**Annie Rosenthal:** In the spring of 2022, my mom went into the mailroom at the university where she works, in DC. In her box, there was a big, flat envelope, addressed to her, Martha Weiss. She didn't recognize the sender: "Jo Nagai." J-O, no E. Inside, there was a handwritten letter, four pages long.

Martha Weiss: So, shall I read you part of the letter?

Rosenthal: Please!

**Martha:** "To Martha Weiss. Hello! Nice to meet you. My name is Jo Nagai. I'm from Japan. I live in Kobe, Japan. I'm in the second grade at Ibuki Elementary School. When I found your research on the internet, I was so delighted."

Rosenthal: Two exclamation points!

Martha: Two bold exclamation points.

**Rosenthal:** My mom is an entomologist. She studies insects. And she gets letters from strangers pretty often. They're mostly about this one study she worked on. She and her student were studying moths. And they figured out that an adult moth could remember something it learned as a caterpillar. Even after metamorphosis, the memory carried through.

It made kind of a splash.

**Molly Webster (***Radiolab***):** What's your—what's your feeling, like, coming out of this?

Martha (on Radiolab): My feeling is "Wow!"

Rosenthal: This is my mom on Radiolab.

**Martha (on Radiolab):** I think it's amazing that a caterpillar can have an experience, go into its chrysalis, five weeks pass, emerge as a seemingly different organism, and that it still can recall experiences that happened to it when it was a caterpillar.

Jad Abumrad (on Radiolab): Freakin' cool, I gotta say.

**Rosenthal:** There were a lot of interviews like that. And a lot of emails.

But the letter that my mom picked up that day at work was different from any of the fan mail she'd gotten before.

For starters, the author was a kid. In second grade. Writing from the other side of the world. But more importantly? He was writing to tell her that he was an insect scientist himself.

In the letter, Jo described his discoveries.

Martha: "I've studied swallowtail butterflies for three years ... "

**Rosenthal:** In kindergarten, he'd investigated how long a swallowtail butterfly could stay alive if it got stuck in its chrysalis. In first grade, he'd found caterpillars that molt more often than usual. But now, Jo said, he was hoping to try something a lot more complicated.

**Martha:** "I've always thought that my butterflies could remember me even after their metamorphosis, because they always flutter around me whenever I try to let them go into nature. But sadly, some say that's impossible and ridiculous. I have some questions to you. Have you ever experimented in swallowtail butterflies? I want to try to find if a swallowtail butterfly could remember what it learned as a caterpillar."

**Rosenthal:** Jo, an eight-year-old, wanted to replicate my mom's groundbreaking experiment—because he wanted to know if his butterflies could remember *him*.

Martha: I came home and said to Dad, "Look what I got in the mail. This is the most fun letter I ever got."

Josh Rosenthal: Yeah, I was there when the package came.

Rosenthal: That's my dad, Josh.

**Josh:** Full-size sheets of paper with his handwritten letters, photos of himself!

Martha: A very cute kid with glasses.

Josh: And his butterflies.

**Martha:** He's looking through a magnifying glass. And then there are two pages of data figures.

**Josh:** I mean, she was laughing and reading with her mouth wide open. I thought it was wonderful.

**Rosenthal:** Jo had no idea what a perfect correspondent he'd found. Because the only audience my mom respects more than her entomological peers is small children.

**Martha:** They are curious about stuff and they haven't figured out that it's boring to look at plants or bugs.

**Rosenthal:** She's diagnosed elementary school as the last chance to intervene—before the veil of indifference descends.

**Martha:** Seventh grade, eighth grade, "Is it gonna be on the test? Do we have to know that?" Second grade, third grade, bingo.

**Rosenthal:** Something horrible must happen in fifth and sixth grade.

**Martha:** Puberty. Everybody becomes more interested in each other than the bugs. Which is good because it helps our species persist.

**Rosenthal:** Outside her academic work, my mom has spent decades weaseling her way into children's classrooms, to make the case for the humble arthropod. She brought poop-shooting caterpillars to my kindergarten. She organized cricket races at my sister's tenth birthday party. Every year, she and her colleagues crawl around the woods collecting caterpillars to show off at schools around the city. They call it the Caterpillar Roadshow.

So, with Jo Nagai — my mom wasted zero time in writing him back.

**Martha:** "Dear Jo Nagai, I was so excited to get your packet in the mail. It was such a fun and interesting letter. I loved reading about your experiences and discoveries and I'm so happy to have a new friend in Japan who loves caterpillars and butterflies as much as I do."

**Rosenthal:** To be clear, she didn't actually think Jo could recreate her experiment. The way that she and her grad student, Doug Blackiston, had done their study, was by training caterpillars to hate a specific smell, and then testing whether, once those caterpillars became moths, they still hated the smell.

They did the training with this elaborate lab set-up where they'd release the chemical smell, then give the caterpillar an electric shock, so it would associate the smell with pain. Not totally a kid-level project. So, in that first letter, my mom suggested Jo try something simpler. Like, teaching butterflies to learn colors.

**Martha:** I could help you test this with your swallowtails, which might be a great research project for third grade.

**Rosenthal:** So here you're giving him the old, "Why don't you try colors before memory through metamorphosis?"

**Martha:** Exactly. "I could write so much more, but want to send this off now, so you will know how happy I am to have heard from you. Your friend, Martha Weiss." And then I included some pictures, a zebra swallowtail butterfly and an eastern tiger swallowtail. Just to show that we both are swallowtail aficionados.

**Rosenthal:** A few weeks later, she got a response.

**Martha:** "Dear Professor Martha Weiss, thank you very much for your reply. I was so happy and surprised to have a reply from you. I couldn't believe it first. Thank you very much."

**Rosenthal:** Jo politely expressed interest in her color-learning experiments and thanked her for the butterfly photos:

Martha: "Their blue is so beautiful and like deep ocean."

