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Introduction

Dinosaurs are as popular now as they have ever been. They insert themselves into our consciousness from all sides, in films, books, magazines, toys, clothing, bags, sticker books, models . . . the list goes on. New dinosaur discoveries are reported in the national news and on social media, and they fascinate people who might not otherwise care much about science. The image retained by the public comes from films and art. Who could forget the most intense moments of the first *Jurassic Park* film, where the kids were pursued round the kitchen by the relentless human-sized *Velociraptors*? But paleontologists remind us that those dinosaurs should have been goose-sized and covered in feathers. Even without the feathers, discovered a few years after the film was produced, dinosaurs that look like a gaggle of enraged geese would not have built the same tension. The filmmakers had demanded human-sized raptors, and the scientists and paleoartists complied. Does it matter?

Two hundred years ago, dinosaurs were hardly known, and what was known was based on a few fragments of fossilized bones. Yet now, images of dinosaurs are unavoidable, part of our visual culture. This book tells the story of how, when, where, and why dinosaurs emerged from the museum store cupboards to become vibrant, moving, living monsters and how paleontologists and paleoartists

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worked together and bickered over the centuries as the image shifted dramatically.

What Are Dinosaurs?

But first, the deceptively simple question: What *are* dinosaurs? The scientific description tells us that dinosaurs were generally large animals, technically reptiles, and closely related to modern crocodilians and birds. They are distinguished from other living and extinct animals by a whole suite of anatomical features, the most obvious of which relate to their *posture* and *gait*. Dinosaurs stand with their legs straight like modern birds and horses, not sprawling like lizards with their arms and legs out to the side (fig. 0.1). Their gait is such that they walk straight, without the sideways movements seen in lizards and crocodilians. Their erect posture and gait are possible because the ancestors of dinosaurs had already evolved some pretty remarkable changes in the various joints along the leg. The ankle and knee joints are backward-and-forward hinges, as in humans. The hip joint accommodates the head of the thigh bone from below, not from the side. The other key feature of Dinosauria when compared to most other reptiles is that they walked high, with just the tip of the toes on the ground and the rest of the foot forming a third crank of the leg, as also seen in dogs and horses, for example. Humans walk with our entire foot stamping flat on the ground.

The first dinosaurs were bipeds, but as dinosaurs became larger, they independently evolved quadrupedality several times, their formerly grasping arms becoming walking limbs. As we shall see, paleontologists and paleoartists struggled to get dinosaurian posture right and far too many tried to show dinosaurs as slow-moving, slouching, and reptilian right up to 1970, even though the bones showed they were wrong.

Dinosaurs evolved during the first half of the Triassic (252–201 million years ago, or Ma) and were abundant in the late Triassic, when all three major groups emerged. The first major split was into the so-called lizard-hipped Saurischia and the bird-hipped Ornithischia. Whereas saurischians have a similar arrangement of the three

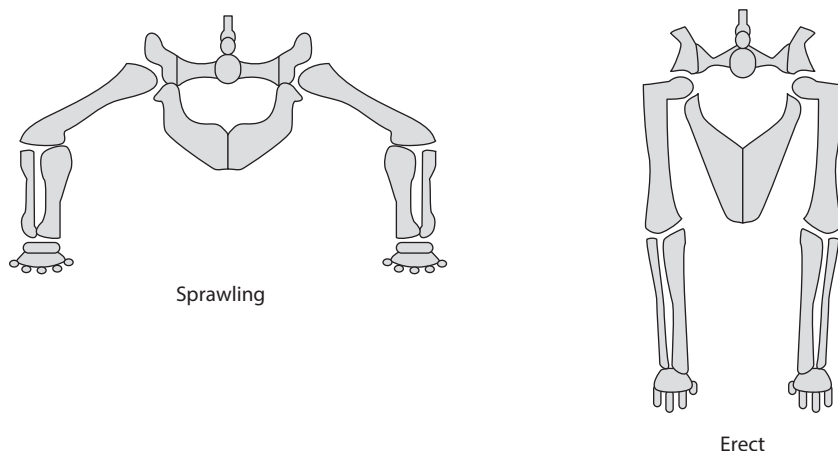


FIGURE 0.1. Cartoons of posture, showing “sprawling” as in salamanders and lizards, and “erect” as in dinosaurs, birds, and mammals.
Credit: Fred the Oyster, Wikimedia.

hip bones to crocodilians and other reptiles, in ornithischians the bone at the front, the pubis, has swung back to run parallel to the bone at the back, the ischium.

