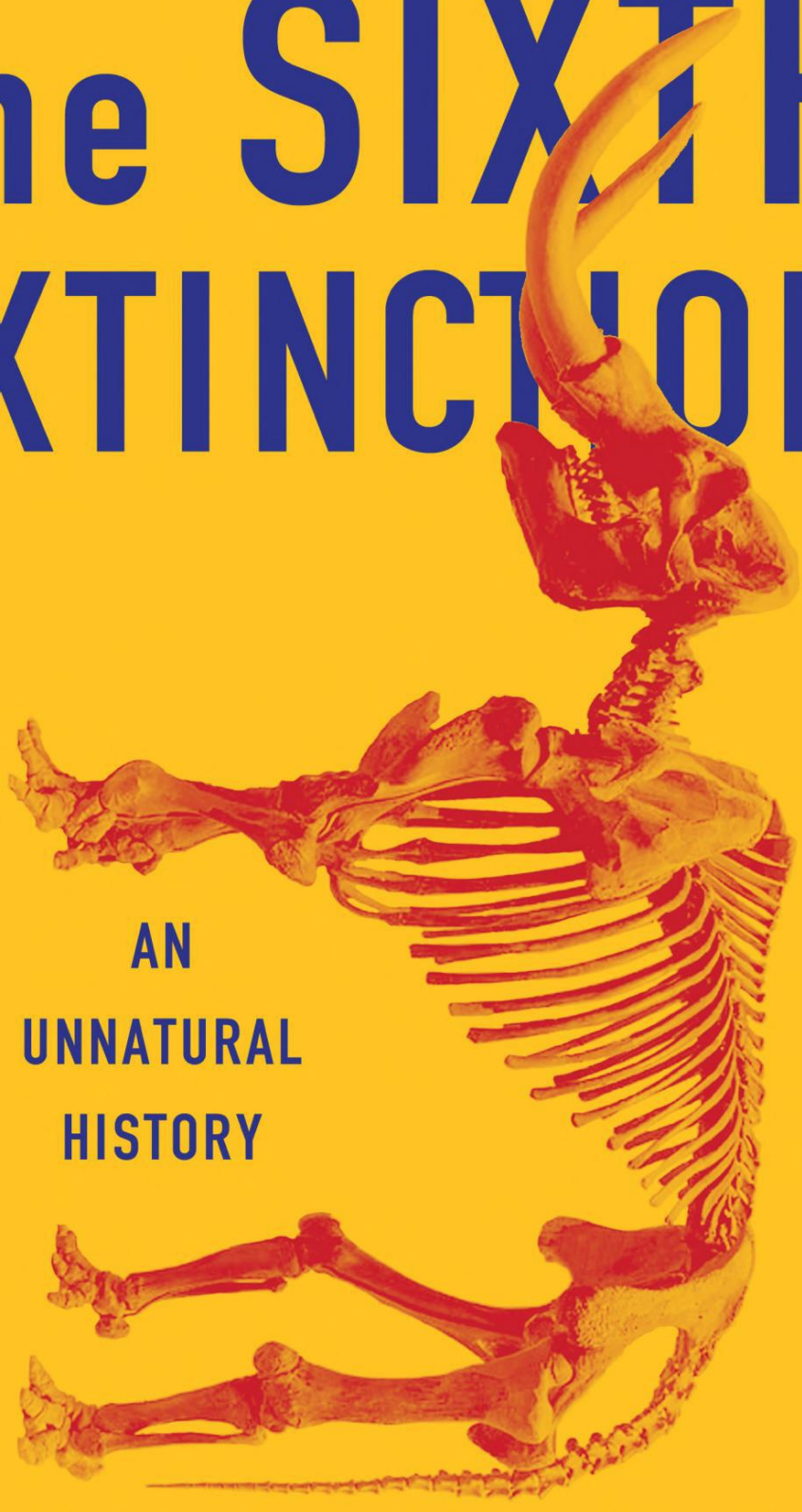
The SIXTH EXTINCTION



AN UNNATURAL HISTORY

ELIZABETH KOLBERT

Author of *FIELD NOTES FROM A CATASTROPHE*

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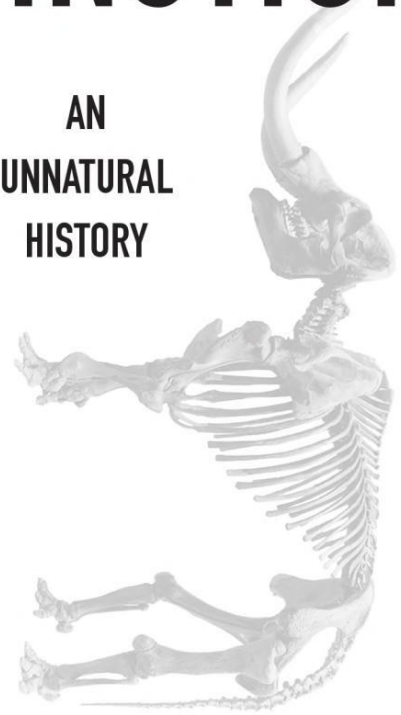

ELIZABETH KOLBERT

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AUTHOR'S NOTE

Though the discourse of science is metric, most Americans think in terms of miles, acres, and degrees Fahrenheit. All the figures in this book are given in English units, except where specially noted.

THE SIXTH EXTINCTION

PROLOGUE

Beginnings, it's said, are apt to be shadowy. So it is with this story, which starts with the emergence of a new species maybe two hundred thousand years ago. The species does not yet have a name—nothing does—but it has the capacity to name things.

As with any young species, this one's position is precarious. Its numbers are small, and its range restricted to a slice of eastern Africa. Slowly its population grows, but quite possibly then it contracts again—some would claim nearly fatally—to just a few thousand pairs.

The members of the species are not particularly swift or strong or fertile. They are, however, singularly resourceful. Gradually they push into regions with different climates, different predators, and different prey. None of the usual constraints of habitat or geography seem to check them. They cross rivers, plateaus, mountain ranges. In coastal regions, they gather shellfish; farther inland, they hunt mammals. Everywhere they settle, they adapt and innovate. On reaching Europe, they encounter creatures very much like

themselves, but stockier and probably brawnier, who have been living on the continent far longer. They interbreed with these creatures and then, by one means or another, kill them off.

The end of this affair will turn out to be exemplary. As the species expands its range, it crosses paths with animals twice, ten, and even twenty times its size: huge cats, towering bears, turtles as big as elephants, sloths that stand fifteen feet tall. These species are more powerful and often fiercer. But they are slow to breed and are wiped out.

Although a land animal, our species—ever inventive—crosses the sea. It reaches islands inhabited by evolution's outliers: birds that lay foot-long eggs, pig-sized hippos, giant skinks. Accustomed to isolation, these creatures are ill-equipped to deal with the newcomers or their fellow travelers (mostly rats). Many of them, too, succumb.

The process continues, in fits and starts, for thousands of years, until the species, no longer so new, has spread to practically every corner of the globe. At this point, several things happen more or less at once that allow *Homo sapiens*, as it has come to call itself, to reproduce at an unprecedented rate. In a single century the population doubles; then it doubles again, and then again. Vast forests are razed. Humans do this deliberately, in order to feed themselves. Less deliberately, they shift organisms from one continent to another, reassembling the biosphere.