Rosenthal: But he stuck to his guns on the memory stuff.

**Martha:** "I really want to prove it's possible that my butterflies can remember what they learned as a caterpillar. I don't want to give up now. I really need your help."

**Rosenthal:** And Jo wasn't waiting for her approval. He told her he'd already started adapting her protocols for his own at-home lab.

Martha: "But I don't have any devices in my house. I can't make electronic shocks."

**Rosenthal:** This wasn't what my mom had expected. The letter was so serious. *Jo* was so serious. So, that summer, they became regular pen pals.

In his emails, Jo kept her up to date on his work. And he was confident! Like, he wasn't afraid to question my mom's research methods. Why, for example, she'd chosen the chemical she'd used to train the caterpillars.

**Martha:** "I have no idea why you picked ethyl acetate for the experiment of *Manduca sexta.*" I felt a little bit defensive about my use of ethyl acetate...

Rosenthal: Still, in every email, Jo thanked my mom for her time and attention.

Martha: "I know you're so busy, but I'm so happy when you write me back."

**Rosenthal:** In the fall, he wrote to say his study was done. It was thirty-three pages, in Japanese, but he'd helpfully translated the basics.

He said he'd done essentially the same study as my mom. Trained caterpillars to hate a smell, tested whether they'd avoid it as butterflies. He'd used a little muscle therapy device to give the shocks, and lavender oil instead of that toxic chemical for the smell. So the caterpillars learned to hate the lavender.

And, according to Jo, when those caterpillars became butterflies, eighty percent of them still avoided the smell.

If what Jo said was true, not only had he replicated my mom and Doug's groundbreaking experiment, at home, over summer vacation, but he'd found their same results in a whole new species. They'd studied moths, but he was the first person in the world to show that memories could persist through metamorphosis in butterflies.

Rosenthal: And what did you think when you got that email?

**Martha:** I was flabbergasted and delighted. And in this letter I thought, holy cow, he's a real scientist, and he's figuring out new stuff.

**Rosenthal:** As the months went on, my whole family became obsessed with Jo. We talked about him all the time.

**Josh:** You just don't expect to see or hear that level of sophistication out of anybody without a PhD.

Rosenthal: My dad again.

Josh: Definitely not someone in elementary school.

**Isabel Rosenthal:** We go to see friends or family or something and we're like, "You gotta know, here's the latest updates on Jo Nagai."

Rosenthal: My sister, Isabel.

**Isabel:** What's the new tea? What's he up to these days? What has he discovered? What kind of, you know, like, advances has he made?

**Harrison Smith:** Every time I talk to your parents, I get the parents update and I get the Jo Nagai update.

Rosenthal: My boyfriend, Harrison.

Harrison: And there's always something exciting.

**Rosenthal:** For example: In September 2022, Jo presented his research to scientists at Shinshu University. Then at Tsukuba University and Saga University. He also graduated from second grade.

And then, in the spring of 2023, Jo wrote to my mom, rather casually, that he had a whole new research question. He wrote, "By the way, I'd like to study if memories can be inherited to the next generation this summer."

Jo wanted to study if caterpillar children could remember things that had happened to their parents.

"I know that most people generally think memories can't be inherited from ancestors," Jo wrote. But he'd found a recent study that suggested it might be possible in nematodes, these tiny, freaky worms. If they could do it, he thought, why not swallowtails?

Martha: It had never occurred to me to even ask that question.

**Rosenthal:** Jo's first study was advanced, but this was a whole other realm. Epigenetics. The ways environment and experience can change how our genes are expressed, even across generations. It's a field of my biology my mom calls The New Frontier. And it's not exactly her area of expertise.

**Martha:** I don't live on the frontier. I live in the heartland. And so when he said, "I read the nematode paper," I had to scramble and find the nematode paper. I was too embarrassed to ask Jo, "Which nematode paper?" Because I didn't want him to be too much ahead of me on the up-to-the-minute research.

**Rosenthal:** The inheritance of memory has only been studied in a few species: those worms, some mice.My mom wrote back to Jo: "This is a controversial topic, but that doesn't mean that it doesn't happen. We can learn more by doing more studies!"

Jo forged ahead. He did his experiment again, but tested a second generation, too, to see if they avoided the same smell he'd trained their parents to hate. And a few months later, he wrote to my mom that the results were clear. His butterflies had passed their memories on to their children.

When I was growing up, bugs were a central feature of our household. They were just always around. My mom raised silkworms in a box in the dining room, and she kept cicada exoskeletons in a jar in the kitchen, which my teenage friends found horrifying. She was waging the pro-bug campaign on the home front. And for a while, it worked.

**Martha:** You don't squish bugs and you don't scream when you find a spider in the bathtub. I consider that a victory.

**Rosenthal:** But I guess at some point, that dreaded veil of indifference fell over me, too. Or maybe it was just puberty. By the time I was in high school, I was less interested in bugs and more interested in people. These days, my extracurricular reading is about stuff like historical memory, how experience moves down through time. That's what I'm always trying to report on, although my editors tend to steer me towards The News.

But now, my mom's tiny genius pen pal was saying he had proof that in this one species, what happens in a parent's early life can show up in their kid. The inheritance of traumatic memory. The caterpillar body keeps the score.

My mom is always warning me against anthropomorphism. But in a way, it seemed like Jo was asking the same question I often am: how we get to be who we are.

Sound of Martha typing

Martha: "How to say butterfly in Japanese."

Typing

Martha: Cho! Oh, I know that. I knew that because Madame Butterfly.

**Rosenthal:** A while back, my mom got this note from Jo:

**Martha:** He said, "Dear Professor Martha Weiss, Hello, how are you? Blah, blah, blah. Is it getting colder in your town too? How do your caterpillars and butterflies spend during cold winter? Well, do you know the International

Congress of Entomology, ICE 2024? The website is as follows, with the URL. It will be held in Kyoto, Japan in 2024. Are you going to come and attend it? If you come there, I'd like to see you and can show you around Kyoto, Osaka, and Kobe, my town."

