revolutions it often happened that dry land, on which vegetation had existed for many years, sank again and was covered with new beds of stone. Hence the Coal beds. Finally came the Chalk beds;[13] they contain no more ammonites, but on the other hand they have other marine animals that are not found today, for example the sea urchin of which the spines are called jew-stones *[Judensteine]*. It should also be noted that the Chalk has only been deposited in certain places.

Thus far has Deluc got at present. He has promised to deal next with the sixth period, in which our continents were put into the state in which they still are today.[14] His opinion is subject to great difficulties, but these letters are very interesting on account of many very firmly handled points of physics and numerous geognostic facts *[geognostische Facta]*. Admittedly it is just this part that is not suitable to be reviewed here.

De Lamétherie himself wants to contribute to this too, and also proposes a new system; but I can tolerate de Lamétherie's method of reasoning as little as his style. A third system, by Father Pini of Turin, was published some months ago, but I know of it only from reviews.[15]

Extract translated from Cuvier to Pfaff, 11 March 1792, printed in Cuvier, Briefen an Pfaff *(1845), pp. 257–60.*

13. [Deluc, like Werner and many others, regarded the distinctive Chalk as the *uppermost* of all the regularly bedded Secondary formations mentioned in this passage, overlain only by loose superficial deposits such as the clay Cuvier had described in Normandy (text 1). This is why Cuvier's much later research around Paris, in which the Chalk featured as the *lowest* of many distinct formations, was in its time so strikingly novel (see chapter 12).]

14. [It is unfortunate that Cuvier did not write this letter a few months later, for we do not have his immediate reaction to Deluc's "sixth period," the part of the "system" that was most important for Cuvier's own later geological views. In the twelve letters published after Cuvier wrote this summary, Deluc duly set out his arguments for claiming that the continents—in their present form as landmasses—were not of great age, because they had emerged from the ocean floor only a few thousand years ago. (Deluc also dealt with matters as diverse as the rings of Saturn, chemical affinities, and gravity itself!)]

15. [De Lamétherie published his own "system" later, as *Théorie de la terre* (1795; 2nd ed. 1797). Ermenegildo Pini (1739–1825) was professor of natural history at the University of Milan and a member of the Barnabite teaching order; his *Rivoluzione del globe terrestre* (Revolutions of the terrestrial globe, 1790–92) had in fact been criticized by Deluc in an earlier letter published by de Lamétherie.]

Martin Rudwick,
Georges Cuvier, Fossil Bones, and
Geological Catastrophes (Univ. of
Chicago Press, 1997)

2

LIVING AND FOSSIL ELEPHANTS

In 1795, three years after Cuvier told his friends in Germany about Deluc's latest theory, the political situation in Paris became more stable, or at least more favorable for scientific work. During the Terror, the most radical and violent phase of the Revolution, many of the old institutions of science had been abolished, or at least disrupted. Many of the most influential savants had fled from the capital.[1] Some, most notably the great chemist (and tax collector) Lavoisier, had even lost their lives at the guillotine. Now yet another coup d'état had given France a politically more moderate government, the so-called Directory, which quickly showed itself more favorable to the sciences than any since the start of the Revolution.

Cuvier therefore made a bold and risky decision to move to Paris in search of a scientific career. In this he was encouraged by meeting a scientific refugee from the capital, who wrote to colleagues there on his behalf. Cuvier had already sent some articles (on invertebrate zoology) to be published in Paris, but he was still scarcely known, and had no certainty of gaining any position. In the event, however, he could hardly

1. The contemporary term "savants" (which was used in English as well as in French) will be used throughout this volume, in place of the misleadingly anachronistic term "scientists." Savants could be learned, expert, or "savant" in any of a wide range of subjects, not just those covered by the modern anglophone meaning of "science"; and they might or might not be "professionals" in the sense of earning their living from such studies.

FIGURE 3 A portrait of Georges Cuvier at the age of twenty-six—possibly a self-portrait—drawn in 1795, around the time he moved to Paris; it may have been made to further his career prospects.

have arrived at a more propitious time. As a result of the Terror, the old networks of patronage that had been essential for making a career in science had been thrown into disarray, and had yet to be reconstituted: a young man of talent had more opportunities than ever before (fig. 3).

Given Cuvier's interests, it is not surprising that he focused his attention on the Muséum National d'Histoire Naturelle (National Museum of Natural History). Almost alone among the major scientific institutions in Paris, this had escaped abolition, because at the height of the

Revolution it had reformed itself in a politically correct manner. Although new in name, it was in fact the direct successor of the old royal botanical garden (Jardin du Roi) and the associated royal museum (Cabinet du Roi). Here at the new Muséum,[2] Cuvier managed—not without opposition—to obtain a junior position as understudy *(suppléant)* to Mertrud, the elderly and undistinguished professor of animal anatomy. The Muséum was to be Cuvier's professional home, and, before long, his domestic home too, for the rest of his life.

Even a modest position at the Muséum placed Cuvier at the world center for the natural history sciences, and its incomparable collections became at once his most important resource. Before the end of the year, his lecture course on comparative anatomy at the Muséum (standing in for his nominal superior) showed Parisian savants that he was a newcomer to be reckoned with. He put his science firmly on the map, by explaining his conception of organisms—though it was not original to him—as functionally integrated "animal machines."

A few weeks earlier, in one of its major acts of cultural politics, the Directory had approved the foundation of a new Institut National. This was intended to repair the revolutionary damage to French science and scholarship, by bringing together in one prestigious body all the branches of knowledge formerly cultivated in the various learned "academies" that had been suppressed. Among these was the old Académie Royale des Sciences (Royal Academy of Sciences), which was in effect revived as the Institut's "class for mathematical and physical sciences." Significantly, it was termed the *First* Class of the Institut (in modern terms the three classes covered, roughly and respectively, mathematics and the natural sciences, the social sciences, and the humanities).

Only a week after Cuvier's inaugural lecture, and doubtless partly as a result of that event, he was elected the youngest member of the First Class. Just as the Muséum became the site of his actual research, so the Institut became the main arena for the exposition of his scientific results, as several of the texts in this volume show. Cuvier's rise to prominence in Parisian science in the years that followed continued to be meteoric, but it was not effortless. Like any scientific career in this period, it required the painstaking construction of networks of patrons and allies, and discreet campaigns against rivals on all sides.

