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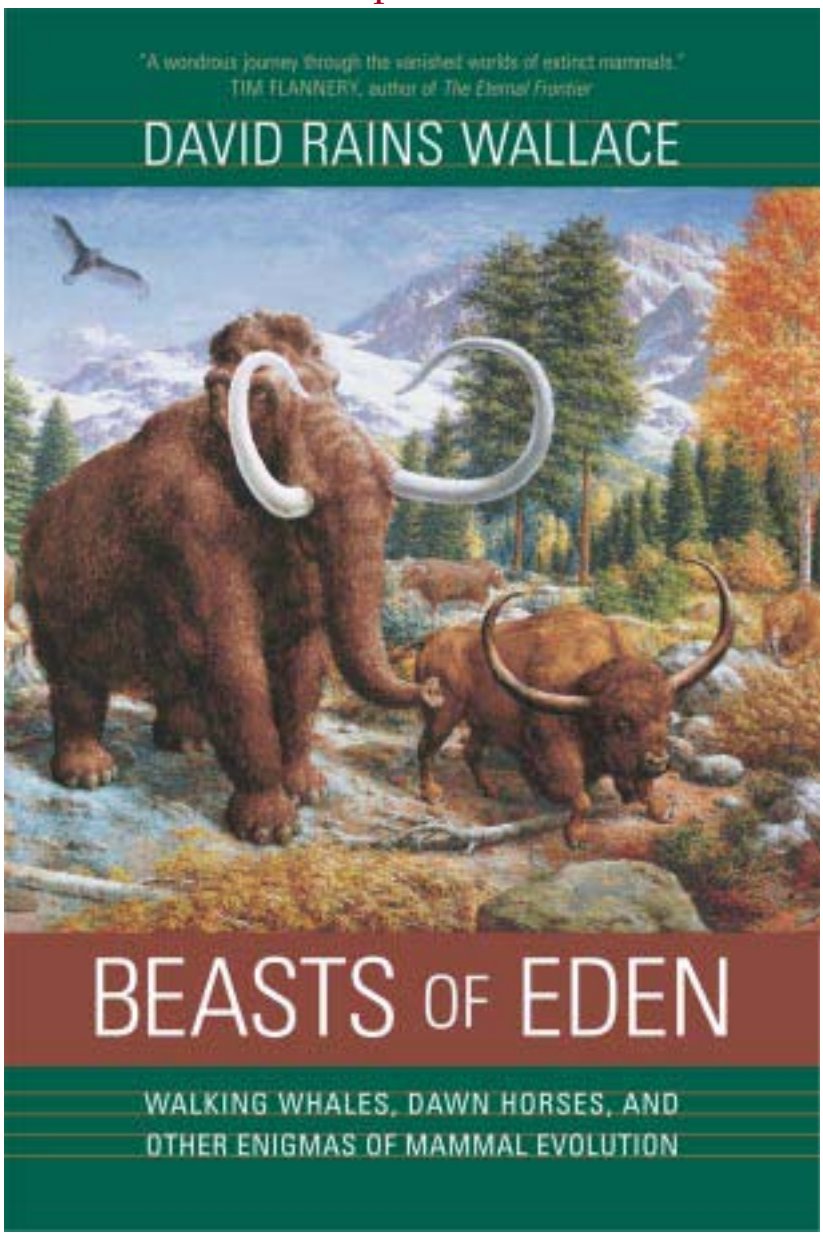

ONE

Pachyderms in the Catacombs

THE MOST STRIKING FIGURE IN the Peabody's *Age of Mammals* comes toward the end, among the Ice Age's brilliant foliage. It is a wooly mammoth, and it takes up most of the wall's height with its rufous bulk, curling tusks, and high-domed cranium. It is the only figure, except for a soaring bird of prey, that extends above the horizon. Unlike the mural's coryphodonts and uintatheres, it is not engaged in a confrontation but gazes forward serenely as though confident of its preeminence. Even the naked pink nostrils at the end of its trunk have a confident air. The entire 60-foot-long painting, with its grandly shifting scenery and dozens of figures, might have been laboring to produce this magnificent and intelligent beast.