Meanwhile, an even stranger and more radical transformation is under way. Having discovered subterranean reserves of energy, humans begin to change the composition of the atmosphere. This, in turn, alters the climate and the chemistry of the oceans. Some plants and animals adjust by moving. They climb mountains and migrate toward the poles. But a great many—at first hundreds, then thousands, and finally perhaps millions—find themselves marooned. Extinction rates soar, and the texture of life changes.

No creature has ever altered life on the planet in this way

before, and yet other, comparable events have occurred. Very, very occasionally in the distant past, the planet has undergone change so wrenching that the diversity of life has plummeted. Five of these ancient events were catastrophic enough that they're put in their own category: the so-called Big Five. In what seems like a fantastic coincidence, but is probably no coincidence at all, the history of these events is recovered just as people come to realize that they are causing another one. When it is still too early to say whether it will reach the proportions of the Big Five, it becomes known as the Sixth Extinction.

The story of the Sixth Extinction, at least as I've chosen to tell it, comes in thirteen chapters. Each tracks a species that's in some way emblematic—the American mastodon, the great auk, an ammonite that disappeared at the end of the Cretaceous alongside the dinosaurs. The creatures in the early chapters are already gone, and this part of the book is mostly concerned with the great extinctions of the past and the twisting history of their discovery, starting with the work of the French naturalist Georges Cuvier. The second part of the book takes place very much in the present—in the increasingly fragmented Amazon rainforest, on a fast-warming slope in the Andes, on the outer reaches of the Great Barrier Reef. I chose to go to these particular places for the usual journalistic reasons—because there was a research station there or because someone invited me to tag along on an expedition. Such is the scope of the changes now taking place that I could have gone pretty much anywhere and, with the proper guidance, found signs of them. One chapter concerns a die-off happening more or less in my own backyard (and, quite possibly, in yours).

If extinction is a morbid topic, mass extinction is, well, massively so. It's also a fascinating one. In the pages that follow, I try to convey both sides: the excitement of what's being learned as well as the horror of it. My hope is that readers of this book will come away with an appreciation of the truly extraordinary moment in which we live.

CHAPTER 1

THE SIXTH EXTINCTION

Atelopus zeteki

The town of El Valle de Antón, in central Panama, sits in the middle of a volcanic crater formed about a million years ago. The crater is almost four miles wide, but when the weather is clear you can see the jagged hills that surround the town like the walls of a ruined tower. El Valle has one main street, a police station, and an open-air market. In addition to the usual assortment of Panama hats and vividly colored embroidery, the market offers what must be the world's largest selection of golden-frog figurines. There are golden frogs resting on leaves and golden frogs sitting up on their haunches and—rather more difficult to understand—golden frogs clasping cell phones. There are golden frogs wearing frilly skirts and golden frogs striking dance poses and golden frogs smoking cigarettes through a holder, after the fashion of FDR. The golden frog, which is taxicab yellow with dark brown splotches, is endemic to the area around El Valle. It is considered a lucky symbol in Panama; its image is (or at least used to be) printed on lottery tickets.

As recently as a decade ago, golden frogs were easy to spot in

the hills around El Valle. The frogs are toxic—it's been calculated that the poison contained in the skin of just one animal could kill a thousand average-sized mice—hence the vivid color, which makes them stand out against the forest floor. One creek not far from El Valle was nicknamed Thousand Frog Stream. A person walking along it would see so many golden frogs sunning themselves on the banks that, as one herpetologist who made the trip many times put it to me, "it was insane—absolutely insane."

Then the frogs around El Valle started to disappear. The problem—it was not yet perceived as a crisis—was first noticed to the west, near Panama's border with Costa Rica. An American graduate student happened to be studying frogs in the rainforest there. She went back to the States for a while to write her dissertation, and when she returned, she couldn't find any frogs or, for that matter, amphibians of any kind. She had no idea what was going on, but since she needed frogs for her research, she set up a new study site, farther east. At first the frogs at the new site seemed healthy; then the same thing happened: the amphibians vanished. The blight spread through the rainforest until, in 2002, the frogs in the hills and streams around the town of Santa Fe, about fifty miles west of El Valle, were effectively wiped out. In 2004, little corpses began showing up even closer to El Valle, around the town of El Copé. By this point, a group of biologists, some from Panama, others from the United States, had concluded that the golden frog was in grave danger. They decided to try to preserve a remnant population by removing a few dozen of each sex from the forest and raising them indoors. But whatever was killing the frogs was moving even faster than the biologists had feared. Before they could act on their plan, the wave hit.

I first read about the frogs of El Valle in a nature magazine for children that I picked up from my kids. The article, which was illustrated with full-color photos of the Panamanian golden frog and

other brilliantly colored species, told the story of the spreading scourge and the biologists' efforts to get out in front of it. The biologists had hoped to have a new lab facility constructed in El Valle, but it was not ready in time. They raced to save as many animals as possible, even though they had nowhere to keep them. So what did they end up doing? They put them "in a frog hotel, of course!" The "incredible frog hotel"—really a local bed and breakfast—agreed to let the frogs stay (in their tanks) in a block of rented rooms.

"With biologists at their beck and call, the frogs enjoyed first-class accommodations that included maid and room service," the article noted. The frogs were also served delicious, fresh meals—"so fresh, in fact, the food could hop right off the plate."

Just a few weeks after I read about the "incredible frog hotel," I ran across another frog-related article written in a rather different key. This one, which appeared in the *Proceedings of the National Academy of Sciences*, was by a pair of herpetologists. It was titled "Are We in the Midst of the Sixth Mass Extinction? A View from the World of Amphibians." The authors, David Wake, of the University of California-Berkeley, and Vance Vredenburg, of San Francisco State, noted that there "have been five great mass extinctions during the history of life on this planet." These extinctions they described as events that led to "a profound loss of biodiversity." The first took place during the late Ordovician period, some 450 million years ago, when living things were still mainly confined to the water. The most devastating took place at the end of the Permian period, some 250 million years ago, and it came perilously close to emptying the earth out altogether. (This event is sometimes referred to as "the mother of mass extinctions" or "the great dying.") The most recent—and famous—mass extinction came at the close of the Cretaceous period; it wiped out, in addition to the dinosaurs, the plesiosaurs, the mosasaurs, the ammonites, and the pterosaurs. Wake and Vredenburg argued that, based on extinction rates among amphibians, an event of a similarly catastrophic nature was currently under way. Their article

was illustrated with just one photograph, of about a dozen mountain yellow-legged frogs—all dead—lying bloated and belly-up on some rocks.

I understood why a kids' magazine had opted to publish photos of live frogs rather than dead ones. I also understood the impulse to play up the Beatrix Potter–like charms of amphibians ordering room service. Still, it seemed to me, as a journalist, that the magazine had buried the lede. Any event that has occurred just five times since the first animal with a backbone appeared, some five hundred million years ago, must qualify as exceedingly rare. The notion that a sixth such event would be taking place right now, more or less in front of our eyes, struck me as, to use the technical term, mind-boggling. Surely this story, too—the bigger, darker, far more consequential one—deserved telling. If Wake and Vredenburg were correct, then those of us alive today not only are

witnessing one of the rarest events in life's history, we are also causing it. "One weedy species," the pair observed, "has unwittingly achieved the ability to directly affect its own fate and that of most of the other species on this planet." A few days after I read Wake and Vredenburg's article, I booked a ticket to Panama.