Once installed in the Muséum, however precariously at first, Cuvier picked up the research on comparative anatomy that he had started in

2. The accent and initial capital will serve hereafter to indicate reference to this specific museum—at the time, the greatest natural history museum in the world.

Normandy. He began to produce important papers on the anatomy of the then poorly understood marine invertebrates, particularly the mollusks. But the resources of the Muséum quickly turned his attention to the vertebrates too, and above all to the mammals. More specifically, he soon saw that some recent acquisitions to the Muséum's collections might make it possible to settle a long-standing problem with far-reaching implications.

It had long been known that large fossil bones and teeth were found widely scattered in northern latitudes, in both the Old World and the New, in "superficial" deposits close to the surface of the ground. They were far from the tropical habitats of all the known large mammals such as elephants and rhinoceros. The identification of these fossil bones, and the explanation of their anomalous geographical position, had long been matters of lively international debate among naturalists.[3] Louis Jean Marie Daubenton (1716–99), now the professor of mineralogy at the Muséum and one of Cuvier's senior colleagues, had been a major contributor to this debate before the Revolution; and George Louis Leclerc, count de Buffon (1707–88), for almost half a century the director *(intendant)* of the Muséum's forerunner, had made the fossil bones a key component in his overarching "theory of the earth." So Cuvier was entering a well-trodden field.

He had one major empirical advantage over his predecessors. Among the incidental spoils of the revolutionary wars were the outstanding collections of the former ruler of the conquered Netherlands. What had recently reached Paris included not only paintings and other items of great artistic importance, but also a major natural history collection. It included specimens that, added to those already at the Muséum, proved to Cuvier's satisfaction that the living African elephant was not the same species as the Indian, as had been commonly supposed; and that the *fossil* elephant or "mammoth" was anatomically distinct from either. Cuvier was not the first naturalist to suspect this; but he alone had both the means and the skill to demonstrate it persuasively.

Just a year after his arrival in Paris, he presented his first paper to the Institut, setting out this argument. A summary of the paper (text 3) was published soon afterward in the *Magasin encyclopédique* (Encyclopedic magazine), a newly founded journal for all the sciences, which took its inspiration from the great French *Encyclopédie,* the supreme emblem of the eighteenth-century Enlightenment. The full version was published three

3. "Naturalists" was the contemporary term for those who studied the sciences of "natural history" such as zoology, botany, and mineralogy; neither term had its modern pejorative overtones of amateurism. "Naturalists" were, in effect, a subset of the larger category of "savants."

years later in the Institut's new *Mémoires,* with several plates of engraved illustrations based on his own drawings of the crucial evidence (see fig. 4).[4]

Cuvier's first major paper displayed remarkable self-assurance—some might term it arrogance—for a twenty-six-year-old with little scientific achievement to his name. Emphasizing the importance of a critical evaluation of factual claims, he confidently rejected the opinions of his distinguished predecessors, on the grounds that their observations had been insufficiently precise. He presented his conclusions about the three distinct species of elephants as a triumph for his own scrupulously exact methods of osteological comparison. Almost in passing, he dismissed any suggestion that the differences might be due to the transformation (in modern terms, evolution) of one species into others—a notion that in general terms was being actively canvassed in Paris at this time—and maintained that to abandon the concept of the stability of natural species would be to subvert the whole taxonomic enterprise. But he was careful to argue that his anatomical approach could only enrich and deepen the traditional zoological emphasis on the externally visible characters of animals. This related his work tactfully to that of an even more youthful colleague, the professor of zoology Étienne Geoffroy Saint-Hilaire (1772–1844), who had helped him gain his position at the Muséum.

Cuvier also presented his work as a demonstration of the way comparative anatomy could be an ancillary but essential tool for establishing the "theory of the earth," or "geology," on less speculative foundations. He argued that his research had undermined the impressive edifice of the celebrated theory of the earth that Buffon had expounded in his "Époques de la nature" (Epochs of nature, 1778). This had been centered on the idea—not original to Buffon—that the earth had had its origin as an incandescent body in space, and that it had cooled gradually to its present surface temperature. Buffon had assumed that the bones found in northern lands were those of elephants and other tropical species, and had therefore used them as evidence of a formerly warmer climate at high latitudes. But if, as Cuvier now argued, the mammoth was not the same species as either of the living elephants, it could well have been adapted to a quite different environment, namely to the cold climates in which its bones were now found; Buffon's argument for a cooling earth, or at least his use of the bones as evidence for it, would then collapse.

Cuvier's inference left new problems, however, above all that of accounting for the difference—as he claimed it to be—between *all* the

4. Cuvier had shown outstanding talent as a biological artist even in his youth; he continued throughout his life to make most of his own drawings, though they then had to pass through the hands of professional engravers before publication.

known fossil species and those now alive. In fact, when he first presented his paper, he made his claim even more sweeping than it appeared in print, because he extended this absolute contrast between fossil and living species to *marine* animals as well as such terrestrial species as the elephants. But after his lecture the "learned conchologists" he had cited must have rejected that claim, insisting that some marine mollusks did have exact "analogues" among fossil shells.[5] Even with an implicit restriction to terrestrial animals, however, his published claim was striking enough.

Cuvier claimed—though without detailed argument—that the evidence pointed to an earlier and *prehuman* "world" that had been "destroyed by some kind of catastrophe." This was a theme that, though not original to him, was to pervade his geological theorizing for the rest of his life. Although he did not explain why the event must have been sudden, he did imply that it was not unique, and that it might be repeated in the future. But he deftly drew back from further speculation of this kind, leaving such matters to a bolder—or perhaps more foolhardy—"genius." This was a neat way of deferring, though with more than a touch of irony, to his senior colleague Barthélemy Faujas de Saint-Fond (1741–1819), who had boldly adopted Deluc's neologism "geology" as the title of his professorship when the Muséum was reconstituted.

