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from the minds of babes



THERE'S AN APP ON MY IPHONE called ColorScanner. It's a tool designed to capture and copy real-world hues so you can refer to them later—perhaps to find a matching shade of paint. But I use it a little differently. I'm an achromat (that is, I see everything in tones of gray), and I open the app when I'm shopping to check the tinge of anything from shirts to rugs.

It's a workaround I figured out on my own, a way to navigate a world not designed for grayscale peepers like mine. To be fair, it's also not a problem most people would even realize needs fixing. Unless, of course, they are the type who looks at things slightly askance. A person, perhaps, like Stacy Branham. One of the early-career scientists honored in this issue as one of *PopSci*'s Brilliant 10, she applies tech in novel ways to improve accessibility. More often than not, she argues, the solutions to our problems have already been invented—we just need to ask the right questions.

Branham's mission is not only a poignant one for me, it's also an example of the ethos driving this entire issue: There's a lot we can learn from being endlessly inquisitive—dare I say "childlike"? It's not that long-held notions about the wisdom of elders are wrong, but more that they're deleteriously one-sided, often casting the young as reckless hotshots. Let's instead think of them as

mavericks. Change agents. Bar raisers.

This collection of stories highlights clever ways of thinking that attack some of our toughest problems from new angles. Sarah Scoles looks inside a camp teaching middle schoolers how to banish bias from artificial intelligence. Gulnaz Khan showcases the upstart metropolises creating blueprints for urbanity everywhere. And Yasmin Tayag argues that, when you sit down and look at the data, any would-be war between the generations turns out to be a load of BS.

Then there are the nine researchers in Branham's cohort, whose collective work could, among other feats, scrub "forever chemicals" from drinking water, speed cancer surgery, nix deepfakes, and create a richly detailed 3D map of the universe. This group of innovators marks a new beginning for the Brilliant 10 awards after a five-year hiatus. We decided to revive the franchise now as a sorely needed reminder of all the vigorous progress already taking shape right under our noses. How novel!

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OUR TWO CENTS

Sleeping with my teddy bear. My parents got it on a trip to Chicago when I was a toddler, and it's so comforting to wrap my arm around it when I tuck myself in.

Sandra Gutierrez,
assistant DIY editor

I've eaten sandwiches in a weird, specific way my entire life. I bite around the outside until I make a sandwich peninsula. Then I devour the middle part.

Stan Horaczek,
senior gear editor

THE CHILDHOOD HABITS WE WON'T QUIT

I got my hands on a Nintendo controller for the first time when I was 4. I turned my love of gaming into a career, and 30 years later, I still play every day.

Mike Epstein,
reviews editor

I still love to dip Hershey chocolate bars into a jar of peanut butter, a simple and tasty pro tip I picked up from my paternal grandmother.

Chuck Squatriglia,
digital edition editor

Hitting the snooze button. When I'm visiting a friend or sitting under a tree, I can't help but reset my mental alarm clock for "five more minutes."

Purbita Saha,
senior editor

what's behind the baby bust?

BY NEEL DHANESHA / ILLUSTRATION BY STUDIO TERP

WHEN THE COMMON ERA STARTED

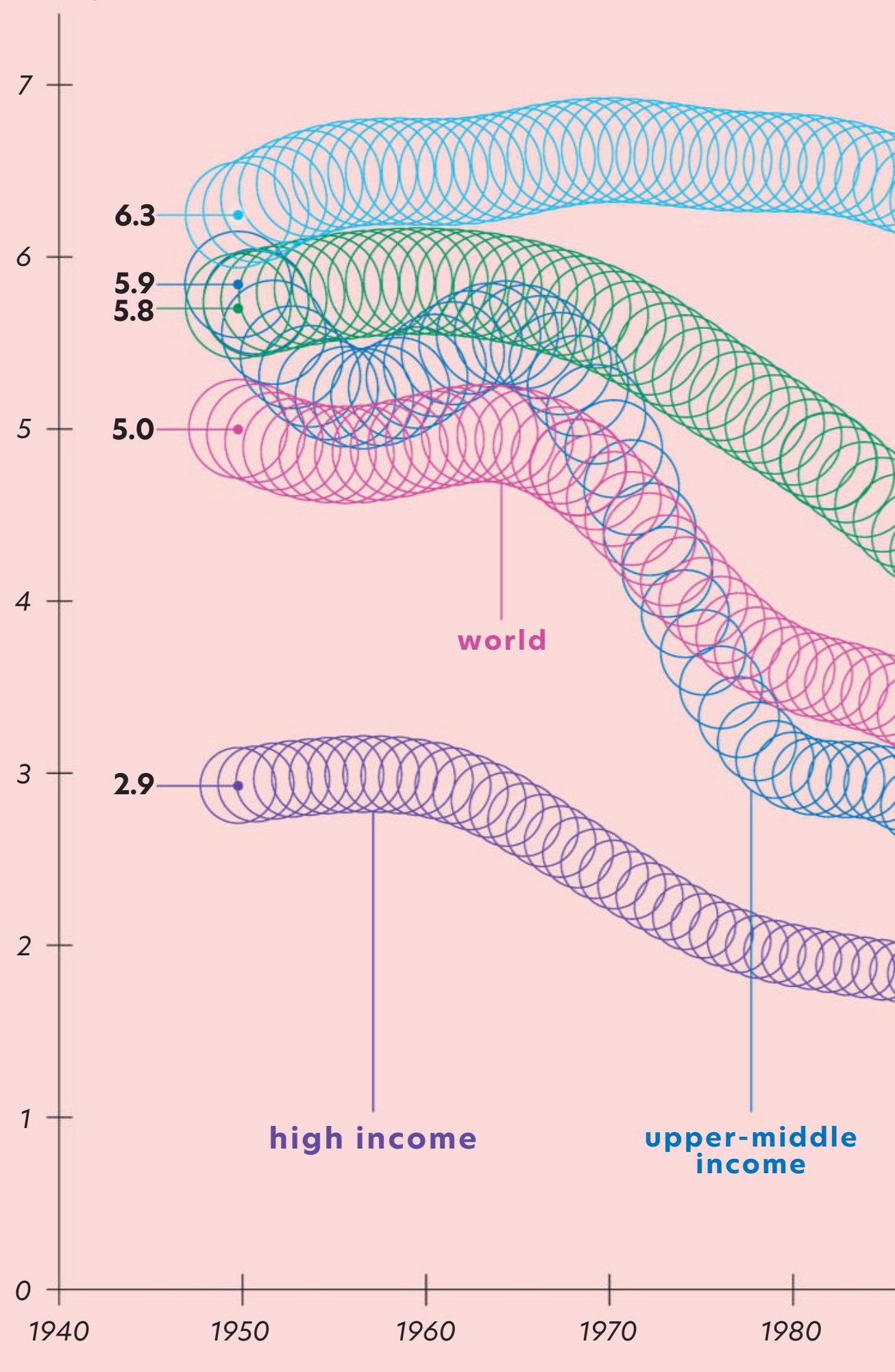
a little over two millennia ago, as few as 170 million *Homo sapiens* lived on Earth. Except for the notable dip caused by the bubonic plague pandemic of the 14th century, that number grew steadily through 1800 to about 910 million. It has since exploded to almost 8 billion.

It seems logical to assume the planet will only grow more crowded. Yet global average birthrates have dropped by half since 1968, to 2.4 children per woman. Nations facing steep declines find this worrying, because dwindling populations can stymie economic growth. But demographers say the trend is neither good nor bad. It simply reflects the ongoing improvements in the lives—and livelihoods—of childbearing women and kids everywhere. Here's a look at some factors driving the change.

CHARTERED

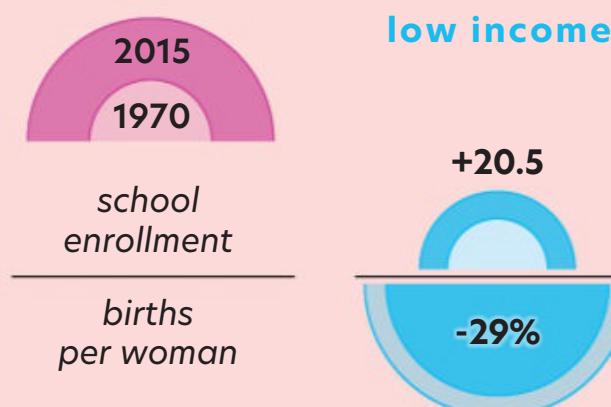
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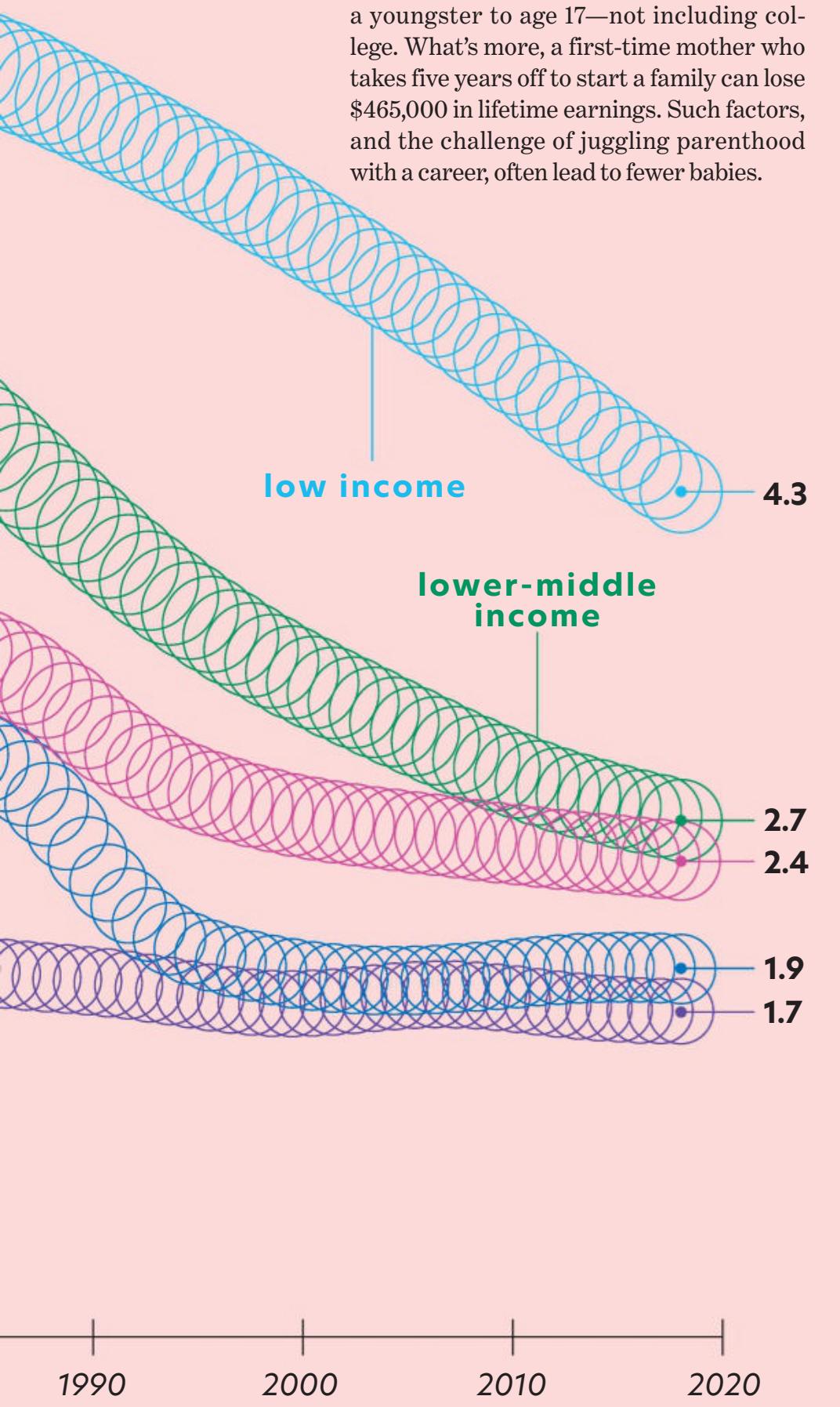
births per woman



Education creates opportunity

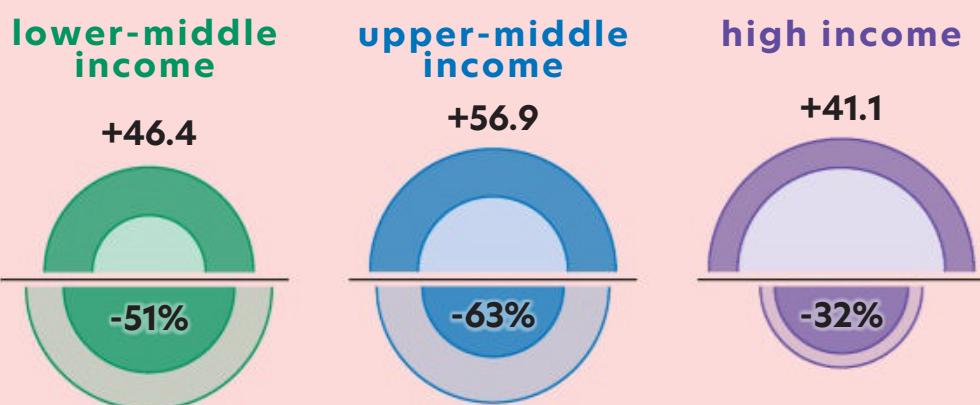
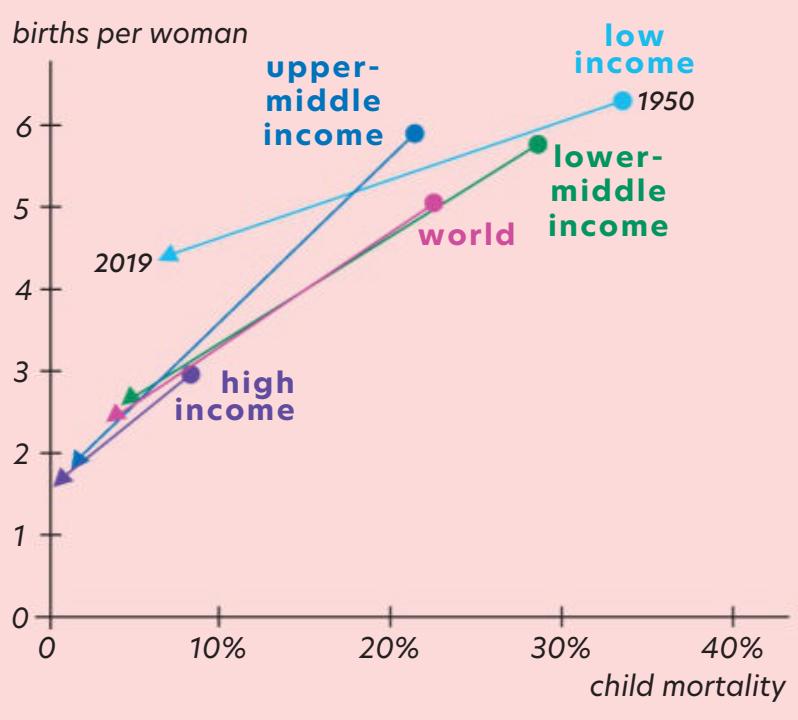
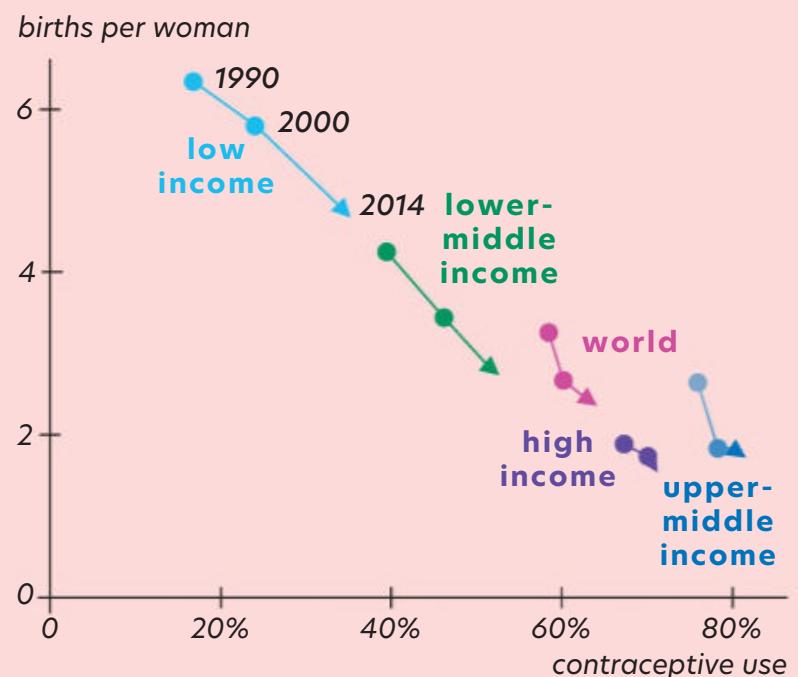
Few things affect population growth more than attending school. In 2010, girls who spent at least eight years in class had an average of two to four kids as adults. That's about half the rate recorded in the 1950s, when access to schooling was far less prevalent. Learning increases opportunity, leading women to delay, or skip, having babies.





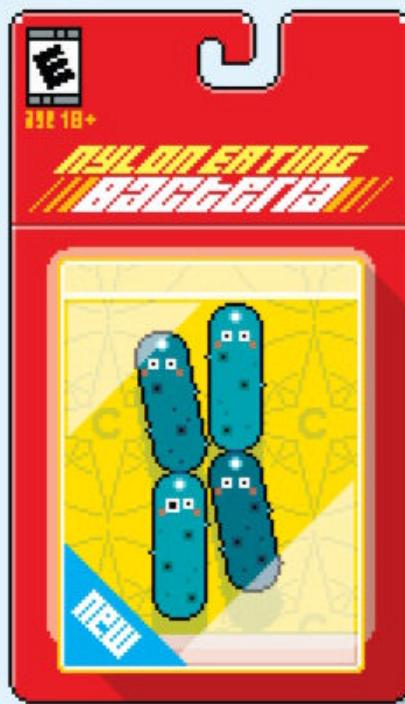
Contraception increases options

Access to birth control fundamentally changed population growth. One study found that, since its debut in the 1960s, the pill had led to 40 percent of the decline in birthrate among married couples in the US. Contraception, education, and work are closely linked; the ability to decide when to become pregnant opens life paths beyond raising kids.



Medicine lengthens lives

Before 1900, half of all children died before age 18, so people bore lots of them to ensure some reached adulthood. Medical advances like vaccines and improved pre- and postnatal care raised the odds of survival, yet even in 1990, one in 11 youngsters worldwide died before turning 5. By 2019, wider access to healthcare cut that to one in 27. As more kids survive childhood, families grow smaller.



Nylon-eating bacteria

In 1975, Japanese scientists discovered a bacterium that digests the synthetic byproducts of nylon manufacturing—substances created just four decades earlier. They found that a few key mutations in the genetic code of *Paenarthrobacter ureafaciens* K172 helped produce these plastic-eating enzymes.



Short-spined sea urchins

Biologists suspect a new species is imminent Down Under. Two types of *Heliocidaris erythrogramma* found off the coast of Western Australia share territory but spawn during different seasons, so they rarely mate. When researchers forced them to do so, some 90 percent of the crosses failed to produce young.



York groundsels

Discovered in England in 1979, *Senecio eboracensis* is a cross between the common groundsel native to Europe and a Sicilian variation introduced to the UK in the 1600s. A lack of records documenting its existence leads botanists to believe it evolved within the past century, but it could be a few hundred years old, in theory.

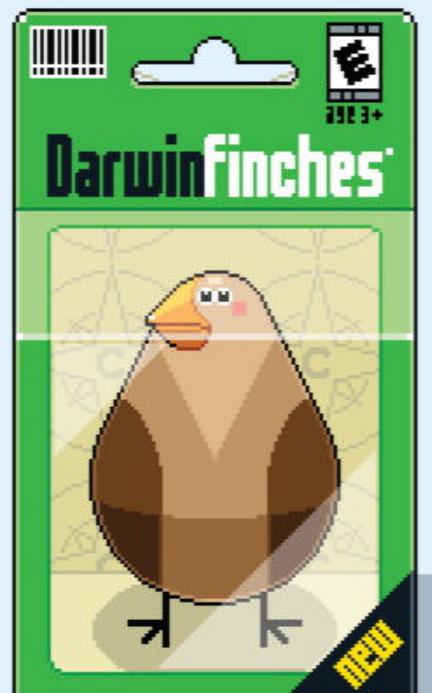
LINEUP

evolutionary infants

WE HUMANS SPLIT FROM our hominid ancestors around half a million years ago, creating a new branch in the tree of life. Natural selection, genetic mutations, and geographic separation can create these new limbs, but just when they sprout remains widely debated. Biologists long thought it occurred when individuals from two groups could not produce fertile offspring, but hybrids like ligers throw even that basic construct into question. The changes at work in DNA are still largely unclear, so studying recent arrivals like these offers insights into budding species.

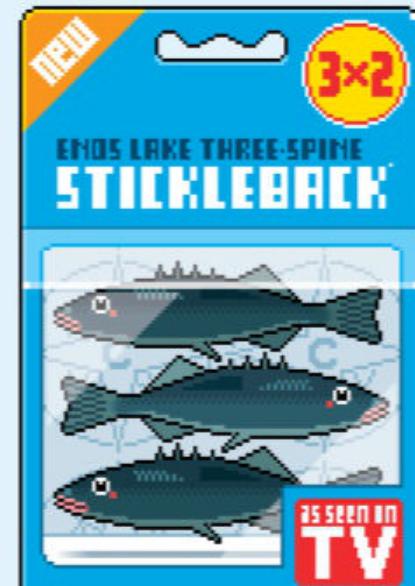
BY HANNAH SEO /

ILLUSTRATION BY TOTTO RENNA



Darwin finches

Forty years ago, a male finch fluttered to the Galápagos island of Daphne Major. The bird, probably a hybrid of two species of ground finch, mated with the local flyers. Their offspring established a new variety—with a distinct song, unique genome, and different beak characteristics—within three generations.



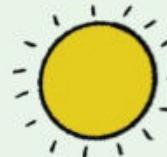
Enos Lake three-spine sticklebacks

Two piscine species unique to a lake in Canada split from a common ancestor 13,000 years ago. One lives in deep water and eats plankton, but an invasive crawfish is pushing it into the shallow water favored by its insect-hunting cousin. Interbreeding is creating one lineage again.

the perfect playground

BY LAUREN LEFFER /

ILLUSTRATION BY CLARA KIRKPATRICK



4 / Celebrate nature

The outdoors is inherently stimulating; being in green spaces can boost the immune system, reduce stress, and promote social interaction. A grassy, wooded spot also offers room to run and plenty of sticks, mud, and other things tykes find irresistible.

5 / Offer solo space

Kids need to socialize, but sometimes they want a place to retreat. Beyond fostering healthy coping mechanisms—especially for youth who have experienced trauma—alone zones like secluded benches help diffuse tensions by providing a respite from peers.

THE BEST PLAY AREAS

offer more than recreation. They provide children with a dynamic classroom in which to hone motor skills, test boundaries, and learn conflict resolution. Yet child development experts and architects alike agree that

many of the spaces we have now don't always facilitate the kind of rich, meaningful play that provides those lessons. They say these six components are critical to creating the ideal outdoor experience—and to making recess as entertaining as possible.

2 / Provide challenges

Allowing rugrats to take age-appropriate risks builds confidence. Fast slides, big swing sets, and plenty of climbing options like trees deliver excitement that staves off boredom. The threat of injury may terrify parents, but statistics don't support such fears.

3 / Cover the basics

The best parks provide everything necessary for an extended stay. Shade, a restroom, somewhere to change diapers or dirty clothes, comfy seating, and a nearby place to grab a snack are key to ensuring fun gets the serious time it deserves.

6 / Incorporate diversity

Playground design must reflect the abilities, languages, and ethnic backgrounds of the entire community. Things like wheelchair accessibility, culturally relevant games, and interactive elements such as drums and chimes make everyone feel included.

ASK US

ANYTHING



MASTER CLASS

WHAT SECRETS CAN BABY BLACK HOLES REVEAL?

BY RAHUL RAO

WHEN FEIGE WANG WAS GROWING

up in Shandong province, China, he liked gazing up at the night sky to look at the stars. Now, as a NASA Hubble fellow at the University of Arizona's Steward Observatory, he looks much deeper into the darkness to contemplate the most distant objects ever studied.

His targets, quasars, are black holes surrounded by disks of gas and stars—the nuclei of primitive galaxies. Their dark hearts suck in nearby matter and

crush the absorbed material into a superhot disk, which burns bright as it shoots out immense amounts of energy. That's the feature that allows us to spot them from so far away. But because it takes billions of years for their light to reach Earth, we see these beacons in the blackness as they existed eons ago.

As one of today's foremost quasar watchers, Wang uses them to gaze into the universe's ancient history. "In the past couple years, I have been pushing to find the most distant ones," he says, since every additional light-year of distance equals another year of cosmic time travel.

In 2021, using a trio of telescopes in Chile and Hawai'i, Wang and his colleagues discovered the farthest quasar yet. Dubbed J0313-1806, it's more than 13 billion light-years away, which means Wang saw it as it was just 670 million years after the Big Bang—when it was practically a newborn.

Wang finds the quasar's black hole particularly fascinating, because according to our current understanding of astrophysics, it shouldn't exist.

J0313-1806 confounds scientists' current theories. Black holes of its size are thought to grow from relatively small "seeds" that then suck up mass over time. One model states that the very first stars might have left such seeds in their wake after living fast and burning out young. Otherwise, clusters of stars collapsing in on themselves could come together to make good fodder.

But neither scenario can explain J0313-1806. Its center is around 1.6 billion times the mass of the sun, and about 500 times more massive than the black

hole at the core of our own galaxy. At that point in the universe's history, the cosmos simply hadn't churned out enough stars to explain the sheer size of J0313-1806's immense center.

Instead, Wang and his colleagues think that raw hydrogen may have seeded the massive object. It's possible that a cloud of gas collapsed, eventually becoming dense enough to birth a black hole, which then ate up stars and other gas. But without other quasars of comparable age to observe, the black hole's provenance remains a mystery.

"We have very little information about the large-scale environment of the earliest quasars," Wang says, since observers are limited by the reach of current instruments.

But he is optimistic that the next generation of sky-watching machines will help us uncover these secrets. The long-awaited James Webb Space Telescope, set to launch in late 2021 and take the throne of the 30-year-old Hubble, will allow astronomers to peer farther back into time than ever before—and take a closer look at J0313-1806. Other incoming scopes will help as well. Chile's Vera C. Rubin Observatory, expected to open in 2023, will scour Earth's southern skies for new quasars, among other things. The Nancy Grace Roman Space Telescope should enter orbit in 2025, where it will peer at infrared wavelengths to spot far-out matter.

Wang hopes such tools will reveal much more about how the earliest black holes grew. "The next decade will be a great time for studying the most distant objects in our universe."

BUT REALLY...

WHICH CAME FIRST:



THE CHICKEN OR THE EGG?

BY ERIN FENNESSY

FROM ARISTOTLE TO

Diderot, the mind-bending conundrum of chicken vs. egg has puzzled deep thinkers and fueled endless classroom debates. But biology has an answer to this philosophical paradox: The thing with wings surely followed cells in a shell.

That's because the earliest creatures birthed from yolks wore scales, not feathers, says Jingmai O'Connor, a paleontologist and curator at the Field Museum in Chicago. Embryos encased in calcium evolved in dinosaurs about 200 million years ago; avian species did not emerge until tens of millions of years later.