THE El Valle Amphibian Conservation Center, or EVACC (pronounced "ee-vac"), lies along a dirt road not far from the open-air market where the golden frog figurines are sold. It's about the size of a suburban ranch house, and it occupies the back corner of a small, sleepy zoo, just beyond a cage of very sleepy sloths. The entire building is filled with tanks. There are tanks lined up against the walls and more tanks stacked at the center of the room, like books on the shelves of a library. The taller tanks are occupied by species like the lemur tree frog, which lives in the forest canopy; the shorter tanks serve for species like the big-headed robber frog, which lives on the forest floor. Tanks of horned marsupial frogs, which carry their eggs in a pouch, sit next to tanks of casque-headed frogs, which carry their eggs on their backs. A few dozen tanks are devoted to Panamanian golden frogs, *Atelopus zeteki*.

Golden frogs have a distinctive, ambling gait that makes them look a bit like drunks trying to walk a straight line. They have long, skinny limbs, pointy yellow snouts, and very dark eyes, through which they seem to be regarding the world warily. At the risk of sounding weak-minded, I will say that they look intelligent. In the wild, females lay their eggs in shallow running water; males, meanwhile, defend their territory from the tops of mossy rocks. In EVACC, each golden frog tank has its own running water, provided by its own little hose, so that the animals can breed near a simulacrum of the streams that were once their home. In one of the ersatz streams, I noticed a string of little pearl-like eggs. On a white board nearby someone had noted excitedly that one of the frogs *"depositó huevos!!"*

EVACC sits more or less in the middle of the golden frog's

A Panamanian golden frog (*Atelopus zeteki*).

range, but it is, by design, entirely cut off from the outside world. Nothing comes into the building that has not been thoroughly disinfected, including the frogs, which, in order to gain entry, must first be treated with a solution of bleach. Human visitors are required to wear special shoes and to leave behind any bags or knapsacks or equipment that they've used out in the field. All of the water that enters the tanks has been filtered and specially treated. The sealed-off nature of the place gives it the feel of a submarine or, perhaps more aptly, an ark mid-deluge.

EVACC's director is a Panamanian named Edgardo Griffith. Griffith is tall and broad-shouldered, with a round face and a wide smile. He wears a silver ring in each ear and has a large tattoo of a toad's skeleton on his left shin. Now in his mid-thirties, Griffith has devoted pretty much his entire adult life to the amphibians of El Valle, and he has turned his wife, an American who came to Panama as a Peace Corps volunteer, into a frog person, too. Griffith

was the first person to notice when little carcasses started showing up in the area, and he personally collected many of the several hundred amphibians that got booked into the hotel. (The animals were transferred to EVACC once the building had been completed.) If EVACC is a sort of ark, Griffith becomes its Noah, though one on extended duty, since already he's been at things a good deal longer than forty days. Griffith told me that a key part of his job was getting to know the frogs as individuals. "Every one of them has the same value to me as an elephant," he said.

The first time I visited EVACC, Griffith pointed out to me the representatives of species that are now extinct in the wild. These included, in addition to the Panamanian golden frog, the Rabbs' fringe-limbed tree frog, which was first identified only in 2005. At the time of my visit, EVACC was down to just one Rabbs' frog, so the possibility of saving even a single, Noachian pair had obviously passed. The frog, greenish brown with yellow speckles, was about four inches long, with oversized feet that gave it the look of a gawky teenager. Rabbs' fringe-limbed tree frogs lived in the forest above El Valle, and they laid their eggs in tree holes. In an unusual, perhaps even unique arrangement, the male frogs cared for the tadpoles by allowing their young, quite literally, to eat the skin off their backs. Griffith said that he thought there were probably many other amphibian species that had been missed in the initial collecting rush for EVACC and had since vanished; it was hard to say how many, since most of them were probably unknown to science. "Unfortunately," he told me, "we are losing all these amphibians before we even know that they exist."

"Even the regular people in El Valle, they notice it," he said. "They tell me, 'What happened to the frogs? We don't hear them calling anymore.' "

WHEN the first reports that frog populations were crashing began to circulate, a few decades ago, some of the most knowledgeable

people in the field were the most skeptical. Amphibians are, after all, among the planet's great survivors. The ancestors of today's frogs crawled out of the water some 400 million years ago, and by 250 million years ago the earliest representatives of what would become the modern amphibian orders—one includes frogs and toads, the second newts and salamanders, and the third weird limbless creatures called caecilians—had evolved. This means that amphibians have been around not just longer than mammals, say, or birds; they have been around since before there were dinosaurs.

Most amphibians—the word comes from the Greek meaning "double life"—are still closely tied to the aquatic realm from which they emerged. (The ancient Egyptians thought that frogs were produced by the coupling of land and water during the annual flooding of the Nile.) Their eggs, which have no shells, must be kept moist in order to develop. There are many frogs that, like the Panamanian golden frog, lay their eggs in streams. There are also frogs that lay them in temporary pools, frogs that lay them underground, and frogs that lay them in nests that they construct out of foam. In addition to frogs that carry their eggs on their backs and in pouches, there are frogs that carry them wrapped like bandages around their legs. Until recently, when both of them went extinct, there were two species of frogs, known as gastric-brooding frogs, that carried their eggs in their stomachs and gave birth to little froglets through their mouths.

Amphibians emerged at a time when all the land on earth was part of a single expanse known as Pangaea. Since the breakup of Pangaea, they've adapted to conditions on every continent except Antarctica. Worldwide, just over seven thousand species have been identified, and while the greatest number are found in the tropical rainforests, there are occasional amphibians, like the sandhill frog of Australia, that can live in the desert, and also amphibians, like the wood frog, that can live above the Arctic Circle. Several common North American frogs, including spring peepers, are able to survive the winter frozen solid, like popsicles. Their extended evolutionary

history means that even groups of amphibians that, from a human perspective, seem to be fairly similar may, genetically speaking, be as different from one another as, say, bats are from horses.

David Wake, one of the authors of the article that sent me to Panama, was among those who initially did not believe that amphibians were disappearing. This was back in the mid–nineteen-eighties. Wake's students began returning from frog-collecting trips in the Sierra Nevada empty-handed. Wake remembered from his own student days, in the nineteen-sixties, that frogs in the Sierras had been difficult to avoid. "You'd be walking through meadows, and you'd inadvertently step on them," he told me. "They were just everywhere." Wake assumed that his students were going to the wrong spots, or that they just didn't know how to look. Then a postdoc with several years of collecting experience told him that he couldn't find any amphibians, either. "I said, 'OK, I'll go up with you, and we'll go out to some proven places,' " Wake recalled. "And I took him out to this proven place, and we found like two toads."

Part of what made the situation so mystifying was the geography; frogs seemed to be vanishing not only from populated and disturbed areas but also from relatively pristine places, like the Sierras and the mountains of Central America. In the late nineteen-eighties, an American herpetologist went to the Monteverde Cloud Forest Reserve in northern Costa Rica to study the reproductive habits of golden toads. She spent two field seasons looking; where once the toads had mated in writhing masses, a single male was sighted. (The golden toad, now classified as extinct, was actually a bright tangerine color. It was only very distantly related to the Panamanian golden frog, which, owing to a pair of glands located behind its eyes, is also technically a toad.) Around the same time, in central Costa Rica, biologists noticed that the populations of several endemic frog species had crashed. Rare and highly specialized species were vanishing and so, too, were much more familiar ones. In Ecuador, the Jambato toad, a frequent visitor to backyard gardens, disappeared in a matter of years. And in northeastern

Australia the southern day frog, once one of the most common in the region, could no longer be found.