TEXT 3

Memoir on the Species of Elephants, Both Living and Fossil

Read at the public session of the National Institute on 15 Germinal, Year IV [4 April 1796][6] by G. Cuvier[7]

CONSIDERABLE DIFFERENCES have long been noted between the elephants of Asia and those of Africa, with regard to their size, their habits,

5. The relevant passage in the manuscript (MS 628, Bibliothèque Centrale, Muséum National d'Histoire Naturelle, Paris) was omitted from the first published text of the paper (translated below as text 3) and its subsequently enlarged versions: see Burkhardt, *Spirit of system* (1977), p. 129 and n. 56.

6. [The date, like several others in this volume, is given in the form of the Republican calendar. This was introduced at the height of the Revolution as part of the effort to eliminate all traces of the culturally Christian past. It had its nominal origin at the declaration of the French Republic in September 1792 (though it was not introduced until Year II, or 1793–94); it divided the year (beginning in September) into twelve new months based on the seasonal weather. The Republican calendar was dropped, and the ordinary (Gregorian) calendar resumed, at the start of 1806. (In this volume Republican years will be denoted by Roman numerals, as they often were at the time.)]

7. This article is an abstract of a detailed paper that will be printed in the Institute's collection,

and the places where they live; and Asiatic peoples have known since time immemorial how to tame the elephants they use for hunting, whereas African elephants have never been subdued, and are hunted only to eat their flesh, to collect their ivory, or to eliminate the danger of their presence. Nonetheless the authors who have dealt with the natural history of elephants have always regarded them as forming one and the same species.

The first suspicions that there are more than one species came from a comparison of several molar teeth that were known to belong to elephants, and which showed considerable differences; some having their crown sculpted in a lozenge form, the others in the form of festooned ribbons.

The arrival in Paris of the natural history collection acquired for the Republic by the Treaty of The Hague has enabled us to turn these suspicions into certainty.[8] It contains two elephant skulls: one, which has the teeth with festooned ribbons, comes from Ceylon; the other, which has only diamond forms, is from the Cape of Good Hope. A glance at these skulls is sufficient to observe, in their profile and all their proportions, differences that do not allow them to be regarded as the same species (fig. 4). It is clear that the elephant from Ceylon differs more from that of Africa than the horse from the ass or the goat from the sheep.[9] Thus we should no longer be astonished if they do not have the same nature or the same habits.

It is to anatomy alone that zoology owes this interesting discovery, which a consideration of the exterior of these animals would only have been able

accompanied by the necessary descriptions and illustrations [Cuvier, "Espèces d'éléphans" (Species of elephants, 1799)].

8. [The treaty established the terms of peace between the victorious French and the Dutch they had defeated. As part of the officially sanctioned cultural looting of the Netherlands, the fine natural history collection of the Stathouder, the Dutch ruler who had fled to England, was removed to the Muséum in Paris.]

9. [The full text of the paper has at this point one of Cuvier's most trenchant statements of his rooted opposition to evolutionary interpretations of organic diversity: "I believe that, after reading this comparative description, which I have made with all possible care and precision, and for which the original specimens exist in the comparative anatomy collection at the Muséum, no naturalist can doubt that there are two quite distinct species of [living] elephants. Whatever may be the influence of climate to make animals vary, it surely does not extend this far. To say that it can change all the proportions of the bony framework *[charpente osseuse]*, and the intimate texture of the teeth, would be to claim that all quadrupeds could have been derived from a single species; that the differences they show are only successive degenerations: in a word, it would be to reduce the whole of natural history to nothing, for its object would consist only of variable forms and fleeting types *[types fugaces]*" (1799, p. 12). The word "dégénérations" was widely used to denote changes *within* a species, forming some new variety; but also, by at least some authors, for changes transforming one species into another.]

