaurs.

The discovery or realization of the nature of the immense dinosaur deposits in the Rocky Mountains (Wyoming chiefly) came in March, 1877; truly a great advance, unequalled by any later discovery in paleontology. The fact that the discovery was made by three observers shows that the seeds of knowledge had been sowed during the preceding quarter of a century, and a realization of the meaning of the "bone rocks" came to three people simultaneously. These were Mr. O. Lucas, then a school teacher, later a clergyman; Professor Arthur Lakes, then a teacher in the school of Mines at Golden, Colorado; and Mr. William ("Bill") Reed, then a section foreman of the Union Pacific Railroad at Como, Wyoming, later the curator of paleontology at the University of Wyoming. Two great deposits were revealed by these discoverers, one of them at the south end of Garden Park, seven miles north of Canon City, Colorado. Here two great quarries were opened up, from one of which Cope secured his huge **Camarasaurus**, now in the American Museum of Natural History; and another quarry close by was opened by Williston for Professor Marsh and later worked by Hatcher for the Carnegie Museum. At the latter quarry was found the type of that long, slender, "whip-tailed" sauropod dinosaur, **Diplodocus**.

Dr. Williston gives the following account (quoted from Matthew, 1915, p. 128) of the opening of the other great dinosaur quarry in the Como Hills of Wyoming.

> "Mr. Reed, tramping over the famous Como Hills after game—he had been a professional hunter of game for the construction camps of the Union Pacific Railroad—in the winter and spring of 1877, observed some fossil bones just south of the railway station (Como) that excited his curiosity. But he . . . did not make the discovery known to Professor Marsh till the following autumn, and then under an assumed name, fearing that (he) would be robbed of the discovery. I was sent to Como in November of 1877 from Canon City. I got off the train at the station after midnight, and enquired for the nearest hotel (the station comprised two houses only), and where I could find Messrs. Smith and Robinson. I was told that the section house was the only hotel in the place and that these gentlemen lived in the country and that there was no regular bus-line yet running to their ranch. A freshly opened box of cigars, however, helped clear up things, and I joined Mr. Reed the next day in opening "Quarry No. 1" of the Como Hills. Inasmuch as the mercury in the thermometer during the next two months seldom reached zero—upward I mean—the opening of this famous deposit was made under difficulties. That so much 'head cheese,' as we called it, was shipped to Professor Marsh was more the fault of the weather and his importunities than our carelessness. However, we found some of the types of dinosaurs that have since become famous.
>
> "My own (Williston's) connection with the discoveries of these old dinosaurs continued only through the following summer, in Wyoming, when we added the first mammals from the hills immediately back of the station (Como), and the types of some of the smaller dinosaurs, and when we explored the vicinity for other deposits on Rock Creek and in the Freeze Out Mountains.

"How many tons of these fossils have since been dug up from these deposits in the Rocky Mountains is beyond computation. My prophecy of hundreds of tons has been fulfilled, and they are preserved in many museums of the world."

The details of the discovery of the Ceratopsia in Niobrara County are given in the section devoted to "The Three-Horned Dinosaurs."

An account of the "Bone Cabin Quarry" is given in another section.

The discovery of an armored dinosaur is told about in the "Preface."

CHAPTER V

Methods of Collecting Dinosaur Bones

The amount of hard work, scientific knowledge and technical skill required to find a dinosaur, excavate and collect the bones for shipment so they will make the trip to the museum, thousands of miles away, where the various parts are assembled, cleared of all encrusting rock, repaired and mounted for exhibition, is known only to those who have experienced it. Such a labor is not only difficult but extremely expensive. The total cost of securing the bones and mounting the skeleton for exhibition must amount to from $200.00 to $300.00 for each bone of the body.

The removal and mounting one of the huge skeletons calls for considerable mechanical aptitude and engineering ability. The amount and nature of the field work required depends on where the fossils are found. If the "find" is inaccessible it may first be necessary to build a road sufficiently good to withstand the stress of heavy loads. If the fossil bones occur near the bottom of a cliff or hill it may be necessary to quarry twenty feet or more of solid rock in order to recover the buried bones. Justification for such an expense depends on the judgment of the collector as to the value of the specimen, so far as can be determined from the scanty evidence exposed. An experienced paleontologist can usually be sure of his evidence, but there is always a wide range for possible mistakes. If he finds a series of dinosaur backbones extending uninterruptedly into a cliff, he may after further extensive quarrying either find a lot more bones, even a complete skeleton, or he may find that all his quarrying is useless expenditure because the bones end a little way within the cliff.

The early collectors in the dinosaur fossil field were perforce content with picking up the bones on or near the surface and little or no quarrying was done. After the western countries became more settled and danger from hostile Indians was removed, better methods of collecting were employed, more accurate field notes were kept and it was possible, after 1880, to make permanent camps near the quarry and devote more attention to scientific details. In earlier days one must use one eye for Indians, and one for fossils, and the rifle took precedence over the collecting pick. In the laboratory, too,

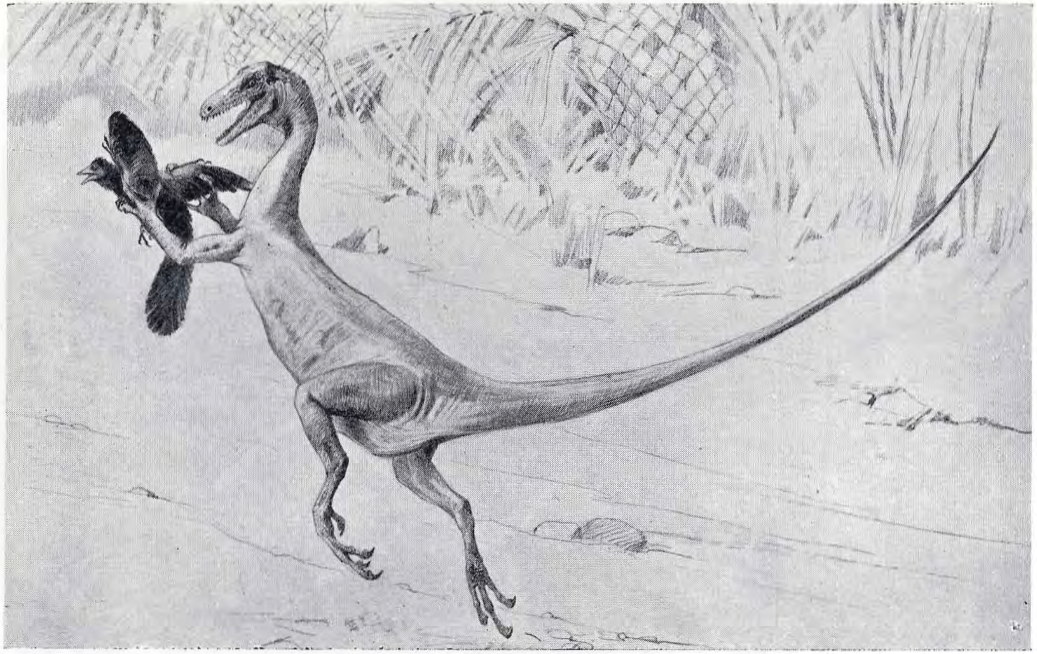


FIGURE 35.—A SMALL, ACTIVE DINOSAUR, ABOUT FIVE FEET IN HEIGHT, FOUND IN WYOMING.

The picture shows one capturing an ancestral bird whose jaws contained sharp teeth like those of a lizard.

—After Brown.

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of broken off teeth of the allosaur were found lying alsongside them, possibly broken off while feeding (Matthew).

A striking contrast with the ponderous allosaur and tyran-

After Osborn, from a drawing by Charles R. Knight.

FIGURE 36.—THIS GREAT CARNIVOROUS DINOSAUR HAS BEEN KNOWN FOR SOME YEARS PAST, BUT ONLY RECENTLY HAS A COMPLETE SKELETON OF IT BEEN PLACED ON EXHIBITION.

The creature is depicted feeding upon the remains of a Brontosaurus, whose actual vertebrae, chiseled by the sharp teeth of some similar creature, are placed beneath the mounted skeleton in the American Museum. Collected at Como Bluffs, Wyoming.—From Brown, National Geographic Magazine.

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nosaur is found in a slender, agile small carnivorous dinosaur, called **Ornitholestes** or bird-catcher, a skeleton of which was secured by the American Museum from the Bone Cabin Quarry in Wyoming. The forefoot has long, slender, clawed digits which may be supposed to have been useful in catching

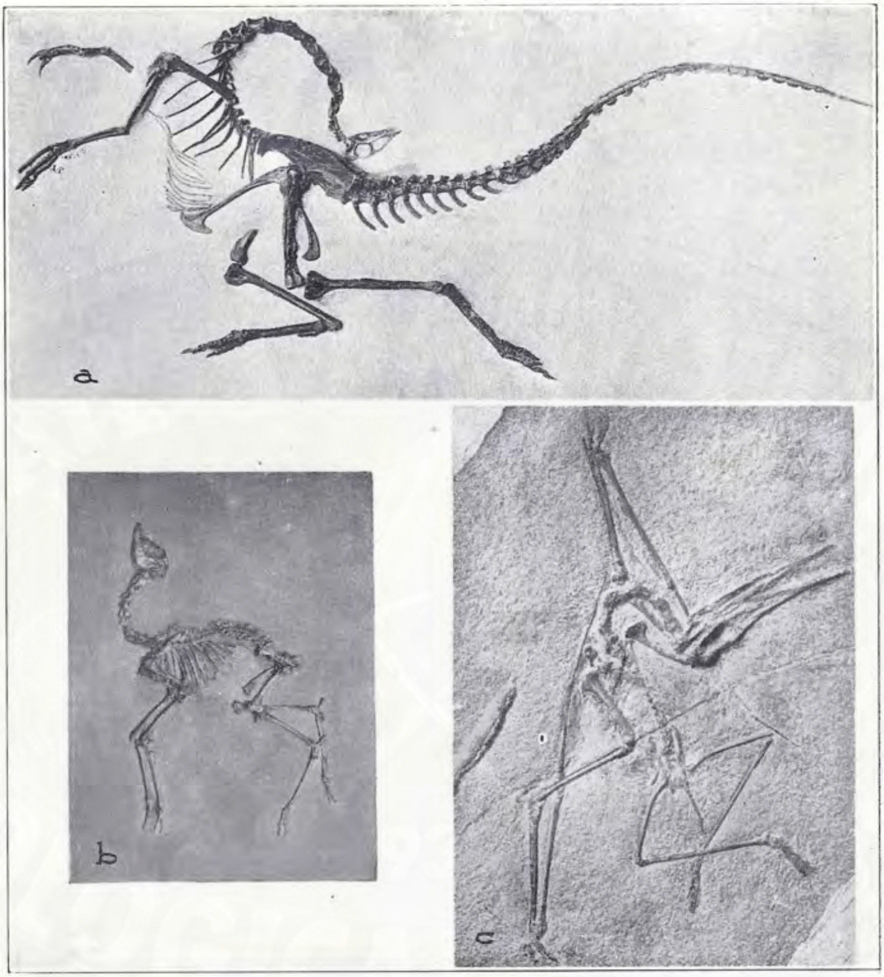

FIGURE 37.

Skeletons of three fossil vertebrates showing the position of the skeleton at death, in the attitude known as Opisthotonos, due to the death spasm or to a neurotoxic condition. The attitude may be indicative of disease.

a=A toothless dinosaur, Struthiomimus altus, from the Cretaceous of Alberta, Canada, as mounted in the American Museum of Natural History. The structure of the body is like that of other small, carnivorous dinosaurs, but the toothless mouth, with jaws probably sheathed in horny plates, indicates an entirely different food habit. The animal was a swift runner, like the ostrich, and the short fore-limbs were used for grasping. The animal may have fed on leaves, insects or small shore-dwelling animals.

b=A small Miocene camel in opisthotonos. Preserved in Carnegie Museum at Pittsburgh. Collected in Western Nebraska.

c=A flying reptile of the Mesozoic, living around the seas and probably feeding on fish.

small prey, reptiles, birds or mammals, whose remains are found mingled in the Mesozoic rocks with those of the dinosaurs.

During the Cretaceous period, the closing stage of the Mesozoic or Age of Reptiles, a number of other small or medium-sized carnivorous dinosaurs have occurred, apparently living in the same areas with the larger kinds. In appearance these small dinosaurs must have looked like two-legged lizards, running and walking on their hind legs, with the long tail stretched out behind to balance the body. Their footprints show that they walked or ran with a narrow treadway.

They did not hop like many modern birds, but walked steadily like the waders. When they rested, the weight of the body was on the legs, and tail.

A related dinosaur, completely toothless, called **Ornithomimus,** is known from the Cretaceous of Alberta, Canada, (Figure 37a). The limbs are long and slender; a long neck; small head and toothless jaws, all of which render this dinosaur singularly bird-like.

The food of the carnivorous dinosaurs was doubtless the living vertebrates of the times, or their dead bodies, for it is probable that these flesh eaters were carrion-feeders. The amount of food required by individual dinosaurs depended upon the activity, temperature and degree of hunger. None of the amphibious dinosaurs were active enough to escape a determined carnivore, but their safety lay in their taking to water, the carnivorous dinosaurs being dwellers of the uplands. The carcasses of the sauropods, however, if drifted ashore offered food for the theropods. The duck-billed dinosaurs were in a similar case. The three-horned dinosaurs were protected well enough to resist attacks from in front, but were susceptible to flank or rear actions. A twenty-five foot **Triceratops,** if attacked by two 48-foot tyrannosaurs, would have little chance of escape, and so long as such huge supplies of meat were at hand the carnivores throve. It is conceivable that the huge quantities of flesh needed by **Tyrannosaurus** was a handicap toward extinction, in the face of a diminishing supply.

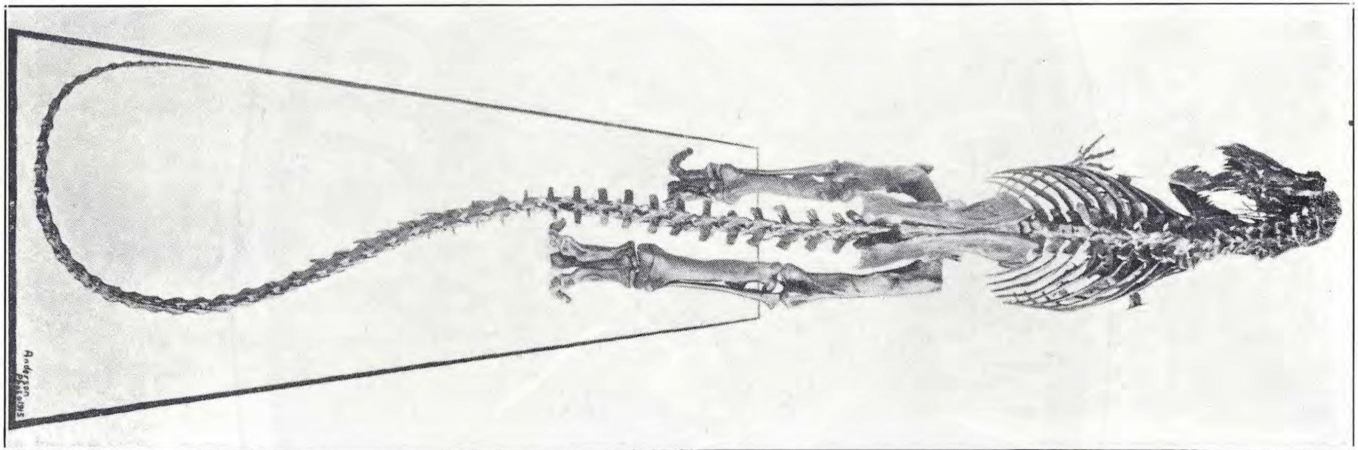

FIGURE 38.

Rear view of the hugest of all the carnivorous Dinosaurs—the skeleton of Tyrannosaurus rex, as mounted in the American Museum of Natural History.—After Osborn.

CHAPTER XVIII

The Three-Horned Dinosaurs

In Niobrara County, Wyoming, there are great beds of sandstone containing the bones of reptiles and some plant impressions which tell of the nature of life during the closing stages of the Age of Reptiles (the Mesozoic) followed shortly

FIGURE 39.

Photograph of a model of an adult, three-horned dinosaur as exhibited in the United States National Museum. The body was covered, probably, with large, horny plates or scales, and the head frill and horns were also covered with horny material, rendering the spines and horns longer and sharper than they appear in the fossils. The long beak, with its horny sheath, was used for securing the plant food, possibly assisted by a long tongue. A weight of many tons is attributed to this dinosaur, for it differs from other dinosaurs in being an upland animal, and its bones are more solid and heavy. The elephantine feet were equipped with hoofs and the creature was four-footed, as distinct from other kinds of reptiles.

The three-horned dinosaurs were the last of their kind to disappear. For hundreds of thousands of years these slow-witted creatures languidly existed, ate and grew fat, until the time they ceased to exist, nobody knows why. But shortly before the beginning of the Age of Mammals they became extinct. Such a wholesale and mysterious destruction of large groups of big animals has happened many times in geological history. Something may have occurred which made it harder for them to fill their big stomachs with proper, nourishing food, and they dwindled away.—Courtesy of Charles W. Gilmore at the U. S. National Museum.

by the Age of Mammals. This somewhat desolate region, as it appears now, was in the Age of Reptiles clothed in luxurious vegetation, the climate and altitude at that time being favorable for plants which now grow much nearer the equator. Large sandstone concretions bearing the fossilized bones of

FIGURE 40.—DISEASE AND INJURY AMONG THE DINOSAURS.

a=Right pelvis of a dinosaur whose skeleton is mounted in the U. S. National Museum, showing at the arrow a huge necrotic sinus, the result of a long-standing infection, following an injury. The animal is called Camptosaurus, and was secured in the Cretaceous of Wyoming.

b, c=Two views of the shoulder blade of a three-horned dinosaur showing a diseased growth of bone on the inner surface, a hook-like exostosis, the origin of which is problematical. Although this growth was doubtless covered, in part, by the sub-scapular muscle, yet it must have caused inflammation along the ribs, and possibly even in the lung sack. The bone is about three feet long and was secured in the Upper Cretaceous of Wyoming.—Courtesy of Charles W. Gilmore.

dinosaurs, yield the information that the huge three-horned dinosaurs, the Ceratopsia, were exclusively plant feeders—stood upon four stumpy legs and had the hugest bony bonnet of any creatures which ever lived. Dull-witted these huge-headed reptiles must have been with a two-pound brain lodged in a thousand pound head. They didn't need much brain, for their lives were not complicated. They ate, they slept and very occasionally they fought—but mostly they slept. Life was easy in those Wyoming-Mesozoic days; food abundant, and enemies few. The carnivorous dinosaurs could have fed full upon the body of a **Triceratops,** for here was tons and tons of meat and bone—could they have gotten it.

Triceratops was tolerably well provided for offense and defense. Its huge horned head, with its extensive bony frill would ward off most attacks, without damage to itself, provided the enemy could be met head first. Attacks on the flanks, however, by hungry carnivorous dinosaurs could not so easily be repelled. Turning to meet such an attack must have been somewhat time-consuming. Injuries on head and body show that such attacks were made, but we cannot tell how many such attempts were successful; and then it may be that the gigantic flesh-eaters were carrion feeders. A herd of the Tyrant-King dinosaurs could have caused wide-spread desolation among the animal life of the Upper Cretaceous—but perhaps they were more sluggish than we anticipate. A small brain in a fifty-foot animal does not suggest much activity—and perhaps one full gorge of meat would last the King dinosaur a week or two.

Cope's collection of fragmentary dinosaurian material made in 1875 and 1876, now in the American Museum of Natural History, formed the starting point in our knowledge of the great three-horned dinosaur group, although Cope did not recognize the existence of the sub-order—Ceratopsia. This was done by Marsh on more complete material secured by Hatcher. Leidy had much earlier described some dinosaur teeth collected in this area by the geologist Hayden in 1855.

In the autumn of 1888 J. B. Hatcher found a pair of very large horn cores thirty-five miles from Lusk, Wyoming, looking so like the horn cores of bison, that Marsh described a new species of bison based on dinosaur horn cores; but at that time no one had dreamed about the existence of the Ceratopsia, as the group of three-horned dinosaurs are called. Early the next spring, 1889, the discovery of the horn cores led Hatcher to the discovery of the great dinosaur-bearing locality in Niobrara County, Wyoming, the collections from which enabled Marsh to define the three-horned dinosaur group, and here

FIGURE 41.—INJURIES AMONG FOSSIL VERTEBRATES.

a=A pair of dinosaur horn-cores, the right one having been broken during life and healed over with new bony growth. Possibly an instance of a fight in the Cretaceous times. Specimen in the U. S. National Museum.

b=A diseased camel foot bone.

c=Leg of a giant turtle which had been bitten off, and healed over.

Hatcher worked from 1889 to 1892, collecting in the four years there half a hundred specimens, several of them fairly complete skeletons.

Horned dinosaurs were discovered also in Colorado, Canada and in Montana, but no locality in the State of Wyoming has equalled the Niobrara County deposits, a history of whose discovery is given by Hatcher in his monograph on the Ceratopsia.

So interesting and important, to lovers of Wyoming, is the history of the discovery of the great deposit of three-horned dinosaurs that we may quote Hatcher's account of the "Discovery of well preserved Remains of Ceratopsia in Converse* County, Wyoming." Prior to this discovery the three-horned dinosaurs had been known only from isolated teeth and fragmentary skeletons.

Hatcher writes:

"In the summer of 1888, under the direction of Prof. O. C. Marsh, I undertook an expedition for the purpose of collecting vertebrate fossils in the Judith River badlands of the upper Missouri River, a locality already rendered classic by the researches of Hayden, Leidy and Cope. While this expedition was not especially successful, 14 boxes (about a ton) of rather fragmentary material was procured, including the skull fragments figured by Marsh and made the type of the new genus and species **Ceratops montanus,** for which a new family, Ceratopsidae, was at the same time proposed. Notwithstanding the fragmentary nature, the remains demonstrated the presence of horned dinosaurs in these deposits, a fact which had been previously suspected by Cope. At the same time they threw much new light on the affinities of the material previously collected by Hayden, Cope, Cannon and others.

"After passing two months in the Judith River badlands with very indifferent success, in the early autumn of the same year (1888), at the instance of Professor Marsh, I proceeded to southern Wyoming to investigate the remains of a fossil vertebrate discovered by Mr. Louis Lamotte, just south of the Seminoe Mountains, on the west side of the North Platte River, about 1 mile from that stream and 40 miles below Fort Steele. These remains proved to belong to the Ceratopsidae, although this was not then suspected by me. There were present parts of the skull, vertebrae, ribs and other portions of the skeleton, all in such a fragmentary and decomposed condition as to render their determination impossible, in the light of what was then known of these dinosaurs.

"After spending some time in this vicinity in a fruitless search for more perfect remains, I decided to abandon this locality and proceed to the White River badlands, lying east of the Black Hills in South Dakota, and pass the remainder of the season in making still further collections of the fossil mammals so abundant in that classic locality. While en route I

* Now Niobrara County.

stopped at Douglas, Wyoming, and there met a former acquaintance, Mr. Deforest Richards, afterwards governor of Wyoming, now deceased, who introduced me to Mr. Charles A. Guernsey. This gentleman, having a general but enthusiastic interest in matters relating to natural history, and especially to geology and paleontology, had, through a long residence in the country as manager and owner of the 'Three-Nine' cattle ranch, succeeded in bringing together a considerable collection of fossils. On inspecting this collection, through the kindness and at the request of Mr. Guernsey, I was impressed with its value, for it contained many specimens of great perfection and beauty, and only a glance was needed to show that the entire lot had been brought together with great judgment and discrimination, such as are rarely seen in amateurs and such as might with profit be emulated even in some of our public museums, especially in their exhibition series.

"Among the many interesting things in this collection I was at once struck with a fragment of a very large horn core. This fragment was about 18 inches long and perhaps 8 inches in least diameter at the base, which was hollow, the cavity being filled with a hard, brown sandstone closely resembling the sandstone concretions that are so abundant in the Laramie. On inquiry Mr. Guernsey informed me that the specimen had been taken from a skull several feet in length which had been found by his ranch foreman, Mr. Edmund B. Wilson, completely embedded in a hard sandstone concretion, weighing not less than 2,000 pounds, that lay in the bottom of a deep canyon about 35 miles north of Lusk, Wyoming. Observing my interest in the specimen, Mr. Guernsey very kindly assured me that if I wished to see the skull he would at some future time conduct me to the locality.

"Having completed my season's work . . . I returned to New Haven on January 3rd, 1889. In the meantime I had written Profesor Marsh several letters concerning this peculiar horn core and he had published, in December 1888, his description of **Ceratops montanus,** from the material which I had collected in the early part of the season in Montana and which for the first time demonstrated the presence of horned dinosaurs in the Judith River beds. This, together with the fact that Cannon, Eldridge and Cross had already recovered undoubted dinosaur remains from the Denver beds, where the type of **Bison alticornis** had been found in situ, caused Professor Marsh to doubt the mammalian nature of the pair of horn cores which constituted the type of the latter and of which I had only seen figures. When I examined these horn cores, I at once recognized the striking similarity between them and the horn core in the collection of Mr. Guernsey. I immediately wrote Mr. Guernsey requesting him to send on his specimen for further examination and comparison. He very kindly and promptly complied with this request, and on its arrival Professor Marsh at once recognized the remarkable similarity between the two specimens, and, after his characteristic nature, became immediately possessed with a burning desire to secure the skull and learn the exact geological horizon from which it came. Accordingly, on February 20, 1889, I left New Haven

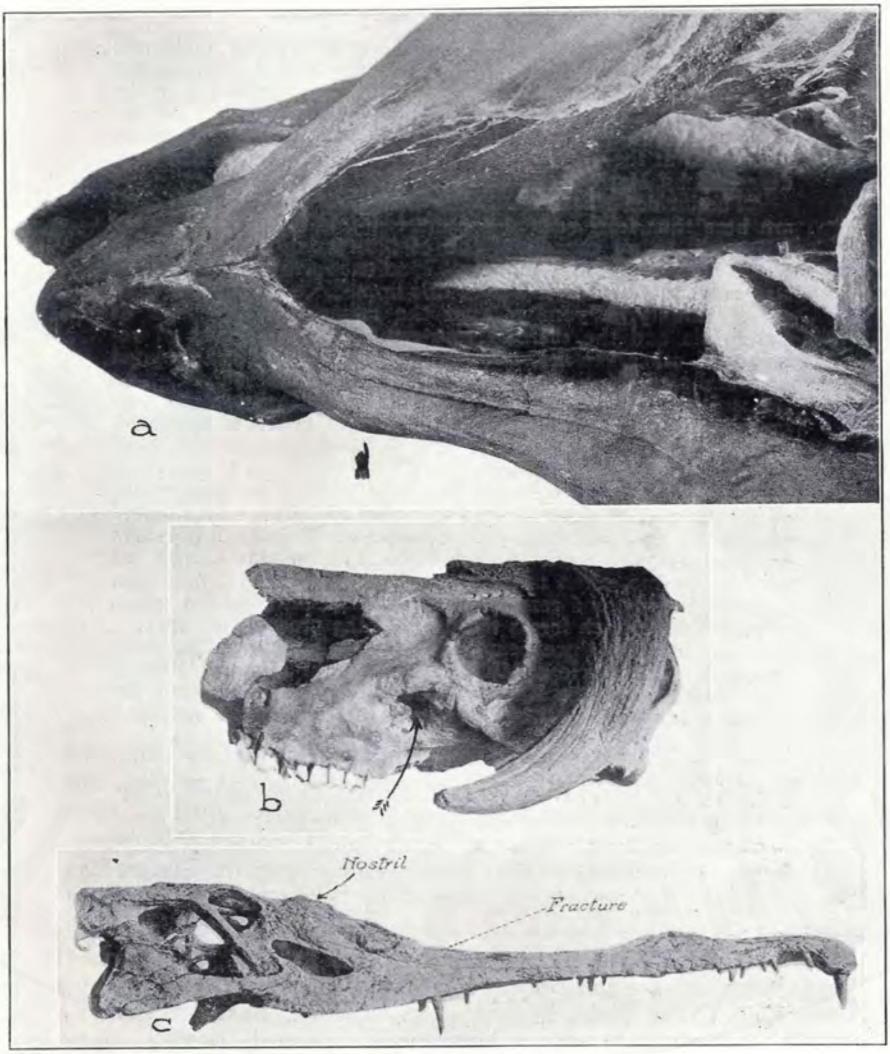

FIGURE 42.—FRACTURE AND NECROSIS IN ANCIENT REPTILES AND IN THE MUSK-OX.

a=Jaw of a three-horned dinosaur showing, at the hand, a green stick fracture, which had healed. Specimen in Yale University Museum, collected in the Lance Formation of Niobrara County, Wyoming.—Courtesy of Professor R. S. Lull.

b=Skull of a Pleistocene Musk-ox showing, at the arrow, a necrosis.

c=Skull of a Triassic phytosaur showing effects of a fracture. The phytosaurs were contemporaneous with the early, small, Triassic Dinosaurs.

for Lusk, Wyoming, and although long delayed by inclement weather, the season being mid-winter, succeeded in securing the remainder of the skull, our party having been conducted to the exact locality by Mr. Wilson, the original discoverer of the specimen. The skull was found embedded in a large sandstone concretion at the bottom of a deep canyon, exactly as had been described by Mr. Guernsey.

"The incidents connected with the procurement of this skull are here thus fully related for the two-fold purpose of giving full credit to all concerned and of illustrating the manner in which one of the most important localities for vertebrate fossils was made known, for it was in this immediate vicinity, in Converse* County, Wyoming, that the remarkable collection of Ceratopsia and the scarcely less remarkable collection of remains of other reptiles, as well as several thousand isolated jaws and teeth of diminutive mammals, were procured. . . . As the work of exploration in this newly discovered locality progressed the exact nature of this remarkable group of dinosaurs was rapidly brought to light and the real affinities of those remains . . . became apparent. . . ."

"Professor Marsh was not slow to recognize the importance of the Converse* County locality, and, with the tenacity and enthusiasm that were so characteristic of him, for four years he continued the work in that region, which was carried on for him by me, often under most discouraging circumstances, but which in the end resulted in the accumulation of the splendid collection which forms the basis of the present monograph. This locality has since been visited by collecting parties sent out from the American Museum of Natural History, Princeton, Chicago, and the Kansas State universities, and from the Carnegie Museum. All of these have met with some success."

All of the thirty-four species of horned dinosaurs discussed in Hatcher's monograph, divided among a dozen genera, are confined to the Cretaceous of the United States, most of them from the sandstone beds of Niobrara County, Wyoming. Since the publication of that book (1907) Barnum Brown has found new and remarkable horned dinosaurs in Canada, and related forms are known from Asia. Some of the dinosaurs known from Europe may belong to this group. The horned dinosaurs were extremely abundant in Montana, and among the Hell Creek beds, in seven years work, Barnum Brown, working for the American Museum of Natural History, identified no less than 500 fragmentary skulls and innumerable bones referable to the three-horned dinosaurs. **Triceratops,** the last of the race of horned dinosaurs, had a skull which, in old individuals, measured 8 feet in length. This animal attained a length of 20 feet and stood 8 feet high at the hips. He was the largest of his kind. The smallest of the group, called **Brachyceratops,** was a little over 5 feet long, and 27 inches high at the hips. Skeletons and restorations of both

* Now Niobrara County.

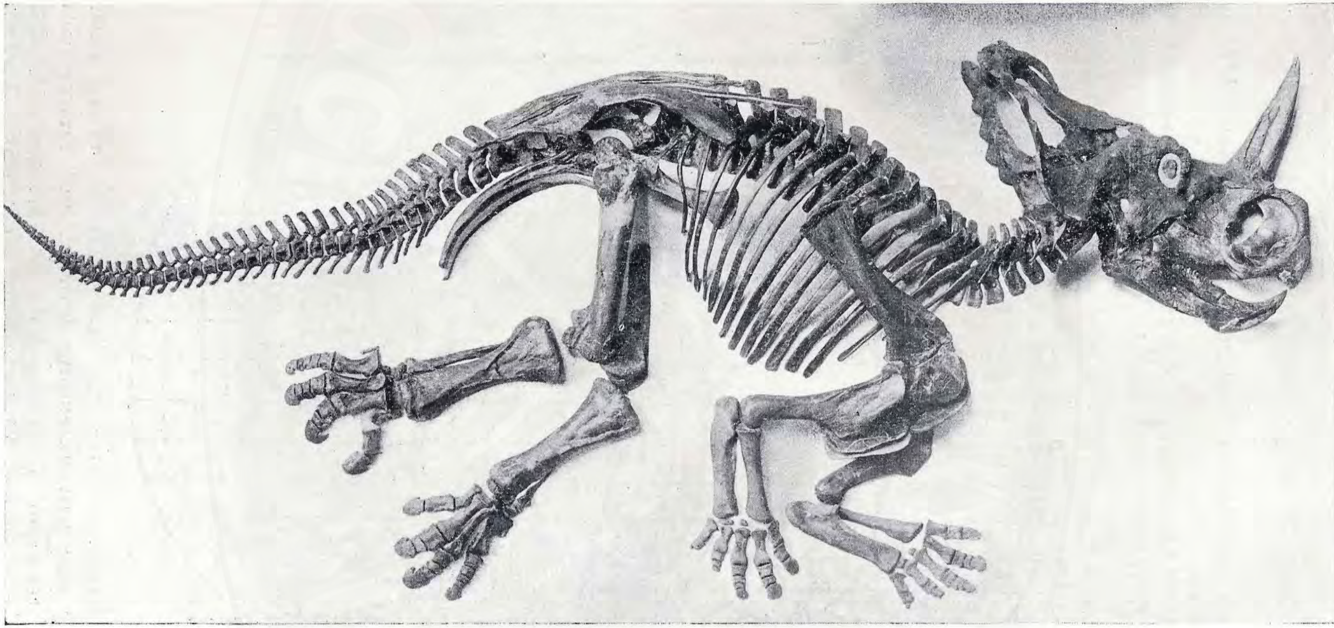

FIGURE 43.—SKELETON OF A HORNED DINOSAUR, MONOCLONIUS.

This nearly complete articulated skeleton is in the American Museum. It is in position as found in the rock, except for the forefeet which were exposed on the surface, disorganized and partly destroyed by weathering. It had a single large nasal horn and rudimentary horns over the eyes. The Triceratops of Wyoming had a large pair of horns over the eyes but the nasal horn was rudimentary.—After Barnum Brown.

dinosaurs are exhibited at the United States National Museum in Washington.

The most striking feature of this group of dinosaurs is the head with the skull armed with horns and a great bony frill

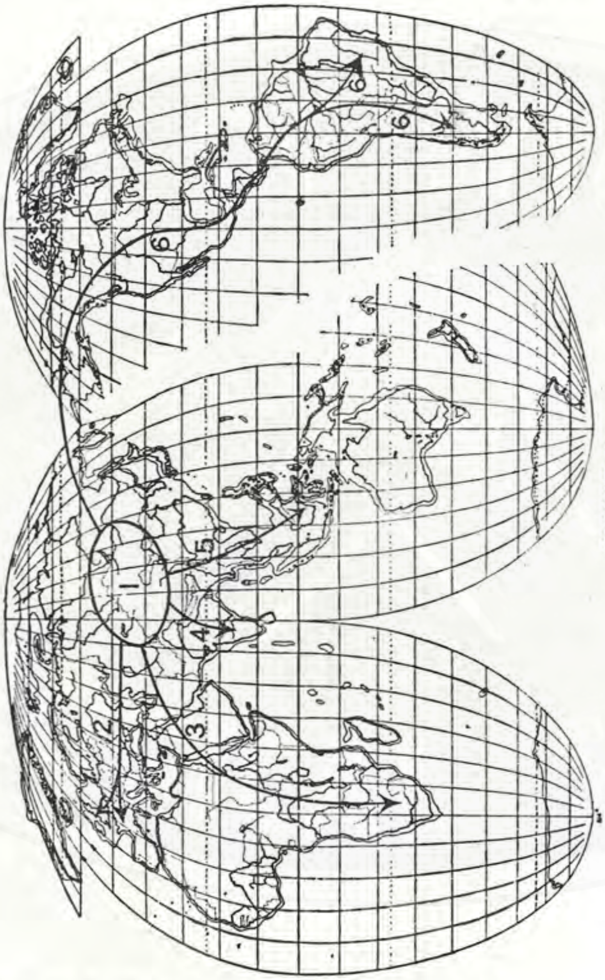

FIGURE 44.
Diagram showing world-wide migration of the giant dinosaurs from Central Asia. —After Osborn.

projecting backwards over the neck. The horns are usually three, with one pair extending upward and forward from above the eyes, and a smaller horn on the nose. In other forms, however, such as **Monoclonious,** geologically older than **Triceratops,** these horn conditions are reversed. The single horn on the nose is larger and the brow horns are quite short. In addition there are small-horned and large-horned dinosaurs belonging to this group; some that have horns curving forward, others that bend backward, others that turn outward, and still others that stand erect. At the present time no one knows whether the horns are found only on the males or whether they represent distinct species (Gilmore).

> "The frill and horn cores of most of these animals were in life undoubtedly invested in a close-fitting covering of horny skin, as implied by the deep ramifying system of depressed channels on their outer surfaces for the transmission of blood-vessels. The character of this covering was probably like that found on the horns of the horned toads . . . this sheath increases the length of the horn. Professor Lull has observed on a young specimen in the Yale Museum 'a layer of black powdery substance, a half inch in thickness, doubtless the carbonized remains of the actual horn, surrounding the base of the horn core.'" (Gilmore).

The majority of the known skulls of the three-horned dinosaurs are those of old animals whose skull bones are so grown together that little can be told of their structure. A few young skulls, however, show that the cranial elements in these huge skulls are those found in other reptiles, though some of them are curiously modified and specialized in certain directions, chiefly for the purpose of affording increased protection to the creature by the growth of horns and frills. The skull is extremely compact and heavy, and is larger than the head of any other known land animal.

The frill is made up of the skull bones known as the parietals and squamosals. Its development has not been uniform in the different kinds of animals, and forms an easy basis for determining the different genera and species. In grown animals the frill is one continuous sheet of bone. Its extreme margins are made more effective as a defense by having the margins curved outward and provided with a series of elongated, acuminate, triangular bony plates, which were doubtless covered with sharp horny spines in life.

The openings of the surface of the skull are two pair of large openings and the large round eye sockets, the nostrils and a median opening called the **postfrontal fontanelle,** unlike anything known in other vertebrates. The opening leads into sinuses in the base of the horns, and the sinuses which exist between the outer and inner layers of bone.

The orbits, containing the eyes are large and deep, possibly the animals could withdraw the eyes into the deep sockets, like some modern reptiles. We have no reason to assume that their vision was exceptional in any way.

When we consider the size of the huge head we find that the brain was smaller, in proportion to head size, than in any other known land vertebrate. The bones surrounding the brain case are very heavy, and the brain was entirely enclosed. There was probably no element of what we call intelligence among these stupid creatures. The sense of smell may have been fairly well developed, but their need for this sense was not great. Hatcher considers that they had a keen sense of vision, but were probably almost deaf to sounds.

The teeth were confined to the posterior half of the mouth, the front part being covered with a hard, sharp horny sheath. The teeth are arranged in series, so that as fast as one is worn out or broken another takes its place. The structure and arrangement of the teeth and jaws would seem to indicate that these animals may have fed on grasses or the stems, branches, leaves and twigs of shrubs and woody trees which were abundant during the Cretaceous. The food was probably taken into the mouth in considerable quantities and was received first into large lateral pouches, from which the material was passed between the jaws, which would act on either side as double-bladed chopping knives, soon reducing the vegetable mass to a condition suitable for its reception into the stomach. The teeth probably functioned as cutting organs rather than as prehensile or crushing organs. The food was reduced by cutting into small bits rather than by crushing or grinding into a pulp. The horny sheaths which doubtless incased the upper and lower beak bones, would have been very efficient as cropping organs. Their chief function would appear to have been the gathering of suitable food, while at the same time being effective as weapons of offense and defense (Hatcher).

The backbone, or vertebral column, was rather short and heavy, as compared to other kinds of dinosaurs. The neck was short and thick, consisting of seven bones. Fourteen backbone joints, or vertebrae, bore ribs, and formed the heavy barrel-shaped body. The sacrum, supporting the heavy hips was unusually long and heavy, consisting of ten segments. The tail was fairly short, but probably dragged on the ground. The spinal cord was only slightly expanded in the sacral region. Tendons, attaching the muscles to the bones, were often ossified, converted into actual bone.

The large hips consist of three bones—ilium, ischium and pubis. These have the customary dinosaurian arrangement.

The shoulder girdle has two bones on each side, a shoulder-blade and a coracoid, usually rounded.

Ribs occur on every backbone joint of the body.

The fore-limb and foot are shorter than the hind foot, and the bones much heavier, marked with strongly developed, roughened projections for the attachment of heavy muscles.

FIGURE 45.
Dinosaur eggs found in the Gobi Desert of Mongolia by the 1923 Expedition of the American Museum of Natural History.—After Osborn.

The causes of extinction of these remarkable reptiles are unknown, but the most reasonable one is that of a changing climate, to which these highly specialized reptiles were unable to adapt themselves.

CHAPTER XIX

Animals Which Lived with the Dinosaurs

In relating the association of Mesozoic animals with the dinosaurs we shall speak more fully about the back-boned animals. The lower groups of animals, called invertebrates, were present in abundance in fresh waters and in the seas. The only possible relation between invertebrates and dinosaurs is that the former may have furnished the reptiles with food, although the majority of known dinosaurs were plant feeders, living on soft verdure along the lakes, marshes and rivers, or on higher land, cropping leaves and twigs of such trees and bushes as still exist, for, by the close of the Age of Reptiles, flowering plants, woody trees, grasses and other plants had assumed a modern aspect. The poplar, willow, oak and maple were trees then as now.

The fishes were abundant throughout the Mesozoic, but were mostly marine. Only three kinds of lung-fishes (dipnoans), at present found in Africa, have been made known from the Dinosaur beds. We do not know that the fishes were important to the dinosaurian reptiles.

Mesozoic amphibians are few, and scantily known. Some years ago I reviewed our knowledge of the frogs and salamanders of the Age of Dinosaurs—but they hardly differ from the frogs and mud-puppies which we see today.

Birds are known from American dinosaur beds only by fragments. I am showing here (Figure 46) a Mesozoic bird, combining many characters. Marine birds, large wingless, toothed, aquatic, fish-eating types and small, winged, toothed, possibly fish-eating birds, about the size of a pigeon, are known from the Kansas chalk.

The distinguishing character of all birds, ancient and modern, is the possession of feathers. No other animal has them. Birds may have arisen from reptiles, but those reptiles are yet unknown, nor do we know the stages in the derivation of feathers from scales. Bird fossils are among the rarest gems of paleontology, but we know a few complete fossil birds, some fossil feathers and a few fossil eggs.

Before the close of the mesozoic turtles had diversified into land-living, marine, and river or swamp turtles.

Crocodilians of several kinds have been found in dinosaur beds, as well as pterodactyles (winged reptiles), lizards, rhyncocephalians, and other reptilian forms. We cannot believe that the presence of any of these reptiles was of any importance to the Dinosaurs. They were merely contempor-

FIGURE 46.—A BIRD OF THE MESOZOIC!

This is not a restoration of any particular bird known from fossils—but it is just a Mesozoic bird, with some of the features of the long-tailed European reptile bird, with claws on the wings. The birds and dinosaurs may have had a common origin—had the same ancestors. Some of the Triassic dinosaurs had many points in common with birds—BUT nothing but birds have ever had feathers! Feathers did, doubtless, arise from scales, but when and how we do not know. Feathers are very ancient, Jurassic, at any rate when we find them well developed in the Jurassic bird, Archaeopteryx, from the Solenhofen slates of Europe. By Jurassic times birds and dinosaurs were far apart! Future discoveries in the early stages of the Mesozoic may tell us more about how the birds and dinosaurs were related. Just now most of the Triassic dinosaurs we know are scraps, and the Triassic birds we do not know at all.

When we compare the ponderous bulk of one of the dinosaurs with the delicate wisp of a humming bird we see nothing in common. We must go far back in geologic time to learn something of those common characters.

aneous. The carnivorous dinosaurs may have eaten some of these other reptiles and some of the gigantic crocodilians may have preyed upon certain unwary dinosaurs, especially some of the young sauropods which lived in the same swampy areas.

Mammals of four large groups were abundant, though small (see Frontispiece). The teeth and bones of many of the smaller Mesozoic mammals that J. B. Hatcher collected from the tops of ant heaps, commonly found in sandy areas. If no ant heaps were present Mr. Hatcher would move an ant colony with a shovel, returning months later to gather the minute fossils brought to the surface by the indefatigable insects. As flesh and blood animals these Cretaceous mammals were tiny, mouse-like in size. There is an idea occasionally expressed that these small mammals hastened the extinction of the dinosaurs by feeding on the reptilian eggs. We do not know, however, whether or not all Dinosaurs laid eggs, and it is probable that the Upper Cretaceous mammals did not live in the same region. These mammals were eaters of roots and other vegetation, eaters of insects, eaters of fruits, seeds, and some were omnivorous. Some of them lived in trees, in holes in the ground and among the rocks. Simpson says:

> "The Mesozoic mammals constituted a little world of their own. In their society were all the fundamental adaptive types of a recent mammalian fauna. Some were chiefly insectivorous, others predaceous, while still others were herbivorous. It is the latter, the Multituberculata, which . . . were the most successful of Mesozoic mammals, for, appearing as early as the very first, they occur at every mammal-bearing horizon in the Mesozoic and even linger into the beginning of the age of mammalian dominance without any remarkable change. They undoubtedly owed this longevity to their complete and successful adaptation, and also to the fact that they alone among Mesozoic mammals did not have to face heavy reptilian competition for food, as did the small insectivores and carnivores. When the more progressive plant-eating mammals of the Paleocene appeared, the days of the Multituberculates were numbered. Yet, so perfect was their adaptation, even then they lingered on until the very moment when the Paleocene herbivores were themselves doomed by the invasion of the modernized mammals, beginning in the earliest true Eocene."