**Rosenthal:** My mom did in fact know the International Congress of Entomology. It's one of the biggest conferences in the field. It was happening in August. She hadn't been planning on going this year, but a personal invite from Jo changed the equation. And once she'd decided to go, there was no question. Actually, all of us would come to Japan. My entire family—plus my boyfriend—bought plane tickets.

In the months leading up to the trip, my mom helped Jo with his application to present a poster at the conference. She thought he had basically a dissertation's worth of research. She, on the other hand, was bringing a plan for an experiment she hadn't actually started yet.

Rosenthal: Maybe he can lend you one paper.

Martha: Yeah. Just, just come on.

**Rosenthal:** I loved the story of Jo. This child prodigy, showing up my mom, Esteemed Entomologist. And I was telling everyone I knew about his big finding. But now we were about to actually meet him, and part of me had started to worry. Over two full years of correspondence, my mom and Jo had never actually spoken. In fact, she wasn't even writing him directly.

Rosenthal: You're emailing his mom's email.

**Martha:** Cuz he doesn't have his own email. So his mother is the invisible portal through whom we communicate. So his mother is named Sarry. And so I get an email from Sarry and it says, "Hi, this is Jo." And then I write to Sarry and say, "Hi, Jo."

Although two times ago I wrote and said, "Hi, Sarry, this is Martha Weiss. Jo invited us to come visit him in Kobe and so I just wanted to check in with you." And have I heard from Sarry? No. But I did hear from Jo what hotel he and his mother, Sarry, will be staying in in Kyoto, so I made reservations at that hotel too. **Rosenthal:** Which—I'm interested in this dynamic. Like, do you feel like you need to talk to his mom?

Martha: I kind of do.

Rosenthal: Cuz you're sort of emailing a child all the time?

**Martha:** Well, I feel the science is between me and Jo. But when he says, come visit me at my home in Kobe, then I need to check with his mom.

Rosenthal: Have you ever thought about, like, Zooming him?

**Martha:** I guess I did initially, but...I don't know, there's something sort of nice about writing.

**Rosenthal:** It's sort of Jane Austen of you guys.

Martha: It's a little more Jane Austen, exactly. I think he feels that way too.

**Rosenthal:** I mean, do you like the mystery? Do you like that we just, like—I mean, Jo Nagai is like a national hero in our house.

**Martha:** Yes. I do like the mystery. I think that's part of it. And to be honest, I'm a tiny bit nervous about meeting him in person.

Rosenthal: What are you nervous about?

**Martha:** I don't know. I mean, I guess our correspondence is, it's all about science and butterflies, and there's nothing else in it. Like, what if he's, like, a mean kid who has temper tantrums and, you know, kicks and screams and bites his baby sister, or—you know?

**Rosenthal:** I can't imagine that Jo is a biter. But are you at all worried that he's a catfish?

**Martha:** Well, let me just say that I only recently learned the term catfish. And some people have said to me, is this kid for real? Do you think that this is an elaborate ploy?

**Rosenthal:** You're sort of a trusting correspondent.

**Martha:** I'm a trusting correspondent. So, can you explain to me exactly what a catfish is?

**Flight attendant:** Welcome to Tokyo. The local time is 2:55 in the afternoon on August 15th. Please stay comfortably seated until the seatbelt sign has been turned off.

**Rosenthal:** When we got to Japan, Jo still had a few days of school before the conference, so we had to find ways to distract ourselves. Which wasn't hard—we were surrounded by amazing and surprising things.

### Toilet noise

**Rosenthal:** Like, the public toilets that automatically make the sound of a waterfall and birds chirping to cover up any embarrassing pee noise. And the beautiful glowing vending machines on every other block. At any time of day or night, you can pop in a couple hundred yen and get a whiskey highball, or a sippy cup of apple juice, or a perfect sports drink called Pocari Sweat.

### Cicadas

But the most amazing and surprising thing? Bugs were everywhere. In the trees outside temples, restaurants. But also, on t-shirts, book covers, street signs.

### Kids chattering

On the subway, we saw a poster for an insect show at the Tokyo Museum of Nature and Science. Inside, the hall was packed with hundreds of people, more excited than I've ever seen anybody in a museum, honestly. And they weren't just stopping at the iridescent butterfly wings. They were reading about the way a spider disguises itself to mimic an ant. Structural color. Parasitic wasps. **Akito Kawahara:** Yeah, you see that a lot in Japan, you know, you go to just a public park in the center of Tokyo and you'll see a parent with a butterfly net with their child carrying a little insect cage.

**Rosenthal:** This is Akito Kawahara. He's a big deal in bug science, the director of a center for butterfly and moth biodiversity in Florida. And he grew up in Tokyo.I called him to ask, basically, is this a thing? Or was I just on high alert for bug stuff? Like, the bug-shaped toys we saw all over the city.

**Kawahara:** So, gacha gachas....So, what it is, is essentially it's a gumball machine, where you put some money, a dollar or two, into a machine...

Martha: One. Two. Three.

Sound of coins going into machine

Kawahara: And a ball comes out.

Martha: Ready?

Rosenthal: Yep.

Sound of machine turning

Kawahara: And inside the ball there's a toy.

Rosenthal: It's a big boy!

**Kawahara:** And there's a whole bunch of insect ones. And some of these insect ones are extremely realistic.

Rosenthal: Yeah, look how much you can make it move around.

Martha: That's a deal for an articulating beetle.

**Rosenthal:** Steal. And then, look, we should get another one, so they can fight!

**Rosenthal:** Japanese pop culture isn't just full of bugs, it's full of *youth* insect enthusiasts. Akito told me about a video game where you play a kid helping a scientist collect and identify escaped bugs. And the guy who created Pokemon: he started out wanting to be an entomologist. The game came straight out of the years he spent scouring the wilderness for bugs.