The first clue to the mysterious killer that was claiming frogs from Queensland to California came—perhaps ironically, perhaps not—from a zoo. The National Zoo, in Washington, D.C., had been successfully raising blue poison-dart frogs, which are native to Suriname, through many generations. Then, more or less from one day to the next, the zoo's tank-bred frogs started dropping. A veterinary pathologist at the zoo took some samples from the dead frogs and ran them through an electron scanning microscope. He found a strange microorganism on the animals' skin, which he eventually identified as a fungus belonging to a group known as chytrids.

Chytrid fungi are nearly ubiquitous; they can be found at the tops of trees and also deep underground. This particular species, though, had never been seen before; indeed, it was so unusual that an entire genus had to be created to accommodate it. It was named *Batrachochytrium dendrobatidis*—*batrachos* is Greek for "frog"—or Bd for short.

The veterinary pathologist sent samples from infected frogs at the National Zoo to a mycologist at the University of Maine. The mycologist grew cultures of the fungus and then sent some of them back to Washington. When healthy blue poison-dart frogs were exposed to the lab-raised Bd, they sickened. Within three weeks, they were dead. Subsequent research showed that Bd interferes with frogs' ability to take up critical electrolytes through their skin. This causes them to suffer what is, in effect, a heart attack.

EVACC can perhaps best be described as a work-in-progress. The week I spent at the center, a team of American volunteers was also there, helping to construct an exhibit. The exhibit was going to be open to the public, so, for biosecurity purposes, the space had to be isolated and equipped with its own separate entrance. There

were holes in the walls where, eventually, glass cases were to be mounted, and around the holes someone had painted a mountain landscape very much like what you would see if you stepped outside and looked up at the hills. The highlight of the exhibit was to be a large case full of Panamanian golden frogs, and the volunteers were trying to construct a three-foot-high concrete waterfall for them. But there were problems with the pumping system and difficulties getting replacement parts in a valley with no hardware store. The volunteers seemed to be spending a lot of time hanging around, waiting.

I spent a lot of time hanging around with them. Like Griffith, all of the volunteers were frog lovers. Several, I learned, were zookeepers who worked with amphibians back in the States. (One told me that frogs had ruined his marriage.) I was moved by the team's dedication, which was the same sort of commitment that had gotten the frogs into the "frog hotel" and then had gotten EVACC up and running, if not entirely completed. But I couldn't help also feeling that there was also something awfully sad about the painted green hills and the fake waterfall.

With almost no frogs left in the forests around El Valle, the case for bringing the animals into EVACC has by now clearly been proved. And yet the longer the frogs spend in the center, the tougher it is to explain what they're doing there. The chytrid fungus, it turns out, does not need amphibians in order to survive. This means that even after it has killed off the animals in an area, it continues to live on, doing whatever it is that chytrid fungi do. Thus, were the golden frogs at EVACC allowed to amble back into the actual hills around El Valle, they would sicken and collapse. (Though the fungus can be destroyed by bleach, it's obviously impossible to disinfect an entire rainforest.) Everyone I spoke to at EVACC told me that the center's goal was to maintain the animals until they could be released to repopulate the forests, and everyone also acknowledged that they couldn't imagine how this would actually be done.

"We've got to hope that somehow it's all going to come

together," Paul Crump, a herpetologist from the Houston Zoo who was directing the stalled waterfall project, told me. "We've got to hope that something will happen, and we'll be able to piece it all together, and it will all be as it once was, which now that I say it out loud sounds kind of stupid."

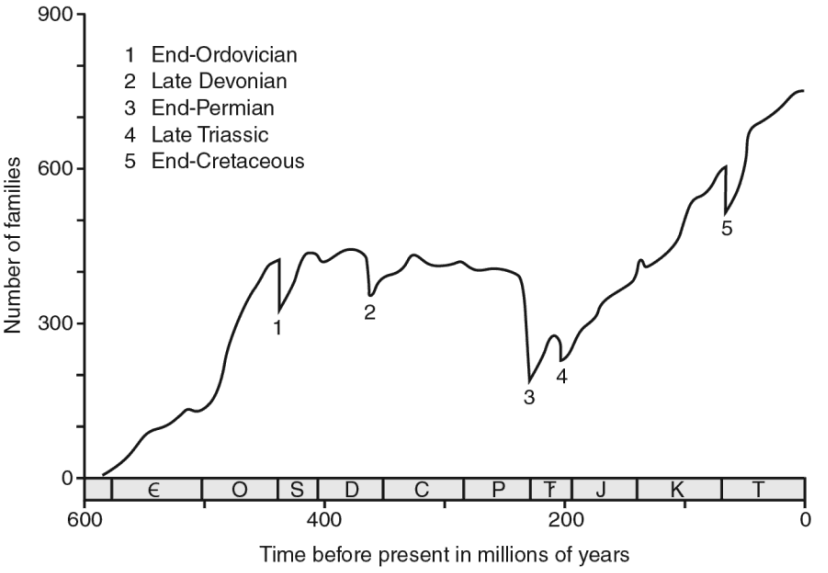
"The point is to be able to take them back, which every day I see more like a fantasy," Griffith said.

Once chytrid swept through El Valle, it didn't stop; it continued to move east. It has also since arrived in Panama from the opposite direction, out of Colombia. Bd has spread through the highlands of South America and down the eastern coast of Australia, and it has crossed into New Zealand and Tasmania. It has raced through the Caribbean and has been detected in Italy, Spain, Switzerland, and France. In the U.S., it appears to have radiated from several points, not so much in a wavelike pattern as in a series of ripples. At this point, it appears to be, for all intents and purposes, unstoppable.

THE same way acoustical engineers speak of "background noise" biologists talk about "background extinction." In ordinary times—times here understood to mean whole geologic epochs—extinction takes place only very rarely, more rarely even than speciation, and it occurs at what's known as the background extinction rate. This rate varies from one group of organisms to another; often it's expressed in terms of extinctions per million species-years. Calculating the background extinction rate is a laborious task that entails combing through whole databases' worth of fossils. For what's probably the best-studied group, which is mammals, it's been reckoned to be roughly .25 per million species-years. This means that, since there are about fifty-five hundred mammal species wandering around today, at the background extinction rate you'd expect—once again, very roughly—one species to disappear every seven hundred years.

Mass extinctions are different. Instead of a background hum

there's a crash, and disappearance rates spike. Anthony Hallam and Paul Wignall, British paleontologists who have written extensively on the subject, define mass extinctions as events that eliminate a "significant proportion of the world's biota in a geologically insignificant amount of time." Another expert, David Jablonski, characterizes mass extinctions as "substantial biodiversity losses" that occur rapidly and are "global in extent." Michael Benton, a paleontologist who has studied the end-Permian extinction, uses the metaphor of the tree of life: "During a mass extinction, vast swathes of the tree are cut short, as if attacked by crazed, axe-wielding madmen." A fifth paleontologist, David Raup, has tried looking at matters from the perspective of the victims: "Species are at a low risk of extinction most of the time." But this "condition of relative safety is punctuated at rare intervals by a vastly higher risk." The history of life thus consists of "long periods of boredom interrupted occasionally by panic."



The Big Five extinctions, as seen in the marine fossil record, resulted in a sharp decline in diversity at the family level. If even one species from a family made it through, the family counts as a survivor, so on the species level the losses were far greater.