O'Connor knows this because in 2019, she and paleontologist Alida Bailleul of the Chinese Academy of Sciences discovered the oldest known unlaid bird egg. They found it in a fossilized *Avimiaia schweitzerae*, a sparrow-size specimen that lived some 120

million years ago in what is now northwestern China.

The egg's design was pretty much set eons before the domestication of jungle fowl. Some features of modern ones, including shell color, evolved alongside dinosaurs. But others, like the chalaza (the membrane that holds the embryo in place), emerged later in the Cretaceous Period, which ended 66 million years ago.

So perhaps it's better to ask, Which came first, the chicken or its egg? This question is harder to answer with certainty. One possibility is that a bird similar to the barnyard staples of today laid a clutch that, due to a small quirk in DNA, held the first true clucker. Pinpointing that exact point of divergence in the family tree has proven difficult, however, because genetic changes happen so slowly. Let's check back on this debate in another century or two.

LITTLE Q

DOES HOMEWORK REALLY MAKE STUDENTS SMARTER?

BY STAN HORACZEK

WHEN YOU'RE A KID, YOUR STANCE ON homework is pretty simple: It's the worst. For parents and teachers, the verdict is more complicated. Data on its benefits are uncertain at best.

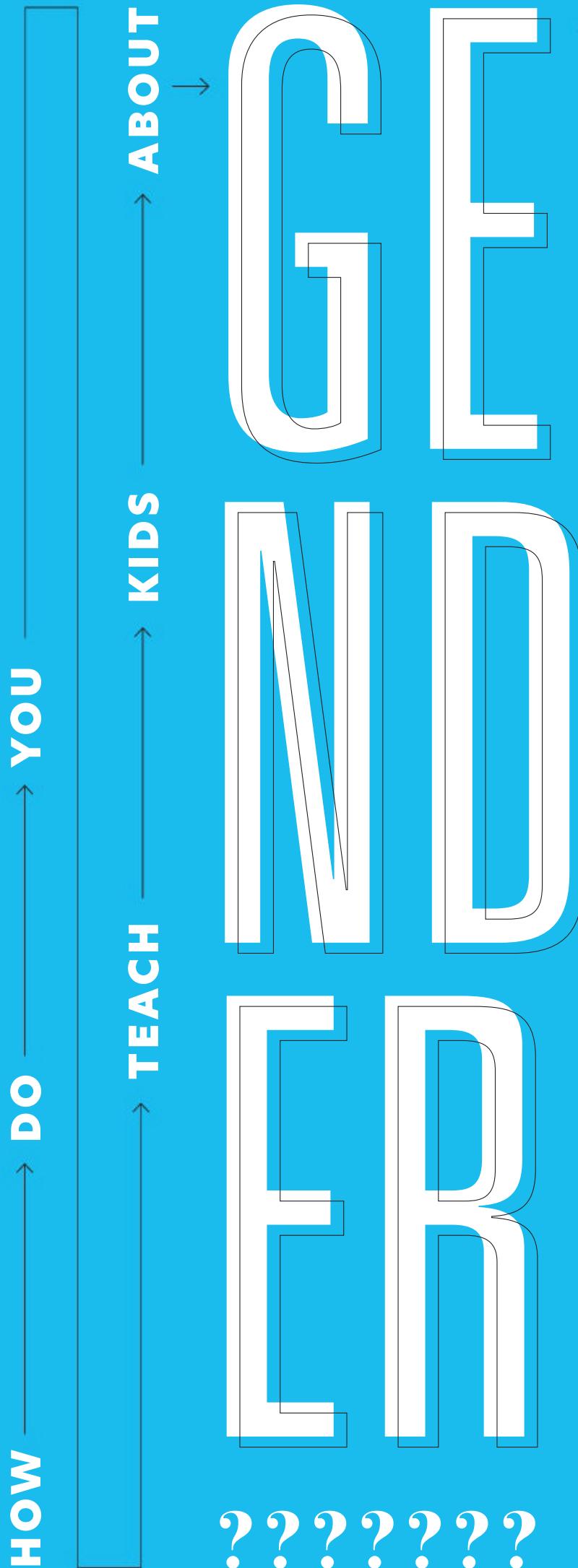
That doesn't stop educators from handing it out, though. According to a 2019 Pew survey, teens spend about an hour studying on their own each day—twice as long as adolescents did in the 1990s. Little ones have it only slightly easier: A 2015 study found first and second graders spend 30 minutes on lessons after school.

But does that grind make students any smarter? A 2012 analysis of more than 18,000 American 10th graders showed that those who completed their math and science chores didn't earn appreciably better grades than those who skipped them. (They did, however, receive superior scores on standardized tests.) But even studies that find a positive correlation between after-school classwork and academic performance concede there are few benefits before students graduate from elementary school.

In fact, evidence shows that saddling students with academic to-dos can harm their well-being. A 2014 study of 4,317 students from 10 high-performing high schools in California revealed the pupils, who averaged 3.1 hours of cramming daily, experienced stress, sleep deprivation, and other negative health effects. Research also suggests the added load can widen the achievement gap between kids from different economic backgrounds.

While some education experts argue that assignments provide a way of monitoring student progress, others favor offering more nuanced feedback than grades to encourage pupils to master the material rather than focus on A's. Still others suggest shorter tasks that go over a given subject repeatedly; the idea, called the spacing effect, is that it's easier to learn information in regular short bursts than in a marathon session.

Ultimately, learning exercises should appeal to a child's innate curiosity. Teachers who've adopted this approach say they see students embrace the opportunity to explore subjects they find interesting—and bring their friends along too. Perhaps the best homework skips the books.



FROM THE MOMENT CHILDREN ARE BORN, they're bombarded with messages on gender. Girls wear pink and boys wear blue; ladies are gentle and gents are tough; lasses are preschool teachers and lads are construction workers. Not all stereotypes are so explicit, but studies suggest that these norms can quickly lead kids to form self-limiting rules, false ideas, and damaging prejudices.

Thankfully, research also offers a solution: Adults should talk to toddlers about gender from the moment they're able to hold a conversation. But these sensitive lessons can be challenging. We asked four child-development experts to lay out some guidance for helping young ones navigate these topics.

Kids need lots of messages to learn within-gender differences and cross-gender similarities. Whenever they

say something like, "Girls like ballet," respond with, "Do we know any girls who hate ballet? Do we know any girls who love football? There isn't anything that *all* girls like to do."

—**Rebecca Bigler**, professor emeritus of psychology at the University of Texas at Austin

If the doctors, dentists, principals, city councilors, and other roles of power are all men, then you want to step back and think about what you're showing the child. If we don't help them understand issues regarding gender discrimination, they might come up with incorrect reasons to explain what they're seeing. That could have really negative implications in terms of their perceptions of what women and non-binary individuals can do."

—**Erin Pahlke**, associate professor of psychology at Whitman College in Washington

Tykes are starting to ask questions on trans identity, probably because of the news and parental discussions around them. I can think of no better way than to address it through a book. One of my favorites is *Red: A Crayon's Story*, which is about a character whose label is red, but he's actually blue.

—**Russ Toomey**, program chair and professor of family studies and human development at the University of Arizona

So much research shows that listening to young people and affirming how they want to express their gender is much healthier than trying to force them into a box that doesn't fit. Give them options for how they want to dress, how they want to wear their hair, and what kind of toys they want to play with. Normalize that there's no right or wrong way to be themselves.

—**Christia Spears Brown**, professor of developmental psychology at the University of Kentucky

WILL WE EVER**REPLICATE****BREAST MILK?**

BY CLAIRE MALDARELLI

IN 1865, GERMAN CHEMIST JUSTUS VON LIEBIG

mixed powdered cow's milk with wheat and malt flours and a bit of potassium bicarbonate to create the first artificial alternative to breastfeeding. Today, 75 percent of infants in the US receive at least some "formula" within their first six months. But despite more than a century of research, no one's been able to decipher the recipe for the real thing, let alone create a perfect analogue.

Human milk is a complex combination of fats, proteins, and carbohydrates that sustain a growing infant and foster

the development of a robust immune system. But chemists and nutritionists haven't yet pinned down all the specific ingredients and what they do. "This is such a humbling area of research," says Rachael Buck, a biologist and immunologist at Abbott Laboratories, which makes the infant formula Similac. Compounding the mystery is the fact that breast milk varies from one person, and even one feeding, to the next.

Still, the synthetic versions are inching closer to mimicking their natural counterpart. Chemists and biomedical engineers at Abbott and Nestlé, which also produces formula, made a key breakthrough about a decade ago when they figured out how to incorporate complex sugars called human milk oligosaccharides. HMOs, about 200 of which have been discovered thus far, feed the intestinal microorganisms that help fight pathogens and prevent inflammation and diseases. Newer data suggest they also help ensure proper brain and immune system development.

Other companies are turning to bioengineering to replicate mammary cells and, in a lab, feed them nutrients so they can proliferate. Even so, the milk they'd produce would, like even the best formulas, lack the antibodies passed from parent to child. Until we crack the code for breast milk's many superpowers, it's impossible to say whether science can mimic them. For now, formula provides a safe and nutritious alternative—one much healthier than the flour-filled cocktail of the 1800s.

POSTCARD

**WHAT'S NEXT FOR THE
BROOD X CICADAS?**

BY LAUREN LEFFER

IN THE STILLNESS OF THE

late-July air, a new generation of cicadas prepared to debut in the broadleaf forests of the mid-Atlantic. Weeks earlier, its parents had staged a loud and messy show during the historic Brood X emergence of 2021. Their offspring greeted the world in a more subdued fashion: They hatched from eggs resembling miniature grains of rice and then quietly dropped to the ground, where they'll take shelter for the next 17 years.

These newborn insects, called nymphs, are so teensy they can wriggle through existing cracks to get to their burrows. Some might follow the tunnels excavated by their elders to dine on sap from small, shallow roots. From there, though, their childhoods are quite mysterious. The critters eat, skulk, and grow in the dark for nearly

two decades. But how?

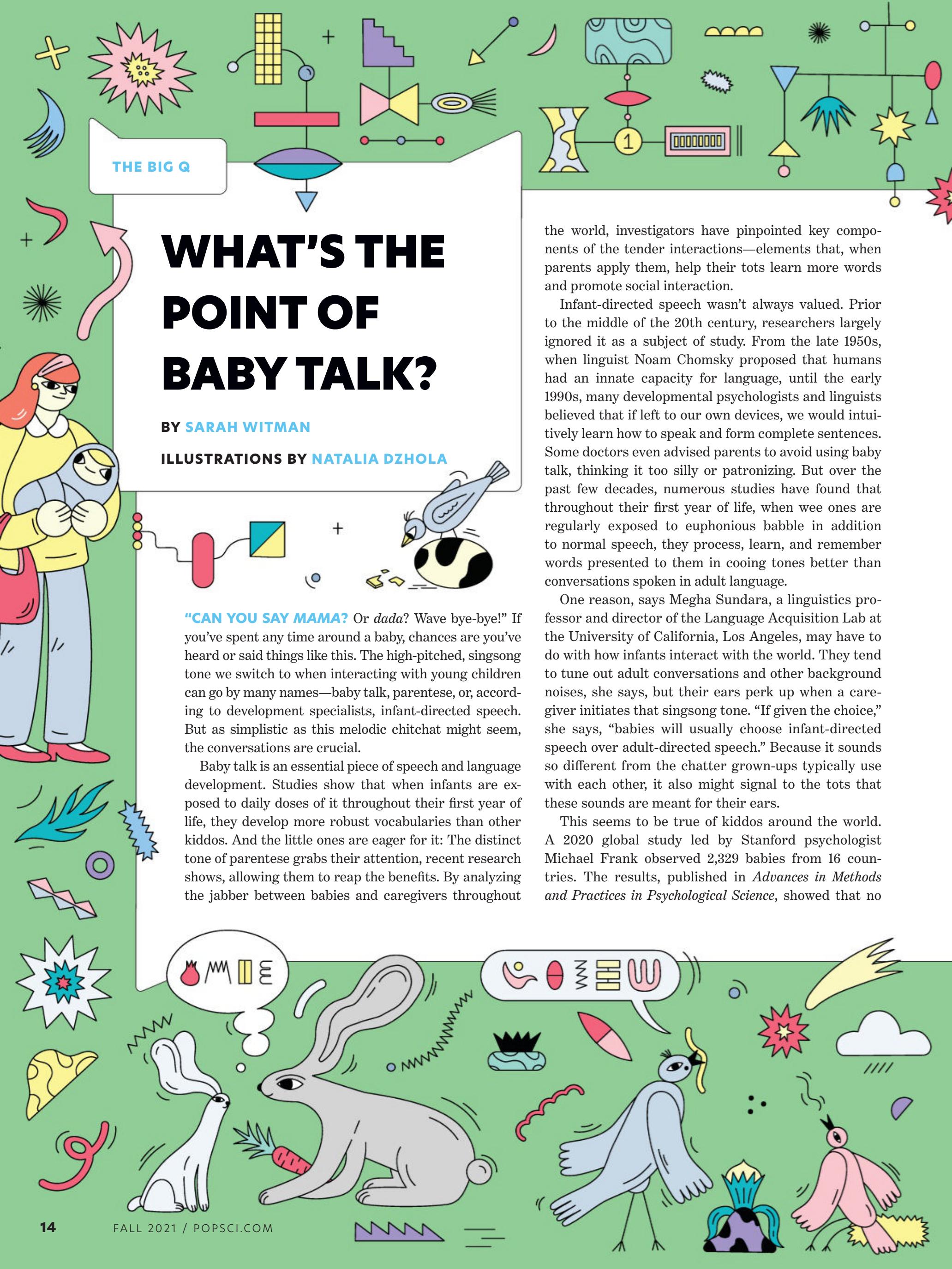
Even with their enormous numbers, periodical cicadas are tough to study. The nymphs die quickly if they're separated from the plants they feed on, so digging them up is less than ideal. "We've always had these fantasies of building an ant farm kind of thing," says John Cooley, an entomologist at the University of Connecticut. Yet a crucial component of the conditions eludes him and his colleagues. "It's something about the soil, something about the kind of roots."

This makes it difficult to map the insects' subterranean journeys, though entomologists find insights where they can. Months-old nymphs are sometimes found dwelling in frosty layers in winter, Cooley says, which raises interesting questions. How do they avoid freezing, for instance, and

how much do they move between different depths in the dirt?

Timekeeping is another puzzle: A brood might mature at different rates but end up surfacing in sync. "Cicadas don't have clocks—they count," Cooley says. Some research suggests that the youngsters track years by noting seasonal changes as trees grow and drop leaves. But no one knows how the bugs remember their tallies.

Thankfully, experts won't have to wait until Brood X reappears in 2038 to see (and hear) live periodical cicadas again. A 221-year dual emergence is set to happen in the Midwestern and Southern US in 2024, when Brood XIII's and Brood XIX's respective 17- and 13-year life cycles will align. Each mass coming-of-age is another chance to learn about some of nature's most patient little ones.



THE BIG Q

WHAT'S THE POINT OF BABY TALK?

BY SARAH WITMAN

ILLUSTRATIONS BY NATALIA DZHOLA

"CAN YOU SAY MAMA? Or dada? Wave bye-bye!" If you've spent any time around a baby, chances are you've heard or said things like this. The high-pitched, singsong tone we switch to when interacting with young children can go by many names—baby talk, parentese, or, according to development specialists, infant-directed speech. But as simplistic as this melodic chitchat might seem, the conversations are crucial.

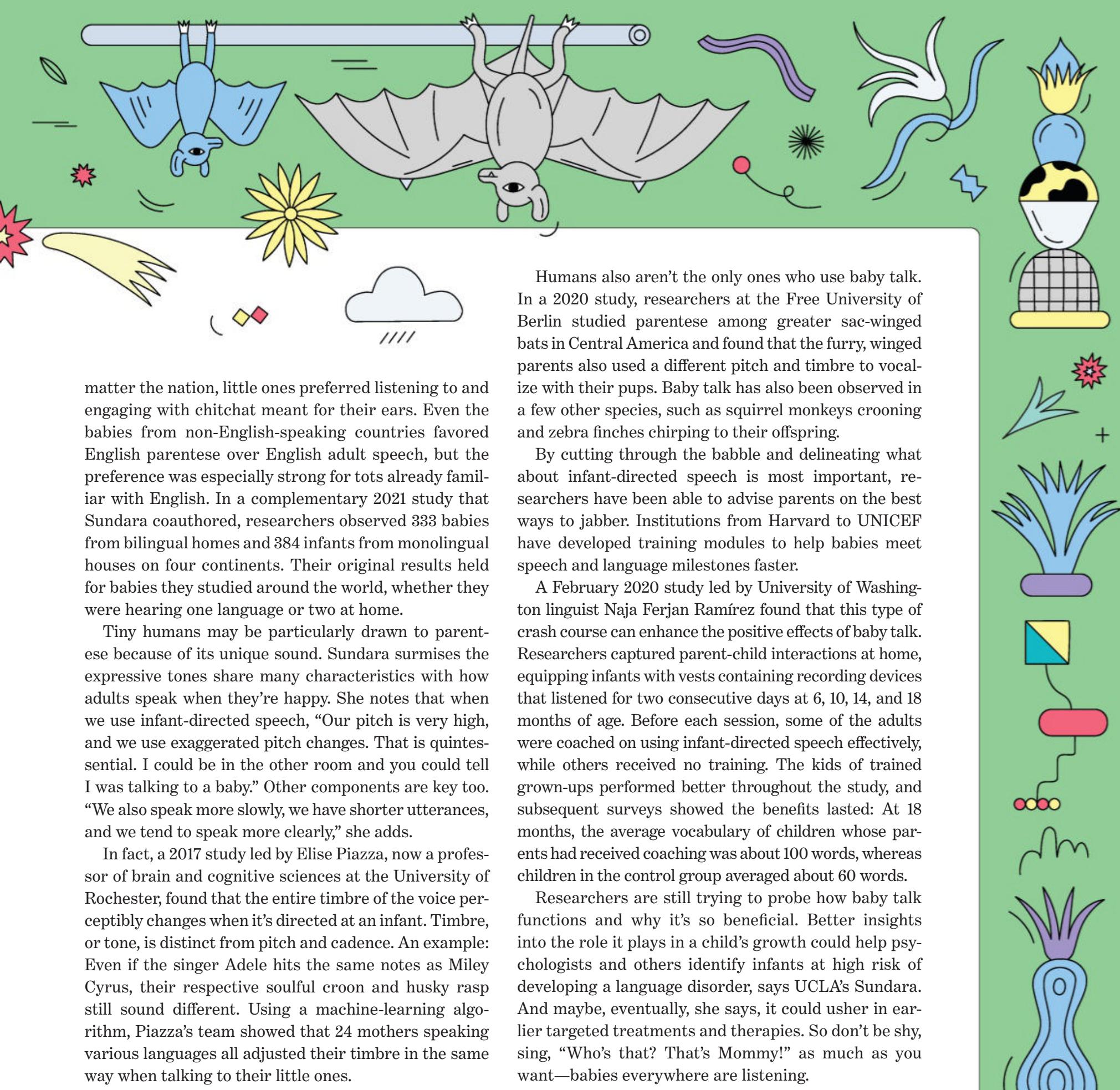
Baby talk is an essential piece of speech and language development. Studies show that when infants are exposed to daily doses of it throughout their first year of life, they develop more robust vocabularies than other kiddos. And the little ones are eager for it: The distinct tone of parentese grabs their attention, recent research shows, allowing them to reap the benefits. By analyzing the jabber between babies and caregivers throughout

the world, investigators have pinpointed key components of the tender interactions—elements that, when parents apply them, help their tots learn more words and promote social interaction.

Infant-directed speech wasn't always valued. Prior to the middle of the 20th century, researchers largely ignored it as a subject of study. From the late 1950s, when linguist Noam Chomsky proposed that humans had an innate capacity for language, until the early 1990s, many developmental psychologists and linguists believed that if left to our own devices, we would intuitively learn how to speak and form complete sentences. Some doctors even advised parents to avoid using baby talk, thinking it too silly or patronizing. But over the past few decades, numerous studies have found that throughout their first year of life, when wee ones are regularly exposed to euphonious babble in addition to normal speech, they process, learn, and remember words presented to them in cooing tones better than conversations spoken in adult language.

One reason, says Megha Sundara, a linguistics professor and director of the Language Acquisition Lab at the University of California, Los Angeles, may have to do with how infants interact with the world. They tend to tune out adult conversations and other background noises, she says, but their ears perk up when a caregiver initiates that singsong tone. "If given the choice," she says, "babies will usually choose infant-directed speech over adult-directed speech." Because it sounds so different from the chatter grown-ups typically use with each other, it also might signal to the tots that these sounds are meant for their ears.

This seems to be true of kiddos around the world. A 2020 global study led by Stanford psychologist Michael Frank observed 2,329 babies from 16 countries. The results, published in *Advances in Methods and Practices in Psychological Science*, showed that no



matter the nation, little ones preferred listening to and engaging with chitchat meant for their ears. Even the babies from non-English-speaking countries favored English parentese over English adult speech, but the preference was especially strong for tots already familiar with English. In a complementary 2021 study that Sundara coauthored, researchers observed 333 babies from bilingual homes and 384 infants from monolingual houses on four continents. Their original results held for babies they studied around the world, whether they were hearing one language or two at home.

Tiny humans may be particularly drawn to parentese because of its unique sound. Sundara surmises the expressive tones share many characteristics with how adults speak when they're happy. She notes that when we use infant-directed speech, "Our pitch is very high, and we use exaggerated pitch changes. That is quintessential. I could be in the other room and you could tell I was talking to a baby." Other components are key too. "We also speak more slowly, we have shorter utterances, and we tend to speak more clearly," she adds.

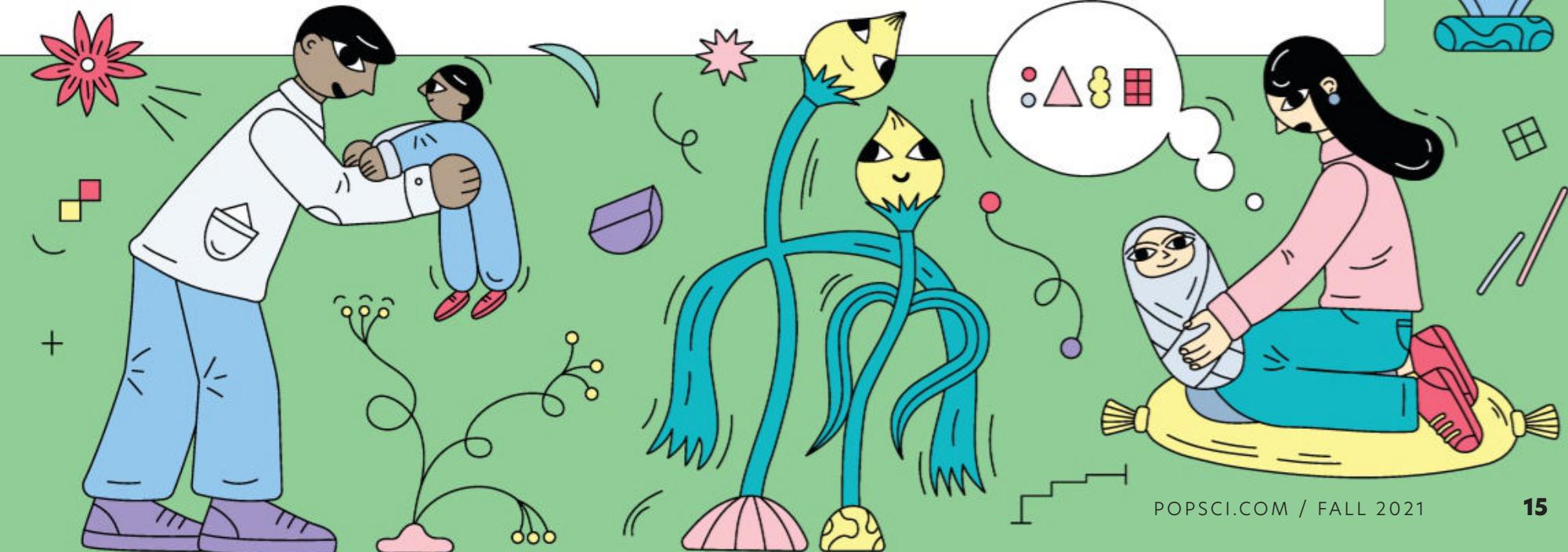
In fact, a 2017 study led by Elise Piazza, now a professor of brain and cognitive sciences at the University of Rochester, found that the entire timbre of the voice perceptibly changes when it's directed at an infant. Timbre, or tone, is distinct from pitch and cadence. An example: Even if the singer Adele hits the same notes as Miley Cyrus, their respective soulful croon and husky rasp still sound different. Using a machine-learning algorithm, Piazza's team showed that 24 mothers speaking various languages all adjusted their timbre in the same way when talking to their little ones.

Humans also aren't the only ones who use baby talk. In a 2020 study, researchers at the Free University of Berlin studied parentese among greater sac-winged bats in Central America and found that the furry, winged parents also used a different pitch and timbre to vocalize with their pups. Baby talk has also been observed in a few other species, such as squirrel monkeys crooning and zebra finches chirping to their offspring.

By cutting through the babble and delineating what about infant-directed speech is most important, researchers have been able to advise parents on the best ways to jabber. Institutions from Harvard to UNICEF have developed training modules to help babies meet speech and language milestones faster.

A February 2020 study led by University of Washington linguist Naja Ferjan Ramírez found that this type of crash course can enhance the positive effects of baby talk. Researchers captured parent-child interactions at home, equipping infants with vests containing recording devices that listened for two consecutive days at 6, 10, 14, and 18 months of age. Before each session, some of the adults were coached on using infant-directed speech effectively, while others received no training. The kids of trained grown-ups performed better throughout the study, and subsequent surveys showed the benefits lasted: At 18 months, the average vocabulary of children whose parents had received coaching was about 100 words, whereas children in the control group averaged about 60 words.

Researchers are still trying to probe how baby talk functions and why it's so beneficial. Better insights into the role it plays in a child's growth could help psychologists and others identify infants at high risk of developing a language disorder, says UCLA's Sundara. And maybe, eventually, she says, it could usher in earlier targeted treatments and therapies. So don't be shy, sing, "Who's that? That's Mommy!" as much as you want—babies everywhere are listening.



