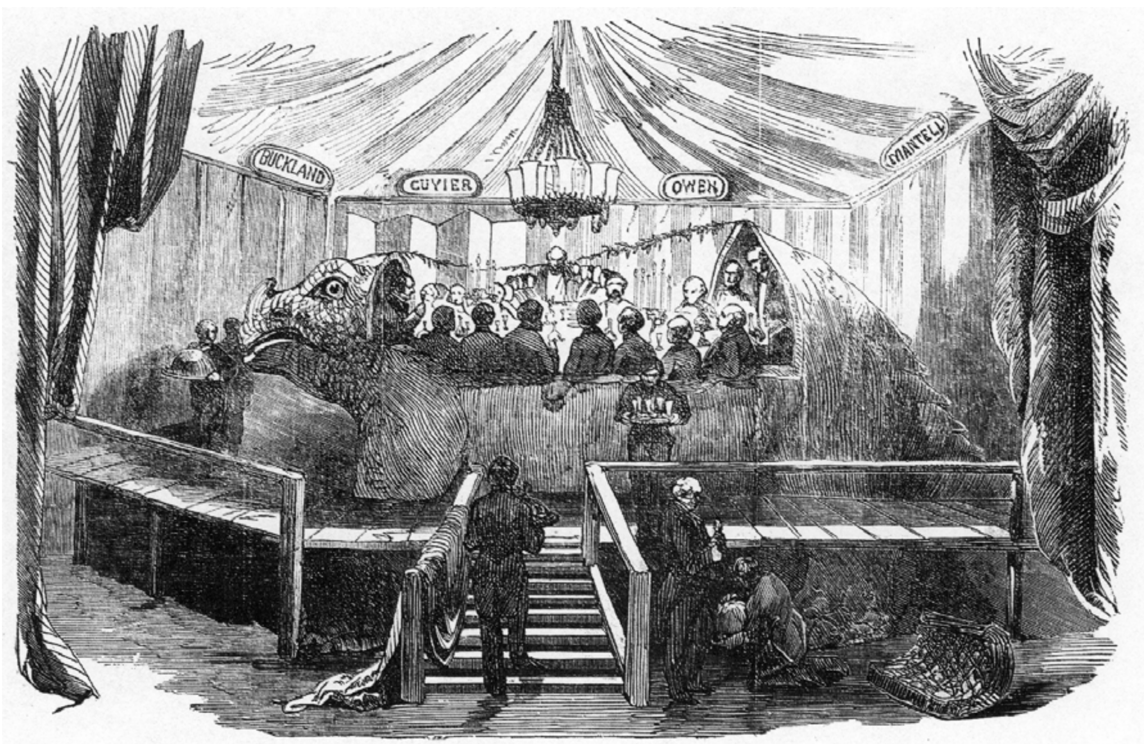
The Mistaken Extinction

Chapter One

Romance vs. Reality: The Seductive Allure of Dinosaurs

Paleontology--the study of fossils from prehistoric animals and plants--has experienced a surge in popular interest over the last couple of decades. Dinosaurs continue to ride on the crest of that wave. However, dinosaurs have never fallen out of favor. Since the famous British anatomist, Richard Owen, first coined the name "Dinosauria" in 1841, dinosaurs have captured the curiosity of both paleontologists and the general public (fig. 1.01). Such attention is well deserved because dinosaurs are widely recognized to have ruled the continents for over 150 million years.



Public relations events were thrown into high gear soon after Richard Owen first recognized the group, Dinosauria. In the early 1850s, as part of the opening for an exhibition of dinosaur models at Sydenham Park in London, Owen held a special-invitation dinner party for 20 guests inside the partially built model of *Iguanodon*. This model, along with others still on view today, were sculpted by Waterhouse Hawkins. (from Norman, D., 1985, The Illustrated Encyclopedia of Dinosaurs, Salamander and Crescent Books, New York, p.11)

As paleontologists, one of the questions the public most commonly asks of us is: "Why are dinosaurs so popular?" There is no single, all-encompassing answer, but we can offer a few reasons. Dinosaurs inspire the imaginations of young and old alike. For many youngsters, like we once were, these magnificent animals represented our first introduction to science. The immense size of many dinosaurs, their strange appearance, and their incredible age all contribute to their mystique. They seem stranger than life, like monsters out of science fiction stories, but their fossilized bones prove that they really lived. To us, that's the key; dinosaurs are not just imaginary. The events of their lives were every bit as real and vital as those of our own.