People here have been insect fans for a long time. More than a thousand years ago, Japanese nobles kept crickets in cages to listen to their chirps. In the late 1800s, kids' magazines aggressively advertised bug collecting to patriotic and masculine boys. By the 1930s, insect hobbyist societies had hundreds of members who'd go on collecting trips, tromping around the forest and posing with their butterfly nets like big game hunters.

Beetles in particular became kind of a status symbol. An exotic pet.

**Kawahara:** It got to the point where, you know, people were trying to grow the biggest beetles and then they would sell them. And in one case, one of the beetles sold for an incredible \$90,000.

Rosenthal: One of Akito's closest friends actually raises beetles.

**Kawahara:** Every time I go back to Japan, he's driving a different colored Ferrari. And oftentimes I joke that I might've made the wrong decision in my career to become a scientist. And maybe I should have just reared beetles and had a life that was different from what I'm doing now.

Rosenthal: Papilio xuthus, is that right?

Martha: That's his butterfly.

**Rosenthal:** At the museum, I thought about Jo. From the distance of my mom's kitchen in DC, his passion had seemed totally unique and mysterious. Here, it suddenly seemed a lot less random.

We found an exhibit about swallowtails and my mom texted Sarry, Jo's mom, a picture. Sarry sent back an emoji of a rabbit with exploding heart eyes. They'd finally made direct adult-to-adult contact. She and Jo and his brother were coming to meet us in two days.

## Sound of train

Rosenthal: We're on the train, finally on our way to meet Jo.

**Martha:** I can't go through with it. I'm getting off at the next station and going back in the other direction.

Rosenthal: Too late.

Announcer: Next station, Himeji.

**Rosenthal:** We pull into the station, get off the train — and there they are. Just on the other side of the turnstile.

Sarry Nagai: Hi, hello!

Martha: Nice to meet you.

**Rosenthal:** I'm trying to be present for the meeting, and also fumbling to get my recorder rolling.

Sarry: Hello, how are you?

Martha: This is my daughter, Annie-

**Rosenthal:** Sarry, in her late thirties, has a ponytail, a white blouse, a parasol for the sun. And then there are the two boys.

Josh: You must be Harry?

**Rosenthal:** Hayato, or Harry, age thirteen. Mid-eighth grade growth spurt, in a huge t-shirt and baseball cap.

And next to him, the man himself.

Josh: Jo?

Jo Nagai: Yeah, I'm Jo.

Josh: A real pleasure. I'm Josh.

**Rosenthal:** He's a pretty small guy, with very discrete bangs, like the tines of a feathery fork. Big Harry Potter glasses and a round little face that makes him look younger than 10. He's wearing a traditional jinbei—a matching wrap-around shirt and shorts—and carrying a backpack about half his height.

Martha: And you have your butterfly net!

Jo: Yes. I have it.

**Rosenthal:** He and my mom are both smiling big, but a little awkward with each other. Like meeting somebody for a first date after you've bared your soul to them over text. For the next few hours, Jo takes the reins. As we walk around the city, he makes the most of opportunities for viewing wildlife. For example, a pigeon we pass.

**Jo:** We can't touch it. But it is very cute.

**Rosenthal:** We visit Himeji Castle, Jo's favorite castle, and he points out big, gulping fish swimming in the moat.

Jo: Oh! It is beautiful.

Martha: Oh yeah, they're blue! Flashing blue.

Jo: Yeah. Beautiful. Wonderful.

**Rosenthal:** And he helps us work on our manners.

Jo: If you eat food, first you say "Itadakimasu."

Rosenthal: Itadakimasu?

Martha: Itadakimasu. What does that mean?

Jo: We eat birds and fish and a lot of creatures, so we have to thank-

Martha: To say thank you.

Rosenthal: To say thank you to the creatures?

Jo: Creatures, yes.

**Rosenthal:** Jo seems to be amazed by basically every living thing we see around us. He's sweet and solicitous. And also, a totally normal kid. Impatient in the heat, hungry for junk food, constantly proposing a game:

Martha: What do you do?

Jo: Pull!

**Rosenthal:** Like, who has the stronger pine needle.

Martha: Okay.

Rosenthal: So Jo's is stronger?

Martha: Are you stronger than me?

Jo: Yeah.

**Rosenthal:** At lunch, Sarry tells us that Jo has been invited to present his research to the crown prince of Japan in a private meeting at the beginning of the conference. He seems unfazed—he says he's "just a little nervous." But he's star-struck by my mom. When we finish eating, she presents Jo with a hand lens, a little magnified glass attached to a ribbon, just like the one she wears around her neck. He makes very direct eye contact and says, "I love this so much. I want it."

Sound of a woman singing

**Rosenthal:** Outside the restaurant, a woman is performing a Japanese version of "Part of Your World," from *The Little Merm*aid. And somehow it feels exactly right.

It's a million degrees out and we're soaked in sweat. All awkwardness gone, everyone is giddy. It feels like a fairytale. Castles and princes. A sage advisor, a young apprentice. We take a bus to the edge of the city and ride a glass gondola high up into the mountains. At the top, we climb out into a cool, sweet-smelling forest. And a symphony of bugs.

Rosenthal: Ooh, what's that?

Jo: It is a beetle. Martha, it is a beetle!

Martha: You found a beetle?

Jo: Beetle. Yeah. Do you need a case? I have a case.

**Martha:** Yes, please. Yes, please. I made a mistake to not bring my cases with me.

Rosenthal: Yeah, Jo came prepared.

**Jo:** I will give you.

Martha: Thank you very much.

**Rosenthal:** At the top of the mountain, Jo sees something. He leaps forward, his net zigzagging back and forth like a banner. And then...

Jo: Martha, I got it!

Martha: You got it?

Jo: Woah. I take it.

