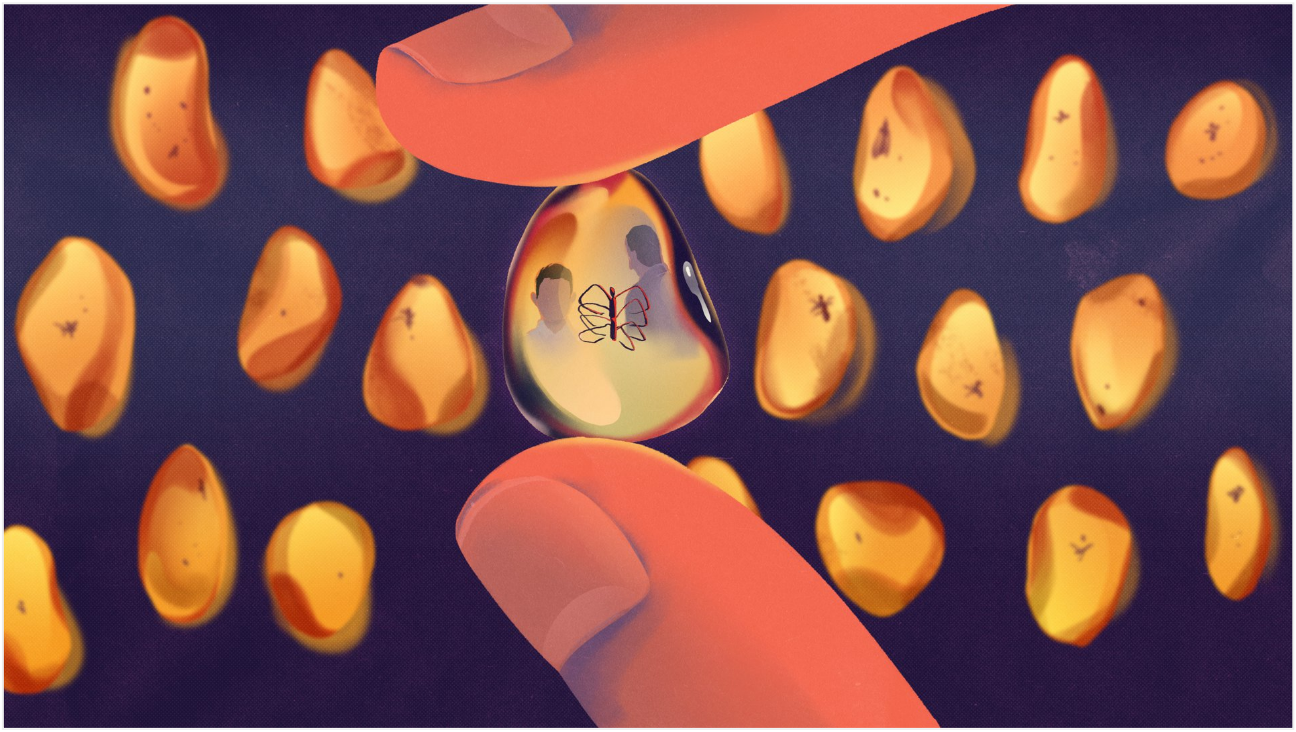
The Human Cost of Amber

Fossils preserved in sap offer an astonishingly clear view of the distant past, but they come at a high price.



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KATHARINE GAMMON

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ILLUSTRATIONS BY CORNELIA LI

MATTHEW DOWNEN HAD never done anything like this before. In a hotel room in Santo Domingo, the capital of the Dominican Republic, he watched as a dealer poured a bag of amber fossils onto a white towel spread over a desk.

The previous night, at the opening reception for the eighth International Conference on Fossil Insects, Arthropods, and Amber, Downen had gotten a tip from a friend: A guy here had spiders fossilized in amber, and he was looking for someone to take them.

Downen, a doctoral student in entomology at the University of Kansas, was initially ecstatic. Spiders for free? He had come to the meeting to present his research on spider diversity in ancient lake beds; more fossilized spiders could expand his findings. When he expressed his enthusiasm, he was quickly introduced to a large, jovial dealer named Jorge, who showed him a smartphone photo of a spider with an unusually long abdomen. "He was like, 'We've got all kinds of amber,'" Downen recalls. Jorge told Downen that if he was interested, he should meet him the next morning at 8—and bring cash. Downen realized that this was a commercial transaction, not a spider free-for-all.

