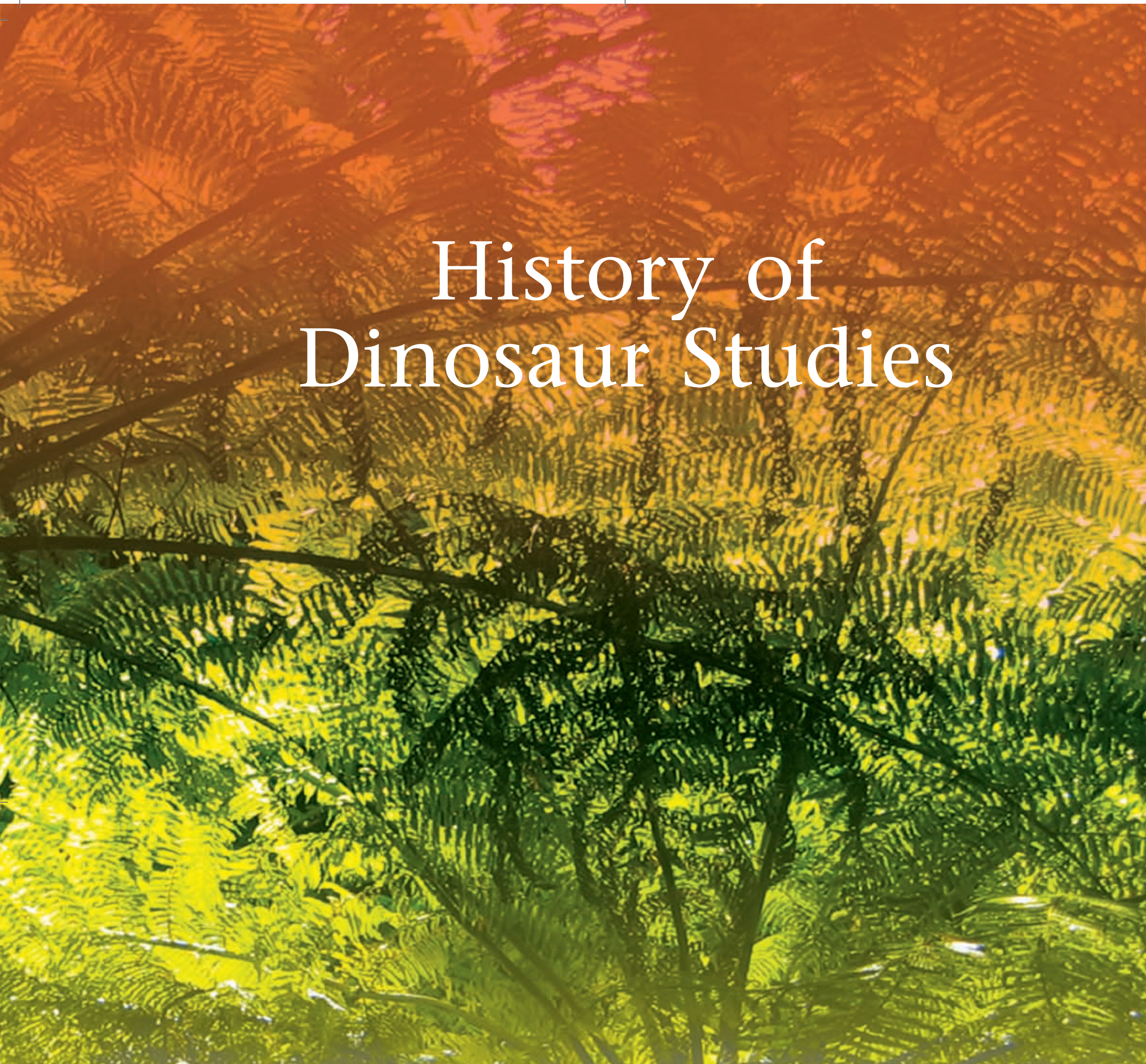
Chapter 3

You have been hearing about dinosaurs ever since you were a child, but because so many new dinosaur books have been published in the past few years you assume that most dinosaur discoveries have been made in the last few decades. So when you glance through one of the latest dinosaur books, you are surprised to find that some famous dinosaurs, such as Stegosaurus *and* Triceratops, *were discovered and named in the nineteenth century. This makes you curious about other well-known dinosaurs, such as* Tyrannosaurus *and* Velociraptor.

Considering that the popularity of dinosaurs seems so recent, what kind of people found and described dinosaur fossils, especially in the nineteenth century? When were the most famous dinosaurs discovered, and by whom? What about dinosaur tracks – when were they found and who first decided that they belonged to dinosaurs? Who found the first recognized dinosaur egg?

History of Dinosaur Studies



Dinosaur Studies before the "Renaissance"

Dinosaur Studies of the Recent Past: Beginnings of a Renaissance and a New Legacy

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The Importance of Knowing the History of Dinosaur Studies

Within a human lifetime, several years may seem like an eternity, especially during our youth, and revived customs within society can take on a completely new appearance when people are experiencing them for the first time. Thus, what seems the latest fashion today actually may be a recycled trend of yesteryear. Such is the case with dinosaurs, which were a hot topic in scientific and public circles in the nineteenth and early twentieth centuries. Although there was sporadic interest in dinosaurs throughout the middle of the twentieth century, the "**Dinosaur Renaissance**" did not begin until during the past 35 years. This cyclicity can be attributed mostly to the people who studied dinosaurs, but it is also dependent on larger societal factors, such as relative public support of science or world wars. In eighteenth and nineteenth century Europe, North America, and South America, people used the beginnings of formalized scientific methods as they made new observations about dinosaur fossils and documented their finds. Some of these people dared to propose new hypotheses about such fossils, some of which, in the face of subsequent research, we ridicule today. However, some hypotheses first proposed during those times have undergone peer review by many generations of scientists and have stood the test of time with little or no modification.

In reading about the people who studied dinosaurs, we can:

1. acquire an appreciation of their legacy;
2. understand how the body of evidence about dinosaurs accumulated over the past several hundred years; and
3. learn how they contributed to what we know about dinosaurs today.

As mentioned before, dinosaur paleontologists were often influenced by social and political circumstances of their times, which affected the quality of their results and subsequent perceptions. As is still evident today, the common thread that connects the extremely diverse personalities in dinosaur studies is their sense of curiosity, whether it is manifested as contemplative inner explorations, or adventurous outer ones. Paleontology, and the people who have studied it, form one of the deepest and most colorful histories of all the sciences.

Dinosaur Studies before the "Renaissance"

Early Recognition of Dinosaur Fossils

Dinosaur fossils are found in the Mesozoic rocks of every continent, which means that dinosaur fossils are in the geographic proximity of many human populations.

> *Indeed, some anthropological examples suggest that dinosaur fossils influenced artwork, oral tradition, and other forms of expression well before written history.*

As people of indigenous societies have always been experienced in the identification of animals, their anatomical traits, and the signs that they leave, they would certainly recognize the animal origin of dinosaur bones and other fossils, such as tracks and eggs, since well before any recorded history. For example, among Native Americans, dinosaur track motifs are evident in some of the Hopi clothing associated with a traditional snake-handling dance; the Hopi inhabit an area well known today for its Jurassic dinosaur tracksites. When Native Americans presented large bones to a nineteenth-century French-Canadian explorer, traveling through a part of Alberta that has abundant Late Cretaceous dinosaur remains, they referred to them as belonging to the "father of all buffaloes." Late nineteenth-century paleontologists reported that the Sioux tribe of the western USA had legends about dinosaur bones, explaining them as the remains of large serpents that burrowed their way into the ground to die after they had been hit by lightning. Near Mesozoic tracksites in southwestern Africa, dinosaur tracks and the animals interpreted as their makers are seen in cave paintings and were the subjects of native songs. In Brazil, early artwork was discovered that is directly associated with a Cretaceous dinosaur track. Additionally, Paleolithic or Neolithic people in Mongolia deliberately altered Cretaceous dinosaur eggshells, and may well have used them for ornamental purposes.

Probably the most intriguing potential reference to dinosaurs in folklore is the griffin, a legendary animal of central Asia. The griffin was said to have the body of a lion, a parrot-like beak, and a pair of wings, and its purpose was to protect its nests of gold. One scholar showed that the geographic range of this legend included the Gobi Desert of Mongolia, where abundant remains of *Protoceratops*, a lion-sized Late Cretaceous ceratopsian with a beak (Chapter 13), are near ancient gold mines. Of course, no wings have ever been found in association with a *Protoceratops*, indicating that, if these dinosaurs were their inspiration, the legend-makers embellished their story (a common practice even in modern societies).

Whether ancient texts actually refer to dinosaur bones is difficult to discern, as are references to dragons in European cultures that some authors have attempted to link to dinosaur fossils. The earliest known reports of "dragon bones" (in Mandarin, *long gu tou*) were written about 300 BCE from the Sichuan province of China, an area well known today for its abundant dinosaur bones. These bones were valued for their purported medicinal value, and some doctors in China still prescribe ground-up dinosaur bones as a cure for some ailments.

Early Scientific Studies of Dinosaurs: The Europeans

Prominent scientists of the fifteenth to the eighteenth centuries connected fossils to formerly-living organisms. Among them were **Leonardo da Vinci** (of *Mona Lisa* fame; 1452–1519), **Niels Stensen** of Denmark (also known as Steno, Chapter 4; 1638–87), **Robert Hooke** (1635–1703), and **Robert Plot** (1640–96) of England. Plot, a museum curator at Oxford, made the first known description and illustration of a dinosaur bone in 1677. The problem with his interpretation is that although he recognized the fossil was a bone, he speculated that it might have belonged to a modern elephant and not a large, extinct, reptile-like animal. **Richard Brookes** made another illustration of this bone in 1763 that shows it as part of a femur from the theropod *Megalosaurus* from the Middle Jurassic of present-day Cornwall (Chapter 9). Neither did Brookes know the true identity of the bone, but this lack of knowledge did not stop him from naming the specimen after its superficial resemblance to a part of human male anatomy, *Scrotum humanum* (Fig. 3.1). One French

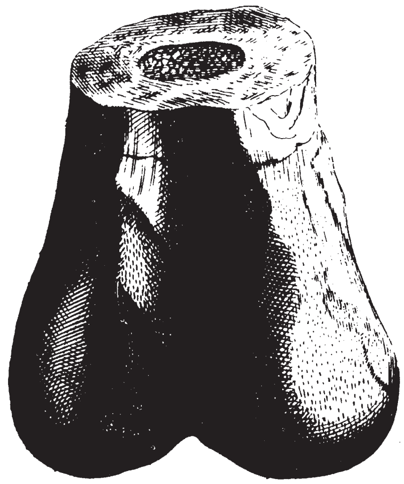


FIGURE 3.1 Sketch of probable dinosaur bone *Megalosaurus*, described by Robert Plot in 1677 in *Natural History of Oxfordshire.*

philosopher, **Jean-Baptiste-René Robinet** (1735–1820), thought the specimen actually represented an attempt by nature to imitate human organs. Fortunately, subsequent scientific knowledge falsified this hypothesis. Nevertheless, French explorers in the eighteenth century made another anatomical analogy when they yearningly named a mountain range in the northwestern part of present-day Wyoming "Les Grande Tetons."