Josh: Wow.

Martha: Oh, that's the one you showed me!

Jo: Yeah.

**Martha:** Ah! That is beautiful! Jo showed me a picture of this and said we might find these.

**Rosenthal:** It's an East Asian Tiger Beetle. Maybe the most flamboyant bug I've ever seen, with a bright green head. Long antennae, blue and rust-colored splotches all over its back.

Martha: Oh my goodness, look at that color!

Sarry: So shiny, and metal color.

Rosenthal: Sarry convinces Jo to let it go.

Jo: I will release it.

**Martha:** Can I hold it for one second? The wings are...Oh! Goodbye! Good luck!

**Jo:** It's very powerful.

Martha: Yeah, he's a strong flyer...

**Rosenthal:** The moon is rising over the city. We catch the last gondola down in the pink light. After dinner, my family boards the train back to our hotel. Hayato and Jo wave from the platform for a full minute — and once our train starts moving, Jo runs after it.

**Martha:** Outside the window of the train, we just saw him speeding along and keeping up with us until our bullet train pulled away and we left him behind. And I just felt like it was the best day ever.

**Rosenthal:** When I was six, a brood of periodical cicadas emerged in DC. Billions of bugs that spend their whole lives underground and tunnel up to the surface just once, after seventeen years. For a few chaotic weeks, the city is completely taken over by their whine.

As you might imagine, while most people saw the cicadas as a menace, my mom was basically hysterical with excitement. Late at night, the bugs would climb up trees around the neighborhood to molt. And one night, she let me and Isabel stay up until midnight to watch.

We walked down the block with flashlights, stopping at a tree. Just above my head, these bright white cicadas with ruby-red eyes were stretching backwards out of their old shells. So new to the world they were still damp.

It felt like I'd been let in on a huge secret, catching them in this private moment in the dark.

# Sound of conference

**Rosenthal:** I was reminded of that night walking into the conference center. Here, I was an interloper again, surrounded by thousands of entomologists, the international denizens of my mom's world.

They weren't the most visually intimidating group—lots of cargo shorts and T-shirts with bug puns on them. But this was their turf. They were keepers of bug knowledge not yet released to the larger world.

I was unprepared for the scene in the poster hall. Alongside the adults, there was an army of young scientists.

**Teenage girl:** Hello, we are from Takatsuki Senior High School. And today we would like to talk about turn alternation of pill bugs.

**Rosenthal:** These were Jo's peers. At ten years old, he wasn't even the youngest presenter.

**Takeru Inagaki:** I'm Takeru Inagaki. I'm in the fourth grade of elementary school. I've been collecting butterflies since I was six years old.

**Rosenthal:** Takeru was approximately three feet tall.

Inagaki: Thank you for listening to my presentation.

Rosenthal: Arigato gozaimasu!

**Shusei:** My research is about leaf-rolling weevils. So do you know leaf-rolling weevils?

**Rosenthal:** Um, no, I don't know them.

Shusei: Okay, so let me explain.

Rosenthal: Shusei is fourteen.

**Rosenthal:** It's a very impressive presentation.

Shusei: Yes, thank you very much.

**Rosenthal:** Are there many students your age who are doing entomological research?

**Shusei:** Uh, yes. Many kids, students, are doing some kind of research about the insects. But his one is really amazing.

Rosenthal: He was looking over at Jo, whose poster was right next door.

Rosenthal: Did he explain it to you already?

**Shusei:** Actually he's my friend. Our house is really close that we can meet each other often.

Rosenthal: And do you guys discuss your research together?

**Shusei:** Yes, yes. He is four years younger than I. But, uh, the things that he is doing is more level high.

**Rosenthal:** Jo was in full networking mode, suit and tie, handing out his business card.

Jo: I'm Jo Nagai. Nice to meet you.

Adult entomologist 1: Nice to meet you.

Adult entomologist 2: So, can we take a picture with you? And the poster?

Jo: Oh, yes.

Adult entomologist 1: You have a bright future in front of you. No doubt about that.

Rosenthal: Hanging around Jo's poster, I met Masato Ono, the conference chair.

Masato Ono: President of Organizing Committee.

Rosenthal: Oh, okay. Wow, okay. Very nice to meet you.

Rosenthal: And Akito Kawahara, the big-name butterfly expert from earlier.

**Kawahara:** He's just incredible. Like, you know, everything that he's done is just, like, incredible. Like, I want him in my lab. I'm secretly like, maybe he wants to do some research in America.

Rosenthal: We stood there watching Jo together.

**Jo:** In the parent's generation, I give the electric shock and the lavender odor. I waited until they became butterflies. And they avoided the lavender odor, so I know they can remember what they learned as caterpillars. In the child's generation, they also avoided lavender odor. So the memories can persist to the next generation.

**Rosenthal:** All day, Jo and his poster were swamped. I could barely see him behind his crowd of admirers. That night, back at the Comfort Inn Kyoto, Jo went straight to the hot tub for a triumphant soak.

Conventional scientific wisdom says it's easier to remember a painful experience than a positive one. That's why, in their original experiment, my mom and Doug decided to teach their caterpillars to hate a smell. Shocking them every time they smelled it. **Martha:** And it was clear from the caterpillar's behavior that they were receiving the shock. And I'll just leave it at that.

Rosenthal: Can you just say what that means?

Martha: (laughs guiltily)

**Rosenthal:** When my mom or her student pushed the button, the caterpillar would start to convulse, and sometimes vomit.

When Jo replicated the experiment, he'd taken a different approach. Instead of high-voltage lab equipment, he'd used that little physical therapy device—a pad that emits small amounts of electricity to treat muscle pain. Jo already had one at home to help with pain in his own shoulders.

Jo: I put the pad on my arms. And inside of the pad there is a caterpillar.

**Rosenthal:** So the caterpillar would be sitting literally on Jo's arm, right between the shock pad and the softest part of his wrist.