CHAPTER XX

Wyoming Dinosaurs Abroad

It will be the purpose of this section to deal with the preservation and exhibition in museums abroad of dinosaur bones and skeletons which had their origin from the geological deposits of Wyoming. So that the Wyomingite, naturally a booster for his native state and its products, may seek out in his foreign travels those specimens from Wyoming, and point with pride, followed by the remark: "Why, there's old Diplodocus. He and I are from the same state!"

There are three ways for foreign museums to secure Wyoming Dinosaurs, and there are many of Wyoming's ancient reptiles in distant collections. The first way is by purchase, either from amateur collectors or from professional fossil hunters. Of the latter type the fossil hunters, Charles Sternberg and his sons, have been most successful. A second method is to secure the specimens through exchange with the American museums, who have duplicate dinosaur material. The third method is through gift.

Some years ago the Carnegie Museum at Pittsburgh secured exceptionally complete skeletal material of the slender, elongate, whip-tail, sauropod dinosaur which Hatcher named **Diplodocus carnegiei.** The animal was 80 feet long, and was taken from the Upper Jurassic rocks of Wyoming. Director W. J. Holland suggested to Andrew Carnegie, founder of the Museum, the making of plaster casts of this exceptional dinosaur, for presentation to certain foreign Museums—a truly princely gift. The plan was immediately authorized and duplicate plaster casts of this huge Wyomingite were presented to the Kings of England and Italy, the Presidents of France and Argentine Republic, and the Emperors of Germany, Austria and Russia. The gifts were accepted and these huge dinosaurians were mounted in the exhibition halls of the National Museums of these countries. This was done prior to 1914. The last one was mounted in Buenos Aires, Argentina, in 1912.

Prior to 1911 Mr. Carl Hagenbeck, in his zoological garden at Stellingen, had had constructed life-size restorations, in concrete, of several of Wyoming's hugest dinosaurs, in connection with his large collection of exotic birds and mammals.

Here the visitor sees his old Wyoming friends, the whip-tail **Diplodocus,** the horned **Triceratops,** and other interesting dinosaurs.

The "Dinosaur Mummy" in the American Museum of Natural History, described in previous pages, is said to be approached or rivalled by a second specimen, collected in 1910 by Charles H. Sternberg in the Upper Cretaceous deposits of Niobrara County, Wyoming, in the Senckenberg Museum of Frankfurt, Germany.

The British Museum of Natural History (Kensington) has a number of dinosaurs from Wyoming, notably a large three-horned reptile from Niobrara County, Wyoming, collected by Charles H. Sternberg.

The money value of dinosaurs which have been collected in Wyoming is revealed in a letter received, September 9th, 1929, from the veteran collector of dinosaurs, Charles H. Sternberg, now residing in San Diego, California, and still hearty and hale after a half century's collecting.

The largest sum ever received for any single specimen of a Wyoming dinosaur was $2,500.00 paid by the Senckenberg Museum at Frankfurt-am-Main, Germany, on the recommendation of Dr. Drevermann. The dinosaur was a second "mummy" of a duckbill or trachodont reptile. The first "mummy," discussed in Chapter XIII, was secured by the American Museum of Natural History, at New York City, for $2,000.00.

A skull of the three-horned dinosaur, **Triceratops,** was sold to the Museum of Natural Sciences, in Paris, at the suggestion of Dr. Marcellin Boule; and another to the British Museum of Natural History, as well as two skeletons of duckbill dinosaurs which were sold for $800.00. A more perfect trachodont dinosaur brought $1,000.00 at Paris.

Two fine skeletons of trachodont dinosaurs, en route to the British Museum, were sunk by a German raider during the war. Mr. Sternberg had worked for four months on these skeletons. Another dinosaur, shipped on another boat, arrived at the British Museum safely.

Doctor Carl Wiman of the University of Upsala, Sweden, secured two skeletons of trachodont dinosaurs and a fine skull of a horned dinosaur by purchase from Mr. Sternberg.

CHAPTER XXI

LIST OF WRITINGS

A List of Books, Memoirs and Papers dealing with the Dinosaurs of Wyoming particularly, but containing a few Titles which show the Relationships of Wyoming Dinosaurs to those of the World:

Brown, Barnum, 1919. Hunting Big Game of Other Days. Natl. Geog. Mag., xxxv.: 407-429. With 25 illustrations.

Author of many other papers on Dinosaurs of Canada and the United States published in the Bulletin of the American Museum of Natural History, where he is in charge of "The Dinosaur Hall," containing the finest assemblage of Dinosaurs of any Museum of the World. Many of these specimens were collected in Wyoming.

Gilmore, Charles W., 1909. A new Rhyncocephalian Reptile from the Jurassic of Wyoming with Notes on the Fauna of Quarry Nine. Proc. U. S. Natl. Mus., xxxvii.: 35-42, illus.

——, **1909.** Osteology of the Jurassic Reptile Camptosaurus, with a Revision of the Species of the Genus and Descriptions of two new Species. Ibid, xxxvi: 197-332, figs., plates 6-20.

——, **1910.** Leidyosuchus sternbergii, a new Species of Crocodile from the Ceratops Beds of Wyoming. Ibid, xxxviii: 485-502, plates 23-29.

——, 1914. Osteology of the Armored Dinosauria in the United States National Museum. Bulletin U. S. National Museum, No. 89: 1-136, plates 1-36.

Author of many other papers on Dinosaurs published by the United States National Museum, where he is in charge of a fine collection of dinosaurian reptiles, many of them collected for Professor O. C. Marsh when he was a member of the National Geological Survey. The collection at Washington contains many mounted skeletons secured from the geological formations of Wyoming.

Hatcher, John B., 1893. The Ceratops Beds of Converse County, Wyoming. Amer. Jour. Science, 3rd ser., xlv: 135-144.

Hatcher, J. B., O. C. Marsh and R. S. Lull, 1907. The Ceratopsia Monograph xlix: 1-295, 125 figures and 51 plates. U. S. Geological Survey.

Many other splendid papers by J. B. Hatcher are issued by the Carnegie Museum at Pittsburgh. Hatcher collected more than forty specimens of the huge three-horned dinosaurs in Wyoming.

Hay, O. P., 1902. Bibliography and Catalogue of the Fossil Vertebrata of North America. Bulletin 179, U. S. Geol. Survey.

The most useful volume on fossil vertebrates ever published. A new edition will be issued soon by the Carnegie Institution of Washington.

Holland, W. J., 1906. The Osteology of Diplodocus. Mem. Carnegie Museum, II, pt. 6: 225-278.

Lucas, Frederick A., 1902. Animals of the past. Chapter VI: The Dinosaurs, pp. 90-109, illus. New York.

Lull, Richard S., 1910. Dinosaurian Distribution (throughout the World). Amer. Jour. Science, xxix, 1-39, illus. January.

——, **1910.** Stegosaurus ungulatus Marsh, recently mounted at the Peabody Museum of Yale University. Ibid, xxx: 361-377, illus.

——, **1915.** The Mammals and Horned Dinosaurs of the Lance Formation of Niobrara County, Wyoming. Ibid, xl: 319-348, illus. October.

——, **1917.** On the Functions of the "Sacral Brain" in Dinosaurs. Ibid, xliv: 471-477. December.

——, **1921.** The Cretaceous Armored Dinosaur, Nodosaurus textilis Marsh. Ibid, I: 97-126, illus. February.

——, **1926.** Early Fossil Hunting in the Rocky Mountains. Natural History, xxvi: 455, illus.

As director of the Peabody Museum of Natural History at Yale University, the author has charge of the large and important Dinosaurs, many of which were collected at Como Bluffs, Wyoming, in the days when Professor O. C. Marsh and his party went "bone hunting." A squad of cavalry was needed for their protection, and no man's rifle was long out of his hand. Dr. Lull is co-author with Hatcher and Marsh of a quarto volume on horned dinosaurs.

Marsh, O. C. 1896. The Dinosaurs of North America. U. S. Geological Survey, 16th Annual Report, pt. 1, pp. 133-414, plates l-lxxxv.

This book summarizes Marsh's numerous papers on Dinosaurs published in the American Journal of Science, during two decades, while the author was actively engaged in the collection and describing numerous dinosaurs from Wyoming. His collections are preserved at the Peabody Museum of Yale University and at the United States National Museum.

Matthew, W. D., 1910. The Pose of Sauropodous Dinosaurs. Amer. Natl., XLIV: 547-560.

——, **1915.** Dinosaurs. Handbook, Series 5, American Museum of Natural History, pp. 1-162, illus. (Out of print.)

——, **1922.** A Super-Dreadnaught of the Animal World. The Armored Dinosaur Palaeoscincus, Natural History, xxii, No. 4, 333 342, illus.

——, **1926.** Early Days of Fossil Hunting in the High Plains. Ibid, xxvi: 449-454, illus.

Moodie, Roy L., 1911. An Armored Dinosaur from the Upper Cretaceous of Wyoming. Kans. Univ. Sci. Bull., vol. 5: 257-273, plates 55-59, 1 text fig.

——, **1914.** The Fossil Frogs of North America. Amer. Jour. Science, xxxviii: 531-536, illus. (Frogs from dinosaur beds.)

——, **1923.** Paleopathology: Dinosaur Pathology.

Mook, C. C., 1916. A Study of the Morrison Formation. Ann. N. Y. Acad. Sci., xxvii: 39-191, 94 figures, 1 plate.

Osborn, Henry Fairfield, 1904. Fossil Wonders of the West. The Dinosaurs of the Bone Cabin Quarry, being the first description of the greatest "Find" of extinct Animals ever made. Century Magazine, lxviii: 680-694, illus. September.

——, **1905.** Western Explorations for Fossil Vertebrates. Pop. Sci. Monthly, 562-568, illus.

——, **1911.** Paleontology. Encyclopaedia Brittanica, 11th edition.

——, **1912.** Crania of Tyrannosaurus and Allosaurus. Integument of Iguanodont Dinosaur, Trachodon. Mem. Amer. Mus. Natl. Hist., N. S., 1, pp. 1-54, plates i-x.

Author of many other memoirs and papers published by the American Museum of Natural History, where for many years he has guided the assembling and discussions of the greatest collection of dinosaurs ever made in the world. Under his direction excavations were carried on at the Bone Cabin Quarry in Albany County, Wyoming, after 1897, securing there seventy-three animals, of which all, save nine, were dincsaurs of various types.

Riggs, E. S., 1900. Fossil Hunting in Wyoming. Science (2) xii: 233.

Simpson, G. G., 1926. The Multituberculates as Living Animals. Amer. Jour. Sci., 5th ser., xi: 228-250, illus.

——, 1926. Fauna of Quarry 9 (At Como Bluffs, Wyo.). Ibid, 5th ser., xii: 1-11.

Wieland, G. R., 1906. Dinosaurian Gastroliths. Science, n. s., xxiii: 819-821.

——, 1907. Gastroliths. Ibid, xxv: 66-67.

Williston, S. W., 1905. The Hallopus, Baptanodon and Atlantosaurus Beds of Marsh. Jour. Geol., xiii: 338-350.

——, 1905. A New Armored Dinosaur from the Upper Cretaceous of Wyoming. Science, N. S., xxii, No. 564, p. 503.

CHAPTER XXII

GLOSSARY

Amphibious Dinosaurs=A group of swamp dwelling, herbivorous reptiles representing the Saropoda of America, Africa and Europe. The sauropod or sauropodous dinosaurs of the genera Brontosaurus, Diplodocus, Camarasaurus, Brachiosaurus, etc.

Arthritides=Diseases of the Joints.

Atlantosaurus Beds=Como Beds where sauropod dinosaurs occur.

Badlands=Bare, rocky hills where fossils are readily found.

Barosaurus=A genus of sauropod dinosaurs with long neck bones.

Brachiosaurus=A genus of sauropod dinosaurs with the front leg as long or longer than the hind leg—America and Africa.

Brachyceratops=A genus of horned dinosaurs of small size.

Brontosaurus=The "thunder lizard." A large sauropod found in Wyoming.

Camarasaurus=A genus of sauropods collected at Garden Park, Colorado, and so named by E. D. Cope on account of the large spaces in the backbones.

Cenozoic=The Age of Mammals.

Ceratopsia=The horned dinosaurs of the Upper Cretaceous.

Comanchean=A geological period between the Jurassic and the Cretaceous. Equivalent to the Morrison Formation.

Como, Wyoming=A railroad station now abandoned.

Concretion=A rounded rock formation, harder than the rest of the rock. In Converse County the three-horned dinosaurs are found in the Lance Beds in sandstone concretions.

Cretaceous=The "chalk age." A geological period of great interest. The closing period of the Mesozoic.

Dipnoans=Lung fishes, found in fresh water deposits.

Dinosauria="Terrible lizards." The name was proposed by Sir Richard Owen for a group of fossil reptiles.

Diplodocus=A genus of sauropod, "whip-tail" dinosaurs found in Colorado and Wyoming.

Exostosis=A pathological growth on bone due to injury.

Extinction=A phase of animal life involving the disappearance of groups of creatures in geological time.

Haemangioma=A vascular tumor.

Iguanodon=A genus of predentate "beaked" dinosaurs found in Belgium.

Lacuna=A space in bone where a bone-cell existed during life.

Lance Beds=A formation in the Upper Cretaceous containing horned dinosaurs.

Matrix=The rock immediately surrounding a fossil.

Mesozoic=The Age of Reptiles, comprising the Triassic, Jurassic, Comanchean and Cretaceous.

Monoclonius=A genus of horned dinosaur with a single long horn on the snout.

Morrison Formation=The dinosaur beds near Morrison, Colorado, are found in Wyoming under the name Como Beds.

Multituberculata=A group of small mammals found in the Mesozoic rocks.

Orbits=The eye sockets.

Permian Period=A division of geological time at the close of the Paleozoic, distinguished also as the "Red Beds."

Phytosauria=A group of Triassic reptiles, crocodile-like in appearance but related to the dinosaurs.

Pineal eye=A sensory structure on top of the brain, possibly for heat perception.

Pus sinus=A pocket of infected matter.

Sacral brain=An enlargement of the spinal cord at the pelvis.

Sauropoda=Amphibious dinosaurs. The name means reptile-foot.

Stegopelta=A genus of armored dinosaurs found in marine sediments near Lander.

Stegosauria=A group of armored dinosaurs found in Wyoming.

Theropoda=The carnivorous dinosaurs.

Trachodon=A genus of duck-billed dinosaur, found as "mummies."

Triceratops=A genus of three-horned dinosaurs.

Tyrannosaurus=A genus of large, carnivorous dinosaurs, found in Montana and Wyoming.

manchian forms were analogous to the browsing ungulates whose brachiodont teeth are fitted to succulent herbage, while the later trachodonts had a dental battery fully as efficient as that of a horse. These dinosaurs chopped their food into short lengths before swallowing, and it may be that the term mastication, which, however, implies a grinding or crushing rather than chopping, may be properly applied to them. Their need of a gizzard-like organ would seem to be less great than in the sauropods.

Stegosaurus, on the other hand, possessed a very imperfect dental battery, as the teeth were both small and relatively few in number—very inadequate apparently for their owner's needs. This genus, however, exhibits a number of characters which, in the Sauropoda, have been taken as indicating an aquatic or at least amphibious life. They are, first, the solid, massive character of the limb bones and the imperfection of their articular ends, those of the stegosaur showing a rugosity fully proportional to those of **Brontosaurus.** The high position of the ribs, bringing the lungs well toward the dorsal side of the body, and the strongly compressed tail with its high neural spines and well developed chevrons are also suggestive. Add to these a mouth armament no more effective than that of a sauropod, and the association of their remains in a common burial, and the inference of similarity of habitus and food is perhaps justified. Just what effect the tall upstanding armor plates would have upon the navigable powers of **Stegosaurus** is not so clear, but they may have incommoded him under such conditions no more than on land.

"It may be fairly assumed, therefore, in view of the wide apparent range of feeding habits on the part of dinosaurs, and their relationship to the crocodiles on the one hand and to the birds on the other, that their digestive system was closely comparable both in the development of its parts and in its innervation to that of these living forms. With the birds, the degree of development of the gizzard varies directly with the consistency of the food. Graminivorous birds possess the strongest muscular layer and the thickest horny lining, while in the series from the insectivorous birds to the birds of prey this condition becomes gradually less marked and the division of labor between the glandular proventriculus and the mechanical gizzard less noticeable (Newton). The assumption of a similar gradation in the development of this organ in the dinosaurs seems also warranted.

Innervation of the Alimentary Canal

"In the reptiles such as the python, crocodile, or turtle, the **vagus** nerve (Xth cranial) is the principal transmitter of stimuli which **initiate** digestive activity, certain of its fibers being distributed to the muscles and mucous membrane of the fauces, the oesophagus, and the stomach, and it finally terminates at the beginning of the intestine at the pancreas.

"Cranial casts of **Tyrannosaurus** and of **Stegosaurus** and **Morosaurus,** representing, therefore, the three main dinosaurian groups, all show exits for the IXth to XIth cranial nerves, thus including the vagus, relatively larger if anything than in the crocodile. It is fair to assume, therefore, that this nerve was at least as well developed in the dinosaurs and that its distribution and function were comparable.

"**Birds**—The vagus (X) of birds arises behind the glossopharyngeal (IX) and is connected therewith as well as with the sympathetic system. After receiving branches from the hypoglossal (XII) and taking up the spinal accessory (XI), the vagus runs down the side of the oesophagus to the ventral side of the proventriculus, where, joining its fellow from the other side, it spreads out to supply the stomach. Other branches, leaving the principal stem of each vagus, supply the liver, heart, and lungs, and, as the recurrent laryngeal branch, also supply the distal portions of the trachea and oesophagus. Some fibres of the vagus often extend beyond the stomach, and are connected with the sympathetic nerves of the trunk, supplying parts of the intestinal canal.

"The approximate agreement in the innervation of both birds and crocodiles is further argument for dinosaurian innervation.

"Certain of the spinal nerves (dorso-lumbar) communicate with the sympathetic system and thence with the alimentary canal, but their function, in so far as it has been observed, principally in man and certain mammals, is **inhibitory**, and hence the reverse of a stimulus to digestion. Such sacral nerves as do pass to the alimentary canal are distributed to the hinder portion only, beyond the glandular or digestive part. They are stimulating, not inhibitory nerves, but their function is merely the elimination of faecal matter and is in no other sense digestive.

"The stomach in the mammal at least is largely automatic in its movements, as is the heart, and while its activity may be initiated or inhibited by impulses from the vagus or sympathetic nerves, the stimuli which cause the rhythmic movement originate in the muscles themselves, for this movement will continue after the severance of all nerve connection with the cerebro-spinal or sympathetic centers. The reptilian heart is notorious for its automatic contraction after its excision from the body, and in all probability the heart and stomach of a dinosaur were fully as automatic.

"All of this seems to show that we have no right in assuming for the dinosaur an innervation or functioning of the alimentary canal at variance with the standardized type of the living amniotic vertebrates.

"The spinal canal of **Stegosaurus ungulatus** has been studied in detail. Not only a sacral dilatation but a **brachial** one as well; that is, from vertebrae VIII to XIII, the maximum width, that of 38 mm., as compared with the average of 25 mm., is attained by vertebra XI, which is exactly opposite the shoulder articulations in the Yale mounted specimen. There is also a corresponding heightening of the canal, although this is a less constant feature, for further back (XV and XVII) there is evidence of a ligament or other delimiting structure below the the bony roof of the neural arch itself. Brachial and sacral dilatations of the neural canal are most marked in the turtles among existing reptiles, owing to the immobility of the trunk and the consequent reduction of its musculature and associated nerves, the two enlargements being necessary where the nerves depart to the limbs. That this is the whole significance of these two enlargements in **Stegosaurus** and also in other dinosaurs I have no doubt, and the relative size of each dilatation bears an approximate ratio to that of the limbs innervated, plus in the hinder pair the huge caudo-femoral and other muscles which actuated the tail.

"I still feel, despite the contention of the German writers, that the 'sacral brain'—which should not be called by such a term—possessed no unusual function whatever, but only the normal one of transmission and reflex action in an unusual degree, and that to invoke any new and unknown function as a reason for its relatively immense size, especially one connected with digestive efficiency, is not justified by the evidence at hand.

"Branca further says: 'We may also think of these animals as sluggish in habit, in consequence of which much less food was required than is the case in an active animal.' On the other hand, in warm-blooded animals the largest species occur in cooler climates, because large animals have 'a relatively smaller radiating surface than smaller ones, a factor of the greatest importance in the regulation of body warmth.' To the first statement I can take no exception. The second, however, gives food for thought. In the first place, is it an invariable rule that the largest species of warm-blooded animals occur in cooler climates? The present-day distribution of the elephant, hippopotamus, and rhinoceros does not bear this out, and even in the Pleistocene the largest elephants, such as **Elephas imperator,** were southern forms compared with the smaller, cold-adapted **E. primigenius.** With marine creatures Branca's statement seems more nearly true, for the walrus and huge sea-elephants are both adapted to cold waters, and the same is true of the right whales, **Balaena mysticetus** and **B. australis.** The sperm whale, on the other hand, is tropical or subtropical, not occurring, except accidentally, in the polar regions (Flower and Lydekker), while the great rorquals (Balaenoptera) are found in all seas except the Arctic and probably the Antarctic also. Of the deer, perhaps the largest living form is the Alaskan moose, while no bears in existence can compare in magnitude with the great Kadiak bear of the same region. But this argument loses weight if the dinosaurs were not warm-blooded, and though the supposition that they were has been advanced, it is not susceptible of proof. It is within the range of possibility that the temperature of the more agile dinosaurs rose appreciably during the time of their activity, as in many of the so-called cold-blooded (poikilothermous) creatures today, but whether or no any dinosaurs had a mechanism for even a partial maintenance of temperature is unknown. If their bodily heat varied with that of the surrounding air, the greater bulk and hence relatively smaller radiating surface would render them less susceptible to rapid temperature changes, and thus prolong their time of activity by tiding over a brief drop in temperature, but would hardly be available in an extended cooler period. That increase of size in dinosaurs was an adaptation for the conservation of energy, and in this way reduced the relative amount of nourishment necessary for their maintenance, seems hardly probable."

A duck-billed dinosaur feeding on the edge of an ancient Wyoming swamp.

CHAPTER XIII

Dinosaur Mummies from the Upper Cretaceous Rocks of Niobrara County

Travellers and residents on the high plains are accustomed to seeing the sun-dried carcasses of stock, with the dried flesh and hide shrunken and stiff against the bones and usually with the body torn open by scavenging birds, coyotes and dogs. Thus we have all the settings for a Mesozoic scene, if we replace the horses and cattle by dinosaurs.

Scientists had long known something of the nature of the scaly skin in patches over isolated areas of the fore limbs, so it was an interesting discovery which the fossil hunters, Charles H. Sternberg and his son George F. Sternberg, made while working in the Upper Cretaceous deposits of Niobrara County, Wyoming, which had already been made famous by the prolonged and successful explorations of J. B. Hatcher for horned dinosaurs.

It was in the lowest levels of this series of rocks that the younger Sternberg made the remarkable discovery of a specimen of a duck-bill or trachodont dinosaur (**Trachodon annectens**), almost complete, encased in the impression-cast of its skin. Fortunately, before the excavation had proceeded far the nature of the skin markings was recognized and the parts were all carefully preserved. This specimen, found in August, 1908, was purchased by the American Museum of Natural History, and has been beautifully figured and described by Professor Osborn (1912). Two years later the Sternbergs discovered another dinosaur "mummy" and that was secured by the Senckenberg Museum of Frankfurt, Germany.

When the first mummy was found the hind feet as well as the posterior part of the pelvis and the entire tail had been eroded away, although it seems probable that the entire body was fossilized. The body lay on its back with all the bones connected; the knees drawn up, the chest opened and upturned. The front legs are outspread, and the head and neck sharply twisted downward and backward to the right side. The dorsal frill of scaly hide is turned to the left.

The attitude of the body is that of an animal which had died a natural death, and had not been torn to pieces by scavenging animals. The shoulder blades are pressed tight to the sides of the ribs and are doubtless in their normal, living position. The breast bones are pulled away from the other bones and the chest sunken in. It is probable that after a natural death the body lay exposed to the drying action of the sun for a long time undisturbed, possibly in a low, flat, sandy area commonly seen in modern rivers at the low water stage. The soft parts of the body thus became thoroughly dried out by the hot sun and dry air, so that the skin becoming hard and leathery had shrunk against the bones, being tightly drawn against all hard surfaces. On the under surfaces of the body the dried skin was drawn within the body cavity, and thrown into creases and folds along the sides of the body and on the arms, because of the drying out of the internal tissues (Osborn).

> "At the termination of the low water season during which this process of dessication took place, the 'mummy' may have been caught in a sudden flood, carried down the stream, and rapidly buried in a bed of fine river sand intermingled with sufficient clayey elements to take a perfect cast of all the epidermal markings before the epidermal tissues became softened under the solvent action of the water." (Osborn).

It had, of course, long been assumed that the dinosaurs being reptiles had a scaly, horny skin, probably highly colored, like the modern lizards and crocodiles. When the dinosaur "mummy" was uncovered it was surprising to note the small size of the scaly tubercles, which are no larger than those seen on modern lizards. The skin itself was not preserved, but a detailed, brilliant cast of the epidermal covering was made over a large part of the body. It was noted that the fore-feet were webbed, being covered with a scaly hide in which the tubercles are both large and small, a condition which prevails throughout the body. In no part of the body, however, are there any evidences of overlapping scales. The skin was tuberculate. For such a large animal the skin is exceedingly thin and the tubercular, epidermal markings are exceedingly fine and delicate. Even the largest tubercular markings on the dinosaur skin are no larger than those seen on the head of the Gila Monster, a large lizard whose skin resembles that of the trachodont dinosaur.

Along the sides of the body there are certain "cluster areas" which were more abundant and heavier on the back near a dorsal frill or fold of tasellated hide. There is no color pattern preserved on the "mummy" but there are indications that there was a pattern and that the back of the animal was dark and the belly light as in modern reptiles.

CHAPTER XIV

Footprints of Dinosaurs

Tracks in the rock are always interesting, and dinosaur tracks especially have attracted a great deal of attention. In fact a distinct science, called **Ichnology**, has grown up around the study of fossil footprints. When three-toed tracks were first found in the red Connecticut Valley sandstone, they were regarded as bird tracks, and some of the early discoveries were said to have been made by "Noah's Raven." Dinosaurs were not known at that time.

These fossil footprints are exceedingly abundant in the rocks of the Newark Series, Triassic, of the New England states, and thousands of specimens have been collected, and stored in a number of the eastern educational institutions.

After the nature of the dinosaurs was somewhat understood from their skeletal remains, the nature of the numerous kinds of tracks was better appreciated. Professor Lull of Yale University has revised our knowledge of the footprints in the light of new information. Certain of these tracks are shown in the accompanying figure.

Large three-toed tracks, probably dinosaurs, have been seen* in Utah, but none occur in Wyoming in any quantity, so far as known, although they may confidently be expected.

A Sauropod Footprint

Professor R. S. Lull says of the only known sauropod footprint:

> "Through the courtesy of Dr. Holland, I have been able to study somewhat critically an undoubted sauropod footprint from the Morrison dinosaur quarry at Canon City, Colorado. Hatcher figures a cast of this track in his memoir on the osteology of **Haplocanthosaurus.** The figure is somewhat deceptive, however, in that it was taken from a plaster cast of the specimen which in turn is a natural cast of the original impression made by the living animal and which is therefore in relief. The surface of the specimen itself is covered with deep pits caused by a solution of the calcareous cement which bound the grains of sand together, thus allowing the latter to be washed out. In the photograph the casts of these pits, being in relief, give the impression of pebbles, whereas the rock in the quarry is a fine-grained, cross-bedded sandstone of uniform texture, without appreciable clay, and not gravelly at all. A microscopic study

* Natural History, xxvii, No. 3, p. 256, figure, 1927.

of the sand-grains themselves show them to be angular with slightly abraded corners, sand of aqueous deposit; but apparently laid down in a lake or bayou, rather than in a normal river as indicated by the absence of clay and the presence of a lime cement. The cross-bedding which the rock exhibits could readily have been made by wave action along the shores of a comparatively shallow delta-lake or bay, and the track, which

FIGURE 17A

Fossil footprints of three-toed Dinosaurs from the Newark series, Triassic, of the Connecticut Valley. These are preserved in Yale University Museum. Note the small tracks in larger slab.—Courtesy of Professor R. S. Lull.

is that of a very young animal, was evidently made under water. The character of the sediment does not give evidence of much vegetable matter at the particular point where the track was made. The footprint is that which one would expect from the known character of the sauropod foot, and is evenly impressed throughout as though the animal's weight were borne equally over the entire sole, evidence in favor of a true walk rather than a sprawling crawl, at any rate when the body was partly waterborne.

"I believe these animals to have been truly aquatic though capable of coming ashore where the substratum was sufficiently firm to support the immense weight, and, while they show no trace of swimming appendages, they doubtless could swim as a hippopotamus does."

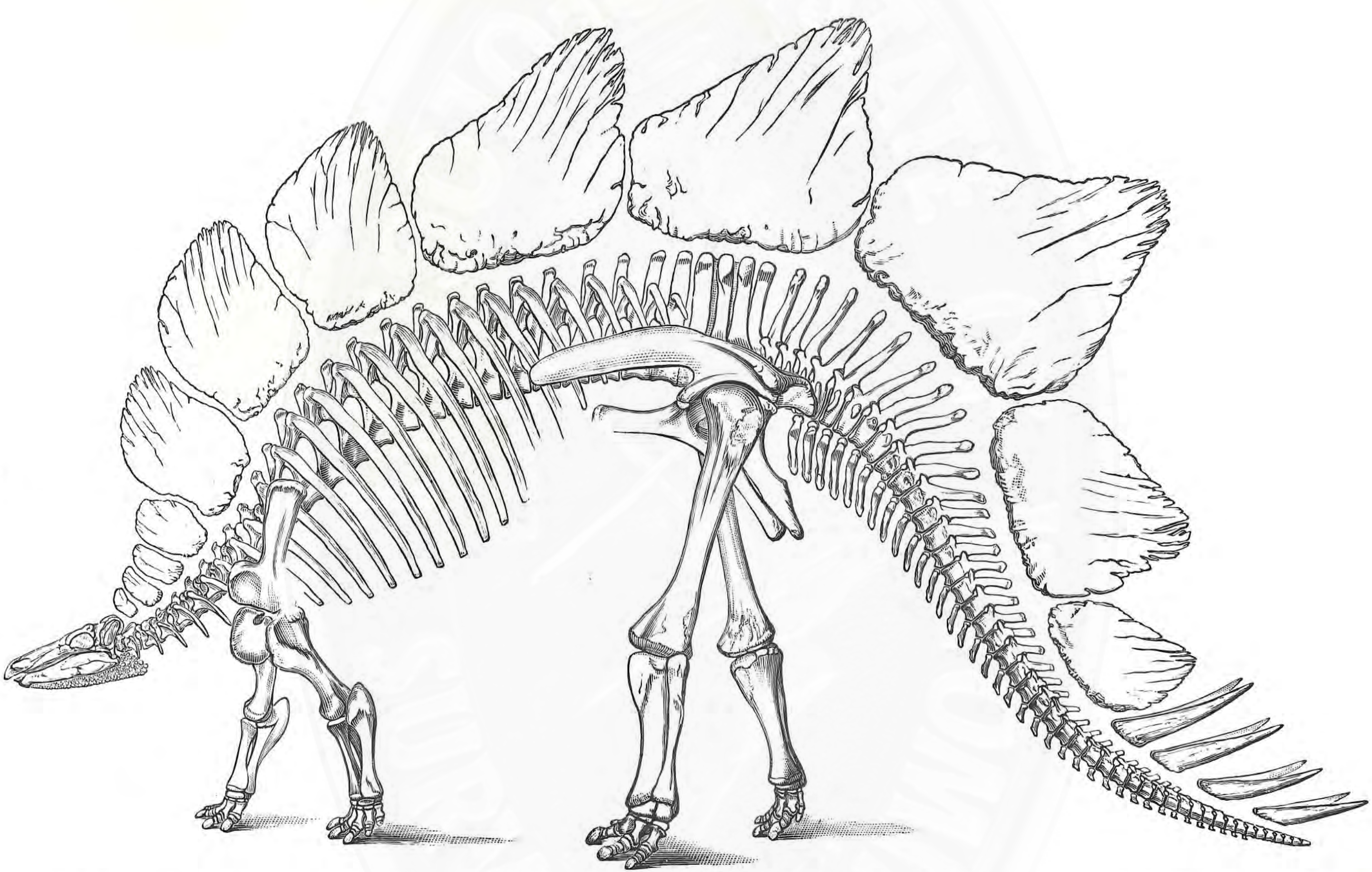

FIGURE 18.

A Restoration of the armored dinosaur, Stegosaurus ungulatus, made by Professor O. C. Marsh soon after its discovery. The two skeletons used in making this restoration were discovered at Como Bluffs, Wyoming, in 1877. The skeleton as now mounted at the Peabody Museum, Yale University, is composed of the two specimens.—After Lull.

CHAPTER XV

The Armoured Dinosauria in Wyoming and Elsewhere

Stegosaurian dinosaurs were first made known in 1877 by Professor O. C. Marsh. Although numerous armored dinosaurs are known, both in America and abroad, yet none is so well known as the genus **Stegosaurus,** which is the best known of them all. The osteology has been described by Marsh, Lull and Gilmore. A species of the **Stegosaurus (S. stenops** Marsh), is fully described by Gilmore from a nearly complete specimen found at Garden Park, Colorado.

Armored dinosaurs, incompletely known, have been found in marine deposits, showing that these animals lived near the sea. I have told in the Preface about the discovery of **Stegopelta** near Lander, in the black, Cretaceous (Hailey) shales and Wieland has told of finding other armored dinosaur material in the Niobrara (Cretaceous) chalk.

The armored dinosaurs of the Red Deer River, Canada, Cretaceous, as collected for the American Museum of Natural History by Barnum Brown, are most wonderfully protected of all known dinosaurs. One of them, called **Paleoscincus,** is known (Figure 25) from practically perfect material. The true skin of the animal was not preserved, but before disintegration had set in an "impression cast" of it was formed in the matrix, containing also the hundreds of small, bony nodules which were embedded in the skin. In the skin were set at intervals, in more or less regular arrangement, the larger flat plates and spines. **Paleoscincus** was a huge armored reptile with a broad, short body, massive legs, thick, heavy tail, and a small, flat-topped, triangular skull. The teeth of this creature are quite like those of other armored dinosaurs. Rings of heavy bone surrounded the tail, like some fossil creatures from South America.

European armored dinosaurs are not so well known as are the American species, of which **Stegosaurus ungulatus** and **S. stenops** are known from exceptionally perfect skeletons. An interesting armor of one of the English dinosaurs consists of a heavy bony shield over the hips, consisting of a mosaic

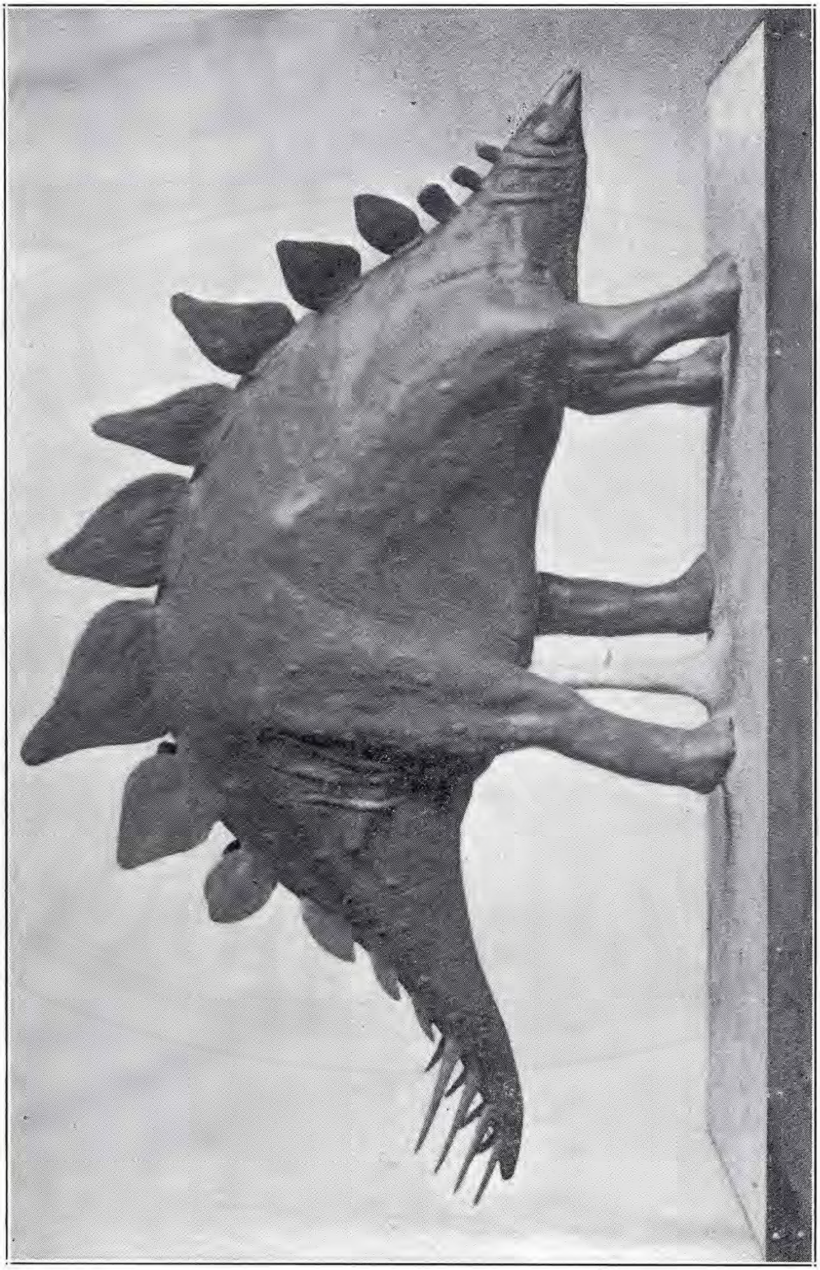

FIGURE 19.

A model showing the probable appearance of the Stegosaurus, based on the mounted skeleton. Modeled by R. S. Lull.

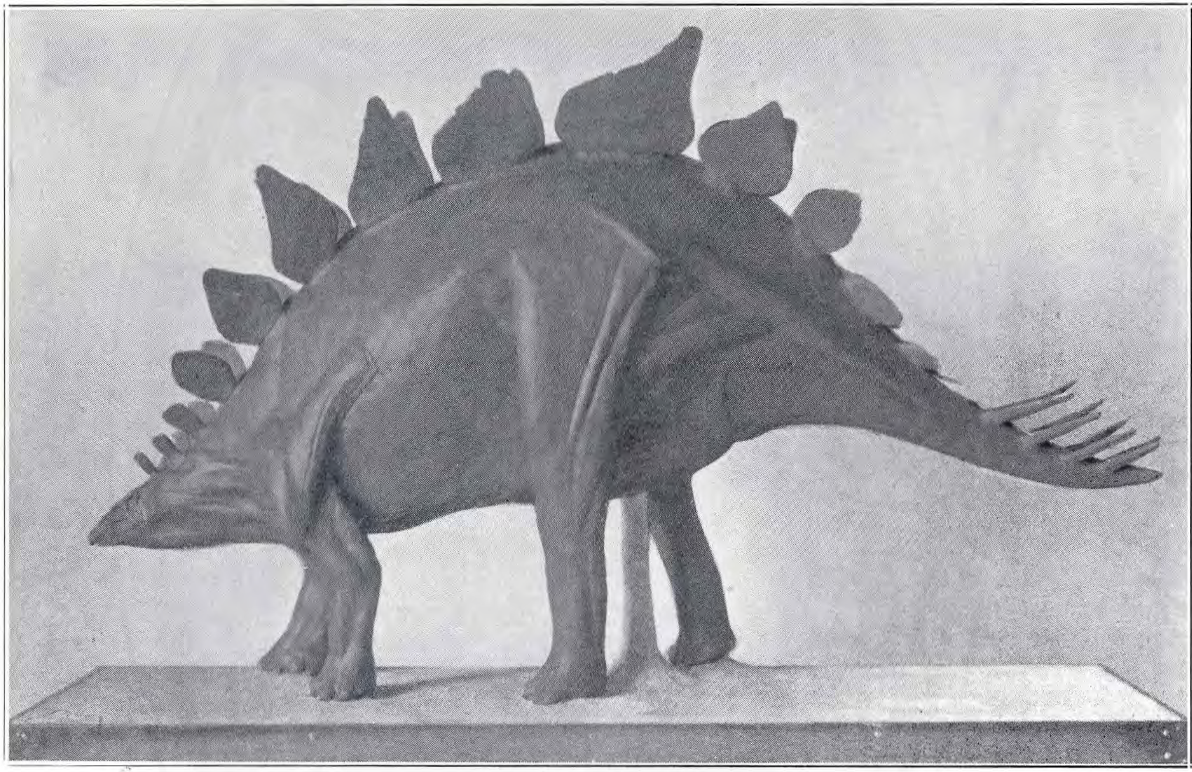

FIGURE 20.
The superficial muscles of the left side of the Stegosaurus based on the mounted skeleton. Modeled by R. S. Lull.

of pentagonal, osseous plates, highly ornamented and looking somewhat like the body armor of some of the glyptodonts found fossil in South America.

All armored dinosaurs are plant-eaters, the anterior "beak" being provided with a horny sheath for cutting off leaves, twigs and succulent stems, as in the three-horned dinosaurs. Often the entire group are spoken of as "the beaked dinosaurs." The duck-billed dinosaur, **Trachodon,** with its amazing dental armature of nearly 2,000 teeth, is likewise a member of the same group, the Predentata.

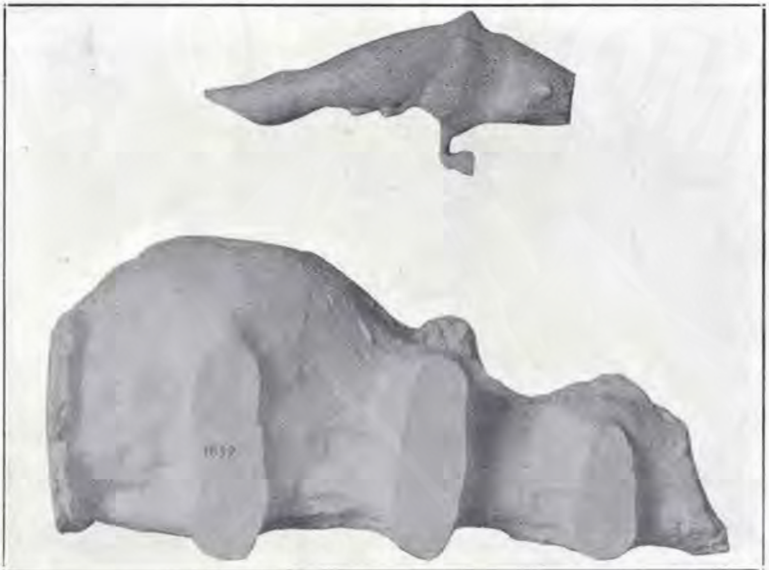

FIGURE 21.

Casts of endocranial and sacral cavities of the Stegosaurus, showing proportions of brain (above) and sacral intumesence (below). The casts are actually one-third larger than the mass of nerve material. One-third natural size.—After Lull.

Stegosaurus is one of the dinosaurian gems of Wyoming, the mounted skeleton at Yale University Museum having been collected at Como Bluffs. The animal presents many peculiar anatomical features, foremost being the remarkable proportions of the body, with the sharply arched vertebral column, short neck, small head, lank, narrow body and extremely long limbs. The tail did not droop abruptly; was probably held high off the ground; and served as an effective weapon, equipped as it was with long, sharp spines. The structure of the entire skeleton was modified to support the heavy armor. The fore-limbs are very powerful; immense rugosities on the bones indicating heavy muscular attachments. The hind limbs are pillar-like, and while powerful are not so strong as the fore limbs.

