CHAPTER X

THE NEW PANGAEA

Myotis lucifugus

The best time to take a bat census is the dead of winter. Bats are what are known as "true hibernators"; when the mercury drops, they begin looking for a place to settle down, or really upside down, since bats in torpor hang by their toes. In the northeastern United States, the first bats to go into hibernation are usually the little browns. Sometime in late October or early November, they seek out a sheltered space, like a cave or a mineshaft, where conditions are likely to remain stable. The little browns are soon joined by the tricolored bats and then by the big browns and the small-footed bats. The body temperature of a hibernating bat drops by fifty or sixty degrees, often to right around freezing. Its heartbeat slows, its immune system shuts down, and the bat, dangling by its feet, falls into a state close to suspended animation. Counting hibernating bats demands a strong neck, a good headlamp, and a warm pair of socks.

In March 2007, some wildlife biologists from Albany, New York, went to conduct a bat census at a cave just west of the city. This was a routine event, so routine that their supervisor, Al Hicks, stayed behind at the office. As soon as the biologists arrived at the cave, they pulled out their cell phones.

"They said, 'Holy shit, there's dead bats everywhere,'" Hicks, who works for New York State's Department of Environmental Conservation, would later recall. Hicks instructed them to bring some carcasses back to the office. He also asked the biologists to photograph any live bats they could find. When Hicks examined the photos, he saw that the animals looked as if they had been dunked, nose first, in talcum powder. This was something he had never encountered before, and he began e-mailing the photographs to all the bat specialists he could think of. None of them had ever seen anything like it either. Some of Hicks's counterparts in other states took a joking tone. What they wanted to know, they said, was what those bats in New York were snorting.

Spring arrived. Bats all across New York and New England awoke from their torpor and flew off. The white powder remained a mystery. "We were thinking, Oh, boy, we hope this just goes away," Hicks told me. "It was like the Bush administration. And, like the Bush administration, it just wouldn't go away." Instead, it spread. The following winter, the same white powdery substance was found on bats in thirty-three caves in four different states. Meanwhile, bats kept dying. In some hibernacula, populations plunged by more than ninety percent. In one cave in Vermont, thousands of corpses dropped from the ceiling and piled up on the ground, like snowdrifts.

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A little brown bat (*Myotis lucifugus*) with white-nose syndrome.

The bat die-off continued the following winter, spreading to five more states. It continued the winter after that, in three additional states, and, although in many places there are hardly any bats left to kill off, it continues to this day. The white powder is now known to be a cold-loving fungus—what's known as a psychrophile—that was accidentally imported to the U.S., probably from Europe. When it was first isolated, the fungus, from the genus *Geomyces*, had no name. For its effect on the bats it was dubbed *Geomyces destructans*.

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WITHOUT human help, long-distance travel is for most species difficult, bordering on impossible. This fact was, to Darwin, central. His theory of descent with modification demanded that each species arise at a single place of origin. To spread from there, it either slithered or swam or loped or crawled or cast its seeds upon the wind. Given a long enough time, even a sedentary organism, like, say, a fungus, could, Darwin thought, become widely dispersed. But it was the limits of dispersal that made things interesting. These accounted for life's richness and, at the same time, for the patterns that could be discerned amid the variety. The barriers imposed by the oceans, for instance, explained why vast tracts of South America, Africa, and Australia, though in Darwin's words "entirely similar" in climate and topography, were populated by entirely *dis*similar flora and fauna. The creatures on each continent had evolved separately, and in this way, physical isolation had been transmuted into biological disparity. Similarly, the barriers imposed by land explained why the fish of the eastern Pacific were distinct from the fish of the western Caribbean, though these two groups were, as Darwin wrote, "separated only by the narrow, but impassable, isthmus of Panama." On a more local level, the species found on one side of a mountain range or a major river were often different from the species found on the other, though usually—and significantly—they were related. Thus, for example, Darwin noted, "the plains near the Straits of Magellan are inhabited by one species of Rhea, and northward the plains of La Plata by another species of the same genus, and not by a true ostrich or emu, like those found in Africa and Australia."

