

THE SCIENCE OF LOST WORLDS

Adrian Mitchell Currie

ISBN 978-1-77385-713-8

THIS BOOK IS AN OPEN ACCESS E-BOOK. It is an electronic version of a book that can be purchased in physical form through any bookseller or on-line retailer, or from our distributors. Please support this open access publication by requesting that your university purchase a print copy of this book, or by purchasing a copy yourself. If you have any questions, please contact us at ucpress@ucalgary.ca

Cover Art: The artwork on the cover of this book is not open access and falls under traditional copyright provisions; it cannot be reproduced in any way without written permission of the artists and their agents. The cover can be displayed as a complete cover image for the purposes of publicizing this work, but the artwork cannot be extracted from the context of the cover of this specific work without breaching the artist's copyright.

COPYRIGHT NOTICE: This open-access work is published under a Creative Commons licence. This means that you are free to copy, distribute, display or perform the work as long as you clearly attribute the work to its authors and publisher, that you do not use this work for any commercial gain in any form, and that you in no way alter, transform, or build on the work outside of its use in normal academic scholarship without our express permission. If you want to reuse or distribute the work, you must inform its new audience of the licence terms of this work. For more information, see details of the Creative Commons licence at: <http://creativecommons.org/licenses/by-nc-nd/4.0/>

UNDER THE CREATIVE COMMONS LICENCE YOU MAY:

- read and store this document free of charge;
- distribute it for personal use free of charge;
- print sections of the work for personal use;
- read or perform parts of the work in a context where no financial transactions take place.

UNDER THE CREATIVE COMMONS LICENCE YOU MAY NOT:

- gain financially from the work in any way;
- sell the work or seek monies in relation to the distribution of the work;
- use the work in any commercial activity of any kind;
- profit a third party indirectly via use or distribution of the work;
- distribute in or through a commercial body (with the exception of academic usage within educational institutions such as schools and universities);
- reproduce, distribute, or store the cover image outside of its function as a cover of this work;
- alter or build on the work outside of normal academic scholarship.



Acknowledgement: We acknowledge the wording around open access used by Australian publisher, **re.press**, and thank them for giving us permission to adapt their wording to our policy <http://www.re-press.org>

Prof. Ichthy's Inaugural Lecture

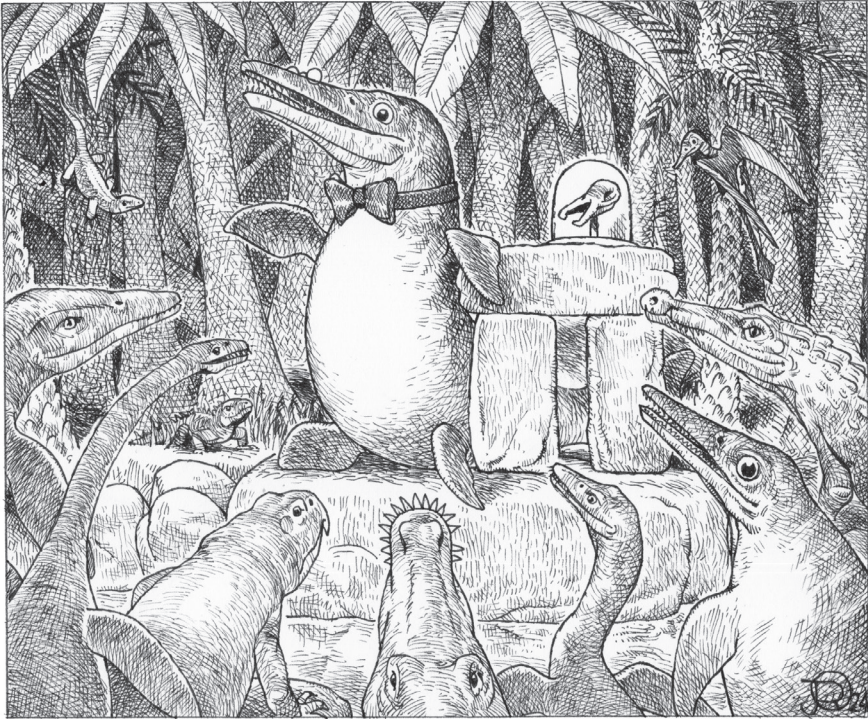


ILLUSTRATION 1.1 Wonderful Changes

The newly minted Prof. Ichthy makes their awkward way to the podium as the auditorium fills with coughs, half-whispered conversations and the susurrations of chair-shuffling.¹ The introduction had been (as usual) too long, and the applause too short, leaving an ungainly space in which Ichthy bustles about, fiddles with the overhead projector, gets the slides in place, fondly pats a glass container in which a strange-looking skull rests, and finally straightens their notes with a near ceremonial flourish.

A silence spreads across the audience (punctuated by an out-of-place “whoop!” from one of Ichthy’s relatives), as Ichthy clears their throat and begins, rather inauspiciously, not with an introduction but with an instruction: “slide.”

Ichthy’s graduate student, waiting by the OHP,² carefully removes the paper obscuring the first transparency, and the strange and remarkable creature on which Ichthy’s career was built is projected onto the screen behind them.

On the screen are two images. One is a fossilized specimen, its head closely resembling the skull on the podium. The specimen is remarkably preserved, more like a mineralized mummy than the usual collection of disarticulated bones. Image two is an illustration Ichthy commissioned to promote their discovery. It depicts a small, mammalian-looking creature. It is clearly a vertebrate, with bilateral symmetry and a rather squat, quadrupedal stance. It is also clearly a mammal, covered in sleek fur. Perhaps more surprising are its webbed feet, and more striking still is its bill. Those versed in anatomy (or who read Ichthy’s work in preparation for the lecture) note other non-mammalian features in the illustration: a lack of clear mammarys and a rather reptile-like stance. Again, clearing their throat, Ichthy begins the lecture proper:

“I put it to you that were it not for this remarkable specimen, we would never have guessed nor imagined the existence of this strange extinct species we now call “Broadfoot.” No doubt, other fossils have told us of the long-ago ‘Age of Mammals.’ We know there was a time in the past when Earth’s dominant animals were these primitive-seeming, furry, warm-blooded, milk-providing creatures. We know they conquered the land, conquered the air,

1 Alert readers might notice some discrepancies between Currie’s text and Robins’ visual depictions of Ichthy’s lecture. As neither could be present, both have resorted to somewhat unreliable second-hand testimony, and this inevitably leads to differences in interpretation.

2 “Overhead projector” for those too young or forgetful.

and conquered the sea. And we know a lot about them in part because of their fossils.”

Ichthy waves one flipper towards the skull on the stage and another at the image behind them.

“But not just their fossils. We know a lot about the ancient mammals because of their surviving cousins. Mammals are smaller nowadays, much diminished by the standards of their grand ancestors: they are reduced to secretive, arboreal, or burrowing creatures. The mammals with whom we share the planet only hint at mammals’ past. And the fossil record has provided many mammalian surprises.”

Ichthy turns, gazing at the skull, their long snout pointing like an arrow.