That’s all a bit technical (fig. 0.2), but the subdivisions of these two great groups are perhaps more important. The saurischians, then, fall into two major groups, the Sauropodomorpha and Theropoda. The sauropodomorphs are all the long-necked plant-eaters like *Brontosaurus* and *Diplodocus*. The theropods are primarily flesh eating, although some in the Cretaceous secondarily became plant-eaters. Most importantly, all the theropods were bipeds, even the six-ton giants like *Tyrannosaurus rex*, but there were many smaller forms and it’s now generally understood and accepted that birds evolved from among the theropods in the Jurassic (201–145 Ma). Because of this, some scientists use the term “non-avian dinosaurs” to refer to all the other, now extinct creatures and distinguish them from birds, but for the purposes of this book, we refer to non-avian dinosaurs as “dinosaurs.”

The ornithischians were all herbivores, including the armored forms such as the Ankylosauria, with their tank-like bodies and sometimes armor-club tails, and the Stegosauria like *Stegosaurus*

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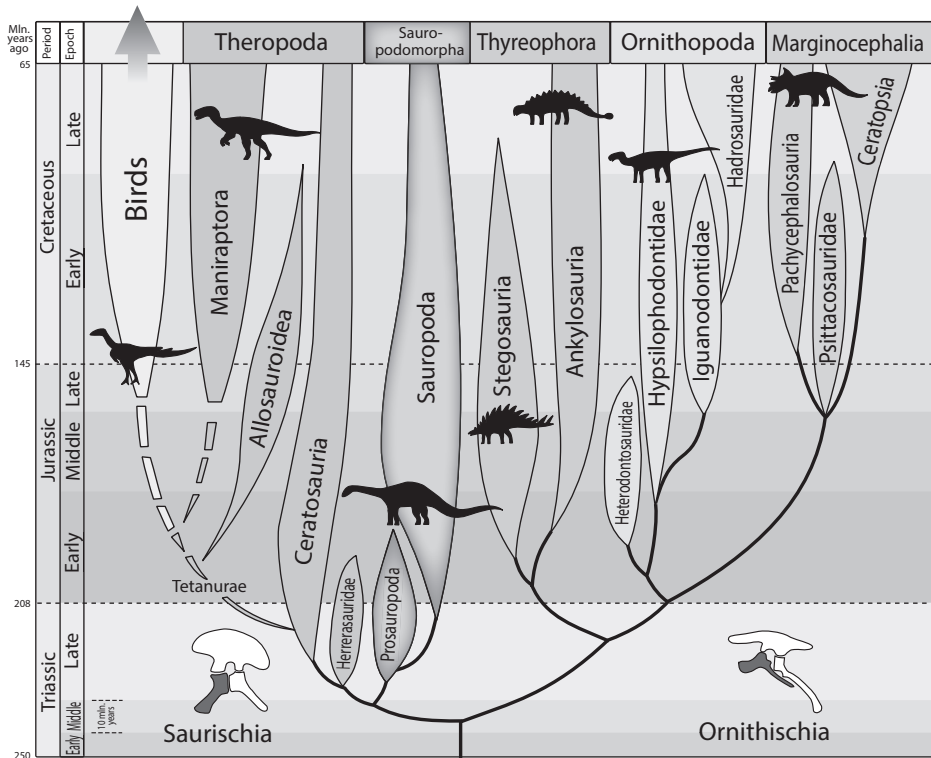


FIGURE 0.2. Evolution of dinosaurs, showing the main groups and their known occurrences through the Mesozoic, as well as the distinguishing hip bone structures of Saurischia and Ornithischia.

