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PART I

Remembrance of Things Past

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Dinosaur Tales

This book is a tale of dinosaurs; who they were, what they did, and how they did it. But, more significantly, it is also a tale of natural history. Dinosaurs enrich our concept of the **biosphere**, the three-dimensional layer of life that encircles the Earth. Our biosphere has a 3.8 *billion*-year history; we, and all other life around us, are merely Earth's latest tenants. To not know the history of life is to not know our organic connections to the biosphere and ultimately to our Earth. To know the history of life is certainly one way to begin to answer the perennial question, "Why are we here?". Dinosaurs have significant lessons to impart in this regard, because as we learn who dinosaurs really are, we can better understand who *we* really are.

Since the first dinosaur bones were identified in the early nineteenth century, both the total number of dinosaurs known, and the rate of finding them, has spiraled almost beyond anybody's expectations. By one estimate, new dinosaur species are reported at a rate of three per month, many coming from previously incompletely explored regions including China and Mongolia, Chile and Argentina, and, most recently, Saharan and sub-Saharan Africa (Figure I.1). We haven't done the math, but we're certain that there are far more trained paleontologists studying the fossil records than there ever were before.

Moreover, it is clear that dinosaurs are no longer your parents' (or is it their parents'?!) cast-iron clunkers. Their relationships to other "reptiles" – and even to us – are not what we thought; their lifestyles are not what we thought; they look very different from what we'd imagined; indeed, almost everything about them has changed since the late 1960s and, thankfully, they're a whole lot more interesting now. If you like dinosaurs, it's a great time to be alive: we're definitely living in a golden age of dinosaur discovery.

The Word "Dinosaur" in this Book

The term "dinosaur" (*deinos* – terrible; *sauros* – lizard) was invented in 1842 by the English naturalist Sir Richard Owen (see Box 16.2) to describe a few fossil bones of large, extinct "reptiles." With modifications (for example, not all dinosaurs are "large"), the name has proven resilient. It has become clear in the past 25 years, however, that not all dinosaurs are extinct; in fact, almost all specialists now agree that *birds are living dinosaurs*. The (technically correct) term **nonavian**

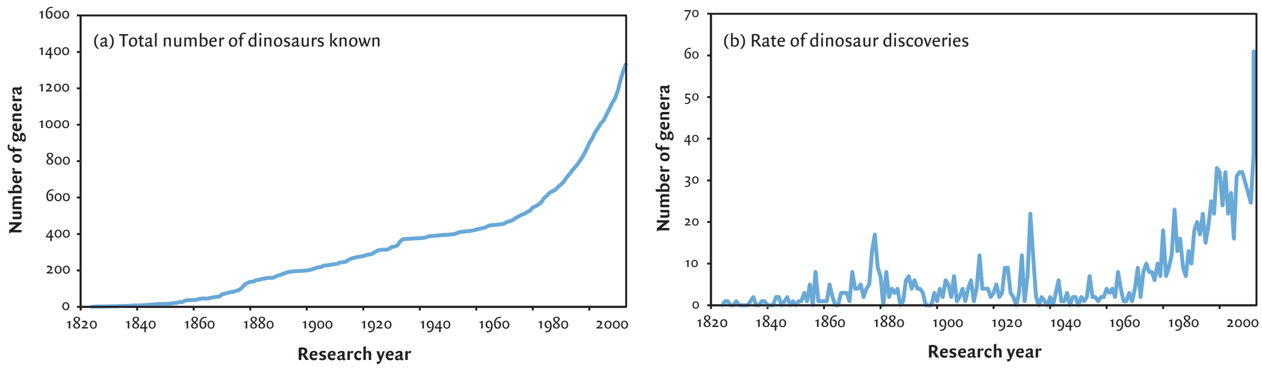

Figure I.1. Paleontologist Michael Benton's compilation of dinosaur discoveries from 1822 to 2014; we've extended his estimates to 2019. (a) Total number of dinosaurs known; (b) rate of dinosaur discoveries. There were spikes in the rate of dinosaur discoveries in the late 1880s and in the early to mid twentieth century, but all of that pales in comparison to what's happening now.

dinosaurs to specify *all* dinosaurs except birds is a mouthful, so we prefer to use the term "dinosaurs" as shorthand for "nonavian dinosaurs." The distinction between nonavian dinosaurs and all dinosaurs will be most relevant only when we discuss the origin of birds and their early evolution in Chapters 6, 7, and 8; there, we'll take care to avoid confusing terminology.

