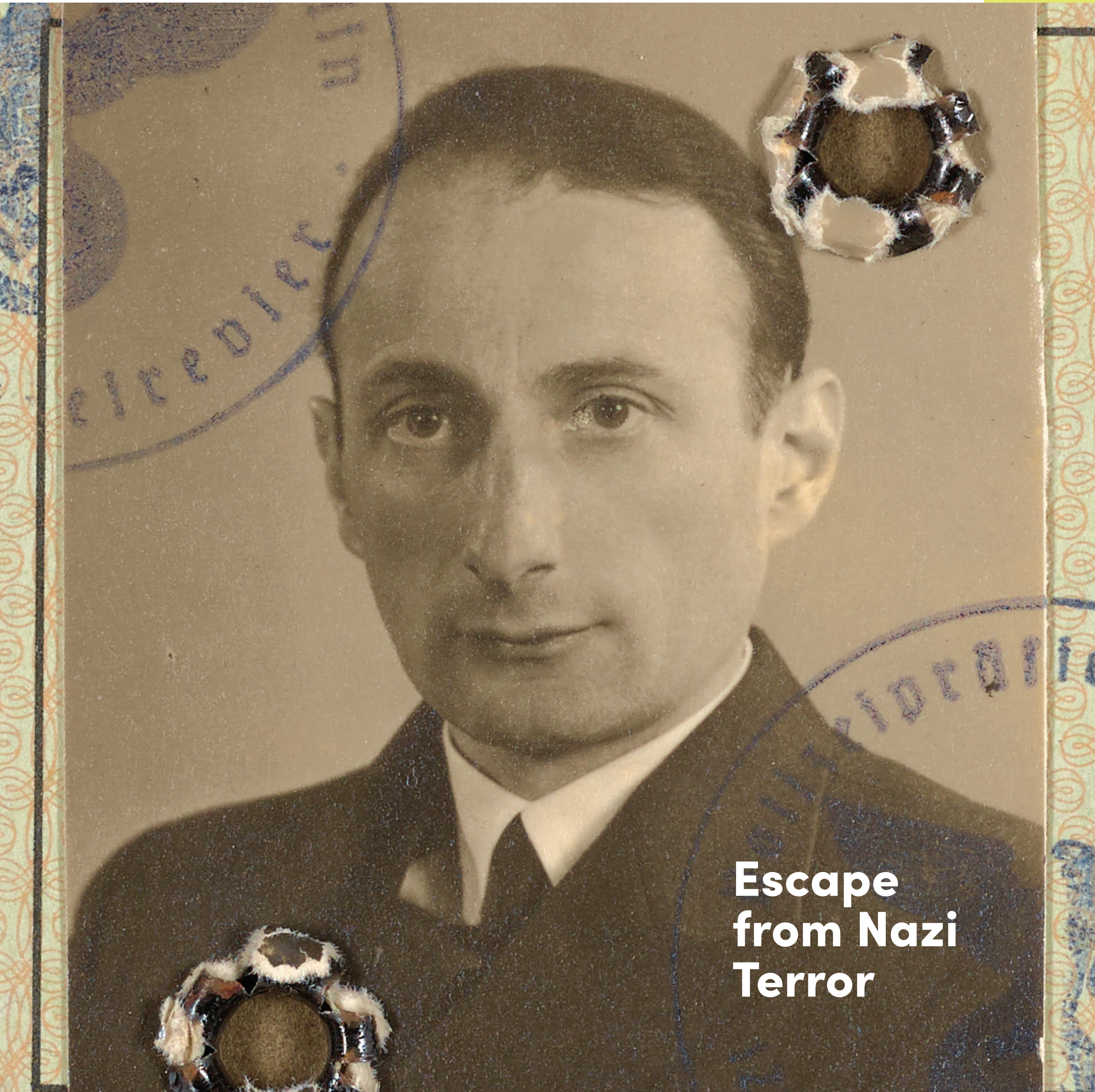
DISTILLATIONS

STORIES FROM THE SCIENCE HISTORY INSTITUTE'S ONLINE MAGAZINE

BEST OF— VOL. 2



Escape from Nazi Terror

DISTILLATIONS

STORIES FROM THE SCIENCE HISTORY INSTITUTE'S ONLINE MAGAZINE

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Letter from the President

I date my introduction to the history of science to an undergraduate seminar I took on the subject, taught by the eminent historian Lynn Sumida Joy. Dr. Joy was mindful that many of her students were skeptical of the value of historical inquiry for understanding science, but she was at pains to show that science has a history—and that we ignore that history at our intellectual and, indeed, moral peril. To reinforce this point, her final examination for the seminar consisted of a single question: "If you had to provide a thorough account of the science of today, without any reference to the past, what would be left out?"

What would be left out? For more than 40 years, the Science History Institute has focused on answering this question. Collecting, interpreting, convening, fostering research—we invest enthusiastically in these activities because they enable the making of histories, and stories, that illuminate science's present by shining a light on its past.

This year's print edition of *Distillations* is a compilation of some of the Institute's best stories. These stories address a diverse array of questions in chemistry, engineering, and the life sciences: What is a Kipp's Apparatus? How did people behave during pandemics past? And which animal was Charles Darwin's preferred object of investigation? The thoroughly documented, compelling, and often surprising answers to such questions animate these stories, which reveal dimensions to current scientific issues and challenges that are too often unremarked and poorly understood. They reveal what is "left out" when we ignore science's history—and point us to new ways of thinking about the science in our lives, today and tomorrow.

Please enjoy this sample of our investigations into science's rich past, and I encourage you to visit **sciencehistory.org/distillations** to read more stories, listen to our podcasts, and watch our videos.

DAVID A. COLE
PRESIDENT AND CEO
SCIENCE HISTORY INSTITUTE

BEST OF

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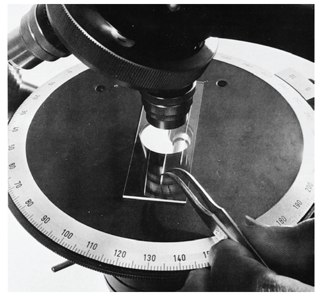

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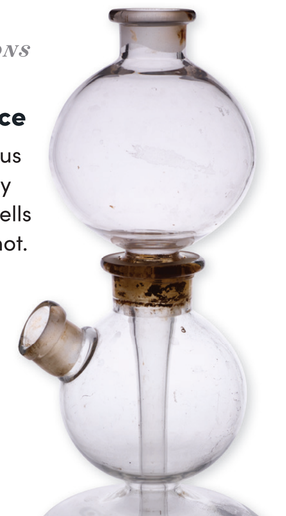
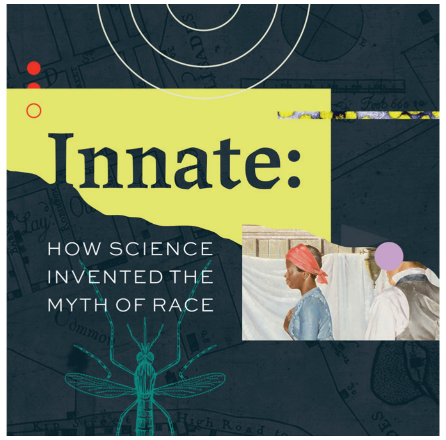


Percy Julian and the False Promise of Exceptionalism

Reflecting on the trailblazing chemist's fight for dignity and the myths we tell about our scientific heroes.