Rosenthal: And so, did you also feel the shock when they felt it?

Jo: Yes.

Rosenthal: Was it painful to you? Or what did it feel like to you?

**Jo:** The first was very good for me, but if I did it every day my arm will be red, pink or red. So I was very—I have pain.

**Rosenthal:** The machine has a bunch of different power levels, from one to fifteen. Jo had stopped at level four.

**Rosenthal:** And what was your thinking about why to use that level of shock and not more shock?

Jo: Um, because they, in the level four, they pop out their osmeterium—

**Rosenthal:** Osmeteria. Little orange horns that pop out of the caterpillar's head when it gets scared.

**Jo:** —so I think it was enough for the caterpillar.

Rosenthal: And so you didn't want to hurt them more than you needed to?

Jo: Yes.

**Rosenthal:** In the breakfast room at the hotel, Jo got the machine out of his backpack for a demonstration, sans caterpillar.

Annie: Okay, where do you put it? On my—

Jo: Here.

**Rosenthal:** He strapped the little pad onto my forearm and pressed the button.

Jo: Is it coming?

**Rosenthal:** I don't feel it yet. Now I feel it a little bit. Number two. Okay, another one. Three. Oh! I feel it! Oh!

Rosenthal: It was a crazy feeling, a huge shudder that made my hand jump.

Martha: Did you see Annie's osmeteria come out?

**Rosenthal:** The science isn't clear on whether bugs feel pain. And, as my mom has explained to me, there aren't a lot of rules around how you should treat them as a researcher.

**Martha:** So, if you're going to do something with a vertebrate, you have to put in a whole animal protocol. It has to be taken care of in an approved animal care and use facility. There's committees that monitor everything. Invertebrates, nobody cares one iota about.

**Rosenthal:** That means it's up to each individual scientist to set their own standards.

Rosenthal: Well, so what's your personal standard for your approach?

**Martha:** That, uh, compassionate, and treat them as if they feel pain. And try to minimize any, um, pain or suffering. While getting our science done.

Rosenthal: Jo seemed to have different priorities.

**Martha:** He could have said, 'Boy, I really want to make sure that they get it and crank it up to nine.' But he didn't do that.

Rosenthal: You're thinking of the caterpillars almost as friends, maybe?

**Jo:** I think it's a friend.

Rosenthal: You think it's a friend?

Jo: But I give the electric shock, so from the caterpillar, I am a bad friend.

I talked to Jo for a long time about this. He told me he doesn't actually want to be an entomologist when he grows up. He wants to be a veterinarian.

Rosenthal: What kind of vet do you wanna be?

Jo: Um, I can fix, um, caterpillars and insects. Both.

**Rosenthal:** Do you know of—are there other insect veterinarians now?

Jo: There are no insect vets now.

**Rosenthal:** So you might be the first insect vet.

Jo: Yes!

**Rosenthal:** Way back in that first letter to my mom, Jo had told her he wanted to study insect memory because he thought his butterflies remembered *him*. Jo had a relationship with the bugs he worked with. And that relationship had shaped his questions, his methodology.

So many scientists see anthropomorphizing as a cardinal sin. But for Jo, I realized, interspecies empathy was kind of a sleeper strength. All this work had come out of his willingness to wonder what a bug might know, or feel.

When I tell people about Jo, they often speculate that his parents must be scientists. That it's a kind of stage-mom situation. They're forcing him to do the research, or doing it for him.

Even my family was surprised to learn that neither of Jo's parents are academics. His dad is an engineer at a tractor company. Sarry stays at home with the kids and teaches English classes. Her real name is Saeko—Sarry is a nickname she picked up, alongside her language skills, during a stint in Illinois.

And Sarry is clear: she's not the one doing the research. The ideas are Jo's ideas. When we ask him questions, she doesn't police his answers, just listens thoughtfully. And when he does something goofy for attention, she laughs and rolls her eyes.

But hanging out with her at the hotel, I learned that she is the one who makes his work possible. She prints out observation sheets for him to fill out, helps him take notes while his arms are caterpillar-covered. Googles what food his bugs can eat.

**Sarry:** There is a rule in our study: If we can't prepare food for the insect, we cannot have it.

Rosenthal: She's the one who typed Jo's emails to my mom, while he dictated.

**Sarry:** I showed him and he read it. And, "What do you think about that?" So I typed, listening, typing together.

**Rosenthal:** Sarry told me she doesn't feel particularly passionate about bugs. But in Jo's creativity, she sees herself. When she was a kid, she says people often told her she was "unique."

Sarry: Yes, everybody say that.

Jo: It's good. It's a great thing.

Rosenthal: Yeah.

**Sarry:** So maybe my unique style persists to Jo, maybe.

Jo: Persist!

Rosenthal: Persists, right! Across generations.

Jo: Two generations.

**Rosenthal:** Well, what about your grandma? Is your grandma unique, or your grandpa?

Sarry: She is normal.

**Rosenthal:** After Jo made his big discovery—that the kid butterfly could remember what happened to the parent—he told me he started thinking about the *third* generation. He wanted to know if the grandchild could remember, too.

That week, we took a trip to Hiroshima, my family and Jo's. We started the day at the atomic bomb memorial.

It was a sunny August morning, just like the one in 1945 when an American plane dropped the bomb called Little Boy on this neighborhood. The exact numbers are hard to pin down, but the bomb killed something like 70,000 people instantly and tens of thousands more in the years to come.

A tour guide walked us around the site. We stopped at the hypocenter, the place where the bomb had made impact—a hospital. And a few blocks away, down by the river, he pointed to a large brick ruin, the remains of a building called the A Bomb Dome.

**Tour guide:** About thirty people were working here, but all people died in a second because it's only 160 meters away from the hypocenter.