“But a mammal like Broadfoot? A web-footed, egg-laying, aquatic mammal with a bill? And moreover, one that, our research suggests, was both venomous and used electricity to detect its prey? Had you told me of such a creature, I would have commended you on your imagination and maybe—*maybe*—would have conceded its existence to be within the realm of possibility. But were it not for the incontrovertible evidence of this remarkable fossilized specimen, I would never have thought it actual.

Indeed, I bet, it wouldn’t have been imagined at all . . .”

This is a book about the limits of imagination and how the sciences of the past extend and challenge those limits. How we imagine the past is highly constrained by what the present is like. Yet what survives from the past, its traces, often reveal histories that buck our expectations. In the future I’ve imagined for Prof. Ichthy, there are no platypuses, nor sufficiently similar descendants, nor analogues of platypuses, for the animal’s existence to have occurred to them. But the remnants of the past, in this instance that fortuitous fossil, reveal a history differing dramatically from what Ichthy and their contemporaries could have imagined.

I’ll call these pasts that diverge from the present *lost worlds*, and the central claim of this book is that without analyzing lost worlds and how scientists tackle them, you won’t understand scientific knowledge of the deep past. What is a “lost world,” then?

In chapter 2, I’ll distinguish between *loss* and *erasure*. One way into the distinction leans on two kinds of evidence that Ichthy highlighted as relevant to Broadfoot. First, fossil evidence: that remarkable specimen. Second,

evidence from platypus-like animals contemporaneous with the scientist. To an extent, “erasure” tracks that first kind of evidence, referring to information and its decay over time: fossils might be destroyed, or we might lack the theories or technology required to “decode” them. “Loss” refers to the second kind of evidence, and thus the ongoing existence of things: if platypuses were to go extinct, there would be none for us to examine. The professor is lucky that Broadfoot’s fossil wasn’t *erased*, because Broadfoot has been *lost* to extinction. Lost worlds, then, are worlds that contain different things, obey differing dynamics—they “work differently”—to the present.

Sometimes the past is hard to know because it has left incomplete records. Sometimes the past is hard to know because the past is weird. “Erasure” is the former, “loss” the latter. The next chapter is devoted to fleshing these concepts out (kindly keep objections in your back pocket until then!), so hopefully, that’s enough for now.

Loss is important. Our knowledge of the past continually confronts the possibility of, and sometimes uncovers, loss: histories that work differently, are governed by different rules, and are populated by different creatures and processes than in our own time. Platypuses are unique and do not exist contemporaneously with Ichthy, and this appears to limit the professor’s capacity to understand platypuses. Loss generates failures of uniformity, and this both challenges our capacity to acquire knowledge concerning the past and increases that knowledge’s significance.³ Uniformity, the past being like the present, is never guaranteed. Failures of uniformity raise challenges: If our knowledge of the past is mediated by our knowledge of the present, then how can we understand pasts that are significantly different from the present? That is, how can we have a science of lost worlds? An account of how loss is (sometimes) overcome, I’ll argue, transforms how we conceive of knowledge about the past, what the past is like, and why knowing about it matters.

In the book’s first half (chapters 2 through 5), I provide an account of the strategies scientists adopt in tackling lost or putatively lost worlds. I’ll emphasize how historical scientists cleverly characterize their past targets—take perspectives on them—which lets them build various connections between the unknown and the known. Iteratively navigating between these connections enables them to gradually build up a rich picture of the past. Thus, the major

3 This focus on uniformity doesn’t force us to tackle the problem of induction, that is, attempt to provide some *a priori* or *a posteriori* justification for taking the future to be like the past on pain of our grounds for empirical knowledge giving way.

conceptual innovations I want to introduce to the epistemology of the historical sciences are, first, the notion of *strategic perspectivalism* and, second, *iteration*. As we'll see, these notions bring together a set of ideas implied but insufficiently emphasized by the literature thus far, but they also explain how historical scientists can reconstruct the past even in circumstances where the past is unfamiliar and weird—or lost.

Throughout the book's second half (chapters 6 to 10), I draw philosophical lessons from my analysis. These lessons concern the modal knowledge scientists provide, the nature of scientific imagination, the “peculiar” history they uncover, and the relationship between the past and the present, on the one hand, and the past and the future, on the other. Let's advertise these Big Claims as a bit of motivation for the reader.

Big Claim 1: *The sciences of the deep past are sciences of deep possibility* (chapter 6). Reconstructing lost worlds requires rich modal knowledge about the deep past. I'll argue that this modal knowledge is best understood as objective, rather than epistemic. Under the right conditions, historical scientists generate bona fide knowledge of not only how the past was, but how the past could have been. Further, I'll characterize this modal knowledge in “artifactualist” terms. Scientists targeting the deep past adopt a broad range of strategies that require generating and examining a wide variety of artifacts. These artifacts possess various dispositional properties, and knowledge of those dispositions grounds inferences about the dispositional properties of entities and processes in the past. So, I argue that in terms of method, the practice of historical science intertwines the present with the past; in terms of dividends, historical science is as much, if not more, about what is possible than what was actual.

Big Claim 2: *The imagination involved in investigating lost worlds is artifactualist* (chapter 7). I'll provide an account of scientific imagination that is firmly rooted in the materiality scientists confront and construct. Scientists think, imagine, and speculate through and with various artifacts. The scientific imagination turns on the embodied coupling of scientific agents and these various artifacts. The properties of available artifacts, then, significantly constrain what scientists can imagine. This somewhat vindicates Ichthy's pessimism about their capacity to have imagined Broadfoot without the fossil discovery.

Big Claim 3: *The Paleobiological past is peculiar* (chapter 8). Realizing that the past consists of lost worlds—worlds populated with differing critters and processes operating by differing dynamics; that is, pasts that play by different

rules—grounds a view of the metaphysics of history that also makes sense of some aspects of the present. Through history, things are lost, but the past also contains innovation and novelty: the generation of *new stuff*. Life's past contains both extinction and speciation, for example. This is because the past doesn't simply involve one thing happening after another, but nor does it behave with unerring uniformity. Rather, pockets of regularity emerge under particular conditions, and fall away again as those conditions change. This is a form of contingency I call *peculiarity*. Peculiarity underwrites a deeply historical conception of the kind of messy, pluralistic, patchworky metaphysics popular among many scientifically-inspired philosophers. Thus, I'll argue that geological and biological history should be understood in (to crib from Cartwright) "dappled" terms, and that these features of history explain why the natural world is disunified (insofar as it is).

Big Claim 4: *Lost worlds and the unprecedented future are epistemically asymmetric* (chapter 9). You might hope that the strategies historical scientists adopt in trying to understand surprising pasts would apply to apprehending unprecedented futures. I'll argue this is true to some extent—many of the basic strategies useful for uncovering the past are applicable to the future (and knowledge, especially modal knowledge, concerning the past is invaluable insofar as it can be turned toward the future). However, there is an epistemic asymmetry between the past and future that is baked into our status as temporally-limited epistemic agents, as knowers moving through time in a single direction. For past worlds, when we're lucky, we have *traces*, that is, downstream remnants of past events. These records of the past are critical for uncovering history's surprises (thus far exemplified by Ichthy's fossil platypus). However, for future worlds, it is unclear what the analogy of "trace" might be: there are (perhaps) no records of the future. As traces are crucial for uncovering lost worlds, not having "traces of the future" undermines our capacity to acquire knowledge of unprecedented worlds. Given the many surprises the deep past has given us, this asymmetry suggests that expecting to get unprecedented worlds right is wildly optimistic—and perhaps dangerous.