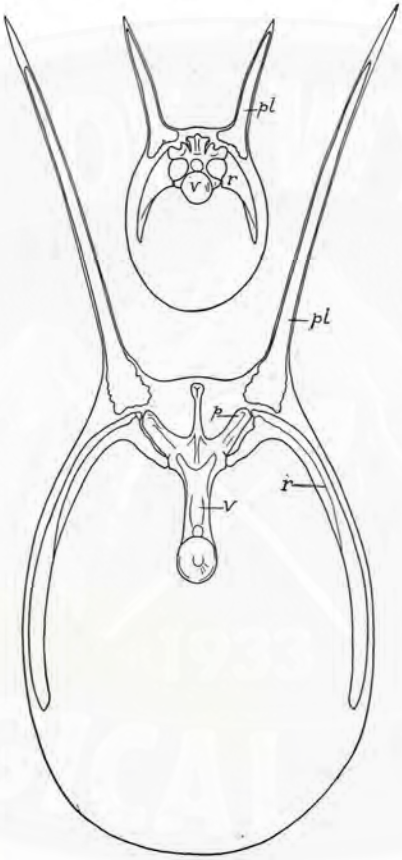

FIGURE 22.

ABOVE: Section of neck of Stegosaurus, showing relation of armor plate to backbone.

BELOW: Section of body.
pl=plate; r=rib; v=vertebrum; p=transverse process

—After Lull.

The backbones were especially modified to support the large, heavy, paired armor plates, of which there were several. The processes on the vertebrate are lengthened and thickened, and the entire back strongly arched upward, thus producing a strong support for the armor. The ribs are T-shaped

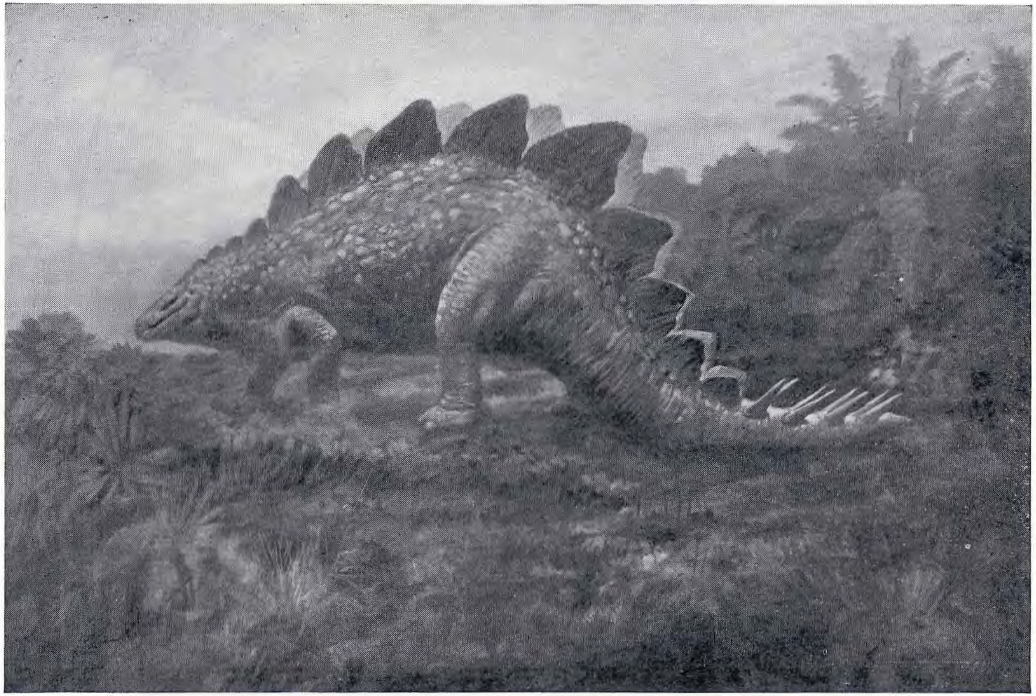

FIGURE 23.—A STEGOSAUR IN WYOMING, MILLIONS OF YEARS AGO.

The most extraordinary feature of this animal was the row of thin plates on either side of the middle line of the back, and the long, heavily armored tail.—After Brown.

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at the points where they meet the backbone, being thus modified to support the great weight.

The feet are large, as if adapted to walking in soft sand or other yielding material. The hand possessed five digits, while the foot possessed three well-developed digits, all doubtless encased in a fleshy pad as in modern elephants.

Teeth are confined to the back of the mouth, as in all "beaked" dinosaurs. They are small and weak, with wavy margins. Their food was doubtless very soft, requiring little mastication.

The brain in this dinosaur is the smallest in proportion to the size of the animal of any known vertebrate, recent or ancient.

The brain and spinal cord are remarkably interesting in that curious, nineteen foot armored dinosaur called **Stegosaurus** (Figure 21). The internal casts are actually larger than the central nervous system, because no reptile brain fits the brain case closely.

The stegosaurian brain is remarkably small, being of less size than an egg of an English sparrow. The entire cranial cavity has a length of less than half an inch, a width of about one-fifth of an inch. The brain cast displaces 56 cc. of water, and had a total estimated weight of two and one-half ounces. The total weight of the entire animal, in life, must have been two or three tons at least so that the brain of an elephant is fifty times the size of the dinosaur.

On the basis of brain weight the stegosaur had no intelligence at all.

The stegosaur brain has a very large olfactory portion, small cerebellum, large medulla, and a hypophysis which is remarkable (Figure 21) not only for its size but also for the peculiar shape.

As we go backward along the spinal cord we find two swellings, intumesences; one at the region of the shoulder, the brachial enlargement; and the other at the hips, "the sacral brain." The former is evident for a space of about four joints.

The neural canal in the sacrum is truly astonishing in size, being more than twenty times the size of the true brain. The "sacral brain" measures in length 1.14 cm., in width 0.95 cm., and displaces 1200 cc. of water.

Professor Lull writes thus of the Armament of this reptile:

> "The exoskeleton of **Stegosaurus** included five types of structure, of which the first consists of small rounded ossicles found in one instance in position beneath the throat. The known armor of the back consisted of four distinct forms of plates in each of which the dorso-ventral diameter is enor-

mously developed, and often the antero-posterior one as well, instead of a normal horizontal expanse, the result being the production of huge upstanding plates arranged in pairs on either side of the median line of the neck, trunk, and proximal part of the tail, while immense bony spines, possibly varying in numbers with the different species, were borne on the distal end of the latter. The plates are differentiated in that those borne upon the neck are short in fore and aft diameter but with

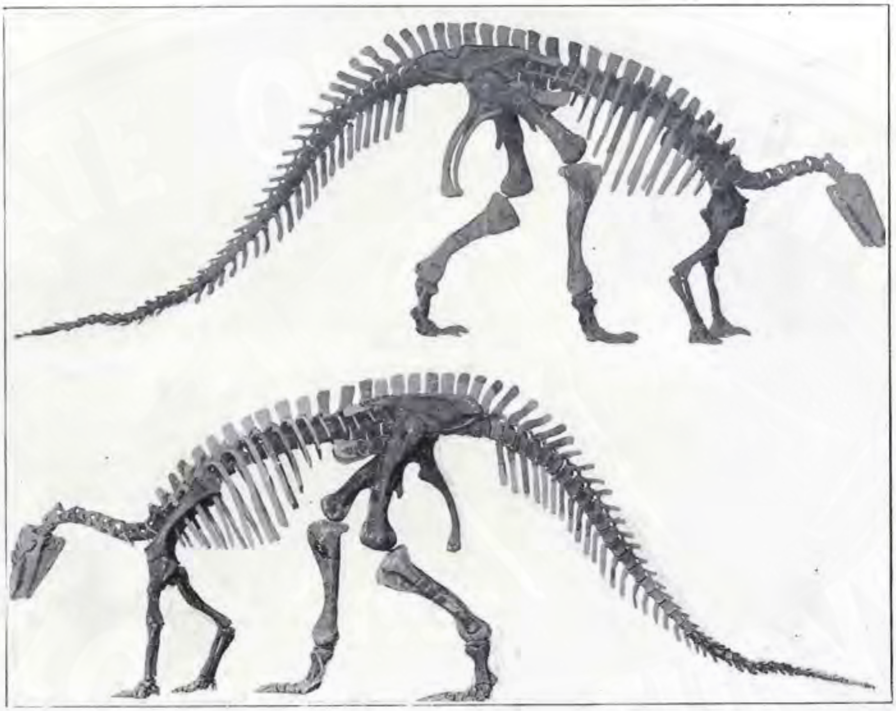


FIGURE 24.

Two sides of a predentate dinosaur skeleton, mounted in the U. S. National Museum. Similar to the stegosaurus but without armor.—After Gilmore.

a heavy base divided longitudinally by a depression which was borne astride the transverse processes and cervical ribs. The trunk plates increase rapidly in dimensions to a maximum size of 71×66 cm. (=28×26 inches) and a weight of 40 pounds for the pair borne over the pelvis. Here the base was thick and rugose but without the longitudinal cleft. These plates were borne above the transverse processes and the proximal portion of the ribs until the sacrum was approached with its widely expanded neural spines to which the weight was transferred, the two rows of plates approaching each other more nearly than in the more anterior region.

"This same type of plate, though with a base somewhat

FIGURE 25.—RESTORATION OF THE PALAEOSCINCUS, A CANADIAN DINOSAUR.
A huge and slow-moving reptile with massive armor, designed for protection against the gigantic carnivorous dinosaurs. Restoration by E. M. Fulda, 1921.—After Matthew.

shortened and at the same time much broader, was borne over similar neural spines on the anterior third of the tail. Here the character of the nueral spines abruptly changes, the broadened summits being lost and the whole spine very much reduced in height. This point, which marks the beginning of the aggressive, flexible portion of the tail, marks also an abrupt

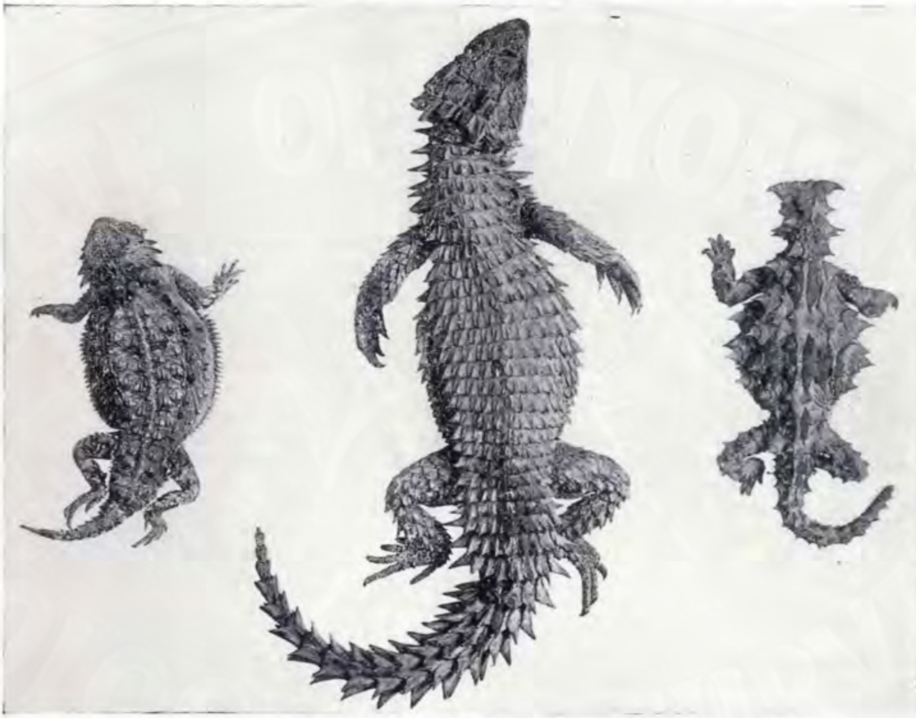


FIGURE 26.

Three modern lizards which, save in their diminutive size, are suggestive of the Palaeoscinus of the Cretaceous Period. The "horned toad" to the left is nearest in proportions. The "spiny lizard" in the center and the "Moloch lizard" to the right also have some points of resemblance. The figures are about two-thirds natural size. Were the little modern lizards as large as a hippopotamus, they would be monsters almost as strange as the long-extinct armored dinosaurs.—After Matthew.

change in the character of the plates, which are now sharp-edged, pointed and bent backward, the base being embedded in the muscles between the neural spines and the vertebral centra. The sharp-edged plates, of which there are three pairs, are followed by four pairs of long spines similarly attached and pointing outward and backward at a decided angle. The longest of these is 25 inches and its present weight 14¼ lbs."

The life conditions and relationships of that most bizarre dinosaurian reptile, **Stegosaurus**, are thus discussed by Lull:

"The genus **Stegosaurus** is confined exclusively to the Morrison formation, upper Jurassic or lower Cretaceous of Wyoming. . . . The character of the environment was probably similar to the conception offered by Hatcher, who believed that the Morrison beds were deposited 'over a comparatively low and level plain which was occupied by an interlacing system of river channels. The climate was warm, and the region was overspread by luxuriant forests and broad savannas . . . conditions doubtless similar to those now found about the mouth of the Amazon and over some of the more elevated plains of western Brazil.' In spite of the numerous remains of plant-feeding animals, the actual relics of fossil plants are relatively few, nor does the sediment in which these remains are found give other evidence of abundant vegetation. Hatcher's inference of 'luxuriant forests' is, therefore, as yet unproved by direct evidence.

"The water areas, as has been shown, were doubtless the dwelling places of the huge contemporaneous Sauropods, while **Stegosaurus** was terrestrial and possibly frequented the forests in search of the tender but luxuriant vegetation upon which it browsed. It may well be that the extreme relative narrowness was an adaptation to forest conditions and afforded ease of passage between the trunks of the tree ferns, conifers, and other vegetation of that day. **Stegosaurus** is rarely found entombed with sauropod dinosaurs, but, on the contrary, is often found isolated or in company with the bipedal unarmored herbivorous **Camptosaurus,** the nearest equivalent of the European **Iguanodon,** and with the fleet **Dryosaurus;** and of carnivores, the agile **Coelurus** and the blood-thirsty **Allosaurus,** which was probably its greatest enemy.

"I imagine much of the bizarre character of the armor of **Stegosaurus** was due to the over-specialization accompanying racial old age, but it was nevertheless in many respects admirably adapted to meet on a more or less equal footing the huge well-armed carnivore last mentioned. It would seem as though **Stegosaurus,** instead of presenting his front to the enemy, turned the rear, possibly crouching low in front as the crocodile does, and, with vigorous sweeps of the terrific tail, impaled the exposed ventral portion of the bipedal carnivore upon the caudal spines and sharp-edged plates.

"The long hind limbs imply a rather rapid progression, while the powerful fore limbs were not only for locomotor purposes but for rapidly pivoting the body to prevent either a frontal or flank attack.

"Of the evolutionary history of **Stegosaurus,** we know but little. It seems, however, to have been a migrant from Europe, having its nearest relative in **Omosaurus,** remains of which are known as far back as the Dogger of England.

"In **Omosaurus durobrivensis** from the Oxfordian of England, which I studied this summer in Cambridge and in the British Museum of Natural History, I find what may readily be a direct ancestor of the American types. The plates and

FIGURE 27.

Protected by thick plates and massive spines, this great armored dinosaur, the top view of which is shown in the picture, must have been a veritable super-dreadnaught of the animal world. Observe the rows of large plates in the neck region and fore part of the trunk.—After Matthew.

spines are present, and, in every respect, the older animal differs only in being of a more generalized character. On the other hand, **O. armatus** of Owen, from the Kimmeridgian, though nearer **Stegosaurus** in time, is less like it than is its predecessor in the rocks. **O. armatus** would seem, therefore, to belong to a different phylum, in many respects more conservative than the true stegosaurs.

"That **Stegosaurs** belonged to the predentate dinosaurs and to the armored Stegosauria, is certain. It is not, however, in the direct line of descent, but rather an over-specialized side branch, which was apparently totally blotted out after Morrison time, despite the fact that most of its associates, except the Sauropoda, lived on.

"The spinescent character of **Stegosaurus** is of course indicative of racial senility, but the modernizing of the flora and the restriction, doubtless, of the special food plant to which the feeble mouth armament was adapted, may have been the immediate cause of extinction."

CHAPTER XVI

The Amphibious Dinosauria

The amphibious dinosaurs are known to paleontologists as members of the Sauropoda (Figure 4). These were the **giant** reptiles, tall of body and extremely long. They were the **largest** land animals which ever lived, being exceeded only in bulk by some of the modern whales. The sauropod dinosaurs were all four-legged, with the hind legs usually the larger, but one genus, called by Riggs the **Brachiosaurus,** had longer fore limbs. The head was very small (Figure 30), with blunt teeth. The neck was long and slender, with an elephantine body and a long tail, which in one genus, **Diplo**docus, stretched out into an almost unbelievable slender length, justifying the term "whip-tail" dinosaur (Figure 31). We believe the body to have been covered by a coarse, rough, but not scaly hide, of great thickness. Like the elephants they had five short toes on each foot, probably buried in life in a large soft pad, but the inner toes had large claws, blunt like those of modern turtles, one in the fore foot, three in the hind .oot.

Sauropod dinosaurs had a world-wide distribution, but in spite of this their appearance is geologically abrupt. We assume that they were derived from some of the carnivorous dinosaurs, because the theropods, as the carnivores are called, were predecessors of the sauropods. The sauropods had a short existence, geologically, being confined to the closing portions of the Jurassic and the Lower Cretaceous, in a period called the Comanchean. Many carnivorous, armored, and beaked dinosaurs lived at the same time with the sauropods, and are found in the same strata of rocks.

Skeletons of various amphibious dinosaurs are mounted in a number of the larger natural history museums. One of the largest skeletons mounted in the American Museum of Natural History in New York City was discovered near Medicine Bow, Wyoming. It is sixty-six feet long and when alive some paleontologists think the animal may have weighed about thirty-eight tons. It is seldom the case that such huge bodies were buried and fossilized and collected in a perfect condition, so that mounted skeletons are usually a combination of two or more individuals, and even then some of the mounted bones are made of plaster. The task of discovering, collecting, cleaning and mounting a huge dinosaur skeleton is one of great difficulty, and may extend over a period of several years. The bones are so fragile that in order to keep them from breaking of their own weight, which in their fossilized state is considerable, special supports and braces must be used.

FIGURE 28.

Bone Cabin Quarry, Wyoming, with camp in background. In the group of workers are Messrs. Lull, Granger, Schneider, and Kaisen.—After Matthew.

It was a matter of much thought and study to determine just what positions the huge bones of these amphibious reptiles assumed in life. They are so entirely unlike other creatures that no one was sure whether the sauropods sprawled as do the crocodiles, or walked uprightly like the elephants do. As far as the backbones and ribs were concerned there was little doubt, because the articulating surfaces were well worn and clearly marked. The huge limb-bones, however, offered only roughened areas, as if the articulations had been cartilaginous. A comparative study of muscles, muscle attachments and limb attitudes among many of the recent reptiles was made, and these conditions compared and applied to the dinosaurs. The results were that an upright, quadrupedal attitude was assigned to the sauropods, and this position has now been generally adopted.

The bodily proportions and general appearance of the large sauropodous dinosaurs was totally unlike anything previously known. It had a long, thick tail like the lizards and crocodiles, a long, flexible neck like an ostrich, a thick, short, slab-sided, bony body, and straight, massive, post-like limbs suggesting the elephant, and a remarkably small head for the size of the body. The head was about the size of that of a horse, with slender ineffective teeth, which must secure food in enough

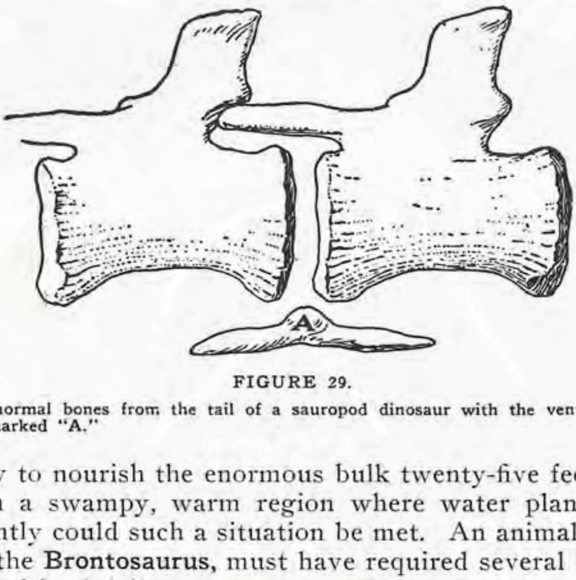


FIGURE 29.

Two normal bones from the tail of a sauropod dinosaur with the ventral arch or chevron, marked "A."

quantity to nourish the enormous bulk twenty-five feet away. Only in a swampy, warm region where water plants grew abundantly could such a situation be met. An animal of such size as the **Brontosaurus**, must have required several hundred pounds of food daily.

Although the limb bones were very heavy, as were the ribs yet the backbone was so hollowed out that it was comparatively light. We may suppose that the heavy limbs acted as weights to hold the reptiles on the bottom of shallow water, where the creatures could feed, and reach air at the surface by using its long flexible neck. If the animal needed to take an extended view of the landscape it was possible for it to rear up on its strong hind legs, and using its tail as a prop, derive benefit from his fifty foot high observation point. The heavy limbs, acting as weights, would anchor the creature more or less securely for such acts.

The brain was comparatively very small, considering the size of the reptile. A cast of the brain case, small though it is, was still larger than the actual brain. We can hardly speak

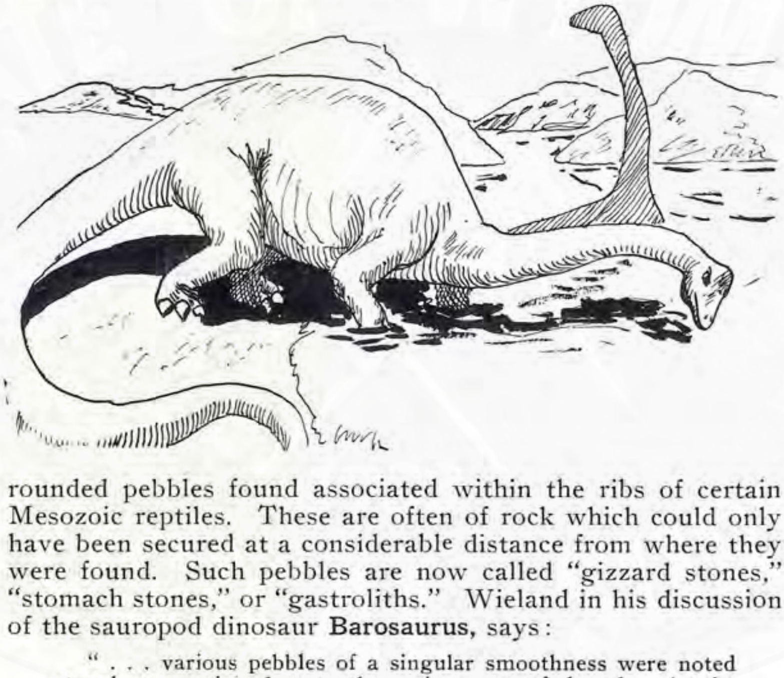
FIGURE 30.

Restored outline of an amphitious dinosaur to show, in black, the relative proportions of the central nervous system—the brain and spinal cord, with the sacral intumesence.

of intelligence in an animal so inadequately equipped with nervous material. The brain, so called out of courtesy to its location in the head, doubtless functioned merely as a mass of reflex centers. Its huge unwieldy size, its gigantic food requirements and its inadequate food-getting mechanisms were undoubtedly critical factors in the extinction of this type of the dinosaurs, which did not survive beyond the Lower Cretaceous.

Wyoming localities furnishing parts of the **Brontosaurus** skeleton mounted in the American Museum, are Nine Mile Crossing of the Little Medicine Bow River, Como Bluffs, and the Bone Cabin Quarry. Another dinosaur of this group reaching a length of 87 feet, was also found in Wyoming.

A number of writers, notably Williston, Wieland, and Brown, have discussed the significance of certain smooth,



rounded pebbles found associated within the ribs of certain Mesozoic reptiles. These are often of rock which could only have been secured at a considerable distance from where they were found. Such pebbles are now called "gizzard stones," "stomach stones," or "gastroliths." Wieland in his discussion of the sauropod dinosaur **Barosaurus,** says:

> " . . . various pebbles of a singular smoothness were noted at only one point close to the main group of dorsals. As the specimen was incomplete the reasonable explanation that these were stomach stones, or as later called, dinosaurian gastroliths, did not then occur to me, their true character being first recognized in examples from the Big Horn mountains."

It is well known today how certain birds and reptiles swallow stones to aid in digestion. I noted a similar habit among the horned toads which feeding on ants had added various quartz pebbles to its stomach contents. So far the amphibious dinosaurs are the only ones known to have had this habit.

CHAPTER XVII

The Carnivorous Dinosauria and Their Food Problem

The flesh-eating dinosaurs all possess sharp, flattened, saw-toothed, cutting teeth and sharp claws on all four feet. The fore-limbs are always small, incapable of functioning in locomotion, so that the theropod dinosaurs were bipedal, walking or leaping with their powerful hind legs, using the heavy tail as a support, just like modern kangaroos. This group of dinosaurs has had the longest history of any of the dinosaurian groups, and they have a wide range in size—some being quite small and slender, others large and powerful. The Theropoda are the stem group of the Dinosauria.

The largest and most powerful of the many kinds of carnivorous dinosaurs is that elephantine giant **Tyrannosaurus rex,** whose skull is over four feet long (50 inches), and the jaw has a height of 35 inches. The teeth are flattened, sharp and numerous. Its body was more than forty feet long and doubtless had a weight of many tons. It was the most powerful engine of destruction in the animal world. Five skulls and complete skeletal material are preserved in the American Museum of Natural History. One of the skulls was secured in the Upper Cretaceous of Niobrara County, Wyoming, and the other material from the Hell Creek Beds of Montana (Upper Cretaceous).

The theropodous dinosaurs were the makers of the abundant three-toed footprints (Figure 17a) which are found in the Triassic of the Connecticut Valley. These dinosaurs ran nimbly about like birds, setting one foot nearly in front of the other, so that the prints of the right and left feet are nearly in a straight line.

Another well-known carnivorous dinosaur from Wyoming is that form called **Allosaurus,** with a hind limb taller than a man, measuring over thirty-four feet long and with a height of over eight feet. This skeleton, shown mounted in the American Museum, feeding on an amphibious dinosaur, has an interesting history. It is a Wyoming treasure, collected in October, 1879 in the Como Bluffs near Medicine Bow at the richest locality for dinosaurs, by Mr. F. F. Hubbell, working for Professor E. D. Cope of Philadelphia. The skeleton was never unpacked by Cope and it lay in its original packing cases for twenty years, until after the acquisition by the

FIGURE 32.—THIS FORMIDABLE DINOSAUR, THE LARGEST OF THE CARNIVOROUS FORMS, WAS SOME 40 FEET IN LENGTH.

It must have presented a most imposing sight as it stalked about in search of food. The great 5-foot jaws were armed with long and sharp teeth, capable of tearing the tough skins of such antagonists as the great Triceratops of the same period. This latter creature could not escape by running away, and so was forced, no doubt, to back into some dense forest growth whenever possible, presenting merely its sharp-horned head to its adversary.—After Brown, National Geographic Magazine.

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American Museum of the entire Cope collection. A few years later when the specimen was finally unpacked in New York it was found to be an exceptionally fine treasure—a paleontological gem, for complete skeletons of fossil vertebrates are quite rare.

Carnivorous dinosaurs are always rare—much more so than those of the amphibious type, occurring in the same beds. A **Brontosaurus** skeleton, obtained in the Bone Cabin Quarry, shows several bones, especially the spines of the tail bones (Figure 34), scored and bitten off, as though by some carni-

FIGURE 33.—A LARGE CARNIVOROUS DINOSAUR FEEDING.
—After Lucas.

vorous animal which had either attacked the brontosaur when alive, or had feasted on the carcass. When the **Allosaurus** jaw was compared with the marks on the brontosaur bones, it was found to fit them exactly, the spacing of the scratches being the same as the spacing of the teeth. Moreover, on taking out the brontosaur backbones from the quarry, a number

FIGURE 34.

Part of the tail of a large amphibious dinosaur, Brontosaurus, showing grooves and scratches cut by the teeth of carnivorous dinosaurs on the neural spines and on the body of the backbone joint in the center. The cuts were made after the death of the amphibious dinosaur. Specimens in the American Museum of Natural History. Collected in Wyoming.—After Osborn.

FIGURE 15.

Microscopic study of a portion of the periphery of the large tumor from the tail of a dinosaur, showing the osseous lacunae, with small canaliculi, arranged around a large vascular opening, thus simulating an Haversian system... The lacunae (bone cells) of the dinosaurs are actually much smaller than other animals. Magnified 300 diameters.

CHAPTER XI

Structure of the Bones of Dinosaurs

A single bone of one of the huge sauropod Dinosaurs may show a weight of nearly 1,000 pounds, and a length of nine feet, as they are recovered from the rocks in a highly petrified condition. On the basis of this enormous weight of a single bone it has been stated that the living dinosaur must have had a weight of from 40 to 50 tons, which is far indeed from being the case. When we examine the internal structure of a huge dinosaur thigh bone great open spaces are found, and under the microscope we find a great abundance of spaces, so the bone was quite light. Instead of being an "earth-quaking thunder lizard" with a weight of half a hundred tons it seems quite probable that the largest of them weighed only about 15 tons, and hardly ever came on land at all. It has been argued that they **must** have come on land to lay their eggs; but we do not know that the amphibious dinosaurs laid eggs. They may have given birth to living young.

Many of the more ancient and all of the carnivorous dinosaurs had hollow limb bones, which rendered them less heavy and at the same time very strong. Some of the smaller dinosaurs were so light-boned as to suggest an arboreal, or tree-living life.

Under the microscope dinosaur bone looks very much like the bone of any other reptile (see figures 15, 16, 17). The spaces occupied by the bone cells, lacunae, are quite similar in shape to the lacunae of other vertebrates, though they are somewhat smaller. Arising from the spindle-shaped bone-cells, are slender tubules, called canaliculi, which carried nourishment to the intervening bony substance, or osteoid substance. The presence of abundant osteoid material is characteristic of all of the lower animals below the mammals.

Vascular spaces are exceedingly abundant in dinosaur bones and must have increased the lightness of the skeleton considerably. Such spaces are of various sizes, ranging from those of microscopic dimensions up to huge spaces. At times the arrangement of the bony elements suggests an Haversian system which is so characteristic of the bones of mammals.

No articular caps, or epiphyses, are present in dinosaur bones, so that growth in length and size continued through-

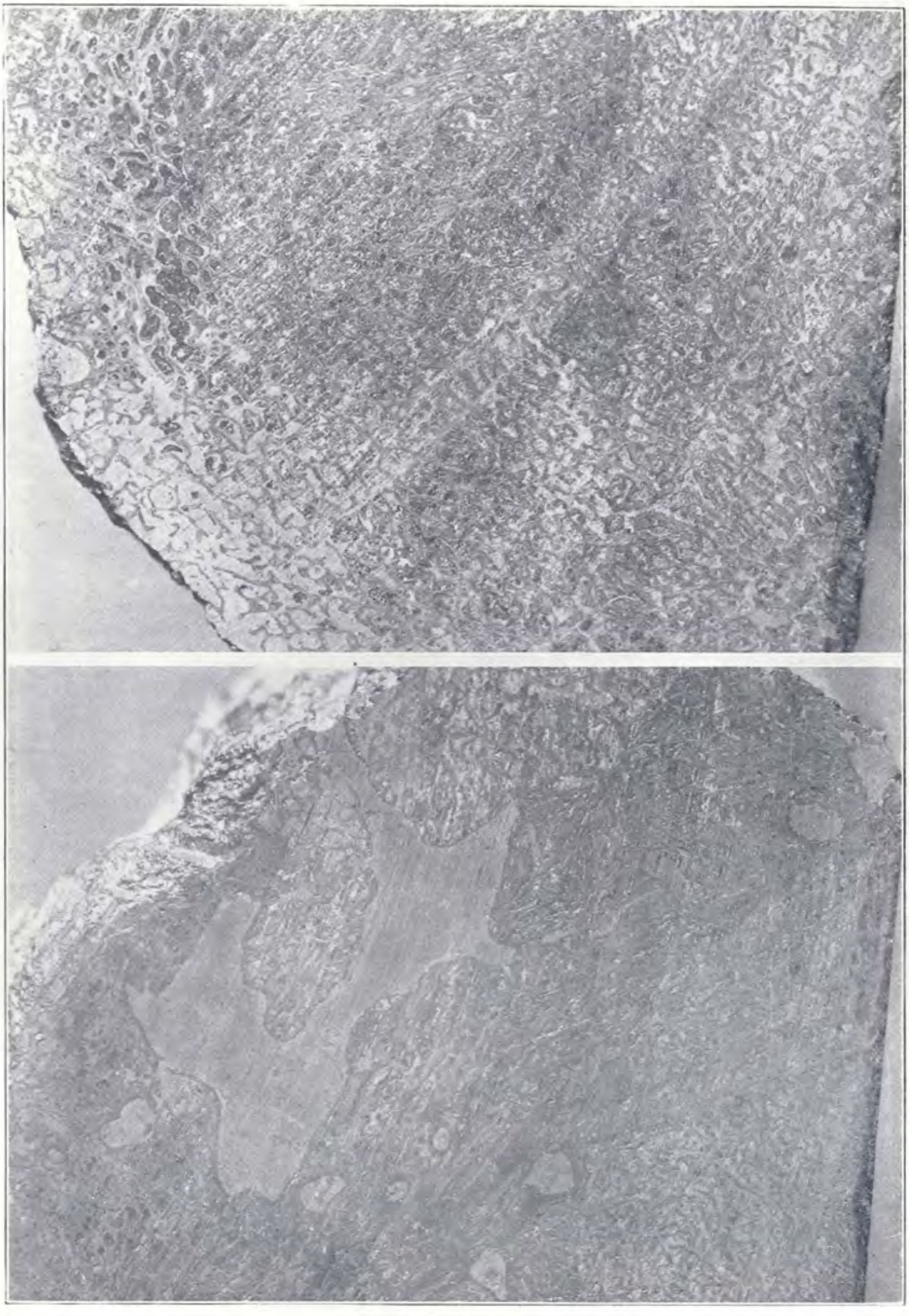

FIGURE 16.

Photographs, slightly enlarged, of vascular spaces seen in the cut surfaces of a dinosaur tumor.

out life. A large-boned dinosaur then is an old one, and the age may have been hundreds of years. They had no enemies of their size, food was abundant and life easy. An age of 1,000 years is not improbable for one of the amphibious dinosaurs. The ends of all dinosaur bones are rough, suggesting the presence of an articular pad of cartilage, from which the end of the bone was nourished.

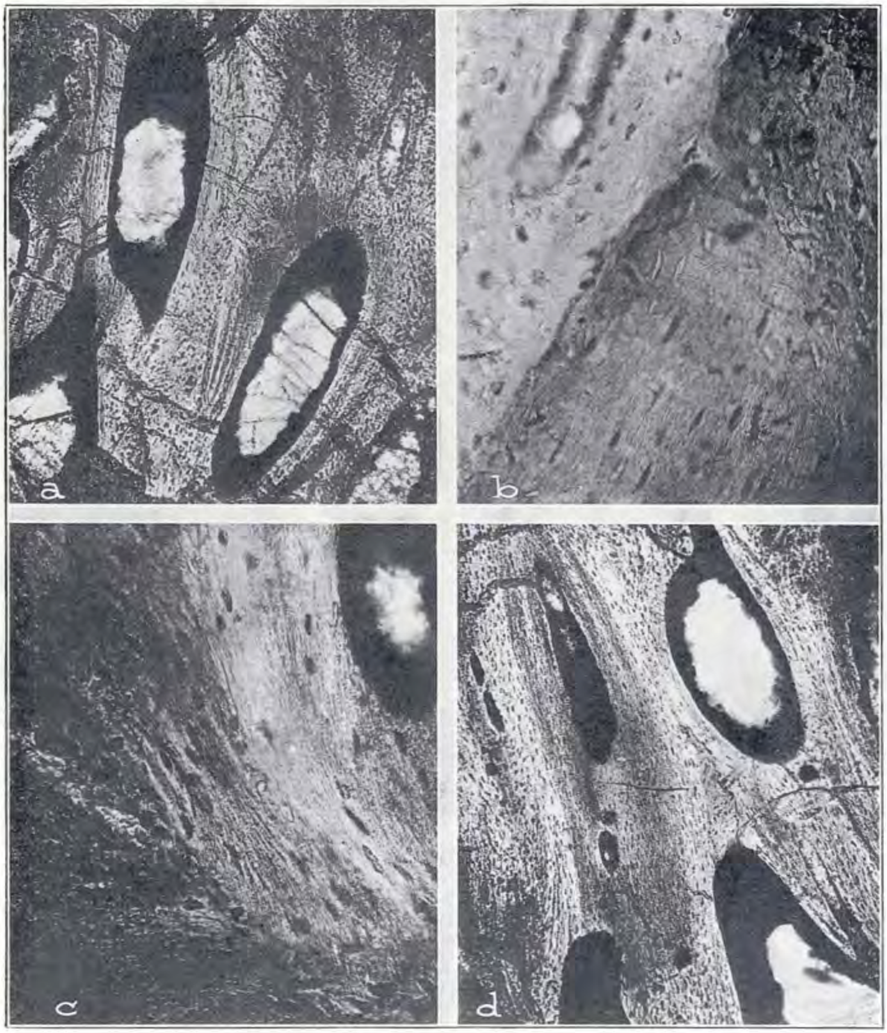

FIGURE 17.

Photomicrographs of normal and pathological dinosaur bone showing vascular spaces and structure of the bone. Magnified.

CHAPTER XII

The "Sacral Brain" of Dinosaurs

The unusual enlargement of the spinal canal in the dinosaurs has long been known and commented upon by various authors, and many attempts have been made to explain the presence, in the sacral region, of a mass of nerve material often many times larger than the brain. It must be remembered, however, that there was a large space around this "sacral brain" and a cast of the cavity in the sacrum is probably twice the size of the actual enlargement in the spinal cord.

The best discussion of this "sacral brain" is that given by Professor R. S. Lull, Professor of Vertebrate Paleontology at Yale University, and I am quoting extensively from his article, "On the Functions of the 'Sacral Brain' in Dinosaurs." The complete reference will be found in the bibliography.

> "Branca, in a discussion of the fauna of Tendaguru, East Africa, makes a number of thought-inspiring comments upon the huge sauropod dinosaurs which the formation contains. Among other points he is striving to account for the maintenance of their immense bulk upon a possibly meagre diet by assuming digestive powers of extraordinary efficiency. For this he offers the following explanation:
>
> "One may be inclined to look for the ability to take care of food solely in the stomach, intestines, or liver. However, in the dinosaurs we may take into consideration something else, i. e., the 'sacral brain,' if we look upon the swelling of the spinal column in the sacrum as a 'brain.' According to Waldeyer, it is indeed thinkable that the sacral brain in dinosaurs had a certain independence, and cared for the functions of **nourishment, digestion,** and procreation [bold type mine], also that through a particularly strong innervation it had become especially powerful, more powerful than the strongest digestive organs could be without such a sacral brain. In man there appear still to be traces of this, but here the sacral section of the spinal column is completely surpassed by the brain.
>
> **Dinosaurian Feeding Habits**
>
> "Our assumption of feeding habits based upon the character of dinosaurian dentition justifies the following conclusions:
>
> "**Theropoda**—These are the carnivorous dinosaurs in a strict sense, with teeth which were in the main prehensile and as such confined to the forward portion of the jaws. They must have been used for rending the prey, for in many instances they are sharp-pointed and compressed, with finely serrated

cutting edges. In **Tyrannosaurus** they become so thick that the knife-like edge is gone, so that these huge beasts must have dismembered their prey by tearing rather than by cutting it. These latter theropods are analogous to the crocodiles in dental equipment; **Allosaurus,** on the other hand, possessed a more efficient dentition.

"The digestive system of the crocodile shows the highest degree of specialization of any living reptiles, as the stomach is very muscular, with lateral tendinous discs forming an organ very suggestive of the gizzard of the graminivorous birds. In front of this gizzard-like stomach is a capacious portion of the oesophagus, within which is held the excess of food over the rather small capacity of the stomach. The stomach digestion is highly efficient, due not alone to its muscular power, but to the strength of the gastric juice, so that even the bones of the prey are dissolved and not passed through the intestine, as with certain carnivorous birds like the owls. Crocodiles occasionally swallow stones to aid in the trituration of their food, just as do the graminivorous birds.

"To what extent the gizzard was developed in the Theropoda is conjectural, but it would seem as though its need were nearly as great with them as with the crocodiles. One aberrant type of theropod, from the Belly River formation of Canada, has just been the subject of an authoritative paper by Professor Osborn. This form is now known to have been absolutely toothless, and several theories have been advanced as to its feeding habits—that it was insectivorous, especially ant-eating, or that it fed on small crustaceans or molluscs of the seashore, or that it was ostrich-like in habits, browsing upon leaves and buds which its prehensile limbs drew within the reach of the horn-sheathed mouth. Such an assumption as the last, which bears the weight of Osborn's own opinion, would seem to imply the presence of a more or less efficient gizzard-like stomach functionally comparable to that of the struthious birds.

"**Sauropoda**—The sauropods are clearly of theropod derivation, but it has been pretty generally assumed that they had forsaken the carnivorous habits of their forebears for a vegetative diet, and the tremendous growth of certain plants such as the water hyacinth in the Nile or the waters of New Zealand seems to offer an analogy to what might well have been true of certain aquatic vegetation of the Mesozoic upon which these creatures fed. The teeth were now solely prehensile, sufficiently so for their owners' purpose, but less efficient than those of the Theropoda. The food was in no sense masticated and the inference that a powerful muscular gizzard-like stomach was developed is irresistible, for which the presence of stomach stones, gastroliths, within the ribs of more than one specimen may be taken as added argument.

"**Predentates**--The predentate dinosaurs, on the other hand, had a differentiated mouth armament. The anterior or prehensile portion was toothless, but was sheathed with a horny, turtle-like, cropping beak of varying form. The posterior portion of the jaws bore the actual dental battery, consisting of a series of successional teeth which also varied in efficiency and degree of development in accordance with their owners' food, as do those of the ungulate mammals. The Jurassic and early Co-

better methods prevailed and collecting dinosaurs was becoming a highly technical undertaking.

Collecting a dinosaur involves first a geological knowledge of the field, and something of the osteology of the various kinds of dinosaurs. Walking along the base of promising

FIGURE 5.—The skeleton of a crested dinosaur exposed in Cretaceous rocks in Canada under the direction of Barnum Brown. This very unusual find, a skeleton over thirty feet long, shows the skin still preserved on the under side. This "duck-bill" dinosaur had a skull surmounted by a high curved crest. Only the tip of the tail was exposed on the surface, thus furnishing a clew to the whole animal. Excavation here was not excessive, but hard work just the same since it all had to be done with pick and shovel.
—After Brown, National Geographic Magazine.

slopes, or in gullies, the collector finds, mingled with broken rock and other "talus" interesting fragments of dinosaur bones. This is a "lead," and by following it up the bank may result in the discovery of other bones still embedded in the cliff, or it may be that the entire specimen has washed out and nothing is left. If there are bones still "in place" it is important to find out what part of the body it is and what kind of a dinosaur the bones represent, and how extensive the area to be involved in the excavation. Subsequent procedure depends upon the circumstances in the immediate vicinity.

If the deposit seems large and promising, after exploration and prospecting with a hand pick, then teams with scrapers may be employed to remove the overlying material, down to within a couple of feet of the specimens. The remainder of the work is by hand. The removal of the encasing rock down to the bones must be carefully done, so as not to injure the bones, leaving enough matrix to support the fossilized skeleton. After all parts are exposed the petrified, and excessively fragile skeletal parts must be "blocked" out for encasing with strips of burlap, dipped in plaster or flour paste, stretched tight and supported by strips of wood. When dry this makes an unyielding case for each section. Then the blocks are underchanneled and turned for trimming and encasing the other surface with plastered burlap strips. Then a firm casing is made of boards and timber, often hauled a hundred miles to the nearest railroad, sufficiently strong to bear the parts, at times weighing thousands of pounds. Such handling in the quarry requires skill and mechanical appliances hardly to be thought of in other kinds of fossil collecting.

After the shipment has reached the museum the mistakes of the collectors become apparent as the encasing materials are removed. Some part, not sufficiently well supported, has been badly broken in transit. Some surfaces were not properly protected by thin paper or shellac. All mistakes and readjustments are noted for correction during succeeding collecting seasons.

The work on a large dinosaur skeleton at the museum is long and tedious, requiring months and years for completion. The removal of the encrusting matrix is laborious and requires the employment of special tools, such as compressed air drills. Repairs and restorations of broken and lost parts must be scientifically accurate. The work in the laboratory must at all times be checked by those whose scientific training has given them knowledge.

The supreme purpose, the end and aim of all collecting and preparation procedures, is the final mounting of the skeleton in such a manner as to reveal the nature of the animal, and thus furnish a check on all scientific discussions. Mounting cannot be properly done without adequate conception of the nature and relationships of each part. This is shown in the eager discussions about the "pose of the sauropod dinosaurs," a few years ago, resulting in our present day conceptions of the attitude of the dinosaurs as shown in the restorations pictured in this book. Knowledge is acquired by trying. This applies to mounting dinosaur skeletons as well as other things.