Credit: Zureks, Wikimedia, CC BY-SA 3.0.

with plates and spines along the middle of the back. Another group of ornithischians includes horn-faced animals like *Triceratops*, collectively the Ceratopsia, and their relatives the Ornithomimidae, unarmored animals such as *Iguanodon* and *Corythosaurus*.

At the end of the Triassic (201 Ma), many early dinosaur groups disappeared, and new forms such as ankylosaurs, stegosaurs, small ornithomimids, and large sauropods came to dominate through the Jurassic. These major groups continued into the subsequent Cretaceous (145–66 Ma), but sauropods were less important in many areas and ornithomimids became the main herbivorous dinosaurs.

Through these three geological periods, the Triassic, Jurassic, and Cretaceous, collectively termed the Mesozoic Era (252–66 Ma), the Earth was very different from today. Climates were warmer and there was no permanent ice, perhaps only some polar ice in winter in the Cretaceous. Also, at the start of the Mesozoic the continents were all joined together as the supercontinent Pangaea, but in the late Triassic, Pangaea began to split apart, with the unzipping of the North Atlantic, as North America drifted away from Europe at a rate of about 1 inch per year. In the late Jurassic and Cretaceous, the South Atlantic opened up between South America and Africa, and the great southern continent Gondwana also began to break up, with Antarctica swinging away from Africa and India and Australia moving eastward. So, for most of the Mesozoic, dinosaurs, as fully land-living animals, could wander across the globe, from Africa to North America, from modern China to modern Australia.

There are other definitions of “dinosaur,” reflecting popular culture. The Merriam-Webster dictionary gives two other meanings along with the scientific ones, which are “any of various large extinct reptiles (such as an ichthyosaur or mosasaur) other than the true dinosaurs” and “one that is impractically large, out-of-date, or obsolete.”¹ Both these definitions are in wide use and, without clarification, can be confusing. The term “dinosaur” is often used, scientifically incorrectly, to refer to other creatures portrayed in popular culture alongside them, such as *Dimetrodon*, flying reptiles such as pterosaurs, and marine creatures such as ichthyosaurs, plesiosaurs, and mosasaurs. And as already mentioned, the word “dinosaur” is also used to refer to “obsolete,” “slow,” or unadaptable, which will be discussed further when we consider the symbolism of dinosaurs in nineteenth-century America.

Dinosaur Discovery

The first dinosaur was named in 1824, the carnivore *Megalosaurus* from the Jurassic, the second in 1825, the herbivore *Iguanodon* from the Cretaceous. The first Triassic dinosaurs were named in the 1830s

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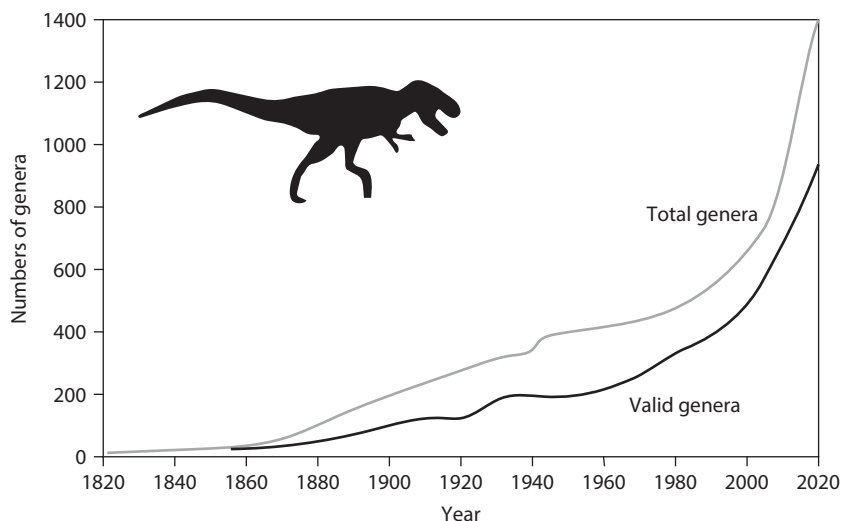


FIGURE 0.3. Naming dinosaurs over the past two hundred years. So far, more than twelve hundred genera, and rather more species, have been named, but many have been named optimistically on limited evidence and so are said to be not valid by other paleontologists. The “now valid” total is about half the “total” number. Credit: Michael J. Benton.