BY ALEXIS J. PEDRICK



This article is part of *Innate: How Science Invented the Myth of Race,* a podcast and magazine project that explores the historical roots and persistent legacies of racism in American science and medicine. It is made possible in part by a major grant from the National Endowment for the Humanities: Democracy demands wisdom. **sciencehistory.org/innate**

There is a letter written on February 3, 1956, by Black American chemist Percy Julian to the president of the American Chemical Society, John Warner.

In it, Julian condemns the organization for distributing a list of "Hotels for Colored Persons" for an upcoming conference in Dallas. Julian is direct and clear about his feelings; he rightly excoriates his scientific community for yielding so easily to the "stupidity" of Southern segregation. He writes,

> It appears to me that the time has come when the great array of capable scientists enrolled in our Society can no longer close their eyes to the "oughtness" involved in a ridiculous American situation like this.

He invokes liberty and democracy and declares the existence of the list a point of embarrassment—a failure.

It's a letter worth reading.

When I first read it, I categorized it quickly. I'm familiar with the history of civil rights and race relations in this country. I'm familiar with Percy Julian too. I learned about him in school as one of the famous Black American scientists who overcame great adversity to become a successful chemist and entrepreneur. His letter fit a mold: *a moment of inspiring bravery—a great man facing down wrongs we thankfully have long since moved on from.*

And certainly, those things are true. Percy Lavon Julian was a trailblazer in chemical synthesis, and his life was marked by moments of bravery.

In 1935 he and his team synthesized physostigmine, a glaucoma treatment that until then was only available from a plant called the Calabar bean. It was an incredible accomplishment for a relatively unknown researcher. The project took three years to complete, and Julian and his team did it without the benefit of modern analytical methods such as mass spectrometry. But earning credit for the discovery took courage; it meant calling out the errors of respected English chemist Robert Robinson, who would later be knighted and awarded a Nobel Prize. Any mistake of his own might have ruined Julian's career.

Instead, the physostigmine work established Julian's reputation, and he went on to develop lucrative methods for producing progesterone and other sex hormones, and after that synthesized cortisone and hydrocortisone, steroids used to treat rheumatoid arthritis and many other ailments. His list of accomplishments is long; Julian possessed a great mind for both science and business.

But as his letter to Warner made clear, being intelligent and capable did not guarantee Julian's humanity in a racist society, nor his right to fully participate in the thing he loved: science.

The Julian I discovered in this letter sat at the intersection of the story of race in this country and in science—a tale of perseverance so powerful as to leave you breathless and, simultaneously, a textbook example of racism stifling potential. Our chief archivist pointed this out to me, and once he did, I could not unsee it. Being excellent did not protect Percy Julian. And that felt startlingly familiar.

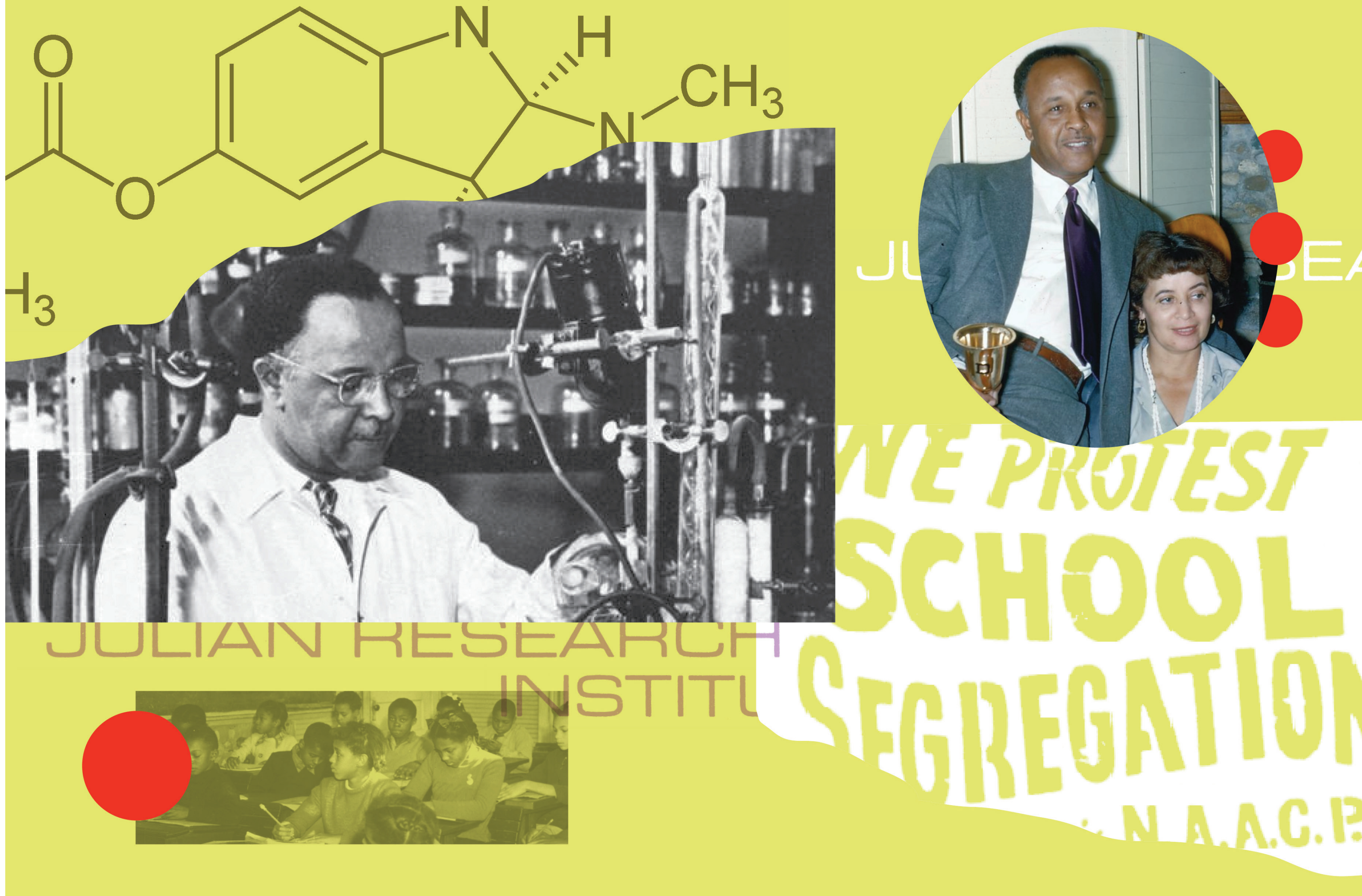


Illustration by WFGD Studio.

Wondering what Julian thought about his experience, I found "On Being Scientist, Humanist, and Negro," an essay he wrote for a 1969 anthology called *Many Shades of Black*. It was a surreal read for me—a Black woman working at the intersection of science and the humanities.