The limits of dispersal concerned Darwin in another way, too, this one harder to account for. As he'd seen firsthand, even remote volcanic islands, like the Galápagos, were full of life. Indeed, islands were home to many of the world's most marvelous creatures. For his theory of evolution to be correct, these creatures must be the descendants of colonizers. But how had the original colonizers arrived? In the case of the Galápagos, five hundred miles of open water separated the archipelago from the coast of South America. So vexed was Darwin by this problem that he spent over a year trying to replicate the conditions of an ocean crossing in the garden of his home in Kent. He collected seeds and immersed them in tanks of salt water. Every few days, he dredged out some of the seeds and planted them. The exercise proved time-consuming, for, he wrote to a friend, "the water I find must be renewed every other day, as it gets to smell horribly." But the results, he thought, were promising; barley seeds still germinated after four weeks' immersion, cress seeds after six, though the seeds "gave out a surprising quantity of slime." If an ocean current flowed at the rate of roughly one mile per hour, then over the course of six weeks a seed could be carried more than a thousand miles. How about an animal? Here Darwin's methods became even more baroque. He sliced off a pair of duck's feet and suspended them in a tank filled with snail hatchlings. After allowing the duck's feet to soak for a while, he lifted them out and had his children count how many hatchlings were attached. The tiny mollusks, Darwin found, could survive out of water for up to twenty hours, and in this length of time, he calculated, a duck with its feet attached might cover six or seven hundred miles. It was no mere coincidence, he observed, that many remote islands have no native mammals save for bats, which can fly.

Darwin's ideas about what he termed "geographical distribution" had profound implications, some of which would not be recognized until decades after his death. In the late nineteenth century, paleontologists began to catalog the many curious correspondences exhibited by fossils gathered on different continents. *Mesosaurus*, for example, is a skinny reptile with splayed-out teeth that lived during the Permian period. *Mesosaurus* remains turn up both in Africa and, an ocean away, in South America. *Glossopteris* is a tongue-shaped fern, also from the Permian period. Its fossils can be found in Africa, in South America, and in Australia. Since it was hard to see how a large reptile could have crossed the Atlantic, or a plant both the Atlantic and the Pacific, vast land bridges extending for several thousand miles were invoked. Why these ocean-spanning bridges had vanished and where they had gone to no one knew; presumably, they had sunk beneath the waves. In the early years of the twentieth century, the German meteorologist Alfred Wegener came up with a better idea.

"The continents must have shifted," he wrote. "South America must have lain alongside Africa and formed a unified block.... The two parts must then have become increasingly separated over a period of millions of years like pieces of a cracked ice floe in water." At one time, Wegener hypothesized, all of the present-day continents had formed one giant supercontinent, Pangaea. Wegener's theory of "continental drift," widely derided during his lifetime, was, of course, to a large extent vindicated by the discovery of plate tectonics.

One of the striking characteristics of the Anthropocene is the hash it's made of the principles of geographic distribution. If highways, clear-cuts, and soybean plantations create islands where none before existed, global trade and global travel do the reverse: they deny even the remotest islands their remoteness. The process of remixing the world's flora and fauna, which began slowly, along the routes of early human migration, has, in recent decades, accelerated to the point where in some parts of the world, non-native plants now outnumber native ones. During any given twenty-four-hour period, it is estimated that ten thousand different species are being moved around the world just in ballast water. Thus a single supertanker (or, for that matter, a jet passenger) can undo millions of years of geographic separation. Anthony Ricciardi, a specialist in introduced species at McGill University, has dubbed the current reshuffling of the earth's biota a “mass invasion event.” It is, he has written, “without precedent” in the planet’s history.

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As it happens, I live just east of Albany, relatively close to the cave where the first piles of dead bats were discovered. By the time I learned about what was going on, white-nose syndrome, as it had become known, had spread as far as West Virginia and had killed something like a million bats. I called up Al Hicks, and he suggested since it was once again bat census season that I tag along for the next count. On a cold, gray morning we met up in a parking lot not far from his office. From there, we headed almost due north, toward the Adirondacks.

About two hours later, we arrived at the base of a mountain not far from Lake Champlain. In the nineteenth century and then again during World War II, the Adirondacks were a major source of iron ore, and shafts were sunk deep into the mountains. When the ore was gone, the shafts were abandoned by people and colonized by bats. For the census, we were going to enter a shaft of what was once the Barton Hill Mine. The entrance was halfway up the mountainside, which was covered in several feet of snow. At the trailhead, more than a dozen people were standing around stomping their feet against the cold. Most, like Hicks, worked for New York State, but there were also a couple of biologists from the U.S. Fish and Wildlife Service and a local novelist who was doing research for a book into which he was hoping to weave a white-nose subplot.

Everyone put on snowshoes, except for the novelist, who, it seemed, had missed the message to bring a pair. The snow was icy and the going slow, so it took half an hour to get maybe half a mile. While we were waiting for the novelist to catch up—he was having trouble with the three-foot-deep drifts—the conversation turned to the potential dangers of entering an abandoned mine. These, I was told, included getting crushed by falling rocks, being poisoned by a gas leak, and plunging over a sheer drop of a hundred feet or more. After another half an hour or so, we reached the mine entrance—essentially a large hole cut into the hillside. The stones in front of the entrance were white with bird droppings, and the snow was covered with paw prints. Evidently, ravens and coyotes had discovered that the spot was an easy place to pick up dinner.