(*Thecodontosaurus*, *Plateosaurus*), and new examples have been added ever since. Those first finds were all from Europe, specifically from England and Germany, but then dinosaurs were found in increasing abundance in North America, then India, then South America, then Russia, Mongolia, China, and other parts of Asia, then Australia, and finally Antarctica in 1986 (fig. 0.3). The first finds were accidental, often in quarries where workers found huge bones as they were extracting building stones. Then the paleontologists of Europe and North America sent out expeditions worldwide, so that today every nation on Earth has its own paleontologists who collect dinosaurs in their own neighborhood. Antarctica was unexpected: Dinosaurs there can only be found on the fringes, where the ice disappears for a short time in summer.

As understanding of dinosaurs grew among scientists, some enthusiastically encouraged the idea that the creatures could be illustrated by artists as if they were living animals; others, however, saw this as unnecessary or even dangerous. Since dinosaurs were

first discovered and named, they have been at the center of a lively, sometimes acrimonious debate, and this controversy still rumbles on, often involving some of the most eminent scientists in the field.

Bristol Meeting

“I hope you and Osborn had a good time and did not try to throw one another overboard during the voyage. Can Osborn tell a mule-story? I doubt it! He doesn’t seem to have had any sense of humour inoculated into him! He is so very serious the whole time.”² Henry Woodward (1832–1921), head of Geology at the Natural History Museum in London, wrote these words in 1898 to his longtime friend, Othniel C. Marsh (1831–1899), professor of paleontology and director of the Peabody Museum at Yale University. Here, he is teasing Marsh, who was sailing back to the United States following the annual meeting of the British Association for the Advancement of Science (BAAS), held that year in Bristol. “Osborn” is Henry Fairfield Osborn (1857–1935), from 1891 a professor at Columbia University and curator of vertebrate paleontology at the American Museum of Natural History. Marsh and Osborn (fig. 0.4) clashed at the Bristol meeting, having previously clashed over their different opinions about reconstructing and restoring ancient animals.

Osborn’s lecture to the BAAS was titled “Restoration by Charles Knight of the Extinct Vertebrates *Brontosaurus*, *Phenacodus*, *Coryphodon*, *Teleoceras*.” (The term “restoration” is used in paleontology to refer to images or models of a prehistoric creature as if it were a living, extant animal.) Osborn was to exhibit four paintings at the meeting to show how his museum enhanced its prehistoric skeleton displays by exhibiting color paintings of the “live” animals in their environments alongside the mounted skeletons. The artist, Charles R. Knight (1874–1953), had worked alongside the museum’s paleontologists to make the images as accurate as possible, and we will meet him properly later, in chapter 4.

The audience was divided over the value of creating and displaying such images. There were those like Osborn who felt the paintings could enhance displays and attract further interest from the public,

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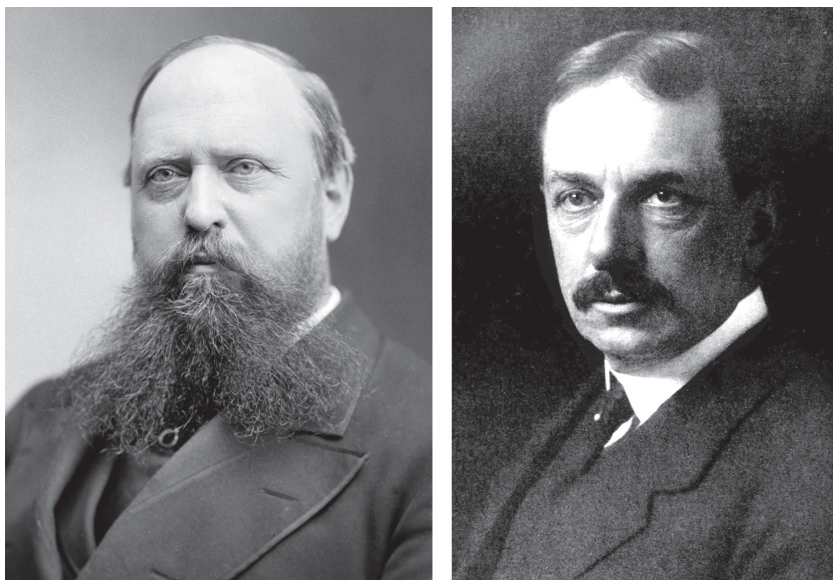