Downen, a baby-faced student who wears an array of jeweled spider-shaped earrings and brooches, knocked on the designated hotel-room door the next morning. His stomach was churning: The ATM in his hotel had been out of pesos that morning, so he had no cash for whatever was about to take place. He was worried that he would be embarrassed, or that Jorge would be angry with him.

Once inside the room, Downen used a jeweler's loupe to peer at the pieces of thumbnail-size golden amber scattered on the towel. He heard a knock at the door, and was surprised when a well-known entomologist entered carrying a bag of samples he had decided not to buy. That entomologist was followed by several more, all of whom seemed to know Jorge. As Downen listened to their orderly, friendly transactions, he separated out the four blocks of amber that interested him most. Each contained a striking fossilized Dominican spider, legs curved beneath its body. He then asked to see the unusual spider he'd glimpsed on Jorge's cellphone the previous night.

That spider was stored in a separate box. Suspended in about one cubic inch of amber, its elongated abdomen looked like a twig. Downen immediately recognized the type from its living relatives, and he knew the long-extinct species hadn't been previously described. A single specimen could earn him a new publication—a sought-after accolade for a graduate student. But the price? Jorge quoted him $15,000. On Downen's student budget, there was no way.

Downen and Jorge turned back to the samples on the desk. "$50 per spider," Downen recalls Jorge saying. "You only want four? You don't want the whole bag?" Downen only wanted four, and he promised to get the money the next day, as soon as he could obtain more cash. He left the room with the spiders in a small plastic baggie and headed to the conference hall.

For scientists, amber is thrilling. It preserves ancient organisms in incredible detail, down to the veins in insect wings and the lenses on fly eyes. It even captures creatures in the middle of actions, such as running or laying eggs or mating. Studying fossils in amber after studying fossils in rock is like switching from grainy black-and-white television to high-definition movies. "With amber, you're actually seeing the full three-dimensional morphology," Downen says. "With fossils in rock, there is compression or flattening, so it's a two-dimensional surface."

While researchers have used amber for decades, new techniques and new finds are making it more scientifically valuable than ever. But amber, it turns out, comes at a high cost—both financial and human.

PEOPLE HAVE ATTRIBUTED mystical and healing properties to amber since Neolithic times. The Greeks knew that when amber is rubbed with wool, it creates sparks, so they dubbed the substance "electrum." Relatively soft, amber has been carved into beads and jewelry since the Bronze Age, and it can be polished to a gleaming finish. Many people have believed that amber's warm color and the way the material holds heat signify healing powers; today people in my Los Angeles neighborhood still adorn their babies with amber necklaces, since the succinic acid in amber is believed to ward off the pain of teething (though no evidence shows that it does).

That amber fossils exist at all is a bit of a miracle—a succession of miracles, even. First, a tree has to be oozing sap (in the Dominican Republic, amber forms from the sap of the Hymenaea tree). Healthy trees don't dribble goo—trees do so only when they are stressed by damage, insects, fires, or disease. The resin acts like a translucent bandage, protecting the tree from further injury.

Then, an insect or other creature has to be trapped in the resin. The most common victims are flies (about half of biological inclusions are flies), but social insects such as ants, bees, and termites are also often found in stalactites of resin. The creature either drowns as the sticky goo fills its mouth and spiracles (bug lungs) or starves as it struggles to escape the resin. Most insects or arthropods fossilized in amber are less than seven-eighths of an inch long, since larger creatures can usually pull themselves out of the resin's deadly grasp.

The resin must then land on wet, swampy soil and, eventually, end up in a freshwater current—if the resin lands on a dry forest floor, it will disintegrate into powder or crack into pieces. Once in freshwater, the resin must flow to an ocean or marsh, where it can be covered by sediment in an oxygenless environment. In this prehistoric kitchen, with millions of years of time plus pressure, the resin hardens into a polymer, in the same way plastic is made from petroleum. The resin has then become amber—nonreactive, stable, and a perfect preserver for the life caught inside.

When plate tectonics or erosion brings the amber to the surface, human hands can pick it up or chisel it out of the surrounding gray layers of lignite. For a chunk of amber to find its way to researchers, somebody has to notice that it has an insect in it. Somebody else has to recognize that the insect is of interest to scientists. "I mean, the chances of an individual specimen actually getting to us seems insanely slim," says Brian Brown, an entomology curator at the Natural History Museum of Los Angeles County.