The experiences of a noted collector in his work on one dinosaur skeleton in the Black Hills, to the east and north of Wyoming, will bring this matter vividly before the reader.* G. R. Wieland, for many years at Yale University, has long had a three-fold interest in fossils—the cycads, giant turtles and dinosaurs, and he has a wide fame in all three. His story follows:

> " . . . in the latter part of August, 1898, I began the excavation for **Barosaurus.** This I carried out alone. The quarry was extended to a sixty foot front, and ran some thirty feet back to a depth of ten feet. The first material secured was fragmentary and seemed to run out following a group of good caudals. Then a well-conserved portion of a proximal caudal was uncovered; but on interrupting the work for further prospecting for the cycads and dinosaurs, the centrum was found cut off by an ugly shear. Nearly decided that the lead had come to an end, on working down to a two-foot lower level, various dorsals, a few chevrons, rib fragments, and a sternal plate, promised a rather featureless aggregate. Much checking with extreme lightness of the vertebral structure made it necessary to hold all parts in place as uncovered. This slow task lasted into the late fall, when cold and dust storms made excavation difficult.
>
> "Finally, in the course of working forward, there came four cervicals running up to one with a centrum three feet long, at once recognized as unparalleled in the Dinosauria; though much more robust types as long are now known. It then appeared that the main group of skeletal elements, although much displaced, or only partly conserved, represented a single individual; but unluckily the long cervicals led out to a gullied surface. All possibility of further recovery was at an end. Yet the result seemed a real triumph, over which Marsh was quite elated; he held in hand novel Dinosaurian material new from the field."

Wieland further notes with this skeleton "various pebbles of a singular smoothness" at a point near the dorsals, which later were called "dinosaurian gastroliths," or stomach stones used in crushing food in the dinosaur stomach.

* Wieland, G. R. 1920. The longneck sauropod Barosaurus. Science, n. s., LI.: 528-530.

CHAPTER VI

Some Famous Collectors and Collections of Dinosaurs

Most of the men who collected dinosaurs in Wyoming made themselves famous by their published studies of fossil vertebrates, and by teaching or developing museums. Most of the collections are now in eastern museums, a few abroad, and a good collection in the University of Wyoming.

The first evidences of dinosaurian reptiles were the footprints, discussed elsewhere, after 1818. The first dinosaur was made known in 1824, so we may say that the study of dinosaurs covers a century. Wyoming dinosaurs did not come to the front, however, until much later, during the late seventies, since which time the deposits have been explored again and again. Dinosaurs will always be found in Wyoming.

To name the men who have collected dinosaurs in Wyoming would be to list most of the vertebrate paleontologists of America, and we shall cover the subject briefly. The rivalry and bitterness associated with the early Wyoming discoveries we shall neglect. It is past history, and not interesting.

The early students of dinosaurs were Leidy, Cope and Marsh. Leidy studied dinosaurs from eastern states. Cope was interested in all lines of vertebrate fossils, but his work did not have a great deal to do with the dinosaurs of Wyoming.- Marsh and the many men who worked with him, developed the field of Wyoming dinosaurs in a large way, and his collections today at Yale University and at the United States National Museum, still remain important, although the lead has long been with the American Museum of Natural History.

Professor O. C. Marsh of Yale University, at his own expense, and later with aid from the United States Geological Survey, sent parties into the states about Wyoming from 1870 on, as opportunity and discoveries were available. Many men of high intellectual ability worked with and for Marsh in the field and in the museum, where was laid a broad foundation for a knowledge of American dinosaurs. Especially in connection with the United States Geological Survey, he established a number of beautifully illustrated memoirs on the various groups of dinosaurs. His general discussion of dinosaurs, published in 1896, was the only volume he lived to see published. His projected treatise on the three-horned dinosaurians, was completed after his death by Hatcher and Lull. His work on the armored dinosaurs has been completed by Gilmore and Osborn has the memoir on the Sauropoda (amphibious dinosaurs) under preparation.

The noted men who worked for and with Marsh became teachers of ability, and investigators in branches of vertebrate paleontology other than dinosaurs. Especially to be noted, among the early workers, was S. W. Williston, who had received training under Professor Benjamin F. Mudge, who had collected for Marsh, footprints from the Coal Measures of Kansas, and some fossils from the Niobrara Cretaceous chalk. Mudge at that time was a teacher at the Kansas Agricultural College at Manhattan, and from him Williston learned the joy, and the disappointments, of fossil hunting. During the seven years Williston spent at Yale, where he took the M. D. and Ph. D. degrees, much time was spent in the employ of Professor Marsh. In this manner Williston was sent to work in the dinosaur quarry at Como Bluffs in 1877. One season he spent 10 months in the field. Merely collecting dinosaur bones, without the added stimulus of scientific discussion, did not appeal to Williston, who turned his attention to medicine, becoming in time, professor of anatomy at Yale. At the University of Kansas, from 1890 to 1902, he made field trips to Wyoming, secured a skull of a three-horned dinosaur, limb bones, and backbones enough for exhibition and teaching.

G. R. Wieland's work at Yale, beginning in 1898, has resulted in the publication of large quarto volumes on Cycads, and numbers of papers on dinosaurs and Cretaceous turtles.

George Baur, a noted morphologist, worked in Paleontology at Yale, ultimately going to the University of Chicago as Professor of Vertebrate Paleontology, whose successor in 1902 was S. W. Williston.

The greatest collector of fossil vertebrates, who worked for Marsh at Yale University, was John Bell Hatcher, who died at the early age of 43. During the twenty years he spent collecting fossil vertebrates he shipped more than 1500 boxes of material to Yale, to the United States National Museum and to the Carnegie Museum. From 1884 to 1892 he shipped 900 boxes of fossil vertebrates to Yale Museum; one of them weighing more than three tons, having the dimensions of ten feet by five feet by six feet. This contained a very large skull of a three-horned dinosaur. He had found his first three-horned skull in 1889 near Lusk, Wyoming, and by 1892 he had collected 50 ceratopsian dinosaurs, 33 of them with skulls.

FIGURE 6.—FOUR DISTINGUISHED PALEONTOLOGISTS

UPPER LEFT: Sir Richard Owen, a noted English anatomist and paleontologist, 1804-1892. A famous writer in many fields, his work on the dinosaurian reptiles is of the greatest value. He proposed the term Dinosauria.

UPPER RIGHT: Professor Othniel Charles Marsh, an American paleontologist, 1831-1897. Professor of Paleontology at Yale University for many years, where in Peabody Museum are stored the vast collections of dinosaurs assembled from the Wyoming fossil beds, and elsewhere, under his supervision.

LOWER LEFT: John Bell Hatcher, American Paleontologist, 1861-1904. He collected, during twenty years, more fossil vertebrates than any other single individual. Much of his work was in Wyoming, where among other materials he collected over 50 three-horned dinosaurs, 33 of them with skulls.

LOWER RIGHT: Professor Samuel Wendell Williston, American anatomist, paleontologist and dipterologist, 1852-1918. A famous collector and student of fossil vertebrates, he worked in Wyoming, during intervals, between 1877 and 1910. Dinosaurs, plesiosaurs, and Triassic vertebrates from the Wyoming fossil fields were well known to him. His latter years were spent in the Permian Red Beds of Texas and New Mexico, from which he studied a large fauna.

The hugest of these had to be lifted fifty feet out of a vertical ravine, and hauled 40 miles to the railroad over a trackless country and across unknown streams. Hatcher revolutionized the collecting of fossil vertebrates, introducing many new procedures. He was later assigned the task of completing the memoir on the Ceratopsia, which he did not live to complete. While not a highly educated man, Hatcher trained himself by observation and reading so that he was able to write a number of valuable scientific papers relating to stratigraphy and vertebrate paleontology. His work at Princeton was on the fossil mammals of Patagonia, and at the Carnegie Museum he assembled from Colorado and Wyoming important sauropod skeletons, at present mounted in the Museum.

Professor R. S. Lull, director of the Peabody Museum and Professor of Paleontology at Yale University, has enhanced the value of the dinosaur collections left by Marsh, by numerous scientific papers, memoirs and the completion of the monograph on Ceratopsia, as well as by further collecting. His revision of dinosaur footprints from the eastern Triassic is a monument of industry in a difficult field.

Professor E. D. Cope, of Philadelphia, sent expeditions into the west after 1869. One collector he employed, J. L. Wortman, rose to an independent position in science by his sagacity and application. Cope's large dinosaurs came in part from Colorado, as well as other states. His quarry at Garden Park, Colorado, was still open in 1907 when I visited it. All of Cope's collections were acquired through purchase by the American Museum of Natural History and the sauropod skeletons are being restudied.

Realizing the importance of the finds being made in Wyoming Professor Wilbur C. Knight conducted successful expeditions into the dinosaur fossil beds for the museum at the University of Wyoming. The aquatic reptiles, called plesiosaurs, attracted his attention and he described these in a short series of scientific papers.

The Field Museum of Natural History, at Chicago, possesses a good collection of sauropod dinosaurs, collected and prepared under the supervision of E. S. Riggs, whose teacher in paleontology was Williston at Kansas University. Riggs collected in Colorado and eastern Wyoming, making a noteworthy discovery of a dinosaur whose fore limbs were longer than the hind limbs: the upper arm bone measuring nearly seven feet in length. A partial skeleton of **Brontosaurus** is mounted in Field Museum.

The Carnegie Museum, at Pittsburgh, has a noteworthy collection of dinosaurian material, collected in part from Wyoming. The collectors for this museum were J. B. Hatcher, J. L. Wortman, Peterson and Earl Douglas. Papers by W. J. Holland and J. B. Hatcher describe much of the material there. It was here that casts of the long, slender sauropod dinosaur, **Diplodocus,** were made for presentation to royal museums abroad. One of their quarries was 13 miles north of the Bone Cabin quarry.

Amherst College has a noteworthy collection of dinosaur footprints from the Triassic, and the paleontological museum is being increased by collections made by Professor F. B. Loomis.

The United States National Museum has a splendid collection of dinosaurs, a part of which were acquired by Marsh, and added to by the present Curator of Vertebrate Paleontology, Charles W. Gilmore. His papers and memoirs are of the highest quality.

A collector of fossil vertebrates who made many notable discoveries of dinosaurs in Wyoming was Charles Sternberg, whose autobiography, "The Life of a Fossil Hunter," is one of America's biographical classics in paleontology. His son discovered in Wyoming the only dinosaur mummies known, acquired by the American Museum of Natural History. The "mummy" reveals the skin pattern over a large area. Sternberg's collections were purchased by many foreign museums. He collected a fine **Triceratops** skull from Wyoming for the British Museum (Natural History) at Kensington. Other museums abroad where paleontology has been developed and where dinosaurs may be seen, some of them from Wyoming, are at Stuttgart, Brussels in Belgium, Berlin, Tuebingen, Paris, and at other large cities.

The finest and most extensive collection of dinosaurs in the world has been left to the last. It represents the guiding genius of one man, Henry Fairfield Osborn, a man of the highest intellectual attainments. Dinosaurs from all over the world—from all continents where dinosaurs are known, are to be found in the American Museum of Natural History, where skeletons and restorations and exhibitions fill the only "Dinosaur Hall" ever built. It is not possible here to give a complete account of the development of this truly wonderful collection. Many men have shared with Osborn the development of the collections of dinosaurian remains, notably W. D. Matthew, Walter Granger, Barnum Brown, J. L. Wortman, and a large staff of research assistants and preparators.

A few localities in Wyoming have been extremely productive of dinosaurian skeletons, the most famous of which is the Bone Cabin Quarry in Albany County, south central

Wyoming, accidentally discovered by Granger in 1897. During the six years quarrying at this locality a car load of dinosaur bones was shipped to New York each year. From this one locality were secured the remains of 73 animals—all of them dinosaurs excepting four crocodiles and five turtles. This was one of the greatest fossil "finds" ever made.

The name "Bone Cabin" was adopted because a Mexican sheepherder had used the gigantic back bones as a foundation for his cabin. There were no surface rocks in the vicinity. At other places in Wyoming similar foundations were made of trunks of petrified trees and had been used to hold the claim or title to a plot of ground.

CHAPTER VII

Occurrence of Dinosaurs in the State of Wyoming

The geographical distribution of the known deposits of dinosaurs in Wyoming shows that these animal remains occurred in selected groups, instead of being scattered singly over wide areas. This is the general situation, but isolated specimens, either single bones or pieces of bones, or incomplete skeletons, are likewise found. A number of the larger deposits are indicated by the large stars in the map in figure 7. The areas in Wyoming are only a part of a greater area of subsidence, as explained by Mr. Brown. Doubtless there are many more large deposits awaiting the searcher after fossils. The quarries opened so far were discovered because erosion had uncovered bones to indicate the positions of buried skeletons.

The areas where dinosaur bones are now found doubtless represent favorable spots in the marshy lowlands which occupied the region after the withdrawal of the seas.

The map shown in figure 8 reveals the abundance of fossils in a given area, about which dinosaur bones are rare or wanting entirely.

Search for dinosaur bones which have been exposed by erosion should be made along the base of "talus slopes," in gullies, or in the cliffs themselves. A little practice will enable the observer to distinguish fragments of fossil bone from other broken detritus. It is quite exciting to follow up such "leads," finding indications here and there, until the "lode" is located.

Wyoming would do well to set aside, for a state park, an area where dinosaur bones are found, for future generations, illustrating the paleontology of the area by partially exposed dinosaurian remains, sheltered from the weather, and properly labeled.

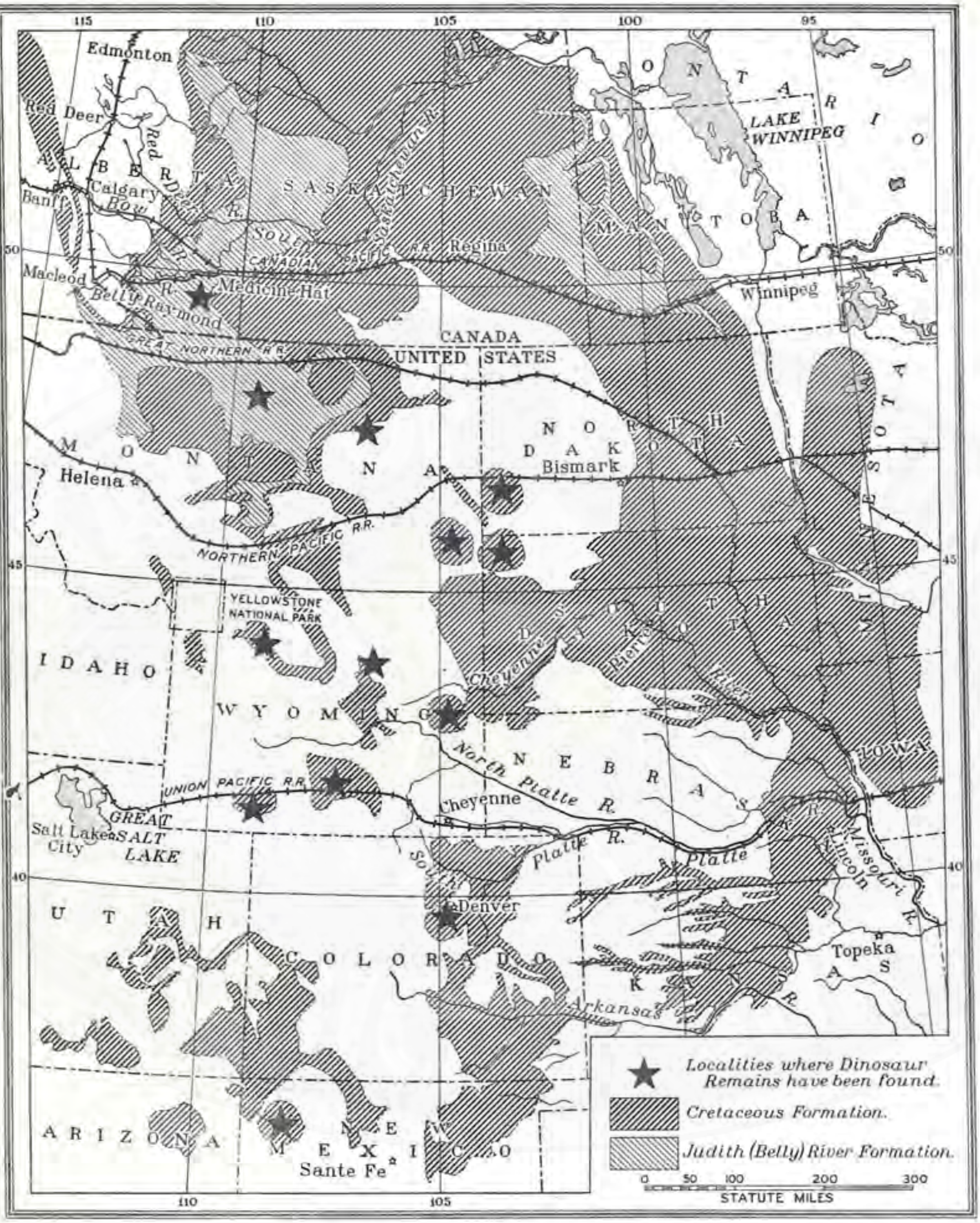

FIGURE 7.—MAP SHOWING THE LOCATION OF SOME OF THE IMPORTANT FINDS OF DINOSAURIAN REMAINS AND AREAS WHERE DEPOSITS WERE LAID DOWN DURING THE TIME THAT THESE ANIMALS LIVED

The most fertile field for the hunter of big game of other days is a vast area of level land, prairie in the east and forested near the mountains, in the province of Alberta, Canada, between the Great Lakes and the Rocky Mountains, just north of the Canadian boundary. In the lower reaches of the Deer River, which drains a part of this region, sea-shells are found in the rocks, indicating that an inland sea, which extended from the Gulf of Mexico to the Arctic Ocean, once covered this area. When the sea-floor was elevated above the ocean this section became a vast jungle-covered swamp. In these marshes of prehistoric times dwelt a host of reptiles known as dinosaurs.—After Brown.

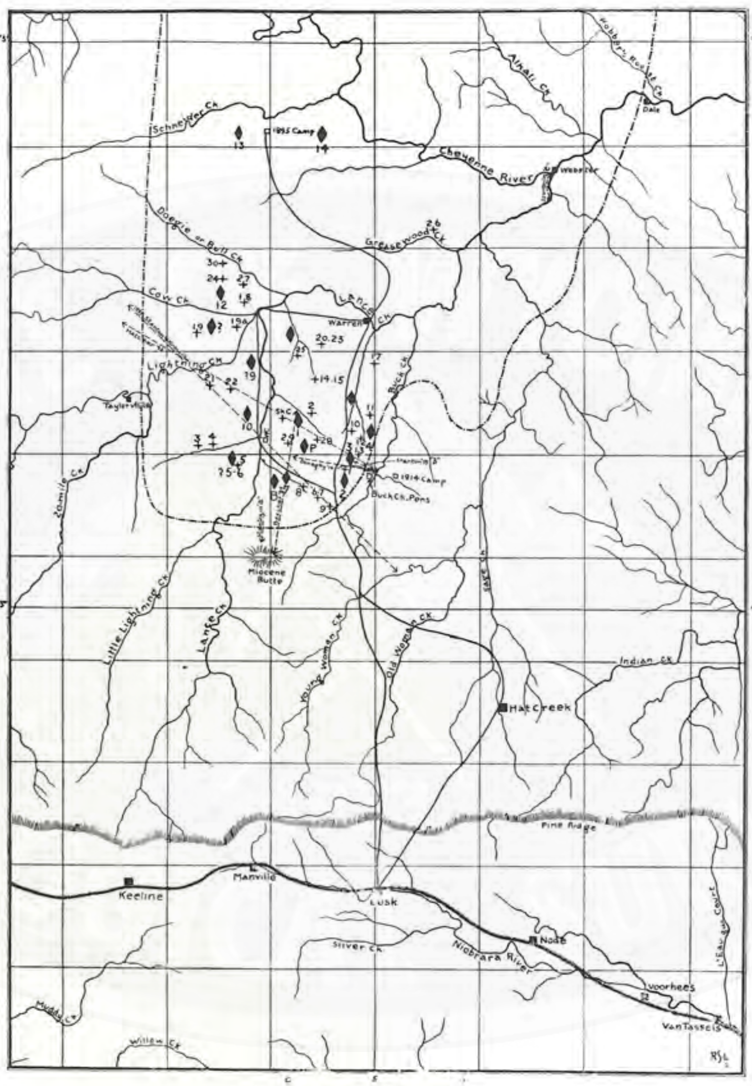

FIGURE 8.

Map of Niobrara County, Wyoming, showing locations of finds of three-horned dinosaurs, Ceratopsia, in association with Cretaceous mammals. Diamonds indicate mammal localities; crosses indicate locations of three-horned dinosaur skulls. The limits of the geological formation, known as the Lance Formation, are shown by dotted lines.—After Lull.

CHAPTER VIII

The Different Kinds of Dinosaurs

Scientists are not agreed as to whether the reptiles commonly called **Dinosaurs** do in reality constitute a definite, natural group. The animals are so diverse in size, ranging from a height of a few inches to a length of many feet (about 80 feet for the longest). They have specialized, during their nine millions of years, into amphibious, plant-eating animals; huge carnivorous types; armored reptiles; beaked, plant-eating, aquatic and dry-land types, in such an amazing array that even paleontologists become dizzy trying to figure it all out.

All of these creatures, however, have characters in common, and we are not yet ready to give up Sir Richard Owen's group name—**Dinosauria.** These common characters are most readily seen in the arrangement of the three hip bones, or pelvis. These three bones are called ischium, ilium and pubis; all three of which take part in the formation of the hip socket—acetabulum—for articulation with the leg bone—femur.

Matthew (1915, p. 27) gives the following convenient groupings as a basis for further discussion:

> "Group I: Theropoda—the Carnivorous Dinosaurs. Provided with sharp pointed teeth, sharp claws, bipedal (walking on two legs—see Frontispiece), with bird-like hind feet, generally three-toed; the fore limbs adapted for grasping or tearing, but not for support of the body. The head is large, neck of moderate length, body unarmored.
>
> "Dinosaurs of this group in America occur in the upper Jurassic Period—**Ornitholestes;** and Upper Cretaceous—**Tyrannosaurus** and others.
>
> "Group II: Sauropoda—the amphibious Dinosaurs. Provided with blunt-pointed teeth and blunt claws, quadrupedal, with elephant-like limbs and feet, long neck and small head. Unarmored American representatives are: **Brontosaurus, Diplodocus, Camarasaurus,** and **Brachiosaurus,** from Colorado and Wyoming. Upper Jurassic and Comanchean.
>
> "Group III: Predentata—the beaked Dinosaurs. Provided with a horny beak on the front of the jaw, cutting or grinding teeth behind it. All plant-eaters, with hoofs instead of claws, and many of them heavily armored. Mostly three short toes on the hind foot, four or five on the fore foot.

"Comprising the following sub-groups:

(1) **Iguanodonts.** Bipedal, unarmored, with a single row of serrated cutting teeth, three-toed hind feet. Jurassic, Comanchean and Cretaceous. American genus—**Camptosaurus.**

(2) **Trachodonts** or **Duck-Billed Dinosaurs.** Similar to the Iguanodonts but with numerous rows of small teeth set close together to form a grinding surface. Cretaceous. Some of these were aquatic.

(3) **Stegosauria-armored Dinosaurs.** Quadrupedal, with elephantine feet, short neck, small head, body and tail armored with massive bony plates and often with large bony spines. Teeth in a single row. Upper Jurassic. Upper Cretaceous.

(4) **Ceratopsia-horned Dinosaurs.** Quadrupedal, short neck, very large head enlarged by a bony frill covering the neck, with a pair of horns over the eyes and a single horn on the snout. Teeth adapted for cutting or grinding food. No body armor. Upper Cretaceous.

Representatives of all these many kinds of dinosaurs have been found in Wyoming.

CHAPTER IX

The Dinosaur-Bearing Rocks of Wyoming

Wyoming is a land of fossils of many kinds, beginning almost with the dawn of animal and plant life on earth. On the flanks of the Wind River Mountains occur unusually perfect, successive series of rocks from which the student may learn the animal communities throughout the entire Paleozoic periods, which witnessed the origin and development of the fishes and fish-like animals;the origin and development of air-breathing, land animals, and on up through the entire Mesozoic. Further afield occur many stages of rocks laid down during the Age of Mammals—the Cenozoic, from which numerous paleontologic gems have been taken.

In Wyoming, as elsewhere, the dinosaurs are confined to the rocks of the Mesozoic—the periods of which are the Triassic, the Jurassic, the Comanchean and the Cretaceous. Each period has numerous subdivisions, which are referred to from time to time (See Figure 1).

Around the city of Lander occur, to the west, numerous outcrops of thick, bright red, layers of sandstone and shale which represent the closing period of the Paleozoic—the Permian, and the opening period of the Mesozoic—the Triassic, during which latter period, elsewhere, the dinosaurs had their origins. Not a fragment, not a tooth nor a bone representing a dinosaur has ever been seen in the Triassic Red Beds of Wyoming. I have followed the exposures of the red Triassic rocks for scores of miles throughout the state, but there are no dinosaurs known from the Triassic of Wyoming.

Professor Case, of the University of Michigan, has discovered small dinosaur bones in the Triassic rocks of Crosby County, Texas. The dinosaurs are also represented in Triassic rocks in Garden Park, Colorado, as well as in the New England states, where the enormous numbers of three-toed, dinosaur tracks are found.

The dinosaurs of several types occur in Wyoming in abundance in what is called the Morrison Formation, or Como or Atlantosaurus beds, belonging either in the Upper Jurassic, Lower Cretaceous or representing a separate period—the Comanchean. The geologists are entirely undecided which is correct. Near the town of Morrison, Colorado, these dinosaur-bearing beds are found, and from which the name for the formation is adopted. The chief dinosaurs are the huge sauropods—the long amphibious animals. Similar beds are found in Utah, where large quarries have been opened. The famous Bone Cabin Quarry, the Como Bluffs and other quarries in Wyoming are all within the Morrison Formation (See paper by Mook). The wierd, armored Stegosauria are confined to rocks of this age in Wyoming and Colorado.

The Cretaceous period, famous for its marine reptiles, witnessed wide expansions of the dinosaur group culminating in the huge carnivorous and three-horned dinosaurs near the close of the period. Naturally we would expect to find land animals in upland deposits, but several discoveries of dinosaurian bones have been made in marine deposits. The explanation, of course, is that these animals had died near the sea shore and their bones had been washed into the sea. Dinosaur bones covered with attached oyster shells have been found in Africa. Cretaceous dinosaurs as found in and near Wyoming are armored, beaked, aquatic, horned and huge carnivores. The occurrence of the horned dinosaurs in the Wyoming Upper Cretaceous sandstone is given in detail elsewhere in this book. In number the Cretaceous dinosaurs outnumber all others, in variety of form as well as in numbers of individuals. The Cretaceous rocks of Wyoming are prolific in their yield of dinosaur remains, often beautifully preserved, competing with Utah, Montana and Alberta, Canada, for leadership in dinosaur production.

CHAPTER X

Evidences of Disease and Injury Among the Dinosaurs

The indications of pathological conditions among the bones of the ancient dinosaurs are relatively rare, and consist, for the most part, of insignificant disturbances; fractures, abscesses, arthritides and a single tumor comprising the catalogue of disease and injury among the dinosaurs.

An enormous fractured rib (Figure 12, d) of one of the huge amphibious dinosaurs is on exhibition in Field Museum,

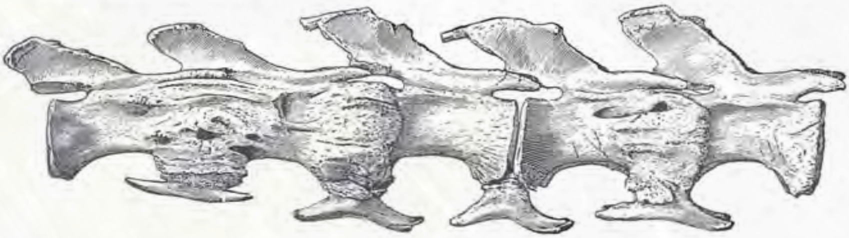

FIGURE 9.

Backbone joints, Nos. 17-21, of the Wyoming whip-tail dinosaur, Diplodocus longus, seen from the right side, showing fusion of the joints by a diseased process called Spondylitis deformans. The series of bones pictured has an actual length of about five feet. The opening seen in the lesion to the left allows an examination of the articular surfaces which are unaffected by disease. A fortunate fracture through the second lesion from the left shows the entire ends of the bones to be healthy. The disease forms a ring-like growth by the ossification of the longitudinal ligaments through disease. At this point the thirty-foot tail of the reptile reached the ground, and Osborn thought the conjoined bones indicated a "resting point" in the tail when the animal reared up on its hind legs like a kangaroo. Specimen in the American Museum of Natural History, X. 1-15.—After Osborn.

associated with an unhealed fracture of an adjoining rib. This was in the "thunder lizard," the largest of the amphibious dinosaurs. The injury could only have come from a blow by another dinosaur, or by a falling rock or tree.

Fractured limb bones are rare among dinosaurs, chiefly because of the size of the bones. An upper arm bone of a horned dinosaur found in Canada by Barnum Brown had suffered an oblique fracture which became badly infected. A pus sinus was formed and the bone did not heal. This is the first indication of a subperiosteal abscess among the dinosaurs, and is clear evidence of the presence of infective germs.

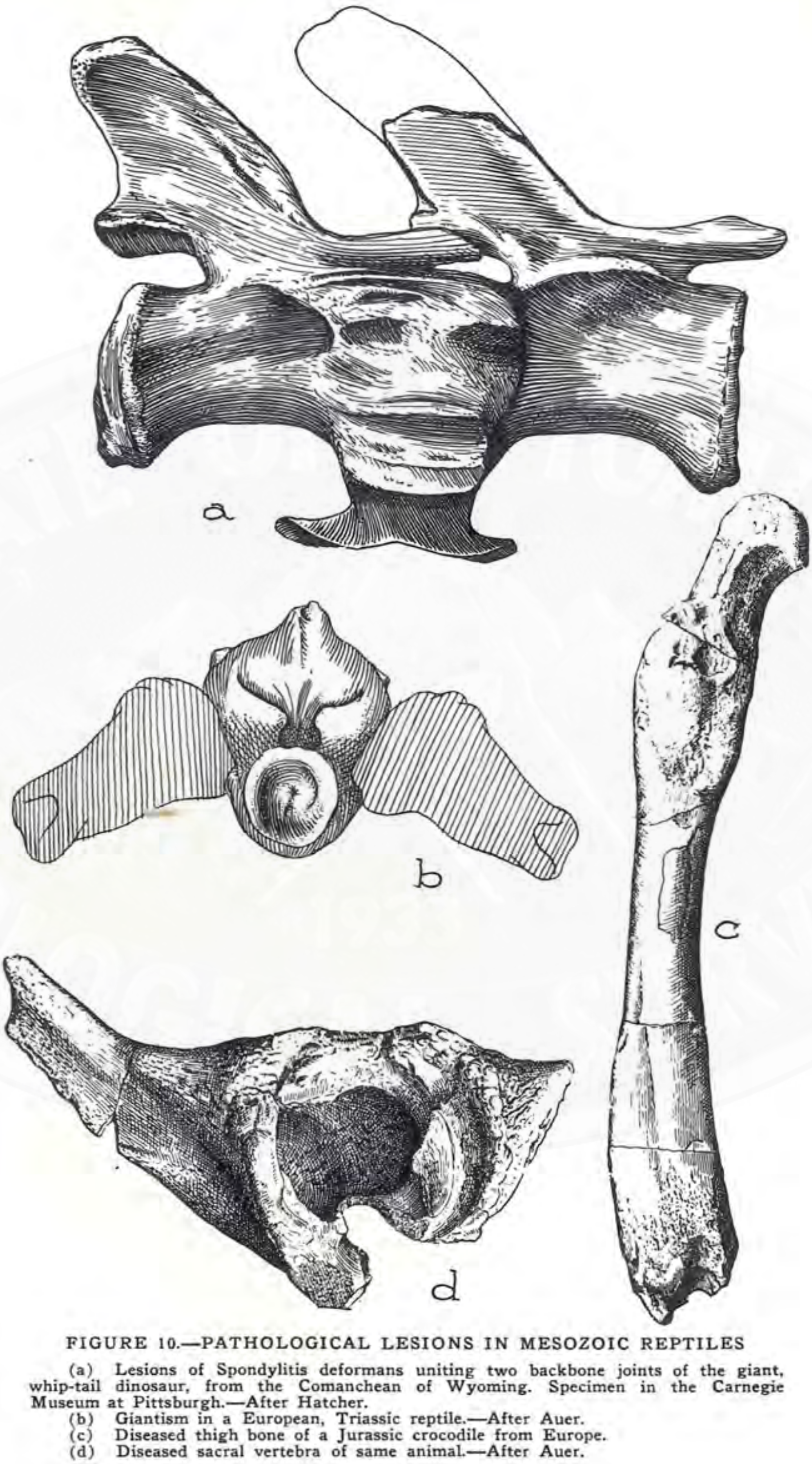

FIGURE 10.—PATHOLOGICAL LESIONS IN MESOZOIC REPTILES

(a) Lesions of Spondylitis deformans uniting two backbone joints of the giant, whip-tail dinosaur, from the Comanchean of Wyoming. Specimen in the Carnegie Museum at Pittsburgh.—After Hatcher.
(b) Giantism in a European, Triassic reptile.—After Auer.
(c) Diseased thigh bone of a Jurassic crocodile from Europe.
(d) Diseased sacral vertebra of same animal.—After Auer.

The right ramus of the jaw of a three-horned dinosaur preserved in Yale University Museum, collected in Wyoming, exhibits a well-healed fracture. There is no callus (Figure 42) but the jaw is deformed. The fracture may have been of the green-stick type.

A broken and healed horn core of another three-horned dinosaur (Figure 41) may be evidence of a fight.

An armor plate of a Stegosaurus, found in Wyoming shows a row of abcsessed pits as if a carnivorous dinosaur had bitten into the armor and the plate had become infected.

Diseases of the joints, called **arthritides,** are fairly common among the dinosaurs, and are of different types. Perhaps the

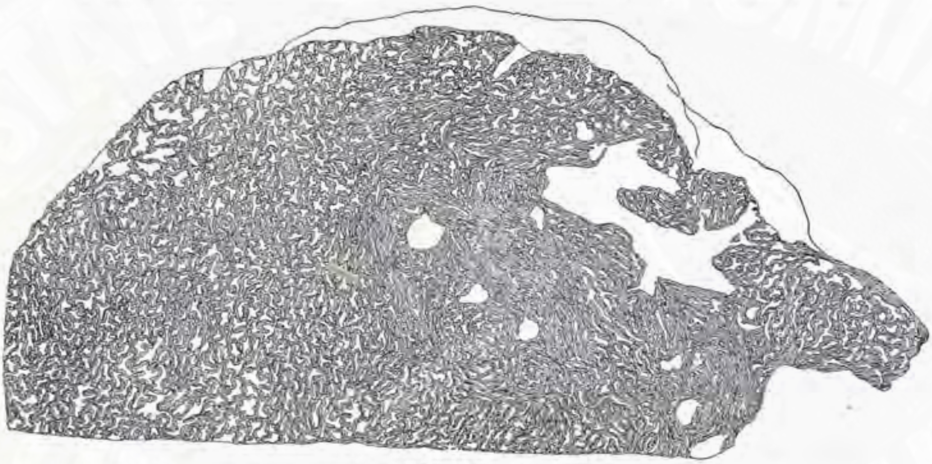

FIGURE 11.

Drawing of a sawn hemisection of the large dinosaur tumor, shown in Figure 14. The dark lines represent bars of bone and the white areas are blood spaces. The tumor is an Haemangioma.

most interesting joint lesion is that of a **tumor** which has united two caudal vertebrae into a solid mass (Figure 14). The specimen was found in Wyoming in the Como Beds, more than half a century ago. The tumor mass, after study, shows all the characters of what medical men call an **haemangioma,** a tumor filled with blood spaces (Figure 16). Its origin may have been due to an injury to the tail, at a point far back from the hips.

The tumor mass resembles closely the tumor-like growths seen on live-oaks. Its mass has invaded the half of each vertebra and entirely filled up the space between the bones. The specimen has a length of 26.5 cm. and a weight of 5.1 kg. The tumor itself is 12 cm. long. Its surface is rather deeply pitted

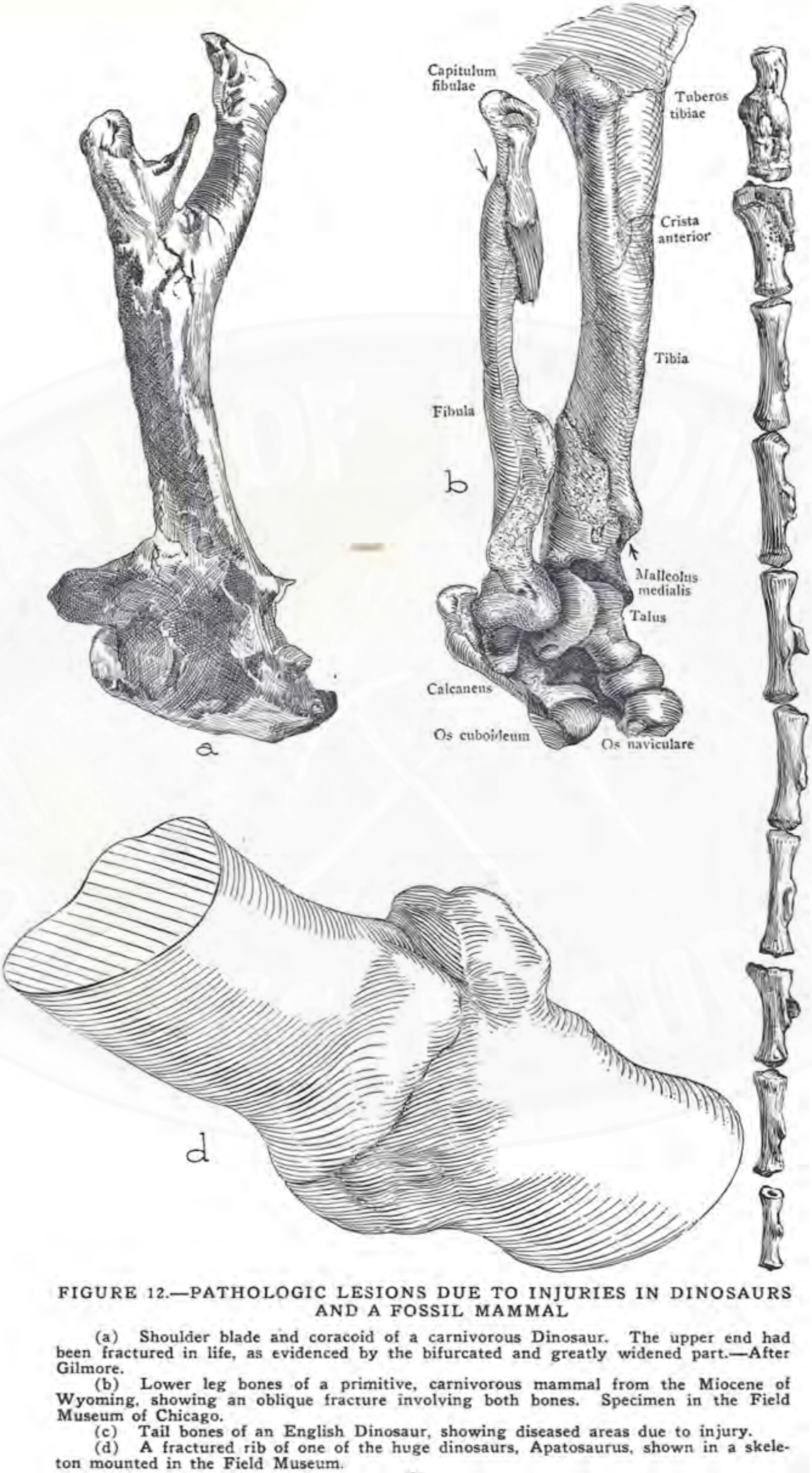

FIGURE 12.—PATHOLOGIC LESIONS DUE TO INJURIES IN DINOSAURS AND A FOSSIL MAMMAL

(a) Shoulder blade and coracoid of a carnivorous Dinosaur. The upper end had been fractured in life, as evidenced by the bifurcated and greatly widened part.—After Gilmore.

(b) Lower leg bones of a primitive, carnivorous mammal from the Miocene of Wyoming, showing an oblique fracture involving both bones. Specimen in the Field Museum of Chicago.

(c) Tail bones of an English Dinosaur, showing diseased areas due to injury.

(d) A fractured rib of one of the huge dinosaurs, Apatosaurus, shown in a skeleton mounted in the Field Museum.

and there is an unusual ventral growth, which is unequal, being larger on one side.

FIGURE 13.—DISEASE AMONG THE DINOSAURS

(a) A diseased joint in the tail of a sauropod Dinosaur.
(b) The Dinosaur Tumor shown in Figure 14.
(c) Dinosaur shoulder blade from Wyoming showing unusual opening.
(d) Outline sketch of one of the huge sauropod Dinosaurs to show, at the arrow, the location of the tumor in the tail.

Sawn sections (Figure 16) show the presence of numerous large and small vascular spaces, which are especially large and numerous near the point where the normal intervertebral space had been.

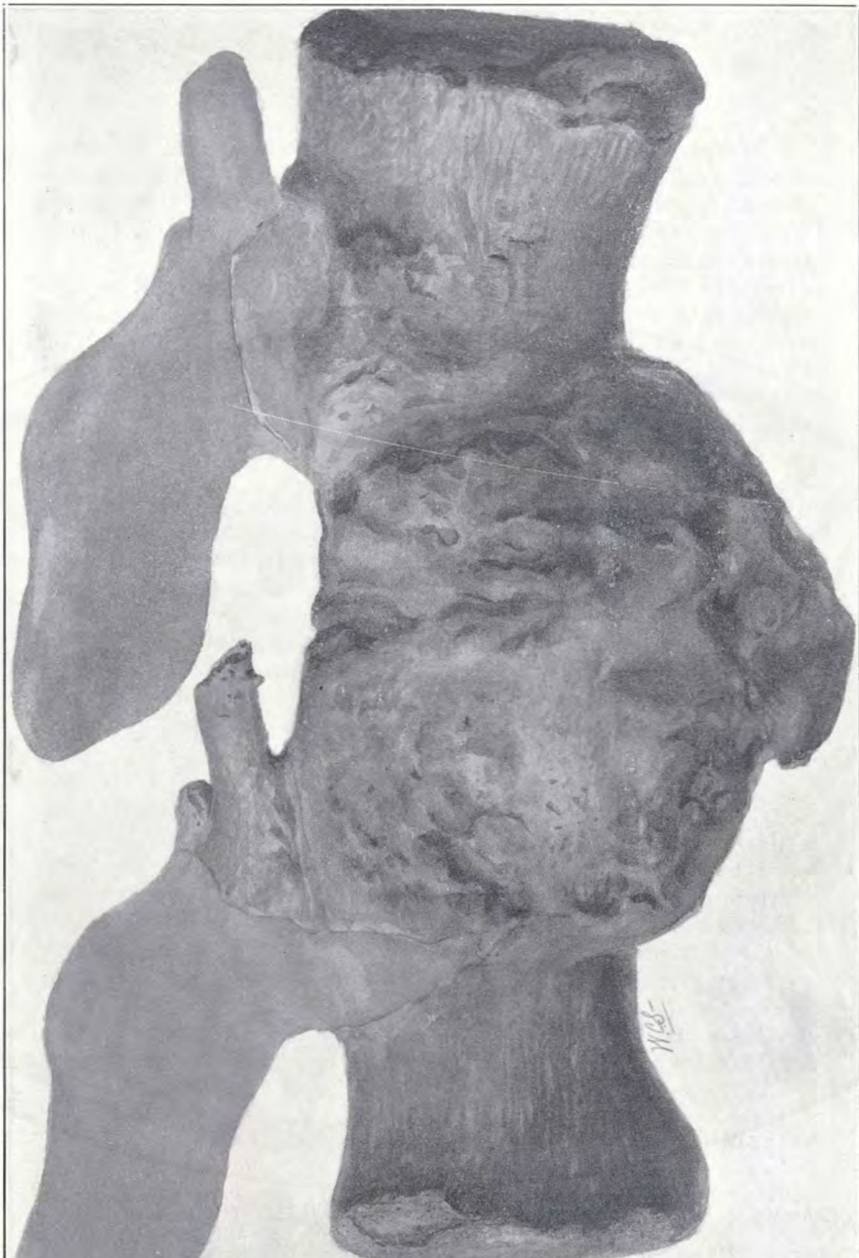

FIGURE 14.

The Haemangioma, or vascular bone tumor, occurs between two caudal vertebrae of a large sauropod Dinosaur, and has firmly united the two bones into a solid mass. The specimen was collected many years ago in the Como Beds of Wyoming, by Dr. S. W. Williston, at the time when these deposits were in the height of their fame as dinosaur quarries.

Microscopical study (Figures 15, 17) shows the presence of scattered lacunae, once occupied by the bone cells; spindle-shaped bodies with short canaliculi. A section of bone taken from the very middle of the tumor shows more compact bony structure than exists at the periphery (Figure 17).