FIGURE 0.4. On opposite sides of the fence: Othniel C. Marsh (1831–1899), left, was loath to sanction life reconstructions of dinosaurs and ancient mammals, whereas Henry Fairfield Osborn (1857–1935), right, was keen to do so and sponsored some of the first full-color artworks of ancient life. Credit: Brady-Handy photograph collection, Library of Congress, Prints and Photographs Division (left), American Museum of Natural History (right).

and others such as Marsh who were vehemently against them. A letter from Marsh to Woodward following the meeting reveals that Osborn was not present in person, but his paper was read and the paintings displayed by paleontologist Harry Seeley (1839–1909) in his place. Marsh stood up to criticize the restorations and when writing to Woodward, expressed his distaste for any such imaginative work:

I fear I started a row by what I said about Restorations yesterday in the Geol. Section. I declined to say anything about the paper when I found Osborn was not to be present & that Seeley had charge, but was told I must say something as part of the animals pictured in the vivid colors were my own species, and that nearly all the material was my own. I therefore spoke a few words of warning about putting flesh and skin and especially color on

skeletons of extinct animals, but my remarks were misunderstood by part of the audience and even by some of the speakers.³

He then added that “Osborn is my fellow passenger and I shall talk the matter over with him.” They were both sailing aboard the RMS *Teutonic*, a passenger ship belonging to the White Star Line that had won the Blue Riband for the fastest transatlantic crossing of five days and sixteen hours in 1891. Marsh and Osborn sailed from Liverpool and had plenty of time to get to know each other, but history does not record whether they discussed their opposing viewpoints or whether indeed they tried to throw each other overboard.

Controversy

But why would two eminent professors threaten fisticuffs over something as trivial as making life restorations of dinosaurs? This example was not the first such clash and certainly would not be the last, as we shall see, when we discuss the paleontologists’ debate over Computer-Generated Imagery (CGI) in movies such as *Walking with Dinosaurs* (chapter 12) and the *Jurassic Park* franchise (chapter 14). Paleontologists are motivated to find and understand fossils, so it might seem evident that they would welcome the chance to bring their ancient creatures to life using whatever media the artists could offer—drawings, paintings, sculptures, or CGI. Yet, the controversy has swirled around the question: *How far should we go?* Even if a dinosaur skeleton is complete, it cannot provide enough information for a detailed reconstruction of the original external appearance, let alone of its behavior, so the paleontologist must decide whether to sanction any kind of reconstruction in the absence of complete information. This can lead to two viewpoints, the cautious or the daring—and unexpectedly, the more daring paleontologists might be regarded as the better scientists, as we shall see.

The cautious position, adopted by Marsh, is to avoid guessing about features for which we don’t have the evidence. This seems perfectly reasonable, and indeed the cautious paleontologist avoids looking like a fool when some contrary additional evidence turns up;

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for example, Marsh would have mentioned that many new dinosaur species were named from skeletons that perhaps lacked a head or tail or a leg or two. What if you advised your artist to draw a particular head even if there were no fossilized skull, and then a more complete skeleton of the same animal was found a year or two later with the skull in place, and showing an entirely different head?

On the other hand, if paleontologists can't advise on reasonable life reconstructions, then who can? After all, professional paleontologists are highly educated and have expanded their knowledge by original research, much of it paid for by the taxpayer, so arguably it's their duty to advise. The more daring position adopted by Osborn, then, would be to say that perhaps we have to make the best of the incomplete skeletons we have, and we can make reasonable inferences. And if new information later shows we got it wrong, it just shows that's the way science goes.