Julian begins the essay by recounting a long-standing academic schism between the sciences and humanities (or "humanism" as he calls it). He's both amused by the barbs the opposing camps lob at one another and empathetic to the anxieties of humanities professors who fear the growth of science education will displace the liberal arts. (It's a battle I recognize from my own work, though one thankfully becoming less common as the importance of placing science in its social context gains greater acceptance.) After a few paragraphs his commentary takes a purposeful turn:

> It is ironic that in this controversy the Negro scientist has been overlooked, for he has bridged the gap between humanism and science, if not always by choice, certainly then by circumstance. Living in a segregated society, . . . he has had to concern himself with the problems of his fellow-men as a humanist, while at the same time pursuing his career as best he could as a scientist.

Julian goes on to reflect on his youth, the experience of becoming a scientist, and the cold welcome he and other Black practitioners received when trying to make their way into the field.

Brilliant as he was, it's a marvel Percy Julian made it.

Julian's grandparents had been slaves. He grew up in Montgomery, Alabama, where the only high school available to him was unaccredited. But his parents had dreams for their children, and in 1916 Julian was accepted to DePauw University, one of the few primarily white colleges to accept Black students. Before Julian's departure, his father, a railway clerk, sent him a letter:

> Our people will never have a future in America if our college-trained men and women do not make friends of the white man. I can conceive of no better way of making friends than the studying together, living together, doing sports together, and enjoying the feeling of belonging to one college family.

His father's idealism clashed with the reality of life in Greencastle, Indiana. Julian struggled to find a place to live and eat. He eventually lived in the attic of a fraternity house where he tended the furnace and waited tables. To keep his place at DePauw, he carried a double load of classes his first two years—high school prerequisites along with his freshman and sophomore courses. Despite these challenges, Julian thrived academically. He graduated valedictorian in 1920; his classmates assumed he would be working in a Harvard lab the next fall.

In his essay Julian recounts the "week of anxious waiting" for his graduate school placement. He stood by as his lab mates received their acceptance letters. Finally, he approached his advisor, who, with some regret, showed Percy the many rejection letters he had received.

> "I also believed that through effort and discipline—through perfection—I could get people to look past my skin color. It was a brutal lesson. I could be excellent, and it might not be enough."

Julian was bright and capable, but he was also Black, and the country's graduate schools saw no future for him in chemistry, neither in an academic lab nor a professional one. They advised him to take a teaching position at a Southern Black college—a job that didn't require a PhD.

These men claimed that they were doing Julian a favor—sparing him years of futility and frustration. In the end, his professor secured him a place at Fisk University in Nashville. Julian describes the devastation of that moment: "There went my dreams and hopes of four years, and as I pressed my lips to hold back the tears, I remembered my breeding, braced myself, and thanked him warmly for thinking of me."

This scene struck me. Julian had cleared every hurdle, done everything expected of him—and then some. It is no exaggeration to say he was exceptional. And yet, his stellar academic performance was not enough to overcome the prejudices of the world he lived in.

My parents had dreams for me too. My father grew up in South Carolina in the 1930s, the son of sharecroppers. He had, at most, an eighth-grade education. My mother grew up in the Northeast in the 1940s. She had to leave high school but eventually got her GED. My parents wanted better opportunities for me than they had themselves, so like Julian's parents they sent me to a primarily white school. And I did well. I took honors and AP courses and earned good grades. My trajectory seemed set.

During my junior year, I met with a guidance counselor to discuss my future; I expected to talk through college applications and scholarship opportunities. Instead, he warned me how hard college was, how rarely people like me succeeded, and how I should consider a backup plan.

I was devastated but also confused. The whole ride home on the bus I kept thinking: *This must be a mistake. Maybe he didn't see my grades.*

I cried to my mother afterward. I understood that racism was not always overt, and I had plenty of experience with the way a subtle turn of phrase or an "innocent" observation could demean or humiliate. But I also believed that through effort and discipline—through perfection—I could get people to look past my skin color. It was a brutal lesson. I could be excellent, and it might not be enough.

As an adult, I can appreciate how difficult it was for my mother to soothe me, encourage me, and still make sure I was prepared for how the world would treat me. As a teenager, I slammed my door and flopped on my bed and declared that I'd never try to do anything ever again.

But I did try to do something again, and my mother took over for my guidance counselor and together we taught ourselves what we needed to know about applying to colleges. She used to have a saying for me, "by hook or by crook," which essentially means "by any means necessary." If there is no door, find a window. If there is no window, find a crack in the wall you might be able to slip through. I took her advice and moved forward.

■

Julian pushed forward too. He took the position at Fisk and found that he enjoyed teaching and the challenge of staying one foot ahead of his brightest students. But he didn't give up on his dreams of working in the lab. He kept clearing hurdles. He secured a grant that gave him admission to Harvard, where he earned a master's degree but was blocked from earning a PhD. So he leapt an ocean, earning his degree at the University of Vienna.

For the rest of his career, Julian continued to navigate the obstacles a racist society threw in front of him. We celebrate his success in doing so because it's astounding. It's also a narrative we're partial to. We are enamored of tales of self-made heroes, who achieve success through determination and independence. Similarly, we tell stories of the lone scientist in a lab, who catapults over obstacles through sheer willpower and genius. These narratives engender pride, self-esteem, empowerment—undoubtedly good things, but these narratives also have shortcomings.

Julian was aware of narrative's dual nature. Perhaps as analog for his own experience, Julian writes about one of the heroes who inspired him to pursue chemistry and apply to college, St. Elmo Brady, the first Black man to receive a PhD in chemistry.

Brady's success in receiving the degree from the University of Illinois was celebrated and highlighted in the Black newspapers of the day. Julian recalls hearing the news himself, in the summer of 1916 when he was applying for college. He writes, "Brady's accomplishment strengthened my determination to attend college."

The PhD was an incredible accomplishment. And yet, even after earning it, Brady found his ambitions blocked. As Julian tells it, Brady struggled to find a job suited to his talent. He was denied access to peer communities, libraries, and labs in a world built on segregation.

> "When we paint Black achievement solely as victory over incredible odds, we inadvertently let the society and institutions responsible for that oppression off the hook. We put the onus of solving racism on the oppressed."

And herein lies the problem with glorifying lone scientific geniuses and self-made heroes. It's simply not how the world works, and it's certainly not how science works.

These stories overlook the importance of networks and institutions to all forms of human success. Whether it was natural philosophers corresponding about the recipe for the philosophers' stone in the 17th century or research assistants who helped run a Nobel Prize–winning scientist's lab gathering for a summer social, science is, and always has been a community. Discovery is buoyed by associations of peers; research is supported by materials and equipment. We say "it takes a village" to raise a child, but it also takes one to move science forward.

Julian recognized this fact. He declares his frustration with the system of segregation, writing that racism had "destroyed the greatest possibility at that time of getting Brady and others on the scientific creative roster." The responsibility for changing this system, he argued, was not on Brady but on formal institutions. He pointed out that Brady's alma mater or another major university could have not only inspired "hundreds of intellectually hungry Brady admirers," but made a real difference in Brady's career by offering him a professorship and welcoming him into its community of fellow scientists.

Julian points to the myriad ways Black students' pursuit of science was hampered by systemic racism, from being denied admission to schools, to having their schools defunded by racist legislation that upheld segregation, to being discouraged from trying to go too far in pursuit of their passion. From his perspective, if we focus only on Brady's achievements, it hides the tragedy of a genius forced to constantly navigate around the barriers of racism.