GOODS

F A L L

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PG

16

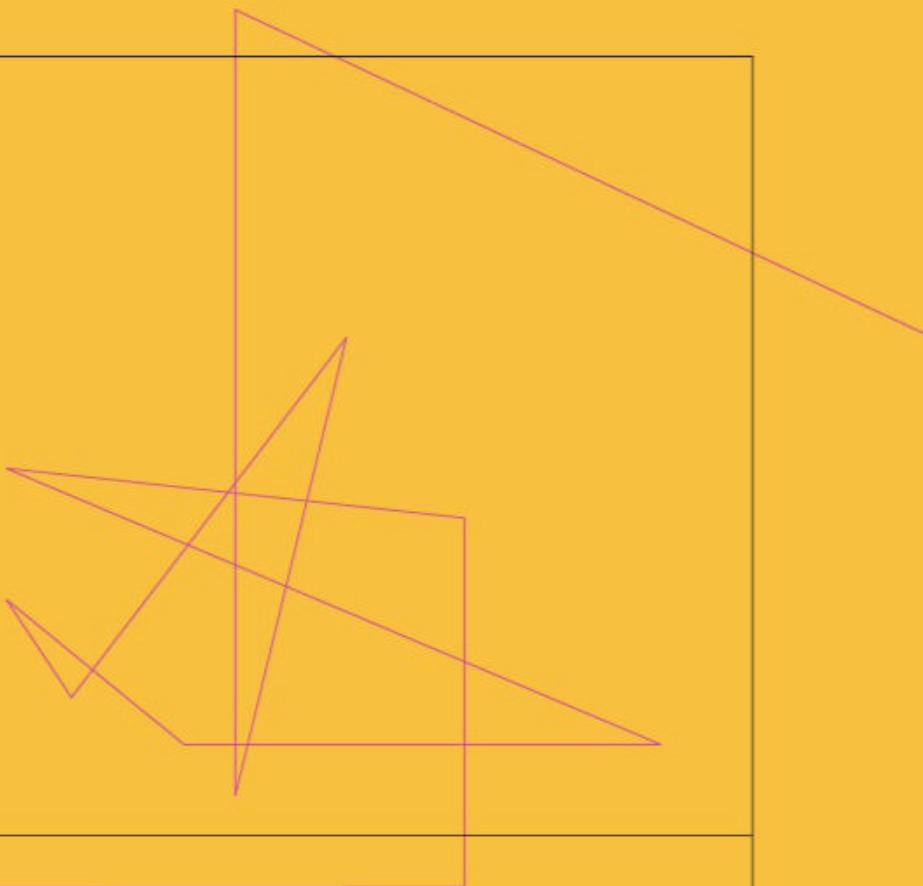
KIDS' SNACKS FOR ADULTS » CHILDHOOD TOYS FIT FOR THE GYM »

A CHROMEBOOK FOR EVERY STUDENT » DIAPER BAG ESSENTIALS

BY STAN HORACZEK

ONE PERFECT THING

1-bit wonder



PLAYDATE IS THE LAST THING YOU'D EXPECT

from a game console in 2021. Its tiny 2.7-inch monochromatic screen delivers a paltry 400-by-240 resolution (that's fewer pixels than an Apple Watch). The display isn't backlit, so you'll need a flashlight if you want to game in the dark. It sports just 16MB of RAM. That's megabytes, not gigabytes.

But boy, is this adorable handheld fun. Without features like ultra-HD graphics and 3D audio to dazzle the senses, players are free to concentrate on the wonderfully simple gameplay.

Playdate comes from Panic, a software outfit in Portland, Oregon, known for taking risks. Back in 2019, it found surprising success with the *Untitled Goose Game*, a title on all major consoles that casts players as a petulant waterfowl causing havoc with townspeople to complete missions. It's weird, but a blast—the same ethos behind this wee gizmo.

The \$179 purchase price includes two dozen games, dished out over 12 weeks to keep things fresh. The titles include everything from quirky side-scrolling adventures to

challenging puzzles. Some defy categorization because they rely on the bright yellow Playdate's built-in crank.

You read that right: a crank, sticking out of the right side. Instead of providing power as such an appendage would to an emergency radio, it adds unique, tactile control that other platforms can't offer. Giving it a spin might make your character move to and fro or allow you to scoot around onscreen objects—in concert with the A/B controls and directional pad you already know so well, of course. Elevating gameplay beyond simple button mashing creates an experience unlike any console or smartphone.

Panic plans to keep expanding the capabilities of its plucky little device with a strong emphasis on community and creativity. A software development kit and browser-based design interface will make it simple for even amateur coders to create games, so you can look forward to many more weird, wonderful titles that further prove you don't need supercomputer-grade graphics to lose a weekend gaming.

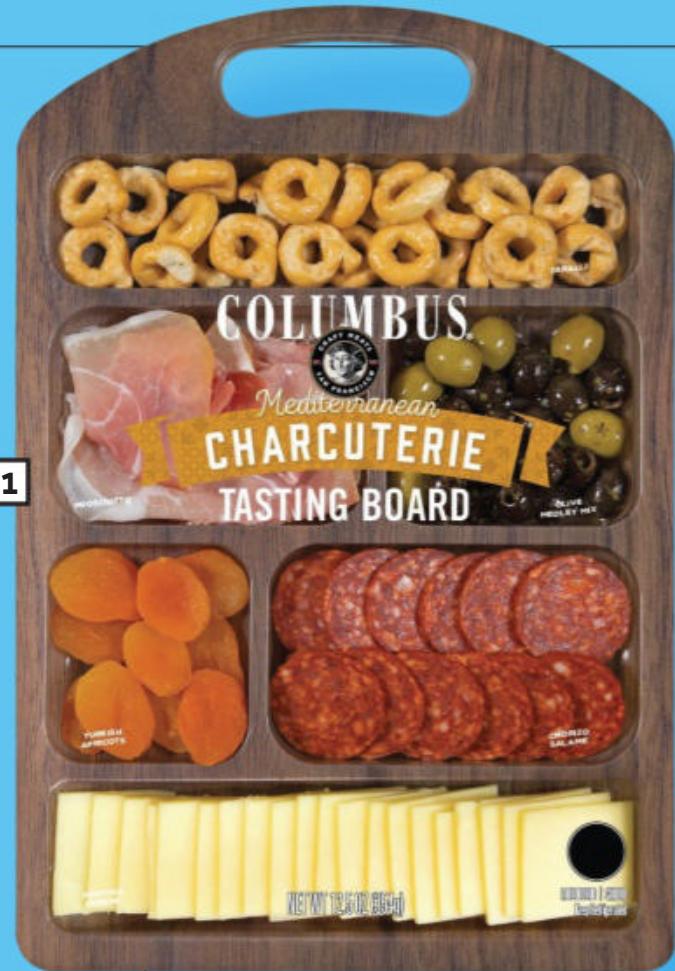


snack time machine

EATING LIKE AN ADULT ISN'T ALWAYS FUN, BUT CHILDHOOD TREATS OFTEN STRETCH THE DEFINITION OF FOOD. THESE SOPHISTICATED BITES RIFF ON YOUR SNACK-DRAWER FAVORITES.



1



2



3



1. Lunchables

An upscale version of the sweaty cheese and meat blocks of yore, **Columbus Charcuterie Tasting Board** feature combinations like Italian salami, white cheddar, and dark chocolate-covered cranberries.

2. Chips

To make **Chickpea Snacks** satisfy cravings for something crunchy and salty, Biена slow roasts organic legumes in sunflower oil, then dusts them in savory flavors like barbecue and habanero.

3. Fruit Roll-Ups

A proprietary dehydration process keeps the mango, banana, and pineapple in **Solely Fruit Jerky** chewy and sweet—without the added sugar and chemical binders often found in similarly sticky treats.



4. Chocolate Milk

Ripple Dairy-Free Pea Milk contains one-third the sugar of the real thing. Making it also requires just 17 percent of the water required for almond milk, and the fact that it's nut-free means it won't trigger allergies.



5. Pop Tarts

Bobo's Toast'r Pastries ditch the frosting, but you won't miss it. An oat cookie wraps naturally sweet organic ingredients with flavors like Blueberry Lemon Poppyseed and Chocolate Almond Butter.



6. Cookies

Each vegan, gluten-free **Munk Pack Protein Cookie** has 16 grams of brown rice and pea protein and 6 grams of oat fiber. They feature flavors like Snickerdoodle and Coconut White Chip Macadamia.

7. Chicken Nuggets

Wheat and soy protein mixed with other plant-based ingredients give **Simulate Nuggs** a bite strikingly similar to that of bird-based chunks, but with about half the fat—and no mystery fillers.

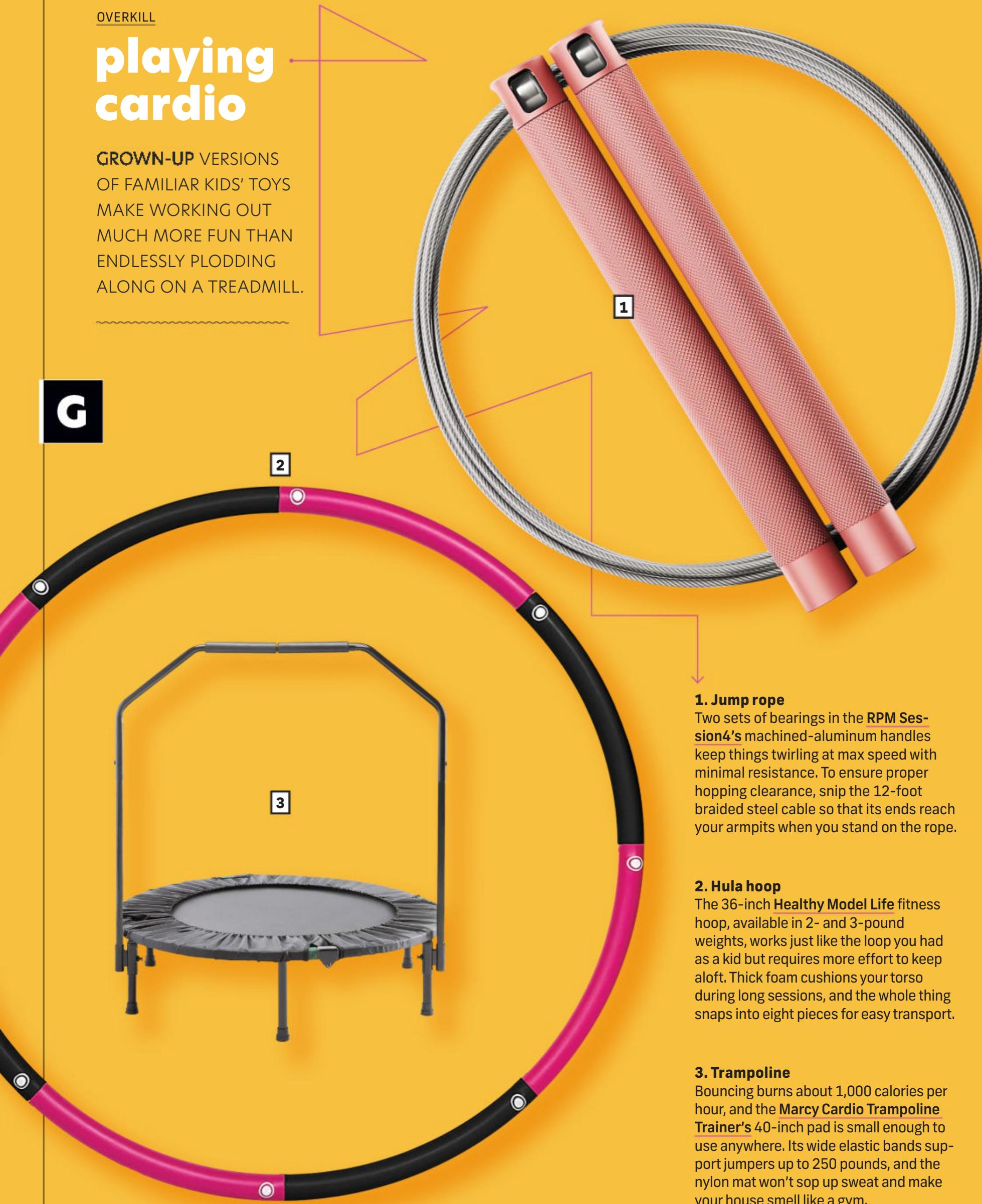


OVERKILL

playing cardio

GROWN-UP VERSIONS OF FAMILIAR KIDS' TOYS MAKE WORKING OUT MUCH MORE FUN THAN ENDLESSLY PLODDING ALONG ON A TREADMILL.

G



1. Jump rope

Two sets of bearings in the [RPM Session4](#)'s machined-aluminum handles keep things twirling at max speed with minimal resistance. To ensure proper hopping clearance, snip the 12-foot braided steel cable so that its ends reach your armpits when you stand on the rope.

2. Hula hoop

The 36-inch [Healthy Model Life](#) fitness hoop, available in 2- and 3-pound weights, works just like the loop you had as a kid but requires more effort to keep aloft. Thick foam cushions your torso during long sessions, and the whole thing snaps into eight pieces for easy transport.

3. Trampoline

Bouncing burns about 1,000 calories per hour, and the [Marcy Cardio Trampoline Trainer](#)'s 40-inch pad is small enough to use anywhere. Its wide elastic bands support jumpers up to 250 pounds, and the nylon mat won't sop up sweat and make your house smell like a gym.

CHOICE

chrome improvement

GOOGLE'S CLOUD-BASED CHROME OS SHRUGS OFF VIRUSES AND NIXES THE NEED FOR CLUNKY SOFTWARE, WHICH HAS MADE IT POPULAR WITH TYKES, PARENTS, AND SCHOOLS. LAPTOPS RUNNING IT CAN SUIT ANY TYPE OF STUDENT.



◀ For the beginner

Dell designed the **Chromebook 3100** to endure the gauntlet of elementary school. With its stout plastic chassis and rubberized edges, this 11.6-inch machine is tough enough to survive a 30-inch fall. Covered ports and a sealed keyboard ensure that a catastrophic juice box failure won't land this machine in the repair shop.



◀ For the power user

Google's Pixelbook Go offers many of the same specs found in top-tier Windows laptops, but it weighs just 2 pounds. The flagship includes a burly Core i7 processor, a generous 16GB of RAM, and a roomy 256GB solid-state drive. Its 12-hour battery life is enough for a full day of studying—or procrastinating.



◀ For the aspiring creative

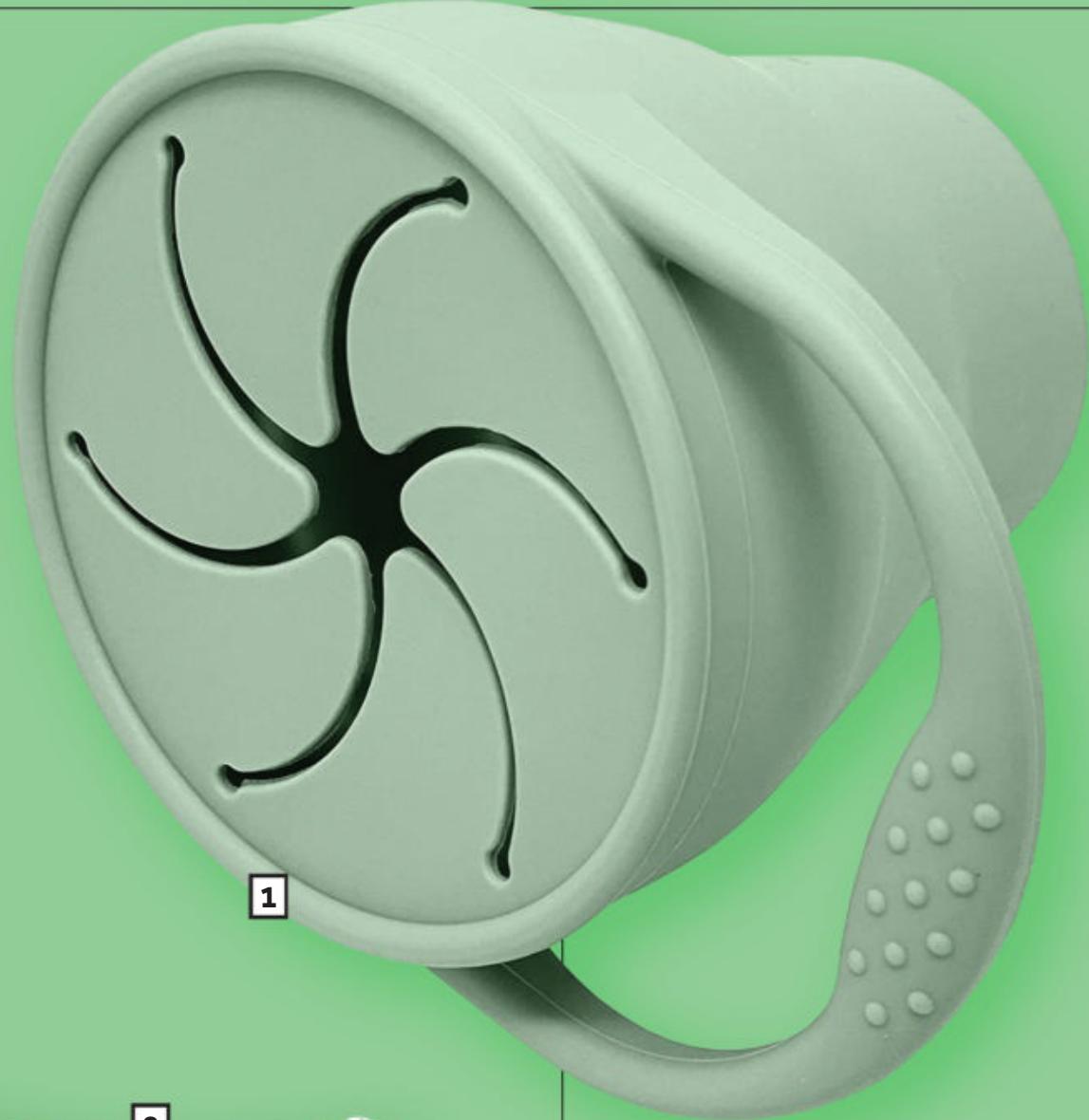
Thanks to its 4,096 levels of pressure sensitivity, the pen nestled in the body of the **Asus Chromebook CM3** can sketch, draw, or write on the removable 10.5-inch HD touchscreen with the precision of an IRL implement. The computer also works with a growing number of standardized third-party styluses for easy upgrades.

precious cargo

A PROPERLY STOCKED DIAPER BAG CAN BE THE ONLY THING THAT STANDS BETWEEN CAREGIVERS AND A LITERAL SH*TSHOW. THESE MUST-HAVES DESERVE A SPOT IN ANY EVERYDAY BABY CARRY.

1. Brave Justice Snack Attack

Five flexible flaps let little hands reach through this collapsible container's lid without removing it, keeping Cheez-It's off your upholstery. It holds up to 8 ounces of a kiddo's favorite food and fits in car cup holders.



2. Alvababy Wet Dry Bag

These waterproof lined polyester totes are roomy enough for a day's worth of dirty cloth diapers. A second spacious zippered compartment provides stowage for clean duds or befouled outfits.



3. OXO Tot-on-the-Go Wipes Dispenser

A sturdy plastic loop allows this container to dangle from a backpack strap. The push-button lid opens with a single snap, allowing quick access for emergency mop-ups.



4. Babyganics SPF 50 Sunscreen

This lotion combines ray-blocking titanium dioxide and zinc oxide with tomato, sunflower, cranberry, and other oils to protect young skin. The zinc means it goes on white, making it easy to see any missed spots.





5

5. Burt's Bees Organic Burp Cloths

Two layers of ring-spun organic cotton give these 16-inch-by-11.8-inch cloths a weave that's soft enough for your baby yet durable enough to avoid pilling or disintegrating after repeated washes.



7

6. Nuby Pacifinder

A spring-loaded clip at the end of this 6-inch nylon strap grabs securely onto clothes or a stroller, so a little one won't be able to huck their binkie onto the nasty floor or into a hidden recess of the car.



6



8

8. Twelvelittle Unisex Courage Backpack

The zipper on the generous main compartment of this nine-pocket bag runs its entire length. That allows the sack to splay open for quick, easy access without digging.



9

9. Skip Hop Pronto Changing Station

This polyester tote contains everything you need for a quick cleanup—a waterproof pad, a case for wipes, and room for a few nappies—yet collapses to about the size of a laptop.



IT'S

PG 25
popsci.com
Fall 2021

The search
for a fountain
of youth has
obsessed
humankind for
millennia, but the
secret may have
been running
through our
veins all along

IN

OUR

By Kat McGowan

Illustrations by
Owen Gent

BLOOD

MOUSE

BLACK

SNUFFLES AROUND A TINY TOWER OF LEGOS, TURNS AWAY, then comes back to snuffle again. He's 18 months old—a senior citizen, in rodent terms. And it's getting tough to keep it all straight. Do these blocks seem familiar to him? Has he seen this thing before?

He's a bit muddled, but that's not his fault. Few new neurons are being born inside his itty-bitty brain. The cells that once exuberantly branched, sending lush offshoots to interweave and connect with others, are now sparse and barren.

This Lego test indirectly measures those physical changes by monitoring his behavior. When mice of a certain age become forgetful, they spend more time checking out little trinkets they've seen before—objects that should warrant only a quick "Oh yeah, that thing again" glance. Cameras and laser-based detectors mounted on the ceiling capture and quantify those pauses and vacillations.

Alana Horowitz, the University of California, San Francisco graduate student conducting this FaceTime lab tour, puts her phone camera right up to the mouse's muzzle. His eyes are bleary, like an old barfly's. He probably hasn't groomed himself recently, she says. His coat looks shabby and worn. You've likely never looked an elderly mouse in the face, but if you did, all of this—the thinning fur, the dim eyes, the hesitation—would be depressingly familiar. He inspires pity. Like sands through the hourglass, little fella.

But in this lab, headed up by neurobiologist Saul Villeda, nobody is sighing and moping over graybeard mice. Here, aging is not a sad fate to bemoan; it's a problem to be solved. And for mice, at least, this team has already figured out how to reverse the damage time brings.

The secret is somewhere within those tiny veins. In a series of studies over the last 15 years, Villeda and others in a few like-minded labs at places like Stanford and Harvard have shown that, when infused with blood from young mice, old ones heal faster,

move quicker, think better, remember more. The experiments reverse almost every indicator of aging the teams have probed so far: It fixes signs of heart failure, improves bone healing, regrows pancreatic cells, and speeds spinal cord repair. "It sounds sensational, almost like pseudoscience," says Villeda. It's some of the most provocative aging research in decades.

These studies, which use a peculiar surgical method called parabiosis that turns mice into literal blood brothers, show that aging is not inevitable. It is not time's arrow. It's biology, and therefore something we could theoretically change. The attempt to turn back the clock in living bodies "is probably the most revolutionary experiment that biologists have done," says Stanford professor of neurology Tony Wyss-Coray, who was Villeda's graduate supervisor and still leads blood-based research on Alzheimer's disease and cognitive decline. "It supports this notion that it is possible to reassemble and fix things that we thought are doomed to die."

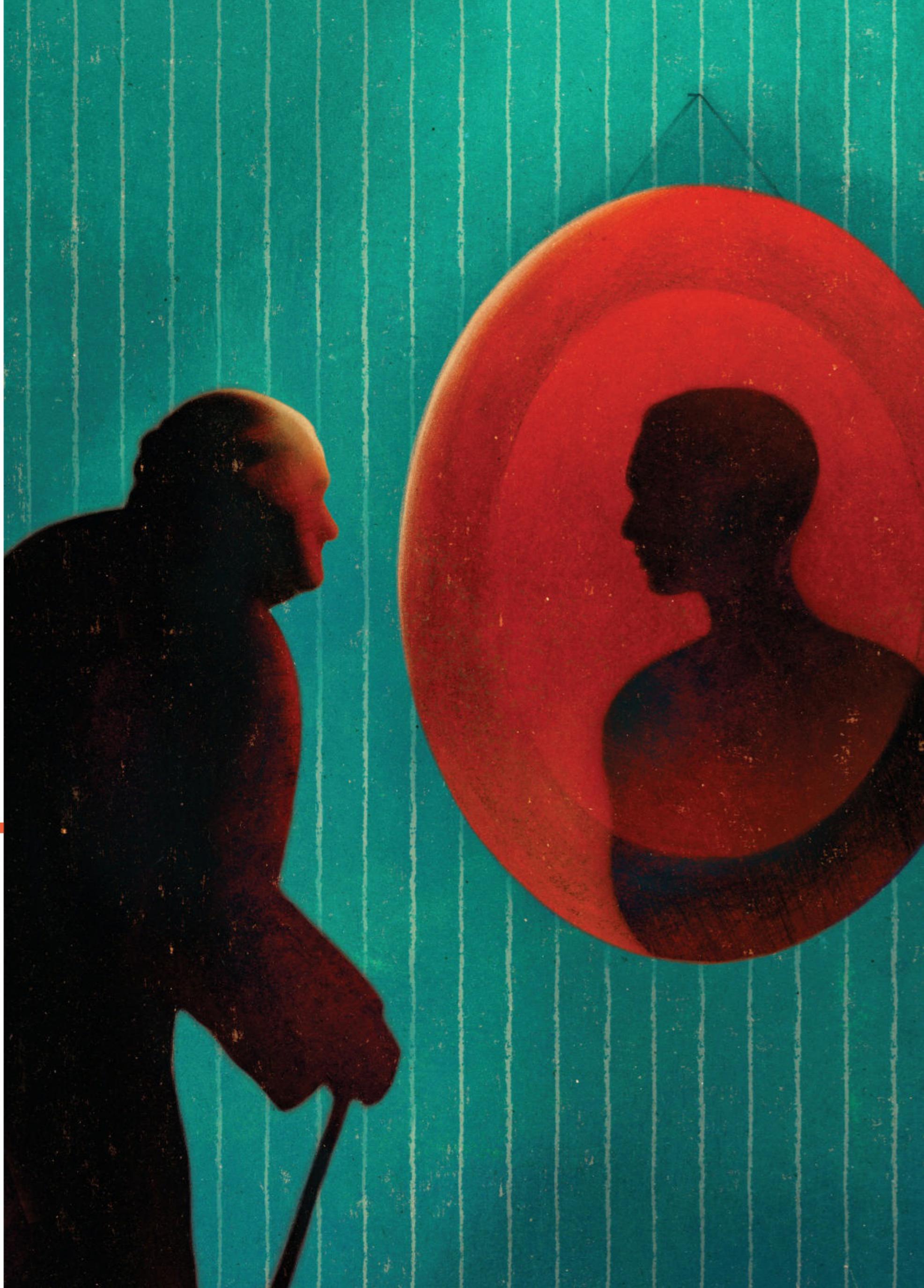
Benjamin Button-ing, of course, isn't natural. But Villeda counters that getting old isn't either: "It is the most artificial construct." Previously, only a very few rare individuals reached 90 or 100. Now, in wealthy nations, it's becoming downright common. With antibiotics, vaccines, public health measures, and a steady food supply, the industrialized world made the long, slow goodbye of aging commonplace—and, along with it, the consequences, such as brittle bones, Alzheimer's disease, diabetes, and heart failure. Young-blood research, like some gory fairy tale, whispers to us that there could one day be a magic pill that can fix it all. The plot twist: That bloody fountain of youth was inside our bodies all along.

Biologists like Villeda just haven't yet figured out why all this trading works.

Blood itself will not become a treatment for old age. It's too messy, too complicated, too dangerous. But because of these labs' findings, we know that somewhere swirling around in young veins are signals that awaken the natural mechanisms to repair and restore the body. These mystery factors, once researchers can identify and fine-tune them, could become precious medicine.

Villeda's group in particular is applying parabiosis to address the toughest task of all: fixing an elderly brain. His team is also testing whether other physiological benefits, like those brought on by fasting or exercise, could be spotted in blood and distilled into a remedy for the aged. "We know there's a needle in this haystack," he says. "We just have to figure it out."

● THE IDEA THAT BLOOD CAN IMPART VIGOR AND vitality has a long and stomach-turning history. Pliny the Elder, writing in first-century Rome, describes people with epilepsy guzzling the gore of wounded gladiators. Similar motifs reappear frequently in European lore: The sickly 15th-century pope Innocent VIII allegedly traded blood with three shepherd boys; all four died shortly thereafter.



Once British physician William Harvey mapped the circulatory system in 1628, swapping fluids became a fad. Across France and England, enterprising proto-scientists linked animals to animals and animals to people, and on and bloody on. Their hypothesis was that blood could remodel the flesh. In 1666, for instance, the legendary natural philosopher Robert Boyle proposed that introducing blood from a cowardly dog into a fierce one might temper the savage beast's nature.