Thus, although a dinosaur bone had been discovered, described, and illustrated by the latter part of the eighteenth century, nobody knew that it was a dinosaur bone. Unfortunately, the original specimen is lost to science. As a result, we cannot independently verify that Plot found the first identifiable dinosaur bone. In 1728, **John Woodward** (1665–1728) of Gresham College, London, catalogued another dinosaur limb bone that was found either in the late seventeenth or early eighteenth century, but he also did not realize the identity of its former owner. Later investigations would confirm that it was indeed from a dinosaur (probably *Megalosaurus* again), which makes it the first known identifiable dinosaur bone; this specimen is currently housed at the University of Cambridge. Subsequent finds of dinosaur bones in Europe, during the late eighteenth and early nineteenth centuries, resulted in people cataloguing and giving descriptions of specimens that approached a scientific methodology. However, hypotheses were rarely offered for most of the specimens and none were considered evidence of a distinctive group of long-extinct animals. In fact, such thinking was discouraged in Europe and its colonies at that time by the strong influence of religious institutions, whose advocates held that all animals on the Earth were created at the same time and none were extinct.

Ironically, a British clergyman, the Reverend **William Buckland** (1784–1856), published the first actual scientific description of a dinosaur. Buckland made his discovery of dinosaur remains around 1815, his find consisting of several serrated, curved teeth, together with a lower jaw containing a tooth comparable to the others (Fig. 3.2). The fossils belonged to *Megalosaurus*, which seems to have been a recurring find for Europeans during the late eighteenth and early nineteenth centuries. After consultations with the renowned French anatomist, **Georges Cuvier** (1769–1832) (whose full and rather officious name was Jean Léopold Nicolas Frédéric Baron Cuvier), and the geologist (and Reverend) **William Daniel Conybeare** (1787–1857), Buckland finally read his paper before a group of scientists at the Geological Society of London in 1824. Thus, Buckland is credited with naming the first dinosaur, although **James Parkinson** (1755–1824) almost named this animal first, in 1822. Another claim to fame for Buckland was that he was an instructor to geologist Sir Charles Lyell (1797–1875), who wrote *Principles of Geology* in 1830, one

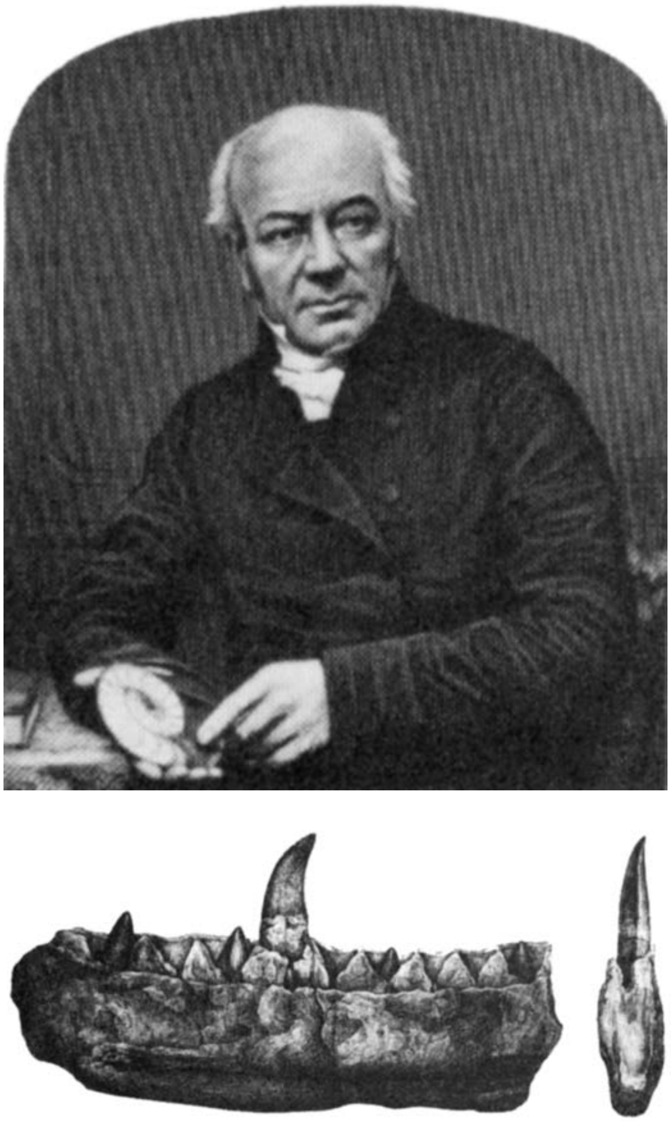


FIGURE 3.2 William Buckland (top) and remains of the first named dinosaur fossil, the lower jaw of *Megalosaurus* (bottom). From Colbert, E. H., 1984, *The Great Dinosaur Hunters and Their Discoveries*, Dover Publications, N.Y., plates 3 and 4.

of the most influential books in the field; he also invented the term "palaeontology" (using the British spelling). As many of the geologic principles advocated by Lyell are still in use today (Chapter 4), Buckland's influence had considerable impact on modern geology.

On a more personal note, Buckland was a strange man who reveled in his oddness (which supports the idea that paleontologists really have not changed very much in the past two centuries). To say that he was eccentric is akin to saying that *Seismosaurus* (Chapter 10) was large. He apparently delighted in proving people wrong; for example, he gained some fame when he correctly identified the purported remains of Saint Rosalia at a religious shrine in Palermo, Italy, as goat bones. He kept a menagerie in his home that included jackals, which were known to eat his free-roaming guinea pigs, and a bear named Tiglath Pileser (named after an Assyrian king, 745–727 BCE). The bear was Buckland's frequent companion at academic functions and was normally clothed in a cap and gown. Buckland's interest in animals extended to consuming them, so through much experimentation he attempted to develop a system of classifying them on the basis of taste alone. Regardless of these quirks, all who knew him regarded him as brilliant and he certainly contributed much to the scientific study of dinosaurs.

FIGURE 3.3 The Mantells, Gideon Algernon (left) and Mary Ann (right), who probably were not co-discoverers of *Iguanodon*. From Psihoyos and Knoebber (1994), *Hunting Dinosaurs*, Random House, N.Y., p. 10.

A contemporary of Buckland and another important contributor to the early scientific investigations of dinosaurs was physician **Gideon Algernon Mantell** (1790–1852), also of England (Fig. 3.3). Only a year after Buckland's description of *Megalosaurus*, Mantell was the first person to name a herbivorous dinosaur and ornithopod, *Iguanodon*. According to a popular anecdote, Mantell's wife, **Mary Ann Mantell** (1796–1869); Fig. 3.3), found the teeth and bones of *Iguanodon* near the property of a patient while she accompanied her husband on a house call. However, Mary Ann Mantell was not seen to go with her husband on house calls, so Gideon Mantell was the only source of this story at first; later he claimed that he found the fossils himself. In her defense, she certainly was knowledgeable about fossils, as demonstrated by the 346 figures of fossils she prepared for a monograph published by her husband in 1822. In 1833, Gideon Mantell found fragments of an ankylosaur (Chapter 12), which he named *Hylaeosaurus*, the sauropod *Pelorosaurus*, and *Regnosaurus*, which has not been classified further because of its few remains. He was sufficiently obsessed by paleontology to fill his home with the remains of many extinct animals (as opposed to Buckland's preference for live, edible ones). This preoccupation resulted in the downfall of his medical practice, the withering of his finances, and the eventual departure of Mary Ann and their children.

Mantell's description of *Iguanodon* skeletal remains was followed by numerous discoveries of probable iguanodontian tracks in Cretaceous strata of southern Britain, leading to some of the first attempts to correlate dinosaur body fossils and trace fossils (Chapter 14). The Reverend **Edward Tagart** first presented his footprint finds in a paper to the Geological Society of London in 1846, where he attributed them to large birds. The possible reptilian origin of the tracks was proposed by 1850, but not until 1862 did **Alfred Tylor**, **T. Rupert Jones**, and **Samuel Beckles** publish separate reports on the hypothesis that these three-toed tracks came from similarly-sized three-toed feet of iguanodontians. This shared hypothesis was apparently derived independently and has not been disproved in the 130 years since; few other dinosaur tracemakers have been proposed for the tracks found in this region.

The study of dinosaurs would be quite different if not for the etymological and paleontological contributions of anatomist Sir Richard Owen (1804–92) (Fig. 3.4).

Anatomist Sir Richard Owen, the British analogue to Georges Cuvier of France, was a contemporary of Buckland and the Mantells. He was an expert on fossil reptiles to the point where

FIGURE 3.4 Sir Richard Owen, inventor of the term "dinosaur". From Psihoyos and Knoebber, 1994, *Hunting Dinosaurs*, Random House, N.Y., page 11.

many people regarded him as the authority on the subject, so his word was often unquestioned (except by Mantell), regardless of the validity of his interpretations. He is best known for his invention of the term **Dinosauria** (whose members were called dinosaurs), which he first used in 1842 in reference to the large, extinct, reptile-like animals described by Buckland and Mantell. Dinosauria is based on the Greek roots *deinos* ("terrible") and *sauros* ("reptile" or "lizard"); in Victorian England, the common usage of the word terrible connoted the awesome nature of these animals, rather than their fearsomeness, poor hygiene, or other negative attributes. As an example of how authorities are not necessarily always correct in science (Chapter 2), Owen did not include three dinosaurs known at the time in his group, Dinosauria: *Cetiosaurus*, a sauropod, *Poekilopleuron*, a theropod, and *Thecodontosaurus*, a prosauropod. Instead, he classified them as unrelated reptiles.

To his credit, Owen recognized several features that are still key to the classification of dinosaurs today (Chapter 5). Also, he was a consultant to artist **Benjamin Waterhouse Hawkins** (1807–89), who produced the first examples of dinosaur artwork (sculptures and drawings). Unfortunately, the scarcity of dinosaur material and scientific hypotheses at the time resulted in Hawkins' artistic reconstructions of dinosaurs as ponderous and heavy-set quadrupeds, thus encouraging a popular misconception that would influence future investigators until the end of the century. In 1854, Owen was the first person to describe and name a dinosaur from South Africa, the Late Triassic prosauropod *Massospondylus* (Chapter 10).

France and Germany were also sites of dinosaur fossil discoveries during the nineteenth century. A Frenchman, **A. de Caumont**, discovered bones of *Megalosaurus* in Normandy in 1828, and in 1838, **Jacques-Amand Eudes-Deslonchamps** (1794–1867) was the first person to name a dinosaur from France, the previously-mentioned *Poekilopleuron bucklandi* (named in honor of Buckland). French paleontologists were also the first to record dinosaur eggshell fragments from the fossil record (Chapter 7). **Jean-Jacques Pouech** (1814–92), a Catholic priest, gave an excellent description of eggshells that, from their size and geologic occurrence (Late Cretaceous), could only have been from dinosaur eggs. In 1869, **Phillipe Matheron** (1807–99), who had followed Pouech's work, hypothesized a connection between Pouech's eggshell fragments and the Late Cretaceous skeletal material of dinosaurs found in Provence. **Paul Gervais** (1816–79), also of France, was the first scientist to conduct detailed analyses of dinosaur eggshell fragments, the results of which he published throughout the 1870s. In Germany, one of the best-known dinosaurs of the Late Triassic, the prosauropod *Plateosaurus* (Chapter 10), was discovered and named in 1837 by **Christian Erich Hermann von Meyer** (1801–69). After this description, other specimens of this dinosaur were found frequently in southern Germany and Switzerland, and beautifully complete examples are displayed in museums throughout Germany.

Although **Charles Robert Darwin** (1809–82) of England was not directly involved with dinosaur studies, he published explanations of how fossil evidence of organisms' descent with modification correlated with his observations of living animals. The timing of his publications provoked an initial discussion of the evolutionary place of dinosaurs in the history of life (Chapter 6). Darwin was a bit shy of controversy but was defended vigorously in public by **Thomas Henry Huxley** (1825–95). Huxley expounded with much delight on the first confirmed specimen (the "London specimen") of *Archaeopteryx*, a Jurassic bird with "reptilian" (dinosaurian) features that was found in 1861 (Chapters 2 and 15). Such a fossil was excellent evidence of predicted "transitional fossils" that showed links in descent between defined, major groups of organisms (Chapter 6). Huxley and Owen often disagreed on many points of evolutionary theory. Nonetheless, Huxley contributed an important insight to Owen's original classification of the Dinosauria that was far ahead of its time. In Huxley's 1868 classification, he recognized the numerous bird-like characteristics of some dinosaurs, an evolutionary linkage that enjoys nearly total support among modern vertebrate paleontologists (Chapters 9 and 15). Before he produced his classification scheme, Huxley had named a Late Triassic dinosaur from South Africa, the prosauropod *Euskelosaurus* (Chapter 10).