Science

Ours is also a tale of science, which is, in turn, all about imagination and creativity, with a little help from data. Creativity is the currency of science; integrity is the currency of the scientist. That is, the value of the science is surely dependent upon the creativity of the scientist; but it is equally dependent upon his or her integrity, because without personal integrity a scientist has nothing of value.

In the following pages, we hope to build a sense of the intellectual richness of science; a quality that philosopher of science Karl Popper called the "logic of scientific discovery." And so if this is a story about science, we'd better articulate what we mean by the word "science."

Science = Testing Hypotheses

Science is the business of constructing testable hypotheses and then testing them. An example of a simple scientific hypothesis is: "The Sun will rise tomorrow." This hypothesis makes specific predictions. Most importantly, the hypothesis that the Sun will rise tomorrow is **testable**; that is, it makes a prediction that can be assessed. The test is relatively straightforward: we wait until tomorrow morning and either the Sun rises or it doesn't.

Notice that here we're not looking for things that *support* our hypothesis; rather, we're looking for things that *test* it. If you were designing a race car, you would not drive it around the block and say, "See, it runs!". Rather, you would subject it to the grueling conditions that it might experience on a race track, to test whether or not the car was up the job. So it is with a scientific hypothesis: it needs to be *tested* and, like the car, continue to run (e.g., fail to be falsified) under the most extreme set of conditions.[1]

So what's *not* science? Important questions that you can't get at using science might be "Is there a God?", "Does she love me?", and "Why don't I like hairy men?". In *Music Man*, Marian "the librarian" Paroo asks "What makes Beethoven great?". She won't learn it from science. Some questions are far better suited to science than others.

The "Proof" is in... the Test!

In our example of a scientific hypothesis (above), if the Sun does not rise, the statement has been *falsified*, or demonstrated to be not correct, and the hypothesis can be rejected. On the other hand, if the Sun rises, the statement has *failed falsification*, and the hypothesis cannot be rejected. For a variety of relatively sophisticated philosophical reasons, scientists do not usually claim that they have *proven* a statement to be true; rather, the statement has simply been tested and not falsified. It turns out that, in a philosophical sense, it is very difficult to "prove" anything. For this reason, scientists rarely use words like "prove" or "true" when discussing their work.

[1] Notice our use of the word hypothesis. It is not some idea or conjecture, as it is used colloquially. Rather, in science, a hypothesis is a (potentially complex) explanation of a (potentially complex) phenomenon, to be tested and, if provisionally accepted, to resist falsification.

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But we *can* test hypotheses, and one of the basic tenets of science is that it consists of hypotheses that have predictions which can be tested. We will see many examples of hypotheses in the coming chapters; to be valid, all must involve testable predictions. Without testability, it may be very interesting; it may be very exciting, it may be very important, but it is not science.

Science in the Popular Media

"Science" is everywhere in the popular media, from Animal Planet to *National Geographic*, to the Weather Channel. That's good; our lives are increasingly intersected by science, and the more savvy we are scientifically, the better the decisions that we can make. But the problem is that not all of the "science" that one sees in the popular media is very scientific!

Among scientists, work is recognized and accepted only after it is peer-reviewed; that is, when it has been vetted and carefully scrutinized by other scientists qualified to evaluate the work. Very commonly, the work goes through multiple cycles of review and revision by the authors in response to the critiques of professionals in the field. At that time – and only at that time – it can be published. This is the time-honored – and time-proven – way of producing the very highest-quality scientific research.

In the popular media, the goals are somewhat different. In movies, on television, and on the radio, the goals are generally entertainment as well as immediacy: publicizing the newest discoveries as quickly as possible. Both of these have very little to do with high-quality science. In the case of immediacy, the rush to publicize can mean that half-baked theories and interpretations are popularized long before they have seen anything like peer review. And when peer review finally comes, the results can be (and have been) devastating.

The goal of entertainment can be equally destructive, in terms of the science. For example, television and radio reports commonly present "the other side" of a particular scientific issue, even when the vast preponderance of scientists take a particular position and the "other side" has very little legitimacy. People can always be found who will voice heterodox opinions, even when their views are plainly way outside of the mainstream of peer-reviewed science. It's always *entertaining* to present controversy.

In paleontology, the quest for entertainment brings a variety of excesses, beyond mere controversy. Size sells; teeth and claws sell; asteroids sell; extinction sells. But ultimately, we hope in this book to show that the real riches – and entertainment – lie in a balanced, undistorted treatment of dinosaurs: a more magnificent, fascinating group of creatures could hardly have been invented, and the ongoing scientific process of revealing who they were and what they did is compelling drama.