**Rosenthal:** The building was the only structure in the area that survived the blast.

**Tour guide:** So it becomes a landmark. People left messages to look for their missing family.

**Rosenthal:** He told us, after the war, people in Japan were divided over what to do with the A Bomb Dome.

**Tour guide:** About sixty percent people said it should be preserved as a symbol of no more Hiroshima. And about thirty-five percent of people said it should be demolished because it evoked painful memory.

**Rosenthal:** After twenty years, the city government decided: there was value in that painful reminder.

Tour guide: We must preserve the A Bomb Dome forever.

**Rosenthal:** In front of us, the building loomed quietly over the river, only portions of its walls still standing. The round roof of the tower had been blown off, the dome itself now skeletal and faded.

I turned to Jo, standing next to me, ready to ask what he thought about all of this. About carrying painful memory across generations. How it works, why we do it, what it means. But he was looking at something else.

Jo: There's some butterflies there.

**Rosenthal:** In the air just by the dome, some flapping wings.

Rosenthal: There's some butterflies there? You found them?

Jo: Yeah. It is a papilio.

Rosenthal: That's your butterfly?

Jo: Yeah.

**Rosenthal:** It was a swallowtail, the kind Jo studies. Watching him watch the butterfly, I remembered, he was a little kid. So mature, so serious, and still—ten years old.

Rosenthal: Did they talk about the bomb in school?

Jo: Um, a little bit. Just a little bit.

Rosenthal: What did they say in school?

**Jo:** Um, in Hiroshima, there was a big bomb. Boom. And so a lot of people died.

Rosenthal: The tour guide moved towards the next stop. Sarry walked with us.

Rosenthal: Have you been to the Memorial Park before?

**Sarry:** When I was a kid, I don't remember well. I went to Nagasaki when I was a high school student as a school trip.

**Rosenthal:** Sarry grew up outside Tokyo. But she told me that her husband, Jo and Hayato's dad, grew up here in Hiroshima.

**Rosenthal:** And was your husband's family already here when the atomic bomb happened?

**Sarry:** Yes, but uh, there is a very small mountain, Hijiyama, "Hiji Mountain." So they lived behind the mountain, so the mountain, Hijiyama, protected them, so they survived.

Rosenthal: Sarry told me another story, too.

In 2011, when she was pregnant with Hayato, she and her husband had been living near Fukushima. She was hoping to give birth on her own birthday, March 11th. But that very afternoon, an earthquake hit, causing the tsunami that disabled Fukushima's three nuclear reactors. It was among the biggest accidents in the history of nuclear power.

In the following days, as radiation made its way into the air and water, Sarry decided to evacuate. She made it to Hiroshima, where her husband's family was, and gave birth to Hayato there.

I couldn't stop thinking about the irony of this story. Fleeing to Hiroshima to escape nuclear radiation. And Sarry, becoming a mother in the place where her son's grandparents had themselves survived an atomic bomb.

Sarry told me she couldn't say for sure how the bomb had impacted her husband's family. Her in-laws had been so young when it happened, and their own parents have passed away now.

But when I got home, I looked up Hijiyama, the hill that had protected them. It's just over a mile and half from the hypocenter. Jo's grandparents had been right there, barely outside the explosion's radius.

Jo: What's your name?

Martha: Martha Weiss. Who are you?

Jo: I'm Jo Nagai. Nice to meet you.

Martha: How long have you been a reporter?

**Jo:** One minute?

Martha: Are you finding it an interesting job?

Jo: Not yet.

Recorder cuts off

Recorder cuts on

Jo: Why do you love insects?

**Martha:** 'Cause they're so cool and interesting. And beautiful. And important. All of those reasons. How about you? Why do you love insects?

Jo: Because it's very beautiful and cool.

Recorder cuts off

**Rosenthal:** My mom and Jo study how bugs learn to hate something—how a traumatic memory is formed and passed down. But listening to them talk about that work, I found myself thinking more and more about how we learn to love the things we love. How we arrive at the questions we each want to ask—and how we try to answer them.

Recorder cuts on

Jo: Uh, my favorite insect?

Martha: Yeah, what's your favorite insect?

**Jo:** My favorite insect is swallowtail butterfly.

Martha: The butterfly or the caterpillar or both?

Jo: Caterpillar!

Recorder cuts off

**Rosenthal:** Watching my mom interact with Jo, I saw so much of what I *hope* to inherit from her. Her sense of wonder and play. Her willingness to take a kid seriously and herself not so much.

Sarry told us that the night before we first met, Jo hadn't been able to sleep. All the time we'd been building up the myth of Jo, they'd been constructing the myth of Martha.

**Sarry:** So maybe three years ago, when he started to exchange letter emails with Martha, we didn't imagine the day meeting in person will come true.

Jo: It's like a dream. Really dream.

**Rosenthal:** On the last morning of the conference, my mom said there was something we needed to do.

All this time, she'd been an advisor to Jo. She'd checked his methods, helped him write his abstract. But she still hadn't seen his actual data. The raw numbers themselves. She didn't know for sure if we could conclude with statistical certainty that his findings were true.

When I stopped to think about it, it seemed crazy that we'd made it through the whole trip without looking at this. But when I said that to my mom, she surprised me.

**Martha:** Is it going to hold up if we do a statistical test? Are we going to see a significant result? In some ways it doesn't really matter because...a ton of other stuff has happened.

**Rosenthal:** And then I surprised myself. Because I sort of disagreed. I was still thinking about the science. This thing about memory and generations. I wanted it to be true.

**Rosenthal:** This is kinda what I'm trying to understand, like—does this finding matter?

**Martha:** Does this finding matter? I mean, does what I do matter? You know, at some level, yes. At some level, no. Um, am I curing cancer? No. Am I stopping climate change? No. Am I helping myself and other people understand how organisms work and how they interact with their environment? Yes. And will that help us maybe understand our environments and our planets better and maybe help us have a little bit more empathy for some of the organisms that we live with? I hope so. But the other reason that it matters is because I care about Jo.