[Read: The scientist who stumbled upon a tick full of 20-million-year-old blood]

Amber is found in many places around the world, from Alaska to Madagascar, but the largest deposits exploited for jewelry and science are in the Dominican Republic, the Baltic region of Europe, and Myanmar, also known as Burma. Each region represents a different era of Earth's geologic past: Dominican amber is the youngest, between 16 and 20 million years old; Baltic amber, which like its Dominican counterpart typically includes ants, flies, and lizards, is 40 million years old; and Burmese amber, whose vertebrate diversity is unparalleled, is about 100 million years old. By comparing the species and ecosystems represented in amber, scientists are starting to tackle giant questions about extinction, conservation, and the evolutionary history of the species we see today.

Though thousands of specimens do find their way into the hands of scientists, many more are put to industrial or decorative use. “The paleontological use—the fossil use—is really only a small amount of amber, and some people say distressingly small, because we know there is another aspect to amber: the private-collector side of things,” Brown says. “There’s a huge private-collector interest, as people who have money buy up huge amounts of some of the really great stuff. And then it's not available for study for scientists or other researchers.”

ON A FOREST PATH in the Dominican Republic’s eastern hills, I passed a tree that was oozing resin, and I reached out to touch the flow. It was firm but viscous; it was easy to see how an ant or lizard could get stuck in its sticky reach. The 16-million-year history of amber on this island is thought to have begun in a world much like this one, full of flowers floating in the breeze, caterpillars creeping up branches, crickets munching foliage, and lines of ants and termites moving busily up and down the conifers.

I had joined a group from the amber conference that was hiking to a working amber mine in the island’s Halto Plano region. We walked past mango trees, friendly pigs, and a few locals who were hacking open fresh coconuts and selling them to the passing scientists. After 20 minutes, the dirt road became a meandering path, then gave way to the bush. Sweat trickled down my back, and I thought of the 5,676 different species of insects that make the island of Hispaniola their home.

The island’s amber was used by the indigenous Taíno people for millennia, and when Columbus landed for the second time on Hispaniola, in 1493, he made a strategic trade: He gave a Taíno chief a strand of Baltic amber in return for shoes decorated with local amber. Gold was the island’s main export for the next four centuries, but when Baltic-amber stocks started to falter in the 1950s, the Dominican government started to invest in training artisans to work with amber. Those artisans were well prepared when global interest in the island’s amber gained steam in the 1960s, and locals started to dig pits and tunnels to mine amber by hand. It is said that in 1966, Dominican miners extracted about 4,000 pounds of amber each month.

The country banned the export of raw, or unpolished, amber in 1979 in a bid to protect local artisans. A decade later, it added to the law: Amber containing insects couldn't be exported without the consent of the National Museum of Natural History.

When the scientists and I reached the amber mine, it was marked by a red tarp propped up to offer some shade over its jagged mouth. It was little more than a hole in the ground, its sides supported by bamboo poles at each corner. Inside, 140 feet below the surface, three men were hand-drilling amber out of the surrounding rock. As we stood watching, a young man beside us walked toward a stationary motorbike whose engine was connected to a pulley. He revved the engine and the bike sprang to life, puffing out a cloud of smoke. The engine yanked the pulley, which raised a rope out of the mine—pulling up first a bucket of fist-size chunks of amber, then the workers themselves. One by one, they emerged, covered in clay, barefoot, and shirtless. They seemed surprised by the dozens of onlookers gathered in the heat of the day, and they sauntered away to talk with the owner of the mine, who was watching nearby.

With the miners safely on the surface, we began to dig through the clay silt around the mouth of the mine. One scientist dropped to his knees and licked the rocks—lignite, in which amber is most often embedded, has a recognizable flat tang. I found two pinkie-nail-size crumbs of clear golden amber embedded in the sediment. Others found more, but none of the bits contained insect inclusions. Small chunks are more likely to contain inclusions than large pieces; most large pieces are formed under the bark of trees, where insects are unlikely to hang out.

After watching the shoeless men chisel more large pieces of raw amber from the mines, our group loaded onto a boat to explore a mangrove swamp. I fell into conversation with Lida Xing, an amber scientist from the China University of Geosciences in Beijing. Xing is something of a nerd superstar in China: He has more than 2.6 million followers on Weibo, China's version of Twitter, and has published a dozen young-adult fantasy books about dinosaurs. A devoted dinosaur hunter, he has examined dinosaur tracks at more than 100 sites across China.