Beyond these Big Claims, I owe the reader a story about why they should care about the general topic of this book. Why is palaeobiological knowledge, or historical knowledge generally, or the nature of the past, something that's worth spending an entire book exploring? Let's see what Ichthy has to say on the topic.

Ichthy regards the audience once more, their maw swinging back from the skull. “As you’ve come all this way, I should say a thing or two about what I think is valuable about the kind of work I do—and why sitting through this lecture is worth it.”

Ichthy glances with mild embarrassment at the gaggle of graduate students in the audience, as they adopt a more philosophical tone than perhaps they’re comfortable with.

“Our perspective is typically rooted in the relatively recent here and now. The way the world appears to be now sets a bunch of expectations about how the world usually is. The now, I suppose, is taken to be the default. Current fauna and flora are dominated by gymnosperms, like conifers and ginkgo, by marine reptiles, such as yours truly, and on land by those lumbering sauropods. And that’s what we expect life to be like. But discoveries like Broadfoot tell us that the here and now is not permanent, that the past is weird, that history doesn’t end, or at least hasn’t yet. Once there was a mammalian world, now there is our own, and we’ve no reason to think that our world is any more stable than theirs was. I don’t think this is just a lesson about biology.”

Another pause from Ichthy, as they venture even further outside of their comfort zone.

“We live in a particular set of cultural, political, and economic conditions, and these structure how we see the world. Just as we project the living world as default, we take our current social worlds as default. Most interestingly, they structure and constrain how we might imagine the world to be different. I wouldn’t have imagined Broadfoot without its specimen, and it is hard to imagine the ways things could be far beyond our immediate experience. History, and the study of history, gives us some of the tools we need to break out of that perspective. So, the kind of work I do is part of that project. Behind all the apparently dry science, work like mine helps us imagine different worlds.”

An account of historical knowledge that emphasizes loss and how the peculiarities of history provide rich insight into possibility offers lessons into how we should think about ourselves, and how we might partly break, or at least loosen, the shackles of our temporally-bound perspective. In addition to disrupting entrenched perspectives, knowing the past matters for understanding how we got to where we currently are and for getting some sense of what might happen in the future. In the book’s final discussion, I’ll turn to the nature of wonder and how knowledge of lost worlds is a powerful source of

wonder. Insofar as wonder is transformative, insofar as it can take us outside of ourselves, and insofar as knowing about history is a source of wonder, historical knowledge is itself transformative. If historical knowledge is valuable, then understanding how we *get* historical knowledge is valuable, and that is what this book is about. So, that's my pitch for sitting through the book and Ichthy's lecture.

In the remainder of this introduction, I'll provide two kinds of context, one philosophical and the other historical. I'll start with history, pointing to the role lost worlds played in early Earth science: 19th-century (proto) palaeontologists and geologists claimed revolutionary significance for their work by emphasizing the differences between their present and the pasts they were uncovering. I'll then switch to philosophy, sketching where we are at vis-à-vis the epistemology of the palaeosciences. The sketch will be drawn to highlight how philosophers have focused on trace records, and their incompleteness, as the main source of, and challenge to, historical knowledge. Thus—if my discussion of loss holds water—that work has been too narrow and needs a course correction. I'll finish off, as is traditional for introductions, with a more systematic sketch of the book's structure.

1. Awful (and Marvellous!) Changes

Prof. Ichthy signals the next slide with a meaningful look at a graduate student, who, with a start, switches to the next image. Projected behind the podium is a series of extinct mammals, from the long-necked *Camelopardalis* to the enormous, aquatic cetacea, all connected by tree-like lines of descent. Broadfoot is prominently displayed amongst the menagerie. Ichthy continues:

“Broadfoot is part of an, until very recently, unknown past, an unknown past unconceived of by our scientific forebearers. After all, who would have imagined a world dominated by the ancestors of the tiny, scampering creatures that are all that remains of Mammalia? That these apparently insignificant animals are the last vestiges of such a remarkable inheritance? I think it no exaggeration to say that the discovery of this mammalian past demonstrated to us that Earth's past has a History.”

Ichthy pauses, readjusting their spectacles before attempting some professorial cheekiness:

“I hope you heard The Capitals there: not just ‘history,’ time passing, but **History**. The past was different from how the present is, in profound, surprising ways. And this matters, I think—the deep

past wasn't just one thing after another, but neither did it occur according to some set of determined, destined laws. The deep past unfolds in beautiful, complex, and ephemeral patterns, and it is the job of folks like me to grapple with those patterns."

The notion of loss I'll develop in the next chapter has interesting resonances with the emphases that 18th- and 19th-century proto-historical-scientists placed on their remarkable discoveries. Their arguments for the significance of their work—and the centre around which the spectacle of early geology turned—were the idea that the past differed surprisingly from the present. By way of historical motivation for the next chapter's conceptual analyses, then, a rather broad historical discussion is in order. Before that, I'll introduce a few more themes of the book via a dive into the inspiration behind Prof. Ichthy.

1.1 Prof. Ichthy Versus Professor Ichthyosaurus

Prof. Ichthy is inspired by Henry De la Beche's caricature *Awful Changes* (see Figure 1.1). This was drawn sometime around 1830 and reprinted many times (William Buckland apparently used an enormous print during his lectures). The cartoon shows "Professor Ichthyosaurus"—spectacles, podium, and all—pontificating on a strange skull before a rapt (and, to my eye, somewhat condescendingly amused) crowd of marine reptiles. Professor Ichthyosaurus remarks that the skull's primitive features clearly distinguish it as among the "lower orders" of animals.

There are three major differences between Prof. Ichthy and Professor Ichthyosaurus. First, the time period mocked by the lecture style. Ichthy appears to be stylistically and technologically rooted sometime in the 1970s, '80s, or '90s (although Robins' visual interpretations hark back to both the earlier 20th century and the more distant Victorian era), while Ichthyosaurus is a firmly 19th-century beast. Second, the taxa of the focal specimen differ: Prof. Ichthy is describing an extinct platypus, Professor Ichthyosaurus an extinct *Homo sapiens*. The third is more relevant and will take some unpacking.

Since Martin Rudwick's (1975) interpretation, it has been widely accepted that De la Beche's cartoon pokes fun at some of the ideas in the first volume of Lyell's *Principles of Geology* (1830). There, Lyell famously introduced ideas that were later dubbed (by Whewell) *uniformitarianism*. Uniformitarianism (at least in Lyell's original formulation) can be approximately understood as the claim that the historical processes that produced geological features are still operating today at more or less the same rates. If so, the thinking



FIGURE 1.1 Henry De la Beche's *Awful Changes*, the Inspiration for Prof. Ichthy. Science Museum Group Collection. © The Board of Trustees of the Science Museum

goes, geologists ought to examine contemporary processes to understand geological features as the products of those processes operating incrementally over significant timescales (see, for instance, Secord 2014; Patton 2014). There is disagreement about how exactly to characterize uniformitarianism in its historical context. Vic Baker (1998), for instance, has associated it with a particular (now outmoded) logic of induction, while David Sepkoski (2020) has emphasized the historical importance of non-uniformitarian thinking, especially as it relates to extinction.