Our curiosity about dinosaurs drives us to want to know everything about their history and way of life. In this pursuit, however, our love of science fiction runs head-long into the methods of scientific research and the limits of scientific knowledge. Fossils of dinosaurs can help us solve many mysteries about their history. The size of the skeletons gives us a good idea about how large these animals were. By studying the shape of their bones and the structure of their skeletons, we can establish which dinosaurs were close and distant evolutionary relatives.

For example, fossils of the earliest known dinosaurs provide evidence of how dinosaurs differ from their reptilian cousins. By studying the structure of the fossilized bones in their hind legs and hips, we have found features which indicate that they walked upright, with their legs extending straight down from the hips to the ground. This erect posture is one of the evolutionary innovations that makes a dinosaur a dinosaur, and its by identifying such features that we can trace the sequence of dinosaur evolution.

All later dinosaurs inherited this new posture from the first dinosaur. Two major groups sprang from this common ancestor. Saurischians contain all the commonly recognized carnivorous dinosaurs, such as *Tyrannosaurus* and *Allosaurus*, as well as the largest dinosaurs, such as *Apatosaurus* and *Diplodocus*. Ornithischians include the armored dinosaurs, such as *Stegosaurus* and *Ankylosaurus*; the duckbills; the horned dinosaurs, such as *Triceratops*; and the thick-skulled pachycephalosaurs.

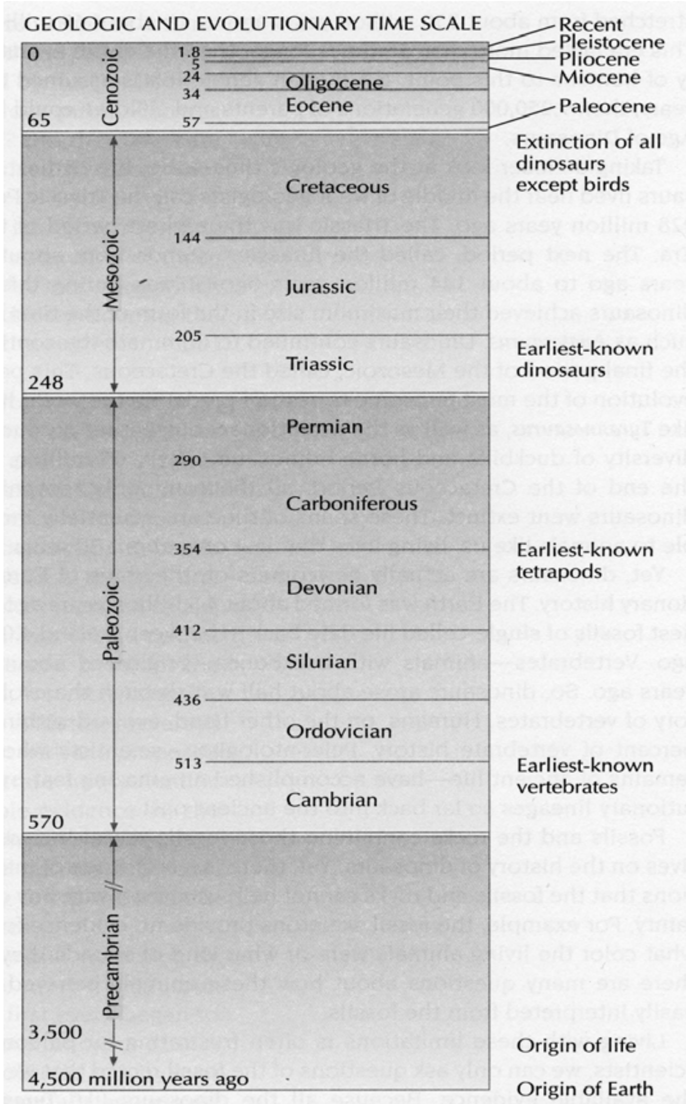
In addition to establishing evolutionary relationships, fossils can provide some information about the behavior of dinosaurs. Sequences of fossil footprints, called trackways, confirm that dinosaurs moved around in an upright or erect posture.

Besides evolutionary relationships and some behaviors, the rocks in which dinosaur fossils are preserved provide clues about what their environment might have been like and how long ago they lived.