His point is well taken. It is an illusion that overcoming racism is something that can be done alone. When we paint Black achievement solely as victory over incredible odds, we inadvertently let the society and institutions responsible for that oppression off the hook. We put the onus of solving racism on the oppressed.

■

I am no longer that teenager who had her heart broken in a guidance counselor's office. But as I reflect, I can't help but wonder if reading "On Being Scientist, Humanist, and Negro" back then might have changed my experience. Maybe it could have helped me make sense of the hurt I felt. Maybe I would have felt less like the failure was mine. Julian believed individual students could overcome this country's racist hurdles, but he also believed only its institutions had the power to make sweeping change. He called on them to do that work. And what's more, he had faith that his community would.

As he wrote to Warner in 1956, "I sincerely feel that there must be thousands of chemists in the ranks of our Society who—like the members of my staff of all races—will boycott such a meeting and refuse to participate in this insult to the individual dignity of their fellow Americans of color."

Like Julian, I have hope too. I learned a lot about the importance of collecting diverse science stories from talking to my archivist colleague. This work matters not just for researchers, but also for storytellers like me. Preserving the history of Black scientists and researchers from other marginalized communities helps us to push beyond the comforting historical narrative. It allows us to celebrate the incredible achievement of someone like Percy Julian, and helps us make science a more welcoming place for the Percy Julians yet to come. D

Alexis J. Pedrick is the Institute's director of digital engagement and cohost of the Distillations *podcast.*

Darwin's Barnacles

How an obsession with crustaceans guided the naturalist toward his most consequential insights.

BY SAM KEAN

If asked to pick an animal that influenced Charles Darwin, most of us would select the same one: the iconic Galápagos finches with their precisely crafted beaks, each tuned to a different ecological niche.

But the truth is, Darwin didn't really care about finches. He collected some during his famous voyage on the *Beagle* but proceeded to make a complete hash of them. He actually misidentified the birds, calling them grosbeaks, and had to be corrected by an expert back in England. Worse, he forgot to record the island of origin for most of the finches, making them useless for evolutionary study. Darwin didn't even specifically mention Galápagos finches in his monumental *On the Origin of Species*.

So while pop culture usually associates evolution with the Galápagos, Darwin left the islands in the same state he'd arrived—a creationist. What animals shaped his theory of evolution, then? Pigeons played a part, as did worms. But the biggest influence on Darwin was a lowly, much-despised marine pest—the barnacle.

In January 1835, three years into the voyage, the *Beagle* anchored off the coast of Chile, and Darwin—who'd been seasick much of the trip—scrambled ashore to walk the beach. He found a lush green canopy covering silky sand, with snow-peaked mountains visible in the distance. Wild potatoes grew near the shore, and otters splashed in the water, hunting crabs.

On the beach Darwin found a strange shell. It was coconut-sized and had a baffling feature: hundreds of millimeter-sized holes, as if somebody had blasted it with tiny buckshot. He'd never seen anything like it.

That night, back on the *Beagle*, Darwin studied the holes under his microscope. Using a needle, he pried something unexpected from inside them—minute barnacles, roughly a tenth of an inch long. They were cream-colored and doubled over on themselves like hairpins.

Unlike other barnacles, these lacked shells. And while most barnacles secrete a cementlike glue and lock themselves on to anything convenient—ships, docks, the bellies of whales—these barnacles were living as parasites inside another creature's shell. No scientist had ever recorded anything like it, and despite all the other wonders Darwin saw on the rest of the voyage, his mind kept circling back to that odd species of barnacle. He nicknamed it Mr. Arthrobalanus, which means "jointed barnacle." On his return to England in 1836, he was eager to study Mr. Arthrobalanus more thoroughly.

Alas, life intervened. As the *Beagle*'s naturalist, Darwin had official reports to write. A general travelogue appeared in 1839, followed by a book on coral reefs in 1842. Meanwhile, Darwin read a gloomy essay by preacher Thomas Malthus on starvation and the struggle for survival. Gradually, over many weeks, this kindled an idea in Darwin. If life was a struggle, then beneficial traits would give some creatures an advantage. As a result, those creatures would have more offspring. It was the first inkling of his now-famous theory of natural selection.

Still, at that point, it was just an inkling—hardly proof. Worse, Darwin soon recognized a big flaw in his idea: uniformity.

On the *Beagle*, Darwin had collected thousands of animals from across the globe, and he, of course, could see differences between different species. But *within* a species, all the individuals looked pretty much the same, even to his naturalist's eye.

This was a problem because natural selection needs variation to work on. If barnacles A, B, and C were all identical, natural selection couldn't distinguish between them, and survival would be purely a matter of luck. To his frustration, Darwin realized that such uniformity could prove fatal to his theory.

However puzzled, Darwin wrote up a summary of his ideas in 1842—along with instructions to his wife, Emma, to publish it if he died suddenly. Then it was back to the *Beagle* grind. Darwin released a book on volcanos (1844), then one on the geology of South America (1846). All the while, his big idea languished. Given how he jumped from topic to topic, some historians have called the Darwin of this period a "genuine dilettante."

And it wasn't just historians. In a letter to botanist Joseph Hooker, Darwin confidentially laid out his theory of evolution and the origin of species, seeking Hooker's input. Hooker was not impressed, and in fact rebuked Darwin. How could Darwin claim to know the origin of species in general, Hooker asked, if he'd never studied even one species in detail?

Darwin was mortified. He'd basically been called an amateur, a dabbler. He needed to rectify the situation immediately.

That's when he remembered Mr. Arthrobalanus. Darwin decided to spend a month describing it in detail to prove his bona fides to Hooker and others. Then he could jump back into his big theory about evolution and shore it up. It all seemed so easy. Instead, barnacles would dominate the next eight years of his life.