“Well, shit,” Hicks said. Bats were fluttering in and out of the mine, and in some cases crawling around on the snow. Hicks went to catch one; it was so lethargic that he grabbed it on the first try. He held it between his thumb and forefinger, snapped its neck, and placed it in a Ziploc bag. “Short survey today,” he announced.

We unstrapped our snowshoes, put on helmets and headlamps, and filed into the mine, down a long, sloping tunnel. Shattered beams littered the ground, and bats flew up at us through the gloom. Hicks cautioned everyone to stay alert. “There’s places that if you take a step you won’t be stepping back,” he warned. The tunnel twisted along, sometimes opening up into concert-hall-sized chambers with side tunnels leading out of them. Some of the chambers had acquired names; when we reached a sepulchral stretch known as the Don Thomas section, we split up into groups to start the survey. The process consisted of photographing as many bats as possible. (Later on, back in Albany, somebody sitting at a computer screen would have to count all the bats in the pictures.) I went with Hicks, who was carrying an enormous camera, and one of the biologists from the Fish and Wildlife Service, who had a laser pointer. Bats are highly social animals, and in the mine they hung from the rock ceiling in crowded clusters. Most were little brown bats—*Myotis lucifugus*, or “lucis” in bat-counting jargon. These are the dominant bat in the northeastern U.S. and the sort most likely to be seen fluttering around on a summer night. As the name suggests, they're little—only about five inches long and two-tenths of an ounce in weight—and brown, with lighter-colored fur on their bellies. (The poet Randall Jarrell described them as being "the color of coffee with cream in it.") Hanging from the ceiling, with their wings folded, they looked like damp pom-poms. There were also small-footed bats (*Myotis leibii*), which can be identified by their very dark faces, and Indiana bats (*Myotis sodalis*), which, even before white-nose, were listed as an endangered species. As we moved along, we kept disturbing the bats, which squeaked and rustled around, like half-asleep children.

Despite the name, white-nose is not confined to bats' noses; as we worked our way deeper into the mine, people kept finding bats with freckles of fungus on their wings and ears. Several of these were dispatched, for study purposes, with a thumb and forefinger. Each dead bat was sexed—males can be identified by their tiny penises—and placed in a Ziploc bag.

Still today, it is not entirely understood how *Geomyces destructans* kills bats. What is known is that bats with white-nose often wake up from their torpor and fly around in the middle of the day. It's been hypothesized that the fungus, which, quite literally, eats away at the bats' skin, irritates the animals to the point of arousal. This, in turn, causes them to use up the fat stores that were supposed to take them through the winter. On the edge of starvation, they fly out into the open to search for insects, which, of course, at that time of year are not available. It's also been proposed that the fungus causes the bats to lose moisture through their skin. This leads them to become dehydrated, which prompts them to wake up to go in search of water. Again they use up critical energy stores and wind up emaciated and, finally, dead.

We had entered the Barton Hill Mine at around 1 PM. By 7 PM we were almost back where we'd started, at the bottom of the mountain, except that now we were on the inside of it. We came to a huge, rusty winch, which, when the mine was operational, had been used to haul ore to the surface. Below it, the path disappeared into a pool of water, black like the River Styx. It was impossible to go farther, and so we began the long climb up.

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THE movement of species around the world is sometimes compared to Russian roulette. As in the high-stakes game, two very different things can happen when a new organism shows up. The first, which might be called the empty chamber option, is nothing. Either because the climate is unsuitable, or because the creature can't find enough to eat, or because it gets eaten itself, or for a host of other possible reasons, the new arrival doesn't survive (or at least fails to reproduce). Most potential introductions go unrecorded—indeed, entirely unheeded—so it's hard to get precise figures; almost certainly, though, the vast majority of potential invaders don't make it.

In the second option, not only does the introduced organism survive; it gives rise to a new generation, which in turn survives and gives rise to another generation. This is what's known in the invasive species community as "establishment." Again, it's impossible to say for sure how often this happens; many established species probably remain confined to the spot where they were introduced, or they're so innocuous they've gone unnoticed. But—and here's where the roulette analogy comes back—a certain number complete the third step in the invasion process, which is "spread." In 1916, a dozen strange beetles were discovered in a nursery near Riverton, New Jersey. By the following year, the insects, now known as *Popillia japonica* or, more commonly, as Japanese beetles, had dispersed in all directions and could be found over an area of three square miles. The year after that, the figure jumped to seven square miles and the year after that to fortyeight square miles. The beetle continued to expand its territory at a geometric rate, each year pushing out into a new concentric circle, and within two decades it could be found from Connecticut to Maryland. (It has since spread as far south as Alabama and as far west as Montana.) Roy van Driesche, an expert on invasive species at the University of Massachusetts, has estimated that out of every hundred potential introductions, somewhere between five and fifteen will succeed in establishing themselves. Of these five to fifteen, one will turn out to be the "bullet in the chamber."