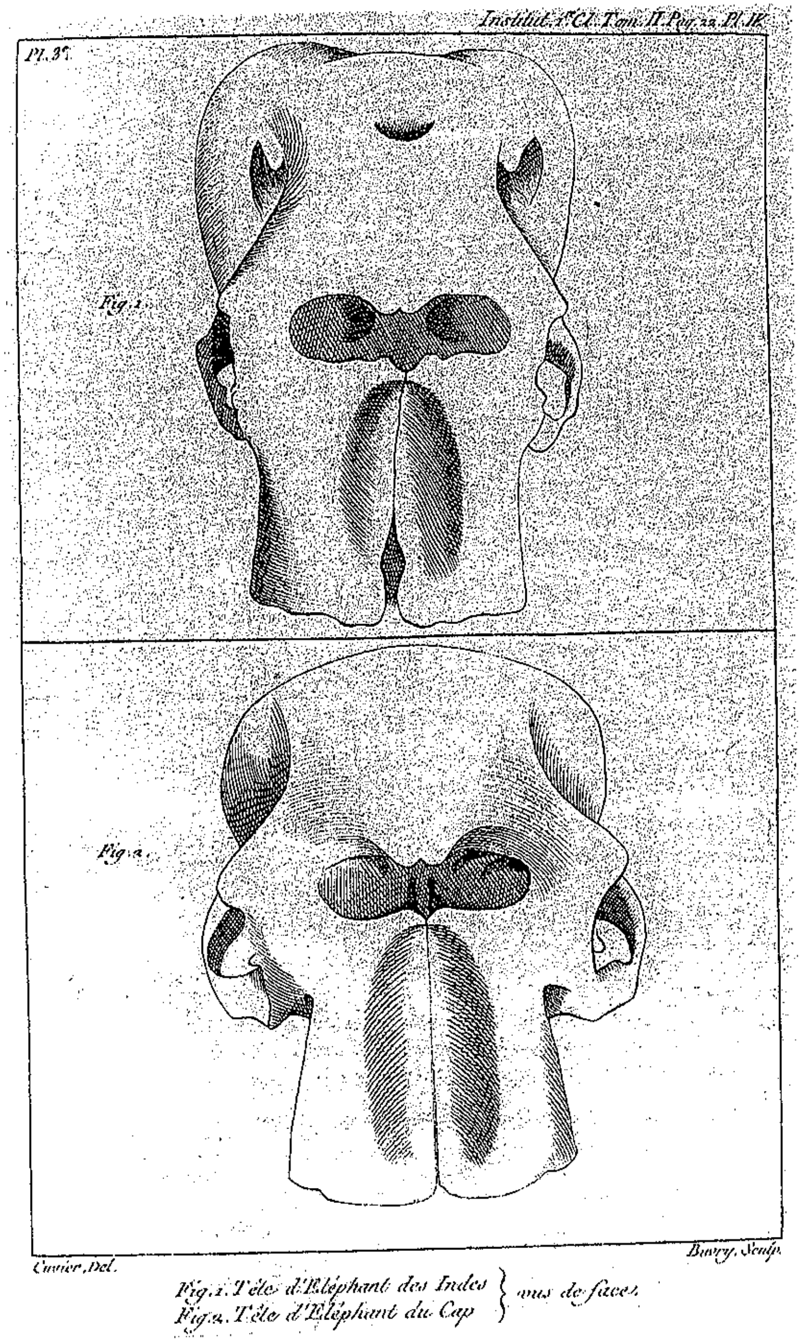

FIGURE 4 The skulls of elephants *(top)* from Ceylon (now Sri Lanka), south of the Indian mainland, and *(bottom)* from the Cape of Good Hope (now in South Africa), engraved from Cuvier's drawings and published in 1799 with the full text of his paper.

to render imperfectly.[10] But there is [also] a science that does not appear at first sight to have such close affinities with anatomy; one that is concerned with the structure of the earth, that collects the monuments of the physical history of the globe, and tries with a bold hand to sketch a picture of the revolutions it has undergone:[11] in a word, it is only with the help of anatomy that *geology*[12] can establish in a sure manner several of the facts that serve as its foundations.

Everyone knows that bones of enormous animals are found underground in Siberia, Germany, France, Canada,[13] and even Peru, and that they cannot have belonged to any of the species that live today in those climates. The bones that are found, for example, throughout the north of Europe, Asia, and America resemble those of elephants so closely in form, and in the texture of the ivory of which their tusks are made, that all savants hitherto have taken them to be the same. Other bones have appeared to be those of rhinoceros, and they are indeed very similar: yet today there are elephants and rhinoceros only in the tropical zone of the Old World. How is it that their carcasses are found in such great numbers in the north of both continents?

On this point, one is left with [mere] conjectures. Some [writers] have invoked great inundations that have transported them there; others suppose that southern peoples led them there in some great military expeditions.[14] The inhabitants of Siberia believe quite simply that these bones come from

10. [Cuvier and other naturalists of his generation were critical of the zoology practiced by their predecessors (e.g. Buffon) for having focused attention on the externally visible characters of animals rather than the internal anatomy revealed by dissection. Cuvier himself was highly skilled in practical dissection; in this respect his studies of molluscan anatomy are even more striking than his work on vertebrates, since they involved much finer manual dexterity.]

11. [In Cuvier's writing and that of his contemporaries, the word "revolution" simply meant major changes in the course of time: it was used for example in the writing of human history to denote the slow rise and fall of civilizations; and in astronomy to denote the regular orbiting of the planets round the sun. It had no *necessary* connotations of suddenness, still less of violence. In effect, what Cuvier termed "catastrophes" (see below) were a special subset of "revolutions."]

12. [The emphasis is not indicated typographically in the original, but is implied by the construction of the sentence. It is important to remember that at this time the term was still a neologism that had been adopted by very few writers other than its author Deluc and Cuvier's colleague Faujas.]

13. ["Canada" included much of what eventually became the United States: in particular, the uncolonized country around the Ohio River, which yielded some of the most problematic fossil bones.]

14. [A huge mass of water sweeping suddenly across the continents (like the tsunamis associated with some submarine earthquakes, but far larger) was a widely favored explanation for the bones found in Siberia. The classical accounts of Hannibal's campaign from North Africa, complete with some military elephants, had been the basis for an earlier explanation of the fossil bones found in Europe, but its plausibility had collapsed as more and more bones were found.]

a subterranean animal like our moles, which never lets itself be taken alive; they name it "mammoth," and mammoth tusks, which are similar to ivory, are for them a quite important item of commerce.

None of this could satisfy an enlightened mind *[un esprit éclairé]*. Buffon's hypothesis[15] was more plausible, if we assume that it was not contentious for reasons of another kind. According to him, the earth had emerged burning from the mass of the sun, and had started to cool from the poles; it was there that living nature had begun. The species that formed first, which had more need of warmth, had been chased successively toward the equator by the increasing cold; and since they had traversed all the latitudes, it was not surprising that their remains were found everywhere.

A scrupulous examination of these bones, made by anatomy, will relieve us of having recourse to any of these explanations, by teaching us that they are not similar enough to those of the elephant to be regarded as absolutely from the same species. The teeth and jaws of the mammoth do not exactly resemble those of the elephant [fig. 5]; while as for the same parts of the Ohio animal, a glance is sufficient to see that they differ still further.[16]

These [fossil] animals thus differ from the elephant as much as, or more than, the dog differs from the jackal and the hyena. Since the dog tolerates the cold of the north, while the other two only live in the south, it could be the same with these animals, of which only the fossil remains are known.

However, while relieving us of the necessity of admitting a gradual cooling of the earth, and while dispelling the gloomy ideas that presented the imagination with northern ice and frost encroaching on countries that today are so pleasant, into what new difficulties do these discoveries not now throw us?

What has become of these two enormous animals of which one no longer finds any [living] traces, and so many others of which the remains are found everywhere on earth and of which perhaps none still exist? The fossil rhinoceros of Siberia are very different from all known rhinoceros. It is the same with the alleged fossil bears of Ansbach;[17] the fossil crocodile of

15. [Buffon, "Époques de la nature" (1778). As a leading philosopher of the Enlightenment, Buffon was an "enlightened mind" par excellence.]

16. ["Ohio animal" referred to bones first found in 1739 on the banks of the Ohio River (in what is now Kentucky): their identity was much disputed during the rest of the eighteenth century, and was not resolved until Cuvier later defined and named the animal *Mastodon*.]