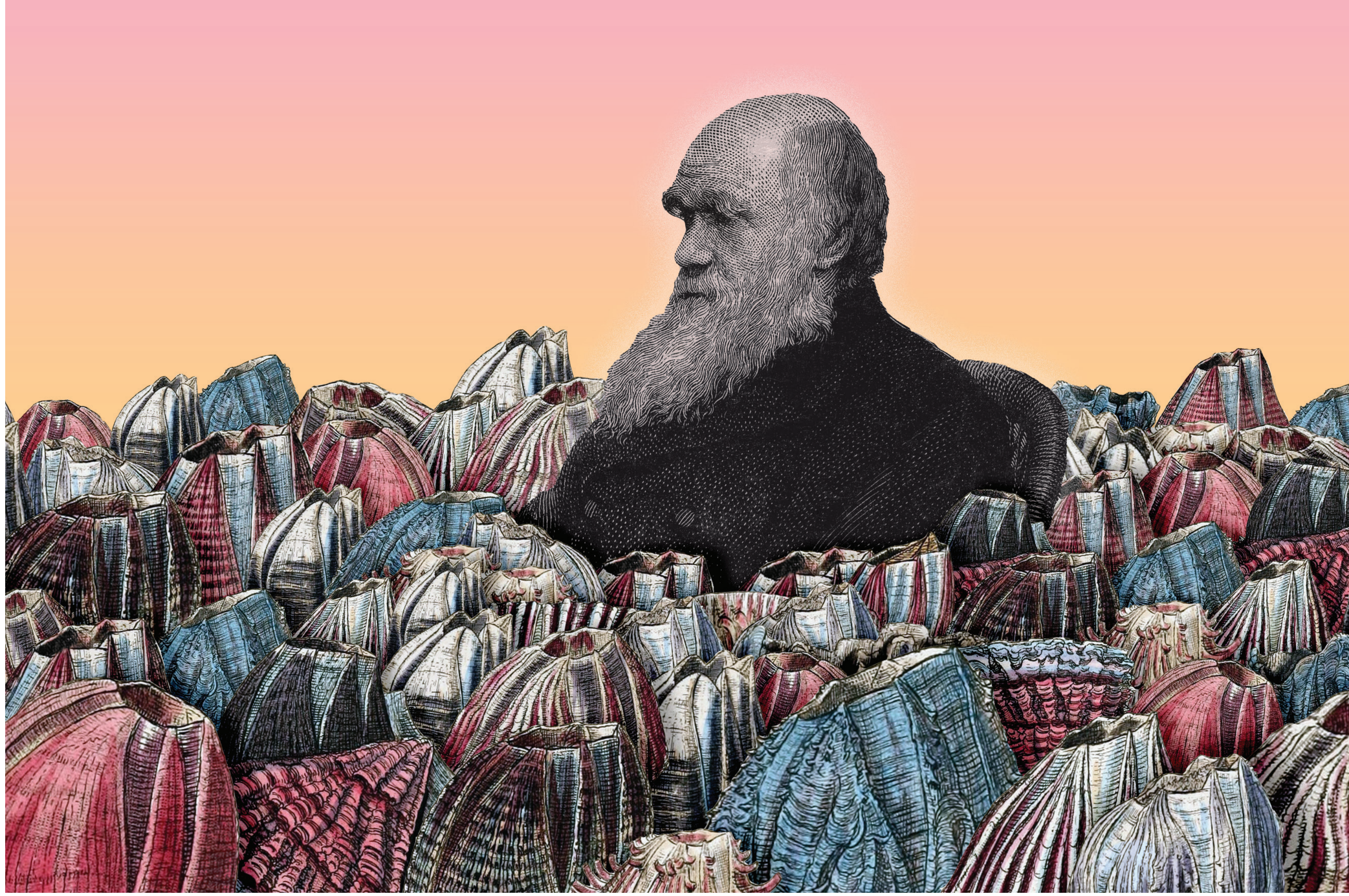


Illustration by Clay Cansler.

To describe Mr. Arthrobalanus, Darwin needed to know what differentiated its species from other species of barnacles. So he began writing letters to museums, requesting barnacle specimens. Unfortunately, it soon became clear that all existing work on barnacles was sloppy and third rate. There were gaps, obvious mistakes, redundancies. With a sigh, Darwin realized he would have to reclassify everything himself. He started writing more letters, requesting more specimens.

Smelly boxes began arriving at his home from all over the world. He kept them in teetering piles in his study. Peering through a microscope, he used pins and porcupine quills to dissect the barnacles and tease apart their wispy organs. Whenever he saw something interesting, he'd push his wheeled stool back and scribble down a note in his atrocious handwriting. But despite the daunting task, he ended up loving the work. As he told a friend, "After having been so many years employed in writing my old geological observations, it is delightful to use one's eyes and fingers again."

He often worked straight through the night beneath an oil lamp—straining so hard that he suffered migraines and intestinal distress, even nightmares. Doctors begged him to stop; his health was nearly broken. Darwin refused. Every day the postman rang, and every day the piles of barnacles grew treacherously taller.

Word about Darwin's mania soon got around. The writer Edward Lytton-Bulwer—he of the thundering cliché, "It was a dark and stormy night"—satirized Darwin in a novel as "Professor Long," a pedantic bore whose interminable lectures on marine critters put everyone within earshot to sleep. Then there was the story about Darwin's son George. As a boy, George visited a friend's house and was flabbergasted to learn that the friend's father had no dissecting desk or microscope. George stammered, "Then where does he do his barnacles?"

But however much people mocked Darwin, his barnacles were providing fascinating insights into evolution. For one thing, he noticed how certain organs in one barnacle species were often repurposed in another species. It's similar to how the forelimbs in ancient mammals got transformed into wings in bats and flippers in dolphins.

Conversely, he discovered that unused organs often withered away, especially when it came to barnacle sex. Mr. Arthrobalanus was a prime example.

All known barnacles then were actually hermaphrodites, with both male and female sex organs. In calling the specimen "mister," Darwin had been joking around. But in truth, the joke was on him. It turned out that Mr. Arthrobalanus's species was not hermaphroditic. In fact, Mr. Arthrobalanus wasn't even a mister—she was *Ms.* Arthrobalanus, a female.

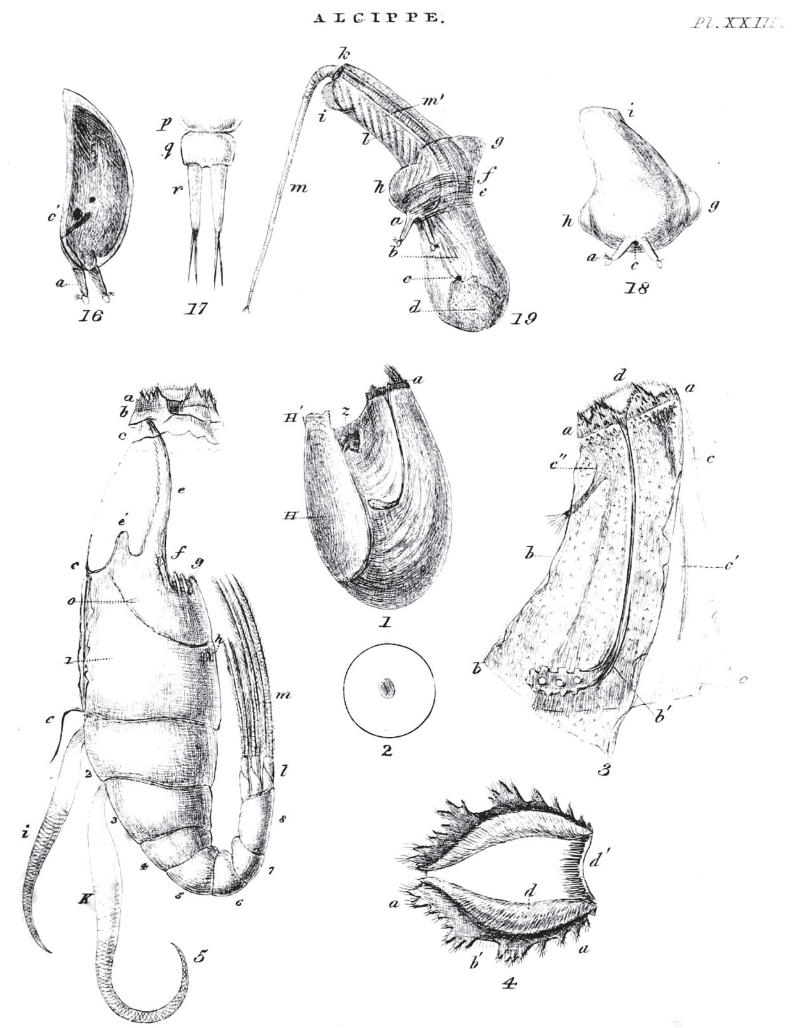
So where were the males? Embarrassingly, Darwin had nearly thrown them away. He'd been finding little tick-like things attached to Ms. Arthrobalanus—parasites, he assumed. So he picked them off. In reality, these "ticks" were the menfolk. They were ten times smaller than the females and consisted of nothing but sacs of sperms. All other body parts on the males, such as stomachs and heads, had been whittled away by evolution.