[Read: The 99-million-year-old dinosaur feathers in a chunk of amber]

Since 2013, Xing has turned his attention to the tons of amber coming out of mines in Myanmar, which have yielded a dizzying array of fossils, including a feathered dinosaur tail and lizard eggs. In early July, Xing published a paper on an unusually long bird toe found in 99-million-year-old amber. I asked Xing what he thought of the mines and amber we had seen that day. "If one is incredibly safe and 10 is completely dangerous, the safety of those mines today were a five or six," he told me. "The mines I've seen in Burma are a nine or 10."

AMBER HAS A WAY of capturing the human imagination—and wallets—and holding it tight. Annual global sales of amber number in the hundreds of millions. Raw amber prices are set by the market, and after the release of the movie *Jurassic Park*, in the early 1990s, prices of amber with insect inclusions —particularly rare mosquitoes—soared. During a more recent craze among Chinese buyers for a rare blue-tinged type of Dominican amber, amber prices reached a record high of $450 a gram—hundreds of times the price of gold. (At that rate, a penny-size chunk of amber would cost about $2,000.)

Though raw amber has a set wholesale price, the price of amber with insect inclusions is more subjective. Dealers who specialize in selling to collectors and scientists first inspect the insect and determine how unusual it is. "If you're talking about an ant, it's not going to be a huge price increase over the cost of the raw amber," says Doug Lundberg of Amberica West, one of the biggest amber-sales websites. "If it's a unique and rare bug, it commands a higher price."

Dealers then assess the clarity of the specimen and the size of the piece of amber surrounding it. "A lot of people want large insects you can actually see without a jeweler's loupe," Lundberg says. "Those don't come along very often."

And forgeries are part of the game, Lundberg says: People have been pouring amberlike goo over flies, lizards, and spiders for at least 600 years. Lundberg has seen forgeries made out of plastic, glass, casein, and copal—young resin that hasn't completed the fossilization process. To test authenticity, dealers use everything from acetone baths (copal gets sticky in acetone, but amber doesn't) to scratches (true amber is only as hard as a fingernail, and will scratch) to salt water (amber and copal float, while glass and some plastics sink). Staying one step ahead of the competition is tricky, Lundberg says, especially if the competition is making fakes.

Lundberg, a high-school science teacher at the U.S. Air Force Academy in Colorado Springs, Colorado, was teaching a course on genetic sequencing when *Jurassic Park* came out in 1993. He had been buying amber from the Dominican Republic, breaking it open, and extracting the proteins in extinct insects. "I had just been playing around in amber before *Jurassic Park* came along," he says. "And suddenly I realized: I had all this amber, and I could sell it."

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It's hard to overstate what *Jurassic Park*, based on Michael Crichton's novel about a group of scientists who re-create dinosaurs from the DNA in blood sucked by a mosquito caught in Dominican amber, did for the world of amber. Prices soared, especially for Dominican amber. Amber shops in Santo Domingo still have the movie's poster hanging over their wares.

[Read: The Jurassic Park period: How CGI dinosaurs transformed film forever]

Meanwhile, some scientists saw—and still see—*Jurassic Park* as a black eye on their field. David Grimaldi, the invertebrate curator at the American Museum of Natural

History in New York, started working on new ways to analyze amber in the early 1990s. The PCR machine, invented in 1985, had allowed scientists to make millions of copies of a single sample of DNA, and PCR analysis by Grimaldi and his colleagues in 1992 indicated that there were snippets of genetic material in a termite in Dominican amber. They published their findings in the journal Science, and the following year, the journal *Nature* published the results of DNA sequencing from a weevil trapped in Lebanese amber. That paper was published on the day the *Jurassic Park* movie came out—potentially the only time the scientific press has timed a paper's release to a pop-culture event, Grimaldi says.

Suddenly, amber was having a moment. The number of people requesting talks and appearances by scientists who were looking for DNA in amber skyrocketed, Grimaldi recalls. The American Museum of Natural History put on a big exhibit on amber—displaying everything from panels from an immense amber room in Russia to late–Stone Age amber carvings to fossils. "That was a huge success of a show," he says. "But the reason it was such a success was *Jurassic Park*. And that really captured the popular imagination."

By the late 1990s, interest in amber began to wane. The initial studies showing that amber could preserve traces of DNA weren't replicated, and scientists eventually abandoned the genetic studies. They now think that DNA degrades after about 6.8 million years, so there's no chance of getting a full sequence based on 100-million-year-old snippets. (Other reasons *Jurassic Park* couldn't happen in real life: There are no known insect-bearing Jurassic ambers, and mosquitoes are incredibly rare in amber.)