Have these positions shifted since 1898? Scientists often argue that knowledge is cumulative—in other words, we learn more as we study more. This position was famously articulated by that most famous of scientists, Isaac Newton, who said, “If I have seen further, it is by standing on the shoulders of giants,” namely his scientific predecessors. It might be expected then that earlier nervousness would have given way to more confidence today. We have many more fossils, we have fossils that show soft tissues like feathers and claws, and we have many technical ways to study the material. Surely what was unknown in 1898 might have become known by 1998 or 2027?

Paleontologists have struggled with dinosaurs for over two hundred years. When the first dinosaurs were named in 1824 and 1825, the debate was whether they were giant lizards or crocodiles. After 1842, we had the word “dinosaur,” invented by Richard Owen (1804–1892), the great British anatomist and paleontologist, and the debates broadened. Owen and contemporaries still debated whether dinosaurs were more like lizards or crocodilians, or even birds or mammals. Owen himself suggested the unthinkable, that dinosaurs might have been warm-blooded, and he referred to the fact they

appeared to have advanced postures; we use the same evidence today to support the same conclusions.

Those opposing viewpoints—to risk and restore or to exercise extreme caution—probably reflect two things: whether the proponent is an educator and their understanding of the scientific method. If you teach students, you must master the topic and find ways to explain complex themes, as suggested by dinosaur expert Tom Holtz of the University of Maryland.⁴ This experience of teaching then helps the scientist explain their work to a journalist or artist, to see the need to do so, and to even enjoy the experience. Many of those who are more cautious or even unwilling to speak about their work are often not educators.

More importantly, a reluctance to explain, and occasionally take risks, might reflect a misunderstanding of the scientific method. Knowledge in the natural sciences is always provisional. The researcher observes a phenomenon, like the pointed teeth of a dinosaur or the fact that the sun rises in the east, considers various possible explanations, and proposes their best hypothesis based on the available evidence. That hypothesis may be correct and will last for centuries, or it might be modified or rejected based on new evidence. For example, up to 1990, most paleontologists said dinosaurs did not have feathers, but then new fossils from China showed that they did (chapter 13), and the explanation was changed. This did not mean that the researchers in the 1980s were fools; they reported their findings based on the featherless dinosaur fossils then available, and it so happens they were wrong, but science is provisional and subject to revision. So, the scientist who criticizes well-researched paleoart might misunderstand that the painting or movie is also a hypothesis based on best current knowledge, but provisional and subject to revision.

When the Nobel Prize-winning physicist Kip Thorne advised on the visualization of a black hole in the 2014 film *Interstellar* in 2014, nobody was upset about the imaginative image, and that image lives on, even though the concept of being able to see a black hole is probably more tenuous than ever seeing a dinosaur. Physicists do

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not seem to get so agitated by the physics of, say, *Star Trek* or a glut of other science films and series. So, could it just be that paleontologists have been more prickly than other scientists?

WHAT THE BOOK IS AND IS NOT

This is not a book about paleoart, nor is it a survey of contemporary paleoart. Certainly, some of the greatest paleoart is included, but it is useful to clarify this statement and the terminology. The term “paleoart” has been defined, according to Witton (2018, 10), as “requiring three elements: 1) being beholden to scientific data; 2) involving a restorative component to fill in missing yet essential biological data; and, of course 3) relating to extinct subject matter such as ancient landscapes, animals and plants.” This definition was first discussed at length at a major traveling exhibition and symposium *Dinosaurs Past and Present*, organized by the Natural History Museum of Los Angeles in 1987. As well as bringing together some of the world’s greatest paleoart, the museum published a series of papers by prestigious paleontologists and paleoartists to explore the nature of paleoart, its practice, and future directions (Czerkas and Olson 1987).