While all of these contentious events were occurring, **Harry Govier Seeley** (1839–1909), of England, noticed an anatomical distinction between two major groups of dinosaurs, and his 1887 report on dinosaur hip structures is still used today for their classification. One group of dinosaurs he characterized as **Saurischia** (reptile-hipped) and the other as **Ornithischia** (bird-hipped), based on the superficial resemblance of these hip structures to modern analogues in reptiles and birds, as well as a few other skeletal traits distinctive to each group (Chapter 5). On the basis of such a distinction, Seeley argued that dinosaurs did not constitute an actual group from the same ancestral stock (**monophyletic**), but arose from separate ancestors (**polyphyletic**). This interpretation touched off a spirited debate about the origin of dinosaurs that lasted for more than 100 years. Seeley, who had grown up poor and so never gained a college degree, was wise enough to work as an assistant to the Reverend **Adam Sedgewick** (1785–1873) at Cambridge University, who along with Charles Lyell was one of the founders of modern geological methods (Chapter 4). Cambridge was the home of the Woodwardian Museum (at that time named after John Woodward, but now named after Sedgewick), which housed the extensive collections of Late Cretaceous fossil animals that Seeley studied.

The main problem faced by paleontologists during the debates over classification was that their attempts to classify and reconstruct dinosaurs were based on fragmentary skeletal remains. For at least one species of dinosaur, **Louis Antoine Marie Joseph Dollo** (1857–1931) of Belgium solved the problem of insufficient evidence with his thorough descriptions of complete skeletons of *Iguanodon* (Chapter 11). Coal miners discovered these in 1878 in Bernissart, Belgium; subsequent excavations recovered 39 individual skeletons from the site, a phenomenal number of specimens even by today's standards. As a result, through vigorous use of scientific methods and access to many skeletons, Dollo cleared up misinterpretations about *Iguanodon* that had persisted since Mantell's original description, such as the placement of its thumb as a nose spike. Most importantly, at a time when all dinosaurs were regarded as **quadrupeds** (using four legs), Dollo firmly established the **bipedal** (two-legged) nature of *Iguanodon*. Huxley proposed the same hypothesis in

1868 for a different dinosaur species found in the USA, discussed below. Dollo, in 1887 alone, published 94 peer-reviewed papers.

Europeans worked very little on African dinosaurs during the nineteenth century, although in 1896 Frenchman **Charles Depéret** (1854–1929) described bones of a previously undiscovered species of sauropod, *Titanosaurus* (Chapter 10), and a theropod, *Majungasaurus* (Chapter 9), from Madagascar. These discoveries foreshadowed the potential for later major discoveries in Madagascar nearly a century later. Another French paleontologist reported dinosaur tracks from Algeria in 1880, but little other information is available about this find. Similarly, no definite reports of dinosaur fossils came out of Australia in the nineteenth century, and it was not until 1903 that **William Hamilton Ferguson** (1861–1957) found a theropod toe bone, nicknamed the "Paterson claw," in Cretaceous rocks of Cape Paterson, Victoria.

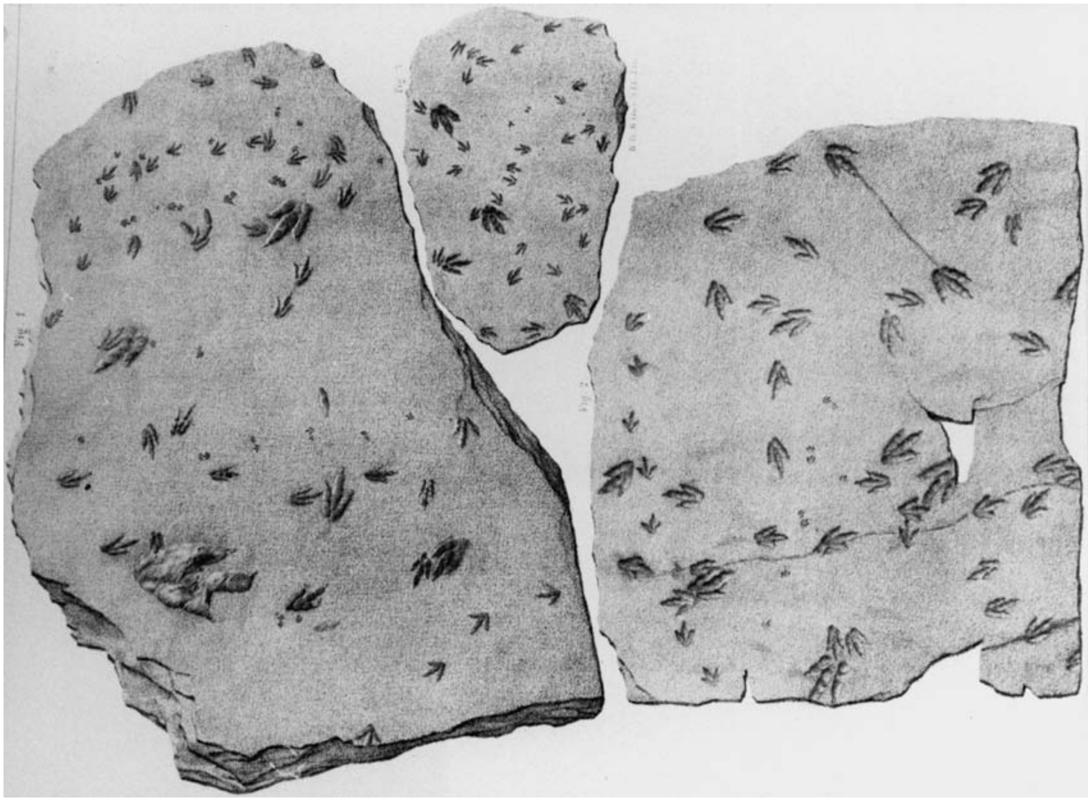
Early Scientific Studies of Dinosaurs: The North and South Americans

Meanwhile, across the Atlantic Ocean, fossil evidence of dinosaurs was being discovered in North America in the latter part of the eighteenth and early part of the nineteenth centuries, although none of it was connected with dinosaurs at the time. The first probable dinosaur-related discovery in North America was in 1787, when anatomist **Caspar Wistar** (1761–1818) presented a bone from Cretaceous rocks of Woodbury, New Jersey to the American Philosophical Society, presided over by **Benjamin Franklin** (1706–90). **George Washington** (1732–99), who is also known for his interest in fossils, examined the same bone and mentioned it in one of his writings. Unfortunately, Wistar interpreted the bone as a large man's femur instead of recognizing it as an ornithopod metatarsal; if he had identified it correctly as reptile-like, this discovery would have preceded Buckland by 28 years. In 1802, **Pliny Moody**, a farm boy and student at Williams College, made a more definitive discovery of dinosaurs in North America when he uncovered a rock with Lower Jurassic theropod tracks while plowing his family's field in South Hadley, Massachusetts. The tracks are still in the possession of nearby Amherst College and on display there. Because they had such a close resemblance to the three-toed morphology of modern bird feet, and religion provided the primary framework for explanations of natural phenomena at the time, the footprints were attributed to "Noah's raven." **William Clark** (of Lewis and Clark fame; 1770–1838) also described a large bone in 1806 that was probably eroding from the Late Cretaceous **Hell Creek Formation** in present-day Montana; hence it was probably from a dinosaur, but Clark interpreted it as the remains of a large fish. Prosauropod remains were found in 1818 by **Solomon Ellsworth, Jr.**, in Upper Triassic deposits of the Connecticut Valley. **Nathan Smith** described these fossils in a published report in 1820, and he interpreted them as possibly human. These four examples were representative of a thankfully short-lived American tradition: the mistaken attribution of dinosaur fossils as representatives of most other recognized vertebrate groups.

Moody's rock slabs containing the "bird" tracks were stored in a quaint building called the ***Appleton Cabinet****, the first structure made for the purpose of holding dinosaur trace fossils; its refurbished version is now a dormitory for students of Amherst College.*

Nevertheless, the lack of connection between dinosaur fossils and their actual identity continued in the voluminous and otherwise groundbreaking work on dinosaur tracks by the Reverend **Edward Hitchcock** (1793–1864; Fig. 3.5). Beginning in 1836, Hitchcock's studies of tracks in Late Triassic and Early Jurassic rocks of the Connecticut Valley represented further discoveries in Moody's (and the

FIGURE 3.5 Edward Hitchcock, describer of numerous examples of Late Triassic and Early Jurassic dinosaur tracks from the Connecticut River Valley, and dinosaur tracks figured in his 1858 publication. From Amherst College Archives and Special Collections, Negative Collection, Box 1, fig. 69, and Box 3, figs 4a–5a.



dinosaurs') old stomping grounds. Hitchcock analyzed thousands of dinosaur tracks, and tracks of dinosaur contemporaries, in his collection at Amherst College, where he was president.

Continuing the original "Noah's raven" theme, Hitchcock interpreted the numerous dinosaur tracks as originating from large, prehistoric birds, which was a perfectly reasonable hypothesis in the light of his data and then-current ideas about dinosaurs. For example, three-toed animals made many of the tracks he described and most of the trackways indicated a bipedalism that had not been yet ascribed to dinosaurs. The tracks also resemble those of flightless birds in some ways, with the notable exception of their large sizes. In an 1844 report, Hitchcock was the first person to describe probable dinosaur **coprolites** (fossilized feces, Chapter 14), which he also attributed to birds. Hitchcock's comprehensive summary of his findings, *Ichnology of New England* (1858), was the first work to prominently use the term

ichnology for the science of traces and trace fossils (Chapters 2 and 14). This classic work is still cited, not only for its extensive illustrations and descriptions of dinosaur tracks, but because it contains some of the few recorded instances of dinosaur sitting traces and tail-drag marks.

Another paleontological enthusiast in Massachusetts at the same time was **John Collins Warren** (1778–1856). Warren was a Harvard physician who also dabbled in fossils while maintaining his primary interest in anatomy; his first exposure to anatomical studies began with his father, who was the founder of Harvard Medical School. The younger Warren studied anatomy with Cuvier in Paris and later performed the first surgery with anesthesia in 1846. In 1854, Warren had the distinction of publishing not only the first photographic illustration of a dinosaur track, but also the first photograph shown in an American scientific publication. Scientific illustration, particularly for such photogenic subjects as dinosaurs, was forever changed, although photography was a new and difficult-to-use medium that would not see extensive use in dinosaur studies until later in the nineteenth century.