The web, a popular and extremely important source of information, is driven by a variety of sometimes-contradictory imperatives (knowledge; entertainment; retail), and our relationship to it is more nuanced. Accessibility, ease, and breadth are its great strengths; reliability and depth can be, but, as always, care about sources is required. Much really good, peer-reviewed science (and lots of other information!) is available on the web; indeed, most major peer-reviewed journals have a significant web presence; some can be found *only* on the web. Information from the websites of professional societies (for example, the Society of Vertebrate Paleontology) is reliable in the way that the peer-reviewed journals published by such societies are reliable. Academic institutions tend to have reliable web pages; although personal web pages, even in an academic context, generally reflect the opinions of their authors, idiosyncratic or not. Wikipedia – a stupendous tool for research and, in our view, a stunning contribution to the availability of human knowledge – reflects the web: it is often very accurate, but it is not without idiosyncratic entries. In short, the web is a powerful tool, to be sure; but *caveat emptor*: Not all sources of information are equivalently authoritative. It is ultimately the longer, more considered process of peer review – of vetting by other specialists – that ensures that the best science trumps "fake news."

SELECTED READINGS

Fastovsky, D. E., Huang, Y., Hsu J., *et al.* 2004. Shape of dinosaur richness. *Geology*, **32**, 877–880. doi: 10.1130/G20695.1.

Starrfelt, J. and Liow, L.-H. 2016. How many dinosaur species were there? Fossil bias and true richness estimated using a Poisson sampling model. *Philosophical Transactions of the Royal Society B*, **371**, 20150219. http://dx.doi.org/10.1098/rstb.2015.0219

Wang, S. and Dodson, P. 2006. Estimating the diversity of dinosaurs. *Proceedings of the National Academy of Sciences*, **103**, 13601–13605. www.pnas.org_cgi_doi_10.1073_pnas.0606028103

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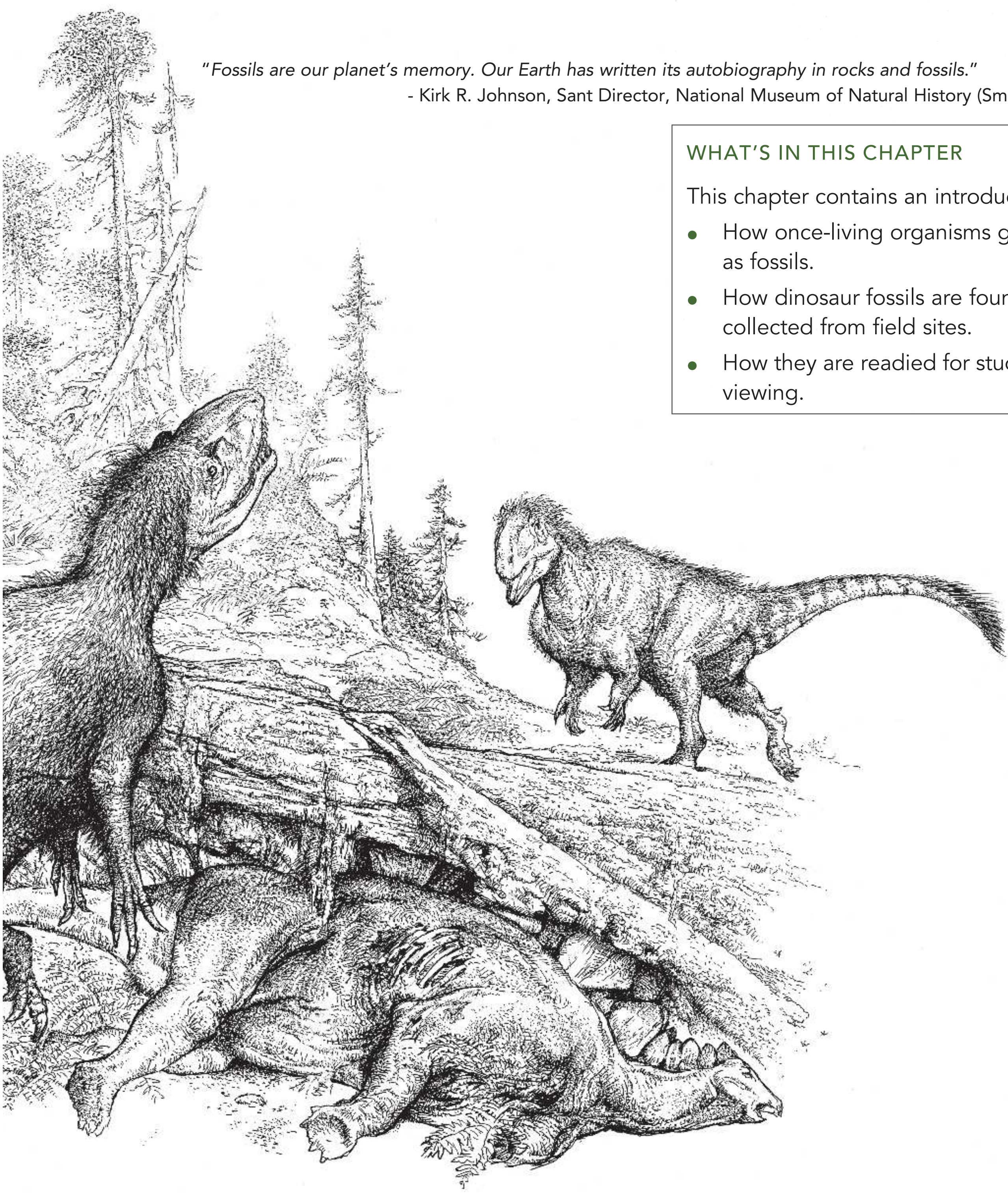
Chapter