Yet if the mammoth implies the culmination of certain valued mammalian qualities, there is another giant beast even nearer to the mural's end that does not. It stands on its hind legs, head slightly cocked, to look back toward the mammoth in a way that is hard to read. It might be challenging, fearful, or curious. Or it might not be looking at the mammoth at all, but simply gazing vacantly into the haze of time. It is hard to imagine what's in the creature's mind, because it is so strange. Unlike the elephantine mammoth, *Megatherium* resembles no familiar living creature. Indeed, there is something of Zallinger's slightly toylike dinosaurs about it. Standing propped on its massive tail, it is nearly as tall as the mammoth, but its small head and pigeon-toed feet make it seem clumsy rather than

Figure 3. *Megatherium* and *Glyptodon* (Pleistocene) from Zallinger's *Age of Mammals* mural. Courtesy Peabody Museum of Natural History, Yale University, New Haven, Conn.

majestic, despite its gigantic claws. Compared to the mammoth's, its eyes are tiny and dull.

The two figures facing each other like heraldic beasts, the one familiar and alert, the other bizarre and sluggish, lend a certain ambiguity to all the activity that precedes them, and this seems more than accidental. While Zallinger places them prominently at the end of mammal evolution's prehistoric story (both vanished less than ten thousand years ago), they figured with equal prominence at the beginning of its historical one, a beginning that also mingled confidence with obscurities. They embody a basic question about evolution—whether it is going "somewhere"—progressing toward "higher" traits like a mammoth's intelligence—or "nowhere"—producing smart and stupid creatures with aimless impartiality. Since the question involves human as well as mammoth intelligence, paleontologists have debated it vigorously since the science began.

The idea that mammals have progressed anywhere over time is a recent one, although the concept of mammals is ancient, reflected in the Greek word for a hairy animal, *therion,* as opposed to a scaly one, *herpeton.* Aristotle recognized a distinct group of air-breathing, live-bearing creatures. "Some animals are viviparous, some oviparous," he wrote. "The viviparous are such as man, and the horse, and those animals which have hair; and of the aquatic animals, the whale kind as the dolphin." He also noted that all viviparous quadrupeds then known had teeth, and described them according to their various dentitions. Aristotle's observations decayed into hearsay and fantasy in Roman writers and medieval bestiaries, but post-Renaissance taxonomists like John Ray reaffirmed them. When Linnaeus created the class Mammalia, based on the feeding of young with milk, in the 1759 edition of his *Systema Naturae,* he included the animals now recognized as such. Except for mythic creatures like griffons, however, the idea that beasts might have been very different in the past—that the earth's living fauna might have changed in major, indeed startling, ways—did not occur to naturalists even during the Enlightenment. They would have to dig into the obscurities beneath living fauna to encounter it.

That period's intellectual capital, still known as the city of light, actually overlies greater areas of darkness than most. One of my more vivid Parisian memories is of a walk through the catacombs below the boulevard Raspail, where grave diggers stacked the bones of six million people when cemeteries overflowed in the late eighteenth century. I don't know of a larger or tidier ossuary. Chamber after chamber was piled to the ceiling with carefully sorted femurs, crania, tibias, or pelvises, and I saw only a few of the man-

made caverns, which extend for over 200 miles. They weren't dug to house the bones, but because Paris happens to be located on one of the world's best deposits of calcium sulfate, also known as gypsum and, when powdered, as plaster of Paris. Malleable, durable, and snowy white, gypsum is a first-rate building material, and miners began quarrying it when the Romans founded the town of Lutetia on the site of Paris two millennia ago.

Authorities have used the gypsum mines to dispose of human remains at least since Romans threw the beheaded corpses of St. Denis and other missionaries into one on "martyr hill"—Montmartre. But more than human bones rest in the gypsum, a sedimentary rock that forms in shallow, coastal ponds where the climate is warm. Such places supported rich prehistoric faunas, as when the Paris gypsum originated some fifty million years ago, and shallow ponds preserve bones well. Fossils were common finds in the quarries as building boomed in the Enlightenment, and miners who had previously discarded bones found that they could sell them to the "savants" who thronged the capital. Displayed in "cabinets" along with crystals and other curiosities, the gypsum fossils included turtle and crocodile skeletons, but most were mammalian, as their owners would have perceived. Most other toothed animals have rows of identical spikes or pegs in their jaws; most mammals have a Swiss Army knife set of incisors, canines, premolars and molars. Since teeth are the most durable vertebrate fossils, collectors could recognize even fragmented beasts.