Despite all of this good science, no one had yet identified a dinosaur fossil from North America until the works of **Joseph Leidy** (1823–91), who initiated Americans' recurring fascination with dinosaurs. Leidy, a physician and anatomist from Philadelphia, Pennsylvania, became bored with medicine and soon turned to paleontology and other aspects of natural history. In 1856 he published a study of the dinosaur teeth found the previous year by **Ferdinand Vandiveer Hayden** in Upper Cretaceous strata of what is now Montana. Leidy named one of the dinosaurs, *Troodon*, on only the basis of these teeth (a risky scientific endeavor), which later studies revealed as one of the most interesting theropods ever found in North America (Chapter 9). It was another dinosaur, however, that would make Leidy a celebrity in the USA. **William Parker Foulke** found a Late Cretaceous dinosaur, the ornithopod (and hadrosaurid) *Hadrosaurus foulkii*, in nearby New Jersey; the dinosaur was graciously named after its discoverer. Foulke had been steered to the site by the landowner and previous discoverer of probable dinosaur bones, **John E. Hopkins**. This dinosaur was similar to and probably related to *Iguanodon*, but Leidy provided an incisive interpretation of it; on the basis of the relatively complete skeleton, he argued convincingly for the inherent bipedalism of a dinosaur. Moreover, he pointed out that, judging from its limbs, *Hadrosaurus* was likely a **facultative quadruped**, meaning that it could have walked on all fours if necessary. This hypothesis was later supported by the find of probable ornithopod tracks that reflect such behavior (Chapters 11 and 14). Furthermore, Leidy proposed a preburial history of the specimen that was probably correct. He thought that this dinosaur originally dwelled on land and its body was washed out to sea, as its remains were found in a marine deposit (Chapter 7).

In 1868, the artist Waterhouse Hawkins, who was living in the USA at the time, attempted to use the same *Hadrosaurus* specimen as a model for artistic reconstruction. Sadly, political problems and vandalism of his works-in-progress led to him being denied an exhibit of the reconstruction, which was to have been displayed in New York City's then newly-established Central Park. Consequently, the best that Hawkins could do was to make a cast of the *Hadrosaurus* skeleton, which remained on public display at the Academy of Sciences of Philadelphia for many years.

Edward Drinker Cope (1840–1897) and Othniel Charles (O.C.) Marsh (1831–99) (Fig. 3.6) (Chapter 2) produced simultaneously some of the most significant finds of dinosaurs in the world.

The melodramatic interactions between Cope and Marsh throughout their careers have inspired bibliographers and paleontologists alike to invoke clichés such as "bitter rivals" and "sworn mortal enemies." These two paleontologists' publicly aired hatred for one another could be the subject of an extensive psychological study

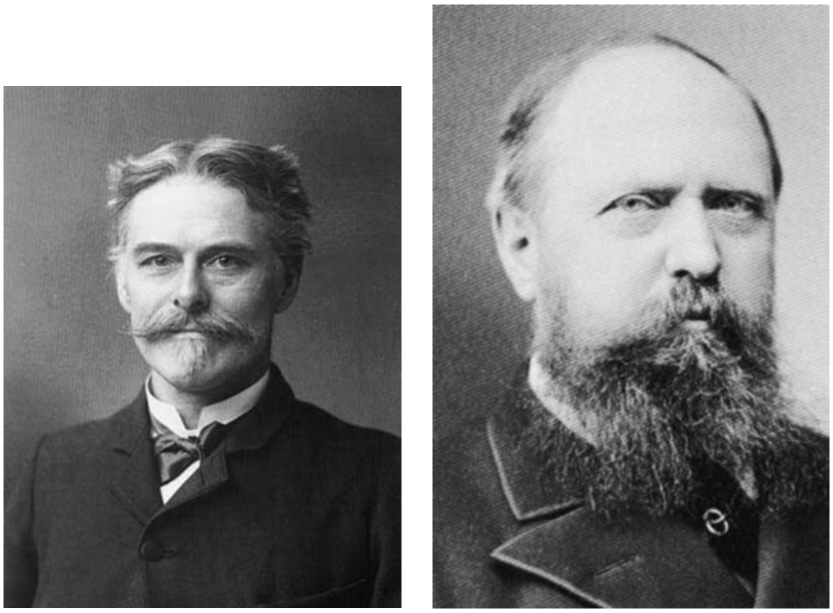


FIGURE 3.6 Edward Drinker Cope (left) and Othniel Charles (O.C.) Marsh (right), productive yet antagonistic contemporaries in dinosaur studies. Reprinted from *Science*, 1897 and 1889, respectively.

on megalomania. One anecdote that is incorrect but nevertheless amusing is that Marsh named coprolites after Cope. Although this book emphasizes Cope and Marsh's scientific contributions, which are unparalleled and may never be equaled, some slight digressions on their personal lives should add insight into them as both scientists and people.

Marsh and Cope had similar financial situations; both received large amounts of money from relatives and thus had few worries about earning a living, which freed their time for academic studies. Cope was the more precocious and prolific of the two, having more than 1400 scientific publications to his credit by the time he died. After he settled in Philadelphia, Cope was briefly a student of Leidy, and he associated himself with the Academy of Natural Sciences there (although Leidy would later distance himself from Cope as a result of the verbal warfare with Marsh). A peer-reviewed journal of **herpetology** (*Copeia*) was named after him in honor of his impressive contributions to the study of reptiles and amphibians. Marsh was not quite as industrious as Cope or as brilliant, but his political acumen was more finely developed, which helped him to gain much government support for his dinosaur studies. Marsh mostly worked through Yale University, where his rich uncle (**George Peabody**) had the **Yale-Peabody Museum of Natural History** built for him. He also held the title of Vertebrate Paleontologist with the newly-formed **United States Geological Survey** (**USGS**) for 10 years and was the president of the National Academy of Science for 12 years.

Cope and Marsh were important in the world of paleontology at the time. For example, when two schoolmasters, **Arthur Lakes** and **Oramel W. Lucas**, independently found dinosaur bones in Morrison, Colorado, and Cañon City, Colorado (respectively) in 1877, they sent news of their finds to Cope and Marsh. This started what was later called the "**Great Dinosaur Rush**," which lasted for nearly 20 years and spanned present-day Colorado, Wyoming, New Mexico, Montana, and other western states. During the ensuing frenzy of exploration and exploitation, the main producer of the numerous dinosaurs named by Cope and Marsh was the **Morrison Formation**, an Upper Jurassic rock unit that still produces many dinosaur fossils today (named after the settlement where Lakes lived). The thousands of dinosaur bones they collected were placed on railroad cars that, through the newly-built transcontinental railroad, could reach western areas that were previously inaccessible to dinosaur paleontologists.

Cope and Marsh's lasting influence is seen through their naming of so many now well-known dinosaurs, such as the thyreophoran *Stegosaurus* (Chapter 12), the sauropods *Diplodocus* and *Apatosaurus* (the latter then named *Brontosaurus*: Chapter 10), the theropods *Allosaurus* and *Ceratosaurus* (Chapter 9), the ceratopsian *Triceratops* (Chapter 13), and the ornithopod *Camptosaurus* (Chapter 11). They also attempted classification schemes, after Huxley but before Seeley, as a synthesis of the dinosaur discoveries made by them and others. Most importantly, they pointed future investigators to the areas of North America with extensive Mesozoic deposits, clearly demonstrating the potential for more dinosaur discoveries.

Marsh was apparently averse to doing most of his own fieldwork, although reportedly during one field excursion he and some assistants met with leaders of the Sioux tribe, **Red Cloud** (1822–1909), **Crazy Horse** (1842–77), and **Sitting Bull** (1831–90), to gain permission for dinosaur prospecting in their territories. Marsh kept his promise to the Sioux that he would search only for dinosaur remains rather than gold, and Sioux scouts were reportedly gratified to find only bones in the possession of Marsh's party when they left. Marsh's assistants were probably also gratified to leave with their lives intact. Cope also went infrequently into the field in the western states, but more often than Marsh and always made significant finds when he did so. During one of Cope's trips, he met with **Charles H. Sternberg** (1850–1943), and they prospected Cretaceous deposits in Montana in 1876. Sternberg later told the now-famous stories of how the two men would typically hunt for dinosaur bones by day, eat an awful late-evening meal, and go to bed. According to Sternberg, Cope would then toss and turn in the throes of nightmares that brought his Mesozoic beasts back to life, wherein they pummeled him. During this same trip, Sternberg and Cope invented a method for protecting fossil specimens for their transport back east, by boiling rice into a paste and mixing it with cloth strips that were draped around the fossils to harden. Several of Marsh's associates modified Sternberg and Cope's technique the next year by using plaster of Paris and burlap, a technique that was used to make casts for broken human bones and is still used by many dinosaur paleontologists today (Chapter 4). Sternberg undoubtedly learned much about dinosaurs during his brief apprenticeship in the field with his nocturnally-tormented mentor. His sons **George**, **Levi**, and **Charles M. Sternberg** (1885–1981) later found more dinosaur bones in Canada than any other family since.

Before the end of the century, several new workers in North America entered the fray between Cope and Marsh and made remarkable contributions to dinosaur studies. These people were **Henry Fairfield Osborn** (1857–1935), **William Berryman Scott**, **Barnum Brown** (1873–1963), **Walter Granger** (1872–1941), and **John Bell Hatcher** (1861–1904). Osborn and Scott were good friends while undergraduates at Princeton University and decided, after being inspired in class one day by their geology professor, **Arnold Guyot** (after whom seafloor volcanoes, guyots, were named), to do the 1877 equivalent of a "road trip." They hopped on a train and went to Wyoming to find fossils. During their travels by train, horse, and wagon, and in between meeting Native Americans and mountain men, they learned much about fossils in a field context. Both became friends with Cope and went to Europe to study with Huxley for a while before they became faculty at Princeton. Osborn left Princeton in 1891 to become a staff member of the now-famous **American Museum of Natural History**, where he founded the Department of Vertebrate Paleontology and later became president.

In 1897, Osborn sent an expedition to look at the Morrison Formation in Como Bluff, Wyoming, the site of much dinosaur work done by Marsh's minions (Fig. 3.7). The group included Brown and Granger, both of whom were novices at fieldwork but would become two of the most important dinosaur paleontologists of the early twentieth century. This initial foray proved, after much searching, that Como Bluff did not have the dinosaurs it used to have. They moved farther to the north

FIGURE 3.7 Barnum Brown (left) and Henry Fairfield Osborn (right) in the field at Como Bluff, Wyoming, in 1897, with a sauropod (*Diplodocus*) limb bone in the foreground and Late Jurassic Morrison Formation cropping out nearly everywhere else. Negative No. 17808, Photo. Menke. Courtesy Dept. of Library Services, American Museum of Natural History.

the next year and discovered an area where dinosaur bones littered the ground in such abundance that a local shepherd had built a cabin out of them. The site, appropriately named **Bone Cabin Quarry**, provided about 30 tons of dinosaur bones of 141 individual skeletons during that year. Seven more annual expeditions by the American Museum followed. The number of individual dinosaurs and tonnage were recorded for six seasons and these records show how such sites can become quickly depleted of dinosaur bones with continued mining (Fig. 3.8).

John Bell Hatcher, during his short life of 42 years, collected 50 ceratopsian skeletons (many with skulls) from Upper Cretaceous deposits in Wyoming, while employed by Marsh from 1889 to 1892. This feat was single-handedly the most quantitatively important contribution to the study of these wonderfully diverse dinosaurs (Chapter 13). Hatcher became so disgruntled with Marsh that he eventually left and was hired by Scott at Princeton, for whom he did more work in Colorado through the turn of the century. In his publications, Hatcher expressed some of his disgust for Cope and Marsh's occasional scientific errors. Sadly, Hatcher

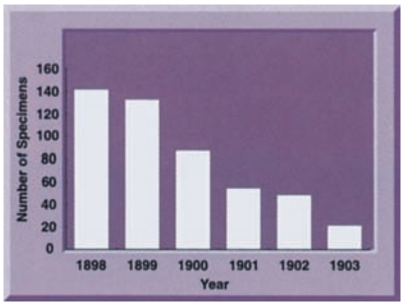


FIGURE 3.8 Bar graph showing decreased productivity of dinosaur bones from the Bone Cabin Quarry in number of specimens collected versus year. Data from Colbert (1968).

died of typhus while writing his classic work, *The Ceratopsia*. But fortunately for science, **Richard Swan Lull** (1867–1957), a paleontologist of some note himself (discussed below), posthumously published the manuscript in 1907.