Other accidents to the enormously elongated tail of the amphibious (sauropod) dinosaurs are known, and have been described by Hatcher, Holland and Osborn (Figures 9, 10, 12 c, 13 a, b, d). These injuries indicate that the tail was either dragged over rough ground, was used as a flail, or was used in swimming, or perhaps all three. One type of pathological change often seen in the tail of the sauropod dinosaurs was a thickening, or ossification of the longitudinal ligaments, producing a condition called **Spondylitis deformans,** which is a very ancient diseased condition, known from early Mesozoic times, and extremely common at the present time.

An infected injury is seen in the tail of a large dinosaur mounted in the Carnegie Museum at Pittsburgh.

Lesions similar to those associated with rheumatism are known in the dinosaurs, and some of them had tooth troubles.

A large dinosaur skeleton, mounted in the United States National Museum (Figures 24, 40, a), shows in one hip a huge bone abscess, due doubtless to a bone injury.

A large hook-like exostosis, following an infection, is seen on the inner face of a shoulder-blade of a three-horned dinosaur (Figure 40). The pathological growth was partly covered by muscle, but it may have rubbed against the ribs. Pathological outgrowths exactly like this are often seen on modern human bones.

All together there is a known array of fifteen different types of pathological processes found among Mesozoic reptiles. Some of these conditions are called arthritides, multiple arthritis, arthritis deformans, tumors of two types, necrosis, hyperostoses and various kinds of fractures and slight injuries.

better methods prevailed and collecting dinosaurs was becoming a highly technical undertaking.

Collecting a dinosaur involves first a geological knowledge of the field, and something of the osteology of the various kinds of dinosaurs. Walking along the base of promising

FIGURE 5.—The skeleton of a crested dinosaur exposed in Cretaceous rocks in Canada under the direction of Barnum Brown. This very unusual find, a skeleton over thirty feet long, shows the skin still preserved on the under side. This "duck-bill" dinosaur had a skull surmounted by a high curved crest. Only the tip of the tail was exposed on the surface, thus furnishing a clew to the whole animal. Excavation here was not excessive, but hard work just the same since it all had to be done with pick and shovel.
—After Brown, National Geographic Magazine.

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slopes, or in gullies, the collector finds, mingled with broken rock and other "talus" interesting fragments of dinosaur bones. This is a "lead," and by following it up the bank may result in the discovery of other bones still embedded in the cliff, or it may be that the entire specimen has washed out and nothing is left. If there are bones still "in place" it is important to find out what part of the body it is and what kind of a dinosaur the bones represent, and how extensive the area to be involved in the excavation. Subsequent procedure depends upon the circumstances in the immediate vicinity.

If the deposit seems large and promising, after exploration and prospecting with a hand pick, then teams with scrapers may be employed to remove the overlying material, down to within a couple of feet of the specimens. The remainder of the work is by hand. The removal of the encasing rock down to the bones must be carefully done, so as not to injure the bones, leaving enough matrix to support the fossilized skeleton. After all parts are exposed the petrified, and excessively fragile skeletal parts must be "blocked" out for encasing with strips of burlap, dipped in plaster or flour paste, stretched tight and supported by strips of wood. When dry this makes an unyielding case for each section. Then the blocks are underchanneled and turned for trimming and encasing the other surface with plastered burlap strips. Then a firm casing is made of boards and timber, often hauled a hundred miles to the nearest railroad, sufficiently strong to bear the parts, at times weighing thousands of pounds. Such handling in the quarry requires skill and mechanical appliances hardly to be thought of in other kinds of fossil collecting.

After the shipment has reached the museum the mistakes of the collectors become apparent as the encasing materials are removed. Some part, not sufficiently well supported, has been badly broken in transit. Some surfaces were not properly protected by thin paper or shellac. All mistakes and readjustments are noted for correction during succeeding collecting seasons.

The work on a large dinosaur skeleton at the museum is long and tedious, requiring months and years for completion. The removal of the encrusting matrix is laborious and requires the employment of special tools, such as compressed air drills. Repairs and restorations of broken and lost parts must be scientifically accurate. The work in the laboratory must at all times be checked by those whose scientific training has given them knowledge.

The supreme purpose, the end and aim of all collecting and preparation procedures, is the final mounting of the skeleton in such a manner as to reveal the nature of the animal, and thus furnish a check on all scientific discussions. Mounting cannot be properly done without adequate conception of the nature and relationships of each part. This is shown in the eager discussions about the "pose of the sauropod dinosaurs," a few years ago, resulting in our present day conceptions of the attitude of the dinosaurs as shown in the restorations pictured in this book. Knowledge is acquired by trying. This applies to mounting dinosaur skeletons as well as other things.

The experiences of a noted collector in his work on one dinosaur skeleton in the Black Hills, to the east and north of Wyoming, will bring this matter vividly before the reader.* G. R. Wieland, for many years at Yale University, has long had a three-fold interest in fossils—the cycads, giant turtles and dinosaurs, and he has a wide fame in all three. His story follows:

> " . . . in the latter part of August, 1898, I began the excavation for **Barosaurus.** This I carried out alone. The quarry was extended to a sixty foot front, and ran some thirty feet back to a depth of ten feet. The first material secured was fragmentary and seemed to run out following a group of good caudals. Then a well-conserved portion of a proximal caudal was uncovered; but on interrupting the work for further prospecting for the cycads and dinosaurs, the centrum was found cut off by an ugly shear. Nearly decided that the lead had come to an end, on working down to a two-foot lower level, various dorsals, a few chevrons, rib fragments, and a sternal plate, promised a rather featureless aggregate. Much checking with extreme lightness of the vertebral structure made it necessary to hold all parts in place as uncovered. This slow task lasted into the late fall, when cold and dust storms made excavation difficult.
>
> "Finally, in the course of working forward, there came four cervicals running up to one with a centrum three feet long, at once recognized as unparalleled in the Dinosauria; though much more robust types as long are now known. It then appeared that the main group of skeletal elements, although much displaced, or only partly conserved, represented a single individual; but unluckily the long cervicals led out to a gullied surface. All possibility of further recovery was at an end. Yet the result seemed a real triumph, over which Marsh was quite elated; he held in hand novel Dinosaurian material new from the field."

Wieland further notes with this skeleton "various pebbles of a singular smoothness" at a point near the dorsals, which later were called "dinosaurian gastroliths," or stomach stones used in crushing food in the dinosaur stomach.

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* Wieland, G. R. 1920. The longneck sauropod Barosaurus. Science, n. s., LI: 528-530.

CHAPTER VI

Some Famous Collectors and Collections of Dinosaurs

Most of the men who collected dinosaurs in Wyoming made themselves famous by their published studies of fossil vertebrates, and by teaching or developing museums. Most of the collections are now in eastern museums, a few abroad, and a good collection in the University of Wyoming.

The first evidences of dinosaurian reptiles were the footprints, discussed elsewhere, after 1818. The first dinosaur was made known in 1824, so we may say that the study of dinosaurs covers a century. Wyoming dinosaurs did not come to the front, however, until much later, during the late seventies, since which time the deposits have been explored again and again. Dinosaurs will always be found in Wyoming.

To name the men who have collected dinosaurs in Wyoming would be to list most of the vertebrate paleontologists of America, and we shall cover the subject briefly. The rivalry and bitterness associated with the early Wyoming discoveries we shall neglect. It is past history, and not interesting.

The early students of dinosaurs were Leidy, Cope and Marsh. Leidy studied dinosaurs from eastern states. Cope was interested in all lines of vertebrate fossils, but his work did not have a great deal to do with the dinosaurs of Wyoming.- Marsh and the many men who worked with him, developed the field of Wyoming dinosaurs in a large way, and his collections today at Yale University and at the United States National Museum, still remain important, although the lead has long been with the American Museum of Natural History.

Professor O. C. Marsh of Yale University, at his own expense, and later with aid from the United States Geological Survey, sent parties into the states about Wyoming from 1870 on, as opportunity and discoveries were available. Many men of high intellectual ability worked with and for Marsh in the field and in the museum, where was laid a broad foundation for a knowledge of American dinosaurs. Especially in connection with the United States Geological Survey, he established a number of beautifully illustrated memoirs on the various groups of dinosaurs. His general discussion of dinosaurs, published in 1896, was the only volume he lived to see published. His projected treatise on the three-horned dinosaurians, was completed after his death by Hatcher and Lull. His work on the armored dinosaurs has been completed by Gilmore and Osborn has the memoir on the Sauropoda (amphibious dinosaurs) under preparation.

The noted men who worked for and with Marsh became teachers of ability, and investigators in branches of vertebrate paleontology other than dinosaurs. Especially to be noted, among the early workers, was S. W. Williston, who had received training under Professor Benjamin F. Mudge, who had collected for Marsh, footprints from the Coal Measures of Kansas, and some fossils from the Niobrara Cretaceous chalk. Mudge at that time was a teacher at the Kansas Agricultural College at Manhattan, and from him Williston learned the joy, and the disappointments, of fossil hunting. During the seven years Williston spent at Yale, where he took the M. D. and Ph. D. degrees, much time was spent in the employ of Professor Marsh. In this manner Williston was sent to work in the dinosaur quarry at Como Bluffs in 1877. One season he spent 10 months in the field. Merely collecting dinosaur bones, without the added stimulus of scientific discussion, did not appeal to Williston, who turned his attention to medicine, becoming in time, professor of anatomy at Yale. At the University of Kansas, from 1890 to 1902, he made field trips to Wyoming, secured a skull of a three-horned dinosaur, limb bones, and backbones enough for exhibition and teaching.

G. R. Wieland's work at Yale, beginning in 1898, has resulted in the publication of large quarto volumes on Cycads, and numbers of papers on dinosaurs and Cretaceous turtles.

George Baur, a noted morphologist, worked in Paleontology at Yale, ultimately going to the University of Chicago as Professor of Vertebrate Paleontology, whose successor in 1902 was S. W. Williston.

The greatest collector of fossil vertebrates, who worked for Marsh at Yale University, was John Bell Hatcher, who died at the early age of 43. During the twenty years he spent collecting fossil vertebrates he shipped more than 1500 boxes of material to Yale, to the United States National Museum and to the Carnegie Museum. From 1884 to 1892 he shipped 900 boxes of fossil vertebrates to Yale Museum; one of them weighing more than three tons, having the dimensions of ten feet by five feet by six feet. This contained a very large skull of a three-horned dinosaur. He had found his first three-horned skull in 1889 near Lusk, Wyoming, and by 1892 he had collected 50 ceratopsian dinosaurs, 33 of them with skulls.

FIGURE 6.—FOUR DISTINGUISHED PALEONTOLOGISTS

UPPER LEFT: Sir Richard Owen, a noted English anatomist and paleontologist, 1804-1892. A famous writer in many fields, his work on the dinosaurian reptiles is of the greatest value. He proposed the term Dinosauria.

UPPER RIGHT: Professor Othniel Charles Marsh, an American paleontologist, 1831-1897. Professor of Paleontology at Yale University for many years, where in Peabody Museum are stored the vast collections of dinosaurs assembled from the Wyoming fossil beds, and elsewhere, under his supervision.

LOWER LEFT: John Bell Hatcher, American Paleontologist, 1861-1904. He collected, during twenty years, more fossil vertebrates than any other single individual. Much of his work was in Wyoming, where among other materials he collected over 50 three-horned dinosaurs, 33 of them with skulls.

LOWER RIGHT: Professor Samuel Wendell Williston, American anatomist, paleontologist and dipterologist, 1852-1918. A famous collector and student of fossil vertebrates, he worked in Wyoming, during intervals, between 1877 and 1910. Dinosaurs, plesiosaurs, and Triassic vertebrates from the Wyoming fossil fields were well known to him. His latter years were spent in the Permian Red Beds of Texas and New Mexico, from which he studied a large fauna.

The hugest of these had to be lifted fifty feet out of a vertical ravine, and hauled 40 miles to the railroad over a trackless country and across unknown streams. Hatcher revolutionized the collecting of fossil vertebrates, introducing many new procedures. He was later assigned the task of completing the memoir on the Ceratopsia, which he did not live to complete. While not a highly educated man, Hatcher trained himself by observation and reading so that he was able to write a number of valuable scientific papers relating to stratigraphy and vertebrate paleontology. His work at Princeton was on the fossil mammals of Patagonia, and at the Carnegie Museum he assembled from Colorado and Wyoming important sauropod skeletons, at present mounted in the Museum.

Professor R. S. Lull, director of the Peabody Museum and Professor of Paleontology at Yale University, has enhanced the value of the dinosaur collections left by Marsh, by numerous scientific papers, memoirs and the completion of the monograph on Ceratopsia, as well as by further collecting. His revision of dinosaur footprints from the eastern Triassic is a monument of industry in a difficult field.

Professor E. D. Cope, of Philadelphia, sent expeditions into the west after 1869. One collector he employed, J. L. Wortman, rose to an independent position in science by his sagacity and application. Cope's large dinosaurs came in part from Colorado, as well as other states. His quarry at Garden Park, Colorado, was still open in 1907 when I visited it. All of Cope's collections were acquired through purchase by the American Museum of Natural History and the sauropod skeletons are being restudied.

Realizing the importance of the finds being made in Wyoming Professor Wilbur C. Knight conducted successful expeditions into the dinosaur fossil beds for the museum at the University of Wyoming. The aquatic reptiles, called plesiosaurs, attracted his attention and he described these in a short series of scientific papers.

The Field Museum of Natural History, at Chicago, possesses a good collection of sauropod dinosaurs, collected and prepared under the supervision of E. S. Riggs, whose teacher in paleontology was Williston at Kansas University. Riggs collected in Colorado and eastern Wyoming, making a noteworthy discovery of a dinosaur whose fore limbs were longer than the hind limbs: the upper arm bone measuring nearly seven feet in length. A partial skeleton of **Brontosaurus** is mounted in Field Museum.

The Carnegie Museum, at Pittsburgh, has a noteworthy collection of dinosaurian material, collected in part from Wyoming. The collectors for this museum were J. B. Hatcher, J. L. Wortman, Peterson and Earl Douglas. Papers by W. J. Holland and J. B. Hatcher describe much of the material there. It was here that casts of the long, slender sauropod dinosaur, **Diplodocus,** were made for presentation to royal museums abroad. One of their quarries was 13 miles north of the Bone Cabin quarry.

Amherst College has a noteworthy collection of dinosaur footprints from the Triassic, and the paleontological museum is being increased by collections made by Professor F. B. Loomis.

The United States National Museum has a splendid collection of dinosaurs, a part of which were acquired by Marsh, and added to by the present Curator of Vertebrate Paleontology, Charles W. Gilmore. His papers and memoirs are of the highest quality.

A collector of fossil vertebrates who made many notable discoveries of dinosaurs in Wyoming was Charles Sternberg, whose autobiography, "The Life of a Fossil Hunter," is one of America's biographical classics in paleontology. His son discovered in Wyoming the only dinosaur mummies known, acquired by the American Museum of Natural History. The "mummy" reveals the skin pattern over a large area. Sternberg's collections were purchased by many foreign museums. He collected a fine **Triceratops** skull from Wyoming for the British Museum (Natural History) at Kensington. Other museums abroad where paleontology has been developed and where dinosaurs may be seen, some of them from Wyoming, are at Stuttgart, Brussels in Belgium, Berlin, Tuebingen, Paris, and at other large cities.

The finest and most extensive collection of dinosaurs in the world has been left to the last. It represents the guiding genius of one man, Henry Fairfield Osborn, a man of the highest intellectual attainments. Dinosaurs from all over the world—from all continents where dinosaurs are known, are to be found in the American Museum of Natural History, where skeletons and restorations and exhibitions fill the only "Dinosaur Hall" ever built. It is not possible here to give a complete account of the development of this truly wonderful collection. Many men have shared with Osborn the development of the collections of dinosaurian remains, notably W. D. Matthew, Walter Granger, Barnum Brown, J. L. Wortman, and a large staff of research assistants and preparators.

A few localities in Wyoming have been extremely productive of dinosaurian skeletons, the most famous of which is the Bone Cabin Quarry in Albany County, south central

Wyoming, accidentally discovered by Granger in 1897. During the six years quarrying at this locality a car load of dinosaur bones was shipped to New York each year. From this one locality were secured the remains of 73 animals—all of them dinosaurs excepting four crocodiles and five turtles. This was one of the greatest fossil "finds" ever made.

The name "Bone Cabin" was adopted because a Mexican sheepherder had used the gigantic back bones as a foundation for his cabin. There were no surface rocks in the vicinity. At other places in Wyoming similar foundations were made of trunks of petrified trees and had been used to hold the claim or title to a plot of ground.

CHAPTER VII

Occurrence of Dinosaurs in the State of Wyoming

The geographical distribution of the known deposits of dinosaurs in Wyoming shows that these animal remains occurred in selected groups, instead of being scattered singly over wide areas. This is the general situation, but isolated specimens, either single bones or pieces of bones, or incomplete skeletons, are likewise found. A number of the larger deposits are indicated by the large stars in the map in figure 7. The areas in Wyoming are only a part of a greater area of subsidence, as explained by Mr. Brown. Doubtless there are many more large deposits awaiting the searcher after fossils. The quarries opened so far were discovered because erosion had uncovered bones to indicate the positions of buried skeletons.

The areas where dinosaur bones are now found doubtless represent favorable spots in the marshy lowlands which occupied the region after the withdrawal of the seas.

The map shown in figure 8 reveals the abundance of fossils in a given area, about which dinosaur bones are rare or wanting entirely.

Search for dinosaur bones which have been exposed by erosion should be made along the base of "talus slopes," in gullies, or in the cliffs themselves. A little practice will enable the observer to distinguish fragments of fossil bone from other broken detritus. It is quite exciting to follow up such "leads," finding indications here and there, until the "lode" is located.

Wyoming would do well to set aside, for a state park, an area where dinosaur bones are found, for future generations, illustrating the paleontology of the area by partially exposed dinosaurian remains, sheltered from the weather, and properly labeled.

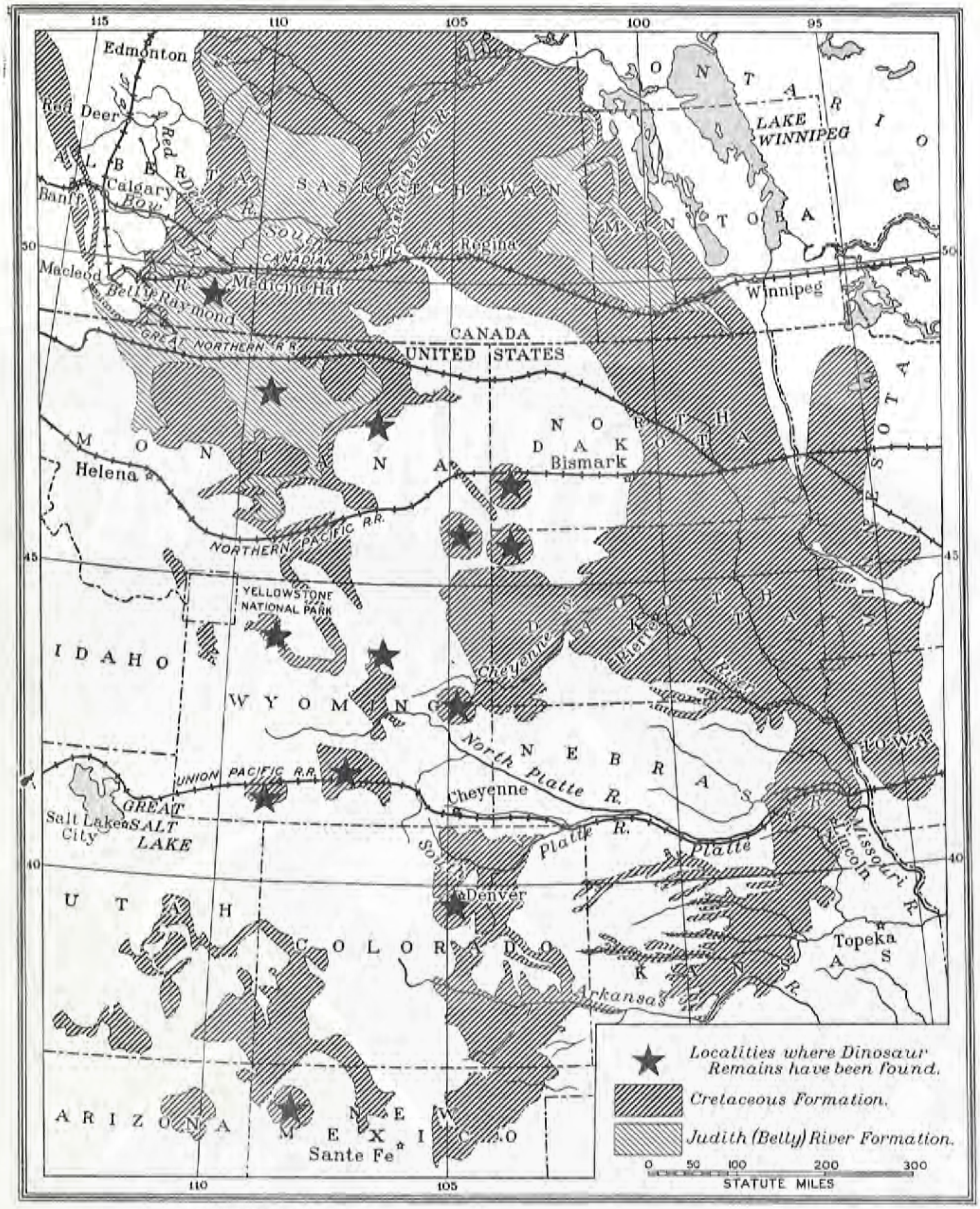

FIGURE 7.—MAP SHOWING THE LOCATION OF SOME OF THE IMPORTANT FINDS OF DINOSAURIAN REMAINS AND AREAS WHERE DEPOSITS WERE LAID DOWN DURING THE TIME THAT THESE ANIMALS LIVED

The most fertile field for the hunter of big game of other days is a vast area of level land, prairie in the east and forested near the mountains, in the province of Alberta, Canada, between the Great Lakes and the Rocky Mountains, just north of the Canadian boundary. In the lower reaches of the Deer River, which drains a part of this region, sea-shells are found in the rocks, indicating that an inland sea, which extended from the Gulf of Mexico to the Arctic Ocean, once covered this area. When the sea-floor was elevated above the ocean this section became a vast jungle-covered swamp. In these marshes of prehistoric times dwelt a host of reptiles known as dinosaurs.—After Brown.

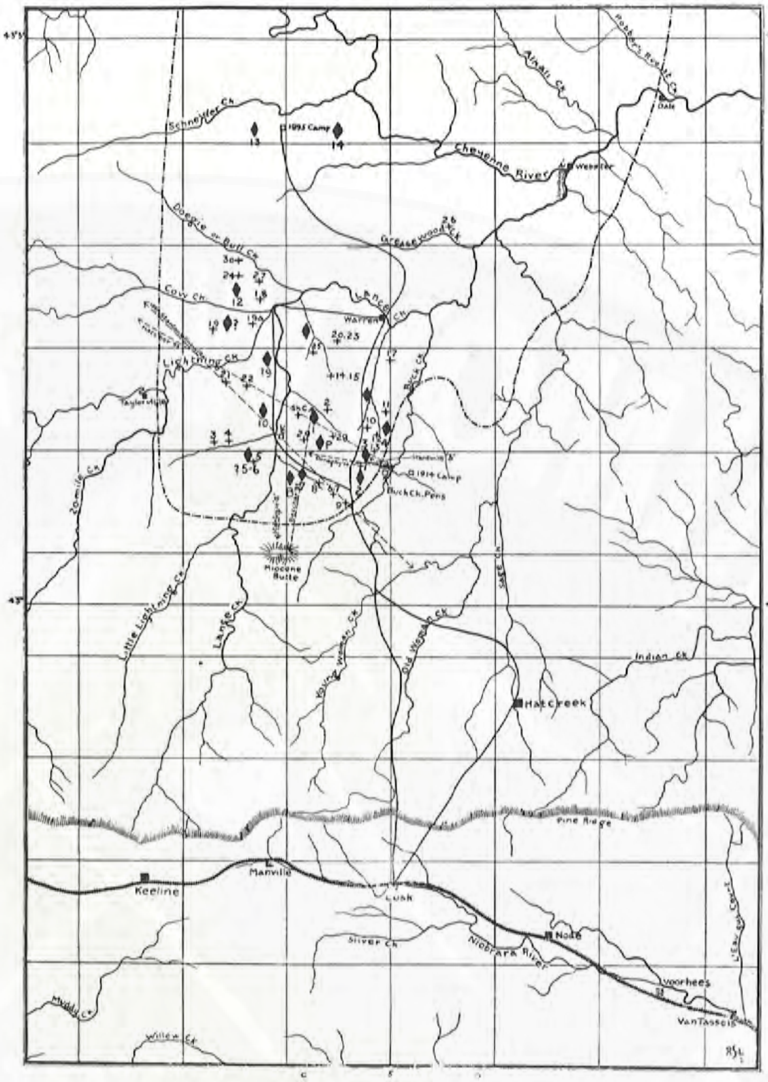

FIGURE 8.

Map of Niobrara County, Wyoming, showing locations of finds of three-horned dinosaurs, Ceratopsia, in association with Cretaceous mammals. Diamonds indicate mammal localities; crosses indicate locations of three-horned dinosaur skulls. The limits of the geological formation, known as the Lance Formation, are shown by dotted lines.—After Lull.

CHAPTER VIII

The Different Kinds of Dinosaurs

Scientists are not agreed as to whether the reptiles commonly called **Dinosaurs** do in reality constitute a definite, natural group. The animals are so diverse in size, ranging from a height of a few inches to a length of many feet (about 80 feet for the longest). They have specialized, during their nine millions of years, into amphibious, plant-eating animals; huge carnivorous types; armored reptiles; beaked, plant-eating, aquatic and dry-land types, in such an amazing array that even paleontologists become dizzy trying to figure it all out.

All of these creatures, however, have characters in common, and we are not yet ready to give up Sir Richard Owen's group name—**Dinosauria.** These common characters are most readily seen in the arrangement of the three hip bones, or pelvis. These three bones are called ischium, ilium and pubis; all three of which take part in the formation of the hip socket—acetabulum—for articulation with the leg bone—femur.

Matthew (1915, p. 27) gives the following convenient groupings as a basis for further discussion:

> "Group I: Theropoda—the Carnivorous Dinosaurs. Provided with sharp pointed teeth, sharp claws, bipedal (walking on two legs—see Frontispiece), with bird-like hind feet, generally three-toed; the fore limbs adapted for grasping or tearing, but not for support of the body. The head is large, neck of moderate length, body unarmored.
>
> "Dinosaurs of this group in America occur in the upper Jurassic Period—**Ornitholestes;** and Upper Cretaceous—**Tyrannosaurus** and others.
>
> "Group II: Sauropoda—the amphibious Dinosaurs. Provided with blunt-pointed teeth and blunt claws, quadrupedal, with elephant-like limbs and feet, long neck and small head. Unarmored American representatives are: **Brontosaurus, Diplodocus, Camarasaurus,** and **Brachiosaurus,** from Colorado and Wyoming. Upper Jurassic and Comanchean.
>
> "Group III: Predentata—the beaked Dinosaurs. Provided with a horny beak on the front of the jaw, cutting or grinding teeth behind it. All plant-eaters, with hoofs instead of claws, and many of them heavily armored. Mostly three short toes on the hind foot, four or five on the fore foot.

"Comprising the following sub-groups:

(1) **Iguanodonts.** Bipedal, unarmored, with a single row of serrated cutting teeth, three-toed hind feet. Jurassic, Comanchean and Cretaceous. American genus—**Camptosaurus.**

(2) **Trachodonts** or **Duck-Billed Dinosaurs.** Similar to the Iguanodonts but with numerous rows of small teeth set close together to form a grinding surface. Cretaceous. Some of these were aquatic.

(3) **Stegosauria-armored Dinosaurs.** Quadrupedal, with elephantine feet, short neck, small head, body and tail armored with massive bony plates and often with large bony spines. Teeth in a single row. Upper Jurassic. Upper Cretaceous.

(4) **Ceratopsia-horned Dinosaurs.** Quadrupedal, short neck, very large head enlarged by a bony frill covering the neck, with a pair of horns over the eyes and a single horn on the snout. Teeth adapted for cutting or grinding food. No body armor. Upper Cretaceous.

Representatives of all these many kinds of dinosaurs have been found in Wyoming.

CHAPTER IX

The Dinosaur-Bearing Rocks of Wyoming

Wyoming is a land of fossils of many kinds, beginning almost with the dawn of animal and plant life on earth. On the flanks of the Wind River Mountains occur unusually perfect, successive series of rocks from which the student may learn the animal communities throughout the entire Paleozoic periods, which witnessed the origin and development of the fishes and fish-like animals;the origin and development of air-breathing, land animals, and on up through the entire Mesozoic. Further afield occur many stages of rocks laid down during the Age of Mammals—the Cenozoic, from which numerous paleontologic gems have been taken.

In Wyoming, as elsewhere, the dinosaurs are confined to the rocks of the Mesozoic—the periods of which are the Triassic, the Jurassic, the Comanchean and the Cretaceous. Each period has numerous subdivisions, which are referred to from time to time (See Figure 1).

Around the city of Lander occur, to the west, numerous outcrops of thick, bright red, layers of sandstone and shale which represent the closing period of the Paleozoic—the Permian, and the opening period of the Mesozoic—the Triassic, during which latter period, elsewhere, the dinosaurs had their origins. Not a fragment, not a tooth nor a bone representing a dinosaur has ever been seen in the Triassic Red Beds of Wyoming. I have followed the exposures of the red Triassic rocks for scores of miles throughout the state, but there are no dinosaurs known from the Triassic of Wyoming.

Professor Case, of the University of Michigan, has discovered small dinosaur bones in the Triassic rocks of Crosby County, Texas. The dinosaurs are also represented in Triassic rocks in Garden Park, Colorado, as well as in the New England states, where the enormous numbers of three-toed, dinosaur tracks are found.

The dinosaurs of several types occur in Wyoming in abundance in what is called the Morrison Formation, or Como or Atlantosaurus beds, belonging either in the Upper Jurassic, Lower Cretaceous or representing a separate period—the Comanchean. The geologists are entirely undecided which is correct. Near the town of Morrison, Colorado, these dinosaur-bearing beds are found, and from which the name for the formation is adopted. The chief dinosaurs are the huge sauropods—the long amphibious animals. Similar beds are found in Utah, where large quarries have been opened. The famous Bone Cabin Quarry, the Como Bluffs and other quarries in Wyoming are all within the Morrison Formation (See paper by Mook). The wierd, armored Stegosauria are confined to rocks of this age in Wyoming and Colorado.

The Cretaceous period, famous for its marine reptiles, witnessed wide expansions of the dinosaur group culminating in the huge carnivorous and three-horned dinosaurs near the close of the period. Naturally we would expect to find land animals in upland deposits, but several discoveries of dinosaurian bones have been made in marine deposits. The explanation, of course, is that these animals had died near the sea shore and their bones had been washed into the sea. Dinosaur bones covered with attached oyster shells have been found in Africa. Cretaceous dinosaurs as found in and near Wyoming are armored, beaked, aquatic, horned and huge carnivores. The occurrence of the horned dinosaurs in the Wyoming Upper Cretaceous sandstone is given in detail elsewhere in this book. In number the Cretaceous dinosaurs outnumber all others, in variety of form as well as in numbers of individuals. The Cretaceous rocks of Wyoming are prolific in their yield of dinosaur remains, often beautifully preserved, competing with Utah, Montana and Alberta, Canada, for leadership in dinosaur production.

CHAPTER X

Evidences of Disease and Injury Among the Dinosaurs

The indications of pathological conditions among the bones of the ancient dinosaurs are relatively rare, and consist, for the most part, of insignificant disturbances; fractures, abscesses, arthritides and a single tumor comprising the catalogue of disease and injury among the dinosaurs.

An enormous fractured rib (Figure 12, d) of one of the huge amphibious dinosaurs is on exhibition in Field Museum,

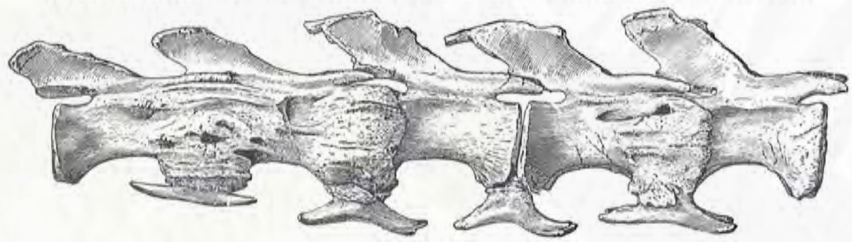

FIGURE 9.

Backbone joints, Nos. 17-21, of the Wyoming whip-tail dinosaur, Diplodocus longus, seen from the right side, showing fusion of the joints by a diseased process called Spondylitis deformans. The series of bones pictured has an actual length of about five feet. The opening seen in the lesion to the left allows an examination of the articular surfaces which are unaffected by disease. A fortunate fracture through the second lesion from the left shows the entire ends of the bones to be healthy. The disease forms a ring-like growth by the ossification of the longitudinal ligaments through disease. At this point the thirty-foot tail of the reptile reached the ground, and Osborn thought the conjoined bones indicated a "resting point" in the tail when the animal reared up on its hind legs like a kangaroo. Specimen in the American Museum of Natural History, X. 1-15.—After Osborn.

associated with an unhealed fracture of an adjoining rib. This was in the "thunder lizard," the largest of the amphibious dinosaurs. The injury could only have come from a blow by another dinosaur, or by a falling rock or tree.

Fractured limb bones are rare among dinosaurs, chiefly because of the size of the bones. An upper arm bone of a horned dinosaur found in Canada by Barnum Brown had suffered an oblique fracture which became badly infected. A pus sinus was formed and the bone did not heal. This is the first indication of a subperiosteal abscess among the dinosaurs, and is clear evidence of the presence of infective germs.

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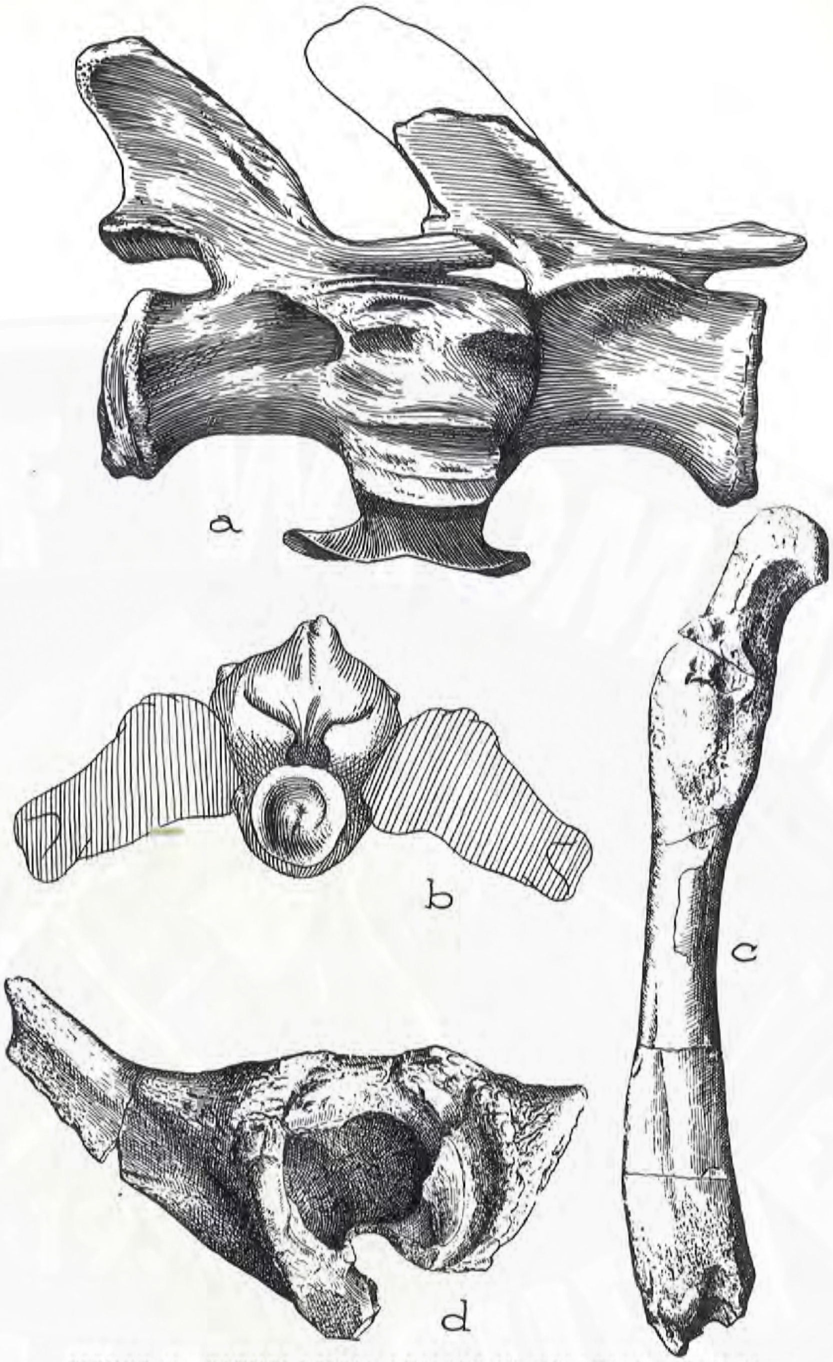

FIGURE 10.—PATHOLOGICAL LESIONS IN MESOZOIC REPTILES

(a) Lesions of Spondylitis deformans uniting two backbone joints of the giant, whip-tail dinosaur, from the Comanchean of Wyoming. Specimen in the Carnegie Museum at Pittsburgh.—After Hatcher.
(b) Giantism in a European, Triassic reptile.—After Auer.
(c) Diseased thigh bone of a Jurassic crocodile from Europe.
(d) Diseased sacral vertebra of same animal.—After Auer.

The right ramus of the jaw of a three-horned dinosaur preserved in Yale University Museum, collected in Wyoming, exhibits a well-healed fracture. There is no callus (Figure 42) but the jaw is deformed. The fracture may have been of the green-stick type.

A broken and healed horn core of another three-horned dinosaur (Figure 41) may be evidence of a fight.

An armor plate of a Stegosaurus, found in Wyoming shows a row of abcsessed pits as if a carnivorous dinosaur had bitten into the armor and the plate had become infected.

Diseases of the joints, called **arthritides,** are fairly common among the dinosaurs, and are of different types. Perhaps the

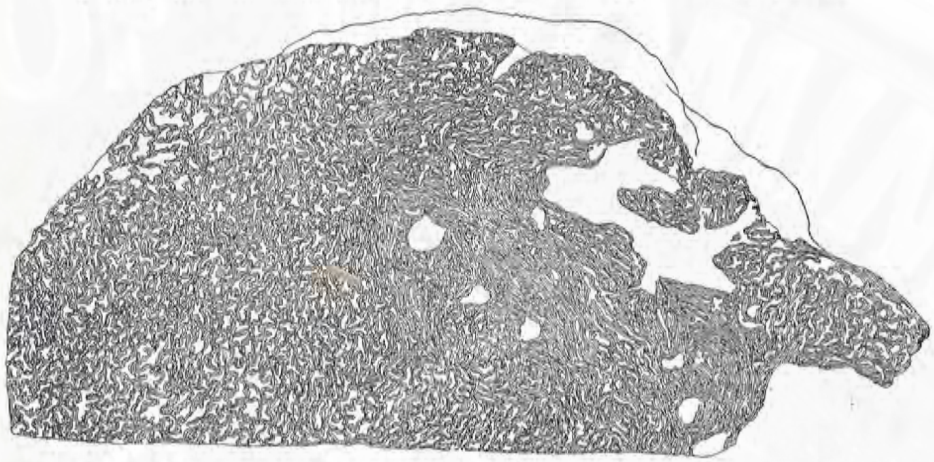

FIGURE 11.

Drawing of a sawn hemisection of the large dinosaur tumor, shown in Figure 14. The dark lines represent bars of bone and the white areas are blood spaces. The tumor is an Haemangioma.

most interesting joint lesion is that of a **tumor** which has united two caudal vertebrae into a solid mass (Figure 14). The specimen was found in Wyoming in the Como Beds, more than half a century ago. The tumor mass, after study, shows all the characters of what medical men call an **haemangioma,** a tumor filled with blood spaces (Figure 16). Its origin may have been due to an injury to the tail, at a point far back from the hips.

The tumor mass resembles closely the tumor-like growths seen on live-oaks. Its mass has invaded the half of each vertebra and entirely filled up the space between the bones. The specimen has a length of 26.5 cm. and a weight of 5.1 kg. The tumor itself is 12 cm. long. Its surface is rather deeply pitted

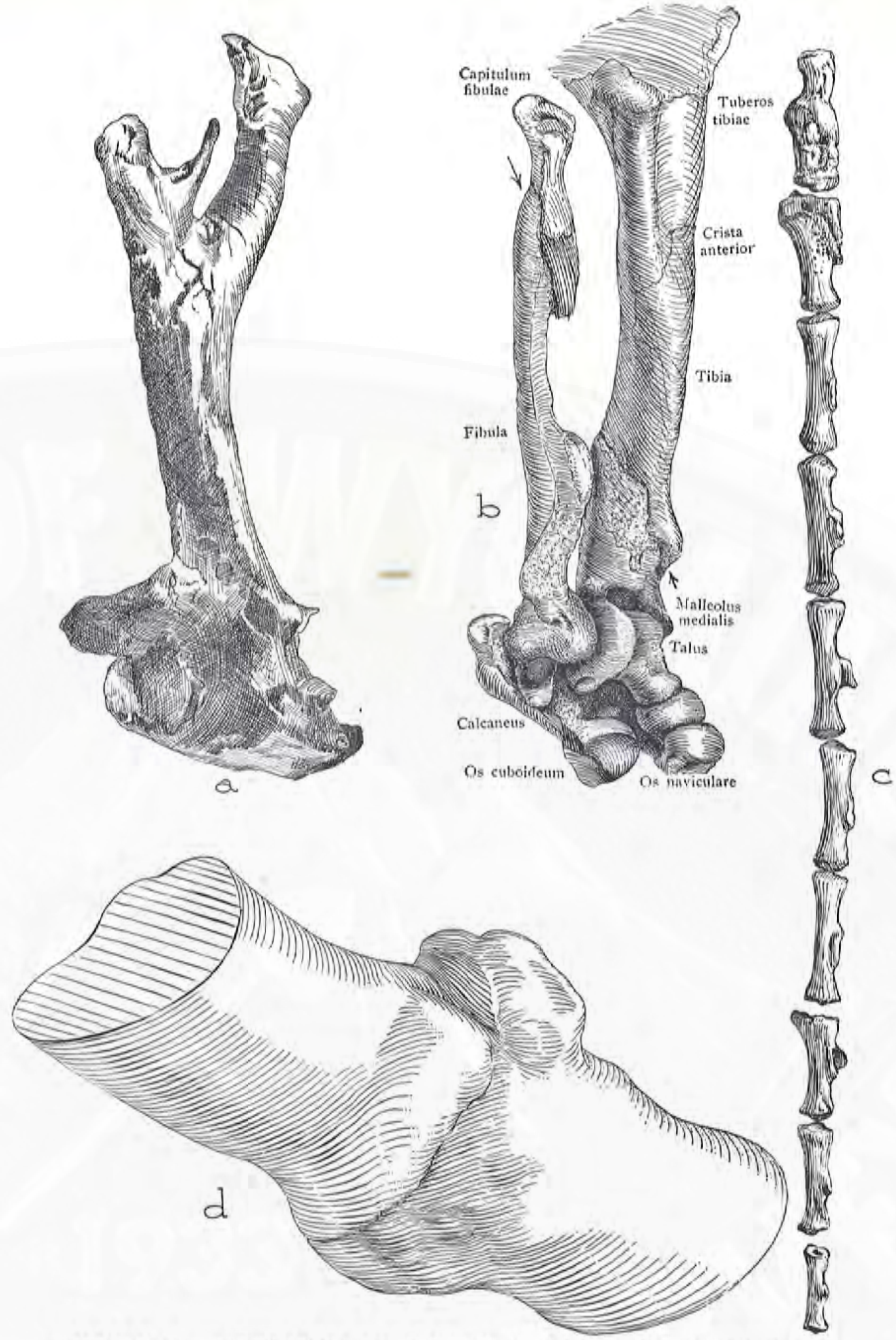

FIGURE 12.—PATHOLOGIC LESIONS DUE TO INJURIES IN DINOSAURS AND A FOSSIL MAMMAL

(a) Shoulder blade and coracoid of a carnivorous Dinosaur. The upper end had been fractured in life, as evidenced by the bifurcated and greatly widened part.—After Gilmore.

(b) Lower leg bones of a primitive, carnivorous mammal from the Miocene of Wyoming, showing an oblique fracture involving both bones. Specimen in the Field Museum of Chicago.

(c) Tail bones of an English Dinosaur, showing diseased areas due to injury.

(d) A fractured rib of one of the huge dinosaurs, Apatosaurus, shown in a skeleton mounted in the Field Museum.

and there is an unusual ventral growth, which is unequal, being larger on one side.