Regarding received ideas about uniformitarianism, we shouldn't accept the historical idealization that Lyell's opponents (dubbed "catastrophists") denied moderate forms of actualism, nor that they clung to somewhat earlier ideas about geological formations occurring through biblically sudden floods

and other events. Rather, they thought that some geological phenomena just couldn't be explained in gradualist terms. As Rudwick puts it, "The observed deformations of strata in many mountains . . . seemed to De la Beche to be inexplicable in terms of very gradual and relatively gentle forces, no matter how long the periods of time during which those forces were inferred to have operated" (Rudwick 1975, 545). Happily, the topic at hand doesn't turn on exactly how we characterize uniformitarianism and catastrophism.

De la Beche's problem with Lyell wasn't only about uniformitarianism's explanatory and investigative reach, but concerned a broader debate about the nature of geological history itself. When Lyell's contemporaries examined the fossil record, they discerned a clear pattern of progress through various ages: from fish, to amphibians, reptiles, and so on, to our own species. Further, 18th-century theorists often took the Earth to be steadily cooling (this was the basis of many attempts to estimate the Earth's age) and explained the structure of the continents as one of flux due to changes in sea levels. By contrast, Lyell denied geological time's "directionality": he denied a pattern of progressive change. As with uniformitarianism, historians differ on how to read Lyell's exact position. Jim Secord, for instance, interprets Lyell in terms of epistemic caution: claims about progress in the fossil record required an "unphilosophical assumption which ignored the patchy nature of the fossil evidence" (Secord 2014, 147). By contrast, Martin Rudwick (along with many of Lyell's contemporaries) sees Lyell defending what Rudwick calls a "steady-state" model of geology. That is, Lyell took the Earth to be in a kind of dynamic equilibrium. "If processes observable at present are representative, in degree as well as in kind, of all those that have acted in the past, there cannot have been any overall directional trend in the history of the earth, which must therefore be in a 'steady-state' condition" (Rudwick 1975, 8). This steady state was maintained by multiple interacting, often mutually-compensating processes. Lyell applied this steady-state approach to the history of life: the fossil record did not represent a series of progressivist changes through some ladder of being. According to Rudwick, this view was not popular.

To most geologists this seemed to be particularly implausible. It involved a complete rejection of the clear trend of palaeontological discovery, which seemed to be uncovering a broadly progressive history from the simpler or lower organisms, through the successive appearance of more complex or higher forms of life, to the geologically recent creation of man

himself. It is well known that Lyell circumvented this evidence by attributing it to differential preservation, and that he asserted that even the higher forms of life (e.g., mammals) had existed at the remotest known periods. (Rudwick 1975, 557)

Although Lyell denied his view was literally cyclic, as Rudwick points out, he was quite understandably interpreted as such by his contemporaries. In the *Principles of Geology* and in various correspondences, Lyell proposed that when the right ecological and environmental conditions arise, so too will the same critters. As Lyell states, quoted by Rudwick: “Then might those *genera* of animals return, of which the memorials are preserved in the ancient rocks of our continents. The huge iguanodon might reappear in the woods, and the ichthyosaur in the sea, while the pterodactyl might flit again through umbrageous groves of tree-ferns” (Rudwick 1975, 558). The combination of a steady-state, homeostatic view of geology with the thought that appropriate species (whether literally the same or not) could arise given the appropriate environmental states, “led [Lyell] inexorably to a view that very similar species must have been produced repeatedly in the past and would continue to be produced indefinitely into the future” (Rudwick 1975, 558). Hence, the topic of De la Beche’s caricature, whose aim was to “help laugh [Lyell’s ideas] out of court” (Rudwick 1992, 45).

Did Lyell in fact adopt a cyclic view of geology and biology? Or, as Secord (2014) suggests, was it instead a theoretically open thought experiment designed to illustrate how little grip we really have on patterns in the deep past? Happily, for my historically instrumental purposes, we can avoid this question: We’re interested not in a historical question about Lyell, but in the philosophical differences between Professor Ichthyosaurus and Prof. Ichthy.

So, (and at long last), we come to the third difference between De la Beche’s Professor Ichthyosaurus and my Prof. Ichthy. They take opposing stances on a question regarding the nature of history. Professor Ichthyosaurus, representing Lyell (fairly or not), takes there to be a *past* but in a sense no real *history*: There is change, but no real direction or story to tell about that change. Geological forces are in a dynamic, steady-state equilibrium, and the relevant biological kinds simply arise as the relevant environments cycle through. By contrast, Prof. Ichthy emphasizes not simply the past but History (capitalized again!). The Earth is not cyclic but is, in some important sense, contingent: what cycles there are, themselves have a history. For Professor Ichthyosaurus, the deep past reveals the *continuity* of the past and present (and presumably

future); its data can be used to underwrite regularities and laws, that is, the rules governing the steady-state system of the Earth (see Gould 1988 for a similar discussion). For Prof. Ichthy, the deep past reveals *discontinuity* of past and present (and presumably future); it shows the limitations of regularities and laws. As we'll see, focusing on lost worlds will help us identify and explore variations and middle-grounds between these two extremes. That is my task in chapter 8.

Despite Lyell's long historical shadow, the birth of geology and palaeontology relied on ideas and rhetoric much closer to Prof. Ichthy than Professor Ichthyosaur. To highlight loss' importance, let's turn to those ideas.

1.2 The Discovery of Loss

Martin Rudwick has beautifully chronicled the slow realization of the Earth's deep history: how natural philosophers “burst the limits of time” in discovering a long pre-human past (Rudwick 2005; 2014). Being pre-human, these pasts differed crucially from the contemporary world. As Ralph O'Connor has shown, 19th-century geologists adopted literary styles that emphasized these differences; rhetorically they “pulled off an imaginative coup—a *coup de théâtre*—by giving their public tantalizing glimpses of an Earth history far longer and stranger than the story of a literal six-day Creation which had held sway over much of that public at the turn of the century” (O'Connor 2008, 2). Thus, the differences between now and then, and the narratives these afforded, formed a central component of the rhetorical strategies these scientists adopted in describing their work and arguing for its importance. This is true regardless of whether they saw clear and clean breaks between the past and present, or whether they viewed the connection more uniformly.

For an early example, George-Louis Leclerc, Comte de Buffon, the 18th-century polymath, attempted to provide an overall picture of a pre-human past by postulating seven epochs of the Earth's history. Our species only appears in the seventh epoch, after a long series of environmental and geological cataclysms and shenanigans. As Rudwick puts it, “The whole of human history was confined to the most recent portion of a far longer temporal sequence. Buffon claimed that since this last metaphorical milestone, there had been few further changes of any significance in the physical world” (Rudwick 2005, 146). That is, the epochs before our arrival were in many ways more dramatic and changeable than our own. In a sense (and in stark contrast to Prof. Ichthy's post-mammalian perspective), the endgame of humanity was

the end of (natural) history. While in the 19th century geologists distanced themselves from the speculative “theories of the Earth” produced by Buffon and others (Rudwick 2005), they nonetheless retained their rhetorical emphasis on “loss.”