In 1667, London's Royal Society hosted a public experiment in which a surgeon paid a man suffering from mental illness to be linked to a living sheep for a few moments via feather quills and silver pipes. Perhaps the gentle lamb's essence might ease his agitation, was the thinking. Afterward the fellow indeed "found himself very well," at least according to the surgeon, and he allegedly went on to spend his fee in the tavern. (The sheep's feelings were not recorded.)

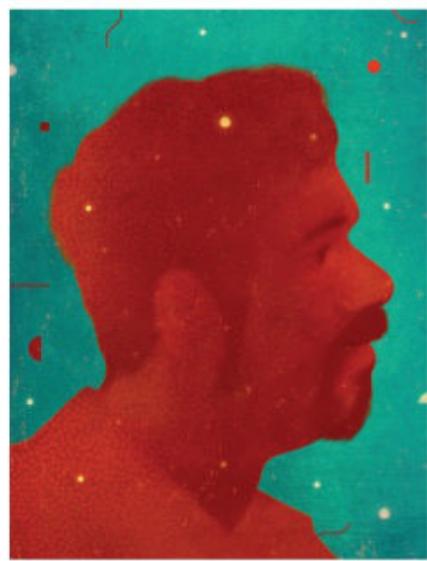
Months later, a Frenchman died following a transfusion, taking the wind out of these blood-spattered sails. The pope himself (Innocent XI, this time) put an end to the practice in 1679.

A new round of transfusion science emerged in the early 19th century, this one with much more scientific rigor. These experiments helped establish the first real knowledge about how to keep injured soldiers from bleeding out or mothers from dying in labor. But it wasn't until 1864 that a Parisian physician working on skin grafts developed true parabiosis: a sustained commingling of the blood supplies of two living creatures.

Knowing that the red stuff flows through every organ and tissue, scientists have used the technique ever since to study bodywide states like obesity and systemic diseases like radiation sickness. If you divert blood from a sickly animal into a healthy one, and that one also becomes ill, it suggests some soluble factor in the blood plays a role. That knowledge, in turn, helps you narrow down what causes the illness or condition. For example, in 1958, scientists linked up rats from a strain prone to tooth decay to rodents from another strain that's naturally resistant to cavities, to test whether something in the blood might account for the differences. In this case, at least, blood swapping made no difference.

Heterochronic parabiosis, in which researchers pair two animals at different points in the lifespan, was first used to study aging in the 1950s. But by the 1990s, it was largely forgotten—until Stanford put it back on the map.

AGING AFFECTS EVERYTHING EVERYWHERE, ALL AT ONCE. The hair grows gray, the bones weaken, the heart falters. Inside cells, DNA replication glitches and stutters, and proteins clump up into sticky globs. Meanwhile, natural repair mechanisms like adult stem cells no longer scurry to replace dead or injured tissues. All



Neurobiologist Saul Villeda is one of many zeroing in on the elixir of youth flowing in our blood.

this happens more or less in sync, as if some systemwide signal has told the whole body to go down the tubes.

This organized process of decrepitude was still largely an enigma in 1993, when biologist Cynthia Kenyon, then at UCSF, discovered that mutating just one gene in a roundworm doubled its lifespan. Her finding helped launch the modern study of aging, but it soon became clear that a one-gene or one-protein approach wasn't going to work, at least not for mammals. "We started to realize that the human body is not a simple assembly of individual molecules, but an incredibly complex physiological machine," says Stanford's Wyss-Coray.

But what is it that coordinates this systemic ruin? Fellow Stanford neurologist Thomas Rando reasoned that it made sense to look in the blood, that witch's brew of biochemical whatnot that bathes the body, pinkie toe to pointer finger. Mostly water, nutrients, and red blood cells, what runs through our veins also transports a huge variety of signaling molecules that coordinate metabolism, immune responses, fight-or-flight reactions, and myriad other activities.

On the theory that blood-borne factors might orchestrate the transitions of aging, Rando and two postdocs in his lab, the husband-and-wife team of Michael and Irina Conboy, turned to heterochronic parabiosis. In the creepy but simple procedure, the surgeon slits two anesthetized mice down their flanks, then sutures and staples them together, side by side. Because these lab animals are so inbred, their immune systems don't attack one another. As the incisions heal, their blood vessels connect, and the two share a supply.

Conjoined, the Frankenmice learn to eat together, make their little nests together, and ramble around as if they're in a three-legged race. Their bodies begin to change. The old mouse's fur gets thicker and silkier. It scrapes together its bedding more quickly. The junior partner loses speed, becomes tentative.

The team's 2005 findings, published in *Nature*, caused a stir. It's like this: If an older mouse's leg gets frozen with a piece of dry ice, the cells in charge of muscle repair don't respond much; the number of active cells increases by just 10 percent or so. But after heterochronic parabiosis, twice as many cells activate in response to injury—a reaction like that of a young animal. Older mouse livers demonstrate a similarly sprightly cellular turnover.

The authors had brain data too, but it was too preliminary to be included in the paper. By 2005, the long-held dogma that adult brains cannot make new cells had softened: Research had shown that certain regions, including the hippocampus, could generate new neurons, but claims of actually restoring function still raised most eyebrows sky-high.

Soon after the Rando paper's publication, Villeda, then just 25, was returning to his graduate studies in Wyss-Coray's lab, one floor away in the same building at Stanford. The son of Guatemalan immigrants, Villeda

had been educated in public schools in Los Angeles with little exposure to science until college, when he walked into a lab and saw a mouse embryo growing in a dish. It blew his mind. He loved science, the challenge, the craziness of it, the fun of it. He was curious and intellectually fearless. That is to say, exactly the type of person to grasp this particular third rail.

"It was very high risk," says Wyss-Coray, who frequently collaborates with Rando. "Most people would say, 'What does blood have to do with the brain? This will absolutely not work.'"

For three years, Villeda did the tiny surgeries and collected evidence. Soon, he could see that new brain cells were in fact surging in old mice. And they looked great.

"When a neuron is born in an old brain, it's [usually] scrunched up," he says, balling up his fist. "In these old brains they looked just like the young ones, beautiful," he continues, stretching out his fingers. Those cells eagerly extended their long tendrils to make connections—the synapses that enable learning, memory, thinking, and everything else an elderly mind often struggles with.

In 2011, Villeda published a paper, also in *Nature*, showing that mature mice in parabiotic pairings sprout two to three times as many new neurons as usual. But the bigger splash came in *Nature Medicine* in 2014, where he demonstrated that the access to young blood not only remodeled old nerve cells so that they looked and responded like younger neurons but also improved aged mouse learning and memory. A group led by Harvard's Amy Wagers published similar results in *Science* at the same time, bolstering both claims.

Wagers and others at places like Columbia Medical Center soon showed that parabiosis could improve the function of heart, bone, and other tissues. These teams worked together to establish a working definition of what really qualifies as rejuvenation, including changes in DNA modification, gene activation, or protein levels characteristic of younger bodies.

As Villeda drew blood, he also collected plasma—blood with the cells removed—from young mice, drop by teeny-tiny drop, and transfused it into older ones. The effect was the same, strongly suggesting that whatever the magic was, it was something dissolved in the fluid itself, some code or key that signaled a fresh start.

THE PLOT TWIST:

THE BLOODY FOUNTAIN

OF YOUTH WAS

INSIDE US ALL ALONG.

"The way I think about it is that there's a lot of information in the blood," he says. Now, at last, they could work on cracking that code—and hopefully doing for humans what they'd already done for mice.

JUST TO GET THIS OUT OF THE WAY: NOBODY'S sewing humans together. Our immune systems would wallop one another, with potentially deadly consequences (the lovely technical term is *parabiotic disharmony*). Transfusing seniors with young blood isn't practical either; people would probably need repeat treatments, with each bringing a risk of infection, allergic reaction, and even injury to the lungs (transfusions sometimes cause a poorly understood immune reaction that ravages their lining). Because the dosing would restart cell division, it might also spark cancerous growths. And we don't even know whether it would produce the desired results in a human being—or what mechanism would be behind the transformation.

Nonetheless, those two 2014 papers inspired a lot of wild ambitions. Rando got calls from cosmetics companies developing elixirs for youthful skin and from men's magazines seeking secrets for reinvigorated muscles. A billionaire invited Wyss-Coray to an Oscar party. (He didn't go.) "You get offers of a lot of money and no oversight," says Villeda; people who owned property in nations with lax regulatory supervision on human research made what he refers to as "indecent proposals."

Longevity enthusiasts eagerly discussed the findings, even though there is little evidence that heterochronic parabiosis extends life; even in rodents, all we know for sure is that it undoes some late-in-life decay. Captains of the tech world also took note. Reputed interest from billionaire founder Peter Thiel inspired a spot-on subplot in the HBO comedy series *Silicon Valley* in which an aging mogul takes a meeting while getting pumped full of blood from a fresh-faced athlete.

Meanwhile, a cottage industry began selling young plasma. Around 2016, Ambrosia, a California company, offered to infuse customers as part of a clinical trial that charged participants \$8,000 to join. (So far, the team has not published any findings in the scientific literature.) Other entities and individuals launched similar efforts, such as a proposed study that would charge large sums to frail elderly people for doses of young plasma.

This "therapeutic plasma exchange" is a legitimate treatment for certain rare autoimmune diseases and problems with coagulation, so these providers are not necessarily required to obtain explicit approval from the Food and Drug Administration so long as they make no unsubstantiated health claims about their regimen. But, of course, they did: Companies marketed benefits for people with memory loss, heart disease, and even Parkinson's. The FDA, now stepping into the regulatory role of the 17th-century pope, released a stern memo in 2019 that curbed the trend.

WHAT IS AVAXHOME?

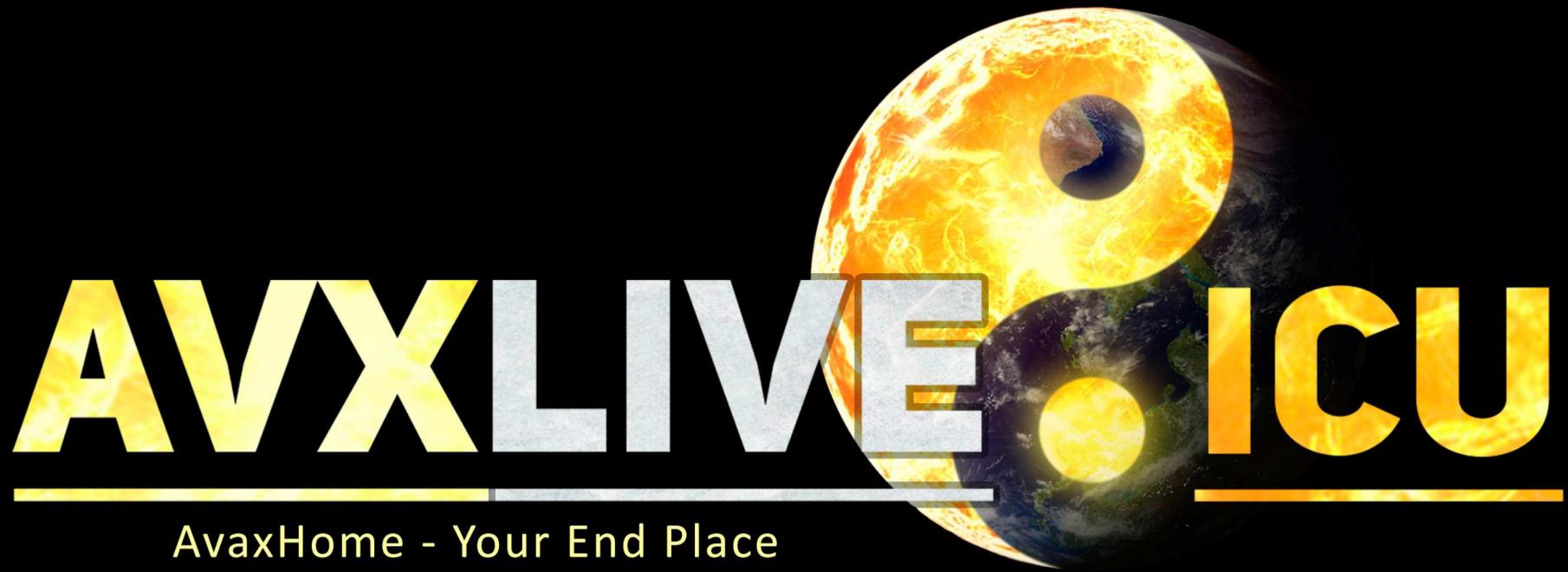
AVAXHOME-

the biggest Internet portal,
providing you various content:
brand new books, trending movies,
fresh magazines, hot games,
recent software, latest music releases.

Unlimited satisfaction one low price
Cheap constant access to piping hot media
Protect your downloadings from Big brother
Safer, than torrent-trackers

18 years of seamless operation and our users' satisfaction

All languages
Brand new content
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Ultimately, these projects made no progress toward the real prize, which is to convert the knowledge gained into a convenient, powerful, and predictable form, such as a pill. "Everyone recognizes this is an incredibly important experiment," says Eric Verdin, CEO of the Buck Institute for Research on Aging, who closely follows parabiosis. "What has been lagging is: How do you translate these discoveries?"

The most straightforward path would be to pinpoint a pro-aging factor in old blood, mouse and human, that a drug could block. Many groups have identified such elements. Villeda and his collaborators, for instance, found that a protein called CCL11 increases in aged humans and mice and is correlated with reduced brain cell birth.

The other obvious tactic is to identify youthful plasma's secret formula and optimize it. The Conboys' research suggests the hormone oxytocin might be a candidate; Wagers has identified the protein GDF11. Combination therapies are also under consideration; the biotech company Wyss-Coray founded is exploring mixtures of hundreds of blood-borne proteins as therapies for a variety of age-related diseases. Villeda is on its board.

It's also possible that the rejuvenating effects seen in experiments don't arise from one magic ingredient, or even from some combination of a dozen or a hundred compounds, but happen simply because the procedure dilutes some unknown harmful substances that accumulate in old blood. From this perspective, there's no particular need for young stuff: Any form of plasma replacement will do. It's sort of like changing the oil in your car.

The Conboys, now both at the University of California, Berkeley, suspect this is the case and are moving forward with tests of the idea. Their recent experiments, published in the journal *Aging*, replaced half the blood of some old mice with a mix of salt water and purified albumin (the main protein in plasma), which successfully rejuvenated the rodents' hearts, livers, and brains. They too are starting a company and are aiming for human clinical trials to determine if simply flushing out the bloodstream can help with problems like frailty and declining cognition.

At this point, the quest for a treatment has no satisfying ending. We know blood does indeed perform some kind of alchemy that can restore and remodel the flesh or hasten its decay. But even as that core mystery lingers, Villeda and others are rushing forward with a bigger project: cracking all the other codes that might be written in blood.

● SAUL VILLEDA IS NOW 40. HIS THICK BLACK HAIR STILL has no tinge of gray. He speaks quickly and laughs often and generally hums with energy. He still seems young, but he is no longer a newbie. At UCSF, he now oversees a group advancing a new era in rejuvenation research. It's looking at other systemic bodily shifts, such as those caused by exercise or diet, to find the mechanisms that can turn back the clock—demonstrating that youthfulness alone is not the only fountain of youth.

Soon after Villeda started his lab in 2013, his postdoc Shelly Fan was eager to begin a risky project. It's well known that exercise can reduce some of the effects of aging on the brain, increasing blood flow to the organ and boosting cell birth in one of the few regions that produce new neurons. The junior researcher wanted to see whether plasma from an active animal could transmit those benefits to a sedentary one—but it would take many years of work to find out.

Villeda was now the senior scientist, fretting that his fearless

young-blood collaborator was taking too big a risk. But he gave her the go-ahead. Shortly after the project got underway, Horowitz took over working with those Lego-snuffing critters. She's spent three years watching mice age, watching them run, watching them remember and forget. "It's long and grueling and tiring," she says.

Mature mice were allowed to sprint as much as they wanted on little exercise wheels for six weeks (these critters typically like a nice, brisk jog). She then collected their plasma and delivered it to aged couch-potato equivalents. These older animals' brains produced extra new neurons, and they aced memory tests. The paper was published in *Science* in summer 2020.

The surprise was that the effects seemed to flow through the liver, which ramped up several factors including an enzyme called GPLD1 that is also plentiful in active elderly humans. Rando and Wyss-Coray, with others, published similar results in *Nature Metabolism*; they found that serum (plasma with clotting factors and platelets removed) taken from exercising older mice restarted the systems responsible for muscle repair.

In addition to exercise, Villeda has played with a regimen known as caloric restriction that cuts food intake by 20 to 30 percent. Historically, the practice has improved age-related declines in brain, metabolism, and cardiac function in lab animals. At Stanford, Rando's group is testing a high-fat, low-carb ketogenic diet. Others are interested in the effects of short-term physical stress (such as from bursts of intense exercise, or maybe even a small dose of radiation).

Blood, this growing body of evidence shows, seems to carry a whole set of messages, each instructing organs to adopt different states: young, old, exercised, lazy, fasting. Since aging appears to change everything, in order to stop or reverse it, we may need to master them all.

And there are undoubtedly still more secrets pumping through our veins. Villeda is exploring platelets, of all things, funny little blood-borne blobs that apparently do a lot more than clot. Plasma rich in the stuff is already used by some sports medicine docs on the (still unproven) theory that it can help heal injuries. The lab has some preliminary evidence, based on an analysis of the proteins in that fluid, that these cell-like fragments are worth investigating further. It's a line of research that might please Villeda's senior-citizen mother, who lives with him and his husband and often reminds him to work on something that might help her aching joints. "I'm starting to branch out beyond the brain because of her," he laughs.

For the record, Villeda does not wish to live forever. He takes no anti-aging supplements and follows no regimens. He does not dream of bygone youth; he wants the life he has now, ruled by curiosity, excitement, and the thrill of discovery. He's not particularly scared of dying, when the time comes. For him, growing older means having his mind blown again and again. He's looking forward to it.



HUMANITY HAS BEEN KICKING AROUND FOR A LONG TIME, SO IT'S HARD TO FIND CITIES THAT ARE DISTINCTLY "NEW." BUT THE RARE NEWCOMERS, TOGETHER WITH REINVENTIONS OF AGING METROPOLISES, ARE TACKLING AGE-OLD PROBLEMS IN NOVEL WAYS. WE SUGGEST THE REST OF THE WORLD TAKE NOTES.



By
**GULNAZ
KHAN**

POPULAR
SCIENCE

WELCOME TO THE NEW METROPOLIS



FALL
2021

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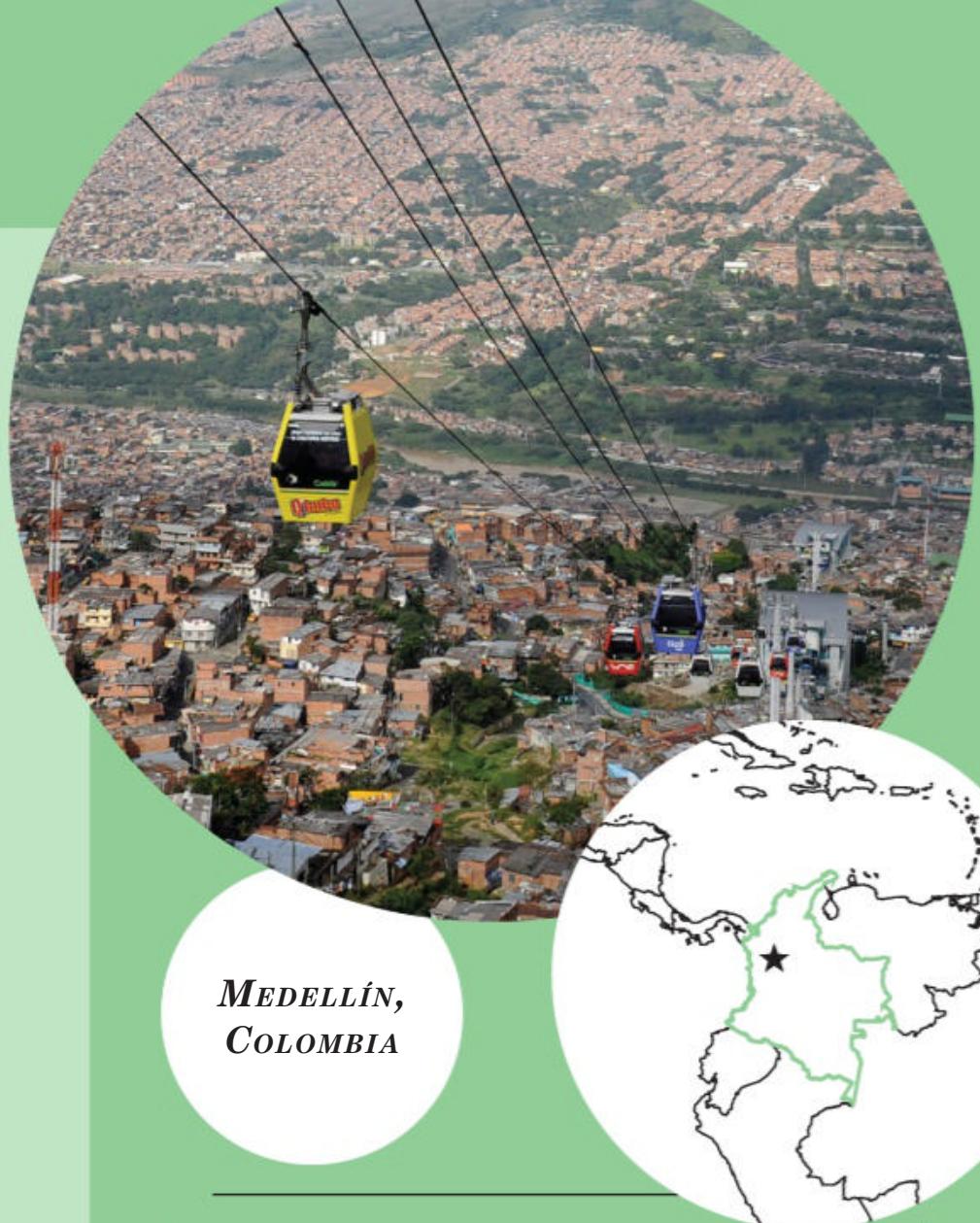
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FROM ROME'S VAST TRAJAN'S FORUM TO

Angkor Wat's stone temples, cities have been magnets for trade, art, and culture since ancient times. Urban living as we know it first emerged around 3500 B.C.E. along the Nile Valley and Sumerian coast. Unlike the semipermanent villages that came before them, these social and political hubs were built around sophisticated systems of agriculture and transportation. Today, around 56 percent of the world's population is urban, and by 2050 that number could jump to around 70 percent, by some estimates.

While metropolises continue to serve as centers for economic growth, they're also facing unprecedented challenges: affordable housing crises, unemployment, healthcare shortages, food and water scarcity, and social inequity. They're also on the front lines of climate change. With 90 percent of all urban areas located on coasts, they're vulnerable to rising seas, in addition to heavy rainfall and extreme heat.

But with these obstacles come opportunities to reimagine our densest spaces. In the past two decades alone, more than 150 new cities have sprung up from scratch in more than 40 countries, and centuries-old settlements have begun to replace their crumbling infrastructures and establish radical new ways of living. Here are seven centers of innovation tackling the most daunting issues of our time—from climate change and overcrowding to biodiversity loss and poverty—that can serve as blueprints for communities around the globe.



THE AERIAL CITY

In the 1980s and '90s, Medellín became infamous as the center of Colombia's drug trade. At the same time, growing political violence in rural areas meant hundreds of thousands of people fled to urban centers in search of safety and economic opportunity. Informal settlements cropped up along the slopes of the Aburrá Valley, where low-income housing crowded on the fringes of the city at an average of around 160 dwellings per acre (about as dense as downtown Chicago or Portland). Public transit couldn't navigate the steep terrain, narrow streets, and numerous streams. The city's most disenfranchised faced hours-long commutes to jobs and basic services, and became increasingly isolated—geographically, socially, and economically. Years of research suggest areas of concentrated poverty experience higher crime rates, poor health outcomes, and low school attendance—but more robust public transit can help create more equitable cities. In 2004, Metro de Medellín introduced a creative, low-cost solution: the first aerial cable car system fully integrated into public transport. Average trip times dropped from 120 minutes to 65. Some planners think it could be a useful model for other cities—from Seattle to Mumbai—where low-wage workers are pushed to the periphery. Medellín's success has inspired similar projects throughout Latin America, including in Caracas, Mexico City, and La Paz.

**TEMPE,
ARIZONA,
US**



THE CARLESS CITY

The desert city of Phoenix is one of the fastest-growing metropolitan areas in the United States, having added more than 750,000 residents in just the past decade. It's also known for being one of the worst culprits when it comes to urban sprawl, meaning residents rely heavily on cars. Just outside Arizona's unsustainable capital, a new apartment development called Culdesac Tempe has set out to be the first automobile-free community created from scratch in the US. Conveniently located along the light-rail line to downtown Phoenix, this neighborhood sits on a 17-acre lot and will feature a restaurant, a coffee shop, an urban market, e-bikes, scooter shares, and 761 apartments. The first residents—who are strictly forbidden to bring in cars or park in surrounding neighborhoods—are expected to arrive in 2022. While Culdesac Tempe's no-car rules may seem extreme, it's the kind of radical action cities are embracing to cut down on parked cars, combat greenhouse gas emissions, and boost health among city dwellers. In fact, the "15-minute city"—a bold urban planning concept based on the idea that everyone should be able to access all their basic needs with a short walk or bike ride—is gaining traction around the world. Paris, for example, has added bike routes and created mini green spaces to increase connectivity and reestablish social connections.



THE FLOATING CITY

Amsterdam was originally founded as a small fishing village in the 13th century, but today it's home to around a million people who live 6.5 feet below sea level. To accommodate the still-expanding population, the locals have had to get creative: They're making more land. In 1996, the construction of IJburg, an archipelago made up of 10 artificial islands, began. The Dutch used a technique called the "pancake method" to form a solid, compacted base. Builders create mesh screens in the size and shape of the future island and secure them underwater without harming wildlife. Then they spray the screens with a layer of sand, which slips through the porous mesh and eventually settles and becomes compacted on the lake bed. Another coating is then sprayed on top, and then another—like pancakes in a stack. When the sand rises around six feet above the water, an island is born. Thus far, four of the seven islands are complete, with networks of buildings, businesses, and walking and biking bridges, all within a 15-minute tram ride of Amsterdam's Central Station. The idea is to moor floating homes to the new land so they can rise with the sea. IJburg is intended to house up to 45,000 people in 18,000 homes, and it could serve as a model of resilience for the 570-plus other cities that are currently at risk from sea-level rise and storm surges by 2050.