The evidence for measuring these vast spans of geologic time comes from layers of volcanic rock preserved among the beds that contain the dinosaur fossils. Some of these volcanic layers are composed of minerals formed, in part, by radioactive atoms. Once the volcanic rock was erupted and cooled, the radioactive "parent" atoms begin breaking down, or decaying, into "daughter" atoms of different composition at a constant rate. This rate can be measured experimentally with sophisticated equipment. In essence, to obtain an age for when the volcanic rock formed, one must measure the proportion between the parent atoms and daughter atoms in the volcanic rock. Then, because we know the rate at which parent atoms decay, an age can be calculated. Such calculations have led us to the realization that the evolutionary roots of dinosaurs stretch back hundreds of millions of years. This process is called radioisotopic dating.

The age of the era during which dinosaurs ruled the Earth is truly mind-boggling (fig. 1.02)[1]. Most of us are used to dealing in time scales ranging from days to decades, but the dinosaurs, as we commonly recognize them, lived more than 60 million years before any people were around. The roots of our own human ancestry stretch back only four or five million years. However, the Mesozoic Era, often termed the Age of Dinosaurs, stretched from about 250 million years ago up to about 65 million years ago. This era lasted more than 35 times longer than the entire evolutionary history of humans to this point. If a human generation is assumed to average 20 years, then 9,150,000 generations of parents and children could be fit into the Age of Dinosaurs.

Taking a closer look at the geologic time scale, the earliest known dinosaurs arose near the middle of what geologists call the Triassic Period--about 228 million years ago. The Triassic was the earliest period of the Mesozoic Era. The next period, called the Jurassic, extends from about 205 million years ago to about 144 million years ago. It was during this period that dinosaurs achieved their maximum size in the form of the titanic sauropods, such as *Apatosaurus*. Dinosaurs continued to dominate the continents during the final period of the Mesozoic, called the Cretaceous. This period saw the evolution of the most fearsome terrestrial predator the world has ever seen, *Tyrannosaurus*, as well as the evolutionary bursts that produced a dazzling diversity of duckbills and horned dinosaurs. Then, 65 million years ago, at the end of the Cretaceous Period, all the commonly recognized kinds of dinosaurs went extinct. These spans of time are essentially incomprehensible to animals like us, living lives that last only about 70 years.



Time scale of Earth and its evolutionary history identifying major eras and periods. Major events in the history of life are listed along the right side. The earliest known humans originated near the start of the Pliocene, less than 5 million years ago. The boundary between the Mesozoic and Cenozoic Eras corresponds to the boundary between the Cretaceous and Tertiary Periods. This is often abbreviated as the K-T boundary. The "K" stands for Cretaceous, which in German is called "Kreide." The Tertiary Period contains all the time intervals from the Paleocene through the Pliocene.

Yet, dinosaurs are actually newcomers on the stage of Earth and evolutionary history. The Earth was formed about 4.5 billion years ago, and the earliest fossils of single-celled life date back to between 3.5 and 4.0 billion years ago. As we shall see in the second part of this book, vertebrates--animals with backbones--originated about 500 million years ago. So, dinosaurs arose about half way through the evolutionary history of vertebrates. Humans, on the other hand, evolved within the last one percent of vertebrate history. Paleontologists--scientists who study fossil remains of ancient life-- have accomplished an amazing feat by tracing evolutionary lineages so far back into the ancient past.

Thus, fossils and the rocks containing those fossils reveal incredible perspectives on the history of dinosaurs. Yet, there are a multitude of intriguing questions that the fossils and rocks cannot help us answer with any degree of certainty. For example, the fossil skeletons provide no evidence for us to judge what color the living animals were or what kind of sounds they made. Also, there are many questions about how these animals behaved that are not easily interpreted from the fossils.

Living with these limitations is often frustrating for paleontologists. As scientists, we can only ask questions of the fossil record that we can test with the available evidence. Because all the dinosaurs like *Tyrannosaurus* and *Triceratops* are extinct, we can't go out to the field and observe how they behaved. Consequently, we can't be certain how *Stegosaurus* used the ornate set of plates on its back, and we don't know for sure whether the duckbills used their crests for amplifying their vocalizations. It's certainly possible, but there is no unequivocal evidence to support these hunches.