But recently, new research into proteomics—the study of amino acids preserved in amber, including Cretaceous-era Burmese amber—is reviving interest in amber within the scientific community. "It's again that the science is being driven by technology, but we are going back with more sophisticated technology," Grimaldi says. In April, scientists were able to recover amino acids from two fossilized feathers in amber. Sequencing ancient proteins could offer another way to examine evolutionary relationships and determine why some species go extinct while others continue to thrive—a question of great interest to Grimaldi, who is using paleontological evidence to test recent claims of an imminent "insect apocalypse." Once again, genetics is on the brink of taking over the world of amber research.

WHEN LIDA XING TOOK the stage at the Santo Domingo conference on a Thursday morning, the audience was ready for a deep dive into Burmese amber. The scientists and dealers at the conference were mostly paleoentomologists—specialists in using amber to understand ancient insects—but Xing didn't start his presentation with striking images of flies or bees. He started with a description of the mines in Myanmar, which he visited twice, in 2014 and 2015, after sneaking over the Chinese-Burmese border disguised in local clothes.

The amber mines are located in the Hukawng Valley of Kachin, Myanmar's northernmost state (also known for other resources such as jade, gold, and wood). In local dialect, the remote jungle valley is known as the "Place of the Devil." As Xing explained, the mines in Hukawng have existed for 100 years, but for decades they were relatively shallow. When ruby miners moved into the area from the south 10 years ago, they used their more sophisticated technology to dig deeper, and began to find new deposits of amber about 100 meters down.

War kept international investors out of the region—the area's Kachin people have been fighting for independence from Myanmar since 1962—but during a cease-fire in the 1990s, a Canadian mining company started to work in the mines, and as scientists and jewelry makers recognized the size and age of the Burmese deposits, interest grew. Around 2010, China's own amber mines were tapped out, and the production of Burmese amber grew. Today an estimated 10 tons of amber is taken out of Burmese mines every year.

Xing told the group that tens of thousands of people work in the Kachin mines, many of them teenagers (the mine shafts are so narrow that only slender people can fit into them, going two at a time), and that hundreds are killed every month when the mines flood or cave in. The area is also loaded with land mines from the ongoing conflict between the Kachin separatists and the Burmese army, so even on the surface, it's easy for locals to get hurt.

Once Burmese amber is extracted from the mines, it's transported—usually via elephant—over pitted paths to trucks that deliver it to markets in the south of China. The generals who control the area sometimes alert Xing when an interesting inclusion is found in the amber. And there are a stunning number of inclusions: In 2000, only 60 total species were described from Burmese-amber deposits. In 2018 alone, 323 new species were described—the largest number in any year, from any location. Today the total number of species described from Burmese-amber deposits is around 1,200. "The sheer volume of papers coming out is absolutely impossible to keep up with," says Andrew Ross of National Museums Scotland. "I'm hoping it's going to level off at some point."

For all those discoveries, though, the mines haven't produced any new amber in two years: As the conflict between the Kachin Independence Army and the Burmese government has raged on, the government has taken over the area where the mines are located, and many of the deepest ones aren't operating. The profits from selling amber are also financing the ongoing conflict in the region, leading to more danger for local people. Xing isn't worried about his research, though: He already has enough Burmese samples for years of analysis.

[Read: In the new Burma, one marginalized group has yet to see peace]

After spending about 10 minutes describing the Burmese mines, Xing addressed some of his most spectacular fossil findings, including a bird wing, frogs, salamanders, snakes, crustaceans—and, possibly, a second dinosaur. Xing displayed a painting of a Cretaceous-era Burmese forest, complete with trees, insects, marine life, and dinosaurs. It was enough to make the heart soar—100-million-year-old life, now known in spectacularly rich detail.

When he finished his talk, the room quieted, and I shifted in my seat, thinking about those teenagers scraping at the hot, dark, wet earth 300 feet below the surface. Then a hand shot up to ask a question: "What beetles are your dinosaur eating?"

Even if it wasn't apparent in that room, a handful of scientists are starting to consider the human cost of buying Burmese amber. At the meeting in Santo Domingo, Grimaldi said he was starting to avoid amber from Myanmar—partly because the Chinese scientists tend to get first dibs, and partly because he knows it has been mined at great risk.