1 To Catch a Dinosaur



"Fossils are our planet's memory. Our Earth has written its autobiography in rocks and fossils."
- Kirk R. Johnson, Sant Director, National Museum of Natural History (Smithsonian).

WHAT'S IN THIS CHAPTER

This chapter contains an introduction to:

- How once-living organisms get preserved as fossils.
- How dinosaur fossils are found and collected from field sites.
- How they are readied for study and public viewing.

Preservation and Fossils

Fossils, the buried remains of organic life, are just about the only evidence we have of the kinds of living creatures that existed on Earth in the past. Fossils are how we know that there were creatures such as dinosaurs. And even that fact is near-miraculous: most organisms don't get fossilized, and undoubtedly only a few of the innumerable dinosaurs that must have once lived have been preserved.

There are many types of fossils: **body fossils**, which commonly involve some **hard part** of the animal (e.g., bones and teeth); **trace fossils**, which are impressions such as animal tracks; and fossils such as **skin impressions** that are a mixture of both. Until the very latest part of the twentieth century, paleontologists thought that dinosaur **soft tissue** – muscles, blood vessels, organs, skin, fatty layers, etc. – were long gone. We assumed that the hard parts would not be as easily degraded over time as the soft tissues. Yet, while this assumption was generally true, new techniques and determined study have revealed all kinds of unexpected preservation, including tissues, cells, and molecules, for example, the discovery of actual red blood cells and connective tissues from *Tyrannosaurus* (see Box 7.1). Fair warning: fossils are no longer just about old bones!

Making Body Fossils

Before Burial

Consider what might happen to a dinosaur – or any land-dwelling vertebrate – after it dies.

Carcasses are commonly **disarticulated** (dismembered), first by predators and then by scavengers, ranging from mammals and birds to beetles and bacteria. Some bones might be stripped clean of meat and left to bleach in the sun. Others might get carried off and gnawed. Sometimes the disarticulated remains are trampled by herds of animals, breaking and separating them further. Plants growing in soils produce acids, such as humic acid, that dissolve bone. But ultimately, the nose knows that the heavy lifting in the world of decomposition is done by bacteria that feast on rotting flesh. If the animal isn't disarticulated right away, it is not uncommon for a carcass to bloat, as feasting bacteria produce gases that inflate the dead body. After a bit, the carcass will likely deflate (sometimes explosively), and then dry out, leaving bones, tissues, ligaments, tendons, and skin like jerky, crusty and inflexible (Figure 1.1).

Figure 1.1. A horse carcass, lying, drying on a grassy plain. It is literally skin and bones, and if buried, it will be on its way to becoming fossilized.

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Burial

Sooner or later bones are either destroyed or buried. If they aren't gnawed and digested as somebody's lunch, their destruction can come from **weathering**, which means that the minerals in the bones break down and the bones wash away. But the game gets interesting for paleontologists when weathering is stopped by rapid burial. At this point, they (the bones, not the paleontologists) become fossils. Figure 1.2 shows two of the many paths that bones might take toward **fossilization**.