Chris Manias’ *Age of Mammals* (2023) chronicles the role of mammalian palaeontology in the developing geosciences through the long 19th century. He provides multiple examples of appeals to differences between the past and present, appeals which aim to underwrite the value of knowing the past. For instance, Richard Owen’s interpretation of the enormous ground sloth *Myiodon* relied on the idea that South America’s tropical fecundity had been pumped up to massive scales in the Pleistocene, and this required enormous animals to tackle the verdant growth. For Owen, *Myiodon*’s morphology was built to uproot enormous trees; it “was assigned the office of restraining the too luxuriant vegetation of a former world” (Manias 2023, 2). So, while in some ways South America’s present was continuous with its past—peopled with jungles and sloths—its past was an exuberant, exaggerated version of its present. *Myiodon*’s previously unseen traits were explained in terms of, and partially evidenced, the idea that South America’s past differed in surprising ways from South America’s present.

On Manias’ account, the idea that the past was in many ways fundamentally different from the present is crucial for 19th-century apologies for palaeontology: “The idea that the world had formerly been inhabited by now-disappeared animals has been highlighted as one of the principal conceptual contributions of the study of fossils. . . . Palaeontology depended on former worlds having vanished, and new forms arising” (Manias 2023, 55).

For another example, Manias recounts Leidy’s description of Wyoming as “a place of dead antiquity,” perceived as “the wreck of another world which was once luxuriant with vegetation and teemed with animals (Manias 2023, 153).” Here, Wyoming is understood as a kind of ruin, evocative of past glories.

Thus, 19th-century geologists invented a non-human history full of change, often but not always understood in progressivist ways: “Deep time was not incomprehensible, but could be understood as a series of worlds, each passing (by admittedly mysterious forces) into the next” (Manias 2023, 170).

In popular treatments, fossils were presented as what O’Connor calls “sublime relics of a legendary past” (O’Connor 2008, 33). Both visual (Rudwick 1992) and textual (O’Connor 2008) descriptions of geological phenomena were used to generate evocative visions of these legends: “Geology’s main claim to poetry consisted in its ability to call up dramatic images of vanished

worlds” (O’Connor 2008, 357). In the 19th-century texts O’Connor describes, various literary techniques are used to draw narrative from geological description. For instance, in textual versions of Victorian diptychs, poets would overlay then and now, as in this Tennyson stanza from *In Memoriam*:

There rolls the deep where grew the tree.

O earth, what changes hast thou seen!

There where the long street roars, hath been

The stillness of the central sea.

(Tennyson, quoted in O’Connor 2008, 365)

Geology reveals a past of change—no steady state but a historical trajectory—wherein oceans cover where forests once stood and busy human streets bustle where oceans once lay. Aesthetically speaking, the gift of geology was the ability to see natural formations in terms of their history. Derek Turner describes this evocatively with the notion of a “stereotemporal experience”: “Like a stereoscope that uses two images of the same item to create an impression of depth, stereotemporal experience merges our current perceptual experience of the landscape with our understanding of its history” (Turner 2019a, 7). Knowledge of the past allows us, too, to observe the changes the Earth has seen.

It is in debate concerning the reality of natural extinction that the historical importance of loss is most clearly felt, especially prior to the 19th century. As Rudwick puts it: “Most naturalists felt an almost gut revulsion against the idea that extinction might be an ordinary feature of the natural world. For it implied that some of the wonderfully diverse species, the fossil remains of which they took such delight in collecting and describing, might have been lost forever” (Rudwick 2005, 243).

The theological upshots of accepting extinction were potentially profound, and at least for some, loss through extinction could be denied. Perhaps, for instance, the thus far largely unexplored (in the colonial sense anyway . . .) New World could be a source of migrated critters and living fossils (we’ll discuss living fossils in chapter 4).⁴ Despite apparent evidence in the fossil record

4 Chris Manias points out to me that there is much disagreement between the historical actors on this point. Cuvier, for instance, doubted the new world housed fauna lost to the old.

of once-common and thriving lineages now unseen (ammonites, for instance), many natural philosophers still doubted that anything was truly “lost.”

For those accepting the possibility of natural extinction, the possibility of patterns of extinction was sometimes extended into the future. Manias quotes Falconer, a 19th century colonial researcher of India’s geology: “We appear to be gradually losing all the larger forms of creation. The elephant and giraffe of the present period will in all probability share the same fate as the Mastodon and Sivatherium of former eras, and be only recognized in the proofs exhibited by the researches of the geologists” (Manias 2023, 106). A differing past, one revealing new worlds and patterns stretching into the present (and into the future), makes knowledge of that past uniquely powerful—and poignant.

Beyond the 19th century, loss again came into prominence, with increasing focus on mass extinctions during the paleobiological revolution (e.g., Jablonski 1989; Raup 1992), coupled with the rising awareness of current plummeting biodiversity due to anthropogenic extinction (Sepkoski 2020). Mass extinctions mattered for many reasons. They represented a case where a signal from the fossil record revealed a surprising, apparently biological pattern with major consequences for understanding the history and nature of life at the macro-scale, a pattern amenable to statistical analysis, simulated study, and so on. It was thus important for establishing the paleobiological revolution’s claims to scientific and theoretical legitimacy (Sepkoski and Ruse 2009). It also, of course, linked the history of life to currently occurring biological cataclysm, if perhaps tenuously (Bocchi et al. 2022). Further, and speaking more to the heart of this book, the occurrence of mass extinctions has been called upon to argue for major discontinuities in the history of life. This, it has been suggested, evidences that macroevolution is not just microevolution scaled up, but works according to its own rules (Jablonski 2005; McConwell and Currie 2017a; Turner and Havstad 2025) and further, that these rules might have changed over time.

At base, the eventual acceptance of extinction and pre-human time in the 19th century, and of mass extinctions towards the end of the 20th century, involved accepting that the past was in many ways not like the present. That is, accepting lost worlds. In a sense, then, my aim in this book is to return philosophical attention to loss. In the next section, we’ll examine recent philosophical work on the sciences of the deep past. These have, by and large, focused on “erasure,” that is, traces or their lack thereof. At least if I’m right, they’ve paid insufficient attention to loss.

2. Trace-Based Reasoning

Prof. Ichthy's graduate student, now getting into the swing of things, deftly replaces one transparency with another. This new slide shows Ichthy's fossilized discovery from several angles. Ichthy gestures at the slide:

"We see here this wonderful specimen, the only trace we have of Broadfoot. And here, Ichthy gestures at the skull, "a plaster cast of its skull. Our knowledge of the past is built upon objects like these. Sometimes I think of them as a bit like documents. That is, they are something to be read, interpreted, and decoded. But fossil specimens are not just code—they're not mere vessels for some abstract 'information.' Broadfoot's mineralized body is also a physical object. Its materiality matters crucially for our understanding of it. The fossil bears information, but that information is laid bare based not only on our understanding of how it formed, but also on how we have manipulated and structured data generated from it. As I have said, it is only in virtue of this wonderful, remarkable, wildly improbable trace, and our discovering it, revealing it, and caring for it, that we know of Broadfoot at all. And our study of it goes far beyond 'reading.' So, an understanding of Broadfoot as a trace, that is, as a fossil, is necessary. But, I think, that is not where the story of our science of Broadfoot can end."