This arrangement startled Darwin. But it also got him thinking, especially when he found another barnacle species with no females. In that species, half the individuals were hermaphrodites and half were dwarf males—males *on their way* to becoming nothing but sperm-filled ticks.

In other words, he'd found a transitional state between hermaphrodites and the distinctly sexed barnacles of Ms. Arthrobalanus. A missing link. The discovery electrified him: "Down among his barnacles," one biographer wrote, "he felt he was seeing evolution in action."

Even better things were coming. Again, Darwin's initial, groping theory of evolution still had a big flaw: uniformity. If all creatures within a species were identical, how would natural selection determine who lived and who died?

But box by box, barnacle by barnacle, Darwin trained his eye and transformed himself into a barnacle expert. As a result, he started noticing variations he had never noticed before. One barnacle might have a thinner shell or wider mouth. Another might have longer legs or oddly shaped internal organs. These were tiny variations, easy to overlook. But they were enough for natural selection to act on.



Illustrations of *Cryptophialus minutus*, the barnacle Darwin nicknamed Mr. Arthrobalanus, from the second volume of his *A Monograph on the Sub-class Cirripedia* (1854). *Figure 1* shows the female with an attached male (*z*). Illustrations by George Sowerby.

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Darwin then extended what he'd learned with barnacles to other creatures. He once marveled over "the variability of every part . . . of every species. When the same organ is rigorously compared in many individuals I always find some slight variability." Later he added, "I am convinced that the most experienced naturalist would be surprised at the number of the cases of variability" throughout nature. This eliminated the fatal flaw in his theory. Despite appearances, nature wasn't uniform at all. Before studying barnacles, Darwin simply lacked the skill and expert knowledge to see all the nuances.

Darwin's experience isn't how we usually envision creative breakthroughs. We expect eurekas, sudden flashes of insight. We want drama. What Darwin did, hunched over those smelly barnacles, seems like the opposite of creativity—petty drudge work. But that patient, yearslong labor was actually critical. Thanks to his obsession with barnacles, his once-vague theory of evolution itself evolved to a higher plane. D

Sam Kean is a best-selling science author. His latest book is The Icepick Surgeon: Murder, Fraud, Sabotage, Piracy, and Other Dastardly Deeds Perpetrated in the Name of Science.

Speaking to the Future

Nuclear waste remains dangerous for millennia, so how do we keep people in the distant future away from it?

BY KIT CHAPMAN

In 1981 the U.S. Department of Energy realized it had a major nuclear waste problem. The waste had been accumulating for the better part of 40 years and was likely to remain deadly to humans for at least 10,000 years. In the past such waste had been dumped into the sea at more than 50 sites in the Atlantic and Pacific oceans, but international treaties and the potential environmental impact meant this was no longer an option. Nor could the waste simply be blasted into space, as some had suggested; if something were to go wrong en route, the rocket could inadvertently irradiate the atmosphere, or scatter radioactive waste onto population centers. The only option was to bury the waste, and that led to a big question. How, exactly, could you warn future generations where you had put it?

The Department of Energy assembled a dream team of communications experts, archaeologists, social scientists, and long-term climatologists to crack the problem. They were called the Human Interference Task Force, and their work would spawn ideas ranging from elaborate monoliths and buried vaults to glow-in-the-dark cats and invented religions.

Language Barriers

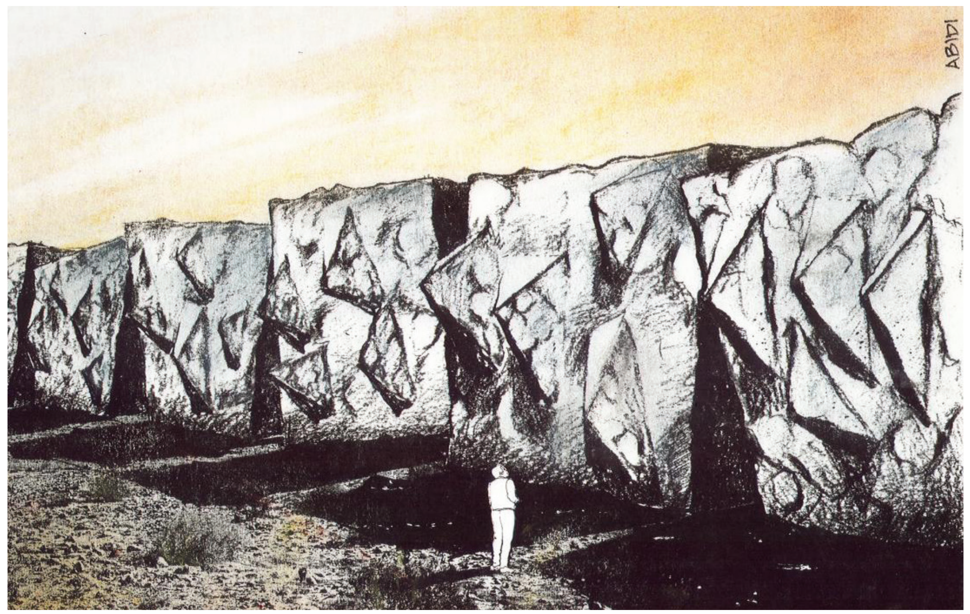
Sending messages into the future isn't as straightforward as it might seem. Language, for example, evolves over time; a thousand years ago English as we know it did not exist. Tamil, considered the oldest language still spoken, is only 5,000 years old, and it has evolved to the point where only a Tamil scholar can understand its oldest texts, written about 2,000 years ago. There is simply no way to predict the languages future generations will use.

As the Human Interference Task Force pointed out, the Rosetta stone enabled the translation of hieroglyphics—unlocking an entire language—thanks to the inclusions of two identical messages in two known languages. Even so, it took 23 years for its symbols to be translated in full. And the Egyptians who inscribed it, the task force writes, "had no way of knowing that Greek would survive longer than their own language."

Visual media have their own drawbacks. While maps marking the location of a waste site could be placed in repositories around the world, there's no guarantee people in the future would know to seek out such a map or that its message would be understood. A cartoon showing someone becoming ill after exposure to nuclear waste read from left to right might provide a clear warning; if read from right to left, the same drawing could appear to describe a miracle cure. Cultural context can also affect the way an image is interpreted. As task force member Thomas Sebeok noted, it may be impossible to tell from a simple pictorial image whether a group of figures holding spears are hunting, fighting, or partying. If images are used, they need careful forethought to avoid ambiguity and multiple ways of providing a warning to ensure the context is understood.