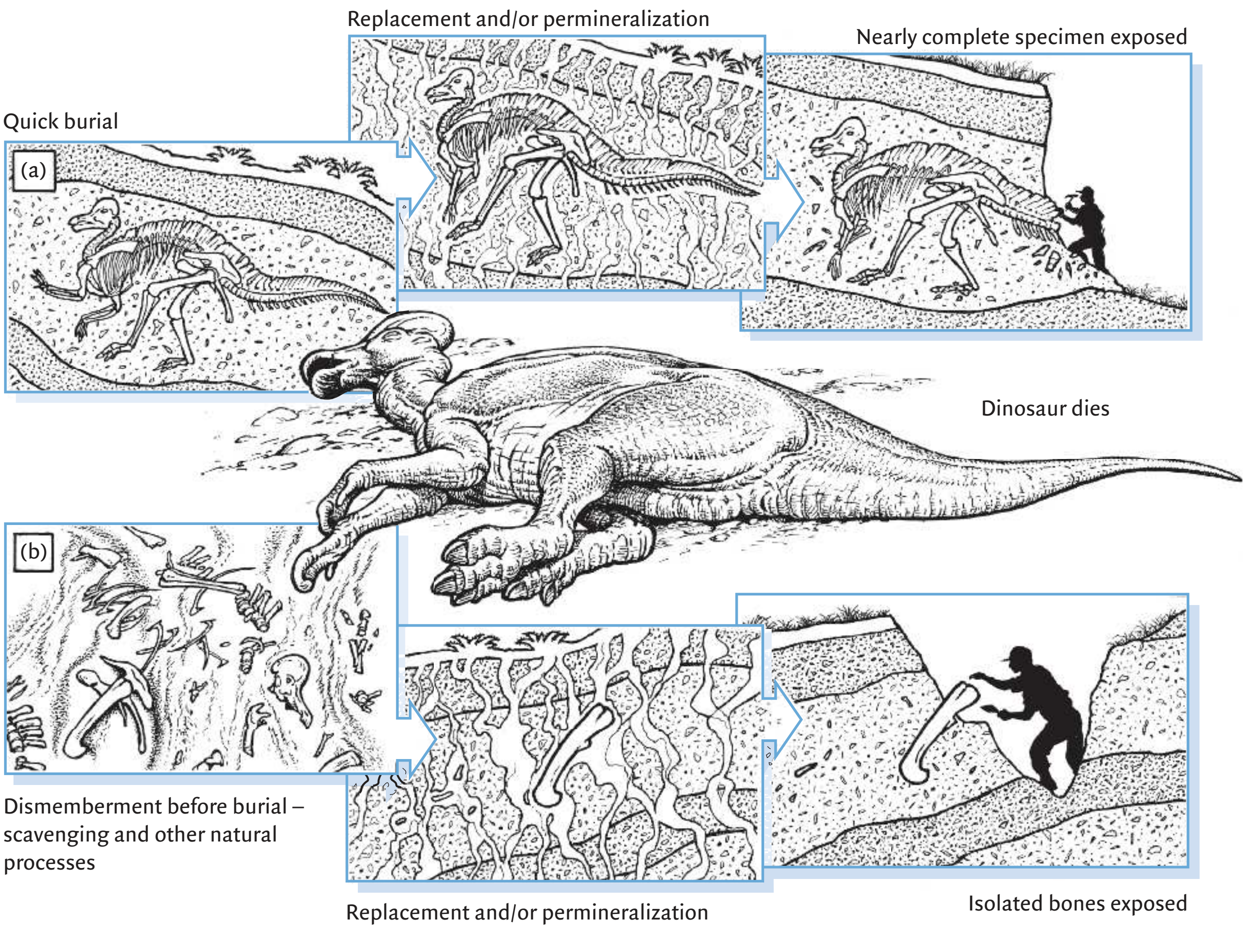

Figure 1.2. Two endpoint processes of fossilization. In both cases, the first step is the death of the animal. Some decomposition occurs at the surface. In the upper sequence (a), the animal dies, the carcass undergoes quick burial, followed by bacterial decomposition underground, and permineralization and/or replacement. Finally, perhaps millions of years later, there is exposure. Under these conditions, when the fossil is exhumed, it is largely complete and the bones articulated (connected). This kind of preservation yields bones in the best condition. In the lower sequence (b), the carcass is dismembered on the surface by scavengers and perhaps trampled and distributed over the region by these organisms. The remains may then be carried or washed into a river channel and buried, replaced, and/or permineralized, eventually to be exposed perhaps millions of years later. Under these conditions, when the fossil is exhumed, it is disarticulated, fragmented, and the fossil bones may show water wear and/or the gnaw marks of ancient scavengers. Different conditions of fossil preservation tell us something about what happened to the animals after death.