The history of the Earth sciences has been understood as the history of a metaphor: *reading the historical record* (Sepkoski 2019; Currie 2023a). Fossils are not literally texts, but we discuss them as such so naturally that the metaphor is nearly, but not quite, dead, and that metaphor has been used extensively more or less since the Earth sciences began. Fossils make up records: records of traces that, if properly read, form the basis of our knowledge of the deep past. These broad brush-strokes can also be applied to the much shorter history of the philosophy of the historical sciences. Debate in that arena has turned on whether various historical records (consisting of fossils, archaeological remains, etc.) are characteristically information retaining or otherwise; the epistemic challenges historical scientists face emerge from incomplete, degraded, and messy records. We can understand this focus in terms of "traces," and I'll call the processes that generate epistemic challenges from a lack of traces "erasure" in the next chapter.

"Traces" are contemporary objects understood in terms of (1) the causal sequences that led to their formation, which, if properly understood, (2) act as

evidence for past states of affairs. For a clichéd example, fossils are products of various fossilization processes, which, in virtue of our understanding of those processes, evidence past organisms. This is “trace-based reasoning”: inferring from a contemporary object to the past via an understanding of the historical processes by which that object formed (Kosso 2001; Jeffares 2008; Currie 2018a; Currie and Killin 2019). Understood as such, traces and trace-based reasoning are everywhere in science. For instance, experiments produce data which we draw upon to test hypotheses. In performing such tests, we rely on metadata concerning the data’s provenance—how and when it was produced, say. Insofar as all data-derived evidential claims rely on knowledge of the data’s provenance, all data-derived evidential claims involve trace-based reasoning. In a sense, then, all science is historical (Currie 2019a; Roth 2019). But traces have a special place in philosophical accounts of historical science, and for good reason: the reliance on historical records—traces—is an obvious starting place for thinking about the status of such sciences. After all, Prof. Ichthy couldn’t have imagined Broadfoot were it not for that remarkably preserved, fortuitous specimen. Bruce Routledge characterizes archaeology “not as a discipline of the past, nor of things, but as a discipline of traces” (Routledge 2023, 2). For Routledge, because traces mediate archaeological knowledge of the past, we’re making a mistake to characterize that knowledge as either about contemporary objects or the past *tout court*. He thus places traces at the centre of archaeological science.

In the past two decades or so, the philosophy of the historical sciences has been shaped by two interrelated debates, both conducted in highly trace-focused ways. First, what is the method of historical science, and how does this relate to its epistemic credentials? Second, what epistemic attitude should we adopt toward the historical sciences?

Regarding the first question, Carol Cleland (2002, 2011, 2013) argues that sciences like palaeontology and geology proceed via *smoking-gun reasoning*. This involves noticing puzzling contemporary correlations among putative traces, generating hypotheses about the past which, if true, would explain those correlations, and then hunting for further traces—smoking guns—which would discriminate among those hypotheses. Cleland takes historical reasoning to be a form of common-cause explanation. Inasmuch as the events posited in the past explain multiple traces, they unify them via a common cause, and those common causes explain the correlations among traces.

Cleland underwrites smoking-gun reasoning with a claim about the relationship between the present and past. She adopts a metaphysical view

whereby causes and effects stand in a one-to-many relationship, and effects themselves are causes of further effects. As such, causal information about an initial cause diversifies and disperses as time goes on (see Fox 2023 for scepticism). As a result, we should expect the strategy of hunting for multiple effects to uncover past causes—developing common-cause explanations that unify those effects—to be a successful strategy.

In Cleland's view, the contemporary plays a crucial role in historical knowledge. For her, in a sense, historical science is in the business of explaining contemporary traces. That is, Cleland gives us a particular account of trace-based reasoning as I characterized it earlier. There are various views that disagree in some philosophical detail or other, but are similarly trace based. Where Carol Cleland emphasizes common-cause explanations, others have argued that consilience—roughly, evidence of differing types and sources pointing to the same conclusion—does the work (Wylie 1999; Forber and Griffith 2011). Still others emphasize the coherence and consistency of historical explanations (Kosso 1993; Kleinhans et al. 2005; Turner 2009; Currie 2017; Currie and Sterelny 2017), while others stress the pluralism and flexibility of historical approaches (Wylie 1999; O'Malley 2016; Currie 2018a), especially in light of their capacity to use innovative technology (Tamborini 2020; Currie 2021a) and speculation (Currie 2018a; Bonnín 2019; Tamborini 2020; Swaim 2024). Regardless, these views all to some extent rely on a particular methodological picture: *historical science is in the business of trace-based reasoning*. So, the philosophical action regards understanding that form of reasoning's nature. Further, an epistemic debate follows from this methodological claim. If historical science is fundamentally about traces, then *the epistemic fate of historical science turns on the richness and accessibility of traces*. Elliot Sober and Mike Steel's discussion is particularly explicit about this.

We are interested in how the natural processes connecting past to present constrain our ability to know about the past by looking at the traces found in the present. An optimistic view of these processes is that the past is potentially an open book; all we need do is understand the connecting processes correctly and look around for the right traces. If the relation of the past state of a system to its present state were deterministic and one-to-one, this optimistic view would be correct. If only we could know the present state with sufficient precision, and if only we could grasp the true mapping function that

connects present and past, we would be home free. (Sober and Steel 2014, 558)

Sober and Steel adopt a formal approach, arguing that (assuming particular temporal branching structures) information loss over time is nearly inevitable, concluding that “the view of evolution as an ‘information destroying process’ is basically right” (Sober and Steel 2014, 571). If evolutionary processes destroy information, then this limits our knowledge of the past. We’ve thus switched from asking after methods of reconstruction to related questions concerning the epistemic fortune of historical science: How much will we be able to know about the past? Sober and Steel tackle the question by asking just how much information will be retained, which is to say, how many traces will there be.

So, on to the epistemic credentials of the historical sciences: should we be pessimistic or optimistic about their epistemic fate? Should we be realists or anti-realists about historical knowledge?

Derek Turner’s arguments in favour of anti-realism about historical science rely on trace-based reasoning (Turner 2004, 2005, 2007). He points to the oft-noted impoverishment of the historical record and argues that our background theories about the processes that form that record should lead us to doubt whether that impoverishment will improve. So, we won’t have many, or good, traces to work with. He further points to our incapacity to intervene in the past: where scientists-of-the-now can generate new evidence via experiments, scientists-of-the-then cannot. So, in comparison to experimental science, historical science has worse evidence and cannot generate its own. For Turner, this should lead us to expect underdetermination problems to be rife: although historical hypotheses may, in principle, be empirically delineated—we can imagine smoking guns—we also should expect smoking guns to be few and far between. That is, much of the time, our available evidence will not decide between our hypotheses.