Why some introduced species are able to proliferate explosively is a matter of debate. One possibility is that for species, as for grifters, there are advantages to remaining on the move. A species that's been transported to a new spot, especially on a new continent, has left many of its rivals and predators behind. This shaking free of foes, which is really the shaking free of evolutionary history, is referred to as "enemy release." There are lots of organisms that appear to have benefited from enemy release, including purple loosestrife, which arrived in the northeastern United States from Europe in the early nineteenth century. In its native habitat, purple loosestrife has all sorts of specialized enemies, including the black-margined loosestrife beetle, the golden loosestrife beetle, the loosestrife root weevil, and the loosestrife flower weevil. All of these were absent in North America when the plant appeared, which helps explain why it's been able to take over boggy areas from West Virginia to Washington State. Some of these specialized predators have recently been introduced into the U.S. in an effort to control the plant's spread. This sort of it-takes-an-invasive-to-catch-an-invasive strategy has a decidedly mixed record. In some cases it's proven highly successful; in other it's turned out to be another ecological disaster. To the latter category belongs the rosy wolfsnail—*Euglandina rosea*—which was introduced to Hawaii in the late nineteen-fifties. The wolfsnail, a native of Central America, was brought in to prey on a previously introduced species, the giant African snail—*Achatina fulica*—which had become an agricultural pest. *Euglandina rosea* mostly left *Achatina fulica* alone and focused its attention instead on Hawaii's small, colorful native snails. Of the more than seven hundred species of endemic snails that once inhabited the islands, something like ninety percent are now extinct, and those that remain are in steep decline.

The corollary to leaving old antagonists behind is finding new, naive organisms to take advantage of. A particularly famous—and ghastly—instance of this comes in the long, skinny form of the brown tree snake, *Boiga irregularis*. The snake is native to Papua New Guinea and northern Australia, and it found its way to Guam in the nineteen-forties, probably in military cargo. The only snake indigenous to the island is a small, sightless creature the size of a worm; thus Guam's fauna was entirely unprepared for *Boiga irregularis* and its voracious feeding habits. The snake ate its way through most of the island's native birds, including the Guam flycatcher, last seen in 1984; the Guam rail, which survives only owing to a captive breeding program; and the Mariana fruit-dove, which is extinct on Guam (though it persists on a couple of other, smaller islands). Before the tree snake arrived, Guam had three native species of mammals, all bats; today only one—the Marianas flying fox—remains, and it is considered highly endangered. Meanwhile, the snake, also a beneficiary of enemy release, was multiplying like crazy; at the peak of what is sometimes called its "irruption," population densities were as high as forty snakes per acre. So thorough has been the devastation wrought by the brown tree snake that it has practically run out of native animals to consume; nowadays it feeds mostly on other interlopers, like the curious skink, a lizard also introduced to Guam from Papua New Guinea. The author David Quammen cautions that while it is easy to demonize the brown tree snake, the animal is not evil; it's just amoral and in the wrong place. What *Boiga irregularis* has done in Guam, he observes, "is precisely what *Homo sapiens* has done all over the planet: succeeded extravagantly at the expense of other species."

With introduced pathogens, the situation is much the same. Long-term relationships between pathogens and their hosts are often characterized in military terms; the two are locked in an "evolutionary arms race," in which, to survive, each must prevent the other from getting too far ahead. When an entirely new pathogen shows up, it's like bringing a gun to a knife fight. Never having encountered the fungus (or virus or bacterium) before, the new host has no defenses against it. Such "novel interactions," as they're called, can be spectacularly deadly. In the eighteen hundreds, the American chestnut was the dominant deciduous tree in eastern forests; in places like Connecticut, it made up close to half the standing timber. (The tree, which can resprout from the roots, did fine even when heavily logged; "not only was baby's crib likely made of chestnut," a plant pathologist named George Hepting once wrote, "but chances were, so was the old man's coffin.") Then, around the turn of the century, *Cryphonectria parasitica*, the fungus responsible for chestnut blight, was imported to the U.S., probably from Japan. Asian chestnut trees, having coevolved with *Cryphonectria parasitica*, were easily able to withstand the fungus, but for the American species it proved almost a hundred percent lethal. By the nineteen-fifties, it had killed off practically every chestnut in the U.S.—some four billion trees. Several species of moths that depended on the tree disappeared along with it. Presumably it's the "novelty" of the chytrid fungus that accounts for its deadliness as well. It explains why, all of a sudden, golden frogs disappeared from Thousand Frog Stream and why amphibians in general are the planet's most threatened class of organism.