In times of panic, whole groups of once-dominant organisms can disappear or be relegated to secondary roles, almost as if the globe has undergone a cast change. Such wholesale losses have led paleontologists to surmise that during mass extinction events—in addition to the so-called Big Five, there have been many lesser such events—the usual rules of survival are suspended. Conditions change so drastically or so suddenly (or so drastically *and* so suddenly) that evolutionary history counts for little. Indeed, the very traits that have been most useful for dealing with ordinary threats may turn out, under such extraordinary circumstances, to be fatal.

A rigorous calculation of the background extinction rate for amphibians has not been performed, in part because amphibian fossils are so rare. Almost certainly, though, the rate is lower than it is for mammals. Probably, one amphibian species should go extinct every thousand years or so. That species could be from Africa or from Asia or from Australia. In other words, the odds of an individual's witnessing such an event should be effectively zero. Already, Griffith has observed several amphibian extinctions. Pretty much every herpetologist working out in the field has watched several. (Even I, in the time I spent researching this book, encountered one species that has since gone extinct and three or four others, like the Panamanian golden frog, that are now extinct in the wild.) "I sought a career in herpetology because I enjoy working with animals," Joseph Mendelson, a herpetologist at Zoo Atlanta, has written. "I did not anticipate that it would come to resemble paleontology."

Today, amphibians enjoy the dubious distinction of being the world's most endangered class of animals; it's been calculated that the group's extinction rate could be as much as forty-five thousand times higher than the background rate. But extinction rates among many other groups are approaching amphibian levels. It is estimated that one-third of all reef-building corals, a third of all freshwater mollusks, a third of sharks and rays, a quarter of all mammals, a fifth of all reptiles, and a sixth of all birds are headed toward

oblivion. The losses are occurring all over: in the South Pacific and in the North Atlantic, in the Arctic and the Sahel, in lakes and on islands, on mountaintops and in valleys. If you know how to look, you can probably find signs of the current extinction event in your own backyard.

There are all sorts of seemingly disparate reasons that species are disappearing. But trace the process far enough and inevitably you are led to the same culprit: "one weedy species."

Bd is capable of moving on its own. The fungus generates microscopic spores with long, skinny tails; these propel themselves through water and can be carried far longer distances by streams, or in the runoff after a rainstorm. (It's likely this sort of dispersal produced what showed up in Panama as an eastward-moving scourge.) But this kind of movement cannot explain the emergence of the fungus in so many distant parts of the world—Central America, South America, North America, Australia—more or less simultaneously. One theory has it that Bd was moved around the globe with shipments of African clawed frogs, which were used in the nineteen-fifties and sixties in pregnancy tests. (Female African clawed frogs, when injected with the urine of a pregnant woman, lay eggs within a few hours.) Suggestively, African clawed frogs do not seem to be adversely affected by Bd, though they are widely infected with it. A second theory holds that the fungus was spread by North American bullfrogs which have been introduced—sometimes accidentally, sometimes purposefully—into Europe, Asia, and South America, and which are often exported for human consumption. North American bullfrogs, too, are widely infected with Bd but do not seem to be harmed by it. The first has become known as the "Out of Africa" and the second might be called the "frog-leg soup" hypothesis.

Either way, the etiology is the same. Without being loaded by someone onto a boat or a plane, it would have been impossible for a frog carrying Bd to get from Africa to Australia or from North America to Europe. This sort of intercontinental reshuffling, which

nowadays we find totally unremarkable, is probably unprecedented in the three-and-a-half-billion-year history of life.

EVEN though Bd has swept through most of Panama by now, Griffith still occasionally goes out collecting for EVACC, looking for survivors. I scheduled my visit to coincide with one of these collecting trips, and one evening I set out with him and two of the American volunteers who were working on the waterfall. We headed east, across the Panama Canal, and spent the night in a region known as Cerro Azul, in a guesthouse ringed by an eight-foot-tall iron fence. At dawn, we drove to the ranger station at the entrance to Chagres National Park. Griffith was hoping to find females of two species that EVACC is short of. He pulled out his government-issued collecting permit and presented it to the sleepy officials manning the station. Some underfed dogs came out to sniff around the truck.

Beyond the ranger station, the road turned into a series of craters connected by deep ruts. Griffith put Jimi Hendrix on the truck's CD player, and we bounced along to the throbbing beat. Frog collecting requires a lot of supplies, so Griffith had hired two men to help with the carrying. At the very last cluster of houses, in the tiny village of Los Ángeles, the men materialized out of the mist. We bounced on until the truck couldn't go any farther; then we all got out and started to walk.

The trail wound its way through the rainforest in a slather of red mud. Every few hundred yards, the main path was crossed by a narrower one; these paths had been made by leaf-cutter ants, making millions—perhaps billions—of trips to bring bits of greenery back to their colonies. (The colonies, which look like mounds of sawdust, can cover an area the size of a city park.) One of the Americans, Chris Bednarski, from the Houston Zoo, warned me to avoid the soldier ants, which will leave their jaws in your shin even after they're dead. "Those'll really mess you up," he observed. The

other American, John Chastain, from the Toledo Zoo, was carrying a long hook, for use against venomous snakes. "Fortunately, the ones that can really mess you up are pretty rare," Bednarski assured me. Howler monkeys screamed in the distance. Griffith pointed out jaguar prints in the soft ground.

After about an hour, we came to a farm that someone had carved out of the trees. There was some scraggly corn growing, but no one was around, and it was hard to say whether the farmer had given up on the poor rainforest soil or was simply away for the day. A flock of emerald green parrots shot up into the air. After another several hours, we emerged into a small clearing. A blue morpho butterfly flitted by, its wings the color of the sky. There was a small cabin on the site, but it was so broken down that everyone elected to sleep outside. Griffith helped me string up my bed—a cross between a tent and a hammock that had to be hung between two trees. A slit in the bottom constituted the entryway, and the top was supposed to provide protection against the inevitable rain. When I climbed into the thing, I felt as if I were lying in a coffin.

That evening, Griffith prepared some rice on a portable gas burner. Then we strapped on headlamps and clambered down to a nearby stream. Many amphibians are nocturnal, and the only way to see them is to go looking in the dark, an exercise that's as tricky as it sounds. I kept slipping, and violating Rule No. 1 of rainforest safety: never grab onto something if you don't know what it is. After one of my falls, Bednarski pointed out to me a tarantula the size of my fist sitting on the next tree over.

Practiced hunters can find frogs at night by shining a light into the forest and looking for the reflected glow of their eyes. The first amphibian Griffith sighted this way was a San Jose Cochran frog, perched on top of a leaf. San Jose Cochran frogs are part of a larger family known as "glass frogs," so named because their translucent skin reveals the outline of their internal organs. This particular glass frog was green, with tiny yellow dots. Griffith pulled a pair of surgical gloves out of his pack. He stood completely still and

then, with a heronlike gesture, darted to scoop up the frog. With his free hand, he took what looked like the end of a Q-tip and swabbed the frog's belly. He put the Q-tip in a little plastic vial—it would later be sent to a lab and analyzed for Bd—and since it wasn't one of the species he was looking for, he placed the frog back on the leaf. Then he pulled out his camera. The frog stared back at the lens impassively.