17. [The bones found in caves in a part of Bavaria that at this time was in the territory of Ansbach, most famously in caves around Muggendorf, between Erlangen and Bayreuth.]

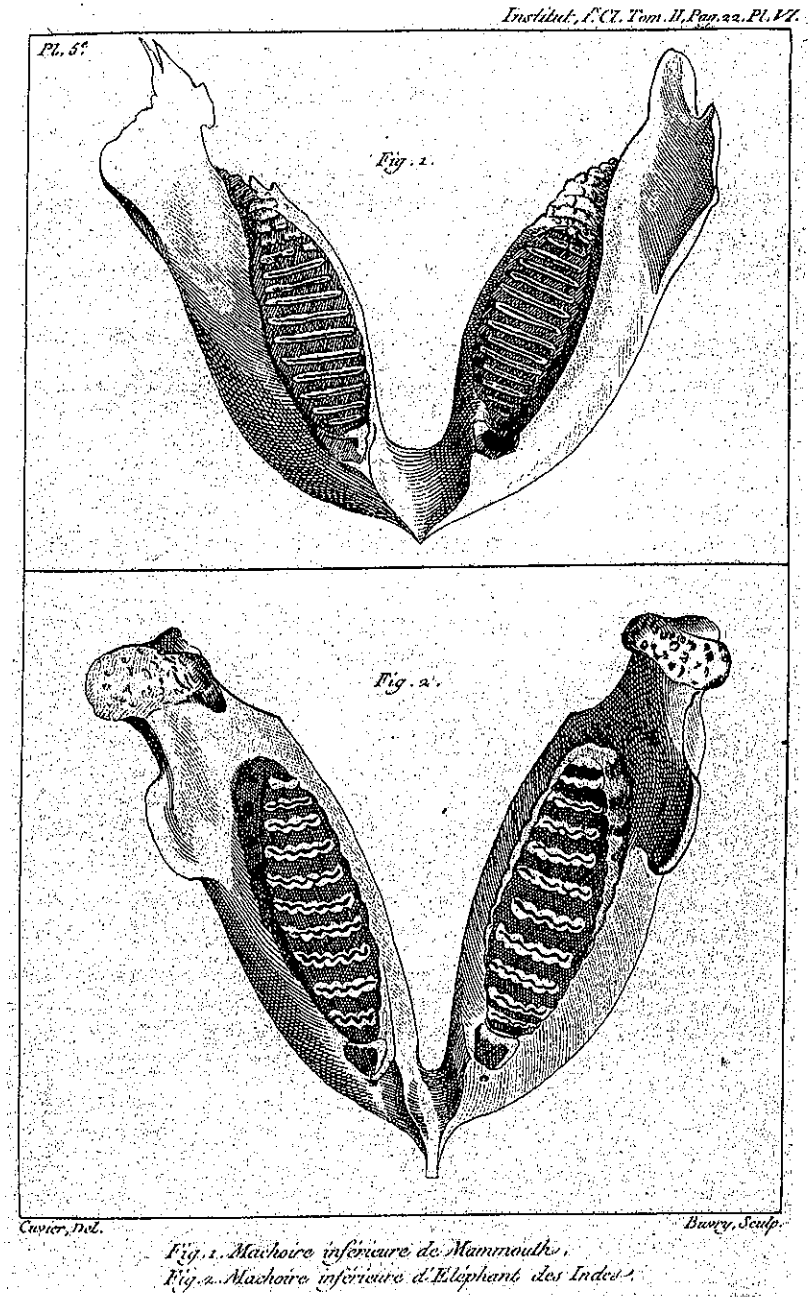

FIGURE 5 The lower jaw of the mammoth *(top)* compared with that of the Indian elephant *(bottom)*, engraved from Cuvier's drawings and published in 1799 with the full text of his paper.

Maastricht; the species of deer from the same locality;[18] the twelve-foot-long animal, with no incisor teeth and with clawed digits, of which the skeleton has just been found in Paraguay [see fig. 6]: none has any living analogue.[19] Why, lastly, does one find no petrified human bone?

All these facts, consistent among themselves, and not opposed by any report, seem to me to prove the existence of a world previous to ours, destroyed by some kind of catastrophe.[20] But what was this primitive earth? What was this nature that was not subject to man's dominion? And what revolution was able to wipe it out, to the point of leaving no trace of it except some half-decomposed bones?

It is not for us [i.e. Cuvier himself] to involve ourselves in the vast field of conjectures that these questions open up. Only more daring philosophers undertake that. Modest anatomy, restricted to detailed study and to the scrupulous comparison of the objects submitted to its eyes and its scalpel, will be content with the honor of having opened up this new highway to the genius who will dare to follow it.

Translated from Cuvier, "Espèces des éléphans" (Species of elephants, 1796).

18. [The "crocodile" was a spectacularly large fossil found in underground quarries near the southern Dutch town. The finest known specimen had recently been brought to Paris, like the elephant skulls, as a trophy of war. It was described and illustrated in a lavishly produced monograph by Faujas, *Montagne de Saint-Pierre de Maestricht* (Saint Peter's Mount at Maastricht, 1799), which he must have been preparing at this time. It was later interpreted as a huge marine lizard, and Cuvier named it *Mosasaurus* (lizard of the Maas or Meuse) (see chapter 13). "Deer" referred to supposed fossil antlers from the same Chalk formation at Maastricht, which Cuvier—once he had seen the specimens—identified as parts of the carapace of a marine turtle.]

19. ["Analogue" was the term used in the contemporary debate about the reality or otherwise of extinction, to denote a living species that was *identical* to one found fossil. For the Paraguay animal, see text 4.]

20. [The full text of the paper has a significant addition at this point: "beings whose place has been filled by those that exist today, which will perhaps one day find themselves likewise destroyed and replaced by others" (1799, p. 21). For Cuvier the present "world" had no finality, and the "catastrophe" that had made the mammoth extinct was certainly not a unique event, and perhaps not even the last of its kind.]

3

THE MEGATHERIUM FROM SOUTH AMERICA

Most of the fossils that Cuvier mentioned in his paper on living and fossil elephants had already been described and discussed by others; but one of them, as he noted, was a recent discovery. Cuvier made this the subject of a separate paper, which he read at the Institut National not long after his first. It greatly increased his personal stake in the field of *fossil* anatomy.