Nonetheless, it is easy to get seduced by the spectacular skeletons. The limitations imposed by the evidence in the rock and fossil records haven't stopped some paleontologists from imaginatively speculating about the use of these unusual structures and many other aspects of dinosaur behavior. The public desperately wants answers to all their questions about dinosaurs, and some paleontologists have been unable to resist the urge to oblige and speculate. The literature of both the scientific and popular press is replete with both intriguing and outrageous claims about how dinosaurs lived and died.

As a result, conflicting claims about dinosaurs, fueled by the public frenzy over blockbusters like *Jurassic Park*, have led to numerous public debates among paleontologists. Were dinosaurs "warm-blooded?" Did they take care of their young? And within the present context: What caused so many dinosaurs to go extinct 65 million years ago?

Our charge in this book is to investigate all the major issues surrounding dinosaur extinction. What do we really know about the extinction of dinosaurs at the end of the Cretaceous Period? To try and solve this case, which is somewhat like an ancient murder mystery, we must examine closely the evidence available in the rock and fossil records. That's the subject of the first several chapters in the Part 1 of this book.

Our review of extinction hypotheses will basically follow the order in which they were proposed. To begin, we will review some of the earlier ideas or hypotheses that sought to explain the cause of dinosaur extinction. In retrospect, some seem comical, but others are more sophisticated. Our goal will be two-fold. First, we will try to distinguish between hypotheses that are scientific and those that are not. As in all scientific disciplines, this distinction depends on whether there is evidence available to test the hypothesis. If the rock and fossil records contain evidence that can be used to test the proposed cause, then the hypothesis is considered to be scientific. If the hypothesis cannot be tested with evidence present in the rock and fossil record, then it falls outside the realm of science. Second, for each scientific extinction hypothesis, we will try to evaluate whether the evidence preserved in the rock and fossil records is consistent or inconsistent with the proposed cause of extinction. This exercise can be used to illustrate how scientific methods work by testing new ideas that are proposed with the available evidence. In the end, the hypothesis that is consistent with, or explains, more evidence than any other will be deemed to be the most likely cause. This rule for making decisions, often called Occam's Razor or the Principle of Parsimony, forms the foundation for choosing between competing scientific hypotheses or theories.

Next, we'll investigate the current debate about dinosaur extinction by exploring clues in the rock record relating to two of the most momentous geological and astronomical events in Earth history. The first event began to be seriously discussed as a cause for the Cretaceous dinosaur extinctions in 1972. It involves the second largest known episode of volcanic activity ever inflicted on the continents of our planet, along with potentially associated changes in the location and configuration of the seas. Massive piles of lava flows that now cover vast areas of India may represent the evidence for these eruptions at the end of the Cretaceous. Because of the enormous amounts of gases and other pollutants erupted during this event, the Earth's environment could have been severely damaged. Could this have caused the extinction of dinosaurs?

Or, was that extinction caused by the Earth-shattering impact of a large comet or asteroid near present-day Yucatan. This stunning hypothesis was put forward in 1980 by some of our colleagues in the Geology and Geophysics Department when we were graduate students at Berkeley. Their scenario suggested that the impact blasted a cloud of debris into orbit, which completely enveloped the Earth. This cloud cut off all light from the Sun for several months, preventing plants from photosynthesizing. With the death of most plants, the herbivorous dinosaurs died out, and with the extinction of their plant-eating prey, so did the carnivorous dinosaurs.

These are both sensational scenarios. Almost immediately after the asteroid hypothesis was published in 1980, both the press and the public became as engrossed in the issues as our scientific community at Berkeley did. As students of professors involved in the debates, we were quickly drawn into the middle of the ensuing exchanges between the proponents of these two competing hypotheses. They were rather daunting but extremely exciting times because we realized that an important phase of evolutionary history might be rewritten right before our very eyes. At stake was the stately and gradualistic view of evolutionary change that had dominated geological and paleontological thinking for the last two centuries. Did catastrophic change, like that predicted by the impact hypothesis, really drive the history of life as some scientists in the 1800s had argued?

Now over 15 years have past since the impact hypothesis was proposed, but still the debate over the cause of the Cretaceous extinctions continues. What new evidence to refute or support the competing ideas has been discovered? By searching for clues in the rock record, we'll first try to establish whether these extraordinary events really happened. Then, we'll try to evaluate the effects that these two events had on dinosaurs and other contemporary life forms, by looking at the fossil record to determine which groups of organisms went extinct and which groups survived.