Enlightenment collectors perceived little else about the plaster-of-Paris bones, however. Georges-Louis Leclerc, comte de Buffon, director of the royal natural history collections, did not encourage such perceptions, ignoring the gypsum fossils in his voluminous writings, and declaring that "the bones, horns, claws, etc. of land animals are seldom found in a petrified state." Like other eighteenth-century naturalists, Buffon was interested mainly in constructing a general "theory of the earth" to match the seventeenth century's Cartesian and Newtonian cosmologies. Finding and classifying bones played no great part in the undertaking.

If Buffon had remarked on the Paris gypsum fauna, its crocodiles and other tropical aspects probably would have pleased him. They coincided with his theory that the earth, gradually cooling from a molten state, had been warmer in the past, and that tropical animals had then inhabited the north, as apparent elephant and rhino bones in Europe and North America seemed to show. Buffon was vague as to how such animals had originally been "born," as he put it, but he assumed that, aside from their emigration to the present-day tropics, they had not changed much since. An

elephantine fossil from Ohio seemed to have nonelephantine teeth, but Buffon's colleague Louis Daubenton thought hippo teeth had gotten mixed with the skull. Buffon did not dwell on such confusions anyway. Intellectual consistency was not required of Bourbon courtiers, and the fact that the Paris gypsum did *not* contain elephants or rhinos might not have bothered him even if he had noticed it.

After Buffon's death in 1788, aristocrats had more to worry about than classifying fossil mammals. A revolutionary mob stripped the count's sarcophagus of its lead lining, and his son went to the guillotine. The fossil trade picked up again after the Terror, however, and a 26-year-old newcomer to Paris was prepared to regard the gypsum bones in a new light. Georges Cuvier, who arrived in 1795 for an interview at the Muséum d'histoire naturelle, was not an aristocrat, or even a savant in quite Buffon's sense. He'd grown up in Montbéliard, then attached to the duchy of Württemberg, and although it was a French-speaking town, it was Lutheran. He'd attended a German academy, the Karlschule in Stuttgart, where he'd studied natural history in the firsthand way that was developing north of the Rhine. Naturalists such as Abraham Werner, a professor at the mining school in Saxony, were more concerned with describing phenomena accurately than with system-building on the Buffon model. They thought the old theorists superficial.

When Cuvier graduated, he had gone to work tutoring the heir of a Norman noble family, the d'Hericys. Although he was at first enthusiastic about the Revolution, he had seen the Terror at work in the city of Caen, and he was relieved when the d'Hericys retreated to the safety of their estate on the coast near Fécamp. There he had improved his spare time by collecting the creatures of tidepools and mudflats, perceptively comparing their diverse structures. He had walked the coastal hills and valleys, observing in Wernerian fashion how local rocks were arranged with fossil-bearing, evidently younger strata toward the top and fossil-barren older rocks at the bottom. Naturalists called the lifeless strata "Primary" and the fossil-bearing ones "Secondary" and "Tertiary." (Although it wasn't quite that simple, because scattered, primitive fossils turned up in upper Primary strata, requiring the addition of a "Transition" category.)

Cuvier was prepared for a museum job after several years of this, and the upheavals that emptied Buffon's tomb had left openings. He was a presentable young man. A portrait from that time, possibly by himself, shows long hair, soulful large eyes, and a sensitive but firm mouth. The clothes are slightly *en deshabille,* giving a rustic air, which must have appealed to

the admirers of Jean-Jacques Rousseau, the philosopher of natural harmony, in the museum's older generation. Within the year, young Georges was substituting for an elderly superior as a lecturer in comparative anatomy, and he soon became a member of National Institute, the successor to Buffon's Royal Academy. He didn't let this go to his head, and he kept working diligently. While continuing his invertebrate research, he branched out into vertebrates with the collections his predecessors had accumulated.