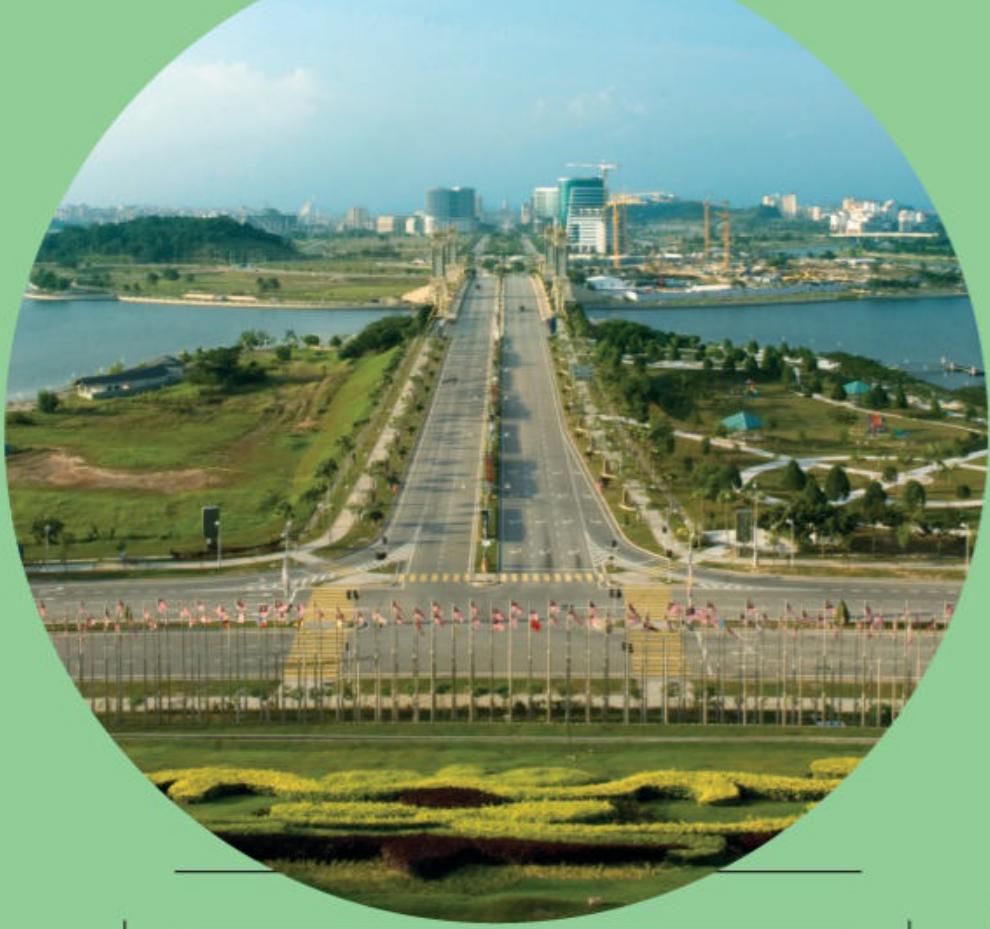
**IJBURG,
AMSTERDAM,
NETHERLANDS**



KIBERA, NAIROBI, KENYA

THE COMMUNAL CITY

Located on the outskirts of Nairobi along the Ngong River, the informal settlement of Kibera is home to about a quarter of a million people living on less than 1 square mile. A typical dwelling is about 12 feet by 12 feet and houses eight or more. Poor drainage, sanitation, and housing infrastructure combined with increasing rainfall mean the largely makeshift structures are especially vulnerable to severe flooding. So in 2006, the nonprofit Kounkuey Design Initiative (KDI) established the Kibera Public Space Project, a network of community-run gathering spots that build flood resilience while creating room for recreation and small businesses. One site serves as a gathering area, school, and place of worship, while its rooftop is used for rainwater harvesting, a technique used to collect and store droplets. When the precious stuff hits the roof, instead of letting it pour freely onto the ground, where it would contribute to flooding, a system of gutters and downspouts channels the liquid into storage tanks, where it can then be used to irrigate a connected greenhouse. KDI has also designed zones that focus on the needs of women and children—like community laundry facilities that sit next to play areas—so women can balance household work and childcare. To date, more than 5,000 residents have been involved in KDI design projects, including the installation of 2,755 feet of new drainage infrastructure, the planting of vegetation to help absorb precipitation, and the construction of these 11 climate-resilient public spaces. These efforts have directly reduced the flood risk for an estimated 8,000 households.



THE GARDEN CITY

In the 1980s and '90s, the Malaysian government sought to consolidate its offices and alleviate traffic in the increasingly congested capital. Putrajaya is the country's urban solution to both overpopulation and pollution. In addition to new infrastructure, it built something more innovative: artificial wetlands. Construction began in 1997 and took 17.5 months to complete. Because wetlands double as natural water-filtration systems, they were created in the valley of the Chua and Bisa rivers, which had been polluted by oil palm and rubber plantations. Builders dug a network of 24 wetland cells, or earthen depressions, and divided them with low dams to create steplike levels. (This design allows water to flow through the cells and empty into Putrajaya Lake.) Each cell was then filled with topsoil, planted, and fully inundated; along with other open spaces like parks and botanical gardens, they now make up more than one-third of the urban area. The wetlands also host more than 25 species of plants and provide habitat for fish and waterbirds. And the government isn't stopping there. By 2025, Putrajaya aims to become a "green city," and it has already increased bike paths and walkways and planted hundreds of thousands of trees to sequester carbon.



PUTRAJAYA, MALAYSIA

**CURRIDABAT,
SAN JOSÉ,
COSTA RICA**



THE *BIODIVERSE* CITY

Costa Rica covers about 0.03 percent of Earth's surface but is home to about 6 percent of the world's biodiversity, and it is a leader in conservation. But San José and the surrounding metropolitan areas aren't immune to the ways modern urbanization impedes those efforts. Just outside the capital, though, Curridabat is doing things differently. Known as Ciudad Dulce (or Sweet City), the district is promoting the idea that healthy urban development should accommodate nature, not the other way around. To put this idea into practice, Curridabat launched reforestation projects, converted natural ravines into public parks, and created tree-covered walking and biking paths. These so-called biocorridors provide habitats for animals, plants, insects, and birds, all while controlling air pollution, keeping the area cooler, and offering shade to residents on hot days. In February 2021, on the second anniversary of Costa Rica's commitment to a national plan to reach zero net emissions by 2050, the government announced a new conservation category to protect at-risk ecosystems in cities across the country: Urban Natural Parks. La Colina de Curridabat Ecological Park is among the first to be granted the designation. Cities around the world should pay attention: Urban parks and green spaces have been shown to promote better mental health, boost social cohesion, encourage physical activity, reduce noise and air pollution, and protect from extreme heat.



**ZHENJIANG,
CHINA**



THE *SPONGE* CITY

Between 1950 and 2018, flooding in China killed an estimated 280,000-plus people and damaged nearly 15 billion acres of land. The nation isn't alone. According to climate change projections, extreme precipitation and flooding are going to increase worldwide, and cities are especially vulnerable. That's because vegetation, soil, and trees—which naturally absorb and store groundwater—are scarce compared to highways and buildings. Nestled on the banks of the Yangtze River in eastern China, Zhenjiang is just one of the country's zones at high risk for inundation. In response to this growing threat, it was one of 16 pilot locations for the "sponge city" project in 2015. The goal is to transform at least 20 percent of the land into permeable surfaces—including parks, rain gardens, green roofs, and pervious pavement—so that neighborhoods can absorb heavy rains. Since the effort launched, Zhenjiang has implemented a rain garden, expanded green spaces, and built storage systems to purify and reuse a deluge. Some 658 Chinese locales have also enacted government-mandated sponge city designs, adapted to their unique geographical needs. Meanwhile, other areas at risk of urban flooding across the globe are deploying their own greening projects to help absorb heavy precipitation, from Philadelphia's Green Acres program to Cairo's rooftop garden initiative.



THE THING ABOUT

BY YASMIN TAYAG

zoomers



millennials



POPSCI.COM

TODAY

IS GEN Z REALLY
THAT DIFFERENT
FROM OTHER
GENERATIONS?
YES AND, WELL,
NO. WHY LUMPING
PEOPLE BY AGE
DOESN'T WORK.

gen x

boomers

FALL 2021

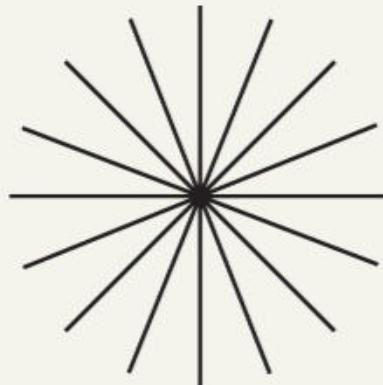
PC 39

one were to make a Generation Z mood board, it might include, in no particular order: TikTok, climate activism, autonomous sensory meridian response (ASMR), Olivia Rodrigo, *Minecraft*, and calling older folks out of date or “cheugy.” A unifying theme, beyond the phone-bound youth associated with these things, is the internet. Climate TikTok galvanizes the young and eco-conscious. Regular TikTok unleashes Gen Z barbs like cheugy unto the group’s predecessors, millennials (ouch). Whispered *Minecraft* commentary does double duty as ASMR. “Drivers License” sped through a global pandemic into the streaming-music hall of fame.

As Gen Z creates and inhabits entire digital worlds of its own, older groups may feel left out—or *pushed* out, if the tone set by some cultural commentators is to be taken seriously. Many of them contend that we are in the midst of a generational war, in which Gen Z dismisses Hogwarts-loving millennials as too self-obsessed to take action against the ice-cappmelting wrongs of their capitalist elders, who respond by scoffing at the snowflakery of modern youth. To which the kids say: OK, boomer.

But take an honest look at the mood board, and any credible basis for war dissipates. Generational labels are so fuzzily defined that it can be hard to tell who belongs in which camp, let alone who’s fighting with whom. (How does one categorize a 34-year-old climate justice advocate who’s definitely a Gryffindor and knows every word to Olivia Rodrigo’s *Sour*? Asking for a friend.) Even where there is tension—take Gen Z’s derision for cheugs—it’s no different from the contempt youth have always directed at older people. And while Gen Zers seem to prefer their phones and friends over everything else, it doesn’t mean they reject their elders and whatever wisdom they may have.

Viewing society through the lens of generational conflict is humorous at best, but it can cause real harm. “These stereotypes are not just a bit of fun,” says Bobby Duffy, a professor



of public policy at King’s College London and author of the forthcoming book *The Generation Myth*. “They are a problem because they affect how we see and therefore deal with big issues” like climate change and social injustice. If we keep raising arms along the fabricated battle lines between generations, then divided we may all fall.

GENERATIONS

are, by and large, ill defined. The simplest explanation comes from demographers and marketers: People born between roughly 1981 and 1996 are millennials, while Gen Z falls between 1997 and 2012.

But birth year isn’t the only factor, and, many would argue, it’s hardly the most important one. The term *generation* originally referred to levels of kinfolk in ancestry (the grandmother, her daughter, her grandchild, and so on). In immigrant studies, it pertains to steps in a family’s lineage after it moves to a new country. It wasn’t until the 19th century that Western philosophers proposed it as a metric to track a society’s progress. German sociologist Karl Mannheim cemented this idea in 1928, positing that generations composed of “youth experiencing the same concrete historical problems” drove social change.

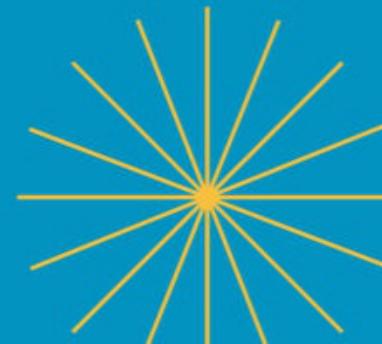
In a 1991 book titled *Generations*, American authors William Strauss and Neil Howe proposed that new groupings appear roughly every two decades according to a cycle of four personality types (idealist, reactive, civic, and adaptive) that repeats every 80 years or so. Academic experts panned this theory for lacking

empirical evidence, but its emphasis on birth year remained, to the chagrin of some scholars. St. Louis University professor Cort Rudolph, who studies aging in the workforce, contends that generations are “not really a ‘thing’ outside of the language that we use variously to describe relatively older/younger people at a given point in history.”

Most academics who study generations acknowledge that doing so is imprecise. “It’s very tricky when you’re talking about generational research because you are in fact generalizing,” says Stanford University anthropologist Roberta Katz, a co-leader of the iGen Project, an in-depth study of British and American kids growing up in a hyperconnected world.

Still, rigorous research on generations exists and can be useful. Thinking about them helps investigators determine how societies change. “We have to understand that there is diversity within generations, but there are some generational factors that are relatively consistent,” says Corey Seemiller, a professor of leadership studies at Wright State University who specializes in Gen Z.

For example, information and misinformation have spread faster during Gen Z’s lifetime than at any other point in history. As a result, they “self-inform in a way that prior generations of young people could not,” says Katz, who is co-authoring a forthcoming book titled *Gen Z, Explained*. (Millennials are referred to as “digital natives,” but she points out that this term refers to fluency with electronic devices, not the unique circumstances of growing up with a vast communication network at your fingertips.) Ultimately, adds Seemiller,



"the fact is that all of Gen Z were born into a world in which the commercial internet exists"—a characteristic no other generation can claim. This makes them different, but it doesn't make them uniquely adversarial.

TENSION

between youth and adults is nothing new. King's College's Duffy points out that after World War I "there was this very clear sense of young people being betrayed by older generations," who had sacrificed mere teenagers in battle. Thus a sense of united consciousness emerged: *They did this to us.*

History repeats. Bruce Gibney's *A Generation of Sociopaths*, published in 2017, blames boomers for squandering the country's post-World War II wealth. Aggrieved environmental activist Greta Thunberg told world leaders at a United Nations climate summit in 2019 that young people "are starting to understand your betrayal." No matter the unique challenges of the present day, feeling screwed over by one's elders is a time-honored tradition.

So is not wanting to hang out with them. In the past, putting up a "No grown-ups" sign on a treehouse would have effectively kept adults out, creating a place where kids could be kids. Not so in the internet era, where most digital spaces are accessible to people of any age. The "creepy treehouse effect" occurs when adults use a social media platform claimed by youth, making it, well, creepy: Turned off by olds on Instagram, Gen Z migrated to Snapchat. When millennials discovered snaps, kids danced over to TikTok. The cycle will likely continue as long as the internet is free and adults can keep up.

Though youth have always wanted separation from their elders, the dynamic may feel more fraught now because "technology makes it easier for adults to show up in their treehouse," explains Seemiller.

That's not to say Gen Z wants to cut

ties with its elders altogether; even though its immersion in devices—and frustration with hopelessly tech-inept parents—can make it seem that way. Seemiller, who has co-led three large national surveys of Gen Z students and published the results in four books, has found that today's youth are actually more likely to look to their parents for advice than previous generations, a trend corroborated by multiple other studies.

Gen Z kids I spoke to seem to agree. Seventeen-year-old Kiera Menor, from Oklahoma City, turns to the internet for schoolwork but to her parents for personal insights. "They're a reliable source," she says. "They've lived more than I have." Chelsea Fuller, a 21-year-old college grad from Lancaster, California, says, "Anything about my body, I would go to my mom." Andrew Heller, 17, from Petaluma, California, wants college guidance from his parents, not from strangers on the internet. "I don't know how much I can trust them," he says.

Parents, understandably, get nervous when they don't know what Gen Z is up to online. Seemiller assures them that kids and teens use tech for the same reasons older folks do: entertainment, finding information, and showing people how to do things (mainly via YouTube). A big goal is connecting with others, which they do differently from older people, who tend to use social media to stay in touch with those they already know. Gen Z also uses it to form new relationships. While millennials met on campus and messaged on Facebook, for Gen Z, TikTok is the college quad. But the impulse to be social is the

same. "The technology provides them with an opportunity to learn and connect in ways that none of us had when we were younger," says Seemiller.

IT'S

easy, and sometimes funny, to play along with the notion of generational stereotypes as they're presented in think pieces and survey results online. They can give a sweeping view of the ways society is changing, offering older people some context for resituating themselves within it. (I accept that millennials are outdated because, honestly, it is cringe-worthy to ascribe one's entire personality to a Hogwarts house.) But these are reductive tropes, and they carry a dangerous suggestion of conflict.

Duffy contends that there is no evidence of a looming generational war. "We don't really want to go to battle with our grandparents on things," he says. "We want them to be looked after because we love them. And they want a better future for their kids and grandkids because they love them." But he cautions that there is a real risk of drifting apart.

Keeping sight of the connections that exist between generations is important because doing so helps maintain optimism and faith in society and thus the willingness to keep working together to improve it.

Indeed, members of Gen Z, at the very least, seem interested in keeping their elders around—as long as they cool it with the digital creepiness. And if we stand by them, maybe there's a thing or two we can learn from them too. As Kiera Menor put it, referring to her *Minecraft* expertise: "I'm a beacon of knowledge."



Baby moths and butterflies pull off some wild
tricks to dodge detection and stay alive.



THE ILLUSIONISTS

Photographs by

Samuel Jaffe, the Caterpillar Lab

Erin Fennelly

By

Studying caterpillars can reveal other minutiae of the natural world. For example, this polka-dotted larva's favorite food, the pink-flowered white turtlehead, has grown increasingly scarce along the East Coast. That's prompted *Euphydryas phaeton* to dine on its distant cousin, English plantain, which suggests the flora are more closely related than believed.

Baltimore checkerspot

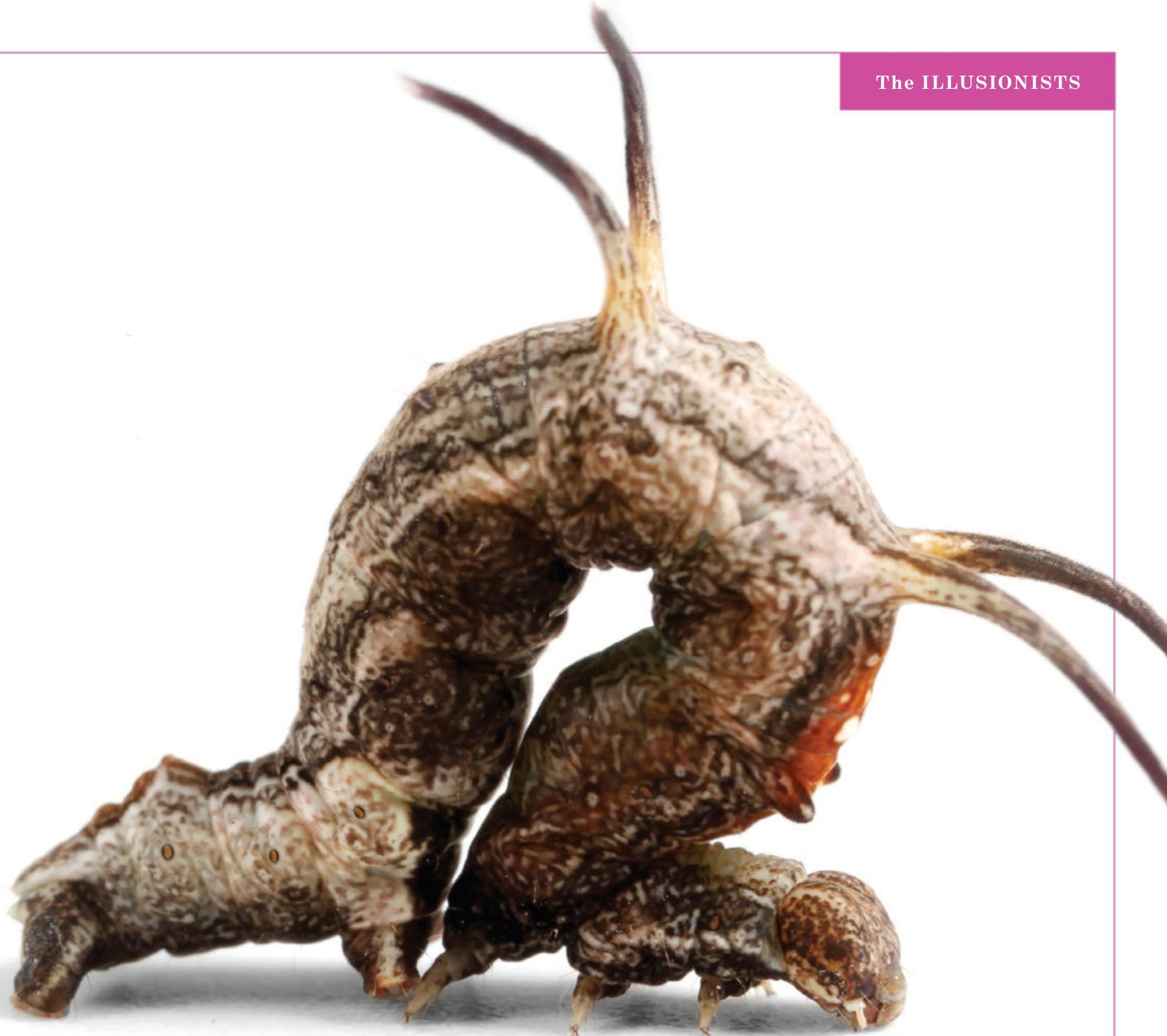


CATERPILLARS ARE MASTERS OF DECEPTION. Some imitate sticks and leaves to avoid becoming lunch. Others flash bright colors to convey their toxic nature. A few even wave pumped-up limbs to frighten foes. ¶ Despite such impressive maneuvers, humans tend to overlook these wee wonders. But they rarely escape the eye of Samuel Jaffe, an entomologist who's spent his life uncovering their anonymous exploits, a fascination that began when he was a kid collecting the critters near his Massachusetts home. ¶ Before long, Jaffe started photographing them. In 2013, that project blossomed into the Caterpillar Lab, an education center in New Hampshire with thousands of live specimens. The nonprofit's scores of caterpillar close-ups provide a fascinating glimpse of the secrets hiding in backyards everywhere, just waiting to be found.

These aptly named insects live on only a few coniferous species and blend into the barbed texture of the branches with their spiky horns. Jaffe believes the shiny spheres atop *Citheronia sepulcralis*'s crown could also mimic dripping sap. Its reliance on pines, however, makes it vulnerable to deforestation.

Pine devil





Filament bearer

Nematocampa resistaria sports four odd tentacles that fill with fluid, swelling large enough to send pursuers running. The critters inhabit yards across the US and look a bit like spiders as they dangle on silk threads, freezing in spooky poses to further deter predators.



Silvery blue

The young *Glauopsyche lygdamus*, which will become a cerulean butterfly, defends itself against wasps and other threats with a security detail of ants. Some varieties of the species feed their guards sugary drops to keep them around. Others excrete a cocktail of chemicals that makes the trusted servants abandon their queen and colony.





●

●



This scrappy city dweller carries its pupal shell throughout its larval stage, adding bits of food, poop, and silk to form a cocoon that can reach the size of a pine cone. Once that's complete, *Thyridopteryx ephemeraeformis* tucks itself inside for seven to 10 days for its transformation into a brown, furry moth.



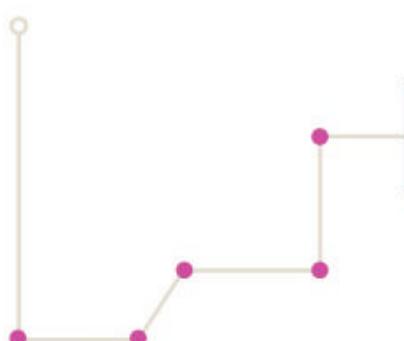
Evergreen bagworm





Milkweed tussock

While it may look like a fluffy ball of yarn, the orange-splotched *Euchaetes egle* signals danger to birds that might otherwise try to chow down—and for good reason. The caterpillar, like the beloved monarch butterfly, absorbs the poisonous cardiac glycosides in the milkweed leaves it eats.





In a vivid display of adaptation, *Heterocampa umbrata* caterpillars change their skin tones to blend in. This one has a pinkish hue to help it fade into the forest floor. Jaffe has seen more green specimens during wet, cool summers and larger numbers of red and other shades in hot, dry conditions.

White-blotched prominent





Black-etched prominent

When *Tecmessa scitascripta* feels threatened, it expands the colorful tentacles located on its last row of limbs by more than half the length of its body. The little critter then flails around, almost as if it's throwing a fit to scare off hungry birds, Jaffe says.

Pitcher plant moth caterpillar

Exyra fax spends its entire childhood inside one of its boggy namesakes. It hatches in the carnivorous flower, slurps up the plant's acidic digestive fluids to fuel its growth, then spins silk to seal the abode and continue feeding on leaf tissue. Some may move on to new hosts and hibernate through winter before completing their life cycle in the spring.



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<body> Li Xin Zhang's summer camp began with sandwiches—not eating them but designing them.

The rising seventh grader listened as teachers asked her and her peers to write instructions for building the ideal peanut butter, jelly, and bread concoction.

Heads down, the students each created their own how-to.

WHEN THEY RETURNED to the Zoom matrix of digital faces and told one another about their constructions, they realized something: Each of them had made a slightly different sandwich, favoring the characteristics they held dear. Not necessarily good, not necessarily bad, but definitely not neutral. Their sandwiches were *biased*. Because *they* were biased, and they had built the recipe.

The activity was called Best PB&J Algorithm, and Zhang and more than 30 other Boston-area kids between the ages of 10 and 15 were embarking on a two-week initiation into artificial intelligence—the ability of machines to display smarts typically associated with the human brain. Over the course of 18 lessons, they would focus on the ethics embedded in the algorithms that snake through their lives, influencing their entertainment, their social lives, and, to a large degree, their view of the world. Also, in this case, their sandwiches.

“Everybody’s version of ‘best’ is different,” says Daniella DiPaola, a graduate student at Massachusetts Institute of Technology who helped develop the series of lessons, which is called Everyday AI. “Some can be the most sugary, or they’re optimizing for an allergy, or they don’t want crust.” Zhang put her food in the oven for a warm snack.

A parent’s code might take cost into account.

A pricey PB&J is low on the world’s list of concerns. But given a familiar, nutrient-rich example, the campers could squint at bias and discern how it might creep into other algorithms. Take, for example, facial recognition software, which Boston banned in 2020: This code, which the city’s police department potentially could have deployed, matches anyone caught on camera to databases of known faces. But such software in general is notoriously inaccurate at identifying people of color and performs worse on women’s faces than on men’s—both of which lead to false matches. A 2019 study by the National Institute of Standards and Technology used 189 algorithms from 99 developers to analyze images of 8.49 million people worldwide. The report found that false positives were uniformly more common for women and up to 100 times more likely among West and East African and East Asian people than among Eastern Europeans, which had the lowest rate. Looking at a domestic database of mug shots, the rate was highest for American Indians and elevated for Black and Asian populations.

The kids’ algorithms showed how preference creeps in, even in benign ways. “Our values are embedded in our peanut butter and jelly sandwiches,” DiPaola says.

The camp doesn’t aim to depress students with the realization that AI isn’t all-knowing and neutral. Instead, it gives them the tools to understand, and perhaps change, the technology’s influence—as the AI creators, consumers, voters, and regulators of the future.



To accomplish that, instructors based their lessons on an initiative called DAILY (Developing AI Literacy), shaped over the past few years by MIT educators, grad students, and researchers, including DiPaola. It introduces middle schoolers to the technical, creative, and ethical implications of AI, taking them from building PB&Js to totally redesigning YouTube's recommendation algorithm. For the project, MIT partnered with an organization called STEAM Ahead, a nonprofit whose mission is to create educational opportunities for Boston-area kids from groups traditionally underrepresented in scientific, technical, and artistic fields. They did a trial run in 2020, then repeated the curriculum in 2021 for Everyday AI, expanding the camp to include middle-school teachers. The goal is for educators across the country to be able to easily download the course and implement it.

DAILY is designed to enable average people to be better informed about AI. "I knew that AI was pretty helpful for humans, and it might be a huge part of our life," Zhang says, reflecting on what

she'd learned. When she started, she says, "I just knew a little bit, not a lot." Coding was totally new to her.

DAILY's creators and instructors are at the forefront of a movement to bake ethics into the development process, as opposed to its being an afterthought once the code is complete. The program isn't unique, though others like it are hardly widespread. Grassroots efforts range from a middle-school ethics offering in Indiana called AI Goes Rural to the website Explore AI Ethics, started for teachers by a Minnesota programmer. The National Science Foundation (NSF) recently funded a high-school program called TechHive AI that covers cybersecurity and AI ethics.