Oral traditions have some evidence of lasting. Icelandic sagas recounting events from the 10th century have been found to be accurate, while we still tell the (albeit highly mythologized) story of the Trojan War, believed to have occurred more than 3,000 years ago. But while there is evidence of oral traditions that have survived close to the time frame needed for nuclear containment—between 7,000 and 10,000 years—modern societies have consistently ignored such generational knowledge.

Forbidding Blocks, a proposed site marker for the Department of Energy's Waste Isolation Pilot Plant. Architect Mike Brill's concept consists of forbidding, stone-and-concrete cubes arranged to discourage human settlement. Drawing by Safdar Abidi.



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In Japan "tsunami stones" have stood for centuries as reminders to avoid building below them in case of tidal waves. In 2011, when the Tōhoku earthquake caused a tsunami, villages above the stones were safe; structures below the stones—including the Fukushima Daiichi nuclear power plant—suffered catastrophic damage. In Canada, Inuit oral traditions had recorded exactly where John Franklin's 1845 expedition to navigate the Northwest Passage became trapped in the ice, including how its members had died; the British refused to believe the Inuit tales, and the expedition's two ships, *Erebus* and *Terror*, remained undiscovered until 2014 and 2016, respectively.

Even if a warning is recognized as such by future generations, it could easily trigger the wrong effect—either by accident or on purpose. For example, the skull and crossbones symbol typically represents death in Western society, but there is no guarantee that this association will continue. And while the dynasties of ancient Egypt left elaborate curses on tombs to ward off grave robbers, the hexes did not deter looters or archaeologists, who if anything took such warnings as a sign of potential treasure.

Finally, these problems all assume the message itself survives. The Human Interference Task Force's goal was to leave a message that could last 10,000 years, or around 300 generations. The oldest known writings, contained on tablets and carved slabs, are about 5,000 years old. Any message would have to endure weathering and potential changes to the climate and be easily found by anyone who stumbled on the disposal site. It would need to be a message that could be understood both by those purposefully trying to break into the vault and by people inadvertently interfering with the waste, such as drillers who might find themselves in the wrong place.

The task force decided to get creative.

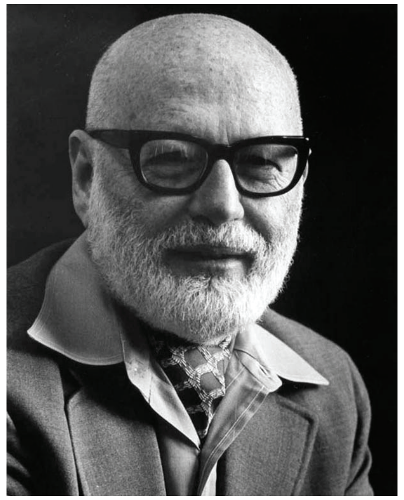
Cats and the Atomic Priesthood

The task force's recommendations for protecting the waste were varied and sensible. It suggested placing the site away from human settlements and natural resources, thus reducing the chance of discovery. It recommended various levels of defense so that even if one warning was ignored or overlooked, another might be effective.

Designs were drawn up for "central monuments" flanked by warning markers, a kind of giant, modern-day Stonehenge. Asphalt would be used as a sealant and a stabilizer for the monuments, protecting them from natural weathering for several thousand years, at minimum. But these plans, the task force acknowledged, didn't focus on the key issue—how to communicate the message.

Sebeok, an Indiana University semiotician—that is, an expert in signs and symbols—was asked to consider the problem. The professor outlined his ideas in a report, *Communication Measures to Bridge Ten Millennia*. In it he explains the basic elements of human communication and tries to expand readers' concepts of what a message can look like. For example, he contemplates a message in the form of an intense, foul odor to drive people away from a waste site. But in the same breath he undercuts the idea, musing that future generations might choose to explore with robots or automatons that wouldn't smell the warning. His point is simple: when trying to transmit a message across millennia, no single method is foolproof. Variation and redundancy are essential. "All channels that seem technically feasible should be utilized," he writes. But to illustrate his point, Sebeok offers a scheme that challenges the notion of "feasible."

Citing Pandora's box and the power of myth to pass down warnings, he proposes a religious mythology, something that could transcend culture and geographical location and establish a lasting folk memory. Annual rituals would establish superstitions to warn people away from the waste sites. "The actual 'truth,'" Sebeok writes, "would be entrusted exclusively to—what we might call for dramatic emphasis—an 'atomic priesthood,' that is, a commission of knowledgeable physicists, experts in radiation sickness, anthropologists, linguists, psychologists, semioticians, and whatever additional expertise may be called for now and in the future." Such a "priesthood" would form the framework of a "relay system" to update the messaging around the site every few generations. One flaw with this plan, Sebeok confesses, is that nothing like it has ever been tried.



Thomas Sebeok, 1976.

The closest precedent folklorists could come up with were the ineffective pharaohs' curses.

Other, even more outlandish proposals followed. First among them was Françoise Bastide and Paolo Fabbri's proposal to breed color-changing cats. Felines have lived side by side with humans for thousands of years. What if they could be used, like canaries in a coal mine, to highlight radioactivity? The duo wrote,

> In order to make humans aware of the presence of atomic radiation, animals can be bred that will react with discoloration of the skin when exposed. Such an animal species should dwell within the ecological niche of humans, and its role as a detector of radiation should be anchored in cultural tradition by introducing a suitable name (e.g., "ray cat") and suitable proverbs and myths.

If your cat changes color, it's time to run away.

The ideas kept coming. Polish science-fiction writer Stanisław Lem suggested breeding "information plants," whose DNA, when deciphered, included a warning. But the idea assumed people would think to sequence the plants before investigating the big, shiny tomb-thing or that the plants wouldn't mutate and cross-fertilize, degrading the message. So Lem also proposed creating satellites that could beam down warnings to anyone listening—although that would imply the ability to detect and decipher such broadcasts.

Philipp Sonntag, from the Social Science Center in Berlin, went even further: he proposed building an artificial moon, with the information "stored in its cellar."

Unsurprisingly, none of the ideas proposed were ever acted on. But the search for a way to talk to the future was not over.

This Is Not a Place of Honor

While outlandish ideas were shelved, the problems of marking nuclear waste repositories continued into the 21st century for countries such as the United States, United Kingdom, Germany, and Sweden.

In 1993 Sandia National Laboratories put together its own report, which focused on preventing intruders from reaching the Waste Isolation Pilot Plant, or WIPP, a deep geological facility for storing nuclear waste in New Mexico. The waste is stored more than 2,000 feet below ground in a salt formation that has been stable for 250 million years. But what was to be done on the surface?

The Sandia planners looked at a host of options, including giant granite spikes designed to scare and intimidate, and a "black hole," a large, basalt or concrete slab designed to be terrifying. This was part of a "physical language" that humans would recognize as hostile. Ultimately, the team decided to erect thirty-two 25-foot-tall granite pillars surrounded by an earthen wall, with a giant granite room at the center of the site containing warnings in seven languages (English, Spanish, Russian, French, Chinese, Arabic, and Navajo), with space for more languages to be added over time. The message would also include phrases such as "this is not a place of honor . . . what is here was dangerous and repulsive to us . . . the danger is still present, in your time, as it was in ours. The danger is to the body, and it can kill." The plans are still being formalized and are expected to be submitted to the U.S. government in 2028; when dealing in millennia, a few decades of careful thought doesn't hurt.