Although admiring Buffon's prose and erudition, Cuvier had little respect for his theorizing. He saw from teeth and other features that the fossil European "elephant," called a *mamut* by Siberians, who sometimes encountered its carcass in permafrost, was a different species than the living Indian and African ones. He saw, furthermore, that it was a species that had probably ceased to exist, although not, he thought, because the climate had become too cold. It differed from the elephant the way "the dog differs from the jackal and hyena," he wrote, and "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." Elephants had not fled south to escape a cooling planet's chill. Another species, adapted to the cold, had disappeared from some other cause, perhaps a catastrophic incursion of the sea.

Zallinger's mammoth seems to commemorate Cuvier's confident insight, and an earlier historical encomium by Henry Fairfield Osborn might caption the great beast's symbolic role in the mural. "The wooly mammoth is the classic of paleontology; it is the first extinct animal to be found by man; it is the first to be used as proof of a universal deluge; it is the first to be used as proof of the existence of a long extinct world of mammalian life antecedent to the deluge; it is the first to receive a scientific description in the Latin language; it is the first to receive a scientific name." Looming against glaciated peaks, furred to its enormous toes, *Mammuthus* leaves no doubt that it "differs from the elephant."

Cuvier further identified vanished kinds of bears, crocodiles, rhinos, and deer, speculating that "some kind of catastrophe" might have extinguished them too. So much for Buffon's magniloquent "theory of the earth" and its cooling planet. Yet such animals were still enough like living ones to make the idea of complete disappearance, extinction, seem tentative. Cuvier fixed that in his next paper, however. A colossal skeleton from South America had arrived in Madrid, and he acquired drawings of it. The twelve-foot-long beast had walked on massively clawed feet, and the American savant

Thomas Jefferson thought a similar one was a giant carnivore, a reasonable conjecture from such massive claws. Cuvier knew enough mammal anatomy, however, to see strong similarities between the skeleton and those of the much smaller herbivorous tree sloths still living in South American forests. The ancient beast's few teeth were peglike, hardly a carnivore's, and he concluded that it was a giant, ground-dwelling sloth. He named it *Megatherium,* "great beast," and it was indeed one of the largest that ever lived, as the specimen that Zallinger painted gazing dimly toward his mammoth demonstrates. *Megatherium* also was one of the strangest mammals ever, as the mural shows, and there was no record in 1792 of any such monster living. If it had been alive in the unknown American interior, Cuvier reasoned, word of it would have reached the coast, and no such reports existed. It was almost certainly extinct.

Extinction was a fairly new idea, transgressing assumptions common since Aristotle about a stable natural order. Cuvier was not the first to have it. Buffon had toyed with it, and Jean-Baptiste Lamarck, Cuvier's senior colleague at the museum, believed that prehistoric species had disappeared. Lamarck had a very different interpretation of the phenomenon than Cuvier, however. He thought species had disappeared not by dying out but by transmuting into new species, a feat accomplished partly by passing newly acquired characteristics to their offspring. Habitually reaching up to browse in trees (to give a popular, if oversimplified, example of Lamarck's thinking), the giraffe gradually might have been transformed from a vanished, short-necked species into a living long-necked one. Life was a process of ever-ascending change, with "animalcules" continually generating spontaneously in water and soil, then transmuting progressively from worms to fishes to lizards to beasts, eventually to savants.

Rousseau had helped launch Lamarck's career, and the aging naturalist's theory was optimistic in keeping with prerevolutionary assumptions about nature's goodness and change's benign possibilities. That Lamarck had developed it during the 1790s may seem surprising in an impecunious member of the minor aristocracy who stayed in Paris through the Terror, but a half century of Enlightenment evidently had influenced him more than mass executions. His vision also reflected his professional specialty. Originally a botanist, he had been named the museum's curator of invertebrate animals when the republic reorganized it, and had become an expert on fossil shells, more abundant in the strata around Paris even than mammal bones. The fossil shells largely were different from living ones, he found, but not all of them, and shells were abundant and diverse from the lowest

strata in which they occurred right up to the highest. This seemed good evidence of the dynamic and continuous process he envisioned.