One key to deciding whether the eruptions or the impact was responsible lies in the proposed durations for these events. Most of the eruptions are thought to have occurred over a period of 500,000 years leading up to the end of the Cretaceous. The effects of the impact, however, are thought to have lasted only between a few months and a few thousand years, at most. Can we tell time precisely enough to distinguish between the effects of these events in rock and fossil records that are 65 million years old? Our ability to do so may well determine whether we can assign responsibility for the extinctions on either of the two proposed causes.

However, the debate over the cause of the Cretaceous dinosaur extinctions was, by no means, the only argument about dinosaur extinction going on at Berkeley when we were students. In the second part of the book, we will turn to investigate a rather startling question that some of our paleontological classmates were beginning to pose: Did all the dinosaurs really go extinct at the end of the Cretaceous? When we first entered college, everyone agreed that they did. Yet, by the time we got to Berkeley, we were startled to find out that this long-accepted evolutionary fact might not be correct.

This debate was catalyzed by a new method of determining evolutionary relationships, called cladistics. Its goal was to sort out smaller groups of organisms within larger groups of organisms by rigorously identifying unique anatomical features that the different groups shared. In essence, members of a group that share a unique feature, like the upright posture of dinosaurs, are descendants of the first animal in which this kind of upright posture evolved. By following the evolutionary trail of anatomical clues from larger groups into smaller groups, such as from dinosaurs into saurischians and ornithischians, one can reconstruct the sequence in which different features and groups evolved.

Applying the cladistic approach to the evolution of vertebrates generated some results that contradicted several long-held evolutionary notions. Consequently, it was very controversial. It ruffled the feathers of many prominent evolutionary biologists. One of our landlords when we studied at Berkeley was intimately involved in these debates. Gareth Nelson, a Curator of Ichthyology at the American Museum of Natural History in New York, was the most prominent and influential proponent of cladistics in the United States. We moved into the house owned by his wife when they got married and she moved to New York to join him. In order to get a break on our rent, we helped him do renovations around the house, and while working, we'd pass the hours discussing cladistics.

One of the most radical results of cladistic analysis suggested that living birds descended from small carnivorous dinosaurs. This analysis formed the basis for the dissertation by one of our classmates and roommates, Jacques Gauthier. Actually, this result was not a totally new idea. Back in the mid-1800s, shortly after Charles Darwin had published his seminal work on evolution, the scientific community was rocked by the discovery of *Archaeopteryx*, a late Jurassic animal that exhibited many reptilian features, but also had feathers like a bird. Eventually, most scientists accepted that *Archaeopteryx* represented the earliest-known bird, but debate continued over whether birds evolved from dinosaurs or other reptiles. More than 100 years later, our roommate had run head-long into the same evolutionary quagmire. As with the debate over Cretaceous extinctions, the intellectual exchanges were electrifying to incoming Ph. D. students like we were. We might actually witness the solution of a long-running evolutionary mystery: From what group did birds really evolve?

Did we witness that solution? To judge, we'll start back at the beginning of life on Earth. By following the trail of anatomical clues leading from the origin of early life forms through the first vertebrates and on into dinosaurs, we'll seek to discover whether any of the organisms that survived the extinctions at the end of the Cretaceous descended from dinosaurs. Are birds such a group? Or, did they descend from early relatives of crocodiles, as many paleontologists have argued over the last century? If birds did evolve from dinosaurs, they would be members of the dinosaur's evolutionary lineage. Therefore, dinosaurs would not really be extinct...at least yet.

Although we will be frank about our own conclusions concerning dinosaur extinction, the point of the book will be to lay out the evidence in these debates so that you can make your own judgments. In laying out the evidence, we have tried to be fair to the competing ideas, although we realize that some of our colleagues have come to different conclusions than ours. More importantly, by reading on, you will have the privilege to serve on the same scientific jury that we and our colleagues have--deliberating over some of the most fascinating mysteries in the history of life.

References for Chapter 1

1. Gradstein, F. M., et al., 1995, A Triassic, Jurassic and Cretaceous time scale, In Berggren, W. A., et al., eds., Geochronology, Timescales and Global Stratigraphic Correlation, SEPM (Soc. for Sed. Geol), Sp. Pub. 54, p 95-126.