Elsewhere in North America, **George Mercer Dawson** (1849–1901), who was the son of the important nineteenth-century geologist, **Sir William Dawson** (1820–99), discovered dinosaur bones in Saskatchewan, Canada in 1874. Like Osborn and Scott, George Dawson had studied with Huxley. Further discoveries were made in 1884 by **Joseph Burr Tyrrell** (1859–1957) in the Red Deer River valley, near Drumheller, Alberta, which was followed by other finds by one of his associates, **Lawrence M. Lambe** (1863–1919). As a member of the Canadian Geological Survey, Lambe took a boat down the Red Deer River in 1897 to document more dinosaur-bearing zones. Through the efforts of the Sternbergs, Brown, and other paleontologists, the Red Deer River area of Canada was revealed as one of the richest deposits of Late Cretaceous dinosaur bones in the world. Dawson, Tyrrell, and Lambe are also fine examples of the benefits of fieldwork for one's health. Dawson was very short and a hunchback, yet he energetically explored the wilderness areas of Saskatchewan, Alberta, and British Columbia for fossils throughout his career. Likewise, Tyrrell and Lambe began fieldwork in the late nineteenth century for health improvement; Lambe continued doing fieldwork until his death in 1919 and Tyrrell lived to the age of 98. In fact, Tyrrell exemplifies the longevity that is characteristic of many well-known, field-oriented paleontologists and geologists from the nineteenth and early twentieth centuries, who had average life spans well above typical life expectancies for their times (Table 3.1).

Only a few discoveries of dinosaurs from South America were documented as dinosaurs during the nineteenth century, although some regions later became history-making spots in dinosaur studies. The first discovery of dinosaur tracks in Columbia, South America, was by **Carl Degenhardt** in 1839, although he, like Hitchcock, thought they were bird tracks. The first discovery of dinosaur bones in the Cretaceous rocks of Patagonia, Argentina, was in 1882 by a military officer known only in historical records as **Commandante Buratovich**. Buratovich sent his finds to the renowned Argentine paleontologist **Florentino Ameghino** (1854–1911), who confirmed for the first time that Argentina had dinosaurs. Ameghino's brother, **Carlos Ameghino** (1865–1936), often assisted him by doing most of their fieldwork. **Francisco P. Moreno** (1852–1919) also found dinosaur bones in Argentina in 1891, reconfirming their presence for future workers. Another Argentine, **Santiago Roth**, began his paleontological career in the same area of Argentina soon after the Cretaceous dinosaur remains were found. In the early part of the twentieth century, Roth contributed to the dinosaur collection of the **Museo de La Plata** in Argentina, of which Moreno was the first director. These dinosaur finds were early indicators of later significant discoveries of skeletal material, eggs, nests, and tracks in Upper Triassic–Upper Cretaceous deposits of Argentina into the twenty-first century. These include some of the largest theropods and sauropods known (Chapters 9 and 11).

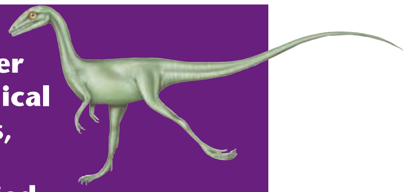


TABLE 3.1 Sample of lifespans of field-oriented paleontologists and geologists mentioned in the chapter who were born before 1900, names listed in chronological order from date of birth. Mean age = 76.6 ± 14.2 years, median = 78 years (n = 29, all male subjects); 34% of sampled people were older than 80 years when they died.

Name	Born	Died	Lifespan
John Collins Warren	1778	1856	78
William Buckland	1784	1856	72
Adam Sedgewick	1785	1873	88
Gideon Algernon Mantell	1790	1852	62
Edward Hitchcock	1793	1864	71
Charles Lyell	1797	1875	78
Christian Erich Hermann von Meyer	1801	1869	68
Phillipe Matheron	1807	1899	92
Jean-Jacques Pouech	1814	1892	78
Paul Gervais	1816	1879	63
Charles H. Sternberg	1850	1943	93
Henry Fairfield Osborn	1857	1935	78
Joseph Burr Tyrrell	1859	1957	98
John Bell Hatcher	1861	1904	43
Eberhard Fraas	1862	1915	53
Earl Douglass	1862	1931	69
Lawrence Lambe	1863	1919	56
Carlos Ameghino	1865	1936	71
Richard Broom	1866	1951	85
Richard Swan Lull	1867	1957	90
Ernest Stromer von Reichenbac	1871	1952	81
Walter Granger	1872	1941	69
Barnum Brown	1873	1963	90
Friedrich von Huene	1875	1969	94
Franz Nopcsa	1877	1933	56
Werner Janensch	1878	1969	91
Roy Chapman Andrews	1884	1960	76
Charles M. Sternberg	1885	1981	96
Yang Zhong-jian (C. C. Young)	1897	1979	82

Scientific Studies of Dinosaurs in the First Half of the Twentieth Century

The turn of the last century was a seamless transition for most dinosaur paleontologists, but the deaths of Cope in 1897 and Marsh in 1899 symbolized the beginning of the new era. As changes in modes of transportation and communication began to make the world a smaller place, the study of dinosaurs became more global, expanding to areas of the world outside Europe and the Americas. Dinosaur paleontologists also became more cooperative and engaged in friendly competition, a spirit that has, for the most part, continued to today. Last, fundamental connections between dinosaur body fossils and trace fossils were made that firmly established the dual importance and complementary nature of these facets for interpreting dinosaurs. But during the first half of the twentieth century, two world wars disrupted dinosaur studies; these wars not only resulted in a huge loss of human life

FIGURE 3.9 Franz Nopcsa, dinosaur paleontologist, Transylvanian nobleman, linguist, spy, and motorcycle enthusiast, shown here in Albanian costume and carrying optional field gear. From Kubacska, András Tasnáde, 1945. Verlag Ungarischen Naturwisenschaftlichen Museum, Budapest/Dover Publications.

but also the destruction of dinosaur skeletons. Some skeletons were sunk during submarine attacks of World War I while being transported across the Atlantic, and other skeletons in German museums were destroyed in bombing raids by Allied forces in World War II.

Of all Europeans who worked on dinosaurs in the early part of the twentieth century, **Franz (Ferenc) Baron von Felsö-Szilvás Nopcsa** (1877–1933) was the most likely contender for William Buckland's position as the most unusual dinosaur paleontologist (Fig. 3.9). The Transylvanian nobleman became a paleontologist by accident after his sister found some bones on her estate. He brought the bones to a university professor to identify, and the professor told him, "Study them yourself," which he did. Although Nopcsa had no prior training in paleontology, he subsequently published a description of the Cretaceous hadrosaur *Telmatosaurus transsylvanicus* in 1900. He then conducted more research on the dinosaurs of his home country, as well as those in England and France. Nopsca soon broadened his scope to include large-scale concepts such as classification schemes, evolutionary relationships of dinosaurs, and integration of the (then) new idea of continental drift with dinosaur distributions (Chapters 4 and 6). Although he was not always correct, Nopcsa's thinking was original, and he may have been the first dinosaur paleontologist to look intensively for sex differences in dinosaur species, a field of study that generated much interest later (Chapters 5 and 8).

In addition to his paleontological ambitions, Nopcsa decided, after traveling through Albania and studying its cultures and dialects, that he was the most qualified person to rule it as king. He planned to accomplish this goal through various imaginative machinations, which he shared with officials of the Austria-Hungarian government. These plans included military strategies for invading Albania and generating revenue for the new nation-state through marriage with a not-then-identified daughter of an also-not-then-identified American millionaire. He figured that it would be no problem to find one after he was crowned as a king. The government declined his offer, and he never did find his hypothetical rich wife. Instead, his life took even stranger turns:

- He was involved in secret missions during World War I as a spy.
- The Romanian government seized his estates.
- He was nearly beaten to death by an angry mob of peasants.
- He was placed in charge of the Hungarian Geological Survey.
- He angrily quit the Survey.
- He took off on a 5500 km long motorcycle ride with his male Albanian secretary, who was also his lover.
- He spent all his money.
- He completed impressive works on dinosaur bone histology as related to their classification.
- He became depressed, shot his lover, and committed suicide.

On a more mundane note, the finds of western North America continued with the prodigious output of Barnum Brown in the early 1900s. In 1902, Brown discovered one of the largest (and certainly the most famous) of land carnivores, *Tyrannosaurus rex*, in the Late Cretaceous Hell Creek Formation of eastern Montana. Brown then followed Lambe by taking a barge down the Red Deer River in 1910, to explore Upper Cretaceous deposits there. For the next six years, Brown and his associates, working through the American Museum, directed by Osborn (who in 1905 named another tyrannosaurid, *Albertosaurus*, from this region: Chapter 9), collected dinosaur bones from two different geologic levels. These vertically-separated levels indicated different times in geologic history (Chapter 4), so Brown's collections contributed greatly to understanding the evolutionary sequences of dinosaurs during the Late Cretaceous. Besides tyrannosaurids, other dinosaurs documented from this area include the hadrosaur *Corythosaurus* (Chapter 11), some ceratopsians, such as *Monoclonius*, *Anchiceratops*, and *Leptoceratops* (Chapter 13), the large theropod *Centrosaurus*, and the ostrich-like theropod *Struthiomimus* (Chapter 9). In 1907, Brown was the first paleontologist to write about dinosaur **gastroliths** ("stomach stones") that dinosaurs probably used for grinding food in their digestive systems (Chapter 14). In his report, Brown noted that he found gravel associated with the skeleton of the hadrosaur *Claosaurus*, which he interpreted as gastroliths, but such hypotheses remain controversial and require much careful documentation before conditional acceptance.

The Sternbergs (Charles M. and his brothers) followed Brown's efforts. Prior to their work in Alberta, the Sternbergs made one of the most unusual and scientifically-valuable dinosaur finds of the time, when they discovered a hadrosaur in Wyoming in 1908 with skin impressions associated with the skeleton (Chapters 6). To confirm that their find was not a fluke, they later found another example nearby, which indicated similar conditions of preservation. The brothers were then employed by the Canadian Geological Survey, which was becoming tired of seeing Americans get all of the credit for dinosaurs found in Canada and then taking the Canadian dinosaurs out of the country to New York City. The Sternbergs started their work in the same Red Deer River area in 1911, using not only a barge for travel but also motorboats for occasional prospecting trips to shore. Among the Sternbergs' discoveries were specimens of the hadrosaur *Prosaurolophus* (Chapter 11), ankylosaurs (Chapter 12), the ceratopsians *Chasmosaurus* and *Styracosaurus* (Chapter 13), and a large theropod, *Gorgosaurus*, which is often viewed as synonymous with *Albertosaurus* (Chapter 9). The area prospected by Brown's group and the Sternbergs (constituting an example of the aforementioned friendly competition) is now known as **Dinosaur Provincial Park**. Within this area is Drumheller, Alberta, home of **Royal Tyrrell Museum of Palaeontology**, which contains some of Canada's finest dinosaur skeletons.

Far to the south of Alberta is another famous museum, one that is built around dinosaurs still in their entombing Upper Jurassic rock. **Dinosaur National**

FIGURE 3.10 Outcrop of Morrison Formation (Late Jurassic) with extremely abundant dinosaur bones, discovered by Earl Douglass in 1909, Dinosaur National Monument, near Jensen, Utah.