Fossil bones are usually found scattered and disarticulated. However, one almost complete assemblage of bones, clearly derived from a single individual of some large animal, had been found in 1789 near Buenos Aires in what was then Spanish South America. Shipped back to Madrid, these bones were assembled at the Gabinete Real (Royal Museum) by Juan-Bautista Bru (1740–99), a conservator there. The most important separate bones and Bru's mounted reconstruction of the whole skeleton were drawn and engraved for him in preparation for a paper he planned to write about it. In 1796 a French official who was visiting Madrid saw the skeleton and obtained a set of Bru's unpublished plates. These were sent to the Institut in Paris, and Cuvier was asked to report on them. In his paper, Cuvier claimed that the unknown animal was an edentate, and named it *Megatherium*, or "huge beast" (text 4).[1]

Cuvier went no farther in a geological direction than to conclude that the megatherium, like other fossil species, must surely be extinct. The paper is included in this volume because it shows the methods of careful anatomical comparison that underlay all Cuvier's geological inferences. Specifically, it illustrates his theoretical concept of the "subordination of characters," according to which the different functions of the animal body formed a kind of natural hierarchy, such that some anatomical features were more reliable than others, for assessing the natural affinities between any one animal and other related forms. The application of this principle, in this case, underlay Cuvier's confident conclusion about the place of the fossil mammal from South America, in relation to living mammals.

However, Cuvier needed practical skills and empirical evidence as well as biological theory. Only a handful of naturalists anywhere had the skill and experience to understand the anatomy of the unfamiliar and exotic edentates, sufficiently for the case in hand; and only at the Muséum in Paris, probably uniquely at the time, could *any* naturalist have found the range of rare specimens necessary to establish by osteological comparison that the huge megatherium was related to the lowly sloths and anteaters. It was a striking conclusion.

The megatherium itself remained in Madrid, but Cuvier's paper—published in the *Magasin encyclopédique* shortly before the one on elephants—made the fossil widely known, particularly since it was accompanied by a crude copy of Bru's engraving of the skeleton (see fig. 6).[2] As an elephant-sized animal quite unlike any living species, it was a sensational addition to the growing collection of large vertebrates that—Cuvier claimed—could not plausibly be supposed to be still alive anywhere on earth.

1. The episode has been the subject of much chauvinistic argument. Rather than feeling that Cuvier had upstaged him, Bru may have valued the French naturalist's authoritative report on the zoological affinities of the animal. Conversely, Cuvier knew almost nothing about its geological context, as the text of his paper shows. Bru's plates were published in Spain later the same year, with his detailed description of the find, and a translation of Cuvier's paper; conversely, when Cuvier came to publish a full version of his own paper, he included a translation of Bru's work.

2. This engraving was copied in turn for the English *Monthly magazine*, and published later the same year with a summary of the paper; among the anglophone naturalists who thus became aware of the megatherium was Thomas Jefferson (1743–1824), not only a prominent politician in the young United States but also a keen naturalist who had already studied similar bones from Virginia. The Spanish translation of Cuvier's paper has been noted already.

TEXT 4

Note on the skeleton of a very large species of quadruped, hitherto unknown, found in Paraguay and deposited in the Cabinet of Natural History in Madrid. Edited by G. Cuvier.

THIS SKELETON is fossil: it was [found] a hundred feet below the surface of a sandy formation *[terrain]* near the river La Plata.[3] It lacks only the tail and some paired bones that have been imitated in wood. It is mounted in Madrid, where Citizen Roume, correspondent of the National Institute, has examined it carefully. The complete figure and all the details have been engraved on five plates in folio format, which are probably intended to illustrate some dissertation of which this skeleton will be the object. The National Institute having received proofs of these plates from Citizen Grégoire, they have served as the basis for the present note, together with a short description sent by Citizen Roume.[4]

This skeleton, shown in [fig. 6], is twelve feet long and six in height. The backbone is composed of seven cervical vertebrae, sixteen dorsal, and four lumbar; there are therefore sixteen ribs. The sacrum is short, the iliac bones very broad; and their plane being almost perpendicular to the spine, they form a wide-open pelvis. There is no pubis or ischium at all, or at least they are lacking in this skeleton, and one can see no mark where they would have been during the life of the animal.

The thigh bones are extremely thick, and those of the legs still more so in proportion. The entire sole of the foot was on the ground when walking. The shoulder blade is much broader than long; there are perfect clavicles, and the two bones of the forearm are separate and movable one on the other. The forelimbs are longer than the rear. Judging by the form of the last phalanges, there must have been very large pointed claws, covered at their base in a bony sheath; it appears that there were only three of these claws on the

3. [It was found at Luján, west of Buenos Aires (in modern Argentina). The "Paraguay" of the title was a mistake, which indicates how little Cuvier knew about the circumstances of the find. The name stuck, and the fossil continued for several years to be called "the Paraguay animal."]

4. ["Citizen" was the egalitarian title that had been imposed at the height of the Revolution, to replace all the subtly nuanced forms of address used under the Old Regime. Cuvier's claim that he knew nothing about the provenance or intended use of the plates was perhaps genuine; on the other hand it may have been a covert way of establishing his own priority in the interpretation of the bones. Henri Baptiste Grégoire (1750–1831) was a priest who had been prominent in Republican politics, and later in setting up the Institut National and other scientific bodies. Philippe-Rose Roume had been on a governmental mission to the French colony of Saint-Domingue (now Haiti).]