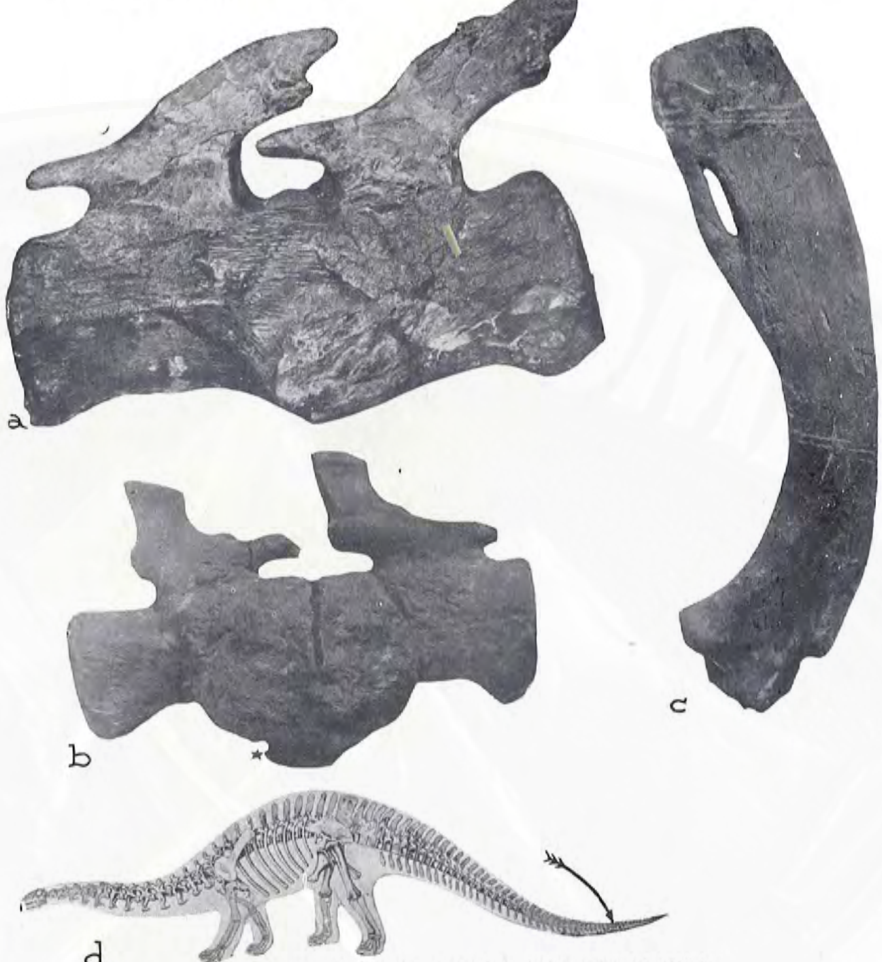

FIGURE 13.—DISEASE AMONG THE DINOSAURS

(a) A diseased joint in the tail of a sauropod Dinosaur.
(b) The Dinosaur Tumor shown in Figure 14.
(c) Dinosaur shoulder blade from Wyoming showing unusual opening.
(d) Outline sketch of one of the huge sauropod Dinosaurs to show, at the arrow, the location of the tumor in the tail.

Sawn sections (Figure 16) show the presence of numerous large and small vascular spaces, which are especially large and numerous near the point where the normal intervertebral space had been.

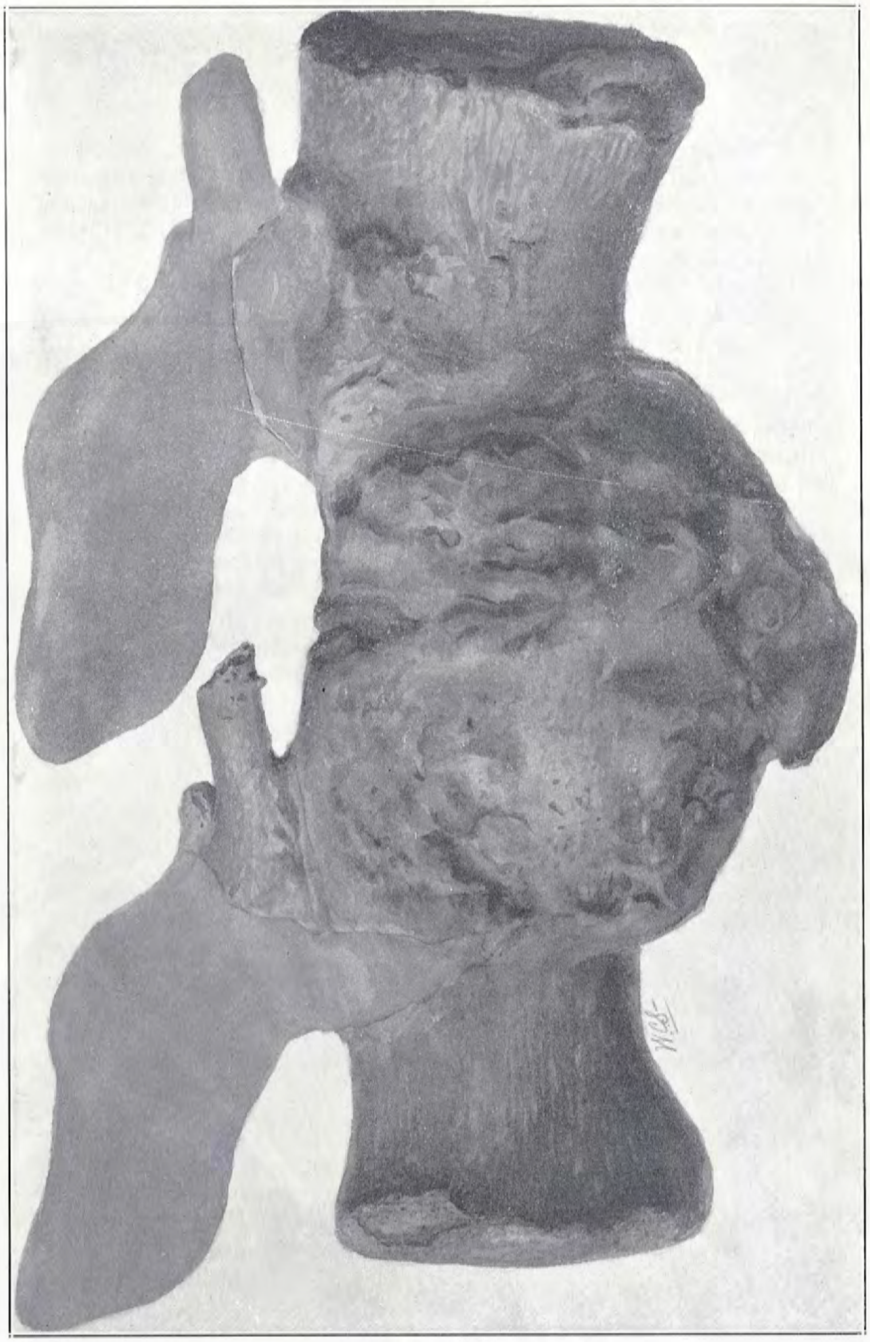

FIGURE 14.

The Haemangioma, or vascular bone tumor, occurs between two caudal vertebrae of a large sauropod Dinosaur, and has firmly united the two bones into a solid mass. The specimen was collected many years ago in the Como Beds of Wyoming, by Dr. S. W. Williston, at the time when these deposits were in the height of their fame as dinosaur quarries.

Microscopical study (Figures 15, 17) shows the presence of scattered lacunae, once occupied by the bone cells; spindle-shaped bodies with short canaliculi. A section of bone taken from the very middle of the tumor shows more compact bony structure than exists at the periphery (Figure 17).

Other accidents to the enormously elongated tail of the amphibious (sauropod) dinosaurs are known, and have been described by Hatcher, Holland and Osborn (Figures 9, 10, 12 c, 13 a, b, d). These injuries indicate that the tail was either dragged over rough ground, was used as a flail, or was used in swimming, or perhaps all three. One type of pathological change often seen in the tail of the sauropod dinosaurs was a thickening, or ossification of the longitudinal ligaments, producing a condition called **Spondylitis deformans,** which is a very ancient diseased condition, known from early Mesozoic times, and extremely common at the present time.

An infected injury is seen in the tail of a large dinosaur mounted in the Carnegie Museum at Pittsburgh.

Lesions similar to those associated with rheumatism are known in the dinosaurs, and some of them had tooth troubles.

A large dinosaur skeleton, mounted in the United States National Museum (Figures 24, 40, a), shows in one hip a huge bone abscess, due doubtless to a bone injury.

A large hook-like exostosis, following an infection, is seen on the inner face of a shoulder-blade of a three-horned dinosaur (Figure 40). The pathological growth was partly covered by muscle, but it may have rubbed against the ribs. Pathological outgrowths exactly like this are often seen on modern human bones.

All together there is a known array of fifteen different types of pathological processes found among Mesozoic reptiles. Some of these conditions are called arthritides, multiple arthritis, arthritis deformans, tumors of two types, necrosis, hyperostoses and various kinds of fractures and slight injuries.

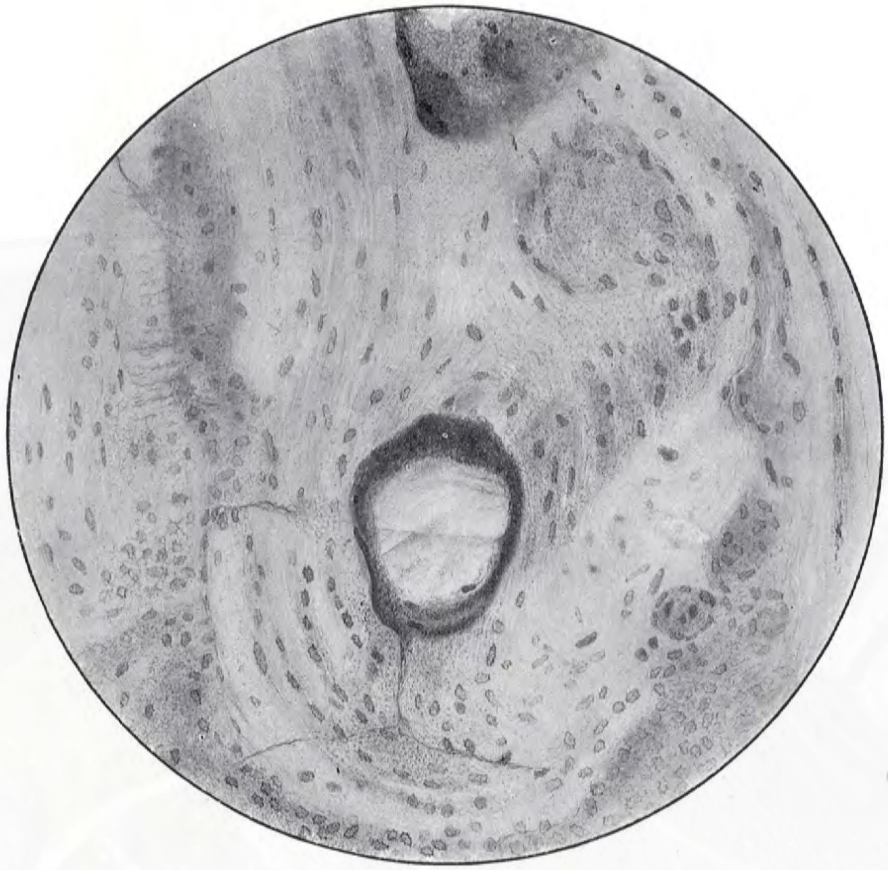

FIGURE 15.

Microscopic study of a portion of the periphery of the large tumor from the tail of a dinosaur, showing the osseous lacunae, with small canaliculi, arranged around a large vascular opening, thus simulating an Haversian system... The lacunae (bone cells) of the dinosaurs are actually much smaller than other animals. Magnified 300 diameters.

CHAPTER XI

Structure of the Bones of Dinosaurs

A single bone of one of the huge sauropod Dinosaurs may show a weight of nearly 1,000 pounds, and a length of nine feet, as they are recovered from the rocks in a highly petrified condition. On the basis of this enormous weight of a single bone it has been stated that the living dinosaur must have had a weight of from 40 to 50 tons, which is far indeed from being the case. When we examine the internal structure of a huge dinosaur thigh bone great open spaces are found, and under the microscope we find a great abundance of spaces, so the bone was quite light. Instead of being an "earth-quaking thunder lizard" with a weight of half a hundred tons it seems quite probable that the largest of them weighed only about 15 tons, and hardly ever came on land at all. It has been argued that they **must** have come on land to lay their eggs; but we do not know that the amphibious dinosaurs laid eggs. They may have given birth to living young.

Many of the more ancient and all of the carnivorous dinosaurs had hollow limb bones, which rendered them less heavy and at the same time very strong. Some of the smaller dinosaurs were so light-boned as to suggest an arboreal, or tree-living life.

Under the microscope dinosaur bone looks very much like the bone of any other reptile (see figures 15, 16, 17). The spaces occupied by the bone cells, lacunae, are quite similar in shape to the lacunae of other vertebrates, though they are somewhat smaller. Arising from the spindle-shaped bone-cells, are slender tubules, called canaliculi, which carried nourishment to the intervening bony substance, or osteoid substance. The presence of abundant osteoid material is characteristic of all of the lower animals below the mammals.

Vascular spaces are exceedingly abundant in dinosaur bones and must have increased the lightness of the skeleton considerably. Such spaces are of various sizes, ranging from those of microscopic dimensions up to huge spaces. At times the arrangement of the bony elements suggests an Haversian system which is so characteristic of the bones of mammals.

No articular caps, or epiphyses, are present in dinosaur bones, so that growth in length and size continued through-

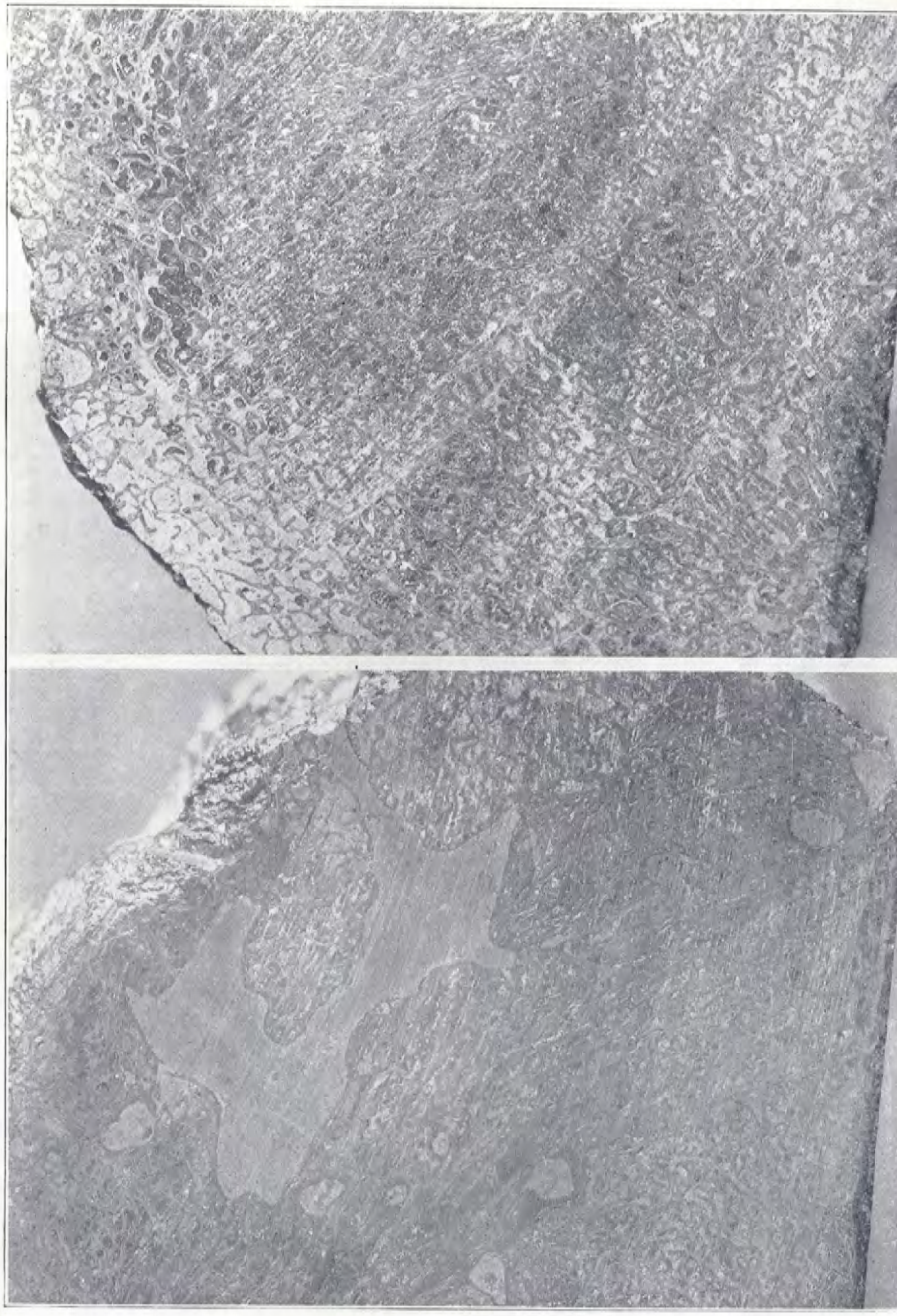

FIGURE 16.

Photographs, slightly enlarged, of vascular spaces seen in the cut surfaces of a dinosaur tumor.

out life. A large-boned dinosaur then is an old one, and the age may have been hundreds of years. They had no enemies of their size, food was abundant and life easy. An age of 1,000 years is not improbable for one of the amphibious dinosaurs. The ends of all dinosaur bones are rough, suggesting the presence of an articular pad of cartilage, from which the end of the bone was nourished.

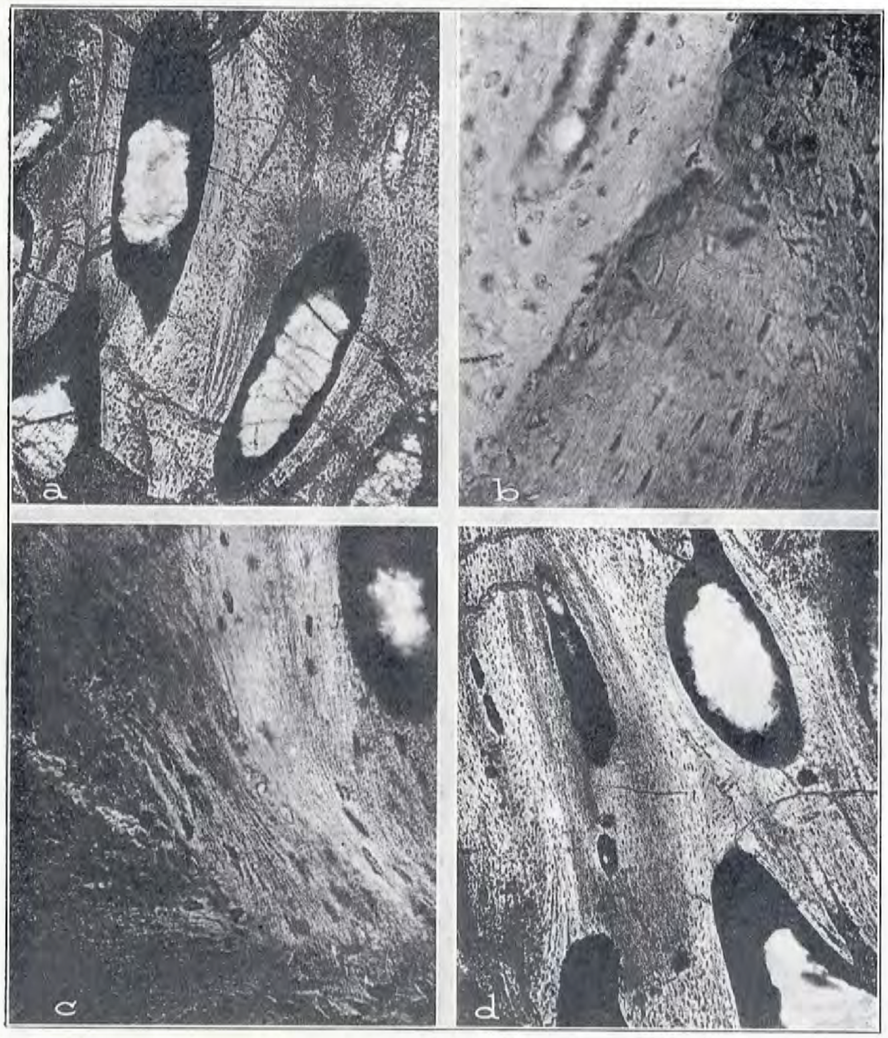

FIGURE 17.

Photomicrographs of normal and pathological dinosaur bone showing vascular spaces and structure of the bone. Magnified.

CHAPTER XII

The "Sacral Brain" of Dinosaurs

The unusual enlargement of the spinal canal in the dinosaurs has long been known and commented upon by various authors, and many attempts have been made to explain the presence, in the sacral region, of a mass of nerve material often many times larger than the brain. It must be remembered, however, that there was a large space around this "sacral brain" and a cast of the cavity in the sacrum is probably twice the size of the actual enlargement in the spinal cord.

The best discussion of this "sacral brain" is that given by Professor R. S. Lull, Professor of Vertebrate Paleontology at Yale University, and I am quoting extensively from his article, "On the Functions of the 'Sacral Brain' in Dinosaurs." The complete reference will be found in the bibliography.

"Branca, in a discussion of the fauna of Tendaguru, East Africa, makes a number of thought-inspiring comments upon the huge sauropod dinosaurs which the formation contains. Among other points he is striving to account for the maintenance of their immense bulk upon a possibly meagre diet by assuming digestive powers of extraordinary efficiency. For this he offers the following explanation:

"One may be inclined to look for the ability to take care of food solely in the stomach, intestines, or liver. However, in the dinosaurs we may take into consideration something else, i. e., the 'sacral brain,' if we look upon the swelling of the spinal column in the sacrum as a 'brain.' According to Waldeyer, it is indeed thinkable that the sacral brain in dinosaurs had a certain independence, and cared for the functions of **nourishment, digestion,** and procreation [bold type mine], also that through a particularly strong innervation it had become especially powerful, more powerful than the strongest digestive organs could be without such a sacral brain. In man there appear still to be traces of this, but here the sacral section of the spinal column is completely surpassed by the brain.

Dinosaurian Feeding Habits

"Our assumption of feeding habits based upon the character of dinosaurian dentition justifies the following conclusions:

"**Theropoda**—These are the carnivorous dinosaurs in a strict sense, with teeth which were in the main prehensile and as such confined to the forward portion of the jaws. They must have been used for rending the prey, for in many instances they are sharp-pointed and compressed, with finely serrated cutting edges. In **Tyrannosaurus** they become so thick that the knife-like edge is gone, so that these huge beasts must have dismembered their prey by tearing rather than by cutting it. These latter theropods are analogous to the crocodiles in dental equipment; **Allosaurus,** on the other hand, possessed a more efficient dentition.

"The digestive system of the crocodile shows the highest degree of specialization of any living reptiles, as the stomach is very muscular, with lateral tendinous discs forming an organ very suggestive of the gizzard of the graminivorous birds. In front of this gizzard-like stomach is a capacious portion of the oesophagus, within which is held the excess of food over the rather small capacity of the stomach. The stomach digestion is highly efficient, due not alone to its muscular power, but to the strength of the gastric juice, so that even the bones of the prey are dissolved and not passed through the intestine, as with certain carnivorous birds like the owls. Crocodiles occasionally swallow stones to aid in the trituration of their food, just as do the graminivorous birds.

"To what extent the gizzard was developed in the Theropoda is conjectural, but it would seem as though its need were nearly as great with them as with the crocodiles. One aberrant type of theropod, from the Belly River formation of Canada, has just been the subject of an authoritative paper by Professor Osborn. This form is now known to have been absolutely toothless, and several theories have been advanced as to its feeding habits—that it was insectivorous, especially ant-eating, or that it fed on small crustaceans or molluscs of the seashore, or that it was ostrich-like in habits, browsing upon leaves and buds which its prehensile limbs drew within the reach of the horn-sheathed mouth. Such an assumption as the last, which bears the weight of Osborn's own opinion, would seem to imply the presence of a more or less efficient gizzard-like stomach functionally comparable to that of the struthious birds.

"**Sauropoda**—The sauropods are clearly of theropod derivation, but it has been pretty generally assumed that they had forsaken the carnivorous habits of their forebears for a vegetative diet, and the tremendous growth of certain plants such as the water hyacinth in the Nile or the waters of New Zealand seems to offer an analogy to what might well have been true of certain aquatic vegetation of the Mesozoic upon which these creatures fed. The teeth were now solely prehensile, sufficiently so for their owners' purpose, but less efficient than those of the Theropoda. The food was in no sense masticated and the inference that a powerful muscular gizzard-like stomach was developed is irresistible, for which the presence of stomach stones, gastroliths, within the ribs of more than one specimen may be taken as added argument.

"**Predentates**—The predentate dinosaurs, on the other hand, had a differentiated mouth armament. The anterior or prehensile portion was toothless, but was sheathed with a horny, turtle-like, cropping beak of varying form. The posterior portion of the jaws bore the actual dental battery, consisting of a series of successional teeth which also varied in efficiency and degree of development in accordance with their owners' food, as do those of the ungulate mammals. The Jurassic and early Comanchian forms were analogous to the browsing ungulates whose brachiodont teeth are fitted to succulent herbage, while the later trachodonts had a dental battery fully as efficient as that of a horse. These dinosaurs chopped their food into short lengths before swallowing, and it may be that the term mastication, which, however, implies a grinding or crushing rather than chopping, may be properly applied to them. Their need of a gizzard-like organ would seem to be less great than in the sauropods.

Stegosaurus, on the other hand, possessed a very imperfect dental battery, as the teeth were both small and relatively few in number—very inadequate apparently for their owner's needs. This genus, however, exhibits a number of characters which, in the Sauropoda, have been taken as indicating an aquatic or at least amphibious life. They are, first, the solid, massive character of the limb bones and the imperfection of their articular ends, those of the stegosaur showing a rugosity fully proportional to those of **Brontosaurus.** The high position of the ribs, bringing the lungs well toward the dorsal side of the body, and the strongly compressed tail with its high neural spines and well developed chevrons are also suggestive. Add to these a mouth armament no more effective than that of a sauropod, and the association of their remains in a common burial, and the inference of similarity of habitus and food is perhaps justified. Just what effect the tall upstanding armor plates would have upon the navigable powers of **Stegosaurus** is not so clear, but they may have incommoded him under such conditions no more than on land.

"It may be fairly assumed, therefore, in view of the wide apparent range of feeding habits on the part of dinosaurs, and their relationship to the crocodiles on the one hand and to the birds on the other, that their digestive system was closely comparable both in the development of its parts and in its innervation to that of these living forms. With the birds, the degree of development of the gizzard varies directly with the consistency of the food. Graminivorous birds possess the strongest muscular layer and the thickest horny lining, while in the series from the insectivorous birds to the birds of prey this condition becomes gradually less marked and the division of labor between the glandular proventriculus and the mechanical gizzard less noticeable (Newton). The assumption of a similar gradation in the development of this organ in the dinosaurs seems also warranted.

Innervation of the Alimentary Canal

"In the reptiles such as the python, crocodile, or turtle, the **vagus** nerve (Xth cranial) is the principal transmitter of stimuli which **initiate** digestive activity, certain of its fibers being distributed to the muscles and mucous membrane of the fauces, the oesophagus, and the stomach, and it finally terminates at the beginning of the intestine at the pancreas.

"Cranial casts of **Tyrannosaurus** and of **Stegosaurus** and **Morosaurus,** representing, therefore, the three main dinosaurian groups, all show exits for the IXth to XIth cranial nerves, thus including the vagus, relatively larger if anything than in the crocodile. It is fair to assume, therefore, that this nerve was at least as well developed in the dinosaurs and that its distribution and function were comparable.

"**Birds**—The vagus (X) of birds arises behind the glossopharyngeal (IX) and is connected therewith as well as with the sympathetic system. After receiving branches from the hypoglossal (XII) and taking up the spinal accessory (XI), the vagus runs down the side of the oesophagus to the ventral side of the proventriculus, where, joining its fellow from the other side, it spreads out to supply the stomach. Other branches, leaving the principal stem of each vagus, supply the liver, heart, and lungs, and, as the recurrent laryngeal branch, also supply the distal portions of the trachea and oesophagus. Some fibres of the vagus often extend beyond the stomach, and are connected with the sympathetic nerves of the trunk, supplying parts of the intestinal canal.

"The approximate agreement in the innervation of both birds and crocodiles is further argument for dinosaurian innervation.

"Certain of the spinal nerves (dorso-lumbar) communicate with the sympathetic system and thence with the alimentary canal, but their function, in so far as it has been observed, principally in man and certain mammals, is **inhibitory,** and hence the reverse of a stimulus to digestion. Such sacral nerves as do pass to the alimentary canal are distributed to the hinder portion only, beyond the glandular or digestive part. They are stimulating, not inhibitory nerves, but their function is merely the elimination of faecal matter and is in no other sense digestive.

"The stomach in the mammal at least is largely automatic in its movements, as is the heart, and while its activity may be initiated or inhibited by impulses from the vagus or sympathetic nerves, the stimuli which cause the rhythmic movement originate in the muscles themselves, for this movement will continue after the severance of all nerve connection with the cerebro-spinal or sympathetic centers. The reptilian heart is notorious for its automatic contraction after its excision from the body, and in all probability the heart and stomach of a dinosaur were fully as automatic.

"All of this seems to show that we have no right in assuming for the dinosaur an innervation or functioning of the alimentary canal at variance with the standardized type of the living amniotic vertebrates.

"The spinal canal of **Stegosaurus ungulatus** has been studied in detail. Not only a sacral dilatation but a **brachial** one as well; that is, from vertebrae VIII to XIII, the maximum width, that of 38 mm., as compared with the average of 25 mm., is attained by vertebra XI, which is exactly opposite the shoulder articulations in the Yale mounted specimen. There is also a corresponding heightening of the canal, although this is a less constant feature, for further back (XV and XVII) there is evidence of a ligament or other delimiting structure below the the bony roof of the neural arch itself. Brachial and sacral dilatations of the neural canal are most marked in the turtles among existing reptiles, owing to the immobility of the trunk and the consequent reduction of its musculature and associated nerves, the two enlargements being necessary where the nerves depart to the limbs. That this is the whole significance of these two enlargements in **Stegosaurus** and also in other dinosaurs I have no doubt, and the relative size of each dilatation bears an approximate ratio to that of the limbs innervated, plus in the hinder pair the huge caudo-femoral and other muscles which actuated the tail.

"I still feel, despite the contention of the German writers, that the 'sacral brain'—which should not be called by such a term—possessed no unusual function whatever, but only the normal one of transmission and reflex action in an unusual degree, and that to invoke any new and unknown function as a reason for its relatively immense size, especially one connected with digestive efficiency, is not justified by the evidence at hand.

"Branca further says: 'We may also think of these animals as sluggish in habit, in consequence of which much less food was required than is the case in an active animal.' On the other hand, in warm-blooded animals the largest species occur in cooler climates, because large animals have 'a relatively smaller radiating surface than smaller ones, a factor of the greatest importance in the regulation of body warmth.' To the first statement I can take no exception. The second, however, gives food for thought. In the first place, is it an invariable rule that the largest species of warm-blooded animals occur in cooler climates? The present-day distribution of the elephant, hippopotamus, and rhinoceros does not bear this out, and even in the Pleistocene the largest elephants, such as **Elephas imperator,** were southern forms compared with the smaller, cold-adapted **E. primigenius.** With marine creatures Branca's statement seems more nearly true, for the walrus and huge sea-elephants are both adapted to cold waters, and the same is true of the right whales, **Balaena mysticetus** and **B. australis.** The sperm whale, on the other hand, is tropical or subtropical, not occurring, except accidentally, in the polar regions (Flower and Lydekker), while the great rorquals (Balaenoptera) are found in all seas except the Arctic and probably the Antarctic also. Of the deer, perhaps the largest living form is the Alaskan moose, while no bears in existence can compare in magnitude with the great Kadiak bear of the same region. But this argument loses weight if the dinosaurs were not warm-blooded, and though the supposition that they were has been advanced, it is not susceptible of proof. It is within the range of possibility that the temperature of the more agile dinosaurs rose appreciably during the time of their activity, as in many of the so-called cold-blooded (poikilothermous) creatures today, but whether or no any dinosaurs had a mechanism for even a partial maintenance of temperature is unknown. If their bodily heat varied with that of the surrounding air, the greater bulk and hence relatively smaller radiating surface would render them less susceptible to rapid temperature changes, and thus prolong their time of activity by tiding over a brief drop in temperature, but would hardly be available in an extended cooler period. That increase of size in dinosaurs was an adaptation for the conservation of energy, and in this way reduced the relative amount of nourishment necessary for their maintenance, seems hardly probable."

A duck-billed dinosaur feeding on the edge of an ancient Wyoming swamp.

CHAPTER XIII

Dinosaur Mummies from the Upper Cretaceous Rocks of Niobrara County

Travellers and residents on the high plains are accustomed to seeing the sun-dried carcasses of stock, with the dried flesh and hide shrunken and stiff against the bones and usually with the body torn open by scavenging birds, coyotes and dogs. Thus we have all the settings for a Mesozoic scene, if we replace the horses and cattle by dinosaurs.

Scientists had long known something of the nature of the scaly skin in patches over isolated areas of the fore limbs, so it was an interesting discovery which the fossil hunters, Charles H. Sternberg and his son George F. Sternberg, made while working in the Upper Cretaceous deposits of Niobrara County, Wyoming, which had already been made famous by the prolonged and successful explorations of J. B. Hatcher for horned dinosaurs.

It was in the lowest levels of this series of rocks that the younger Sternberg made the remarkable discovery of a specimen of a duck-bill or trachodont dinosaur (**Trachodon annectens**), almost complete, encased in the impression-cast of its skin. Fortunately, before the excavation had proceeded far the nature of the skin markings was recognized and the parts were all carefully preserved. This specimen, found in August, 1908, was purchased by the American Museum of Natural History, and has been beautifully figured and described by Professor Osborn (1912). Two years later the Sternbergs discovered another dinosaur "mummy" and that was secured by the Senckenberg Museum of Frankfurt, Germany.

When the first mummy was found the hind feet as well as the posterior part of the pelvis and the entire tail had been eroded away, although it seems probable that the entire body was fossilized. The body lay on its back with all the bones connected; the knees drawn up, the chest opened and upturned. The front legs are outspread, and the head and neck sharply twisted downward and backward to the right side. The dorsal frill of scaly hide is turned to the left.

The attitude of the body is that of an animal which had died a natural death, and had not been torn to pieces by scavenging animals. The shoulder blades are pressed tight to the sides of the ribs and are doubtless in their normal, living position. The breast bones are pulled away from the other bones and the chest sunken in. It is probable that after a natural death the body lay exposed to the drying action of the sun for a long time undisturbed, possibly in a low, flat, sandy area commonly seen in modern rivers at the low water stage. The soft parts of the body thus became thoroughly dried out by the hot sun and dry air, so that the skin becoming hard and leathery had shrunk against the bones, being tightly drawn against all hard surfaces. On the under surfaces of the body the dried skin was drawn within the body cavity, and thrown into creases and folds along the sides of the body and on the arms, because of the drying out of the internal tissues (Osborn).

> "At the termination of the low water season during which this process of dessication took place, the 'mummy' may have been caught in a sudden flood, carried down the stream, and rapidly buried in a bed of fine river sand intermingled with sufficient clayey elements to take a perfect cast of all the epidermal markings before the epidermal tissues became softened under the solvent action of the water." (Osborn).

It had, of course, long been assumed that the dinosaurs being reptiles had a scaly, horny skin, probably highly colored, like the modern lizards and crocodiles. When the dinosaur "mummy" was uncovered it was surprising to note the small size of the scaly tubercles, which are no larger than those seen on modern lizards. The skin itself was not preserved, but a detailed, brilliant cast of the epidermal covering was made over a large part of the body. It was noted that the fore-feet were webbed, being covered with a scaly hide in which the tubercles are both large and small, a condition which prevails throughout the body. In no part of the body, however, are there any evidences of overlapping scales. The skin was tuberculate. For such a large animal the skin is exceedingly thin and the tubercular, epidermal markings are exceedingly fine and delicate. Even the largest tubercular markings on the dinosaur skin are no larger than those seen on the head of the Gila Monster, a large lizard whose skin resembles that of the trachodont dinosaur.

Along the sides of the body there are certain "cluster areas" which were more abundant and heavier on the back near a dorsal frill or fold of tasellated hide. There is no color pattern preserved on the "mummy" but there are indications that there was a pattern and that the back of the animal was dark and the belly light as in modern reptiles.

CHAPTER XIV

Footprints of Dinosaurs

Tracks in the rock are always interesting, and dinosaur tracks especially have attracted a great deal of attention. In fact a distinct science, called **Ichnology,** has grown up around the study of fossil footprints. When three-toed tracks were first found in the red Connecticut Valley sandstone, they were regarded as bird tracks, and some of the early discoveries were said to have been made by "Noah's Raven." Dinosaurs were not known at that time.

These fossil footprints are exceedingly abundant in the rocks of the Newark Series, Triassic, of the New England states, and thousands of specimens have been collected, and stored in a number of the eastern educational institutions.

After the nature of the dinosaurs was somewhat understood from their skeletal remains, the nature of the numerous kinds of tracks was better appreciated. Professor Lull of Yale University has revised our knowledge of the footprints in the light of new information. Certain of these tracks are shown in the accompanying figure.

Large three-toed tracks, probably dinosaurs, have been seen* in Utah, but none occur in Wyoming in any quantity, so far as known, although they may confidently be expected.

A Sauropod Footprint

Professor R. S. Lull says of the only known sauropod footprint:

> "Through the courtesy of Dr. Holland, I have been able to study somewhat critically an undoubted sauropod footprint from the Morrison dinosaur quarry at Canon City, Colorado. Hatcher figures a cast of this track in his memoir on the osteology of **Haplocanthosaurus.** The figure is somewhat deceptive, however, in that it was taken from a plaster cast of the specimen which in turn is a natural cast of the original impression made by the living animal and which is therefore in relief. The surface of the specimen itself is covered with deep pits caused by a solution of the calcareous cement which bound the grains of sand together, thus allowing the latter to be washed out. In the photograph the casts of these pits, being in relief, give the impression of pebbles, whereas the rock in the quarry is a fine-grained, cross-bedded sandstone of uniform texture, without appreciable clay, and not gravelly at all. A microscopic study

* Natural History, xxvii, No. 3, p. 256, figure, 1927.

of the sand-grains themselves show them to be angular with slightly abraded corners, sand of aqueous deposit; but apparently laid down in a lake or bayou, rather than in a normal river as indicated by the absence of clay and the presence of a lime cement. The cross-bedding which the rock exhibits could readily have been made by wave action along the shores of a comparatively shallow delta-lake or bay, and the track, which

FIGURE 17A

Fossil footprints of three-toed Dinosaurs from the Newark series, Triassic, of the Connecticut Valley. These are preserved in Yale University Museum. Note the small tracks in larger slab.—Courtesy of Professor R. S. Lull.

is that of a very young animal, was evidently made under water. The character of the sediment does not give evidence of much vegetable matter at the particular point where the track was made. The footprint is that which one would expect from the known character of the sauropod foot, and is evenly impressed throughout as though the animal's weight were borne equally over the entire sole, evidence in favor of a true walk rather than a sprawling crawl, at any rate when the body was partly water-borne.

"I believe these animals to have been truly aquatic though capable of coming ashore where the substratum was sufficiently firm to support the immense weight, and, while they show no trace of swimming appendages, they doubtless could swim as a hippopotamus does."

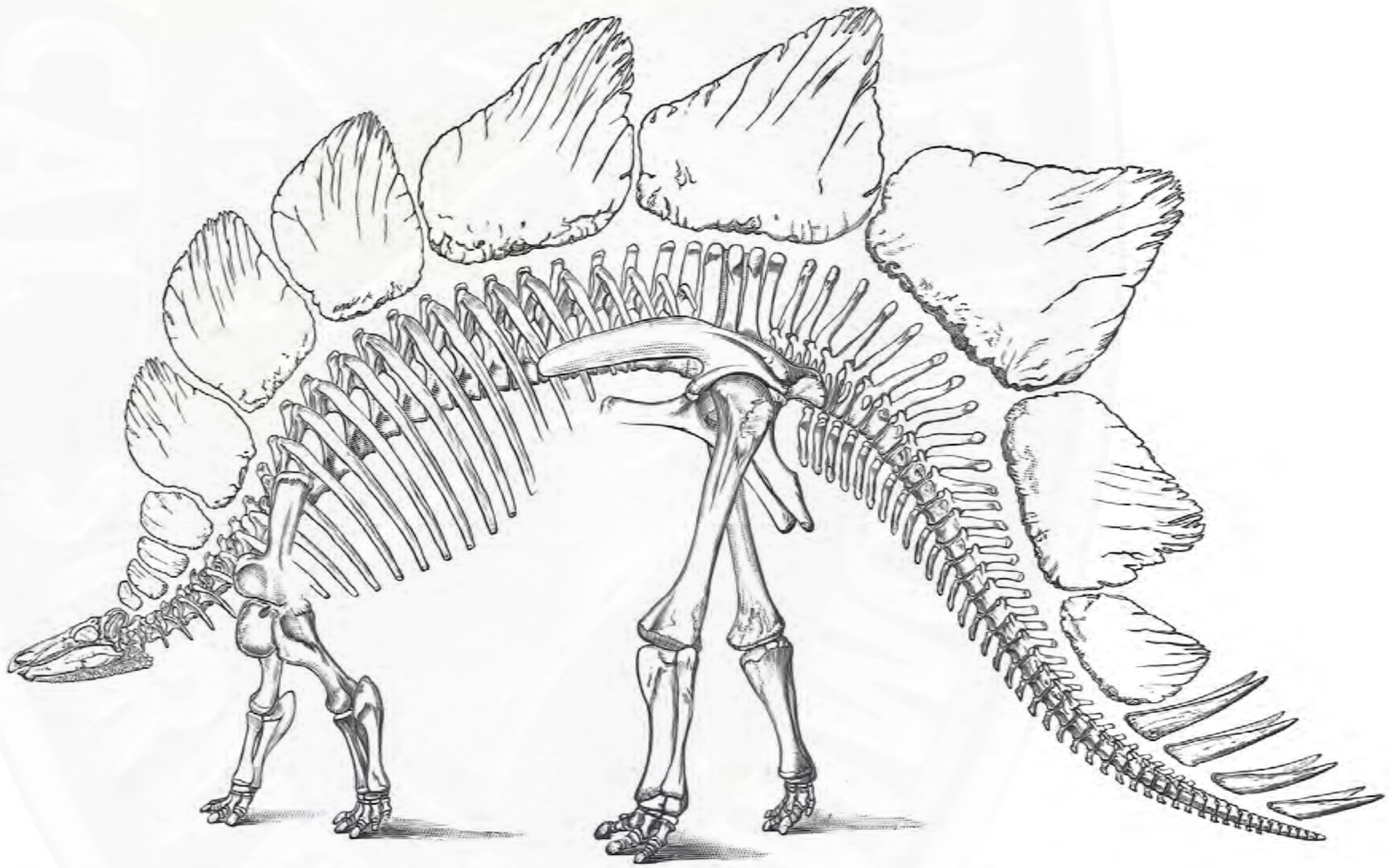

FIGURE 18.

A Restoration of the armored dinosaur, Stegosaurus ungulatus, made by Professor O. C. Marsh soon after its discovery. The two skeletons used in making this restoration were discovered at Como Bluffs, Wyoming, in 1877. The skeleton as now mounted at the Peabody Museum, Yale University, is composed of the two specimens.—After Lull.

CHAPTER XV

The Armoured Dinosauria in Wyoming and Elsewhere

Stegosaurian dinosaurs were first made known in 1877 by Professor O. C. Marsh. Although numerous armored dinosaurs are known, both in America and abroad, yet none is so well known as the genus **Stegosaurus,** which is the best known of them all. The osteology has been described by Marsh, Lull and Gilmore. A species of the **Stegosaurus (S. stenops** Marsh), is fully described by Gilmore from a nearly complete specimen found at Garden Park, Colorado.

Armored dinosaurs, incompletely known, have been found in marine deposits, showing that these animals lived near the sea. I have told in the Preface about the discovery of **Stegopelta** near Lander, in the black, Cretaceous (Hailey) shales and Wieland has told of finding other armored dinosaur material in the Niobrara (Cretaceous) chalk.

The armored dinosaurs of the Red Deer River, Canada, Cretaceous, as collected for the American Museum of Natural History by Barnum Brown, are most wonderfully protected of all known dinosaurs. One of them, called **Paleoscincus,** is known (Figure 25) from practically perfect material. The true skin of the animal was not preserved, but before disintegration had set in an "impression cast" of it was formed in the matrix, containing also the hundreds of small, bony nodules which were embedded in the skin. In the skin were set at intervals, in more or less regular arrangement, the larger flat plates and spines. **Paleoscincus** was a huge armored reptile with a broad, short body, massive legs, thick, heavy tail, and a small, flat-topped, triangular skull. The teeth of this creature are quite like those of other armored dinosaurs. Rings of heavy bone surrounded the tail, like some fossil creatures from South America.