Monument, near Jensen, Utah, contains about 1500 *in situ* dinosaur bones, which are available for public viewing today (Fig. 3.10). This happy circumstance was prompted largely by the efforts of **Earl Douglass** (1862–1931). In 1909, when Douglass discovered this site (probably the most important Late Jurassic dinosaur deposit in the world), he found what turned out to be a nearly complete specimen of *Apatosaurus* (Chapter 10). Subsequent quarrying from 1909 to 1922, sponsored by industrialist and philanthropist **Andrew Carnegie** (1835–1919) for his Carnegie Museum (now the **Carnegie Museum of Natural History**, in Pittsburgh, Pennsylvania), yielded numerous skeletal remains of *Allosaurus*, *Apatosaurus*, *Diplodocus*, *Dryptosaurus*, and *Stegosaurus*. One of the more significant specimens was a juvenile *Camarasaurus* that was nearly complete and articulated, a very unusual find (Chapters 7 and 10). Workers at this site may have been the first to use explosives, such as dynamite (invented by **Alfred Bernhard Nobel**, 1833–97, of Nobel Prize fame), for extracting dinosaur skeletons from their rocky matrix, a practice that has mercifully lessened since then. Two interesting side notes are that the trivial name in *Apatosaurus louisae* was named after Carnegie's wife, Louise, and "*Diplodocus*" was the subject of the first (but certainly not last) dinosaur-themed pub song.

Similar dinosaur quarries in the western United States, which were found and mined during the first half of the twentieth century, were the **Howe** and **Cleveland-Lloyd** Quarries. The Howe Quarry was named after rancher **Barker Howe**, who discovered dinosaur bones on his property in northwestern Wyoming and called in Barnum Brown to investigate in 1934. Brown and his assistants then uncovered a dense accumulation of Late Jurassic bones. The extreme density is confirmed by actual data. Brown mapped meticulously in approximately 1 m^2 intervals. The assemblage includes mostly sauropods, such as *Apatosaurus*, *Barosaurus*, *Camarasaurus*, and *Diplodocus* (Chapter 10). Their maps show the distribution of the bones (Fig. 3.11). Bone abundance can be calculated using the following information:

$$A = lw \qquad (3.1)$$

where $\boldsymbol{A}$ is area, $\boldsymbol{l}$ is length, and $\boldsymbol{w}$ is width. The area of the Howe Quarry was 14×20 m, hence its total area was

$$A = 14 \times 20 \text{ m} = 280 \text{ m}^2 \qquad (3.2)$$

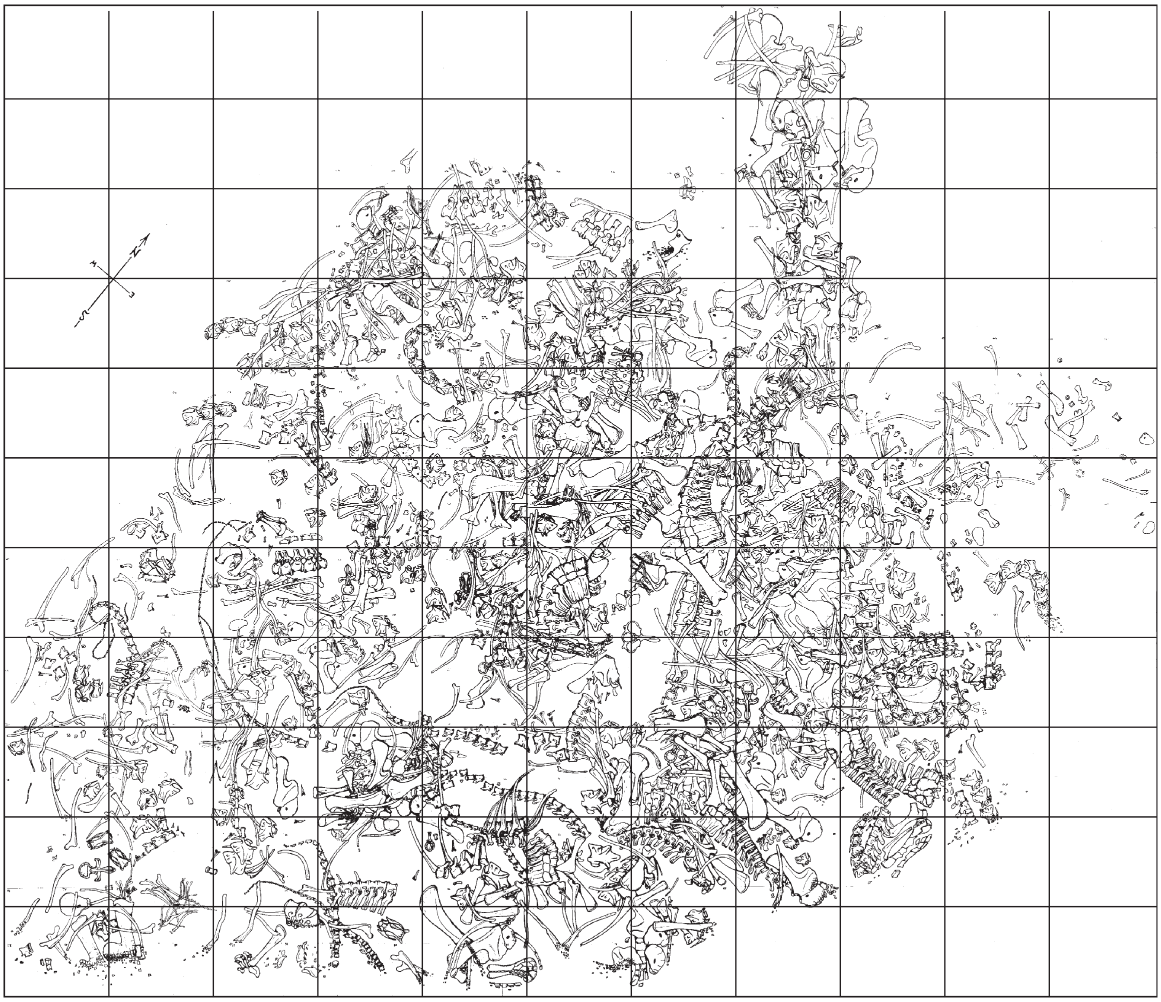


FIGURE 3.11 Map of Howe Quarry, showing horizontal distribution and concentration of dinosaur bones in the quarry area. Squares represent approximately meter squares. Neg. No. 314524. Courtesy Department of Library Services, American Museum of Natural History.

Bone abundance can be calculated by dividing the number of bones by the area:

$$B_a = N/A_t \tag{3.3}$$

where $\boldsymbol{B_a}$ is bone density in bones per square meter, $\boldsymbol{N}$ is total number of bones, and $\boldsymbol{A_t}$ is total area. Knowing that at least 4000 bones were recovered from this area,

$$B_a = 4000 \text{ bones}/280 \text{ m}^2 = 14 \text{ bones/m}^2 \tag{3.4}$$

Keep in mind that this number is equivalent to the mean number of bones per square meter, which does not take into account that some meter squares may not have had bones, or other squares had considerably more than 14. Additionally, looking at a bone map clearly shows how some bones transect the meter-square boundaries, leading to some restrictions about how to count bones within an area. Nevertheless, such calculations provide a measure of the relative abundance of skeletal components at a given site. Bone mapping, done at the Howe site by Brown's assistant **Roland T. Bird** (1899–1978), was the first attempt to record such information in this amount of detail. This method is now a standard procedure at any dinosaur bone deposit because it provides much evidence for hypotheses about the post-death history of a dinosaur assemblage. For example, an abundance of dinosaur bones probably indicates rapid burial of a number of dinosaurs together, through some unusual event such as a river flood or ash deposit (Chapter 7). The Howe Quarry also yielded dinosaur skin impressions, as well as a few dinosaur trace fossils, such as gastroliths and tracks.

The Cleveland-Lloyd Quarry, which was first uncovered near the small, eastern Utah town of Cleveland in 1937, also had a high bone density of Late Jurassic dinosaurs in a relatively small area. With the guidance of **William Lee Stokes** (1915–95) of Princeton University from 1937 to 1941, more than 12,000 dinosaur bones were recovered from the site, of which 60% to 70% are from *Allosaurus* and the rest from such dinosaurs as *Camarasaurus*, *Stegosaurus*, and the ornithopod *Camptosaurus*. The assemblage is unusual in its concentration of allosaur skeletons, leading to hypotheses that explain why so many meat-eaters would be in such a small area (Chapters 7 and 9). Stokes later adopted Utah as his home and spent much of his career at the University of Utah.

Roland Bird, who mapped the Howe Quarry, became more famous for his work with dinosaur tracks, particularly in eastern Texas, but also in Arizona, Colorado, and Utah. Like many early dinosaur-fossil discoverers, Bird had little formal academic training but had developed a successful search pattern for dinosaur fossils through extensive experience (Chapter 2). After finding several tracksites in Jurassic and Cretaceous rocks of some western states, he decided that these sites were too inaccessible. Subsequently, he followed up a tip and in 1939 went to Glen Rose, Texas, where he found dinosaur tracks exposed in Lower Cretaceous rocks of the Paluxy River. These tracks were made by a variety of theropods, but most importantly included undoubted sauropod tracks (some more than a meter wide), the first reported scientifically from the geologic record. One excellent paleontological point of discussion provoked by the sauropod tracks was whether they indicated that sauropods had aqueous habits (which was presumed at the time) or whether they walked on dry land (Chapters 10 and 14).

In 1909, another prolific Late Jurassic dinosaur site was investigated in an area far removed from Utah – **Tendaguru**, in present-day Tanzania. The region was a German colony at the time (German Protectorate East Africa) and in 1907 **Bernhard Sattler**, an engineer with a German mining company, discovered some large bones there. **Eberhard Fraas** (1862–1915), of the Royal Naturaliensammlung (Staatliches Museum für Naturkunde) in Stuttgart, Germany then examined these bones later that year. Fraas caught amoebic dysentery while doing fieldwork before visiting Tendaguru, but he managed to make the four- to five-day hike to the field site to confirm that the large bones were indeed from dinosaurs. While he was there, he even directed some excavation and recovery efforts. **Werner Janensch** (1878–1969) conducted later expeditions from 1909 to 1913 and was ably assisted by **Boheti bin Amrani**, a native of the region (Fig. 3.12). After World War I, the area came under British control and expeditions from 1924 to 1931 were arranged through the British Museum, again using the expert guidance of Amrani. The logistics for these forays were daunting because, unlike the American West, no railroads went into the area. There were also few automobiles and no roads, so local workers were employed to carry the dinosaur bones away on foot. Through this labor-intensive method, the local people in the employ of earlier German expeditions carried out about 225 tons of bones, the hike from the site taking four to five days. Collectively, all work done in Tendaguru resulted in the uncovering of a new species of stegosaur, *Kentrosaurus* (Chapter 12), the theropod *Elaphrosaurus* (Chapter 9), and the ornithopod *Dryosaurus* (Chapter 11), but the deposit is best known for its diverse sauropod assemblage, consisting of *Barosaurus*, *Brachiosaurus*, *Dicraeosaurus*, *Janenschia*, and *Tornieria* (Chapter 10).

FIGURE 3.12 Boheti bin Amrani at Tendaguru of what is present-day Tanzania, uncovering a sauropod rib during one of the German expeditions to the region. Dr. Bernard Krebs, Lehrstuhl für Paläontologie der Freien Universität, Berlin/Dover Publications.

In South Africa, **Richard Broom** (1866–1951), originally from Scotland and yet another physician who was much more enthused about long-dead subjects than his living patients, published papers in 1904 and 1911 on a few dinosaur finds in the Karoo basin, an area well known for its vertebrate fossils. These papers were significant because no dinosaurs had been described from South Africa since the times of Owen and Huxley, so future workers were encouraged to explore more in this area. Sure enough, **Sydney Haughton** of England and **E. C. N. van Hoepen** of South Africa soon followed Broom's works in 1915 to 1924 and expanded upon the knowledge of Late Triassic dinosaurs (such as the prosauropod *Melanorosaurus*; Chapter 10) in that region.