So, rampant underdetermination should lead to pessimism regarding our knowledge of the deep past. Turner’s pessimism can be compared with Carol Cleland’s appeals to the many-to-one relationship between causes and effects (Currie 2018a, chap. 5). Recall that she argues that as causes breed multiple effects, which themselves act as causes for further effects, we should expect the world’s current state to overdetermine its past state. If that were right, we’d have some grounds to expect many traces to be available to test historical hypotheses; over time, then, underdetermination would be resolved. By

contrast, Turner points to the degradation of evidence and our helplessness to improve that situation. He thus expects underdetermination to remain.

We have what appears to be an impasse: the epistemic fortune of the historical sciences turns on whether much information from the past has been retained or destroyed. If the former, perhaps we have grounds for optimism; if the latter, we have grounds for pessimism. Or perhaps there are further contextual elements that should lead to pessimism at some times and optimism at others, maybe depending on the kind of epistemic good that interests us (Currie 2018a, chap. 10), the stage of research (Tucker 2011), or the granularity of claims (Malaterre 2024). In *Rock Bone and Ruin* (2018a), I pointed to the creativity and pluralism—“methodological omnivory”—of historical scientists toward defending a (maybe cautiously) optimistic position. A major part of the argument involved pointing to non-trace forms of evidence (simulations, analogies, and so on) that historical scientists could draw on.⁵ Although I argued that traces don’t exhaust what there is to say about historical knowledge, the discussion was nonetheless rooted in that trace-centric tradition.

Joyce Havstad (2019) has argued that philosophers should be agnostic regarding optimism or pessimism about historical science (although, as Turner (2016) has pointed out, agnosticism might not be an option scientists can afford). For Havstad, no one has given sufficient reason to decide whether, at the end of the day, historical processes are generally information-destroying or information-preserving. Part of her argument involves considering situations where the retention of traces seems highly implausible. For instance, she asks us to imagine: “An unseen bubble, landing on the surface of a lake, and dissipating without any sort of ever-recoverable trace. Or maybe a fleeting, ancient pathogen—one that wreaks havoc on a population of soft-bodied organisms whose fossils, if any remain, show no accessible evidence of the biological attack” (Havstad 2019, 3).

In the parlance of the next chapter, we’d say Havstad has described cases involving *complete erasure*. The possibility of such circumstances, she argues, should motivate agnosticism about historical science.

A further argument for a sort of agnosticism (or at least quietism!) regarding our epistemic attitude toward historical knowledge begins with a

5 Recently, Franziska Reinhard has provided an expanded notion of “traces” that includes more than simply direct causal descendants. This expanded notion is, I suspect, another way of pushing against comparatively limited conceptions of historical evidence (Reinhard forthcoming).

turn from considering traces as *evidence* to considering traces as *data*. We can understand “data” as physical objects that, under the right conditions, might be “enriched” to act as evidence. That is, data is potential evidence (Leonelli 2016, 2018; Boyd 2018; Watkins 2024). Along this vein, I have recently characterized the palaeosciences as often facing *epistemic scarcity*: circumstances where data are rare and fragile, hard to manage and non-renewable (Currie 2021a). Some of these features relate to the traces themselves but others relate to how historical scientists manage the traces as data: their storage, handling, the applicable techniques and technologies of analysis, and so on. Beyond traces, there are also worries about metadata. For instance, what data gets recorded about extraction during fieldwork?. Thus, information might be lost across “phenomena time” by, for instance, geological processes, but also “data time,” by, for instance, scientists misplacing or destroying specimens (see Leonelli 2018; Watkins 2024a; Wylie 2024).

The upshot of this focus on data is that, in addition to worrying about information loss from the deep past, we also need to worry about the fate of data in the record-making and managing practices of scientists themselves. In my 2021a paper, I argued that, once we take data into account, debates about the underdetermination or otherwise of historical hypotheses become intractable. This is because we now need to not only track information loss and retention on nature’s schedule, but also need to track this across the practices of scientists. Notice still that the epistemic situation—scarcity—is characterized in terms of *data*, which, in the palaeosciences, typically means traces and records. So, the data-oriented view thus far is still highly trace-focused.

Alison Wylie’s analyses of archaeology often involve rich accounts of the challenges from traces and how archaeologists respond to them. Consider, for instance, her discussion of “shadow-data”: “[A]rchaeology as a discipline is defined by the challenges of working with gaps and absences in its primary data. The shadows archaeologists wrestle with are not just a function of the notoriously fragmentary and incomplete nature of the surviving ‘data imprints’ of past lives but reflect, as well, the paucity and instability of the inferential resources they rely on to ‘bring data to light . . . to realize its value’ as evidence” (Wylie 2017, 204).

Archaeologists often face not only an incomplete record but an unstable base to make inferences from that record. That is, their understanding of *how* the archaeological record has formed is also fragile. To grasp the epistemic challenges of uncovering the past, then, is to understand the strategies historical scientists adopt to mitigate and overcome incomplete data sets and

incomplete understanding of how that data formed. To an extent, I don't disagree with this. But, I think, to understand the value of traces, the value of past knowledge, and the epistemic situation faced by historical scientists, we must attend to what I'll call "loss" as well as incomplete records.

So, debate about the epistemic and methodological prowess of the historical sciences has turned on questions about traces. To the extent that the record is impoverished, so much the worse, but to the extent that the record is rich—or historical scientists have the tools and resources to mitigate a lack of richness—so much the better.

Another way into trace-based reasoning starts by considering how scientists construct proxies and measurements. Instead of asking how traces might serve as evidence about the past, we instead ask how Earth scientists use the palaeontological and geological records to carve up the past and measure time (Boudinot and Wilson 2020; Bokulich 2020, 2021a; Bocchi et al. 2022; Wilson and Boudinot 2022; Watkins 2024b). This involves considering how we conduct measurements on a trace that might act as a stand in for measuring some quantity in the past. Palaeoclimatologists measuring the oxygen content of an ice core to reconstruct past temperatures, palaeontologists sampling fossil diversity to infer past biodiversity, and archaeologists measuring carbon decay to estimate burial date, are all engaging in proxy measurement. This literature is less focused on general questions about the epistemic fate of historical science, but nonetheless is focused on traces and, thus, on what I'll call "erasure."

I'm not all that interested in directly engaging with trace-centric views, or the philosophical positions discussed above (see *Rock, Bone and Ruin* Currie 2018a for that!). I'm rather arguing for a broader reframing. Those philosophers rightly emphasize traces, but nonetheless miss the critical importance of the contemporary in thinking about history. For Cleland, Turner, and others, current observations matter insofar as they are treated like traces, that is, remnants of the past. But consider Professor Ichthy's discussion of their remarkable find. Their discovery of Broadfoot was remarkable because there is nothing like Broadfoot in the contemporary world: its unique features were unprecedented in science. This is not a claim about traces, but a claim about what exists. It doesn't concern erasure, but loss. Because Broadfoot-like critters are extinct in Ichthy's reality, they are extremely hard for them and their contemporaries to investigate and understand. This, I'll argue throughout, transforms how we should conceive of historical knowledge and the nature of the deep past itself.