Historically, ethics hasn't been incorporated into technical AI education. "It's something that has been lacking," says Fred Martin, professor and associate dean for teaching, learning and undergraduate studies at the University of Massachusetts Lowell. In 2018, Martin co-founded the AI4K12 initiative, which produced guidelines for teaching AI in K-12 schools. "We conceived of what we call five big ideas of AI, and the fifth is all about ethics." He's since seen AI ethics education expand and reach younger students, as evidenced by AI4K12's growing database of resources.

<quote> By teaching kids early what ethical AI looks like, how unfairness gets in there, and how to work around it, educators hope to enable them to recognize that unfairness when it occurs

The directory links to MIT offerings, including DAILY. Ethics is “front and center in their work,” Martin says. “It’s important that kids begin learning about it early so they can be informed citizens.”

At the Everyday AI workshop, the hope is that students will feel empowered. “You do have agency,” says Wesley Davis, a instructor at the 2020 pilot camp.

“You have the agency to understand. You have the agency to explore that curiosity, down to creating a better system, creating a better world.

“That’s a little flowery-philosophical,” he laughs. But that peculiar mix of idealism and cynicism is the specialty of teenagers. And so when asked if she thought she could, someday, make AI better than today’s, Zhang gave a resounding “Maybe.”

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DAILY BEGAN AS a way to right a wrong. Blakeley Payne (née Hoffman), a computer science major at the University of South Carolina, was hanging out in 2015 with her best friend, who had just applied for a job at Twitter. The rejection came back in a blink. How could the company possibly have decided so quickly that she wasn’t “a good fit”? They posited that perhaps an algorithm had made the decision based on specific keywords. Mad, Payne began reading up on research about bias in, and the resulting inequities caused by, AI.

Since Payne’s experience, AI partiality in hiring has become a famously huge problem. Amazon, for instance, made headlines in 2018 when Reuters reported that the company’s recruitment engine discriminated against women—knocking out résumés with that keyword (as in “women’s chess club captain”) and penalizing applicants for having gone to women’s colleges. Turns out developers had trained their algorithm using “résumés submitted to the company over a 10-year period,” according to Reuters, most of which had come from men. A 2021 paper in *International Journal of Selection and Assessment* found that people largely rate a human’s hiring judgment as more fair than an algorithm’s, though they often perceive automation to be more consistent.

At first, the whole situation soured Payne on her field. Ultimately, though, she decided to try to improve the situation. When she graduated in 2017,

and devise strategies to correct the problem. “Ethics has been taught either as a completely separate course or in the last two or three lessons of a semester course,” says DiPaola.

she enrolled at MIT as a graduate student to focus on AI ethics and the demographic where education could make the most difference: middle-school students. Kids this age are often labeled “AI natives.” They’ve never not known the tech, are old enough to consider its complications, and will grow up to make the next versions.

Over the next couple of years, Payne developed one of the first AI ethics curricula for middle graders, and her master’s thesis helped inform another set of interactive lessons, called “How to Train Your Robot.” When she graduated in 2020 and went on to do research for the University of Colorado, Boulder, MIT scholars like DiPaola continued and expanded her efforts.

Payne’s projects helped lay the groundwork for the larger-scale DAILY program, funded by the NSF in March 2020. DAILY is a collaboration among the MIT Scheller Teacher Education Program (STEP), Boston College, and the Personal Robots Group at the MIT Media Lab, an interdisciplinary center where DiPaola works. A second NSF grant, in March 2021, funds a training program to help teachers use DAILY in their classrooms. By forging partnerships with districts in Florida, Illinois, New Mexico, and Virginia and with youth-education nonprofits like STEAM Ahead, the MIT educators are able to see how their ivory-tower lessons play out. “The proving ground for any curriculum is in the real classroom and in summer camps,” says DiPaola.

When those kids—and many adults, even—think of AI, one thing usually comes to mind: robots. “Robots from the future, killer robots that will take over the world, superintelligence,” says DiPaola. “It was a big shock to them that AI is actually in the technologies they use every single day.”

Teachers have often told the STEP Lab’s Irene Lee, who oversees the grants, that they didn’t realize AI was being “deployed.” They thought it was an abstraction in labs. “Deployed?!” Lee says to them. “You’re immersed in it!”

It’s in smart speakers. It recommends a Netflix film to chill to. It suggests new shoes. It helps give the yea or nay on bank loans. Companies weed out job applicants with it; schools use it to grade papers. Perhaps most importantly to the summer-camp students, it powers apps like TikTok and whatever meme-bending video the platform surfaces.

They know that when they're looking at cat-mischief TikToks, they'll get recommendations for similar ones, and that *their* infinite scroll of videos is different from their friends'. But they don't usually realize that those results are AI's doing. "I didn't know all these facts," says Zhang.

Soham Patil, one of her camp-mates, agrees. A rising eighth grader, he'd been studying how AI works and writing software recreationally for a few months before the program. "I kind of knew how to code, but I didn't really know the practical uses of AI," Patil says. "I knew how to use it but not what it's for."

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PATIL, ZHANG, AND their peers' next activity involved a different food group: noodles. They saw on their screens a member of a strange royal family—a cat wearing a tiara, with hearts for eyes.

"There is a land of pasta known for most excellent cuisine with a queen who wants to classify all the dry pasta in her land and store them in bins," reads the lesson. "... YOU, as a subject in PastaLand, are tasked with building a classification system that can be used to describe and classify the pasta so the pasta can easily be found when the queen wants a certain dish."

Ethics of monarchy aside, the students' goal was to develop an identification system called a decision tree, which arrives at classification by using a series of questions to

That, she says, conveys a specific lesson: "Ethics is kind of an afterthought." < / quote>

sort objects based on their characteristics, first into two groups, then each of those into two more groups, then each of those into two more, until there is only one kind of object left in each group. For pasta, STEP Lab's Lee explains, "The first question could be, 'Is it long?' 'Is it curly?' 'Does it have ridges?' 'Is it a tube?'" Zhang's team started with "Is it round?" "Is it long?" and "Is it short?"

As before, though, when the kids reassembled, they realized their questions were all different: Some might ask whether a piece of pasta can hold a lot of sauce or only a little. Another might separate types based on whether they're meant to be stuffed or not. Patil noticed that some kids would try to separate the unclassified pasta into two roughly equal groups at every juncture.

"Could someone who is blind follow their key?" the teachers asked. What about the subjectivity in simply determining what "long" is? Even pasta was influenced by culture, experience, and ability. The students then extended this realization—that it's easy to bake in bias, exclude people, or misread your opinions as objective—to higher-stakes situations. Predictive policing is an example. The technology uses past crime data to forecast which areas are high risk or who is purportedly most likely to offend. But any AI that uses legacy data to predict the future is liable to reinforce past prejudices. A 2019 *New York University*

Law Review paper looked at case studies in Illinois, Arizona, and Louisiana and noted that a failure to reform such systems risks "creating lasting consequences that will permeate throughout the criminal justice system and society more widely."

The students could see, again, how AI-based choices affect outputs. "They can know, 'If I design it this way, these people will be impacted positively, these people will be impacted negatively,'" says DiPaola. They can ask themselves, *How do I make sure the most vulnerable people are not harmed?*

AI developers find themselves grappling with these questions more frequently, in part because their work now touches so many aspects of people's lives. The biases in their code are largely society's own. Take recommendation algorithms like YouTube's, which former Google developer Guillaume Chaslot asserts drive viewers toward more sensationalistic, more divisive, often misinformational videos—to keep more people watching longer and attract advertising. Such a choice arguably favors profits over impartiality.

By teaching kids early what ethical AI looks like, how unfairness gets in there, and how to work around it, educators hope to enable them to recognize that unfairness when it occurs and devise strategies to correct the problem. "Ethics has been taught either as a completely separate course or in the last two or three lessons of a semester course," says DiPaola. That, she says, conveys an implicit lesson: "Ethics doesn't need to be thought of at the same time as you're actually building something, or ethics is kind of an afterthought."

Better integration of ethics is important to Denise Dreher, a database programmer who recently retired from the IT department of St. Paul, Minnesota's Macalester College. As a personal project, she has been cataloging curricula like DAILY and making the K-12 lessons available on her website, Explore AI Ethics, for teachers to use in the classroom. She believes that AI education should look more like engineering instruction. "There's a long and very good tradition of safety and ethics for engineer training," she says, "because it's a profession," one with a codified career path. You can't just go build a bridge, or get through bridge-building school without having to work through the implications of your bridge.

"AI?" she continues. "Any 10-year-old in your basement can do it."

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AS CAMP PROGRESSED, the ethical questions grew bigger, as did the technology that students dealt with. One day, Mark Zuckerberg—CEO of Facebook, a social network largely populated by olds—appeared on their screens. "I wish I could

keep telling you that our mission in life is connecting people, but it isn't," Zuckerberg said. "We just want to predict your future behaviors. ... The more you express yourself, the more we own you."

That would be an unusually candid speech. And, actually, the whole thing looked a little off. Zuckerberg's eyelids were a little blurrier than the rest of him. And he stared at the camera without blinking for longer than a normal person would. These, instructors pointed out, are tells.

He didn't look like a normal person because he wasn't a normal person. He wasn't even a real person. He was a deepfaked videomorph giving a deeply faked speech. A deepfake is footage or an image produced by an AI after it parses lots of footage or photos of someone. In this case, the software learned how Zuckerberg looks and sounds saying different words in different situations. With that material, it assembled a Zuck that doesn't exist, saying something he never said. "It's kind of hard to think how AI could create a video," says Patil.

Zhang, whose preferred social medium is YouTube, watches a lot of videos and already assumed that not all of them are "real"—but didn't have any tools to parse truth from fiction till this course.

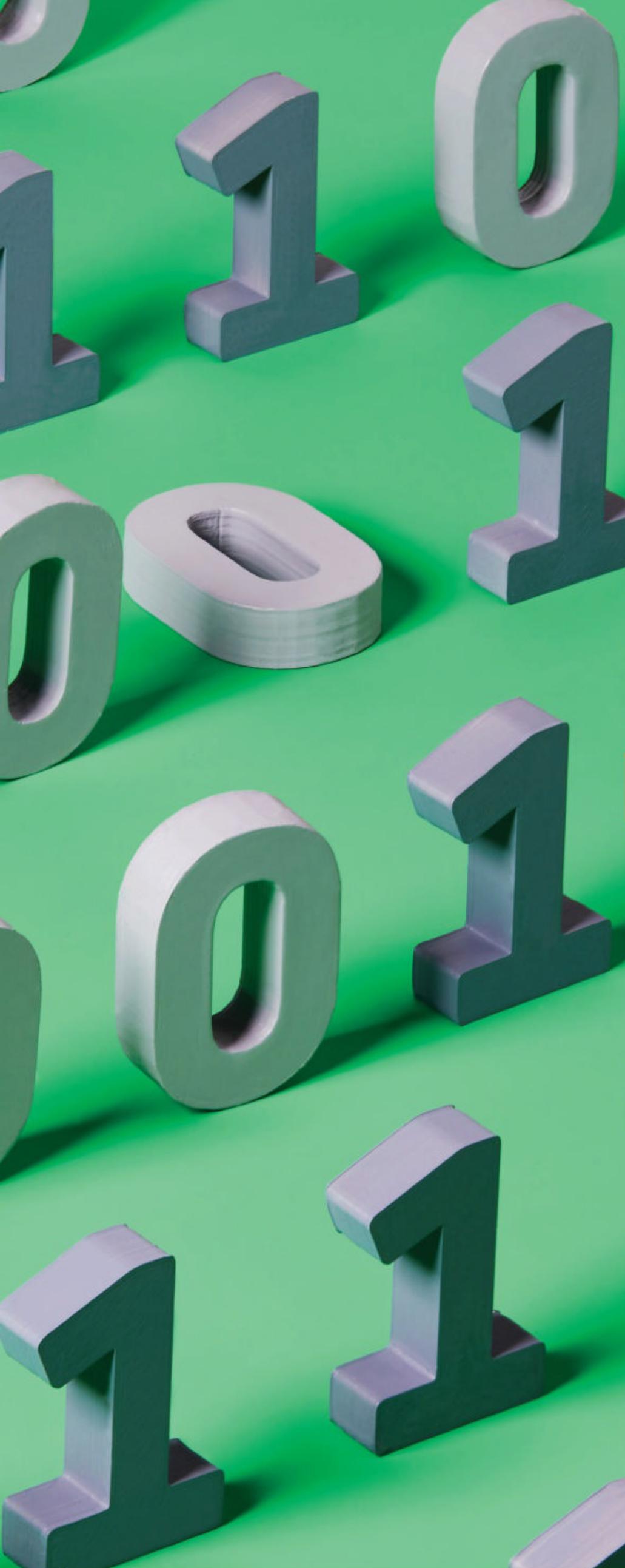
The campers had all likely encountered AI-based fakery before. An app called Reface, for example, lets them switch visages with another person—a popular TikTok hobby. FaceTune conforms selfies to conventional European standards of beauty, bleaching teeth, slimming noses, pouting up lips. But they can't always tell when someone else has been tuned. They may just think that so-and-so just had a good complexion day.

In fake visual media, the real and synthetic—the human and the AI—have two faces that look nearly identical. When the kids fully grasp that, "It's a moment where shit gets real, so to speak," says Gabi Souza, who worked at the camp both summers. "They know that you can't trust everything you see, and that's important to know, especially in our world of so much falsehood so widely propagated." They at least know to question what's presented.

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NOT ALL LESSONS went over so well. "There are a couple of activities that even in person would be scratching at the top level of comprehension," says instructor Davis. Patil, for instance, had a hard time understanding the details of neural networks, software inspired by the brain's interconnected neurons. The goal of the code is to recognize patterns in a dataset and use those patterns to make predictions. In astronomy, for instance, such programs can learn to predict what type of galaxy is shining in a telescope picture. At camp, the kids acted like the nodes of a neural network to predict the caption for a photo of a squirrel "water-skiing" in a pool. It worked kind of like a game of





telephone: Teachers showed the picture to several students, who wrote down keywords describing it, and then each passed a single word on to students who hadn't seen the image. Those kids each picked two words to pass to a final camper, who chose four words for the caption. For the "nodes," understanding their role in that network, and transposing that onto software, was hard.

But even with the activities that didn't melt youthful brains, how well a lesson went depended on "how many students had breakfast this morning, is it Monday or is it Thursday afternoon," says Davis. It wasn't all canoes and archery, like traditional camps. "It's a lot of work," says Zhang.

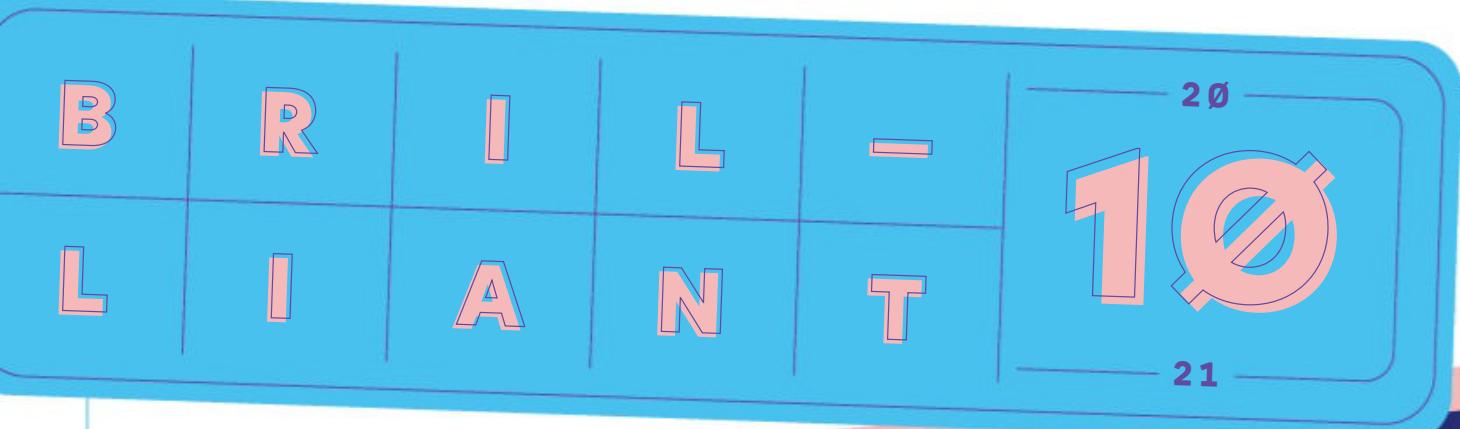
Making AI education accessible, and diversely implemented, is more complicated than teaching it in person to private-school kids who get MacBook Pros. While the collaboration partners had always planned to make the curriculum virtual to make it more accessible, the pandemic sped up that timeline and highlighted where they needed to improve, like by making sure that the activities would work across different platforms and devices.

Then there are complications with the Media Lab's involvement. The organization came under fire in 2019 for taking money and ostensible cultural cachet from convicted sex offender Jeffrey Epstein, which led to the departure of the lab's director. Writer Evgeny Morozov, who researches the social and political implications of technology, pointed out in the *Guardian* that the "third culture" promoted by organizations like the lab—where scientists and technologists represent society's foremost "deep thinkers"—is "a perfect shield for pursuing entrepreneurial activities under the banner of intellectualism." Perhaps you could apply that criticism to Personal Robots director Cynthia Breazeal, whose company garnered around \$70 million in funding between 2014 and 2016 for a "social robot" named Jibo that would help usher in a new era of human-machine interaction. The story had an unhappy ending: delayed shipments, dissatisfied customers, layoffs, a sell-off of intellectual property, and no real revolution.

But those too are perhaps good lessons for students to learn while they're young. Flashy, fancy things can disappoint in myriad ways, and even places that teach ethics early can nevertheless have lapses of their own. And maybe that shouldn't be so surprising: After all, the problems with AI are just human problems, de-personified.

The seamy undersilicon of AI—its discrimination, its invasiveness, its deception—didn't, though, discourage campers from wanting to join the field, as both Zhang and Patil are considering.

And now they know that, more likely than not, no matter what job they apply for, an algorithm will help determine if they're worthy of it. An algorithm that, someday, they might help rewrite.





THE START OF SOMETHING BIG

FRESH EYES CAN change the world, and a world stressed by a pandemic, climate change, and inequity is one more ripe for change than we have ever experienced before. That's why, after a five-year break, *Popular Science* is bringing back the Brilliant 10: an annual roster of early-career scientists and engineers developing ingenious approaches to problems across a range of disciplines. To find those innovators, we embarked on a nationwide search, vetting hundreds of researchers from institutions of all stripes and sizes. These thinkers represent our best hopes for navigating the unprecedented challenges of tomorrow—and today.



MAKING FUTURE FORECASTS LESS HAZY

ALLISON WING SEES a hole in the world's major climate models: The reports published by the Intergovernmental Panel on Climate Change factor in water vapor, but not the way it forms clouds—or, more specifically, the way they cluster in the skies. In fact, says the Florida State University meteorologist, these airborne puffs may be the biggest source of uncertainty in our environmental projections. Wing's models and simulations could help predict how a hotter planet will reshape clouds and storms and whether these changes will, in turn, exacerbate global warming.

It's already apparent that cloud patterns can produce distinct local effects. "When clouds are clumped together, rather than being randomly distributed," Wing explains, "the atmosphere overall is drier and warmer, and there's actually less cloud coverage overall. And that affects how radiative energy flows through our climate system."

Wing's findings, published in the *Journal of Advances in Modeling Earth Systems* in 2020, suggest that the nuances of cloud behavior may alter notions of what

our climate future looks like and perhaps how fast we'll reach it. "Not just how they're clustering," she says, "but everything about them." She—together with a group of 40 international scientists she leads in running mathematical simulations of the atmosphere—wants to get a better grip on how factors like cloud density, height, and brightness could change as the planet warms. Zeroing in on those details may hone the accuracy of global warming projections.

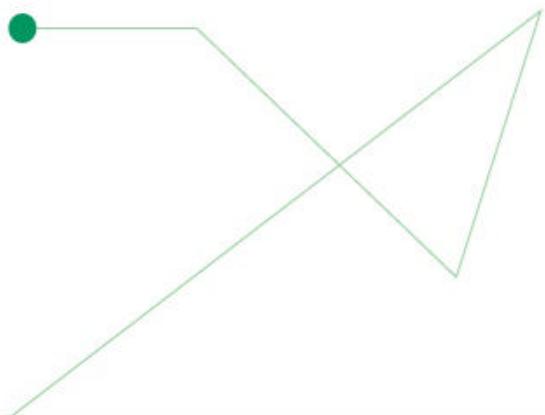
In the here and now, Wing wants to answer questions about extreme weather events, such as what controls the number of hurricanes we have in a given year and why big storms are getting larger and wetter faster. Her work points at a sort of "cloud greenhouse effect" in which

the infrared radiation reflected as the sun warms the Earth gets trapped under nascent storms, which makes stronger tempests build more quickly. She hopes observational data from the Jet Propulsion Laboratory's CloudSat research satellite, which she got access to as part of a 2021 NASA grant, will verify this phenomenon's existence.

By simulating past hurricanes in vivid detail—a process involving so many variables that Wing runs them on the National Center for Atmospheric Research's supercomputer in Wyoming—she hopes to render the re-creations more realistically over time. Eventually, though, she wants to tap NASA's satellite imagery (aka the real world) to make potentially lifesaving predictions.



TURBOCHARGING SURGICAL PATHOLOGY



WHEN IT COMES to speedy biopsy results, nothing beats Mohs surgery. To minimize scarring, pathologists analyze excised skin cancers on site to ensure all dangerous cells are gone. Other common cancer surgeries, such as those for the prostate and breast, still rely on lab work that takes days to confirm clear margins, which can mean repeat procedures are necessary. And it's all very labor-intensive. Michael Giacomelli, a University of Rochester biomedical engineer, has a microscope that could put even Mohs surgery's turnaround time to shame—spotting cancerous cells from a variety of tumors in near-real time.

The key is going small. The type of imager he's built, a two-photon microscope, has been around for decades, but their hefty price tags (often \$500,000 or more) and sprawling form factors (components are often racked in a space the size of a utility closet) make them impractical for most operating rooms. The scopes spy sick cells with the help of lasers: Tumor cells have characteristically enlarged nuclei, due to their excess of DNA; when soaked in a specialized dye, the oversize organelles fluoresce under the laser light. "They're able to reach into a wet, bloody, messy mass of tissue and look at what's inside," Giacomelli explains.

With a background in optics, he knew that smaller, lighter lasers were being used for welding and on factory floors. The key was to find dyes that operated at their wavelength and that wouldn't ruin human tissue for more in-depth follow-up in a traditional lab. He identified one suitable hue in



a derivative of the ink in pink highlighters. After years of trial and error, which began at MIT, and a few iterations, the laser that sets it alight weighs 5–25 pounds. Combined with a microscope, monitor, CPU, keyboard, and joystick, the system fits on a handcart compact enough to wheel between surgeries. The price tag: around \$100,000.

With more than 100,000 breast cancer surgeries and millions of skin cancer procedures each year in the US, the impact could be profound. Since 2019, an earlier version of Giacomelli's system (one the size of a washing machine) has been in a clinical trial for breast cancer patients at Beth Israel hospital in Boston. And a study on prostate cancer screening published in *Modern Pathology* found doctors could ID malicious cells just as well with the new system as with traditional methods. Next, Giacomelli wants to trial his new, sleeker setup on Mohs and other skin cancer surgeries. He's also interested in getting his imaging equipment into rural clinics that don't have tissue labs nearby for fast answers. And modifying his scope for 3D imaging, which could improve outcomes for complexly shaped cancers like melanoma, could also open doors: Looking at tumors in 2D limits our understanding of what's going on, he says. "I really think 3D imaging is going to be huge for diagnosis."





UNTANGLING TRANSGENERATIONAL TRAUMA

BIANCA JONES MARLIN credits her siblings for inspiring her career. All 30-plus of them. That's not a typo: Her folks took in dozens of foster kids. "My siblings have gone through things you wouldn't even want to imagine," she says. That's

why Marlin, a psychologist and neuroscientist at Columbia University who has now fostered children herself, studies a unique sliver of epigenetics, or the impact our environments and behaviors have on our genes. She documents how stress and

trauma pass between generations, even when forebears have little or no contact with their descendants.

"The world changes your brain and your body—and also your offspring," she says. "That has such strong implications for society, for the way we predict what's going to happen in the future." Communities that have endured famine, genocide, or any number of other struggles, she points out, may experience heightened anxiety and PTSD in later generations. Revealing the levers by which stress "travels to the future" could open pathways to therapy and prevention—breaking the chain of trauma.

Marlin began her work, which centers on brain development and learning, by identifying one of the mechanisms responsible for a seismic shift in social behavior. In 2015, she showed how the hormone oxytocin sensitizes mouse moms to their pups' distress calls. And since then, she's studied the effects of environmental stress and trauma in lab mice.

But how are those changes passed down? "That is the beautiful, essential question that we're working on," Marlin says. Until now, scientists have seen such effects only anecdotally: For example, an infamous famine in the Netherlands at the end of World War II increased health issues like diabetes, high blood pressure, and schizophrenia not only in those it affected, but also in their children, suggesting that reproductive cells could convey a memory of the trauma. Through her work on mice, Marlin has demonstrated how a learned behavior (associating the smell of almond with an electric shock) is tied to an increase in olfactory cells that respond to that scent in progeny. "We talk about it in culture," she notes, "but because we don't know the mechanism, it's considered a myth."

Marlin's aware that her findings could be used to stigmatize groups of people—even harm them. "I would be disappointed if, 15 years from now, people were able to take the work that we have done and use that as a wall—assuming that because your ancestors went through this, you obviously are going to suffer from this too," she says. Or worse, she continues, malicious actors could torture or terrorize with the explicit intention of harming future generations.

The positive ramifications are enough to keep her going. "If we can induce negative changes and dramatic changes, we also can induce positive," Marlin says. "That's the beauty of epigenetics. It's not permanent."





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DUSTING FOR DIGITAL FINGERPRINTS TO FIND DEEPFAKES

"IT IS IMPOSSIBLE for a criminal to act, especially considering the intensity of a crime, without leaving traces of this presence," wrote Edmond Locard, a 20th-century forensic science pioneer. It's a quote Matthew Stamm frequently references. The Drexel University computer engineer isn't after fingerprints or hair strands, however; his tools and techniques instead detect even the most subtle alterations to digital objects: deepfakes.

Since its earliest Reddit days in 2017, deepfaking has graduated from a revolting prank—using AI to put celebrity actors' faces on porn stars' bodies—to an alarming online threat that involves all sorts of synthetic multimedia. Since detection is even newer than the act itself, no one has a grasp on how widespread the phenomenon has become. Sensity, an Amsterdam-based security firm, reported that the examples spotted by its homegrown sniffer doubled in the first six months of 2020 alone. But that number is

surely low, especially with the release of easy-to-use apps like MyHeritage, Avatarify, and Wombo, which have already been used to animate tens of millions of photos.

"The ability to rapidly produce visually convincing, completely fake media has outpaced our ability to handle it from a technological end. And importantly, from a social end," notes Stamm. According to a 2021 Congressional Research Service report, the acts pose considerable national security threats. They can be used to spread false propaganda with the intent to blackmail elected officials, radicalize populations, influence elections, and even incite war.

The budding threat has prompted a growing number of companies and researchers—including biggies like Microsoft and Facebook—to develop software that sniffs out AI fakes. But Stamm, who's funded by DARPA to build automatic deepfake detectors, notes that artificial intelligence is used to make only

a small subset of the tampered media we have to worry about. People can use Adobe Photoshop to create so-called cheapfakes or dumbfakes without specialized talent or hardware. In 2019, videos of Nancy Pelosi were altered by slowing soundtracks to make her appear drunk, slurring her words. In 2020, chopped-up videos made then-candidate Joe Biden appear to fall asleep during an interview.