Cuvier conceived a darker vision, particularly after 1796, when he began studying Paris gypsum bones that the museum had acquired from a defunct collector. They were diverse as well as abundant, so much so, in fact, that confident young Georges was daunted. "I found myself as if placed in a charnel house," he wrote, "surrounded by mutilated fragments of many hundred skeletons of more than twenty kinds of animals, piled confusedly around me." Professionalism overcame bewilderment, however. "The task assigned me was to restore them all to their original positions," he continued. "At the voice of comparative anatomy every bone and fragment of a bone resumed its place." Cuvier developed a technique he called "correlation of parts" to reconstruct animals from incomplete fossils. Even if only the teeth and feet of an animal remained, he could tell if it was a carnivore or an herbivore because carnivores had shearing teeth and claws; herbivores grinding teeth and hooves. The technique would prove to have limitations, but it worked so well for Cuvier that the novelist Honoré de Balzac hailed him as a magician.

As he studied them through the next decade, Cuvier realized that the gypsum fossils were much more unusual than anyone had thought. In the first place, they were embedded deep in the sedimentary rock, unlike most fossil bones then known, which came from loose surface deposits of sand or gravel. This meant, according to Wernerian stratification, that they were much older than fossils such as mammoths. Cuvier thought that the gypsum had formed "many thousands of centuries" before the present. In the second place, some of the species he restored were much less like living French mammals even than mammoths were unlike elephants.

The bones included eight species—in two genera—of hoofed mammals, which Cuvier called "pachyderms"—thick-skinned beasts. The first genus he reconstructed had a head and teeth resembling a South American tapir's but feet more like a camel's. He named it *Palaeotherium,* ancient beast, and identified five species, ranging from horse to sheep size. The second genus, which he called *Anoplotherium,* "unguarded beast," because it lacked canine teeth, was even stranger. Although they had similar teeth and feet, the three species he placed in it were very different in outward appearance. *A. commun,* the commonest, had had a long tail and "much the same stature as an otter." He thought it had probably lived in water, although its teeth showed that it had eaten plants rather than fish. A short-tailed one, *A. medium,* was "light like a gazelle or roe deer" and had prob-

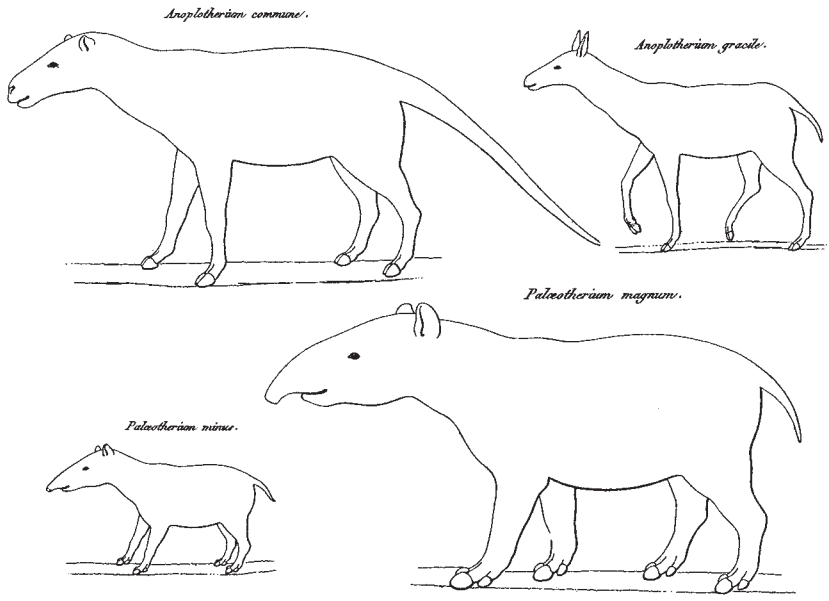

Figure 4. Cuvier's restorations of Paris gypsum mammals. From Georges Cuvier, *Recherches sur les ossemens fossiles* (2d rev. ed., Paris, 1822), 3: 38, pl. 66.

ably looked like one, although only distantly related to antelope or deer. The third species, *A. minus,* had the size and proportions of a hare, but, again, only a distant relationship to rabbits.