We continued to grope through the blackness. Someone spotted a La Loma robber frog, which is orangey-red, like the forest floor; someone else spotted a Warzewitsch frog, which is bright green and shaped like a leaf. With every animal, Griffith went through the same routine: snatching it up, swabbing its belly, photographing it. Finally, we came upon a pair of Panamanian robber frogs locked in amplexus—the amphibian version of sex. Griffith left these two alone.

One of the amphibians that Griffith was hoping to catch, the horned marsupial frog, has a distinctive call that's been likened to the sound of a champagne bottle being uncorked. As we sloshed along—by this point we were walking in the middle of the stream—we heard the call, which seemed to be emanating from several directions at once. At first, it sounded as if it were right nearby, but as we approached, it seemed to get farther away. Griffith began imitating the call, making a cork-popping sound with his lips. Eventually, he decided that the rest of us were scaring the frogs with our splashing. He waded ahead, and we stayed for a long time up to our knees in water, trying not to move. When Griffith finally gestured us over, we found him standing in front of a large yellow frog with long toes and an owlish face. It was sitting on a tree limb, just above eye level. Griffith was looking to find a female horned marsupial frog to add to EVACC's collection. He shot out his arm, grabbed the frog, and flipped it over. Where a female horned marsupial would have a pouch, this one had none. Griffith swabbed it, photographed it, and placed it back in the tree.

"You are a beautiful boy," he murmured to the frog.

Around midnight, we headed back to camp. The only animals that Griffith decided to bring with him were two tiny blue-bellied poison frogs and one whitish salamander, whose species neither he nor the two Americans could identify. The frogs and the salamander were placed in plastic bags with some leaves to keep them moist. It occurred to me that the frogs and their progeny, if they had any, and their progeny's progeny, if they had any, would never again touch the floor of the rainforest but would live out their days in disinfected glass tanks. That night it poured, and in my coffin-like hammock I had vivid, troubled dreams, the only scene from which I could later recall was of a bright yellow frog smoking a cigarette through a holder.

CHAPTER II

THE MASTODON'S MOLARS

Mammut americanum

EXTINCTION MAY BE THE FIRST SCIENTIFIC IDEA THAT KIDS today have to grapple with. One-year-olds are given toy dinosaurs to play with, and two-year-olds understand, in a vague sort of way at least, that these small plastic creatures represent very large animals. If they're quick learners—or, alternatively, slow toilet trainers—children still in diapers can explain that there were once lots of kinds of dinosaurs and that they all died off long ago. (My own sons, as toddlers, used to spend hours over a set of dinosaurs that could be arranged on a plastic mat depicting a forest from the Jurassic or Cretaceous. The scene featured a lava-spewing volcano, which, when you pressed on it, emitted a delightfully terrifying roar.) All of which is to say that extinction strikes us as an obvious idea. It isn't.

Aristotle wrote a ten-book *History of Animals* without ever considering the possibility that animals actually had a history. Pliny's *Natural History* includes descriptions of animals that are real and descriptions of animals that are fabulous, but no descriptions of

animals that are extinct. The idea did not crop up during the Middle Ages or during the Renaissance, when the word "fossil" was used to refer to anything dug up from the ground (hence the term "fossil fuels"). In the Enlightenment, the prevailing view was that every species was a link in a great, unbreakable "chain of being." As Alexander Pope put it in his *Essay on Man*:

> All are but parts of one stupendous whole,
> Whose body nature is, and God the soul.

When Carl Linnaeus introduced his system of binomial nomenclature, he made no distinction between the living and the dead because, in his view, none was required. The tenth edition of his *Systema Naturae*, published in 1758, lists sixty-three species of scarab beetle, thirty-four species of cone snail, and sixteen species of flat fishes. And yet in the *Systema Naturae*, there is really only one kind of animal—those that exist.

This view persisted despite a sizable body of evidence to the contrary. Cabinets of curiosities in London, Paris, and Berlin were filled with traces of strange creatures that no one had ever seen—the remains of animals that would now be identified as trilobites, belemnites, and ammonites. Some of the last were so large their fossilized shells approached the size of wagon wheels. In the eighteenth century, mammoth bones increasingly made their way to Europe from Siberia. These, too, were shoehorned into the system. The bones looked a lot like those of elephants. Since there clearly were no elephants in contemporary Russia, it was decided that they must have belonged to beasts that had been washed north in the great flood of Genesis.

Extinction finally emerged as a concept, probably not coincidentally, in revolutionary France. It did so largely thanks to one animal, the creature now called the American mastodon, or *Mammut americanum*, and one man, the naturalist Jean-Léopold-Nicolas-Frédéric Cuvier, known after a dead brother simply as

Georges. Cuvier is an equivocal figure in the history of science. He was far ahead of his contemporaries yet also held many of them back; he could be charming and he could be vicious; he was a visionary and, at the same time, a reactionary. By the middle of the nineteenth century, many of his ideas had been discredited. But the most recent discoveries have tended to support those very theories of his that were most thoroughly vilified, with the result that Cuvier's essentially tragic vision of earth history has come to seem prophetic.

WHEN, exactly, Europeans first stumbled upon the bones of an American mastodon is unclear. An isolated molar unearthed in a field in upstate New York was sent off to London in 1705; it was labeled the "tooth of a Giant." The first mastodon bones subjected to what might, anachronistically, be called scientific study were discovered in 1739. That year, Charles le Moyne, the second Baron de Longueuil, was traveling down the Ohio River with four hundred troops, some, like him, Frenchmen, most of the others Algonquians and Iroquois. The journey was arduous and supplies were short. On one leg, a French soldier would later recall, the troops were reduced to living off acorns. Sometime probably in the fall, Longueuil and his troops set up camp on the east bank of the Ohio, not far from what is now the city of Cincinnati. Several of the Native Americans set off to go hunting. A few miles away, they came to a patch of marsh that gave off a sulfurous smell. Buffalo tracks led to the marsh from all directions, and hundreds—perhaps thousands—of huge bones poked out of the muck, like spars of a ruined ship. The men returned to camp carrying a thigh bone three and a half feet long, an immense tusk, and several huge teeth. The teeth had roots the length of a human hand, and each one weighed nearly ten pounds.

Longueuil was so intrigued by the bones that he instructed his troops to take them along when they broke camp. Lugging

the enormous tusk, femur, and molars, the men pushed on through the wilderness. Eventually, they reached the Mississippi River, where they met up with a second contingent of French troops. Over the next several months, many of Longueuil's men died of disease, and the campaign they had come to wage, against the Chickasaw, ended in humiliation and defeat. Nevertheless, Longueuil kept the strange bones safe. He made his way to New Orleans and from there shipped the tusk, the teeth, and the giant femur to France. They were presented to Louis XV, who installed them in his museum, the Cabinet du Roi. Decades later, maps of the Ohio River valley were still largely blank, except for the *Endroit où on a trouvé des os d'Éléphant*—the "place where the elephant bones were found." (Today the "place where the elephant bones were found" is a state park in Kentucky known as Big Bone Lick.)

Longueuil's bones confounded everyone who examined them. The femur and the tusk looked as if they could have belonged to an elephant or, much the same thing according to the taxonomy of the time, a mammoth. But the animal's teeth were a conundrum. They resisted categorization. Elephants' teeth (and also mammoths') are flat on top, with thin ridges that run from side to side, so that the chewing surface resembles the sole of a running shoe. Mastodon teeth, by contrast, are cusped. They do, indeed, look as if they might belong to a jumbo-sized human. The first naturalist to study one of them, Jean-Étienne Guettard, declined even to guess at its provenance.