European armored dinosaurs are not so well known as are the American species, of which **Stegosaurus ungulatus** and **S. stenops** are known from exceptionally perfect skeletons. An interesting armor of one of the English dinosaurs consists of a heavy bony shield over the hips, consisting of a mosaic

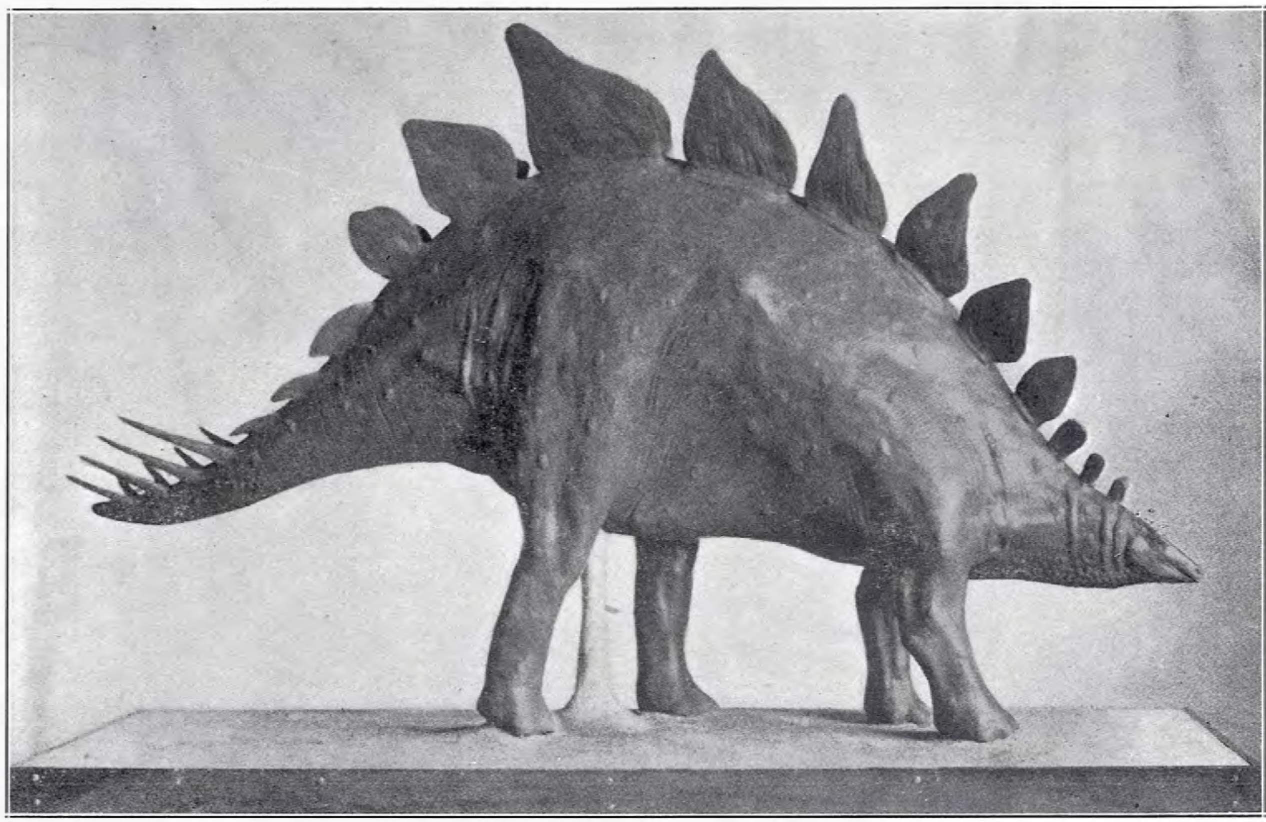

FIGURE 19.
A model showing the probable appearance of the Stegosaurus, based on the mounted skeleton. Modeled by R. S. Lull.

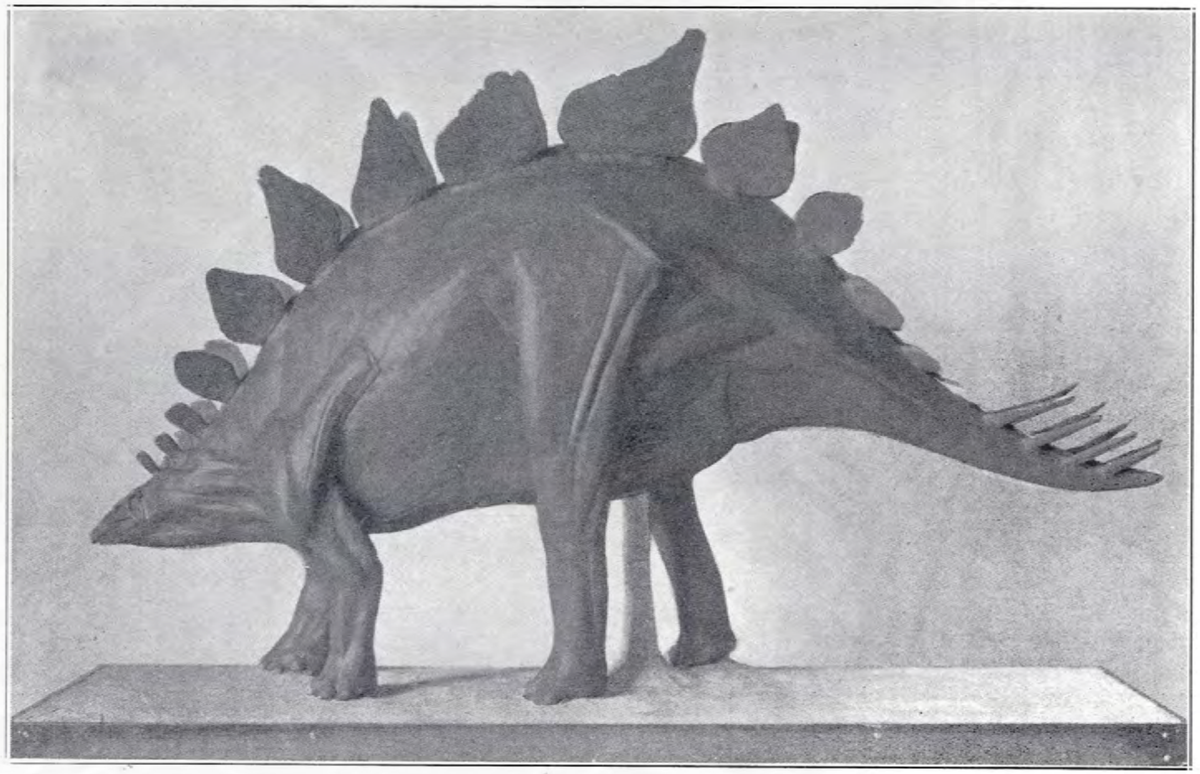

FIGURE 20.
The superficial muscles of the left side of the Stegosaurus based on the mounted skeleton. Modeled by R. S. Lull.

of pentagonal, osseous plates, highly ornamented and looking somewhat like the body armor of some of the glyptodonts found fossil in South America.

All armored dinosaurs are plant-eaters, the anterior "beak" being provided with a horny sheath for cutting off leaves, twigs and succulent stems, as in the three-horned dinosaurs. Often the entire group are spoken of as "the beaked dinosaurs." The duck-billed dinosaur, **Trachodon,** with its amaz-

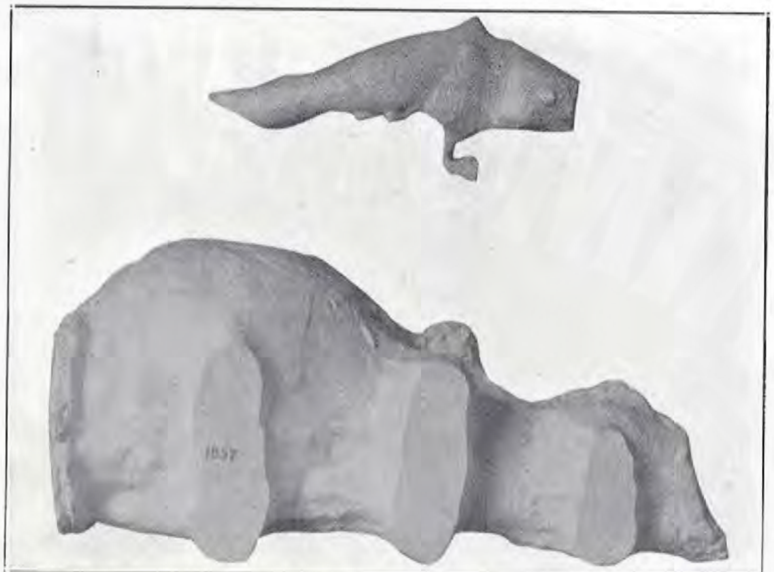

FIGURE 21.

Casts of endocranial and sacral cavities of the Stegosaurus, showing proportions of brain (above) and sacral intumescence (below). The casts are actually one-third larger than the mass of nerve material. One-third natural size.—After Lull.

ing dental armature of nearly 2,000 teeth, is likewise a member of the same group, the Predentata.

Stegosaurus is one of the dinosaurian gems of Wyoming, the mounted skeleton at Yale University Museum having been collected at Como Bluffs. The animal presents many peculiar anatomical features, foremost being the remarkable proportions of the body, with the sharply arched vertebral column, short neck, small head, lank, narrow body and extremely long limbs. The tail did not droop abruptly; was probably held high off the ground; and served as an effective weapon, equipped as it was with long, sharp spines. The structure of the entire skeleton was modified to support the heavy armor. The fore-limbs are very powerful; immense rugosities on the bones indicating heavy muscular attachments. The hind limbs are pillar-like, and while powerful are not so strong as the fore limbs.

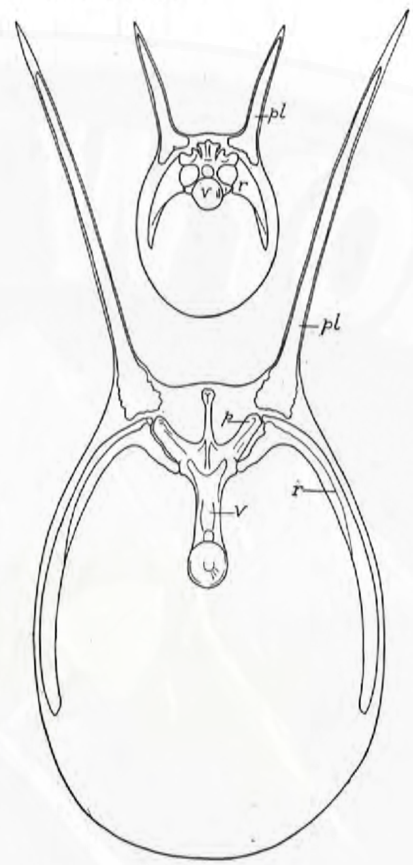

FIGURE 22.

ABOVE: Section of neck of Stegosaurus, showing relation of armor plate to backbone.
BELOW: Section of body.
pl=plate; r=rib; v=vertebrum; p=transverse process
—After Lull.

The backbones were especially modified to support the large, heavy, paired armor plates, of which there were several. The processes on the vertebrate are lengthened and thickened, and the entire back strongly arched upward, thus producing a strong support for the armor. The ribs are T-shaped

FIGURE 23.—A STEGOSAUR IN WYOMING, MILLIONS OF YEARS AGO.

The most extraordinary feature of this animal was the row of thin plates on either side of the middle line of the back, and the long, heavily armored tail.—After Brown.

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at the points where they meet the backbone, being thus modified to support the great weight.

The feet are large, as if adapted to walking in soft sand or other yielding material. The hand possessed five digits, while the foot possessed three well-developed digits, all doubtless encased in a fleshy pad as in modern elephants.

Teeth are confined to the back of the mouth, as in all "beaked" dinosaurs. They are small and weak, with wavy margins. Their food was doubtless very soft, requiring little mastication.

The brain in this dinosaur is the smallest in proportion to the size of the animal of any known vertebrate, recent or ancient.

The brain and spinal cord are remarkably interesting in that curious, nineteen foot armored dinosaur called **Stegosaurus** (Figure 21). The internal casts are actually larger than the central nervous system, because no reptile brain fits the brain case closely.

The stegosaurian brain is remarkably small, being of less size than an egg of an English sparrow. The entire cranial cavity has a length of less than half an inch, a width of about one-fifth of an inch. The brain cast displaces 56 cc. of water, and had a total estimated weight of two and one-half ounces. The total weight of the entire animal, in life, must have been two or three tons at least so that the brain of an elephant is fifty times the size of the dinosaur.

On the basis of brain weight the stegosaur had no intelligence at all.

The stegosaur brain has a very large olfactory portion, small cerebellum, large medulla, and a hypophysis which is remarkable (Figure 21) not only for its size but also for the peculiar shape.

As we go backward along the spinal cord we find two swellings, intumesences; one at the region of the shoulder, the brachial enlargement; and the other at the hips, "the sacral brain." The former is evident for a space of about four joints.

The neural canal in the sacrum is truly astonishing in size, being more than twenty times the size of the true brain. The "sacral brain" measures in length 1.14 cm., in width 0.95 cm., and displaces 1200 cc. of water.

Professor Lull writes thus of the Armament of this reptile:

> "The exoskeleton of **Stegosaurus** included five types of structure, of which the first consists of small rounded ossicles found in one instance in position beneath the throat. The known armor of the back consisted of four distinct forms of plates in each of which the dorso-ventral diameter is enor-

mously developed, and often the antero-posterior one as well, instead of a normal horizontal expanse, the result being the production of huge upstanding plates arranged in pairs on either side of the median line of the neck, trunk, and proximal part of the tail, while immense bony spines, possibly varying in numbers with the different species, were borne on the distal end of the latter. The plates are differentiated in that those borne upon the neck are short in fore and aft diameter but with

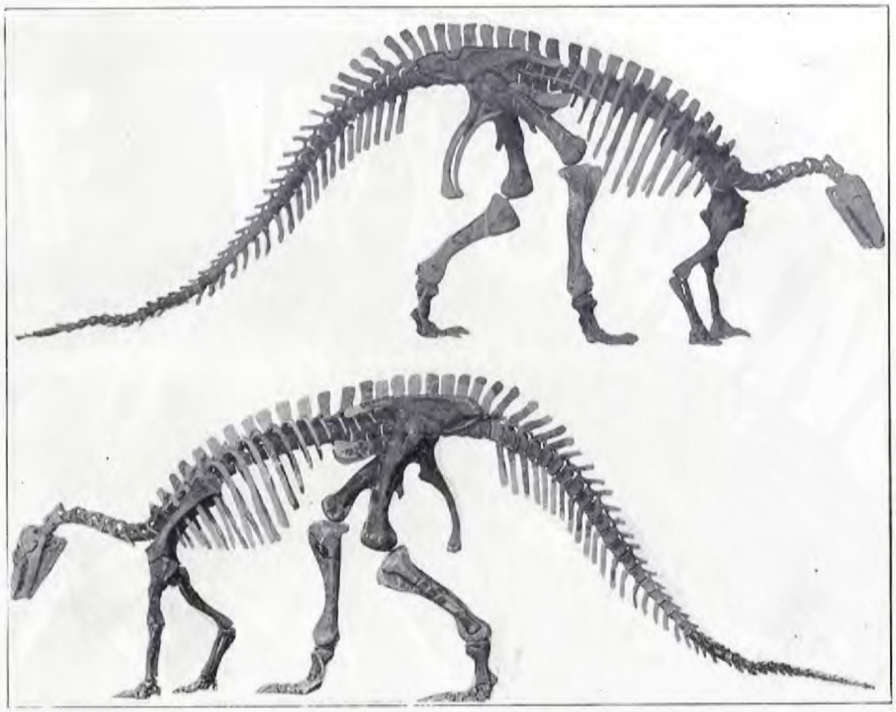

FIGURE 24.

Two sides of a predentate dinosaur skeleton, mounted in the U. S. National Museum. Similar to the stegosaurus but without armor.—After Gilmore.

a heavy base divided longitudinally by a depression which was borne astride the transverse processes and cervical ribs. The trunk plates increase rapidly in dimensions to a maximum size of 71×66 cm. (=28×26 inches) and a weight of 40 pounds for the pair borne over the pelvis. Here the base was thick and rugose but without the longitudinal cleft. These plates were borne above the transverse processes and the proximal portion of the ribs until the sacrum was approached with its widely expanded neural spines to which the weight was transferred, the two rows of plates approaching each other more nearly than in the more anterior region.

"This same type of plate, though with a base somewhat

FIGURE 25.—RESTORATION OF THE PALAEOSCINCUS, A CANADIAN DINOSAUR.
A huge and slow-moving reptile with massive armor, designed for protection against the gigantic carnivorous dinosaurs. Restoration by E. M. Fulda, 1921.—After Matthew.

shortened and at the same time much broader, was borne over similar neural spines on the anterior third of the tail. Here the character of the nueral spines abruptly changes, the broadened summits being lost and the whole spine very much reduced in height. This point, which marks the beginning of the aggressive, flexible portion of the tail, marks also an abrupt

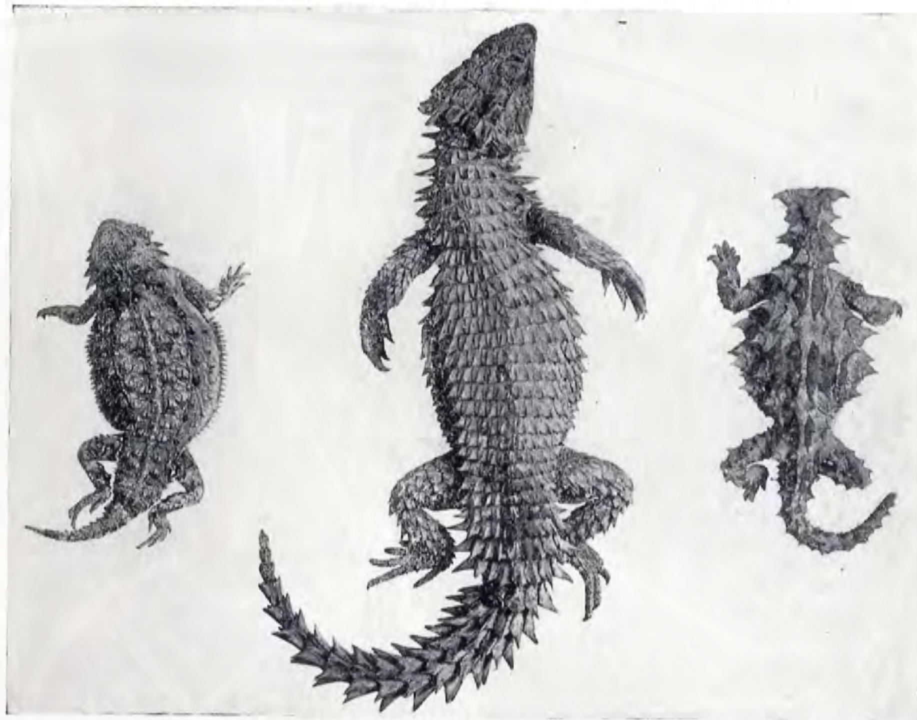

FIGURE 26.

Three modern lizards which, save in their diminutive size, are suggestive of the Palaeoscinus of the Cretaceous Period. The "horned toad" to the left is nearest in proportions. The "spiny lizard" in the center and the "Moloch lizard" to the right also have some points of resemblance. The figures are about two-thirds natural size. Were the little modern lizards as large as a hippopotamus, they would be monsters almost as strange as the long-extinct armored dinosaurs.—After Matthew.

change in the character of the plates, which are now sharp-edged, pointed and bent backward, the base being embedded in the muscles between the neural spines and the vertebral centra. The sharp-edged plates, of which there are three pairs, are followed by four pairs of long spines similarly attached and pointing outward and backward at a decided angle. The longest of these is 25 inches and its present weight 14¼ lbs."

The life conditions and relationships of that most bizarre dinosaurian reptile, **Stegosaurus**, are thus discussed by Lull:

"The genus **Stegosaurus** is confined exclusively to the Morrison formation, upper Jurassic or lower Cretaceous of Wyoming. . . . The character of the environment was probably similar to the conception offered by Hatcher, who believed that the Morrison beds were deposited 'over a comparatively low and level plain which was occupied by an interlacing system of river channels. The climate was warm, and the region was overspread by luxuriant forests and broad savannas . . . conditions doubtless similar to those now found about the mouth of the Amazon and over some of the more elevated plains of western Brazil.' In spite of the numerous remains of plant-feeding animals, the actual relics of fossil plants are relatively few, nor does the sediment in which these remains are found give other evidence of abundant vegetation. Hatcher's inference of 'luxuriant forests' is, therefore, as yet unproved by direct evidence.

"The water areas, as has been shown, were doubtless the dwelling places of the huge contemporaneous Sauropods, while **Stegosaurus** was terrestrial and possibly frequented the forests in search of the tender but luxuriant vegetation upon which it browsed. It may well be that the extreme relative narrowness was an adaptation to forest conditions and afforded ease of passage between the trunks of the tree ferns, conifers, and other vegetation of that day. **Stegosaurus** is rarely found entombed with sauropod dinosaurs, but, on the contrary, is often found isolated or in company with the bipedal unarmored herbivorous **Camptosaurus**, the nearest equivalent of the European **Iguanodon**, and with the fleet **Dryosaurus**; and of carnivores, the agile **Coelurus** and the blood-thirsty **Allosaurus**, which was probably its greatest enemy.

"I imagine much of the bizarre character of the armor of **Stegosaurus** was due to the over-specialization accompanying racial old age, but it was nevertheless in many respects admirably adapted to meet on a more or less equal footing the huge well-armed carnivore last mentioned. It would seem as though **Stegosaurus**, instead of presenting his front to the enemy, turned the rear, possibly crouching low in front as the crocodile does, and, with vigorous sweeps of the terrific tail, impaled the exposed ventral portion of the bipedal carnivore upon the caudal spines and sharp-edged plates.

"The long hind limbs imply a rather rapid progression, while the powerful fore limbs were not only for locomotor purposes but for rapidly pivoting the body to prevent either a frontal or flank attack.

"Of the evolutionary history of **Stegosaurus**, we know but little. It seems, however, to have been a migrant from Europe, having its nearest relative in **Omosaurus**, remains of which are known as far back as the Dogger of England.

"In **Omosaurus durobrivensis** from the Oxfordian of England, which I studied this summer in Cambridge and in the British Museum of Natural History, I find what may readily be a direct ancestor of the American types. The plates and

FIGURE 27.

Protected by thick plates and massive spines, this great armored dinosaur, the top view of which is shown in the picture, must have been a veritable super-dreadnaught of the animal world. Observe the rows of large plates in the neck region and fore part of the trunk.—After Matthew.

spines are present, and, in every respect, the older animal differs only in being of a more generalized character. On the other hand, **O. armatus** of Owen, from the Kimmeridgian, though nearer **Stegosaurus** in time, is less like it than is its predecessor in the rocks. **O. armatus** would seem, therefore, to belong to a different phylum, in many respects more conservative than the true stegosaurs.

"That **Stegosaurs** belonged to the predentate dinosaurs and to the armored Stegosauria, is certain. It is not, however, in the direct line of descent, but rather an over-specialized side branch, which was apparently totally blotted out after Morrison time, despite the fact that most of its associates, except the Sauropoda, lived on.

"The spinescent character of **Stegosaurus** is of course indicative of racial senility, but the modernizing of the flora and the restriction, doubtless, of the special food plant to which the feeble mouth armament was adapted, may have been the immediate cause of extinction."

CHAPTER XVI

The Amphibious Dinosauria

The amphibious dinosaurs are known to paleontologists as members of the Sauropoda (Figure 4). These were the **giant** reptiles, tall of body and extremely long. They were the **largest** land animals which ever lived, being exceeded only in bulk by some of the modern whales. The sauropod dinosaurs were all four-legged, with the hind legs usually the larger, but one genus, called by Riggs the **Brachiosaurus,** had longer fore limbs. The head was very small (Figure 30), with blunt teeth. The neck was long and slender, with an elephantine body and a long tail, which in one genus, **Diplo-**docus, stretched out into an almost unbelievable slender length, justifying the term "whip-tail" dinosaur (Figure 31). We believe the body to have been covered by a coarse, rough, but not scaly hide, of great thickness. Like the elephants they had five short toes on each foot, probably buried in life in a large soft pad, but the inner toes had large claws, blunt like those of modern turtles, one in the fore foot, three in the hind .oot.

Sauropod dinosaurs had a world-wide distribution, but in spite of this their appearance is geologically abrupt. We assume that they were derived from some of the carnivorous dinosaurs, because the theropods, as the carnivores are called, were predecessors of the sauropods. The sauropods had a short existence, geologically, being confined to the closing portions of the Jurassic and the Lower Cretaceous, in a period called the Comanchean. Many carnivorous, armored, and beaked dinosaurs lived at the same time with the sauropods, and are found in the same strata of rocks.

Skeletons of various amphibious dinosaurs are mounted in a number of the larger natural history museums. One of the largest skeletons mounted in the American Museum of Natural History in New York City was discovered near Medicine Bow, Wyoming. It is sixty-six feet long and when alive some paleontologists think the animal may have weighed about thirty-eight tons. It is seldom the case that such huge bodies were buried and fossilized and collected in a perfect condition, so that mounted skeletons are usually a combination of two or more individuals, and even then some of the mounted bones are made of plaster. The task of discovering, collecting, cleaning and mounting a huge dinosaur skeleton is one of great difficulty, and may extend over a period of several years. The bones are so fragile that in order to keep them from breaking of their own weight, which in their fossilized state is considerable, special supports and braces must be used.

FIGURE 28.

Bone Cabin Quarry, Wyoming, with camp in background. In the group of workers are Messrs. Lull, Granger, Schneider, and Kaisen.—After Matthew.

It was a matter of much thought and study to determine just what positions the huge bones of these amphibious reptiles assumed in life. They are so entirely unlike other creatures that no one was sure whether the sauropods sprawled as do the crocodiles, or walked uprightly like the elephants do. As far as the backbones and ribs were concerned there was little doubt, because the articulating surfaces were well worn and clearly marked. The huge limb-bones, however, offered only roughened areas, as if the articulations had been cartilaginous. A comparative study of muscles, muscle attachments and limb attitudes among many of the recent reptiles was made, and these conditions compared and applied to the dinosaurs. The results were that an upright, quadrupedal attitude was assigned to the sauropods, and this position has now been generally adopted.

The bodily proportions and general appearance of the large sauropodous dinosaurs was totally unlike anything previously known. It had a long, thick tail like the lizards and crocodiles, a long, flexible neck like an ostrich, a thick, short, slab-sided, bony body, and straight, massive, post-like limbs suggesting the elephant, and a remarkably small head for the size of the body. The head was about the size of that of a horse, with slender ineffective teeth, which must secure food in enough

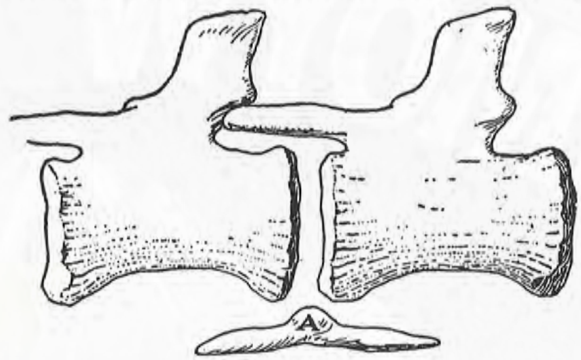

FIGURE 29.

Two normal bones from the tail of a sauropod dinosaur with the ventral arch or chevron, marked "A."

quantity to nourish the enormous bulk twenty-five feet away. Only in a swampy, warm region where water plants grew abundantly could such a situation be met. An animal of such size as the **Brontosaurus**, must have required several hundred pounds of food daily.

Although the limb bones were very heavy, as were the ribs yet the backbone was so hollowed out that it was comparatively light. We may suppose that the heavy limbs acted as weights to hold the reptiles on the bottom of shallow water, where the creatures could feed, and reach air at the surface by using its long flexible neck. If the animal needed to take an extended view of the landscape it was possible for it to rear up on its strong hind legs, and using its tail as a prop, derive benefit from his fifty foot high observation point. The heavy limbs, acting as weights, would anchor the creature more or less securely for such acts.

The brain was comparatively very small, considering the size of the reptile. A cast of the brain case, small though it is, was still larger than the actual brain. We can hardly speak

FIGURE 30.

Restored outline of an amphibious dinosaur to show, in black, the relative proportions of the central nervous system—the brain and spinal cord, with the sacral intumescence.

of intelligence in an animal so inadequately equipped with nervous material. The brain, so called out of courtesy to its location in the head, doubtless functioned merely as a mass of reflex centers. Its huge unwieldy size, its gigantic food requirements and its inadequate food-getting mechanisms were undoubtedly critical factors in the extinction of this type of the dinosaurs, which did not survive beyond the Lower Cretaceous.

Wyoming localities furnishing parts of the **Brontosaurus** skeleton mounted in the American Museum, are Nine Mile Crossing of the Little Medicine Bow River, Como Bluffs, and the Bone Cabin Quarry. Another dinosaur of this group reaching a length of 87 feet, was also found in Wyoming.

A number of writers, notably Williston, Wieland, and Brown, have discussed the significance of certain smooth,

rounded pebbles found associated within the ribs of certain Mesozoic reptiles. These are often of rock which could only have been secured at a considerable distance from where they were found. Such pebbles are now called "gizzard stones," "stomach stones," or "gastroliths." Wieland in his discussion of the sauropod dinosaur **Barosaurus**, says:

> " . . . various pebbles of a singular smoothness were noted at only one point close to the main group of dorsals. As the specimen was incomplete the reasonable explanation that these were stomach stones, or as later called, dinosaurian gastroliths, did not then occur to me, their true character being first recognized in examples from the Big Horn mountains."

It is well known today how certain birds and reptiles swallow stones to aid in digestion. I noted a similar habit among the horned toads which feeding on ants had added various quartz pebbles to its stomach contents. So far the amphibious dinosaurs are the only ones known to have had this habit.

CHAPTER XVII

The Carnivorous Dinosauria and Their Food Problem

The flesh-eating dinosaurs all possess sharp, flattened, saw-toothed, cutting teeth and sharp claws on all four feet. The fore-limbs are always small, incapable of functioning in locomotion, so that the theropod dinosaurs were bipedal, walking or leaping with their powerful hind legs, using the heavy tail as a support, just like modern kangaroos. This group of dinosaurs has had the longest history of any of the dinosaurian groups, and they have a wide range in size—some being quite small and slender, others large and powerful. The Theropoda are the stem group of the Dinosauria.

The largest and most powerful of the many kinds of carnivorous dinosaurs is that elephantine giant **Tyrannosaurus rex,** whose skull is over four feet long (50 inches), and the jaw has a height of 35 inches. The teeth are flattened, sharp and numerous. Its body was more than forty feet long and doubtless had a weight of many tons. It was the most powerful engine of destruction in the animal world. Five skulls and complete skeletal material are preserved in the American Museum of Natural History. One of the skulls was secured in the Upper Cretaceous of Niobrara County, Wyoming, and the other material from the Hell Creek Beds of Montana (Upper Cretaceous).

The theropodous dinosaurs were the makers of the abundant three-toed footprints (Figure 17a) which are found in the Triassic of the Connecticut Valley. These dinosaurs ran nimbly about like birds, setting one foot nearly in front of the other, so that the prints of the right and left feet are nearly in a straight line.

Another well-known carnivorous dinosaur from Wyoming is that form called **Allosaurus,** with a hind limb taller than a man, measuring over thirty-four feet long and with a height of over eight feet. This skeleton, shown mounted in the American Museum, feeding on an amphibious dinosaur, has an interesting history. It is a Wyoming treasure, collected in October, 1879 in the Como Bluffs near Medicine Bow at the richest locality for dinosaurs, by Mr. F. F. Hubbell, working for Professor E. D. Cope of Philadelphia. The skeleton was never unpacked by Cope and it lay in its original packing cases for twenty years, until after the acquisition by the

FIGURE 32.—THIS FORMIDABLE DINOSAUR, THE LARGEST OF THE CARNIVOROUS FORMS, WAS SOME 40 FEET IN LENGTH.

It must have presented a most imposing sight as it stalked about in search of food. The great 5-foot jaws were armed with long and sharp teeth, capable of tearing the tough skins of such antagonists as the great Triceratops of the same period. This latter creature could not escape by running away, and so was forced, no doubt, to back into some dense forest growth whenever possible, presenting merely its sharp-horned head to its adversary.—After Brown, National Geographic Magazine.

American Museum of the entire Cope collection. A few years later when the specimen was finally unpacked in New York it was found to be an exceptionally fine treasure—a paleontological gem, for complete skeletons of fossil vertebrates are quite rare.

Carnivorous dinosaurs are always rare—much more so than those of the amphibious type, occurring in the same beds. A **Brontosaurus** skeleton, obtained in the Bone Cabin Quarry, shows several bones, especially the spines of the tail bones (Figure 34), scored and bitten off, as though by some carni-

FIGURE 33.—A LARGE CARNIVOROUS DINOSAUR FEEDING.
—After Lucas.

vorous animal which had either attacked the brontosaur when alive, or had feasted on the carcass. When the **Allosaurus** jaw was compared with the marks on the brontosaur bones, it was found to fit them exactly, the spacing of the scratches being the same as the spacing of the teeth. Moreover, on taking out the brontosaur backbones from the quarry, a number

FIGURE ?4.

Part of the tail of a large amphibious dinosaur, Brontosaurus, showing grooves and scratches cut by the teeth of carnivorous dinosaurs on the neural spines and on the body of the backbone joint in the center. The cuts were made after the death of the amphibious dinosaur. Specimens in the American Museum of Natural History. Collected in Wyoming.—After Osborn.

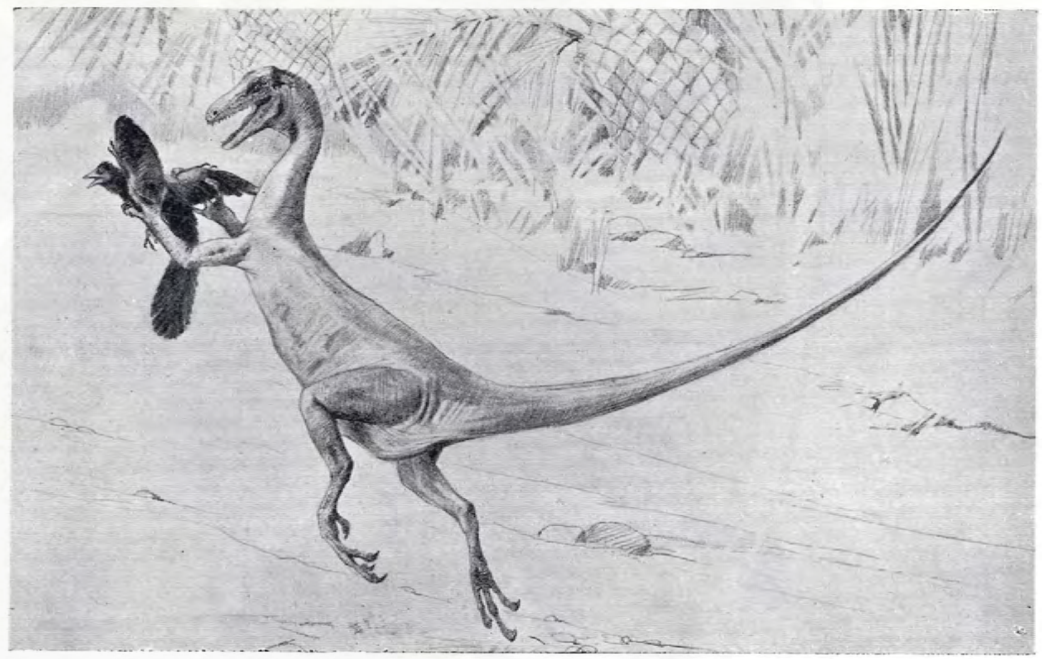

FIGURE 35.—A SMALL, ACTIVE DINOSAUR, ABOUT FIVE FEET IN HEIGHT, FOUND IN WYOMING.

The picture shows one capturing an ancestral bird whose jaws contained sharp teeth like those of a lizard.
—After Brown.

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of broken off teeth of the allosaur were found lying alsongside them, possibly broken off while feeding (Matthew).

A striking contrast with the ponderous allosaur and tyran-

After Osborn, from a drawing by Charles R. Knight.

FIGURE 36.—THIS GREAT CARNIVOROUS DINOSAUR HAS BEEN KNOWN FOR SOME YEARS PAST, BUT ONLY RECENTLY HAS A COMPLETE SKELETON OF IT BEEN PLACED ON EXHIBITION.

The creature is depicted feeding upon the remains of a Brontosaurus, whose actual vertebrae, chiseled by the sharp teeth of some similar creature, are placed beneath the mounted skeleton in the American Museum. Collected at Como Bluffs, Wyoming.—From Brown, National Geographic Magazine.

nosaur is found in a slender, agile small carnivorous dinosaur, called **Ornitholestes** or bird-catcher, a skeleton of which was secured by the American Museum from the Bone Cabin Quarry in Wyoming. The forefoot has long, slender, clawed digits which may be supposed to have been useful in catching

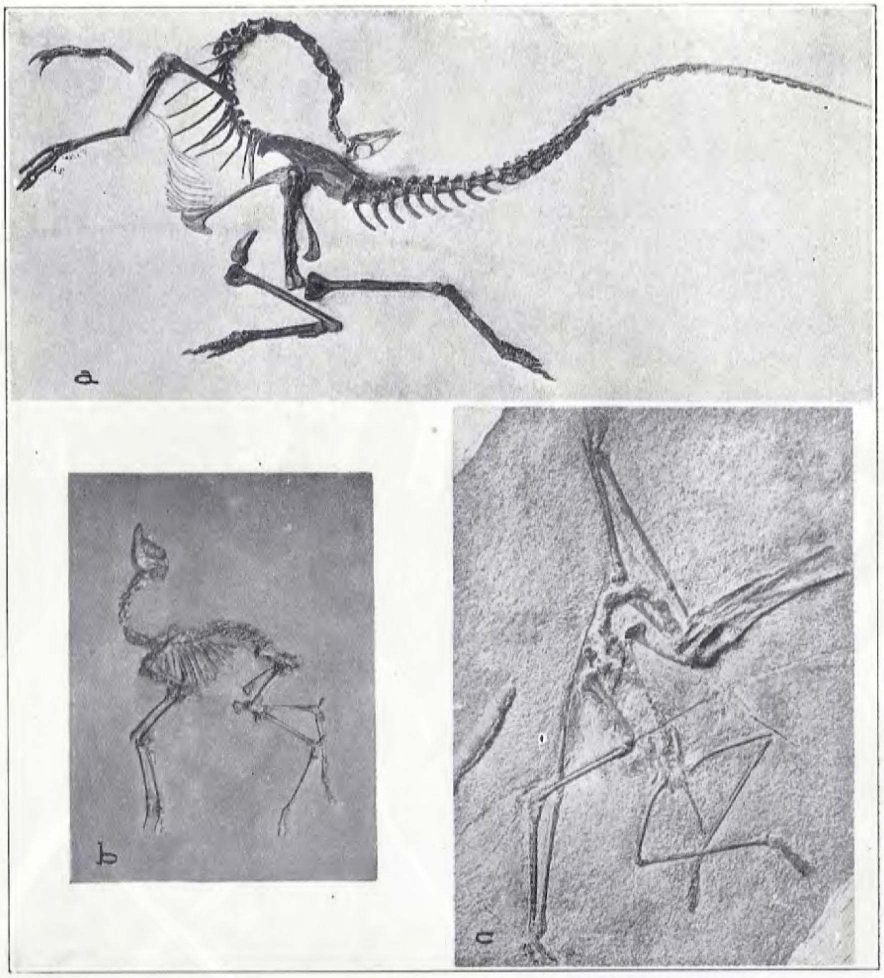

FIGURE 37.

Skeletons of three fossil vertebrates showing the position of the skeleton at death, in the attitude known as Opisthotonos, due to the death spasm or to a neurotoxic condition. The attitude may be indicative of disease.

a=A toothless dinosaur, Struthiomimus altus, from the Cretaceous of Alberta, Canada, as mounted in the American Museum of Natural History. The structure of the body is like that of other small, carnivorous dinosaurs, but the toothless mouth, with jaws probably sheathed in horny plates, indicates an entirely different food habit. The animal was a swift runner, like the ostrich, and the short fore-limbs were used for grasping. The animal may have fed on leaves, insects or small shore-dwelling animals.

b=A small Miocene camel in opisthotonos. Preserved in Carnegie Museum at Pittsburgh. Collected in Western Nebraska.

c=A flying reptile of the Mesozoic, living around the seas and probably feeding on fish.

small prey, reptiles, birds or mammals, whose remains are found mingled in the Mesozoic rocks with those of the dinosaurs.

During the Cretaceous period, the closing stage of the Mesozoic or Age of Reptiles, a number of other small or medium-sized carnivorous dinosaurs have occurred, apparently living in the same areas with the larger kinds. In appearance these small dinosaurs must have looked like two-legged lizards, running and walking on their hind legs, with the long tail stretched out behind to balance the body. Their footprints show that they walked or ran with a narrow treadway.

They did not hop like many modern birds, but walked steadily like the waders. When they rested, the weight of the body was on the legs, and tail.

A related dinosaur, completely toothless, called **Ornithomimus,** is known from the Cretaceous of Alberta, Canada, (Figure 37a). The limbs are long and slender; a long neck; small head and toothless jaws, all of which render this dinosaur singularly bird-like.

The food of the carnivorous dinosaurs was doubtless the living vertebrates of the times, or their dead bodies, for it is probable that these flesh eaters were carrion-feeders. The amount of food required by individual dinosaurs depended upon the activity, temperature and degree of hunger. None of the amphibious dinosaurs were active enough to escape a determined carnivore, but their safety lay in their taking to water, the carnivorous dinosaurs being dwellers of the uplands. The carcasses of the sauropods, however, if drifted ashore offered food for the theropods. The duck-billed dinosaurs were in a similar case. The three-horned dinosaurs were protected well enough to resist attacks from in front, but were susceptible to flank or rear actions. A twenty-five foot **Triceratops,** if attacked by two 48-foot tyrannosaurs, would have little chance of escape, and so long as such huge supplies of meat were at hand the carnivores throve. It is conceivable that the huge quantities of flesh needed by **Tyrannosaurus** was a handicap toward extinction, in the face of a diminishing supply.

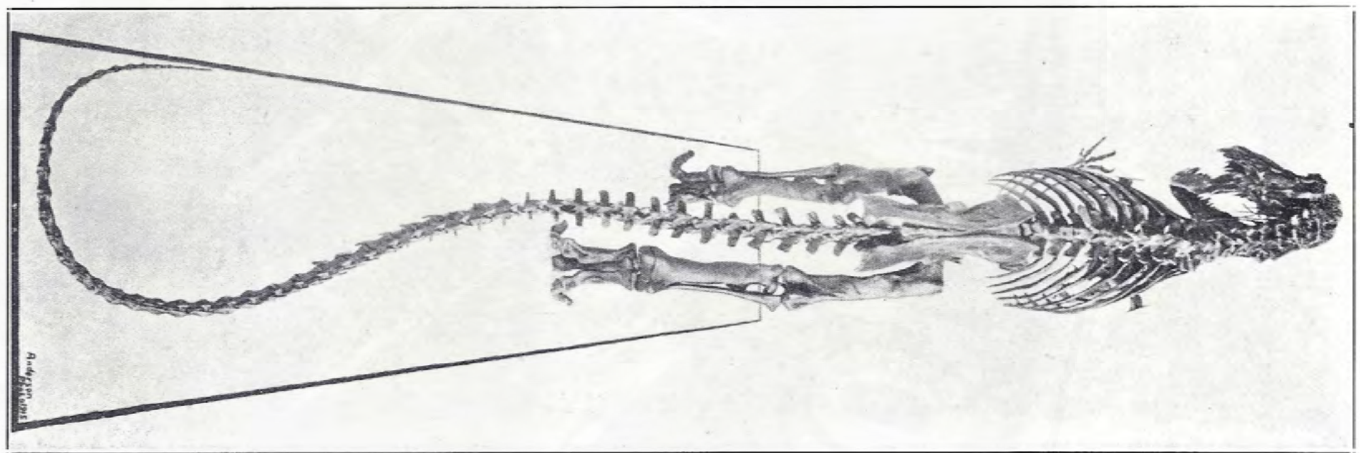

FIGURE 38.

Rear view of the hugest of all the carnivorous Dinosaurs—the skeleton of Tyrannosaurus rex, as mounted in the American Museum of Natural History.—After Osborn.

CHAPTER XVIII

The Three-Horned Dinosaurs

In Niobrara County, Wyoming, there are great beds of sandstone containing the bones of reptiles and some plant impressions which tell of the nature of life during the closing stages of the Age of Reptiles (the Mesozoic) followed shortly

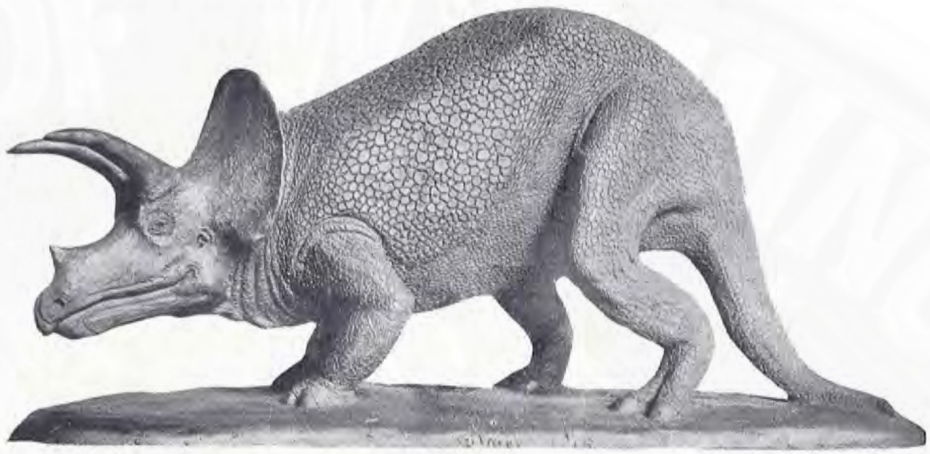

FIGURE 39.