**Rosenthal:** Jo. Who'd spent five of his ten years of life on these studies, and reached out to a scientist across the world to help him find answers. This was important to him, and he was important to us. And so we needed to know.

**Martha:** ...Three, four, five, six, seven, eight, nine, ten, eleven, twelve, thirteen, fourteen, fifteen, sixteen, seventeen, eighteen.

**Rosenthal:** Jo and Sarry brought his research binder to my mom's hotel room.

Martha: ...lavender. How many butterflies?

**Rosenthal:** Together, we went through it, page by page.

**Jo:** ...nine of them went to the sugar water!

**Rosenthal:** My mom asked about his controls, and they double checked his counts.

Martha: ...three, four, five, six, seven.

**Rosenthal:** And then she said they needed to do a test.

**Martha:** It's a test of probability. It's how likely something is to happen by chance. If we take our ten yen coin and we flip it in the air, how many times are we going to get the castle, and how many times are we going to get the ten?

**Rosenthal:** Jo looked at her for a second, a little confused.

**Martha:** Why don't you do it for me ten times and tell me each time what you get. Just quickly.

Martha: Okay, so you've got a ten.

Rosenthal: Jo and my mom sat at the table—

Jo: Ten.

**Rosenthal:** Sarry and I on twin beds, watching them flip the coin.

**Jo:** Palace.

Rosenthal: In my head, I was cataloguing all the little happenings that got us here.

Jo: Ten.

Martha: Okay.

**Rosenthal:** That Jo found my mom's research, and could understand it. That he had a mom who could and would help him do his *own* research.

Jo: Ten.

**Rosenthal:** That my mom would be so willing to get on board.

Jo: Palace.

**Rosenthal:** And to rope the rest of us in, too.

Jo: Ten. Palace.

Martha: Stop.

Rosenthal: Five tens, five palaces.

**Martha:** And that is pretty much what you would expect, because they're the same. And half the time it's going to be one, and half the time it's going to be the other, right?

**Rosenthal:** But then there were all these other things. The reasons behind those happenings—the histories that had made all of us the people we are.

**Martha:** What if you did that and you got a ten, ten times in a row? What would you think?

**Jo:** The ten is very heavy.

Martha: That there's something a little weird going on with that coin, right?

**Rosenthal:** I kept getting stuck on strange connections. Fukushima on Sarry's birthday. Her giving birth in Hiroshima. Jo's butterfly by the A Bomb Dome. The fact that a small boy whose grandparents survived an atomic bomb was studying the ways trauma unfolds over generations. A family that understood so viscerally the effects of scientific innovation without compassion—and a kid who cared so much about minimizing pain.

And the more I thought about it, the more connections I drew. My mom studies the way memories from youth show up in adulthood. Her dad was a psychoanalyst and theorist of childhood trauma—named Joe.

After the tour in Hiroshima, I'd asked my mom — didn't all these things seem related? And very practically, she'd shrugged her shoulders and told me she didn't know.

**Martha:** Part of the reason that I like looking at this kind of thing in a simple system like caterpillars and butterflies is that you can do a test and you can figure something out and you can see what is transmitted in particular ways. And in humans, you are never gonna be able to figure this out! There's genetics and there's nature and there's nurture and there's growing up in the same household as people and there's imitation and there's psychology and there's all those kinds of things. And it's really complicated.

**Rosenthal:** You like having a question you can actually answer.

Martha: Yes.

**Rosenthal:** Here in miniature, in the hyper-specific, bug biology world I'd always shrugged off, we could actually get that answer.

**Martha:** What we do first when we're doing this test is we figure out what our expectation is, okay? And so for our first generation, we had forty-four caterpillars made choices, right?

Jo: Yes.

**Martha:** We would expect, if they hadn't learned anything, we would expect that twenty-two of them, half of them, would go to sugar, Pocari Sweat, and that twenty-two of them would go to lavender, right?

**Rosenthal:** And having just said how valuable the details of the science turn out to be, you don't really need to know how to do statistical analysis to understand what comes next.

**Martha:** So we're just going to go times two equals six point oh seven. Okay? Is six point oh seven smaller or larger than three point eight four one?

Jo: Larger.

**Martha:** Larger. So that means that this result is very unlikely to happen just by chance. This means that something happened to those butterflies to make them make that choice. So that is what we call a statistically significant result.

**Rosenthal:** In the months since we got back from Japan, my mom and Jo have been drafting a paper on his findings together. They're going to send it to the Journal of the Lepidopterists' Society. To tell them: we think this is really true. Butterflies *can* remember something they learned as caterpillars—and their kids can inherit that memory, too.

In DC, my mom's been reading up on epigenetics. She told me she's been thinking about our conversations, remembering things from her own childhood. And from when she was pregnant with me. She spent a long time in the hospital in the months before I was born, and a student had brought her a bunch of caterpillars to keep her company. Next to her bed, in a little plastic shoebox.

And as her stomach ballooned, with fetus me inside, the caterpillars crawled out of their box and into different corners of the room, to pupate.

**Martha:** As we know, lots of things are going on inside that chrysalis. So they were changing in the same way that you were changing. And then they emerged as butterflies, and you emerged as a little red frog with a weak chin.

Annie: Oh my god.

**Rosenthal:** Jo, meanwhile, is finessing his study on butterfly grandchild memory. He's about to finish fifth grade. A Japanese TV station recently aired an episode about him. When he opens the door to the camera crew, *MTV Cribs*-style, he's wearing the hand lens my mom gave him on a ribbon around his neck.

Recorder cuts on suddenly

Jo: Ahhhh. Uh, can you get it more loud?

Annie: Mhm. See how this sounds?

**Jo:** Ahhhh. Ah ah ah ah ah.

Annie: Loud? Too loud?

**Jo:** No.

Recorder cuts off