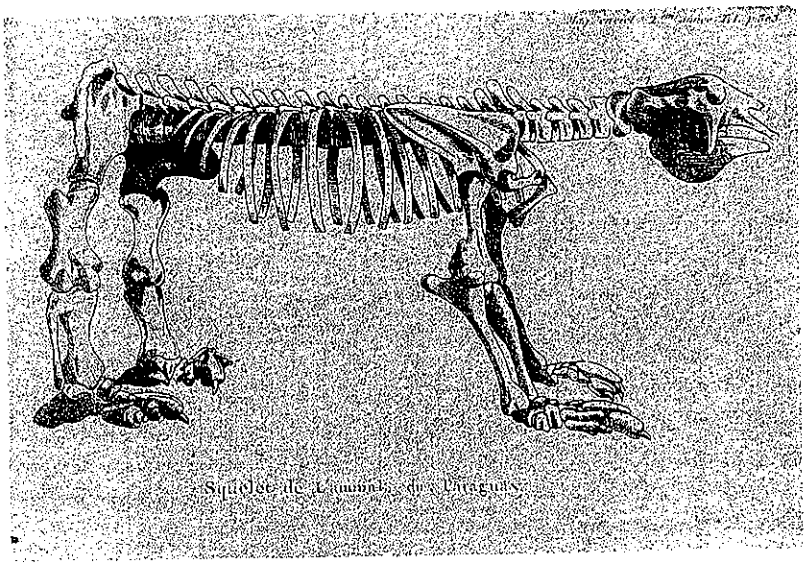

FIGURE 6 Bru's reconstruction of the skeleton from South America, as redrawn to illustrate Cuvier's paper on what he named the megatherium.

forefeet and a single one on the rear feet, and that the other digits lacked them and perhaps that they were entirely hidden under the skin.

The head is the most singular part of this skeleton. Its occiput is elongated and flattened, but it is fairly convex above the eyes. The two jaws form a considerable toothless projection, and have at the back of the mouth only four teeth on each side, both above and below, all of them molars, with a flat crown and channeled transversely. Above all one should notice the breadth of the sides of the lower jaw, and the large apophysis placed at the base of the zygomatic arch.

This animal differs, in the ensemble of its characters, from all known animals; and each of its bones, considered separately, also differs from the equivalent bones of all known animals. This is what results from a detailed comparison of this skeleton with those of other animals, and will easily be seen by all who are familiar with this kind of research; for none of the animals that approach this one in size have either pointed claws, or a form of head, of shoulder blades, of clavicles, of pelvis, or of limbs like those of this animal.

As for the place of this quadruped in the [natural] system, it is marked perfectly by a simple inspection of the ordinary *indicative characters*;[5] that

5. [That is, the features that most clearly reveal the natural affinities of an organism, locating it in a "natural" taxonomic classification, rather than in an "artificial" one designed purely for ease of identification.]

is to say the claws and the teeth. They show that it ought to be placed in the family of unguiculates lacking incisor teeth; and in fact it has striking affinities with these animals in all parts of its body. This family comprises the sloths *(Bradypus)*, the armadillos *(Dasypus)*, the pangolins *(Manis)*, the anteaters *(Myrmecophaga)*,[6] and the aardvark *[orycterope]* or Cape anteater.

The sloths and anteaters have claws exactly like those of our animal, borne in the same way on an axis, and encased at their base by a bony sheath; they have, like it, several digits that are obliterated and lack claws; such that it is among their species that one finds the least common arrangements, such as two digits in front and three behind, or two and four, or three and three, etc. Our animal also has a number of claws that is singular and indeed hitherto unique, namely three in front and a single one behind.

The greater length of the forelimbs is a character singularly specific to the sloth genus, but is much stronger among them than it is here, and it is the principal cause of their slow gait. In this respect, our animal is thus distanced a little from the sloth genus and approaches those that have greater equality between their extremities. The extraordinary thickness of the rear limbs is also found, to some extent, in the pangolin, which has the thigh and leg bones thicker in proportion to their length than any other animal, except this one.

The family of animals of which we speak presses on the heel when walking, as does this Paraguay animal. Most of its species have similar clavicles. If in fact the pelvis has no pubis or ischium at all, it is likewise in this family alone that we would find a faint trace of this anomaly. It is true that the two-toed sloth has these two bones, but they are not fused in front, and always remain separate. This same two-toed sloth has an arm bone wholly like this one, above all in the breadth of the lower part. Finally, it also resembles it in the thickness of the bone from the elbow toward the wrist, a fairly rare character among the quadrupeds.

As for the head, although it is very different from all known forms, it is nonetheless again in the family of edentates that one finds forms from which it is less distant than all the others; but, in order to grasp the relations better, it is well to give here a brief sketch of the forms of the head that this family show us.

The anteaters and pangolins have no teeth; their lower jaw, serving only to house the tongue, is slender and without any strength in its bones or in the muscles that close it; there is no coronoid apophysis at all, and the

6. [These four Latin names were printed as footnotes, and identified as being those of Carl von Linné (1707–88) the Swedish naturalist and leading taxonomist (better known as Linnaeus, from his publications in Latin).]

zygomatic arch is imperfect; the head itself is conical or even elongated into a cylinder. This form is also that of the aardvark or Cape anteater, but the latter is provided with molar teeth, and it feeds on roots; the jaw is broad behind, and provided with a coronoid apophysis for the insertion of the temporal muscle.

The armadillos have nearly the same kind of life as the aardvark and the same form of jaws, with very similar teeth; their head is only a little shorter and more pointed. In both genera the zygomatic arch is complete, curved downward, without separate apophysis. There are isolated molars with simple pointed crowns, seven or eight in number.

The sloths, living in trees and feeding on leaves that need to be crushed, have jaws that are shorter and consequently stronger. The lower jaw is very thick; its coronoid apophysis projects strongly; the part without teeth forms a remarkable protuberance, above all in the unau or two-toed sloth—one also sees this in the lower jaw of the elephant. The intermaxillary bone is very small, which means that the maxillary also partly surrounds the opening of the nostrils—one scarcely sees this except in the rhinoceros, as a result of the same small size of the intermaxillary bone. Finally, in the sloths the zygomatic arch has at its base a fairly long descending apophysis, to which no quadruped shows any similarity (if one excepts the kangaroo or great jerboa of New Holland [Australia], the *Didelphis gigantea* of Gmelin).[7]

If one now compares the head of our animal (see [fig. 7, bottom]) with that of the sloths, one will find there all the characters minutely conserved, despite the total difference that results from that of the proportion of the parts. This apophysis of the notch of the zygomatic arch, this projection of the anterior part of the lower jaw, the small size of the incisor bone [premaxilla], and its distance from the nasal bones, are clear-cut characters that leave no doubt.