So, accepting my moral doesn't at all mean that much of the rich work already done in the philosophy of palaeoscience must be thrown out; rather, the view is that it has been too narrow. There is still a lot of work to be done on erasure, but so too is there work to be done on loss.

Before moving on, it is worth emphasizing (as Ichthy does) that traces are not mere bearers of information, but physical objects that scientists and others extract, examine, manipulate, store, and organize. Historical science often involves intimate and embodied interactions between specimen and scientist—specimens are both data themselves and sources of data—and the creative and rich ways that historical scientists manage the various challenges such obstinate objects present are crucial for understanding how trace-based reasoning proceeds (Wylie 2021; Chapman and Wylie 2018; Currie 2021a). Although in a big way this book is saying “don't just think about traces,” it perhaps ironically also points out that once we take loss into account, why traces are so valuable becomes much clearer.⁶

Let's finish with two caveats.

First, there is an ever-present danger for “state of the literature” sketches like I've just provided. Of necessity—and design—these will foreground some elements of a discourse and background others (Currie and Walsh 2019). This can have deleterious effects if given too much authority, as any particular framing will place some work and questions as central, while relegating others to the fringe. And there are many other ways one might frame the philosophy of the palaeosciences: one might focus on the dynamics of explanations (Dresow 2021; Meneganzin and Currie 2022), or reduction (Grantham 1999), or start not with historical science as the focus, but the Earth sciences instead (Bokulich and Oreskes 2017; Ohnesorge and Watkins 2024). Overall, the argumentative focus of philosophers frequently makes us untrustworthy historians, especially when it comes to our own history, so I hope the reader takes the above survey with sufficient critical salt.

Second, it would be a little surprising if philosophical analysis of historical knowledge didn't bump up against something like loss now and then. And indeed, throughout the book, I'll point to overlap with previous work. Discussion of uniformitarianism and its limits is one place to look. Take Max Dresow's recent discussion, for instance: “The present may be ‘the key

6 I think I could be fairly read here as conceding to Alison Wylie's (2019) argument that the distinction I drew between “trace-based” and “non-trace-based” evidence draws the two apart too starkly: You don't get trace-based reasoning without non-trace-based input, and vice versa.

to the past,’ but there is no guarantee that this key will unbolt every door. Sometimes the past is truly alien—a ‘foreign country,’ as L. P. Hartley put it in *The Go-Between*. In such cases, ordinary reasoning strategies are prone to break down, raising the question of what limits exist to our knowledge of geohistory” (Dresow 2023, 407).

Here, Dresow puts his finger on the central insight I’m pushing: Our knowledge isn’t only limited because the past has left insufficient records, but also because the past is unfamiliar. The past sometimes leaves faint traces; the past is sometimes weird. Both matter for our knowledge of it.

3. Roadmap and Strategy

This book is centred around a set of episodes in the history of life: the Avalonian Ediacaran, when the first (that we know of) metazoans arose. In chapter 2, I’ll introduce some of that science and draw on it to explain the conceptual machinery that forms the book’s core. The aim of that machinery, briefly, is to expand our usual conception of the epistemic resources and challenges available to historical scientists. Where philosophical discussion has focused on *erasure*—whether past information has made it into the present—we should also care about *loss*—whether what existed in the past exists now.

Chapter 2, then, raises a question: How do we discover lost worlds? Through chapters 3, 4, and 5, I develop an answer to this question by articulating a set of strategies scientists adopt to accommodate and overcome the challenge of loss. Each chapter is named for one of the strategies. *Artificing* involves constructing something similar to the lost target. *Grafting* involves linking the lost target to something in the present via lines of causal ancestry. *Anchoring* involves examining aspects of the lost target across a set of differing analogues. Table 1.1 provides a quick, rough first-pass at these. In chapter 5, I’ll introduce Table 2.1, which is much more careful.

Through chapters 3 to 5, a general solution to the challenge of loss emerges, centred on a common thread through those strategies. First, what I’ll call *strategic perspectivalism*: the capacity of historical scientists to characterize their systems of interest in ingenious ways, enabling them to gain empirical and theoretical traction on those systems. Second, *iterativity*: how historical scientists navigate between these various strategic perspectives in surprisingly productive ways.

Each chapter will include examples from our Ediacaran mainstay, but will be accompanied by other palaeoscientific exemplars. I intend these cases

Table 1.1. Strategies, an Initial Sketch

Strategy	Basic Idea	Broadfoot Example
Artificing	Construct a model of the lost world.	A puppet with Broadfoot's gait.
Grafting	Examine the lost world's downstream ancestors.	Other extant or extinct mammals.
Anchoring	Examine multiple independent instances of the lost world's properties.	Evolutionary convergences with Broadfoot's traits (e.g., other electrosensing taxa)

to accumulate throughout the book, particularly through chapters 2 to 5. Each will be called back to, and sometimes expanded upon, as we move through the book's argument. I will focus on palaeobiological examples—apologies to those more interested in palaeoclimatology, archaeology, human history, or the other rich areas of the palaeosciences that should divert our attention. As the charlatan says, I leave for future work considering to what extent my arguments extend beyond palaeontology. While on that topic, allow me a quick methodological insert.

I am officially agnostic as to what extent my arguments rely on the particulars of the sciences I attend to, and to what extent I'm describing science generally. My approach to philosophy is to think through particular instances of scientific reasoning, and, as such, I don't think it is particularly useful for me to make general claims. Rather, I see myself as providing philosophical insight to the kinds of sciences I know well, insights that I hope might be of use to those who know other sciences.

My aim is to correctly characterize the *strategies* scientists use to uncover lost worlds. For me, scientific strategies are abstractly described approaches to tackling epistemic challenges. As such, although they partly depend on correctly describing and interpreting scientific work, they are fundamentally normative: The strategies are *good* strategies when they are appropriate to the context the scientist works within and their aims. As such, I'm not committed to the truth or plausibility of any particular first-order scientific claim about the past. In principle, all the science I interpret could turn out to be mistaken, and my arguments could still go through (although somewhat embarrassing—see Turner 2016 for discussion of these bad philosophical bets).

From chapter 6, I shift to a set of applications and upshots of the view developed in the first half of the book, mainly aiming to provide a picture

of the value and nature of historical knowledge and scientific imagination. These include the following. First, a defence of the modal nature of knowledge generated by the deep past, a kind of minimal modal realism grounded in a commitment to artifactualism (chapter 6). Second, a discussion of the nature and limits of scientific imagination with particular focus on palaeoart (chapter 7). Third, an argument for the “peculiarity” of biological and geological history and how this underwrites a disunified, “dappled” picture of the present (chapter 8). Fourth, an exploration of whether the strategies employed to understand lost pasts might be fruitfully applied to unprecedented futures (chapter 9). And finally, fifth, a conclusion that wraps up the book overall and turns to the relationship between history and wonder (chapter 10).

Overall, I hope you walk away with a new appreciation for the creativity of historical scientists, as well as a new respect for and understanding of the nature and value of the knowledge they produce, and of course, the worlds they reveal.