Stamm's approach to image analysis can catch even simple manipulations, no matter how convincing. "Every processing element, every physical hardware device that's involved in creating a piece of media, leaves behind a statistical trace," he notes. He based his algorithms on a concept called forensic similarity, which spots and compares the digital "fingerprints" left behind in different regions. His software breaks images into tiny pieces and runs an analysis that compares every part of the photo with every other part to develop localized evidence of just about any kind of nefarious editing.

Stamm's latest work focuses on emotional consistency, matching voice patterns (intensity and tone) with facial characterizations (expressions and movements) in video. Inspired by Stamm's wife, a psychologist, the idea stems from the notion that it's difficult for video manipulations to sustain emotional consistency over time, especially in voices, he says. These techniques are still in development, but they show promise.



REMOVING 'FOREVER CHEMICALS' FROM DRINKING WATER

THE CAPE FEAR RIVER in North Carolina feeds drinking water for much of the southeastern part of the state. But for decades the chemical giant DuPont fed something unsavory into the waterway: PFAS, or per- and poly-fluoroalkyl substances, chains of tightly bonded carbon and fluorine with a well-earned rep as “forever chemicals.” A subset of them—PFOA and PFOS—can contribute to elevated cholesterol, thyroid disease, lowered immunity, and cancer. The Centers for Disease Control and Prevention has found them in the bloodstreams of nearly every American it’s screened since 1999. While DuPont (via a division now called Chemours) phased out production in 2013, the remnants of old formulations of household staples like Teflon, Scotchgard, and Gore-Tex linger.

Frank Leibfarth, a chemist at the University of North Carolina at Chapel Hill, has a filter that can remove these toxins—and he’s starting with the Tarheel State’s polluted waterways.

Leibfarth specializes in fluorinated polymers like PFAS. Before the NC Policy Collaboratory funded him to help with the state’s water pollution problem in 2018, he was focused on finding cheap and sustainable alternatives to single-use plastics, whose exteriors are sometimes hardened with fluorine. Leibfarth’s solution took its cue from diapers: “They’re super-absorbent polymers that suck up lots of water,” he says. He developed a fluorine-based resin that’s similar

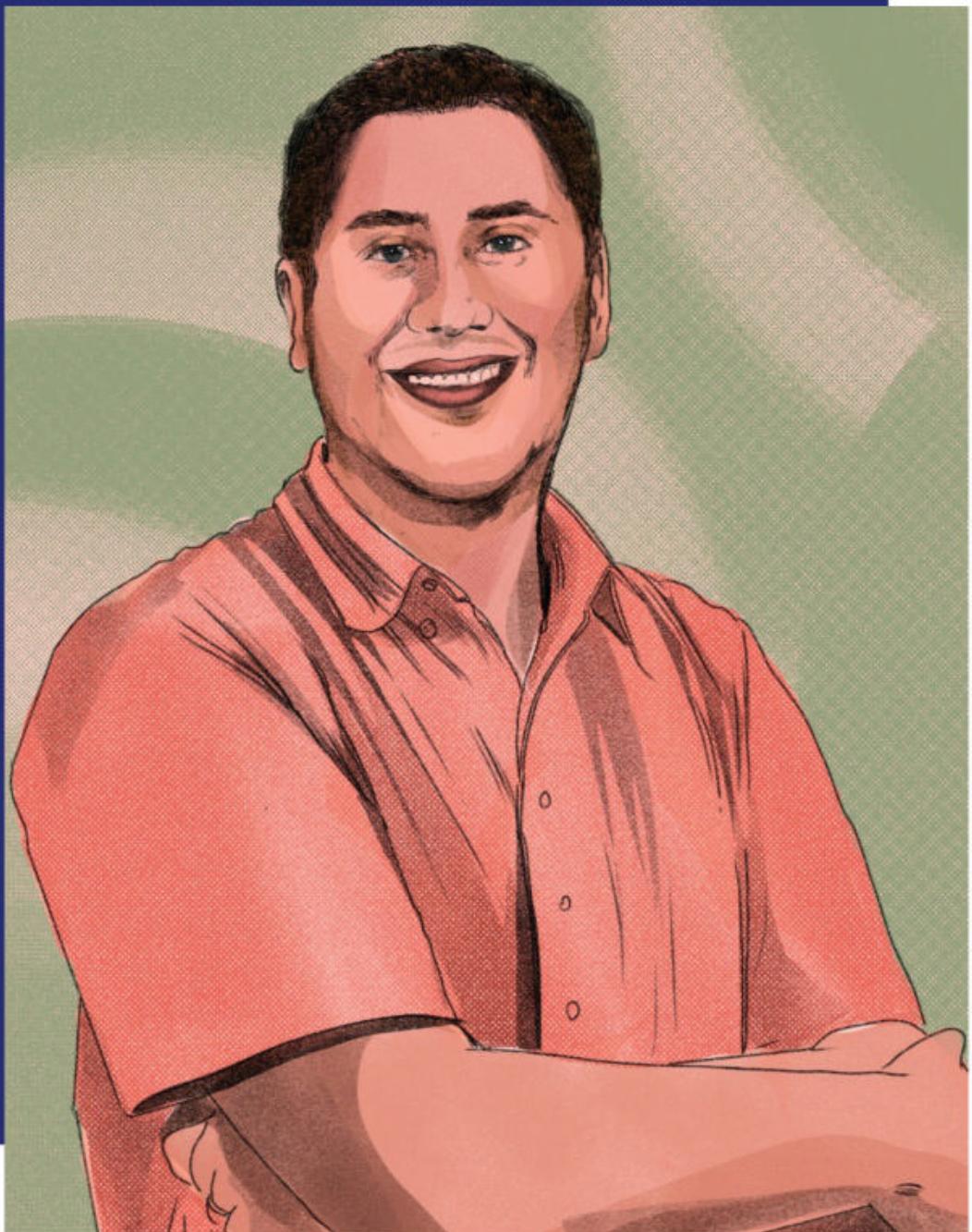
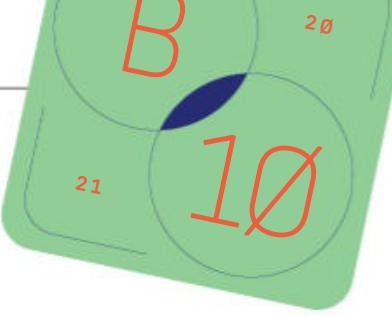
enough in structure to PFAS to attract the compounds and hold on to them. The material filters nearly all of these substances from water, and 100 percent of PFOA and PFOS, according to results his team published in the journal *American Chemical Society Central Science* in April 2020. The material is cheap and scalable, so municipal water treatment plants can deploy the filters as an additional cost-effective filtration step.

The North Carolina legislature is considering a series of PFAS-remediation bills in 2021, one of which would fund commercializing Leibfarth’s solution, including manufacturing the resin and fitting it to municipal filtration systems.

Other locales will surely follow. According to the nonprofit Environmental Working Group, as of January 2021 there are more than 2,000 sites across the US with documented PFAS contamination. Seven states already enforce limits on the chemicals in their drinking water—with more to follow.

Amid all this, the Environmental Protection Agency in March 2021 identified another new PFAS exposure threat: the very same hardened plastic containers that Leibfarth’s initial work aims to make obsolete. “I want to change the field’s thinking,” he says, “about what is needed to develop materials that are both useful and sustainable at the same time.”





POWERING ELECTRONICS WITHOUT BATTERIES

OUR LOVE OF PERSONAL gadgets is causing a major pileup. Based on current trends, humanity's battery-powered gizmos could number in the trillions by 2030. Josiah Hester, a computer engineer at Northwestern University, hopes to keep those power-hungry devices from overloading landfills with their potentially toxic power cells. His plan is simple and radical: Let these little computers harvest their own juice.

Hester's team creates arrays of small, smart, battery-free electronics that grab ambient energy. His work is based on a concept known as intermittent computing, an approach that can deal with frequent interruptions to power and internet connectivity—in other words, devices that do their jobs without a constant hum from the grid.

His team assembles circuit boards that combine off-the-shelf processors from companies like Texas Instruments with sensors and circuitry to tap power sources like the sun, radio waves from the environment, thermal gradients, microbes, and impact forces. The team also writes the custom software to keep the sensors running. The most notable feature of these circuit boards? No batteries. Juice flows through capacitors when it's available, and devices are designed to handle brief power-downs when it's not.

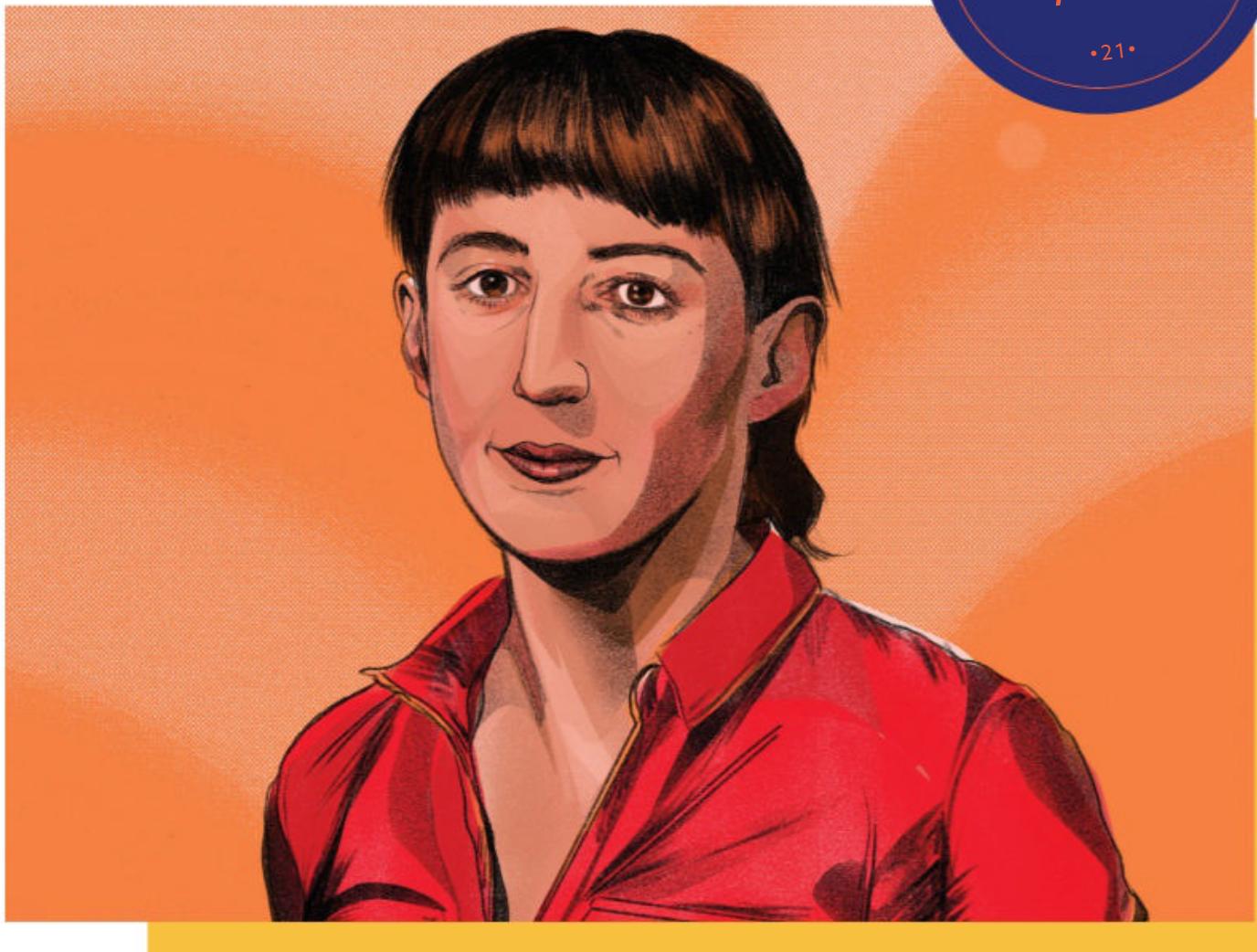
In 2020, Hester debuted his proof of concept: a handheld gaming device (ENGAGE) modeled after a classic Game Boy. Its power comes from small solar cells framing its screen and from the impacts of button presses, which generate electricity when a magnet drops through a coil. (Shakable Faraday flashlights work in a similar way.) The toy is no match for the energy-gobbling processors in most immersive platforms on the market, but it's a harbinger of what's to come. During the pandemic, Hester's lab developed a "smart mask" prototype decked out with tiny sensors that check vital signs like temperature, heart rhythm, and respiratory rate—all powered by the vibrations from the user's breaths.

Untethering devices from the electrical grid also makes them more practical for remote applications. Hester has several programs underway, including one to monitor wild rice habitats and avian flocks in the Kakagon Sloughs, a Great Lakes conservation area managed by the Ojibwa people. When the sensors, which harvest energy from soil microbes and sunshine, are deployed later this year, they'll track water quality and the sounds of crop-ravaging waterfowl. He's also working with the Nature Conservancy to set up noninvasive, solar-powered cameras on Palmyra Atoll, an island in the heart of the Pacific Ocean surrounded by more than 15,000 acres of coral reef. Once a weather station and monitoring site for nuclear testing, the spot is now perfectly stationed to track migrating birds and, perhaps eventually, the effects of climate change on marine species.

As Hester pushes the limits of intermittent computing to improve device sustainability, he's guided by a philosophy he attributes to his Native Hawaiian upbringing. It boils down to a simple question: "How do you make decisions now that will have positive impacts seven generations in the future?"

10

STORING DATA IN CHEMICAL SOUP



ACCORDING TO A RECENT REPORT, Earth only has enough permanent physical storage space to hold on to some 10 percent of the more than 64 billion terabytes of data humans generated in 2020. Luckily for us, not every meme and tweet needs to live forever. But given that our output has doubled since 2018, it's reasonable to fear that crucial information like historical archives and precious family photos could find itself homeless in the near future. That's the problem Brenda Rubenstein, a theoretical chemist at Brown University, hopes to solve. She wants to tap into evolution's storage designs (read: molecules) to create a radical new type of hard drive—a liquid one. Her chemical computers use tiny dissolved molecules to crunch numbers and store information.

In 2020, she and her colleagues converted a cocktail of small amines, aldehydes, carboxylic acids, and isocyanides into a kind of binary code puree. "The way you can store information in that disordered mixture of molecules floating around is through their presence or absence," Rubenstein notes. "If the molecule is there, that's a one, if a molecule is not there, that's a zero." The method, published in *Nature Communications*, successfully stored and retrieved a scan of a painting by Picasso. In 2021, her team used a similar slurry to build a type of AI called a neural network capable of recognizing simple black-and-white images of animals, like kangaroos and starfish.

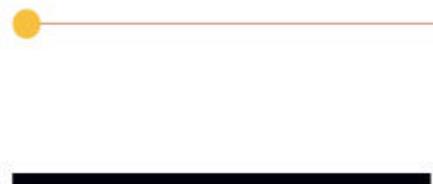
Molecular storage has already been in the works.

Experiments with embedding info into DNA, or long-chain molecules, date back to the early 2000s, and tech titans like Microsoft and IBM have entered the mix, along with specialty companies and the US federal research agency for spies, IARPA.

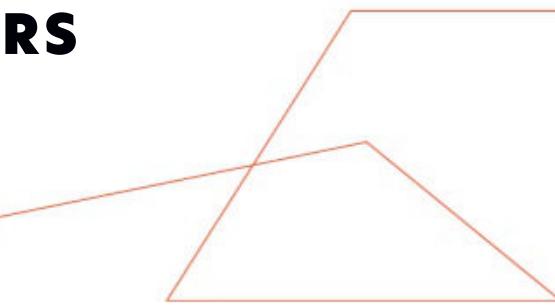
But small molecules may have distinct advantages over DNA. Compared to the double helix, their structures are simpler to synthesize (cheaper to manufacture), more durable (less susceptible to degradation), and less error prone (because reading and writing don't require sequencing or encoding). What's more, according to Rubenstein's rough calculations, a flask of small molecules could hold the same amount as 200 Empire State Buildings' worth of terabyte hard drives. When they're stored as dried crystals, the molecules' lifespans could outlast even modern storage media—perhaps in the thousands of years compared to current hard drives' and magnetic tapes' 10 to 20. The main trade-off is speed. Rubenstein's tech would take about six hours to store this article, for example, and you would need specialized equipment like a mass spectrometer to read it back, making the method better suited to archival preservation than daily computing.

Within the last few years, Rubenstein and her colleagues have filed a chemical computing patent, and they are in talks with a venture capital firm to launch a startup focused on harnessing the budding new technology. "What gets me up in the morning," says Rubenstein, "is the prospect of computing using small molecules."

TRACKING PUBLIC HEALTH WITH SMART SEWERS



THE NAME BEIJING often conjures images of skyscrapers, traffic, and crowds. But Fangqiong Ling, who grew up in the city of more than 20 million, thinks of its scenic lakes, which still bear their 17th-century Qing dynasty names:



Qianhai, Houhai, and Xihai. Ling studied algae blooms in these pools in high school. She and her classmates used benthic invertebrates (such as crayfish, snails, and worms) to analyze water quality, knowing that different groups of species tend to

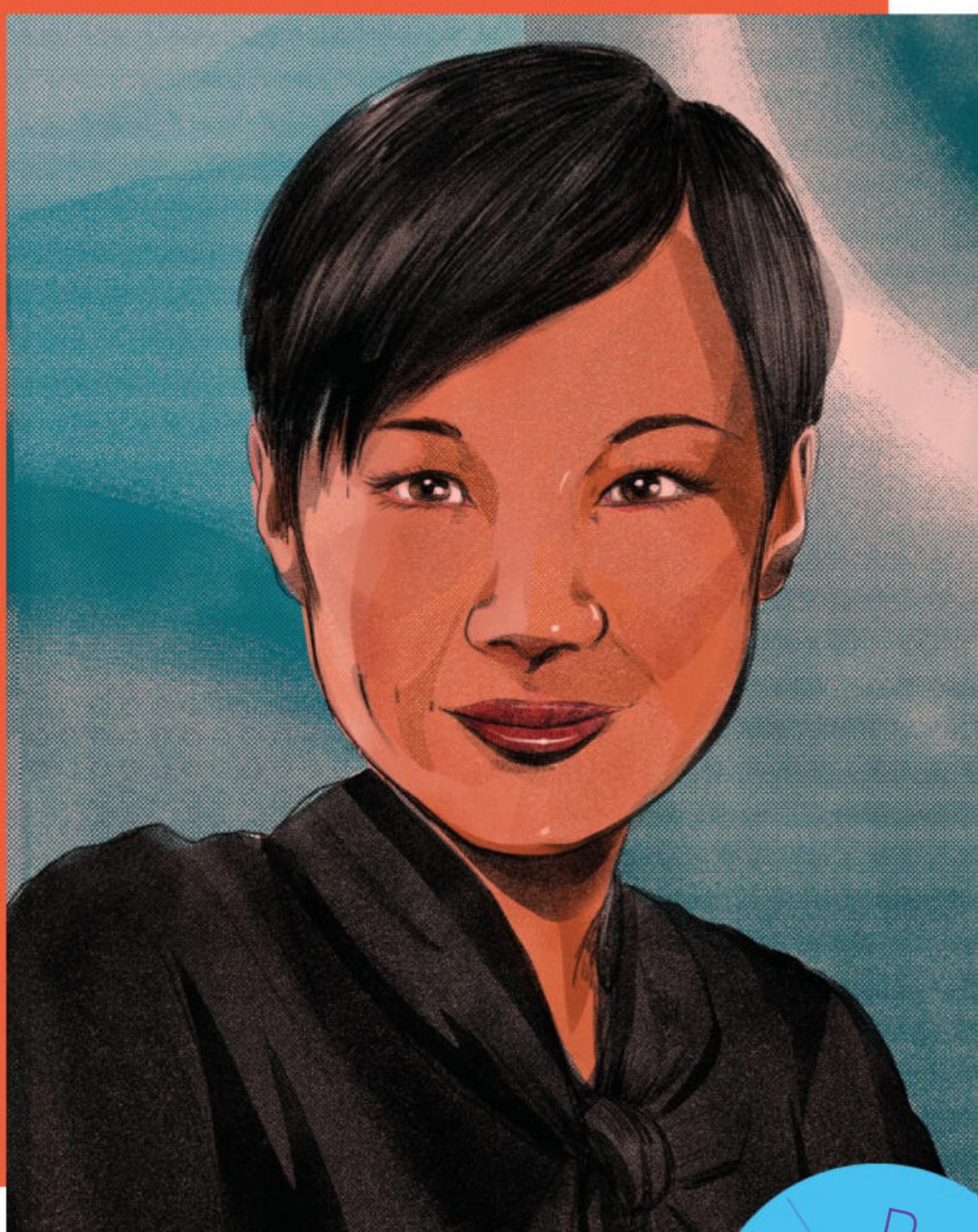
gather in clean or polluted environments. She's been turning smaller and smaller biological organisms into sensors ever since.

Ling, an environmental microbiologist and chemical engineer at Washington University in St. Louis, still studies the H₂O that flows through urban infrastructure. But she's transitioned from water quality to wastewater-based epidemiology (WBE) and the use of "smart sewers."

This concept isn't new: Public health officials have sampled sewage for years to detect a wide spectrum of biologics and chemicals—including illicit drugs, viruses, bacteria, antibiotics, and prescription medications. But they have lacked tools to accurately account for the number of human sources represented in their samples, making it hard to assess the scope and scale of contamination. If a sewage sample turns up high concentrations of nicotine, for example, the spike could be the result of one toilet flush from a hardcore smoker close to the collection area, or the culmination of many smokers across the city. Substitute coronavirus or anthrax, and it's easy to see how the difference matters.

Ling's breakthrough was figuring out how to use the relative numbers of people's gut bacteria in wastewater—revealed by rapidly sequencing their RNA—to estimate the true size of the population that contributed to that sample.

Her field is having a moment. During COVID-19, many cities have turned to WBE, which has exploded from a dozen or so projects to more than 200 worldwide. In 2020 the Centers for Disease Control and Prevention announced a new National Wastewater Surveillance System as a public health tool. With a 2021 National Science Foundation grant, Ling wants to improve population estimates to the point where the comings and goings of commuters, tourists, and other transients don't skew results. Those tools are a step toward automatic, highly accurate assessments of contaminants and contagions in precise locations. "Microbes really have a very fundamental relationship with humans and our cities," Ling notes. "I'm just trying to dig out the stories they have to tell."





SHINING LIGHT ON DARK MATTER

THE STANDARD COSMOLOGICAL model describes how stars, planets, solar systems, and galaxies—even little-understood objects like black holes—congealed from a raucous cloud of primordial particles. While there's abundant evidence to support the big bang (such as the expansion of the universe and the background radiation the cosmic event left behind), there are some vexing gaps. Dark matter, for instance. For galaxies to rotate at the speeds we observe, there should be at least five times more mass than we've been able to lay eyes on. "We have no evidence that dark matter exists, except that it is necessary for the universe to end up where we are today," says Michael Troxel, a cosmologist at Duke University. To piece together what's missing, Troxel builds maps of the universe larger and more precise than any before.

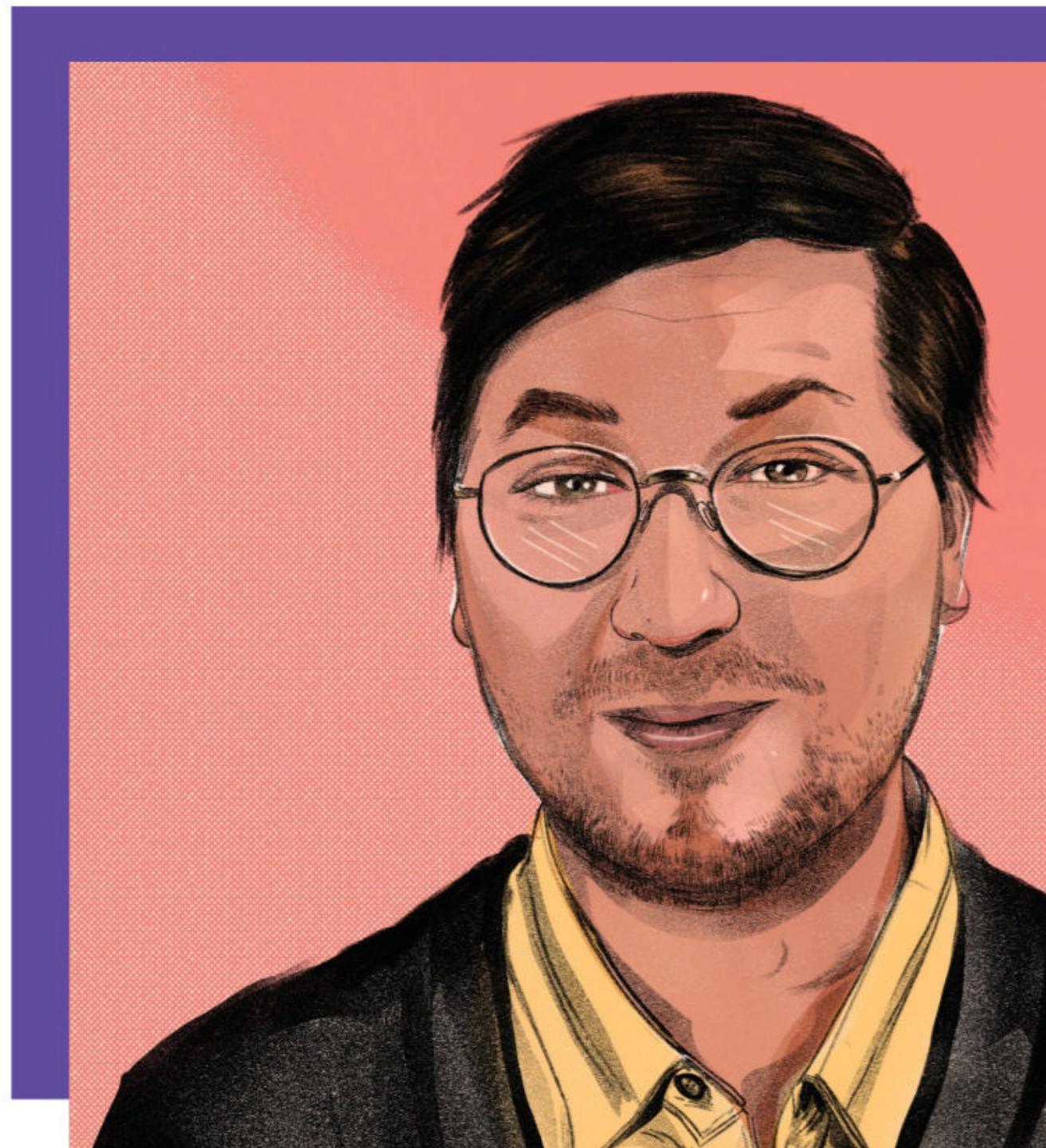
Since 2014, Troxel has worked with the Dark Energy Survey (DES), an ambitious international collaboration of more than 400 scientists, to address critical unknowns in the universe. To scope out distant skies, DES fitted a custom 570-megapixel camera with an image sensor highly attuned to red light—as objects move farther away, their wavelengths appear to stretch, making them look increasingly crimson—and mounted it on a telescope perched high in

the Chilean Andes. From that vantage, it can spot some 300 million galaxies.