The term “paleoimagery” is sometimes used for artwork, in any media, that represents paleontological subjects that do not fulfill this definition of “paleoart.” In the wider context of art and art history, images created under specific conventions, such as botany, are referred to as “botanical illustration,” whereas images with plants in them are more generally known as “botanical art.” The same convention applies to natural history illustration and scientific illustration, so it might have been more consistent to use the term “paleoillustration” rather than “paleoart,” but that has rarely been done. We also use the term “paleomedia” to refer generally to representations of paleontology subjects in any media, including art, film, documentary, marketing, balloons, and clothing. There are some excellent publications about the history of paleoart (Czerkas and Olson 1987; Davidson 2008; White 2012; White 2017) and contemporary paleoart (White 2017), including more general discussions around the direction of today’s paleoart (Conway 2012). Similarly, this book is

not about “how to” create paleoart; again, there are publications in print that cover the subject comprehensively (Witton 2018).

This book tells the story of how dinosaurs became the popular icons they are today. We are aware there are many examples of innovative dinosaur imagery that we have not been able to include, but the story spans two centuries, and we focus on the key images that defined each era, with a focus on scientific evidence and opinion on the one hand, and the artist and their available media on the other.

Through this span of two hundred years, dinosaurs were pictured in many different ways, first as almost mythical dragons in apocalyptic, Old Testament biblical deluges (chapter 1), and then in Owen’s unexpectedly mammal-like images in the first life-sized sculptures aimed at the public (chapter 2). With the first discoveries of dinosaurs in North America in the 1850s, the rhino-like dinosaur became more kangaroo-like as the first mounted skeleton reared up high (chapter 3); subsequently a new era of illustration was marked by the growth in museum exhibits and their use of full-color paintings of dinosaurs in their landscapes by artist Charles Knight (chapter 4). As the demand for dinosaur illustrations grew, a few women paleoartists stepped out of the shadows to contribute to popular publications (chapter 5).

In their second century, dinosaurs hit the silver screen, but their first animated appearance, although based on a real dinosaur, was in no way meant to be educational; rather, *Gertie the Dinosaur* was a 1914 music hall act (chapter 6). Dinosaurs on screen evolved with a variety of animation technologies, from stop-motion animation (chapter 7) to full-color feature film (chapter 8). Yet from 1920 to 1950, dinosaurs were in the “doldrums”—there were only a handful of paid dinosaur experts around the world and very little academic interest in paleontology.

Interest picked up from the 1950s to the 1970s, and it was all happening in Othniel Marsh’s old museum, the Peabody Museum of Natural History at Yale University, New Haven, Connecticut. First came the Rudolph Zallinger mural in the museum in the 1950s (chapter 9), and this would have been enough to infuriate Marsh. At the same time, the truly giant size of many dinosaurs made them

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attractive to business for marketing campaigns (chapter 10). Marsh would have been even more astonished when the urbane and cautious, but hugely iconoclastic, paleontologist John Ostrom (1928–2005) took his old job. Ostrom showed that dinosaurs were warm-blooded and closely related to birds, and his student Robert Bakker (b. 1945) fused art and science to trigger the revolution in 1969 with the first of many drawings and papers in which he showed dinosaurs as fast, smart, and hot-blooded (chapter 11).

Science and animation technology came together in the 1990s to show Ostrom and Bakker were right—dinosaurs had feathers and so must have been warm-blooded and indeed the ancestors of birds (chapter 13). The new age of dinosaurian paleontology was marked by an explosion of activity, with new museums, new hires, and expeditions that unearthed dozens of new dinosaurs each year. Improving computation made it possible to produce truly lifelike animations of dinosaurs for the first time, in *Jurassic Park* (1993), the BBC's ground-breaking documentary series *Walking with Dinosaurs* (1999), and their successors (chapters 12 and 14).

Dinosaurs—or, to be precise, the non-avian dinosaurs—famously died out 66 million years ago. Here too, the science has been evolving fast: Was it fast or slow; was it caused by climate change, volcanic eruption, or meteorite impact? What if dinosaurs had survived? Here we see science, paleoart, film, and indeed fantasy working hand in hand (chapter 15). If the image of the dinosaur has evolved so much in a mere two hundred years—six or seven generations—what can we expect in the future?

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