Also working on Late Triassic dinosaurs, especially those of southern Germany, was **Friedrich von Huene** (1875–1969). Von Huene greatly expanded the studies of the abundantly represented Late Triassic prosauropod *Plateosaurus*. Early in his long career, he reviewed critically all of the previous classifications of dinosaurs and re-affirmed in 1914, on the basis of much evidence, the dual classification system of Saurischia and Ornithischia for the dinosaurs (Chapter 5). He also described, for the first time, dinosaurs from the Upper Triassic of Brazil and did fieldwork wherever he could find Triassic rocks, which included the five continents of Europe, North America, South America, Africa, and Asia. Because of his breadth of experience with these earliest of dinosaurs, he provided much knowledge toward their evolutionary history (Chapter 6), and in 1932 published a comprehensive evaluation of the Saurischia. He also was well known for his hiking ability, and while in his 80s decided to attend a scientific meeting by walking 150 km for three days across southern Germany.

Like von Huene, Richard Lull (mentioned earlier) was an important synthesizer of knowledge about Late Triassic dinosaurs, especially those of the Connecticut Valley. Much of his work was done at the same time as his German counterpart. Lull, a former student of Osborn, was the first person to begin the arduous task of reconciling and correlating Hitchcock's dinosaur tracks with potential tracemakers, which he did by examining new discoveries of body fossil of dinosaurs in the same area. This integration of body and trace fossil evidence of dinosaurs had been attempted in other areas before, but never to the extent that Lull pursued it. His efforts resulted in a much better model of how a comprehensive approach to dinosaur fossils could enhance the quality of hypotheses about them. In 1915, Lull also reviewed all known fossil evidence (plants, insects, fish, reptiles, and dinosaurs) associated with Upper Triassic rocks of the Connecticut Valley, in an attempt to reconstruct the dinosaurs' paleoenvironments, one of the first serious studies of the paleoecology of a terrestrial ecosystem.

No history of dinosaur studies is complete without mentioning the Mongolian expeditions, first mounted by the American Museum and represented by the semi-legendary character of **Roy Chapman Andrews** (1884–1960). Chapman humbly began his career with the museum by performing janitorial duties, and eventually worked his way into the technical staff. Ironically, in light of his contributions to later discoveries, he was not primarily a dinosaur paleontologist and was mostly interested in studying mammals. Osborn, who became president of the museum in 1908, shared Andrews' interest in mammals, and Andrews persuaded him to mount a paleontological expedition to central Asia to search for the fossil ancestral remains of the most important mammals of all (to them), humans. Osborn agreed and the first Central Asiatic expedition, led by Andrews and accompanied by experienced paleontologist Walter Granger, went into the Gobi Desert of Mongolia in 1922. The trip failed in its goal to find fossils of humans, but did find the first confirmed dinosaur nests with eggs, although the identities of the egg layers were mistaken for the next 70 years (Chapter 9). French paleontologists had documented dinosaur eggs without nests in the nineteenth century. Skeletal material derived from this and successive expeditions from 1922 to 1930 included abundant specimens of the marginocephalians *Protoceratops* and *Psittacosaurus* (Chapters 7 and 13), the inappropriately-named theropod *Oviraptor* (Chapter 9), and the evil-looking *Velociraptor* and *Saurornithoides* (Chapter 9), all found in Cretaceous rocks.

Chapman has often been cited as the possible inspiration for the character Indiana Jones, a fictional **archaeologist** (someone who studies human artifacts, which is very different from a paleontologist: see Chapter 1). The producers of the Indiana Jones films have never admitted that Chapman was their source. Regardless, Chapman's expeditions and his exploits were certainly extraordinary for their time. He took advantage of his knowledge of Asian languages to work with his Chinese hosts and established his headquarters in Beijing; he navigated field crews in automobiles; and he arranged for the rendezvous of camel herds that carried gasoline and other supplies across the desolate terrain. Chapman was also an excellent marksman and was rarely photographed in the field without some type of firearm within his reach (Fig. 3.13). Bandits were bothersome in the region, and he reportedly shot some of them. Fortunately, most fieldwork in Mongolia and other areas of the world today is threatened more by bad weather or diminishing coffee supplies than hostile raiders.

In the late 1940s, Russian expeditions to Mongolia followed the American efforts through the auspices of the Russian Paleontological Institute, led by paleontologist (and famed Russian science-fiction writer) **Ivan A. Efremov** (1907–72) and herpetologist **Anatole K. Rozhdestvensky**. In these excursions they found more examples of the previously discovered Cretaceous dinosaurs of that region, as well as some important new finds, such as the ankylosaur *Pinacosaurus* (Chapter 12), hadrosaur *Saurolophus* (Chapter 11), and the large theropod *Tarbosaurus*, which is so similar to *Tyrannosaurus* that it is now considered an Asian variant of the species (Chapter 9). The continued success of the Russian expeditions ensured that more

FIGURE 3.13 Roy Chapman Andrews (right), in the Bain-Dzak area, Mongolia, with Late Cretaceous dinosaur eggs in front of him and his bandit-prevention device behind him. Negative No. 410760, Photo. Shackelford. Courtesy Department of Library Services, American Museum of Natural History.

investigators would follow; a Polish–Mongolian research group returned to the area in the 1960s, as did American Museum paleontologists in the 1990s. Renowned paleontologist **Zofia Kielan-Jaworowska** led the Polish–Mongolian expedition, which also included participants **Teresa Maryanska** and **Halszka Osmólska**, who are still considered to be Poland's leading experts on dinosaurs.

China has been one of the most productive countries for dinosaur fossils, and this status will most likely continue for many years to come. The long-known plethora of dinosaur bones in China led to initial studies, mostly by Westerners in cooperation with Chinese scientists, resulting, in 1922, in the description of *Euhelopus*, a Jurassic sauropod (Chapter 12). One of the pioneers of dinosaur paleontology was **Yang Zhong-jian** (1897–1979), known as **C. C. Young** in Western scientific literature. Yang, who officially became China's first professional vertebrate paleontologist in 1927, was also the co-discoverer of the first documented dinosaur tracks in China, which were found in Jurassic rocks of the Shanxi Province in 1929. In 1936, he led a combined Chinese and American group, which uncovered the unusually long-necked sauropod *Omeisaurus* (Chapter 10). Yang's studies in Canada, England, the USA, and Germany helped him to establish excellent contacts with Western scientists, which paved the way for exploration of the vast outcrops of Mesozoic strata in his country. Locations in China have produced one of the most productive dinosaur egg sites in the world (Chapters 2 and 8) and many species of feathered non-avian theropods and birds (Chapters 9 and 15).

Dinosaur trace fossils, other than tracks and nests, received some recognition early in the twentieth century, although some of them were not appreciated until recently. Coprolites were reported in dinosaur-bearing rocks by Hitchcock in 1844, but the first dinosaur coprolite was not interpreted until 1903 by **C.-E. Bertrand** of Belgium. His specimen came from the same Cretaceous deposit that provided Dollo with so many iguanodontian skeletons. After Barnum Brown interpreted gastroliths early in that century, von Huene in 1932 reported other gastroliths in association with bones of the Late Triassic prosauropod *Sellosaurus* (Chapter 10). In 1942, Stokes described a similar occurrence of stones found with Late Jurassic sauropod remains. **W. D. Matthew** first interpreted dinosaur toothmarks, which are often preserved in dinosaur bones, in association with a potential tracemaker in 1908. In this study, he noted that the tooth spacing of the Late Jurassic theropod *Allosaurus* matched the toothmarks on bones of *Apatosaurus*, a sauropod that lived at the same time. This approach provided an intuitive method for better determination of feeding relationships among dinosaurs (Chapters 8 and 9). Although they were always a part of dinosaur studies, dinosaur trace fossils began to gain more attention from dinosaur paleontologists in the latter half of the twentieth century, as trace fossils supplemented or, in some cases, surpassed the information derived from dinosaur body fossils.

Dinosaur Studies of the Recent Past: Beginnings of a Renaissance and a New Legacy

The Latter Half of the Twentieth Century and Globalization of Dinosaur Studies

The preceding history arbitrarily cuts off at about 1950 and is thus incomplete, but it provides a summary of dinosaur studies up to that point.

Observant readers may have noticed that one continent, Australia, has barely been mentioned, and Antarctica completely neglected. This lack of information is because Australia has become a discovery site for abundant dinosaur fossils (especially tracks) only in the past 35 years, and the first discovery of an Antarctic dinosaur was not until 1986. However, both of these continents will undoubtedly see expanded research as these finds inspire increased exploration.

Discussion of the people in dinosaur studies during the latter half of the twentieth century must be limited for several reasons. One reason is that the author of this book does not feel qualified to judge which of these people (many of whom are still active in the discipline, and perhaps reading this) deserve mention as important contributors to the long-term history of dinosaur studies. Such a pronouncement will be much easier to make in another 50 years or so, when the enduring contributions made by these investigators will be more evident. Of course, some genuinely notable discoveries already happened in the latter half of the twentieth century and beginning of the twenty-first, and those discoveries and the people associated with them will be mentioned where appropriate. Time will tell whether these contributions will make paleontological history. With that said, three paleontologists in the latter half of the twentieth century, **Edwin H. Colbert**, **John Ostrom**, and **José F. Bonaparte**, stand out for providing the most long-lasting scientific contributions from which all modern investigators in dinosaur studies will benefit.

Edwin H. Colbert (1905–2001) is best known in dinosaur paleontology for his discovery, in 1947, of a site that contained hundreds of the Late Triassic theropod *Coelophysis bauri* (Chapter 11). The site, in the **Chinle Formation** at Ghost Ranch, New Mexico, was located near the summer home of famed painter **Georgia O'Keeffe** (1887–1986), who occasionally stopped by the excavation to talk with Colbert. Late Triassic dinosaurs have always held a special interest to paleontologists, because they represent the earliest dinosaurs (Chapter 6). Thus for Colbert to document such a rich find was a major contribution to our understanding of the origin of dinosaurs and a source of detailed paleontological information about them. For example, because of their abundance, growth series and population structures for this theropod could be proposed. This is an unusual situation for any dinosaur species because of the rarity of multiple specimens of the same species. Additionally, cannibalism was first interpreted for this species based on the specimens from Ghost Ranch, where juvenile bones were thought to be inside the body cavities of an adult. This has been re-interpreted, however, because the bones of one were actually just on top of another, rather than inside of it (Chapter 9). Furthermore, the unusual occurrence of so many individuals of a single species of carnivorous dinosaur, similar to the findings in the Cleveland-Lloyd Quarry, led to some debated hypotheses regarding the pre-burial history of the assemblage, as well as implied social behavior (Chapter 6). Colbert was also well known for his excellent textbooks on vertebrate paleontology and popular books on dinosaurs, which have helped to educate aspiring vertebrate paleontologists worldwide. His fascinating works on the history of dinosaur studies also gave science enthusiasts a sense of the uniqueness of using fieldwork to search for the remains of long-dead animals. Colbert's historical works were a major source of information for this chapter, and they certainly set the standard for all future bibliographers of dinosaur paleontologists.

John Ostrom (1928–2005) is credited with sparking the Dinosaur Renaissance of the past 30 years by his detailed examination and consequent hypotheses of the Early Cretaceous theropod *Deinonychus* (Chapter 9), which he first reported in 1969. Ostrom, through convincing use of his data on *Deinonychus*, revived the idea (first proposed by Huxley and unintentionally augmented by the work of Hitchcock in the nineteenth century) that some dinosaurs were more active and bird-like in their behavior, rather than reptilian. Ostrom's interpretation was based on **functional morphology**, the study of how the form of an animal relates to its functions, an approach that had been used before in dinosaur studies but rarely so effectively. New interest thus began in studying the extent of this bird-like behavior in some dinosaurs, namely whether it was reflected by physiological indicators of endothermy (Chapter 8) or was related to evolutionary links between dinosaurs and modern birds (Chapter 15). Ostrom also made a very important discovery while examining a skeleton in a small Dutch museum. Ostrom recognized the skeleton, identified initially as a pterosaur (flying reptile), as a previously unknown specimen of *Archaeopteryx*, one of only seven ever described.