The great thickness of the sides of the lower jaw, which even surpasses that of the elephant, seems to indicate that the large animal we are examining doubtless did not content itself with leaves, but—like the elephant and the rhinoceros—broke and crushed the branches themselves. The flat-crowned serrated teeth would have been highly appropriate for this use. The sloths have teeth that are more or less similar, but more separated. Moreover, they have two more teeth in the upper jaw; but a still more important difference is that their anterior teeth are longer, and pointed in the form of fangs or canine teeth, which does not seem to have been the

7. See [fig. 7, top], the head of the unau or two-toed sloth; and [center,] that of the ai or three-toed sloth.

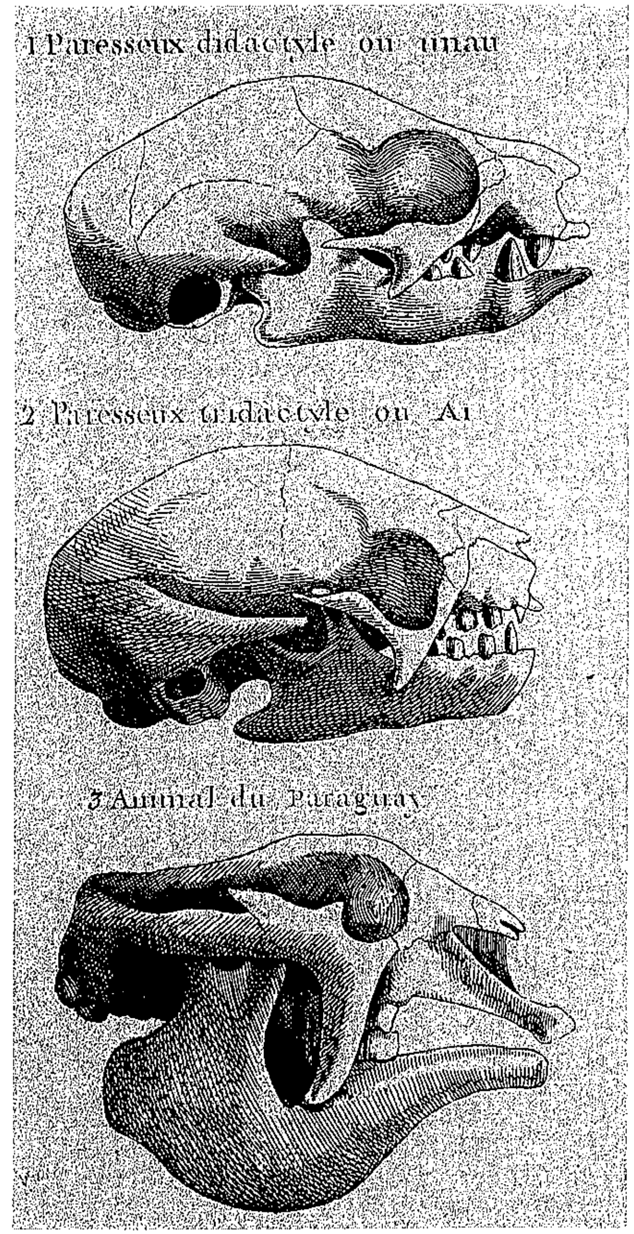

FIGURE 7 The skulls of the two-toed sloth *(top)* and three-toed sloth *(center)*, compared to that of the far larger fossil megatherium *(bottom)*; engravings illustrating Cuvier's paper. Note that all three skulls are drawn at the same size on paper, to facilitate comparison of their shapes and proportions.

case in the Paraguay animal. The position of the nasal bones in the latter have an affinity with that of the elephant and the tapir, which makes me suspect that it had a trunk; but it would have been very short, since the length of the neck and head together equals that of the forelimbs.

Be that as it may, we find in the absence of canine teeth, and in the shortness of the muzzle, characters sufficient to constitute a new genus in the family of edentates. It should be placed between the sloths and the armadillos, since it combines the shape of the head of the former with the dentition of the latter. It would be necessary to know particulars that this skeleton cannot give us, such as the nature of the integument, the form of the tongue, the position of the teats, etc., in order to determine more exactly which of these genera it approaches most closely. Meanwhile I believe I can give it the generic name of *Megatherium,* and the trivial name *Megatherium americanum.*

It adds to the numerous facts that tell us that the animals of the ancient world *[ancien monde]* all differ from those we see on earth today; for it is scarcely probable that, if this animal still existed, such a remarkable species could hitherto have escaped the researches of naturalists. At the same time it is a new and very powerful proof of the invariable laws of the subordination of characters, and of the justice of the consequences that have been deduced from them, for the classification of organisms *[corps organisés].* In those two respects it is one of the most precious discoveries that have been made for a long time in natural history.

Translated from Cuvier, "Squelette trouvé au Paraguay" (Skeleton found in Paraguay, 1796).

4

A RESEARCH PROGRAM ON FOSSIL BONES

In 1798, two years after his papers on elephants and the megatherium, Cuvier outlined what was now explicitly his own research agenda, in a paper to the Société d'Histoire Naturelle de Paris (Paris Natural History Society). A summary was published in the bulletin of the Société Philomathique, another informal scientific body in Paris, dominated by young savants such as Cuvier.

Cuvier explained that he planned to study the comparative anatomy of *all* fossil mammals, and he listed no fewer than twelve distinct species on which he had already started work. They included not only the mammoth and the megatherium, but also the puzzling "Ohio animal," fossil species of rhinoceros and hippopotamus, the huge-antlered deer or "elk" from the peat bogs of Ireland, an alleged bear from caves in Germany, a doglike carnivore from Paris itself, and several others less clearly defined. As in his paper on elephants (text 3), Cuvier concluded that it was not true that the species now living in the tropics had formerly lived at higher latitudes (as Buffon had argued); conversely, he claimed that these fossil species had had a wide geographical distribution but were truly extinct. What was new was Cuvier's final remark, clearly if covertly directed at self-styled "geologists" such as Faujas: "in view of this, it is up to geologists to make such changes or additions to their systems as they consider