A FEW WEEKS LATER, after learning more about the Burmese mines from press reports, Grimaldi had made a clear decision. "The situation in Myanmar sounds sickening. I'm out; no more Burmese amber purchases, not if it fuels this bloodshed and violence," he told me via email. "I will continue to work on material at hand, that's it." I also heard from the L.A. County Museum of Natural History scientist Brian Brown. "I am shocked and dismayed by this information, and I want nothing to do with such violence," he wrote. "I am not buying any more Burmese amber, although I will work on the material I already have in hand."

How much should scientists care about where their samples come from? I asked myself, and others, that question many times during the week I spent in the Dominican Republic. Many of the scientists shrugged off the question, or said it didn't apply to the work they did. Only a few truly engaged. "I want to be able to sleep at night," said Leyla Seyfullah, a paleobotanist at the University of Göttingen in Germany. Seyfullah has drawn a line for herself: She studies only specimens that she personally digs up, or that she buys directly from miners. In the Dominican Republic, she bought a large chunk of fossilized tree bark from the amber miners—a specimen she said will be used as a teaching tool.

As soon as you start paying for something, you open up a world of questions about its true cost. Seyfullah was slightly queasy about all the wheeling and dealing she saw at the meeting. She's a paleobotanist, and plant fossils aren't as lucrative a market—so she hadn't dealt with the commercial aspect of amber before. As soon as you start putting a number on the value of a scientific sample, science changes in intangible and tangible ways, as valuable specimens often end up in the hands of collectors. Seyfullah still fantasizes about a world where specimens for scientific study are freely given, but she knows that's not likely to happen in the near future.

When Xing mentioned that the teenagers working in the mines weren't there because they wanted to be, Seyfullah turned to her seatmate and said, "That sounds like slave labor." "It's kind of tacitly acknowledged in these discussions, but no one has used the word slave," she told me. "Perhaps it's labor that's not free and willing, but not completely forced. It's still not okay." And between the lines of Xing's talk, she heard hints of another problem: "It sounds like there's an invisible infrastructure of people controlling the trade routes with guns, and they're somehow getting it over the border to the markets in China."

Seyfullah did start talking with her colleagues at the meeting about the ethical considerations of buying and studying Burmese amber. Some of them, she said, reasoned that their business helps desperate people make a living. Others reasoned that since scientific uses represent less than 1 percent of the overall amber market, jewelry makers should lead the ethical charge.

Seyfullah doesn't buy these arguments. There's also a scientific case against working with Burmese amber, despite the dizzying array of new species it contains: Since scientists haven't studied the areas in Myanmar where the amber is being dug up, there's no way to accurately know its age. Some researchers think the Burmese samples span at least 5 million years. "We don't even have photographs of the layers in this region, so it's so hard to interpret these features—you just don't know where the inclusions fit in the Cretaceous," Seyfullah said. Some scientists are in it just to be the "first person to describe stuff," she said, but she wants the full picture of where the new findings exist in the broader geological history. Why were these trees secreting so much resin during these particular times? Were there rapid weather changes, or giant fires or floods?

The ethical questions are complicated by the fact that amber falls into a gray area in museum collections and export laws. In botany, a specimen must have a museum's collection number on it to even be eligible for publication. There's a botanical code and an animal code. Not so with amber. And in Myanmar, for example, exporting fossils without permission is illegal, but amber is classified as a gemstone.

Amber does fall under the auspices of the Nagoya Protocol, which provides a legal framework for the equitable sharing of benefits arising out of the utilization of genetic resources. But that protocol was set up to make sure local and indigenous people receive profits from developing products (medicines, materials, and the like) taken from their land—it's not about protecting people from unethical or illegal labor practices. "Amber isn't rhino horn. It's not an orchid. It just doesn't fall under most agreements about collection from overseas," Seyfullah said. "It's also not going extinct, so the paperwork you need to import it is much less complicated."

Right now, it's up to each museum, or each individual scientist, to decide which specimens to purchase—and there is no consensus.

At the end of the conference, the International Palaeoentomological Society chose the location for its next meeting. Representatives from Germany and China made their pitches to the members. The scientists dropped their votes into a box, one by one. The election was close—just four votes separated the two potential hosts. In the end, China won, assuring that the scientific discoveries coming out of Myanmar are enough to assuage the ethical burden of their provenance. I went home with a small sandwich baggie of amber, which I inadvertently smuggled back to Los Angeles (taking raw, non-polished amber out of the Dominican Republic is illegal), and Matthew Downen took home his four spiders, after he scrounged up the pesos to pay Jorge. Seyfullah took home her chunk of fossilized tree bark, and Xing went home with half of a lizard in Dominican amber.

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