Dinosaurs from Europe and North America were studied the most during the nineteenth century and interest expanded to Africa and Asia in the first half of the twentieth century. But research in South America in the latter half of the twentieth century was prompted largely by the efforts of **José F. Bonaparte**. Of all living paleontologists, Bonaparte has named or co-named the largest number of dinosaur genera (10 as of the writing of this book), including *Argentinosaurus* (a huge sauropod; Chapter 10), *Carnotaurus* (a large, horned theropod; Chapter 9), and *Abelisaurus*, the latter a representative of a group of Cretaceous theropods unique to South America. His discoveries, primarily in his native Argentina, have shown important evolutionary relationships between dinosaurs of separate continents, especially the "southern continents" of South America, Africa, India, Australia, and Antarctica, which formed one landmass in southern latitudes, called **Gondwana**, during much of the Jurassic (Chapters 4 and 6). Bonaparte is the former student of influential American vertebrate paleontologist **Alfred Sherwood Romer** (1894–1973), and is continuing his tradition of excellence.

Other notable dinosaur paleontologists, who have already encouraged much interest in dinosaurs in the USA and abroad, include Americans **Robert T. Bakker**, **John (Jack) R. Horner**, and **Paul C. Sereno**, as well as **Martin G. Lockley**, originally from Wales but now based in the USA. Bakker, a former student of Ostrom, is best known for his role as a publicly visible cheerleader for alternative views of dinosaurs as active animals more akin to birds and mammals, as opposed to their previous stereotype as sluggish reptilians. He is also one of the best popularizers of contentious ideas about dinosaurs that have provoked much discussion and attempts at refutation; his main theses are summarized in his 1986 book *The Dinosaur Heresies*. Jack Horner, along with his now deceased friend **Bob Makela**, began his career as an amateur paleontologist and discovered dinosaur-nesting horizons of the Late Cretaceous ornithopod *Maiasaura*, the first dinosaur nests found in North America (Chapters 8 and 11). This work and further investigations changed the conception of dinosaurs from solitary and uncaring creatures to social, nurturing animals. In a relatively short time, Sereno and his research teams have chalked up a remarkable number of noteworthy dinosaur discoveries in remote areas of Argentina, Morocco, Niger, and Inner Mongolia. Included in his scientifically important contributions are the discovery and description of what are possibly the oldest known dinosaurs or dinosaur ancestors (Chapter 6), and he has otherwise made significant advances in the cladistic classification of dinosaurs. Lockley is the most recognized dinosaur ichnologist in the world, having studied and written about dinosaur tracks and their scientific pertinence in numerous peer-reviewed journal articles and books intended for public consumption. Although most of his work has been in the track-rich Mesozoic strata of the western United States, he has also studied dinosaur tracks from Argentina, Bolivia, Brazil, Portugal, Spain, central Asia, China, and Korea, thus considerably augmenting the skeletal record for dinosaurs formerly missing from many of these regions. Lockley and the other aforementioned paleontologists are especially well known for their educational outreach efforts, whether through books written for interested lay people or lectures given in public forums.

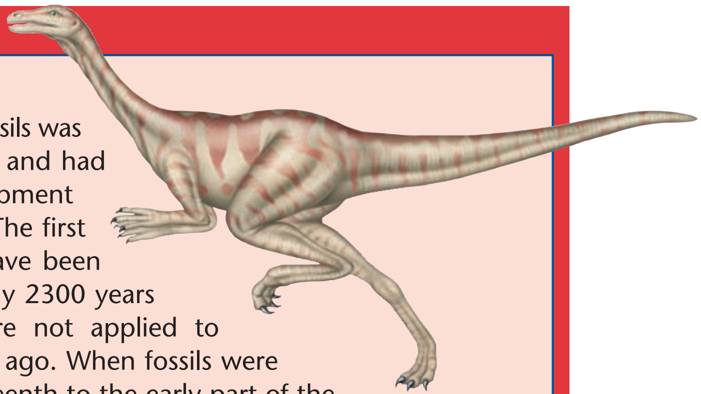
Of course, modern dinosaur paleontologists are members of an increasingly global science. A short list, for purely practical reasons of limited space, might include **Phillip J. Currie** of Canada, **Dong Zhi-Ming** of China, **Altangerel Perle** of Mongolia, **Patricia Vickers-Rich**, **Thomas Rich**, and **Tony Thulborn** of Australia, **Konstantin Mikhailov** of Russia, **Anusuya Chinsamy-Turan** of South Africa, **Fernando Novas** and **Rudolfo Coría** of Argentina, and **Armand de Ricqlès** of France. Further internationalization of dinosaur studies and inclusion of more participants from less industrialized nations should continue as Internet communications become accessible in more places and bureaucratic obstacles lessen. Stricter immigration control in the USA since 2001, however, has significantly decreased the number of foreign-born graduate students and scientists entering the USA, which may adversely affect future cooperation. Likewise, large-scale warfare in the Middle East since 2003 has hampered the participation of USA scientists in projects taking place in countries opposed to US-led war efforts.

Perspectives in the Past, Present, and Future of Dinosaur Studies

Advances in dinosaur studies in the past 25 years are exhilarating. The fast pace of these discoveries and the competition for coverage of these discoveries by the popular press ensures that the history of dinosaur studies will be continually changing, but all of this is still a direct result of the science behind such discoveries. One of the fringe benefits of the ongoing popularity in dinosaurs is that many professional paleontologists can write books for a general audience on their favorite subjects while still retaining their scientific integrity. Some of these books summarize evidence, hypotheses, and in some cases speculations about dinosaurs, whether based on information gathered in the past two centuries or just in the past few years. Knowing the history of dinosaur studies gives us a perspective as to how the science, especially in terms of its knowledge, has evolved and changed through the centuries, change that is still happening today. Scientists try to learn not just from their mistakes but from the mistakes of others, so no doubt some of the "certainties" of dinosaur paleontology today will be ridiculed (in an understanding sort of way) by future generations of paleontologists.

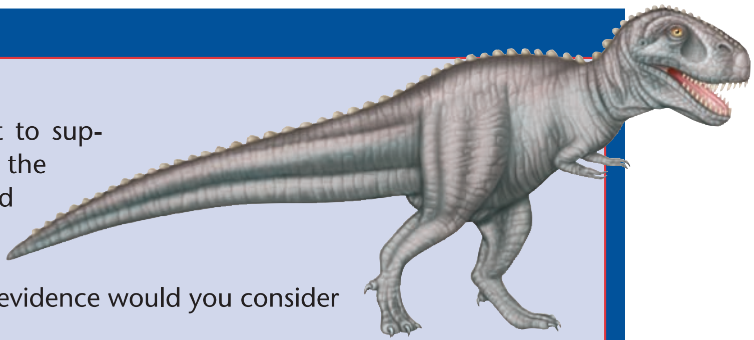
In contrast, some aspects of how paleontologists went about their work and made their discoveries in the past are unlikely to change. Despite the sophistication of modern technology, much of dinosaur paleontology still involves wandering through remote areas of the world, looking at the ground, and using search patterns. The human element of such explorations will also be both a source of constancy and unpredictability. As demonstrated previously, knowing about the people involved in dinosaur paleontology also helps in understanding that scientists are real people who have jealousies, fears, prejudices, greed, and occasionally nasty tempers. However, when all is said and done, they love their science. Additionally, society and politics have influenced the course of paleontological studies, and provide valuable context for certain dinosaur discoveries and their interpretations. Lastly, as we have seen, many dinosaur discoveries were made by amateurs and later described by professional paleontologists, demonstrating how paleontology is one of the few sciences where amateurs have made and continue to make important contributions.

SUMMARY



The biological origin of dinosaur fossils was probably evident to early peoples and had some influence on cultural development of some prehistoric populations. The first written reference to what may have been dinosaur fossils was in China nearly 2300 years ago, but scientific methods were not applied to these fossils until about 200 years ago. When fossils were discovered in Europe from the fifteenth to the early part of the nineteenth centuries, the voice of reason, so often associated with the rise of scientific thought in Western civilizations, rejected fossils as the remains of extinct organisms. However, these errors were eventually recognized, which demonstrates that science is a self-correcting enterprise. Early workers in England, such as William Buckland, the Mantells, and Richard Owen, were responsible for the gestation of dinosaur studies. French, German, American, Canadian, and Argentinian paleontologists investigated both dinosaur body fossils and trace fossils in the remainder of the nineteenth century. In part, the first half of the twentieth century represented a continuation of this work, but it also was marked by exploration of Asia (particularly China and Mongolia), Africa, and more of the Americas. Unfortunately, two world wars interrupted most international cooperation on dinosaur paleontology, but most relations resumed in the 1950s. The study of dinosaurs began its climb to its current exalted state when new hypotheses about dinosaurs, in the late 1960s and early 1970s, received increased publicity. The recent resurgence of new discoveries and hypotheses in the 1990s and early part of the twenty-first century ensures that the future study of dinosaurs will continue to make history. Dinosaur paleontology is now, more than ever, a global science and its evolution indicates that trend will continue in the future.

DISCUSSION QUESTIONS



1. How would you attempt to support the hypothesis that the "dragon bones" described in ancient Chinese texts refer specifically to dinosaur bones? What sort of evidence would you consider convincing?
2. The rivalry of Cope and Marsh, which was a major motivator behind their enormous number of significant dinosaur discoveries and other contributions to paleontology, brings up an interesting ethical question (Chapter 2). Did the value of their discoveries outweigh the costs of their enmity? In other words, did the ends justify the means?
3. The field party sent by Osborn to Como Bluff in 1897 was unsuccessful, but it forced Osborn to look at a different nearby locality, which resulted in the "Bone Cabin" find of thousands of dinosaur bones. What other instances in the chapter seemed to show similarly discouraging circumstances that caused the people involved to accomplish tasks that actually resulted in later success?
4. The phrase "degrees of separation" refers to how one person who has met two other people represents one degree of separation that links the two, who might never meet. Which historical examples of "degrees of separation" surprised you with regard to dinosaur paleontologists and non-paleontological figures? (For example, how many degrees of separation are there between Sitting Bull and Roy Chapman Andrews?)
5. This chapter presents data that could support the statement that a career of paleontology and geology fieldwork has known health benefits and results in a significantly increased lifespan (see Table 3.1). How would you test this statement? What are potential sources of error in these data, such as in calculations of the ages of the geologists and paleontologists?
6. After finding a bone bed in Cretaceous rocks, you set about mapping the area containing the exposed bones. The area measures 13.5 $\times$ 22.5 m and contains about 1250 bones. What is the approximate bone density of this bed (in m^2)? What are some factors that might cause variations in this average?
7. In the accounting of the history of dinosaur studies, is there any evidence of the effect of language barriers on worldwide exploration for dinosaurs in the nineteenth and early part of the twentieth century? On the basis of dissimilarities in language and culture, what areas of the world would have been the most difficult for Europeans and North Americans to arrange visits? What areas, however remote, were more conducive to investigations?
8. Identify and count how many of the nineteenth century geologists and paleontologists were clergymen. How did some of their findings conflict with the religious conventions of the time? Additionally, how many of the people mentioned from the nineteenth century were

DISCUSSION QUESTIONS Continued

physicians? How would their medical background have helped them to become vertebrate paleontologists?

9. Written history sometimes reflects the choices of historians. How could you find more evidence of paleontologists in the nineteenth and early twentieth century than what was already mentioned in the chapter, if most mainstream books do not mention them?
10. Pick three people mentioned in the chapter that you would like to meet (they do not have to be paleontologists or geologists). What are some questions you would ask each person relating to dinosaurs and why?

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