"What animal does it come from?" he asked plaintively in a paper delivered to France's Royal Academy of Sciences in 1752.

In 1762, the keeper of the king's cabinet, Louis-Jean-Marie Daubenton, tried to resolve the puzzle of the curious teeth by declaring that the "unknown animal of the Ohio" was not an animal at all. Rather, it was two animals. The tusks and leg bones belonged to elephants; the molars came from another creature entirely. Probably, he decided, this other creature was a hippopotamus.

Right around this time, a second shipment of mastodon bones was sent to Europe, this time to London. These remains, also from Big Bone Lick, exhibited the same befuddling pattern: the bones and tusks were elephant-like, while the molars were covered in knobby points. William Hunter, attending physician to the queen, found Daubenton's explanation for the discrepancy wanting. He offered a different explanation—the first halfway accurate one.

"The supposed American elephant," he submitted, was a totally new animal with "which anatomists were unacquainted." It was, he decided, carnivorous, hence its scary-looking teeth. He dubbed the beast the American *incognitum*.

France's leading naturalist, Georges-Louis Leclerc, Comte de Buffon, added yet another twist to the debate. He argued that the remains in question represented not one or two, but three separate animals: an elephant, a hippopotamus, and a third, as-yet-unknown species. With great trepidation, Buffon allowed that this last species—"the largest of them all"—seemed to have disappeared. It was, he proposed, the only land animal ever to have done so.

In 1781, Thomas Jefferson was drawn into the controversy. In his *Notes on the State of Virginia*, written just after he left the state's governorship, Jefferson concocted his own version of the *incognitum*. The animal was, he maintained with Buffon, the largest of all beasts—"five or six times the cubic volume of the elephant." (This would disprove the theory, popular in Europe at the time, that the animals of the New World were smaller and more "degenerate" than those of the Old.) The creature, Jefferson agreed with Hunter, was probably carnivorous. But it was still out there somewhere. If it could not be found in Virginia, it was roaming those parts of the continent that "remain in their aboriginal state, unexplored and undisturbed." When, as president, he dispatched Meriwether Lewis and William Clark to the Northwest, Jefferson hoped that they would come upon live *incognita* roaming its forests.

"Such is the economy of nature," he wrote, "that no instance can be produced of her having permitted any one race of her animals

to become extinct; of her having formed any link in her great work so weak as to be broken."

Cuvier arrived in Paris in early 1795, half a century after the remains from the Ohio Valley had reached the city. He was twenty-five years old, with wide-set gray eyes, a prominent nose, and a temperament one friend compared to the exterior of the earth—generally cool but capable of violent tremors and eruptions. Cuvier had grown up in a small town on the Swiss border and had few contacts in the capital. Nevertheless, he had managed to secure a prestigious position there, thanks to the passing of the ancien régime on the one hand and his own sublime self-regard on the other. An older colleague would later describe him as popping up in Paris "like a mushroom."

Cuvier's job at Paris's Museum of Natural History—the democratic successor to the king's cabinet—was, officially, to teach. But in his spare time, he delved into the museum's collection. He spent long hours studying the bones that Longueuil had sent to Louis XV, comparing them with other specimens. On April 4, 1796—or, according to the revolutionary calendar in use at the time, 15 Germinal Year IV—he presented the results of his research at a public lecture.

Cuvier began by discussing elephants. Europeans had known for a long time that there were elephants in Africa, which were considered dangerous, and elephants that resided in Asia, which were said to be more docile. Still, elephants were regarded as elephants, much as dogs were dogs, some gentle and others ferocious. On the basis of his examination of the elephant remains at the museum, including one particularly well-preserved skull from Ceylon and another from the Cape of Good Hope, Cuvier had recognized—correctly, of course—that the two belonged to separate species.

"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," he declared. Among the animals' many distinguishing characteristics were their teeth. The elephant from Ceylon had molars with wavy ridges on the surface "like festooned ribbons," while the elephant from the Cape of Good Hope had teeth with ridges arranged in the shape of diamonds. Looking at live animals would not have revealed this difference, as who would have the temerity to peer down an elephant's throat? "It is to anatomy alone that zoology owes this interesting discovery," Cuvier declared.

Having successfully, as it were, sliced the elephant in two, Cuvier continued with his dissection. The accepted theory about the giant bones from Russia, Cuvier concluded after "scrupulous examination" of the evidence, was wrong. The teeth and jaws from Siberia "do not exactly resemble those of an elephant." They belonged to another species entirely. As for the teeth of the animal from Ohio, well, a single glance was "sufficient to see that they differ still further."

"What has become of these two enormous animals of which one no longer finds any living traces?" he asked. The question, in Cuvier's formulation, answered itself. They were *espèces perdues*, or lost species. Already, Cuvier had doubled the number of extinct vertebrates, from (possibly) one to two. He was just getting going.

A few months earlier, Cuvier had received sketches of a skeleton that had been discovered on the bank of the Río Luján, west of Buenos Aires. The skeleton—twelve feet long and six feet high—had been shipped to Madrid, where it had been painstakingly reassembled. Working from the sketches, Cuvier had identified its owner—once again, correctly—as some sort of outlandishly oversized sloth. He named it *Megatherium*, meaning "giant beast." Though he had never traveled to Argentina, or, for that matter, anywhere farther than Germany, Cuvier was convinced that *Megatherium* was no longer to be found lumbering along the rivers of South America. It, too, had disappeared. The same was true of the so-called Maastricht animal, whose remains—an enormous,

pointy jaw studded with sharklike teeth—had been found in a Dutch quarry. (The Maastricht fossil had recently been seized by the French, who occupied the Netherlands in 1795.)

And if there were four extinct species, Cuvier declared, there must be others. The proposal was a daring one to make given the available evidence. On the basis of a few scattered bones, Cuvier had conceived of a whole new way of looking at life. Species died out. This was not an isolated but a widespread phenomenon.

"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," Cuvier said. "But what was this primitive earth? And what revolution was able to wipe it out?"

SINCE Cuvier's day, the Museum of Natural History has grown into a sprawling institution with outposts all over France. Its main buildings, though, still occupy the site of the old royal gardens in the Fifth Arrondissement. Cuvier didn't just work at the museum; for most of his adulthood, he also lived on the grounds, in a large stucco house that has since been converted into office space. Next to the house, there's now a restaurant and next to that a menagerie, where, on the day that I visited, some wallabies were sunning themselves on the grass. Across the gardens, there's a large hall that houses the museum's paleontology collection.

Pascal Tassy is a director at the museum who specializes in proboscideans, the group that includes elephants and their lost cousins—mammoths, mastodons, and gomphotheres, to name just a few. I went to visit him because he'd promised to take me to see the very bones Cuvier had handled. I found Tassy in his dimly lit office, in the basement under the paleontology hall, sitting amid a mortuary's worth of old skulls. The walls of the office were decorated with covers from old Tintin comic books. Tassy told me he'd decided to become a paleontologist when he was seven, after reading a Tintin adventure about a dig.