Even before the cause of white-nose syndrome was identified, Al Hicks and his colleagues suspected an introduced species. Whatever was killing the bats was presumably something they'd never encountered before, since the mortality rate was so high. Meanwhile, the syndrome was spreading from upstate New York in a classic bull's-eye pattern. This seemed to indicate that the killer had touched down near Albany. Suggestively, when the die-off began to make national news, a spelunker sent Hicks some photographs he'd shot about forty miles west of the city. The photos dated from 2006, a full year before Hicks's coworkers had called him to say "Holy shit," and they showed bats with clear signs of white-nose. The spelunker had taken his pictures in a cave connected to Howe Caverns, a popular tourist destination which offers, among other attractions, flashlight tours and underground boat trips.

"It's kind of interesting that the first record we have of this is photographs from a commercial cave in New York that gets about two hundred thousand visits a year," Hicks told me.

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INTRODUCED species are now so much a part of so many landscapes that chances are if you glance out your window you will see some. From where I'm sitting, in western Massachusetts, I see grass, which someone at some point planted and which most definitely is not native to New England. (Almost all the grasses in American lawns come from somewhere else, including Kentucky bluegrass.) Since my lawn is not particularly well kept, I also see lots of dandelions, which came over from Europe and spread just about everywhere, and garlic mustard, also from Europe, and broadleaf plantains, yet another invader from Europe. (Plantains—*Plantago major*—seem to have arrived with the very first white settlers and were such a reliable sign of their presence that the Native Americans referred to them as "white men's footsteps.") If I get up from my desk and walk past the edge of the lawn, I can also find: multiflora rose, a prickly invasive from Asia; Queen Anne's lace, another introduction from Europe; burdock, similarly from Europe; and oriental bittersweet, whose name speaks to its origins. According to a study of specimens in Massachusetts herbaria, nearly a third of all plant species documented in the state are "naturalized newcomers." If I dig down a few inches, I'll encounter earthworms, which are also newcomers. Before Europeans arrived, New England had no earthworms of its own; the region's worms had all been wiped out by the last glaciation, and even after ten thousand years of relative warmth, North America's native worms had yet to recolonize the area. Earthworms eat through leaf litter and in this way dramatically alter the makeup of forest soils. (Although earthworms are beloved by gardeners, recent research has linked their introduction to a decline in native salamanders in the Northeast.) As I write this, several new and potentially disastrous invaders appear to be in the process of spreading in Massachusetts. These include, in addition to *Geomyces destructans*: the Asian long-horned beetle, an import from China that feeds on a variety of hardwood trees; the emerald ash borer, also from Asia, whose larvae tunnel through and thereby kill ash trees; and the zebra mussel, a freshwater import from Eastern Europe that has the nasty habit of attaching itself to any available surface and consuming everything in the water column.

"Stop Aquatic Hitchhikers," declares a sign by a lake down the road from where I live. "Clean *all* recreational equipment." The sign shows a picture of a boat entirely coated in zebra mussels, as if someone had mistakenly applied mollusks instead of paint.

Wherever you are reading this, the story line is going to be roughly the same, and this goes not just for other parts of the United States but all around the world. DAISIE, a database of invasives in Europe, tracks more than twelve thousand species. APASD (the Asian-Pacific Alien Species Database), FISNA (the Forest Invasive Species Network for Africa), IBIS (the Island Biodiversity and Invasive Species Database), and NEMESIS (the National Exotic Marine and Estuarine Species Information System) track thousands more. In Australia, the problem is so severe that from preschool on, children are enlisted in the control effort. The city council in Townsville, north of Brisbane, urges kids to conduct "regular hunts" for cane toads, which were purposefully, albeit disastrously, introduced in the nineteen-thirties to control sugarcane beetles. (Cane toads are poisonous, and trusting native species, like the northern quoll, eat them and die.) To dispose of the toads humanely, the council instructs children to "cool them in a fridge for 12 hours" and then place them "in a freezer for another 12 hours." A recent study of visitors to Antarctica found that in a single summer season, tourists and researchers brought with them more than seventy thousand seeds from other continents. Already one plant species, *Poa annua*, a grass from Europe, has established itself on Antarctica; since Antarctica has only two native vascular plant species, this means that a third of its vascular plants are now invaders.