Another fossil, the skeleton of a small clawed mammal, was an even greater departure from living European ones, and it permitted a spectacular demonstration of Cuvier's anatomical powers. He quickly discerned a similarity to American opossums, but the skeleton's gypsum matrix hid one proof of its marsupial nature—a pair of pelvic bones thought to support the animal's pouch. Cuvier surmised that the bones lay under some of the vertebrae, and took a calculated gamble with the precious fossil. "So I sacrificed the remains of these vertebrae," he wrote.

> I excavated carefully with a sharp, steel point, and had the satisfaction of exposing . . . the two supernumerary or marsupial bones I was looking for. This operation was done in the presence of some persons to whom I had announced the results in advance with the intention of proving to them—by the act—the justice of my zoological theories . . . from then on, nothing was left to be desired for a complete demonstration of

> the proposition already so singular and indeed important, that there are in the plaster quarries that surround Paris, at great depth and under various beds filled with marine shells, the remains of animals that can only be of a genus now confined entirely to America.

Cuvier realized, also, that this world of tapirlike and opossumlike mammals differed from anything else in the Paris basin rocks. Below the gypsum, the basin's older stratum was chalk, a soft limestone that contained seashells and marine reptiles, like a giant "crocodile" he had mentioned in his elephant paper (he later realized that it was a seagoing lizard, eventually named *Mosasaurus*), but no land animals. Above the gypsum, there were still more beds of marine and freshwater sediments, full of shells, but also empty of land vertebrates. Only in the loose, pebbly deposits at the top did significant land mammal bones again appear, and they were of species closely related to living ones, like deer and cattle. Unlike shellfish, land mammals had inhabited the Paris region only at widely separated intervals.

It was all very well for Lamarck to go on about an ever-ascending continuum of life, with his shells in every stratum below the city. Cuvier saw a brilliant mammalian world that had risen, Edenlike, from the ocean, but then had sunk again, leaving no connections with living France, and only tenuous ones with continents half a world away. The gypsum contained no evidence that *Palaeotherium* or *Anoplotherium* had transmuted into some extant genus in accordance with Lamarck's theory. Indeed, one of the species, *Palaeotherium crassum,* "stout ancient beast," had a skeleton so *like* a living tapir's that Cuvier was "persuaded that most travelers would have confused the two animals if they had existed in the same epoch." If transmutation was the rule of life, why would an extinct animal remain so much like a living one despite their separation by time and space? Tapirlike mammals might have migrated from France to America across a land bridge after the Paris gypsum had sunk, but that would not have required that they be transformed. Mummified animals that the museum zoologist, Étienne Geoffroy Saint-Hilaire, had brought back from Napoleon's Egyptian expedition seemed the same as living ones, although four thousand years older.

Cuvier's was a vision of change, but of change without progressive continuity, and thus without the Enlightenment's worldly optimism. He came to see animal life as divided into four *embranchements*—vertebrata, articulata, mollusca, and radiata—which, like prerevolutionary France's social *états,* were too essentially different to transmute from one into the other.

An 1805 portrait suggests a different mood from the decade before, with hair in crisp Empire style, eyes shrunk and hardened, and lips with a slight, disdainful curl. To Lamarck, who sank into blindness and poverty in old age, Cuvier's vision must have seemed a grim retreat for natural philosophy, closing barely glimpsed vistas of progress. If lower animals such as reptiles had not given birth to mammals, how had mammals appeared? If extinct species had not given birth to living ones by hereditary transmutation, how had living animals appeared? It must have seemed to leave life's history in darkness, illuminated only by the catastrophic interventions of an inscrutable Providence.

Cuvier's vision has been interpreted as a reactionary return to biblical fundamentalism. An 1813 English translation of his *Discours sur les révolutions de la surface du globe* with notes by Robert Jameson, a conservative Scottish naturalist, assumed that his fauna-swallowing catastrophes provided evidence for Genesis. Recent historians of science like Martin Rudwick, however, find no real indication of biblical creationism in the original French. Indeed, Cuvier was quite prepared to debunk supposed evidence of biblical events. Since 1725, scholars had regarded a human-sized fossil skull and ribcage from a German limestone quarry as a victim of Noah's flood, a *Homo diluvii testis.* On an 1811 visit to Amsterdam, where the fossil resided, the anatomist chipped away the stone beside the ribcage to reveal stubby legs, demonstrating that it was the skeleton of a giant Tertiary salamander, not a biblical man.