Photograph of a model of an adult, three-horned dinosaur as exhibited in the United States National Museum. The body was covered, probably, with large, horny plates or scales, and the head frill and horns were also covered with horny material, rendering the spines and horns longer and sharper than they appear in the fossils. The long beak, with its horny sheath, was used for securing the plant food, possibly assisted by a long tongue. A weight of many tons is attributed to this dinosaur, for it differs from other dinosaurs in being an upland animal, and its bones are more solid and heavy. The elephantine feet were equipped with hoofs and the creature was four-footed, as distinct from other kinds of reptiles.

The three-horned dinosaurs were the last of their kind to disappear. For hundreds of thousands of years these slow-witted creatures languidly existed, ate and grew fat, until the time they ceased to exist, nobody knows why. But shortly before the beginning of the Age of Mammals they became extinct. Such a wholesale and mysterious destruction of large groups of big animals has happened many times in geological history. Something may have occurred which made it harder for them to fill their big stomachs with proper, nourishing food, and they dwindled away.—Courtesy of Charles W. Gilmore at the U. S. National Museum.

by the Age of Mammals. This somewhat desolate region, as it appears now, was in the Age of Reptiles clothed in luxurious vegetation, the climate and altitude at that time being favorable for plants which now grow much nearer the equator. Large sandstone concretions bearing the fossilized bones of

FIGURE 40.—DISEASE AND INJURY AMONG THE DINOSAURS.

a=Right pelvis of a dinosaur whose skeleton is mounted in the U. S. National Museum, showing at the arrow a huge necrotic sinus, the result of a long-standing infection, following an injury. The animal is called Camptosaurus, and was secured in the Cretaceous of Wyoming.

b, c=Two views of the shoulder blade of a three-horned dinosaur showing a diseased growth of bone on the inner surface, a hook-like exostosis, the origin of which is problematical. Although this growth was doubtless covered, in part, by the sub-scapular muscle, yet it must have caused inflammation along the ribs, and possibly even in the lung sack. The bone is about three feet long and was secured in the Upper Cretaceous of Wyoming.—Courtesy of Charles W. Gilmore.

dinosaurs, yield the information that the huge three-horned dinosaurs, the Ceratopsia, were exclusively plant feeders—stood upon four stumpy legs and had the hugest bony bonnet of any creatures which ever lived. Dull-witted these huge-headed reptiles must have been with a two-pound brain lodged in a thousand pound head. They didn't need much brain, for their lives were not complicated. They ate, they slept and very occasionally they fought—but mostly they slept. Life was easy in those Wyoming-Mesozoic days; food abundant, and enemies few. The carnivorous dinosaurs could have fed full upon the body of a **Triceratops,** for here was tons and tons of meat and bone—could they have gotten it.

Triceratops was tolerably well provided for offense and defense. Its huge horned head, with its extensive bony frill would ward off most attacks, without damage to itself, provided the enemy could be met head first. Attacks on the flanks, however, by hungry carnivorous dinosaurs could not so easily be repelled. Turning to meet such an attack must have been somewhat time-consuming. Injuries on head and body show that such attacks were made, but we cannot tell how many such attempts were successful; and then it may be that the gigantic flesh-eaters were carrion feeders. A herd of the Tyrant-King dinosaurs could have caused wide-spread desolation among the animal life of the Upper Cretaceous—but perhaps they were more sluggish than we anticipate. A small brain in a fifty-foot animal does not suggest much activity—and perhaps one full gorge of meat would last the King dinosaur a week or two.

Cope's collection of fragmentary dinosaurian material made in 1875 and 1876, now in the American Museum of Natural History, formed the starting point in our knowledge of the great three-horned dinosaur group, although Cope did not recognize the existence of the sub-order—Ceratopsia. This was done by Marsh on more complete material secured by Hatcher. Leidy had much earlier described some dinosaur teeth collected in this area by the geologist Hayden in 1855.

In the autumn of 1888 J. B. Hatcher found a pair of very large horn cores thirty-five miles from Lusk, Wyoming, looking so like the horn cores of bison, that Marsh described a new species of bison based on dinosaur horn cores; but at that time no one had dreamed about the existence of the Ceratopsia, as the group of three-horned dinosaurs are called. Early the next spring, 1889, the discovery of the horn cores led Hatcher to the discovery of the great dinosaur-bearing locality in Niobrara County, Wyoming, the collections from which enabled Marsh to define the three-horned dinosaur group, and here

FIGURE 41.—INJURIES AMONG FOSSIL VERTEBRATES.

a=A pair of dinosaur horn-cores, the right one having been broken during life and healed over with new bony growth. Possibly an instance of a fight in the Cretaceous times. Specimen in the U. S. National Museum.

b=A diseased camel foot bone.

c=Leg of a giant turtle which had been bitten off, and healed over.

Hatcher worked from 1889 to 1892, collecting in the four years there half a hundred specimens, several of them fairly complete skeletons.

Horned dinosaurs were discovered also in Colorado, Canada and in Montana, but no locality in the State of Wyoming has equalled the Niobrara County deposits, a history of whose discovery is given by Hatcher in his monograph on the Ceratopsia.

So interesting and important, to lovers of Wyoming, is the history of the discovery of the great deposit of three-horned dinosaurs that we may quote Hatcher's account of the "Discovery of well preserved Remains of Ceratopsia in Converse* County, Wyoming." Prior to this discovery the three-horned dinosaurs had been known only from isolated teeth and fragmentary skeletons.

Hatcher writes:

"In the summer of 1888, under the direction of Prof. O. C. Marsh, I undertook an expedition for the purpose of collecting vertebrate fossils in the Judith River badlands of the upper Missouri River, a locality already rendered classic by the researches of Hayden, Leidy and Cope. While this expedition was not especially successful, 14 boxes (about a ton) of rather fragmentary material was procured, including the skull fragments figured by Marsh and made the type of the new genus and species **Ceratops montanus,** for which a new family, Ceratopsidae, was at the same time proposed. Notwithstanding the fragmentary nature, the remains demonstrated the presence of horned dinosaurs in these deposits, a fact which had been previously suspected by Cope. At the same time they threw much new light on the affinities of the material previously collected by Hayden, Cope, Cannon and others.

"After passing two months in the Judith River badlands with very indifferent success, in the early autumn of the same year (1888), at the instance of Professor Marsh, I proceeded to southern Wyoming to investigate the remains of a fossil vertebrate discovered by Mr. Louis Lamotte, just south of the Seminoe Mountains, on the west side of the North Platte River, about 1 mile from that stream and 40 miles below Fort Steele. These remains proved to belong to the Ceratopsidae, although this was not then suspected by me. There were present parts of the skull, vertebrae, ribs and other portions of the skeleton, all in such a fragmentary and decomposed condition as to render their determination impossible, in the light of what was then known of these dinosaurs.

"After spending some time in this vicinity in a fruitless search for more perfect remains, I decided to abandon this locality and proceed to the White River badlands, lying east of the Black Hills in South Dakota, and pass the remainder of the season in making still further collections of the fossil mammals so abundant in that classic locality. While en route I

* Now Niobrara County.

stopped at Douglas, Wyoming, and there met a former acquaintance, Mr. Deforest Richards, afterwards governor of Wyoming, now deceased, who introduced me to Mr. Charles A. Guernsey. This gentleman, having a general but enthusiastic interest in matters relating to natural history, and especially to geology and paleontology, had, through a long residence in the country as manager and owner of the 'Three-Nine' cattle ranch, succeeded in bringing together a considerable collection of fossils. On inspecting this collection, through the kindness and at the request of Mr. Guernsey, I was impressed with its value, for it contained many specimens of great perfection and beauty, and only a glance was needed to show that the entire lot had been brought together with great judgment and discrimination, such as are rarely seen in amateurs and such as might with profit be emulated even in some of our public museums, especially in their exhibition series.

"Among the many interesting things in this collection I was at once struck with a fragment of a very large horn core. This fragment was about 18 inches long and perhaps 8 inches in least diameter at the base, which was hollow, the cavity being filled with a hard, brown sandstone closely resembling the sandstone concretions that are so abundant in the Laramie. On inquiry Mr. Guernsey informed me that the specimen had been taken from a skull several feet in length which had been found by his ranch foreman, Mr. Edmund B. Wilson, completely embedded in a hard sandstone concretion, weighing not less than 2,000 pounds, that lay in the bottom of a deep canyon about 35 miles north of Lusk, Wyoming. Observing my interest in the specimen, Mr. Guernsey very kindly assured me that if I wished to see the skull he would at some future time conduct me to the locality.

"Having completed my season's work . . . I returned to New Haven on January 3rd, 1889. In the meantime I had written Professor Marsh several letters concerning this peculiar horn core and he had published, in December 1888, his description of **Ceratops montanus,** from the material which I had collected in the early part of the season in Montana and which for the first time demonstrated the presence of horned dinosaurs in the Judith River beds. This, together with the fact that Cannon, Eldridge and Cross had already recovered undoubted dinosaur remains from the Denver beds, where the type of **Bison alticornis** had been found in situ, caused Professor Marsh to doubt the mammalian nature of the pair of horn cores which constituted the type of the latter and of which I had only seen figures. When I examined these horn cores, I at once recognized the striking similarity between them and the horn core in the collection of Mr. Guernsey. I immediately wrote Mr. Guernsey requesting him to send on his specimen for further examination and comparison. He very kindly and promptly complied with this request, and on its arrival Professor Marsh at once recognized the remarkable similarity between the two specimens, and, after his characteristic nature, became immediately possessed with a burning desire to secure the skull and learn the exact geological horizon from which it came. Accordingly, on February 20, 1889, I left New Haven

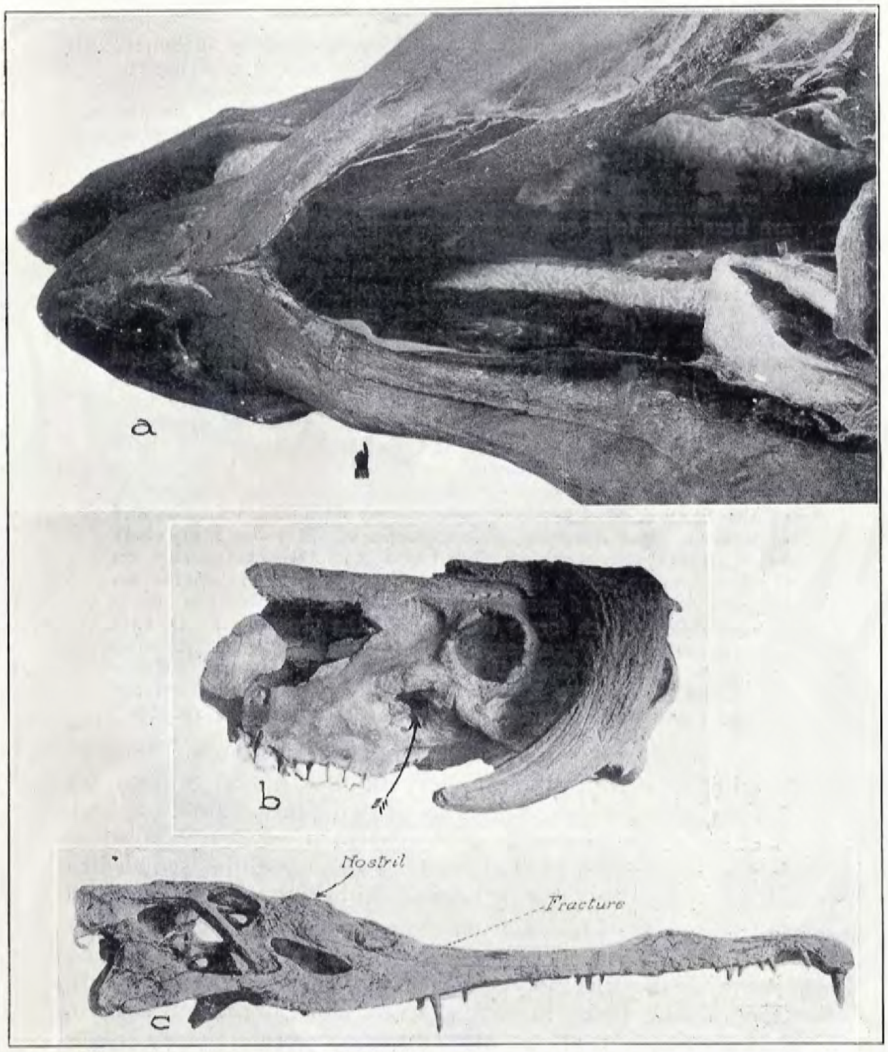

FIGURE 42.—FRACTURE AND NECROSIS IN ANCIENT REPTILES AND IN THE MUSK-OX.

a=Jaw of a three-horned dinosaur showing, at the hand, a green stick fracture, which had healed. Specimen in Yale University Museum, collected in the Lance Formation of Niobrara County, Wyoming.—Courtesy of Professor R. S. Lull.

b=Skull of a Pleistocene Musk-ox showing, at the arrow, a necrosis.

c=Skull of a Triassic phytosaur showing effects of a fracture. The phytosaurs were contemporaneous with the early, small, Triassic Dinosaurs.

for Lusk, Wyoming, and although long delayed by inclement weather, the season being mid-winter, succeeded in securing the remainder of the skull, our party having been conducted to the exact locality by Mr. Wilson, the original discoverer of the specimen. The skull was found embedded in a large sandstone concretion at the bottom of a deep canyon, exactly as had been described by Mr. Guernsey.

"The incidents connected with the procurement of this skull are here thus fully related for the two-fold purpose of giving full credit to all concerned and of illustrating the manner in which one of the most important localities for vertebrate fossils was made known, for it was in this immediate vicinity, in Converse* County, Wyoming, that the remarkable collection of Ceratopsia and the scarcely less remarkable collection of remains of other reptiles, as well as several thousand isolated jaws and teeth of diminutive mammals, were procured. . . . As the work of exploration in this newly discovered locality progressed the exact nature of this remarkable group of dinosaurs was rapidly brought to light and the real affinities of those remains . . . became apparent. . . ."

"Professor Marsh was not slow to recognize the importance of the Converse* County locality, and, with the tenacity and enthusiasm that were so characteristic of him, for four years he continued the work in that region, which was carried on for him by me, often under most discouraging circumstances, but which in the end resulted in the accumulation of the splendid collection which forms the basis of the present monograph. This locality has since been visited by collecting parties sent out from the American Museum of Natural History, Princeton, Chicago, and the Kansas State universities, and from the Carnegie Museum. All of these have met with some success."

All of the thirty-four species of horned dinosaurs discussed in Hatcher's monograph, divided among a dozen genera, are confined to the Cretaceous of the United States, most of them from the sandstone beds of Niobrara County, Wyoming. Since the publication of that book (1907) Barnum Brown has found new and remarkable horned dinosaurs in Canada, and related forms are known from Asia. Some of the dinosaurs known from Europe may belong to this group. The horned dinosaurs were extremely abundant in Montana, and among the Hell Creek beds, in seven years work, Barnum Brown, working for the American Museum of Natural History, identified no less than 500 fragmentary skulls and innumerable bones referable to the three-horned dinosaurs. **Triceratops,** the last of the race of horned dinosaurs, had a skull which, in old individuals, measured 8 feet in length. This animal attained a length of 20 feet and stood 8 feet high at the hips. He was the largest of his kind. The smallest of the group, called **Brachyceratops,** was a little over 5 feet long, and 27 inches high at the hips. Skeletons and restorations of both

* Now Niobrara County.

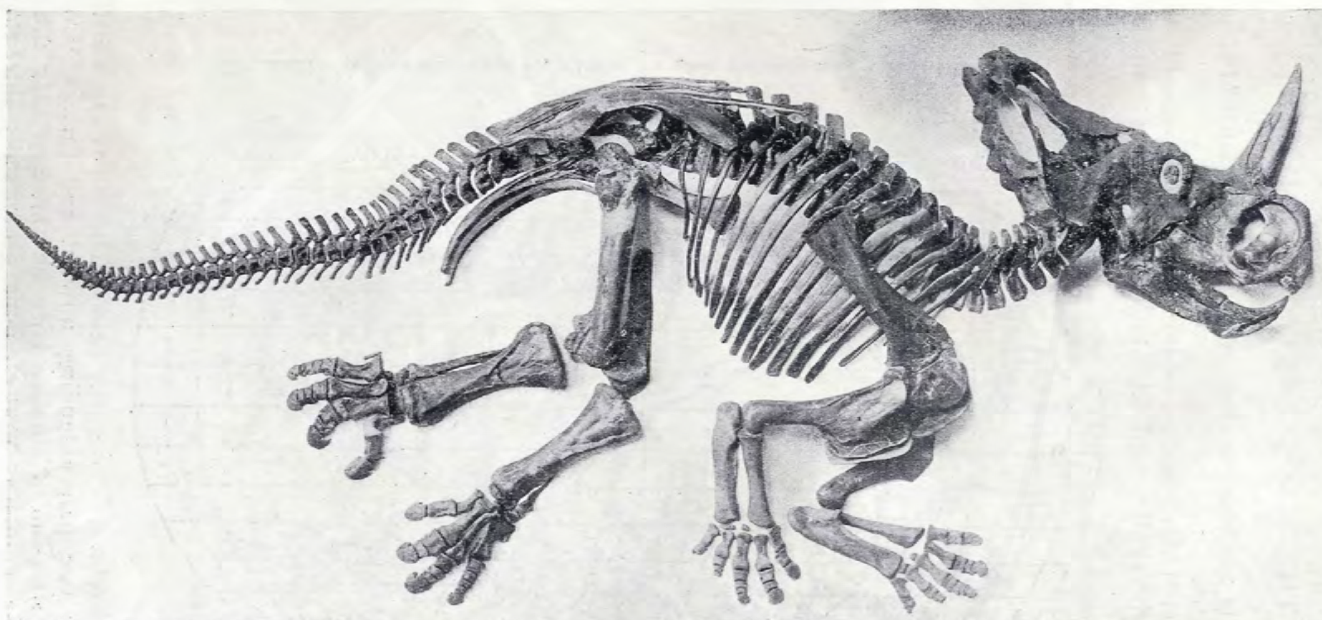

FIGURE 43.—SKELETON OF A HORNED DINOSAUR, MONOCLONIUS.

This nearly complete articulated skeleton is in the American Museum. It is in position as found in the rock, except for the forefeet which were exposed on the surface, disorganized and partly destroyed by weathering. It had a single large nasal horn and rudimentary horns over the eyes. The Triceratops of Wyoming had a large pair of horns over the eyes but the nasal horn was rudimentary.—After Barnum Brown.

dinosaurs are exhibited at the United States National Museum in Washington.

The most striking feature of this group of dinosaurs is the head with the skull armed with horns and a great bony frill

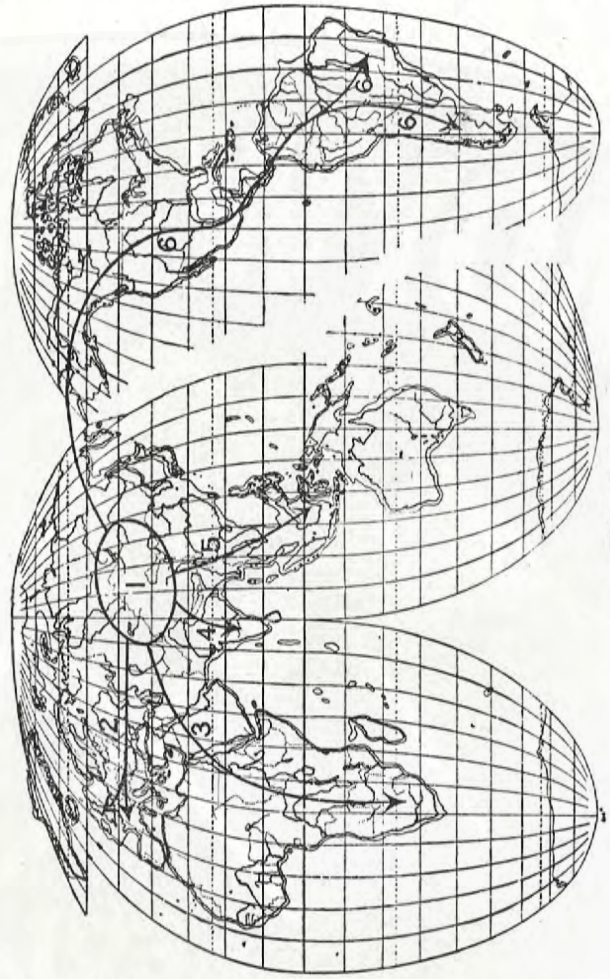

FIGURE 44.
Diagram showing world-wide migration of the giant dinosaurs from Central Asia. —After Osborn.

projecting backwards over the neck. The horns are usually three, with one pair extending upward and forward from above the eyes, and a smaller horn on the nose. In other forms, however, such as **Monoclonious,** geologically older than **Triceratops,** these horn conditions are reversed. The single horn on the nose is larger and the brow horns are quite short. In addition there are small-horned and large-horned dinosaurs belonging to this group; some that have horns curving forward, others that bend backward, others that turn outward, and still others that stand erect. At the present time no one knows whether the horns are found only on the males or whether they represent distinct species (Gilmore).

> "The frill and horn cores of most of these animals were in life undoubtedly invested in a close-fitting covering of horny skin, as implied by the deep ramifying system of depressed channels on their outer surfaces for the transmission of blood-vessels. The character of this covering was probably like that found on the horns of the horned toads . . . this sheath increases the length of the horn. Professor Lull has observed on a young specimen in the Yale Museum 'a layer of black powdery substance, a half inch in thickness, doubtless the carbonized remains of the actual horn, surrounding the base of the horn core.'" (Gilmore).

The majority of the known skulls of the three-horned dinosaurs are those of old animals whose skull bones are so grown together that little can be told of their structure. A few young skulls, however, show that the cranial elements in these huge skulls are those found in other reptiles, though some of them are curiously modified and specialized in certain directions, chiefly for the purpose of affording increased protection to the creature by the growth of horns and frills. The skull is extremely compact and heavy, and is larger than the head of any other known land animal.

The frill is made up of the skull bones known as the parietals and squamosals. Its development has not been uniform in the different kinds of animals, and forms an easy basis for determining the different genera and species. In grown animals the frill is one continuous sheet of bone. Its extreme margins are made more effective as a defense by having the margins curved outward and provided with a series of elongated, acuminate, triangular bony plates, which were doubtless covered with sharp horny spines in life.

The openings of the surface of the skull are two pair of large openings and the large round eye sockets, the nostrils and a median opening called the **postfrontal fontanelle,** unlike anything known in other vertebrates. The opening leads into sinuses in the base of the horns, and the sinuses which exist between the outer and inner layers of bone.

The orbits, containing the eyes are large and deep, possibly the animals could withdraw the eyes into the deep sockets, like some modern reptiles. We have no reason to assume that their vision was exceptional in any way.

When we consider the size of the huge head we find that the brain was smaller, in proportion to head size, than in any other known land vertebrate. The bones surrounding the brain case are very heavy, and the brain was entirely enclosed. There was probably no element of what we call intelligence among these stupid creatures. The sense of smell may have been fairly well developed, but their need for this sense was not great. Hatcher considers that they had a keen sense of vision, but were probably almost deaf to sounds.

The teeth were confined to the posterior half of the mouth, the front part being covered with a hard, sharp horny sheath. The teeth are arranged in series, so that as fast as one is worn out or broken another takes its place. The structure and arrangement of the teeth and jaws would seem to indicate that these animals may have fed on grasses or the stems, branches, leaves and twigs of shrubs and woody trees which were abundant during the Cretaceous. The food was probably taken into the mouth in considerable quantities and was received first into large lateral pouches, from which the material was passed between the jaws, which would act on either side as double-bladed chopping knives, soon reducing the vegetable mass to a condition suitable for its reception into the stomach. The teeth probably functioned as cutting organs rather than as prehensile or crushing organs. The food was reduced by cutting into small bits rather than by crushing or grinding into a pulp. The horny sheaths which doubtless incased the upper and lower beak bones, would have been very efficient as cropping organs. Their chief function would appear to have been the gathering of suitable food, while at the same time being effective as weapons of offense and defense (Hatcher).

The backbone, or vertebral column, was rather short and heavy, as compared to other kinds of dinosaurs. The neck was short and thick, consisting of seven bones. Fourteen backbone joints, or vertebrae, bore ribs, and formed the heavy barrel-shaped body. The sacrum, supporting the heavy hips was unusually long and heavy, consisting of ten segments. The tail was fairly short, but probably dragged on the ground. The spinal cord was only slightly expanded in the sacral region. Tendons, attaching the muscles to the bones, were often ossified, converted into actual bone.

The large hips consist of three bones—ilium, ischium and pubis. These have the customary dinosaurian arrangement.

The shoulder girdle has two bones on each side, a shoulder-blade and a coracoid, usually rounded.

Ribs occur on every backbone joint of the body.

The fore-limb and foot are shorter than the hind foot, and the bones much heavier, marked with strongly developed, roughened projections for the attachment of heavy muscles.

FIGURE 45.
Dinosaur eggs found in the Gobi Desert of Mongolia by the 1923 Expedition of the American Museum of Natural History.—After Osborn.

The causes of extinction of these remarkable reptiles are unknown, but the most reasonable one is that of a changing climate, to which these highly specialized reptiles were unable to adapt themselves.

CHAPTER XIX

Animals Which Lived with the Dinosaurs

In relating the association of Mesozoic animals with the dinosaurs we shall speak more fully about the back-boned animals. The lower groups of animals, called invertebrates, were present in abundance in fresh waters and in the seas. The only possible relation between invertebrates and dinosaurs is that the former may have furnished the reptiles with food, although the majority of known dinosaurs were plant feeders, living on soft verdure along the lakes, marshes and rivers, or on higher land, cropping leaves and twigs of such trees and bushes as still exist, for, by the close of the Age of Reptiles, flowering plants, woody trees, grasses and other plants had assumed a modern aspect. The poplar, willow, oak and maple were trees then as now.

The fishes were abundant throughout the Mesozoic, but were mostly marine. Only three kinds of lung-fishes (dipnoans), at present found in Africa, have been made known from the Dinosaur beds. We do not know that the fishes were important to the dinosaurian reptiles.

Mesozoic amphibians are few, and scantily known. Some years ago I reviewed our knowledge of the frogs and salamanders of the Age of Dinosaurs—but they hardly differ from the frogs and mud-puppies which we see today.

Birds are known from American dinosaur beds only by fragments. I am showing here (Figure 46) a Mesozoic bird, combining many characters. Marine birds, large wingless, toothed, aquatic, fish-eating types and small, winged, toothed, possibly fish-eating birds, about the size of a pigeon, are known from the Kansas chalk.

The distinguishing character of all birds, ancient and modern, is the possession of feathers. No other animal has them. Birds may have arisen from reptiles, but those reptiles are yet unknown, nor do we know the stages in the derivation of feathers from scales. Bird fossils are among the rarest gems of paleontology, but we know a few complete fossil birds, some fossil feathers and a few fossil eggs.

Before the close of the mesozoic turtles had diversified into land-living, marine, and river or swamp turtles.

Crocodilians of several kinds have been found in dinosaur beds, as well as pterodactyles (winged reptiles), lizards, rhyncocephalians, and other reptilian forms. We cannot believe that the presence of any of these reptiles was of any importance to the Dinosaurs. They were merely contempor-

FIGURE 46.—A BIRD OF THE MESOZOIC!

This is not a restoration of any particular bird known from fossils—but it is just a Mesozoic bird, with some of the features of the long-tailed European reptile bird, with claws on the wings. The birds and dinosaurs may have had a common origin—had the same ancestors. Some of the Triassic dinosaurs had many points in common with birds—BUT nothing but birds have ever had feathers! Feathers did, doubtless, arise from scales, but when and how we do not know. Feathers are very ancient, Jurassic, at any rate when we find them well developed in the Jurassic bird, Archaeopteryx, from the Solenhofen slates of Europe. By Jurassic times birds and dinosaurs were far apart! Future discoveries in the early stages of the Mesozoic may tell us more about how the birds and dinosaurs were related. Just now most of the Triassic dinosaurs we know are scraps, and the Triassic birds we do not know at all.

When we compare the ponderous bulk of one of the dinosaurs with the delicate wisp of a humming bird we see nothing in common. We must go far back in geologic time to learn something of those common characters.

aneous. The carnivorous dinosaurs may have eaten some of these other reptiles and some of the gigantic crocodilians may have preyed upon certain unwary dinosaurs, especially some of the young sauropods which lived in the same swampy areas.

Mammals of four large groups were abundant, though small (see Frontispiece). The teeth and bones of many of the smaller Mesozoic mammals that J. B. Hatcher collected from the tops of ant heaps, commonly found in sandy areas. If no ant heaps were present Mr. Hatcher would move an ant colony with a shovel, returning months later to gather the minute fossils brought to the surface by the indefatigable insects. As flesh and blood animals these Cretaceous mammals were tiny, mouse-like in size. There is an idea occasionally expressed that these small mammals hastened the extinction of the dinosaurs by feeding on the reptilian eggs. We do not know, however, whether or not all Dinosaurs laid eggs, and it is probable that the Upper Cretaceous mammals did not live in the same region. These mammals were eaters of roots and other vegetation, eaters of insects, eaters of fruits, seeds, and some were omnivorous. Some of them lived in trees, in holes in the ground and among the rocks. Simpson says:

> "The Mesozoic mammals constituted a little world of their own. In their society were all the fundamental adaptive types of a recent mammalian fauna. Some were chiefly insectivorous, others predaceous, while still others were herbivorous. It is the latter, the Multituberculata, which . . . were the most successful of Mesozoic mammals, for, appearing as early as the very first, they occur at every mammal-bearing horizon in the Mesozoic and even linger into the beginning of the age of mammalian dominance without any remarkable change. They undoubtedly owed this longevity to their complete and successful adaptation, and also to the fact that they alone among Mesozoic mammals did not have to face heavy reptilian competition for food, as did the small insectivores and carnivores. When the more progressive plant-eating mammals of the Paleocene appeared, the days of the Multituberculates were numbered. Yet, so perfect was their adaptation, even then they lingered on until the very moment when the Paleocene herbivores were themselves doomed by the invasion of the modernized mammals, beginning in the earliest true Eocene."

CHAPTER XX

Wyoming Dinosaurs Abroad

It will be the purpose of this section to deal with the preservation and exhibition in museums abroad of dinosaur bones and skeletons which had their origin from the geological deposits of Wyoming. So that the Wyomingite, naturally a booster for his native state and its products, may seek out in his foreign travels those specimens from Wyoming, and point with pride, followed by the remark: "Why, there's old Diplodocus. He and I are from the same state!"

There are three ways for foreign museums to secure Wyoming Dinosaurs, and there are many of Wyoming's ancient reptiles in distant collections. The first way is by purchase, either from amateur collectors or from professional fossil hunters. Of the latter type the fossil hunters, Charles Sternberg and his sons, have been most successful. A second method is to secure the specimens through exchange with the American museums, who have duplicate dinosaur material. The third method is through gift.

Some years ago the Carnegie Museum at Pittsburgh secured exceptionally complete skeletal material of the slender, elongate, whip-tail, sauropod dinosaur which Hatcher named **Diplodocus carnegiei.** The animal was 80 feet long, and was taken from the Upper Jurassic rocks of Wyoming. Director W. J. Holland suggested to Andrew Carnegie, founder of the Museum, the making of plaster casts of this exceptional dinosaur, for presentation to certain foreign Museums—a truly princely gift. The plan was immediately authorized and duplicate plaster casts of this huge Wyomingite were presented to the Kings of England and Italy, the Presidents of France and Argentine Republic, and the Emperors of Germany, Austria and Russia. The gifts were accepted and these huge dinosaurians were mounted in the exhibition halls of the National Museums of these countries. This was done prior to 1914. The last one was mounted in Buenos Aires, Argentina, in 1912.

Prior to 1911 Mr. Carl Hagenbeck, in his zoological garden at Stellingen, had had constructed life-size restorations, in concrete, of several of Wyoming's hugest dinosaurs, in connection with his large collection of exotic birds and mammals.

Here the visitor sees his old Wyoming friends, the whip-tail **Diplodocus,** the horned **Triceratops,** and other interesting dinosaurs.

The "Dinosaur Mummy" in the American Museum of Natural History, described in previous pages, is said to be approached or rivalled by a second specimen, collected in 1910 by Charles H. Sternberg in the Upper Cretaceous deposits of Niobrara County, Wyoming, in the Senckenberg Museum of Frankfurt, Germany.

The British Museum of Natural History (Kensington) has a number of dinosaurs from Wyoming, notably a large three-horned reptile from Niobrara County, Wyoming, collected by Charles H. Sternberg.

The money value of dinosaurs which have been collected in Wyoming is revealed in a letter received, September 9th, 1929, from the veteran collector of dinosaurs, Charles H. Sternberg, now residing in San Diego, California, and still hearty and hale after a half century's collecting.

The largest sum ever received for any single specimen of a Wyoming dinosaur was $2,500.00 paid by the Senckenberg Museum at Frankfurt-am-Main, Germany, on the recommendation of Dr. Drevermann. The dinosaur was a second "mummy" of a duckbill or trachodont reptile. The first "mummy," discussed in Chapter XIII, was secured by the American Museum of Natural History, at New York City, for $2,000.00.

A skull of the three-horned dinosaur, **Triceratops,** was sold to the Museum of Natural Sciences, in Paris, at the suggestion of Dr. Marcellin Boule; and another to the British Museum of Natural History, as well as two skeletons of duckbill dinosaurs which were sold for $800.00. A more perfect trachodont dinosaur brought $1,000.00 at Paris.

Two fine skeletons of trachodont dinosaurs, en route to the British Museum, were sunk by a German raider during the war. Mr. Sternberg had worked for four months on these skeletons. Another dinosaur, shipped on another boat, arrived at the British Museum safely.

Doctor Carl Wiman of the University of Upsala, Sweden, secured two skeletons of trachodont dinosaurs and a fine skull of a horned dinosaur by purchase from Mr. Sternberg.

CHAPTER XXI

LIST OF WRITINGS

A List of Books, Memoirs and Papers dealing with the Dinosaurs of Wyoming particularly, but containing a few Titles which show the Relationships of Wyoming Dinosaurs to those of the World:

Brown, Barnum, 1919. Hunting Big Game of Other Days. Natl. Geog. Mag., xxxv.: 407-429. With 25 illustrations.

Author of many other papers on Dinosaurs of Canada and the United States published in the Bulletin of the American Museum of Natural History, where he is in charge of "The Dinosaur Hall," containing the finest assemblage of Dinosaurs of any Museum of the World. Many of these specimens were collected in Wyoming.

Gilmore, Charles W., 1909. A new Rhyncocephalian Reptile from the Jurassic of Wyoming with Notes on the Fauna of Quarry Nine. Proc. U. S. Natl. Mus., xxxvii.: 35-42, illus.

——, 1909. Osteology of the Jurassic Reptile Camptosaurus, with a Revision of the Species of the Genus and Descriptions of two new Species. Ibid, xxxvi: 197-332, figs., plates 6-20.

——, 1910. Leidyosuchus sternbergii, a new Species of Crocodile from the Ceratops Beds of Wyoming. Ibid, xxxviii: 485-502, plates 23-29.

——, 1914.. Osteology of the Armored Dinosauria in the United States National Museum. Bulletin U. S. National Museum, No. 89: 1-136, plates 1-36.

Author of many other papers on Dinosaurs published by the United States National Museum, where he is in charge of a fine collection of dinosaurian reptiles, many of them collected for Professor O. C. Marsh when he was a member of the National Geological Survey. The collection at Washington contains many mounted skeletons secured from the geological formations of Wyoming.

Hatcher, John B., 1893. The Ceratops Beds of Converse County, Wyoming. Amer. Jour. Science, 3rd ser., xlv: 135-144.

Hatcher, J. B., O. C. Marsh and R. S. Lull, 1907. The Ceratopsia Monograph xlix: 1-295, 125 figures and 51 plates. U. S. Geological Survey.

Many other splendid papers by J. B. Hatcher are issued by the Carnegie Museum at Pittsburgh. Hatcher collected more than forty specimens of the huge three-horned dinosaurs in Wyoming.

Hay, O. P., 1902. Bibliography and Catalogue of the Fossil Vertebrata of North America. Bulletin 179, U. S. Geol. Survey.

The most useful volume on fossil vertebrates ever published. A new edition will be issued soon by the Carnegie Institution of Washington.

Holland, W. J., 1906. The Osteology of Diplodocus. Mem. Carnegie Museum, II, pt. 6: 225-278.

Lucas, Frederick A., 1902. Animals of the past. Chapter VI: The Dinosaurs, pp. 90-109, illus. New York.

Lull, Richard S., 1910. Dinosaurian Distribution (throughout the World). Amer. Jour. Science, xxix, 1-39, illus. January.

——, **1910.** Stegosaurus ungulatus Marsh, recently mounted at the Peabody Museum of Yale University. Ibid, xxx: 361-377, illus.

——, **1915.** The Mammals and Horned Dinosaurs of the Lance Formation of Niobrara County, Wyoming. Ibid, xl: 319-348, illus. October.

——, **1917.** On the Functions of the "Sacral Brain" in Dinosaurs. Ibid, xliv: 471-477. December.

——, **1921.** The Cretaceous Armored Dinosaur, Nodosaurus textilis Marsh. Ibid, I: 97-126, illus. February.

——, **1926.** Early Fossil Hunting in the Rocky Mountains. Natural History, xxvi: 455, illus.

As director of the Peabody Museum of Natural History at Yale University, the author has charge of the large and important Dinosaurs, many of which were collected at Como Bluffs, Wyoming, in the days when Professor O. C. Marsh and his party went "bone hunting." A squad of cavalry was needed for their protection, and no man's rifle was long out of his hand. Dr. Lull is co-author with Hatcher and Marsh of a quarto volume on horned dinosaurs.

Marsh, O. C. 1896. The Dinosaurs of North America. U. S. Geological Survey, 16th Annual Report, pt. 1, pp. 133-414, plates 1-lxxxv.

This book summarizes Marsh's numerous papers on Dinosaurs published in the American Journal of Science, during two decades, while the author was actively engaged in the collection and describing numerous dinosaurs from Wyoming. His collections are preserved at the Peabody Museum of Yale University and at the United States National Museum.

Matthew, W. D., 1910. The Pose of Sauropodous Dinosaurs. Amer. Natl., XLIV: 547-560.

——, **1915.** Dinosaurs. Handbook, Series 5, American Museum of Natural History, pp. 1-162, illus. (Out of print.)

——, **1922.** A Super-Dreadnaught of the Animal World. The Armored Dinosaur Palaeoscincus, Natural History, xxii, No. 4, 333 342, illus.

——, **1926.** Early Days of Fossil Hunting in the High Plains. Ibid, xxvi: 449-454, illus.

Moodie, Roy L., 1911. An Armored Dinosaur from the Upper Cretaceous of Wyoming. Kans. Univ. Sci. Bull., vol. 5: 257-273, plates 55-59, 1 text fig.

——, **1914.** The Fossil Frogs of North America. Amer. Jour. Science, xxxviii: 531-536, illus. (Frogs from dinosaur beds.)

——, **1923.** Paleopathology: Dinosaur Pathology.

Mook, C. C., 1916. A Study of the Morrison Formation. Ann. N. Y. Acad. Sci., xxvii: 39-191, 94 figures, 1 plate.

Osborn, Henry Fairfield, 1904. Fossil Wonders of the West. The Dinosaurs of the Bone Cabin Quarry, being the first description of the greatest "Find" of extinct Animals ever made. Century Magazine, lxviii: 680-694, illus. September.

——, **1905.** Western Explorations for Fossil Vertebrates. Pop. Sci. Monthly, 562-568, illus.

——, **1911.** Paleontology. Encyclopaedia Brittanica, 11th edition.

——, **1912.** Crania of Tyrannosaurus and Allosaurus. Integument of Iguanodont Dinosaur, Trachodon. Mem. Amer. Mus. Natl. Hist., N. S., 1, pp. 1-54, plates i-x.

Author of many other memoirs and papers published by the American Museum of Natural History, where for many years he has guided the assembling and discussions of the greatest collection of dinosaurs ever made in the world. Under his direction excavations were carried on at the Bone Cabin Quarry in Albany County, Wyoming, after 1897, securing there seventy-three animals, of which all, save nine, were dinosaurs of various types.

Riggs, E. S., 1900. Fossil Hunting in Wyoming. Science (2) xii: 233.

Simpson, G. G., 1926. The Multituberculates as Living Animals. Amer. Jour. Sci., 5th ser., xi: 228-250, illus.

——, 1926. Fauna of Quarry 9 (At Como Bluffs, Wyo.). Ibid, 5th ser., xii: 1-11.

Wieland, G. R., 1906. Dinosaurian Gastroliths. Science, n. s., xxiii: 819-821.

——, 1907. Gastroliths. Ibid, xxv: 66-67.

Williston, S. W., 1905. The Hallopus, Baptanodon and Atlantosaurus Beds of Marsh. Jour. Geol., xiii: 338-350.

——, 1905. A New Armored Dinosaur from the Upper Cretaceous of Wyoming. Science, N. S., xxii, No. 564, p. 503.

CHAPTER XXII

GLOSSARY

Amphibious Dinosaurs=A group of swamp dwelling, herbivorous reptiles representing the Saropoda of America, Africa and Europe. The sauropod or sauropodous dinosaurs of the genera Brontosaurus, Diplodocus, Camarasaurus, Brachiosaurus, etc.

Arthritides=Diseases of the Joints.

Atlantosaurus Beds=Como Beds where sauropod dinosaurs occur.

Badlands=Bare, rocky hills where fossils are readily found.

Barosaurus=A genus of sauropod dinosaurs with long neck bones.

Brachiosaurus=A genus of sauropod dinosaurs with the front leg as long or longer than the hind leg—America and Africa.

Brachyceratops=A genus of horned dinosaurs of small size.

Brontosaurus=The "thunder lizard." A large sauropod found in Wyoming.

Camarasaurus=A genus of sauropods collected at Garden Park, Colorado, and so named by E. D. Cope on account of the large spaces in the backbones.

Cenozoic=The Age of Mammals.

Ceratopsia=The horned dinosaurs of the Upper Cretaceous.

Comanchean=A geological period between the Jurassic and the Cretaceous. Equivalent to the Morrison Formation.

Como, Wyoming=A railroad station now abandoned.

Concretion=A rounded rock formation, harder than the rest of the rock. In Converse County the three-horned dinosaurs are found in the Lance Beds in sandstone concretions.

Cretaceous=The "chalk age." A geological period of great interest. The closing period of the Mesozoic.

Dipnoans=Lung fishes, found in fresh water deposits.

Dinosauria="Terrible lizards." The name was proposed by Sir Richard Owen for a group of fossil reptiles.

Diplodocus=A genus of sauropod, "whip-tail" dinosaurs found in Colorado and Wyoming.

Exostosis=A pathological growth on bone due to injury.

Extinction=A phase of animal life involving the disappearance of groups of creatures in geological time.

Haemangioma=A vascular tumor.

Iguanodon=A genus of predentate "beaked" dinosaurs found in Belgium.

Lacuna=A space in bone where a bone-cell existed during life.

Lance Beds=A formation in the Upper Cretaceous containing horned dinosaurs.

Matrix=The rock immediately surrounding a fossil.

Mesozoic=The Age of Reptiles, comprising the Triassic, Jurassic, Comanchean and Cretaceous.

Monoclonius=A genus of horned dinosaur with a single long horn on the snout.

Morrison Formation=The dinosaur beds near Morrison, Colorado, are found in Wyoming under the name Como Beds.

Multituberculata=A group of small mammals found in the Mesozoic rocks.

Orbits=The eye sockets.

Permian Period=A division of geological time at the close of the Paleozoic, distinguished also as the "Red Beds."

Phytosauria=A group of Triassic reptiles, crocodile-like in appearance but related to the dinosaurs.

Pineal eye=A sensory structure on top of the brain, possibly for heat perception.

Pus sinus=A pocket of infected matter.

Sacral brain=An enlargement of the spinal cord at the pelvis.

Sauropoda=Amphibious dinosaurs. The name means reptile-foot.

Stegopelta=A genus of armored dinosaurs found in marine sediments near Lander.

Stegosauria=A group of armored dinosaurs found in Wyoming.

Theropoda=The carnivorous dinosaurs.

Trachodon=A genus of duck-billed dinosaur, found as "mummies."

Triceratops=A genus of three-horned dinosaurs.

Tyrannosaurus=A genus of large, carnivorous dinosaurs, found in Montana and Wyoming.

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