From the standpoint of the world's biota, global travel represents a radically new phenomenon and, at the same time, a replay of the very old. The drifting apart of the continents that Wegener deduced from the fossil record is now being reversed—another way in which humans are running geologic history backward and at high speed. Think of it as a souped-up version of plate tectonics, minus the plates. By transporting Asian species to North America, and North American species to Australia, and Australian species to Africa, and European species to Antarctica, we are, in effect, reassembling the world into one enormous supercontinent—what biologists sometimes refer to as the New Pangaea.

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Aeolus Cave, which is set into a wooded hillside in Dorset, Vermont, is believed to be the largest bat hibernaculum in New England; it is estimated that before white-nose hit, nearly three hundred thousand bats—some from as far away as Ontario and Rhode Island—came there to spend the winter. A few weeks after I went with Hicks to the Barton Hill Mine, he invited me to accompany him to Aeolus. This trip had been organized by the Vermont Fish and Wildlife Department, and at the bottom of the hill, instead of strapping on snowshoes, we all piled onto snowmobiles. The trail zigged up the mountain in a series of long switchbacks. The temperature—about twenty-five degrees—was far too low for bats to be active, but when we parked near the entrance to the cave I could see bats fluttering around. The most senior of the Vermont officials, Scott Darling, announced that before going any farther, we'd all have to put on latex gloves and Tyvek suits. This seemed to me to be paranoid—a gesture out of the novelist's white-nose subplot; soon, however, I came to see the sense of it.

Aeolus was created by water flow over the course of thousands and thousands of years. To keep people out, the Nature Conservancy, which owns the cave, has blocked off the entrance with huge iron slats. With a key, one of the horizontal slats can be removed; this creates a narrow gap that can be crawled (or slithered) through. Despite the cold, a sickening smell emanated from the opening—half game farm, half garbage dump. The stone path leading to the gate was icy and difficult to get a footing on. When it was my turn, I squeezed between the slats and immediately slid into something soft and dank. This, I realized, picking myself back up, was a pile of dead bats.

The entrance chamber of the cave, known as Guano Hall, is maybe thirty feet wide and twenty feet high at the front. Toward the back, it narrows and slopes. The tunnels that branch off from there are accessible only to spelunkers, and the tunnels that branch off from those are accessible only to bats. Peering into Guano Hall, I had the sense I was staring into a giant gullet. The scene, in the dimness, was horrific. There were long icicles hanging from the ceiling, and from the floor large knobs of ice rose up, like polyps. The ground was covered with dead bats; some of the ice knobs, I noticed, had bats frozen into them. There were torpid bats roosting on the ceiling, and also wide-awake ones, which would take off and fly by or, sometimes, right into us.

Why bat corpses pile up in some places, while in others they get eaten or in some other way disappear, is unclear. Hicks speculated that the conditions at Aeolus were so harsh that the bats didn't even make it out of the cave before dropping dead. He and Darling had planned to do a count of the bats in Guano Hall, but this plan was quickly abandoned in favor of just collecting specimens. Darling explained that the specimens would be going to the American Museum of Natural History, so that there would at least be a record of the hundreds of thousands of *lucis* and northern long-eared and tricolored bats that had once wintered in Aeolus. "This may be one of the last opportunities," he said. In contrast to a mine, which has been around for at most a few centuries, Aeolus, he pointed out, has existed for millennia. It's likely that bats have been hibernating there, generation after generation, since the cave's entrance was exposed at the end of the last ice age.

"That's what makes this so dramatic—it's breaking the evolutionary chain," Darling said. He and Hicks began picking dead bats off the ground. Those that were too badly decomposed were tossed back; those that were more or less intact were sexed and placed in two-quart plastic bags. I helped out by holding the bag for dead females. Soon it was full and another one was started. When the specimen count hit somewhere around five hundred, Darling decided that it was time to go. Hicks hung back; he'd brought along his enormous camera and said that he wanted to take more pictures. In the hours we had been slipping around in the cave, the carnage had grown even more grotesque; many of the bat carcasses had been crushed, and now there was blood oozing out of them. As I made my way up toward the entrance, Hicks called after me: "Don't step on any dead bats." It took me a moment to realize he was joking.