Cuvier was made a baron and peer of France under King Louis-Philippe, and later portraits of him depict a fat, bemedaled member of the elite. Liberals like the American historian George Bancroft cordially disliked him. Yet he did not participate actively in the post-Napoleonic period's religious and intellectual reaction. France's leading Protestant, he married a Catholic and ignored the evangelical fervors that swept Europe before his death in 1832. His devoutly Protestant daughter failed to evangelicize him, and he spent much of his later career modernizing the French school system.

Cuvier probably saw nothing backward in his vision. As one of a new generation of empiricists, he prided himself on not answering questions without evidence. He was prepared to say that mammals came after reptiles because he found no mammal bones among the giant lizards of the sub-gypsum chalk. He likewise was prepared to say that mammoths and megatheres came after palaeotheres, and that humans came after them all. Indeed, he was the first to say such things from fossil evidence instead of

speculation—the first, as he said, to have "burst the limits of time." The concrete evidence of his gypsum mammals raised the novel possibility that the strange life of the past might be reconstructed. "[S]uch reconstructions . . . were the most vivid expressions of his ambition to demonstrate that reliable human knowledge of the prehuman world was not unattainable," Rudwick observes. "The best guarantee of such knowledge was his demonstration of the sheer 'otherness' of the animal world he had discovered; it was not a mere variant of the present, but a truly different 'ancient world.' A *real* history of life on earth was within grasp."

Yet for all his precise empiricism, Cuvier was enigmatic. Although he envisioned mammal faunas changing through migration, he showed little curiosity about the migrations. While debunking Buffon's assumption that mammothlike beasts had failed to reach South America, he insisted that the Spanish had not found a single quadruped exactly like the Old World's on that continent. Although he suspected that causes other than present-day natural forces might have destroyed fossil worlds, he refused to speculate at any length as to what they might have been. To have devoted so much of his life to retrieving the past but shown so little public interest in the question of origins and ends suggests a deliberate reticence. And Cuvier did not simply ignore the theorizing of others, he attacked it. His eulogy of Lamarck—so mocking that the Académie des sciences refused to have it printed as Cuvier's envoy read it to them—dismissed savants who "laboriously constructed vast edifices upon wholly imaginary bases, resembling those enchanted palaces of our old romances, that one may cause to vanish in thin air by shattering the talismans upon which their very existence depends."

Lamarck's remains went from a rented grave into the catacombs, uniting him forever with the Paris gypsum. Cuvier's higher status entitled him to tomb, but the gypsum's compound of suave lime and caustic sulfur seems to have entered his bones while he lived. Historians often quote Balzac's praise: "Is not Cuvier the greatest poet of our century? . . . our immortal natural historian has reconstructed worlds from bleached bones." The lengthy passage that contains the praise is equivocal, however, as if questioning the value of knowing that yesterday's beasts were so different from today's without knowing why. The novel in which it appears, *La Peau de chagrin* (translated as *The Wild Ass's Skin*), is a fable on life's incalculability, the story of a magic horsehide that shrinks every time its owner makes a wish on it. Balzac invokes Cuvier after describing the junk shop where his doomed hero gets the skin:

Have you ever plunged into the immensity of space and time by reading the geological treatises of Cuvier? . . . As one penetrates from seam to seam, from stratum to stratum and discovers, under the quarries of Montmartre or the schists of the Urals those animals whose fossilized remains belong to antediluvian civilizations, the mind is startled to catch a vista of the milliards of years and the millions of people which the feeble memory of man and an indestructible divine tradition have forgotten . . . he digs out fragments of gypsum, decries a footprint, and cries out: "Behold!" And suddenly marble turns into animals, dead things live anew, and lost worlds are unfolded before us! . . . In the presence of this awesome resurrection due to the voice of a single man, that tiny grain granted to our use in this nameless infinity, which is common to all spheres and which we have baptized as TIME, that minute of life seems pitiable. We wonder, crushed as we are under so many worlds in ruin, what can our glories avail, our hatreds and our loves, and if it is worth living at all.