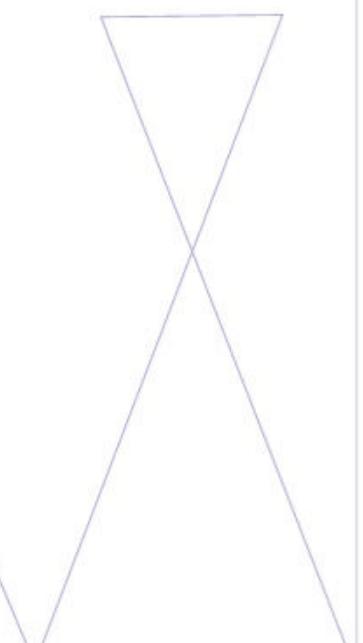
Now co-chair of the DES Science Committee, Troxel coordinated the analysis of data collected through 2016, and, in doing so, spied dark matter's myriad fingerprints on celestial bodies across spacetime in exquisite detail. The brightness and redness of objects indicates both their distance and—because the universe is expanding—how long they've been traveling. Modeling subtle bends in light (think magnified or stretched waves) called weak gravitational lensing reveals massy objects both seen and unseen. And the makeup of the objects themselves helps fill in the picture even more: Troxel used machine learning to classify patterns in galaxy colors (shades of red and faintness) and mathematical modeling to infer shapes (elliptical, spiral,

irregular), netting a catalog of more than 1,000 types of galaxies. Having a reference for what clusters *should* look like helps efforts to detect distortions that may point to dark matter. "That allows us to reconstruct this 3D picture of not just what the universe looks like now, but how it looked 6 or even 9 billion years ago," Troxel explains.

The findings, announced in May 2021, cover one-eighth of Earth's sky and more than 100 million galaxies. By the time the results of the full DES data set are published (possibly by 2023), Troxel is hopeful we'll be able to predict and calculate dark matter. "There's going to be this watershed moment where we measure the right thing, or we measure the things we're measuring now with enough precision that we're going to fundamentally learn where physics is broken," he says. "We're almost there."



ADAPTING TECHNOLOGY FOR THOSE WHO NEED IT MOST



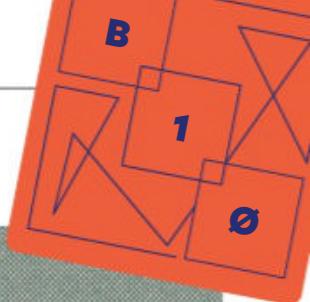
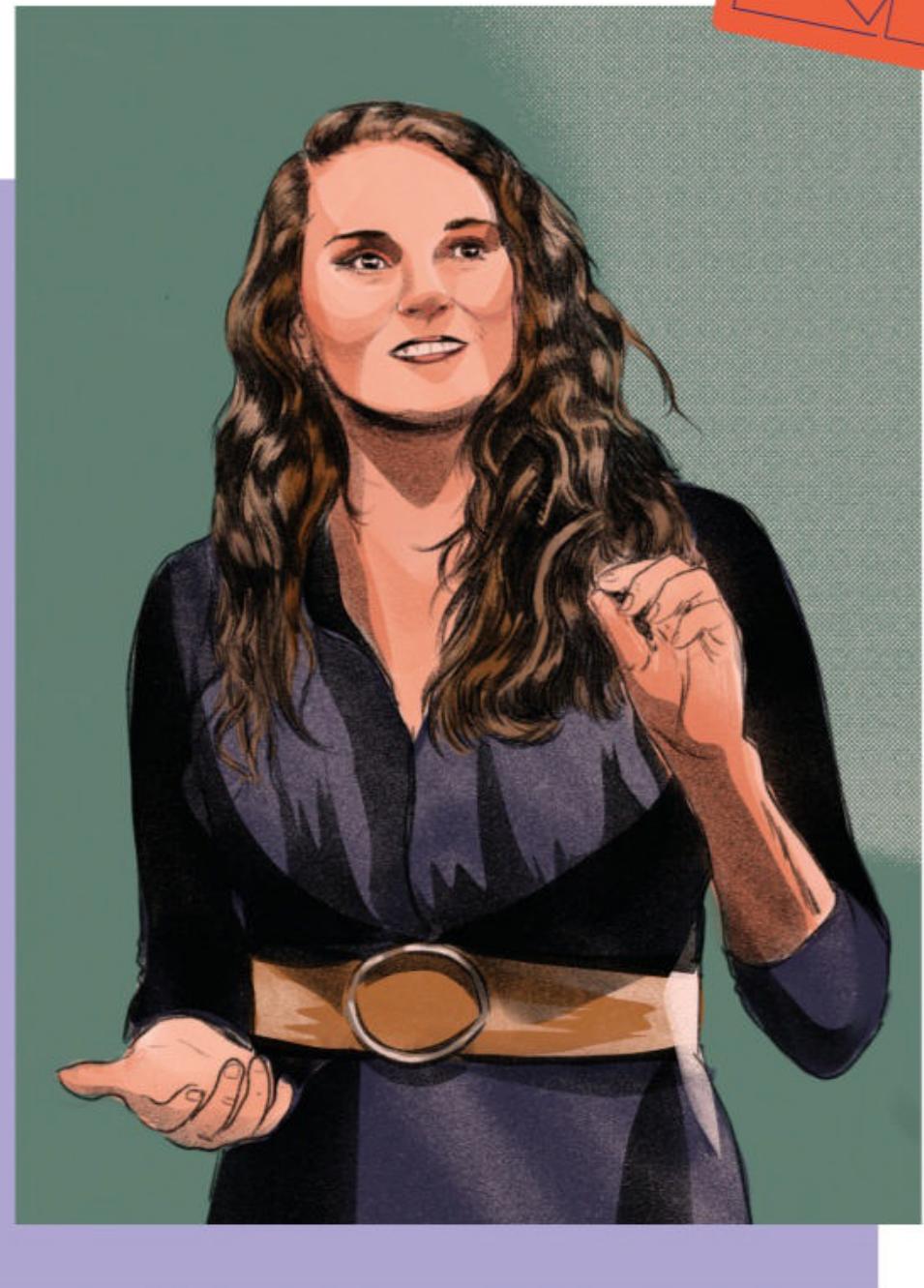
TO STACY BRANHAM, people with disabilities are the original life hackers—and that's a bad thing. The University of California, Irvine computer scientist doesn't think anyone should have to be a MacGyver just to get through life. Marginalized groups often adapt apps and gadgets to suit their needs. In the 1950s, for instance, visually impaired people manipulated record players to run at higher speed, allowing them to "skim" audio books for school or work; today, browser extensions that hasten videos have the same effect. Branham wants to use similar insights to design better products from the start. "Innovation is having the right people in the room," she says.

Branham takes off-the-shelf technologies, like virtual assistants, and puts them together in novel ways to address the needs of underserved communities. One of her projects, nicknamed Jamie, provides step-by-step directions to help the elderly and people with disabilities navigate Byzantine airport checkpoints, signs, and corridors. Jamie uses voice assistance, a geolocation system that takes cues from sources like Bluetooth beacons and WiFi signals, "staff-sourcing" (daily reports by airport employees about dynamic changes like repair work), and audio cues or vibrations. COVID-19 derailed plans to pilot the system at Los Angeles International Airport, but Branham expects to resurrect it soon. "It was built from the

beginning with input from people who are blind, people who are wheelchair users, and people who are older adults," she says, but the resulting tech will benefit anyone who gets lost in airports.

Next, Branham wants to adapt text-to-speech tech to help blind people read with their children. Her proposed Google Voice-based app will act as an interpreter for e-books, prompting caregivers via earbuds with the right words and descriptions of images so they can have a richer story-time experience with their families.

When modern tools are designed with disabled communities in mind, there's often a widespread benefit—see, for example, the now-ubiquitous curb cuts that enable passage for those with strollers and luggage as much as those in wheelchairs. Branham also points out how software like hers could help others, like those who speak English as a second language. Ultimately, she measures success unlike most people developing personal electronic gizmos: not by whether she can create flashy new features, but by whether the offerings of innovation and science are accessible to the people who might need them the most.



LIFE LAB

TO BE YOUNG



ILLUSTRATIONS BY YIFAN WU

FALL 2021 / PG 72 / POPSCI.COM

► 101

eternal salad

YOU DON'T NEED to buy magic beans in aisle five for a grocery store miracle. Just save those unused bits of fruits and veggies you cast aside while preparing dinner. With a little bit of luck and care, you can grow them over and over again.

→ BY ELLEN AIRHART

FIND THE BEST SOURCE

Some producers spray certain crops, like potatoes, with chemicals to keep them from sprouting in storage. To avoid this, buy directly from a farmer (and get their growing tips too). You can try planting store-bought produce, but you may have less success.

PICK THE RIGHT PLANT

Roots on veggies such as onions, bok choy, and fennel mean they'll likely regenerate. Others can grow from small pieces—think carrot tops, garlic cloves, chunks of ginger, and potato eyes. Fruits with obvious seeds, including tomatoes, citrus, and apples, are also worth experimenting with—but your version might not look or taste like the original.

BUILD YOUR NURSERY

If you're using seeds, germinate them in a wet paper towel before planting. Scraps with roots, as well as bitsy pieces, can just go straight into a terracotta vessel with potting soil. Make sure you clean your trowel so you don't pass on any bacteria.

CONTROL THE CLIMATE

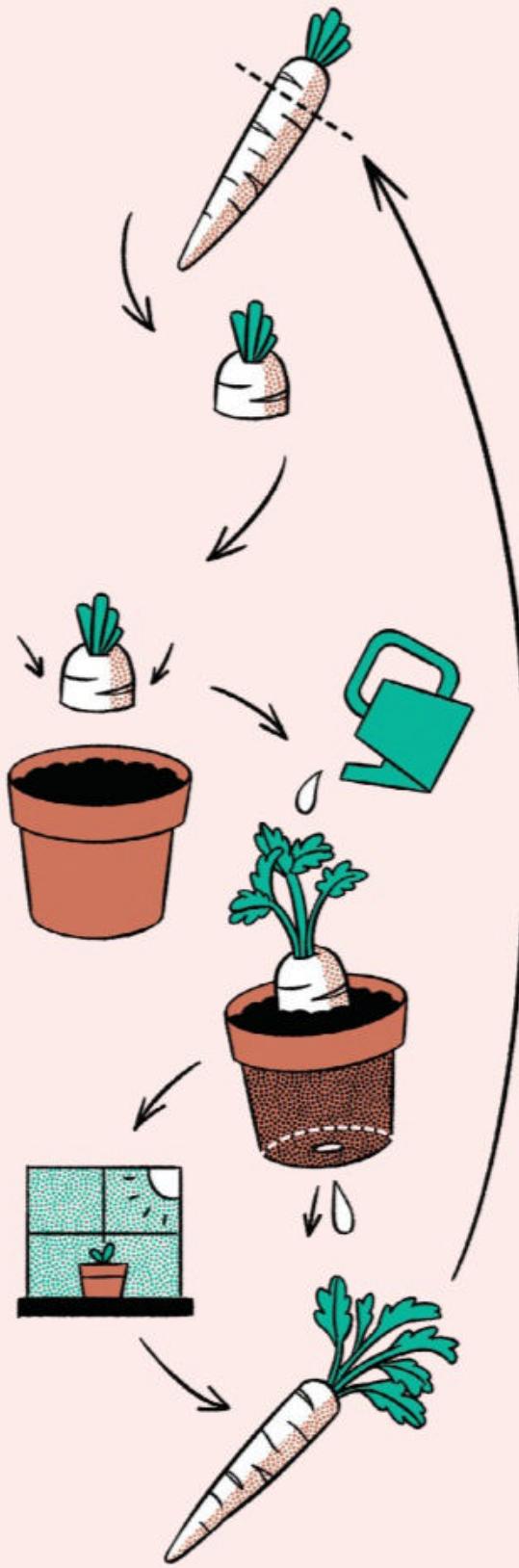
Different plants need various temperatures, humidity levels, and drainage. General tips include picking a receptacle with holes at the bottom and buying a humidifier if you live in a dry area. Unless you get ample sunshine indoors, you'll probably also need to purchase a grow light to ensure your home-grown crops get the right amount of electric rays.

QUEUE UP A MEAL

Monitor how your plants are doing too—don't just set 'em and forget 'em. Probe the soil with your finger or a moisture meter to ensure it's not too wet or parched, and check any leaves and stems to confirm they're a healthy color and pest-free. This routine has an added benefit: Interacting with indoor plants may reduce physical and psychological stress.

RESTART THE CYCLE

Snip, tug, or pick your produce and get it right into your next homemade dish for an added zest of self-sufficiency. Once you get the hang of farming scraps, you can (theoretically) keep that same plant going forever. Just eat, sow, and repeat.



► FINE-TUNE

forever fit

→ BY CHUCK SQUATRIGLIA

YOU DON'T HAVE to spend hours sweating in the gym each day to lead a long, healthy life. A few simple lifts and stretches can help maintain strength, improve mobility, and prevent aches as you age. The key is to focus on what some trainers call "functional fitness"—exercises that translate to everyday tasks like hauling groceries and taking out the trash.

A move called the weighted carry is a good place to start. Take a dumbbell in each hand, hold them at your sides, keep your spine straight, and walk. A trap bar dead lift imitates lifting something off the floor, working the legs and back. And squats are another great exercise, as they reinforce the lower body by mimicking rising from a chair.

Stretching is also essential because it increases flexibility and prevents injuries. Slowly rolling your neck and shoulders does wonders for tight muscles. Bending at the waist and reaching for your toes in a forward fold loosens the lower back. Finish by sitting on the floor with feet together and knees apart in the butterfly pose to work the hips and thighs.

Round things out with frequent walks, which provide low-impact cardio. They also deliver a sunny dose of vitamin D, which helps build strong bones. Just don't forget the sunscreen.

"FOREVER FIT" ADAPTED FROM POPSCI.COM; REPORTING BY SARA CHODOSH, RACHEL FELTMAN, AND GRACE WADE



► BUILDING BLOCKS

gen z's guide to cassette players

FROM THE MID-1960S to the early 2000s, cassettes reigned supreme with audiophiles thanks to their portability, low price, and crisp sound quality. They eventually lost their throne (first to CDs, and then to MP3s and streaming platforms), but they recently became trendy again.

Before you rush out to buy one of these retro devices, however, just know you'll need a few tools to help you enjoy the full tape deck experience.

→ BY SANDRA GUTIERREZ G.

A / SPARE BATTERIES

Cassette players typically use a pair of AAs or AAAs to roll the tape across a magnet at 1.875 inches per second. As the power drains, the sound becomes unstable. Stashing a couple in your pocket or purse can save you on the go.

C / NO. 2 PENCIL

Save some juice by rewinding your cassette with your muscles. Just insert a No. 2 pencil into the left spool on the side you're listening to and rapidly rotate your wrist clockwise. If the tape unspools, reel it back in and start over.

B / WIRED LISTENING DEVICE

Some modern decks may be Bluetooth capable, but you're more likely to need headphones or a speaker with a 3.5-millimeter jack. Nab an aux cable and you'll also be able to link your portable player to any car with a matching port.

D / ADHESIVE TAPE

Before you record a mixtape, ensure the plastic tabs on the top edge are intact: They help engage the recording mechanism and wipe the ribbon before adding new tunes. If they're gone, just cover the bare slots with sticky tape.



▶ JUST TRY THIS

plant parenthood for newbies

→ BY ELLEN AIRHART

YOUR FAVORITE HOUSEPLANT'S native environment may be a lot different from your home. Take jade, for example. This succulent hails from the Eastern Cape of South Africa, where it endures unpredictable rainfall and drought. So constant, anxious watering could make *Crassula ovata* feel as if it's living in one of the雨iest places on the planet.

Whatever the species, overhydrating your leafy friends prevents them from absorbing the oxygen they need and literally suffocates them. The roots rot and turn

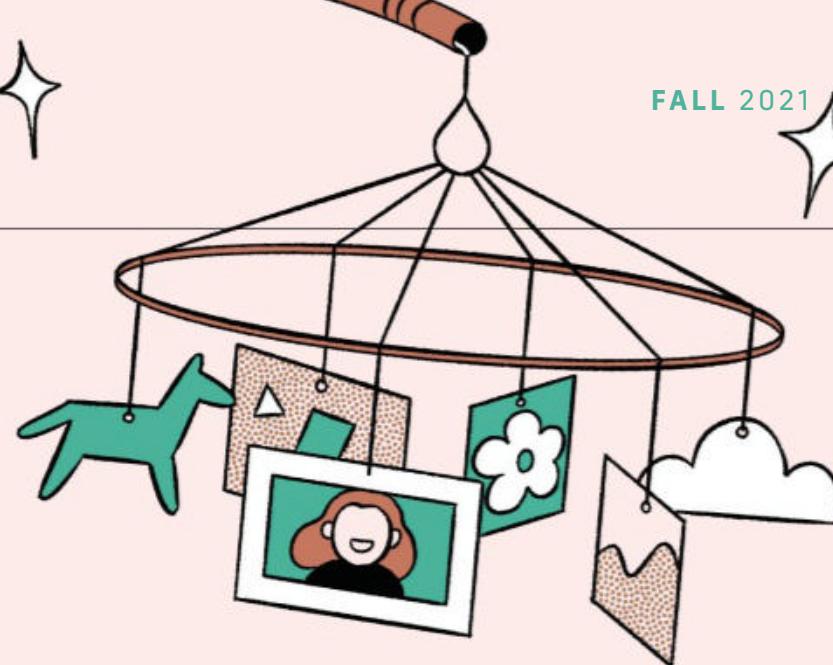
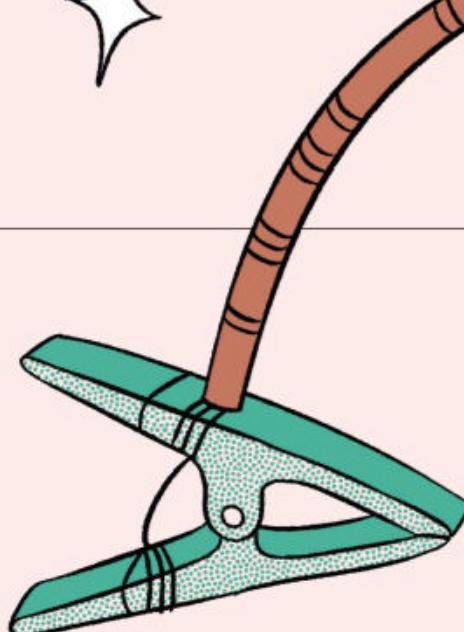
brown, while the leaves wilt and yellow. And stopping the deluge may not make much of a difference—decay starts below the surface, so when you begin to see the damage, it's probably too late already.

The best solution here is prevention. Find out how much water your houseplant needs, and set your flora in a well-draining medium. A mix of regular potting soil and perlite—expanded volcanic glass that absorbs moisture—can do wonders, especially for succulents like the jade. Your chlorophyll babies will surely thank you.

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▶ PROJECT

the mind molder

Time: 1 hour

Cost: \$45

Difficulty: Easy

Materials:

- Flexible metal electrical conduit
- Spring clamp
- String
- 24 inches of 10-gauge copper wire
- Electrical tape
- An 8-inch wooden hoop
- Items to hang from the mobile



Tools:

Metal hacksaw, measuring tape, and scissors.

RIGHT AFTER BABIES are born, every stimulus around them helps shape their squishy brain. This is why it's important to keep them interacting with their surroundings as much as possible in a safe way. Enter the mobile, a vibrant gizmo with hanging objects that will provide your child with hours

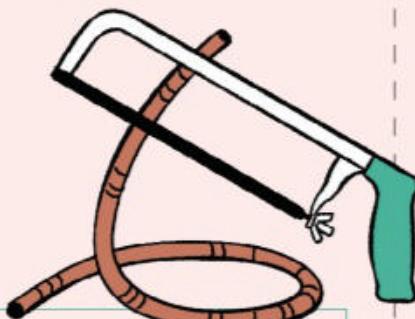
of entertainment even when they're doing nothing but lying snugly in the crib.

In their first year of life, infants move through multiple cognitive stages and developmental milestones. That's why the best mobiles grow along with them, and this homemade one does the trick.

→ BY JOHN KENNEDY

STEP 1

Saw the conduit to 16 inches. Babies can't see farther than 8 to 12 inches until they're about 4 months old, so this will give you flexibility to put the mobile close and move it farther as your kid's vision develops with time.



WARNING If you're slicing this material, do it by hand. Don't use an electric saw.

STEP 2

Run the copper wire through the conduit. It'll act as a spine and help the tube maintain its shape. You'll use the extra wire on each end to fasten your mobile together.

STEP 3

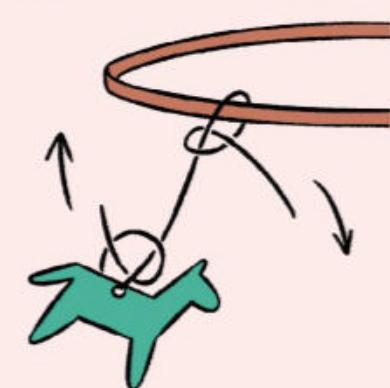
Wrap one end of the wire around the clamp. This will hold your entire structure to the crib railing. Twist the other end into a keyhole loop to hold the dangly elements. Cover any sharp edges with electrical tape.

STEP 4

Cut eight 6-inch pieces of string. Tie one end of each to the wire loop at the end of the conduit and the other to the wooden hoop. Make sure the knots are evenly spaced. Repeat until you have what looks like a wheel with spokes.

WARNING Don't

make the strings any longer than 6 inches—if the mobile accidentally falls into the crib, loose strands could wrap around the baby's neck.



STEP 5

Use 6-inch strings to hang features from the wooden ring. Grayscale shapes are best for infants—print photos of faces and objects the child knows.

WARNING Eliminate choking hazards by laminating paper bits and choosing items bigger than the tube of a toilet paper roll.

STEP 6

At six months, switch the ornaments for bright cloth toys. As the kid grows, adjust the flexible mount to keep the mobile well out of reach.



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LIFE LAB



► TROUBLESHOOTING

foodie in training

IN MOST CASES, a tyke's refusal to tuck into certain dishes is a normal phase that will eventually pass. But sometimes, the habit persists well into adulthood, making every dinner a challenge. These three tips will get anybody—from youngsters to elders—to chow down.

→ BY JEAN LEVASSEUR

MAKE MEALTIME FUN

Parents should introduce flavors by offering children small bits to study, smash, and taste. Older kids and grown-ups should venture into the kitchen, as they're more likely to try grub they've helped prepare. Cute dinnerware also makes things more tempting.

STIR IN SMALL CHANGES

Add new foods to known favorites by, say, sprinkling some chopped broccoli over mac and cheese or pairing shellfish with mashed potatoes. Patience and familiarity are key, especially with children: It can take as many as 10 encounters for them to form an opinion.

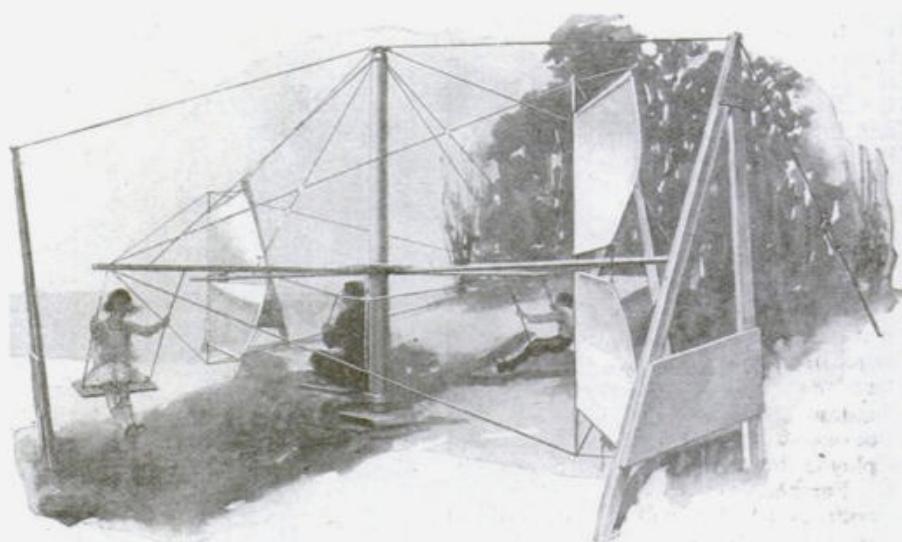
THINK POSITIVE

Labeling someone a picky eater can create a self-fulfilling prophecy. Instead, little ones need to hear uplifting phrases like "It's OK that you don't like that yet." Adults internalize the pressure to eat, so go slow and leave the door open to change.

CENTENARIAN

Updating the science of the PopSci archives

BY BILL GOURGEY



riding the wind

Merry-go-rounds were iconic in the hearts and minds of kiddos and grown-ups alike after the turn of the 20th century. Walt Disney cited the spinning spectacles as his inspiration for the Happiest Place on Earth, and carnival folk dubbed them “the First Ride.” During this golden age of carousels, *Popular Science* even offered readers instructions for building their own. But given that fewer than half of American homes had access to electricity at the time, that 1919 model got its power from the wind.

Before electrification in the late 19th century, manual cranks, pedals, mules, and, eventually, steam spun the whirling stages, which sported simple features like suspended seats and benches. Voltage allowed designers to introduce the classic bobbing horses, organ music, festive lights, and double decks.

But appetites for old-school thrills are on the rise. “Small is beautiful, and less complex is more fun,” says William Henry Dentzel III, a fifth-generation merry-go-round maker who runs the renowned Dentzel Carousel Company, whose credits include the King Arthur Carousel that’s been turning in the heart of Disneyland since it opened in 1955. While he admires the craftsmanship of the flashy attractions built by his forebears, he’s found that folks tend to prefer a more mechanical experience. His throwback offerings, which dot parks from California to Mississippi, are hand cranked, pulled by ropes, and pedal powered (sometimes by the riders

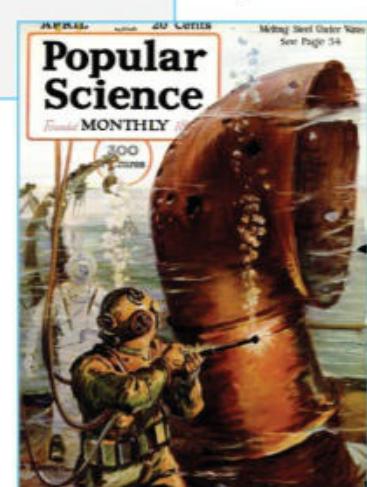
themselves). A crowdfunding campaign out of Venice, California, hopes to add a bike-pedaled version to Centennial Park.

While Dentzel’s a fan of grid-free electric carousels like the solar-charged models increasingly popular at conservation-minded zoos (he built the world’s first such ride in 2005), he believes that adding layers of technology is often a quick way around good mechanics. “Nowadays, we overengineer a lot of things because we can, and it ends up defeating the purpose of what we’re trying to do,” he says.

Still, even with his push toward greater simplicity, Dentzel has no plans to harness the wind. He does insist, however, on restoring something that a lot of carousel makers ditched late in the golden age: rings that patrons grab and toss to win prizes as they twirl. Wherever he’s installed that extra game, ridership has doubled. “Frankly, merry-go-rounds are pretty boring without them,” he says.

April 1919

After the close of World War I, the Allies counted more than 21 million tons of sunken ships and debris at the bottom of the ocean. As part of their salvage efforts, underwater blacksmiths wielded specialized torches that used a jet of air to clear the way for their steel-melting flames.



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