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WHEN, exactly, the New Pangaea project began is difficult to say. If you count people as an invasive species—the science writer Alan Burdick has called *Homo sapiens* "arguably the most successful invader in biological history"—the process goes back a hundred and twenty thousand years or so, to the period when modern humans first migrated out of Africa. By the time humans pushed into North America, around thirteen thousand years ago, they had domesticated dogs, which they brought with them across the Bering land bridge. The Polynesians who settled Hawaii around fifteen hundred years ago were accompanied not only by rats but also by lice, fleas, and pigs. The "discovery" of the New World initiated a vast biological swap meet—the so-called Columbian Exchange—which took the process to a whole new level. Even as Darwin was elaborating the principles of geographic distribution, those principles were being deliberately undermined by groups known as acclimatization societies. The very year *On the Origin of Species* was published, a member of an acclimatization society based in Melbourne released the first rabbits into Australia. They've been breeding there like, well, rabbits ever since. In 1890, a New York group that took as its mission "the introduction and acclimatization of such foreign varieties of the animal and vegetable kingdom as might prove useful or interesting" imported European starlings to the U.S. (The head of the group supposedly wanted to bring to America all the birds mentioned in Shakespeare.) A hundred starlings let loose in Central Park have by now multiplied to more than two hundred million.

Still today, Americans often deliberately import "foreign varieties" they think "might prove useful or interesting." Garden catalogs are filled with non-native plants, and aquarium catalogs with non-native fish. According to the entry on pets in the *Encyclopedia of Biological Invasions*, every year more non-indigenous species of mammals, birds, amphibians, turtles, lizards, and snakes are brought into the U.S. than the country has native species of these groups. Meanwhile, as the pace and volume of global trade have picked up, so, too, has the number of accidental imports. Species that couldn't survive an ocean crossing at the bottom of a canoe or in the hold of a whaling ship may easily withstand the same journey in the ballast tank of a modern cargo vessel or the bay of an airplane or in a tourist's suitcase. A recent study of non-indigenous species in North American coastal waters found that the "rate of reported invasions has increased exponentially over the past two hundred years." It attributed the accelerating pace to the increased quantities of goods being transported and also to the increased speed with which they travel. The Center for Invasive Species Research, which is based at the University of California-Riverside, estimates that California is now acquiring a new invasive species every sixty days. This is slow compared to Hawaii, where a new invader is added each month. (For comparison's sake, it's worth noting that before humans settled Hawaii, new species seem to have succeeded in establishing themselves on the archipelago roughly once every ten thousand years.)

The immediate effect of all this reshuffling is a rise in what might be called local diversity. Pick any place on earth—Australia, the Antarctic Peninsula, your local park—and, more likely than not, over the last few hundred years the number of species that can be found in the area has grown. Before humans arrived on the scene, many whole categories of organisms were missing from Hawaii; these included not only rodents but also amphibians, terrestrial reptiles, and ungulates. The islands had no ants, aphids, or mosquitoes. People have, in this sense, enriched Hawaii greatly. But Hawaii was, in its prehuman days, home to thousands of species that existed nowhere else on the planet, and many of these endemics are now gone or disappearing. The losses include, in addition to the several hundred species of land snails, dozens of species of birds and more than a hundred species of ferns and flowering plants. For the same reasons that local diversity has, as a general rule, been increasing, global diversity—the total number of different species that can be found worldwide—has dropped.

The study of invasives is often said to have begun with Charles Elton, a British biologist who published his seminal work, *The Ecology of Invasions by Animals and Plants*, in 1958. To explain the apparently paradoxical effects of moving species around, Elton used the analogy of a set of glass tanks. Imagine that each of the tanks is filled with a different solution of chemicals. Then imagine every tank connected to its neighbors by long, narrow tubes. If the taps to the tubes were left open for just a minute each day, the solutions would slowly start to diffuse. The chemicals would recombine. Some new compounds would form and some of the original compounds would drop out. "It might take quite a long time before the whole system came into equilibrium," Elton wrote. Eventually, though, all of the tanks would hold the same solution. The variety would have been eliminated, which was just what could be expected to happen by bringing long-isolated plants and animals into contact.

“If we look far enough ahead, the eventual state of the biological world will become not more complex, but simpler—and poorer,” Elton wrote.

Since Elton’s day, ecologists have tried to quantify the effects of total global homogenization by means of a thought experiment. The experiment starts with the compression of all the world’s landmasses into a single megacontinent. The species-area relationship is then used to estimate how much variety such a landmass would support. The difference between this figure and the diversity of the world as it actually is represents the loss implied by complete interconnectedness. In the case of terrestrial mammals, the difference is sixty-six percent, which is to say that a single-continent world would be expected to contain only about a third as many mammalian species as currently exist. For land birds, it’s just under fifty percent, meaning such a world would contain half as many bird species as the present one.