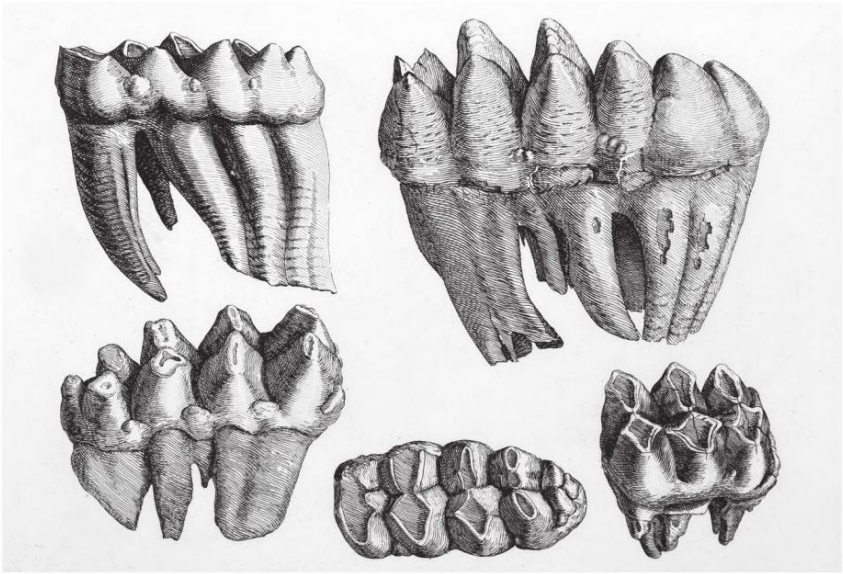
We chatted about proboscideans for a while. "They're a fascinating group," he told me. "For instance, the trunk, which is a change of anatomy in the facial area that is truly extraordinary, it evolved separately five times. Two times—yes, that's surprising. But it happened five times independently! We are forced to accept this by looking at the fossils." So far, Tassy said, some 170 proboscidean species have been identified, going back some fifty-five million years, "and this is far from complete, I am sure."

We headed upstairs, into an annex attached to the back of the paleontology hall like a caboose. Tassy unlocked a small room crowded with metal cabinets. Just inside the door, partially wrapped in plastic, stood what resembled a hairy umbrella stand. This, Tassy explained, was the leg of a woolly mammoth, which had been found, frozen and desiccated, on an island off northern Siberia. When I looked at it more closely, I could see that the skin of the leg had been stitched together, like a moccasin. The hair was a very dark brown and seemed, even after more than ten thousand years, to be almost perfectly preserved.

Tassy opened up one of the metal cabinets and placed the contents on a wooden table. These were the teeth that Longueuil had schlepped down the Ohio River. They were huge and knobby and blackened.

"This is the Mona Lisa of paleontology," Tassy said, pointing to the largest of the group. "The beginning of everything. It's incredible because Cuvier himself made the drawing of this tooth. So he looked at it very carefully." Tassy pointed out to me the original catalog numbers, which had been painted on the teeth in the eighteenth century and were now so faded they could barely be made out.

I picked up the largest tooth in both hands. It was indeed a remarkable object. It was around eight inches long and four across—about the size of a brick and nearly as heavy. The cusps—four sets—were pointy, and the enamel was still largely intact. The roots, as thick as ropes, formed a solid mass the color of mahogany.



This engraving of mastodon teeth was published with a description by Cuvier in 1812.

From an evolutionary perspective, there's actually nothing strange about a mastodon's molars. Mastodon teeth, like most other mammalian teeth, are composed of a core of dentin surrounded by a layer of harder but more brittle enamel. About thirty million years ago, the proboscidean line that would lead to mastodons split off from the line that would lead to mammoths and elephants. The latter would eventually evolve its more sophisticated teeth, which are made up of enamel-covered plates that have been fused into a shape a bit like a bread loaf. This arrangement is a lot tougher, and it allowed mammoths—and still allows elephants—to consume an unusually abrasive diet. Mastodons, meanwhile, retained their relatively primitive molars (as did humans) and just kept chomping away. Of course, as Tassy pointed out to me, the evolutionary perspective is precisely what Cuvier lacked, which in some ways makes his achievements that much more impressive.

"Sure, he made errors," Tassy said. "But his technical works, most of them are splendid. He was a real fantastic anatomist."

After we had examined the teeth for a while longer, Tassy took me up to the paleontology hall. Just beyond the entrance, the giant femur sent to Paris by Longueuil was displayed, mounted on a pedestal. It was as wide around as a fencepost. French schoolchildren were streaming past us, yelling excitedly. Tassy had a large ring of keys, which he used to open up various drawers underneath the glass display cases. He showed me a mammoth tooth that had been examined by Cuvier and bits of various other extinct species that Cuvier had been the first to identify. Then he took me to look at the Maastricht animal, still today one of the world's most famous fossils. (Though the Netherlands has repeatedly asked for it back, the French have held on to it for more than two hundred years.) In the eighteenth century, the Maastricht fossil was thought by some to belong to a strange crocodile and by others to be from a snaggle-toothed whale. Cuvier would eventually attribute it, yet again correctly, to a marine reptile. (The creature later would be dubbed a mosasaur.)

Around lunchtime, I walked Tassy back to his office. Then I wandered through the gardens to the restaurant next to Cuvier's old house. Because it seemed like the thing to do, I ordered the *Menu Cuvier*—your choice of entrée plus dessert. As I was working my way through the second course—a very tasty cream-filled tart—I began to feel uncomfortably full. I was reminded of a description I had read of the anatomist's anatomy. During the Revolution, Cuvier was thin. In the years he lived on the museum grounds, he grew stouter and stouter, until, toward the end of his life, he became enormously fat.

WITH his lecture on "the species of elephants, both living and fossil," Cuvier had succeeded in establishing extinction as a fact. But his most extravagant assertion—that there had existed a whole lost world, filled with lost species—remained just that. If there had indeed been such a world, traces of other extinct animals ought to be findable. So Cuvier set out to find them.

As it happens, Paris in the seventeen-nineties was a fine place to be a paleontologist. The hills to the north of the city were riddled with quarries that were actively producing gypsum, the main ingredient of plaster of Paris. (The capital grew so haphazardly over so many mines that by Cuvier's day cave-ins were a major hazard.) Not infrequently, miners came upon weird bones, which were prized by collectors, even though they had no real idea what they were collecting. With the help of one such enthusiast, Cuvier had soon assembled the pieces of another extinct animal, which he called *l'animal moyen de Montmartre*—the medium-sized animal from Montmartre.

All the while, Cuvier was soliciting specimens from other naturalists in other parts of Europe. Owing to the reputation the French had earned for seizing objects of value, few collectors would send along actual fossils. But detailed drawings began to arrive from, among other places, Hamburg, Stuttgart, Leiden, and Bologna. "I should say that I have been supported with the most ardent enthusiasm . . . by all Frenchmen and foreigners who cultivate or love the sciences," Cuvier wrote appreciatively.

By 1800, which is to say four years after the elephant paper, Cuvier's fossil zoo had expanded to include twenty-three species he deemed to be extinct. These included: a pygmy hippopotamus, whose remains he discovered in a storeroom at the Paris museum; an elk with enormous antlers whose bones had been found in Ireland; and a large bear—what now would be known as a cave bear—from Germany. The Montmartre animal had, by this point, divided, or multiplied, into six separate species. (Even today, little is known about these species, except that they were ungulates and lived some thirty million years ago.) "If so many lost species have been restored in so little time, how many must be supposed to exist still in the depths of the earth?" Cuvier asked.

Cuvier had a showman's flair and, long before the museum employed public relations professionals, knew how to grab attention. ("He was a man who could have been a star on television