If we look even farther ahead than Elton did—millions of years farther—the biological world will, in all likelihood, become more complex again. Assuming that eventually travel and global commerce cease, the New Pangaea will, figuratively speaking, begin to break up. The continents will again separate, and islands will be re-isolated. And as this happens, new species will evolve and radiate from the invasives that have been dispersed around the world. Hawaii perhaps will get giant rats and Australia giant bunnies.

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The winter after I visited Aeolus with Al Hicks and Scott Darling, I went back with another group of wildlife biologists. The scene in the cave was very different this time around but no less macabre. Over the course of the year, the piles of bloody dead bats had almost completely decomposed, and all that was left was a carpet of delicate bones, each no thicker than a pine needle.

Ryan Smith, of the Vermont Fish and Wildlife Department, and Susi von Oettingen, of the U.S. Fish and Wildlife Service, were running the census this time around. They started with a cluster of bats hanging at the widest part of Guano Hall. On closer inspection, Smith noticed that most animals in the cluster were already dead, their tiny feet hooked to the rock in rigor mortis. But he thought he saw some living bats among the corpses. He called out the number to von Oettingen, who’d brought along a pencil and some index cards.

“Two *lucis*,” Smith said.

“Two *lucis*,” von Oettingen repeated, writing the number down.

Smith worked his way deeper into the cave. Von Oettingen called me over and gestured toward a crack in the rock face. Apparently at one point there had been dozens of bats hibernating inside it. Now there was just a layer of black muck studded with toothpick-sized bones. She recalled having seen, on an earlier visit to the cave, a live bat trying to nuzzle a group of dead ones. “It just broke my heart,” she said.

Bats’ sociability has turned out to be a great boon to *Geomyces destructans*. In winter, when they cluster, infected bats transfer the fungus to uninfected ones. Those that make it until spring then disperse, carrying the fungus with them. In this way, *Geomyces destructans* passes from bat to bat and cave to cave.

It took Smith and von Oettingen only about twenty minutes to census the nearly empty Guano Hall. When they were done, von Oettingen tallied up the figures on her cards: eighty-eight *lucis*, one northern long-eared bat, three tricolored bats, and twenty bats of indeterminate species. The total came to 112. This was about a thirtieth of the bats that used to be counted in the hall in a typical year. “You just can’t keep up with that kind of mortality,” von Oettingen told me as we wriggled out through the opening in the slats. She noted that *lucis* reproduce very slowly—females produce only one pup per year—so even if some bats ultimately prove resistant to white-nose, it was hard to see how populations could rebound.

Since that winter—the winter of 2010—*Geomyces destructans* has been traced to Europe, where it appears to be widespread. The continent has its own bat species, for example, the greater mouse-eared bat, which is found from Turkey to the Netherlands. Greater mouse-eared bats carry white-nose but don’t seem to be bothered by it, which suggests that they and the fungus evolved in tandem.

Meanwhile, the situation in New England remains bleak. I went back to Aeolus for the count in the winter of 2011. Just thirty-five live bats were found in Guano Hall. I returned to the cave in 2012. After we’d hiked all the way up to the entrance, the biologist I was with decided it would be a mistake to go on: the risk of disturbing any bats that might be left outweighed the benefits of counting them. I hiked up again in the winter of 2013. By this point, according to the U.S. Fish and Wildlife Service, white-nose had spread to twenty-two states and five Canadian provinces and had killed more than six million bats. Although the temperature was below freezing, a bat flew up at me as I stood in front of the slats. I counted ten bats clinging to the rock face around the entrance; most of them had the desiccated look of little mummies. The Vermont Fish and Wildlife Department had posted signs on two trees near the entrance to Aeolus. One said: “This cave is closed until further notice.” The other announced that violators could be fined “up to $1000 per bat.” (It was unclear whether the sign referred to living animals or to the much more plentiful dead ones.)

Not long ago, I called Scott Darling to get an update. He told me that the little brown bat, once pretty much ubiquitous in Vermont, is now officially listed as an endangered species in the state. So, too, are northern long-eared and tricolored bats. “I frequently use the word ‘desperate,’” he said. “We are in a desperate situation.”

The same corner of Guano Hall photographed in, from left to right: the winter of 2009 (with hibernating bats), the winter of 2010 (with fewer bats), and the winter of 2011 (with no bats).

“As a brief aside,” he went on, “I read this news story the other day. A place called the Vermont Center for Ecostudies has set up this Web site. People can take a photo of any and all organisms in Vermont and get them registered on this site. If I had read that a few years ago, I would have laughed. I would have said, ‘You’re going to have people sending in a picture of a *pine tree*?’ And now, after what’s happened with the little browns, I just wish they had done it earlier.”