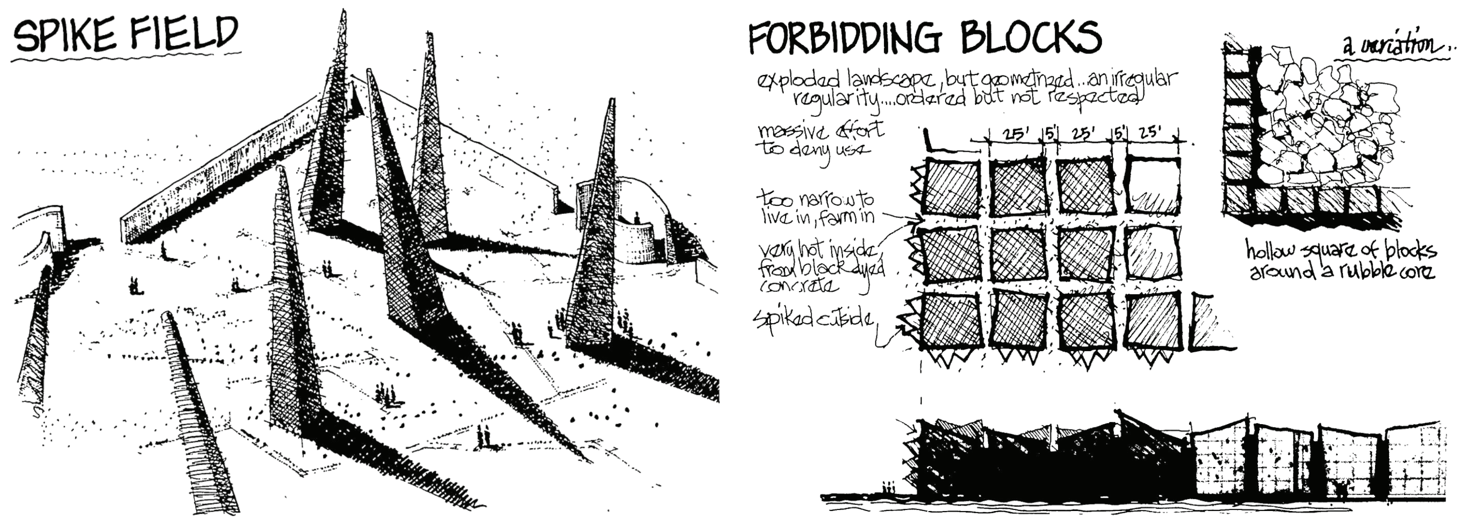
Despite decades of effort from some of the world's best minds, we still haven't come up with a simple, surefire way to warn future generations of the dangers of radioactive waste. With that in mind, European officials are wondering if we need to leave a message at all.

Finland's spent-nuclear-fuel repository is scheduled to come online in 2023. Built in Eurajoki on the country's west coast, the facility, named Onkalo, will also see waste placed deep underground, sealed in boron steel and copper capsules that should survive for 100,000 years. Rather than mark the site with elaborate structures, the Finnish approach is far simpler—around 2120 they're going to bury the facility, leave no markings of any kind, and hope nobody digs there.

It's a risky strategy; after all, it's hard to hide a giant mine from the world, and a single accident, even in such a remote location, could be enough to expose the waste to humans of the far future. But the Finns reckon we're overlooking a simple fact: we're assuming that future humans won't be smart enough to know what radioactivity is or what a nuclear waste site could look like. And if civilization's collapse wipes away future generations' knowledge of radioactivity and leaves them unaware of the dangers of nuclear waste, any survivors would have far bigger problems than accidentally opening the wrong door.

Perhaps we don't need to speak to the future after all. Perhaps it's enough to believe that the future is smart enough to listen. D

Kit Chapman is a science journalist and course leader for the master's degree in journalism program at Falmouth University in the United Kingdom.



Mike Brill's conceptual designs for Spike Field (*left*) and Forbidding Rocks (*right*), two proposed site markers for the Waste Isolation Pilot Plan.

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American Fevers, American Plagues

How yellow fever outbreaks in the early United States anticipated much of what we lament about the COVID-19 era.

BY THOMAS APEL

Autumn in Philadelphia usually brought people outdoors, but this year the city was all shuttered up. Although it had been several months since it first appeared, the epidemic still raged, and no one really knew when it would end. Doctors urged people to stay home, avoid unnecessary contact, and observe good personal hygiene.

Citizens still argued among themselves about the disease, and while many scoffed at the recommendations from so-called experts, most grudgingly listened. And so the lockdown halted commerce and disrupted the normal rhythms of social life. As one observer remarked, "Business . . . became extremely dull. Mechanics and artists were unemployed; and the streets wore the appearance of gloom and melancholy."

Such was the scene when yellow fever ravaged Philadelphia in 1793, although it could just as well describe the city, or most any American city, in fall 2020 at the height of the COVID-19 pandemic.

It's been said many times during the past three years that the COVID-19 pandemic is unprecedented in American history. But the nation's history has now been bookended by two great outbreaks. The first began when yellow fever struck Philadelphia in 1793, killing 5,000 of the city's 50,000 inhabitants, and continued to 1805 in a series of terrifying epidemics that scourged New York and Philadelphia. Close attention to the nation's first epidemic reveals striking similarities with its most recent. From the lack of preparation to ruthless politicization of medical opinions, yellow fever anticipated much of what we have come to know and lament about COVID-19.

A man with severe yellow fever symptoms. From Etienne Pariset and André Mazet's *Observations sur la fièvre jaune, faites à Cadix, en 1819* (Observations on Yellow Fever, Made at Cadiz, in 1819).

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Yellow fever is caused by a virus that spreads through the bites of female *Aedes aegypti* mosquitoes. It is often classed with tropical diseases, such as malaria, dengue fever, and more recently Zika fever, but it is far more violent. The name of the disease comes from the jaundice it produces as the virus pummels the victim's liver. Even in modern settings, mortality rates are as high as 5%, and death comes in a grisly, painful manner, from massive internal hemorrhaging.

Before it arrived in Philadelphia in 1793, yellow fever was a relatively common disease in the Atlantic. It was certainly well documented and described in the medical literature of the period, something every trained physician would have read about. Although the fever made sporadic appearances in Philadelphia, New York, and Charleston, its true home was in the sugar colonies of the Caribbean.

During the Seven Years' War (1754–1763), the fever tormented the French, Spanish, British, and American soldiers who trespassed in Caribbean waters. Merchants who plied the routes between the major commercial centers of British North America and the Caribbean islands always knew the danger that lurked there. As Americans began importing more sugar, coffee, and rum from the islands in the years leading up to 1793, some must have guessed that someday yellow fever would come along too.

Philadelphia's Delaware River waterfront in 1800, engraving by William Birch.

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And come it did. From 1793 to 1805, yellow fever visited the United States every year. After the great epidemic of 1793, it returned to Philadelphia with devastating effect in 1797 (≈1,500 deaths), 1798 (3,645 deaths), and 1799 (≈1,000 deaths); it assailed New York in 1795 (≈800 deaths), 1798 (2,080 deaths), and 1803 (≈700 deaths); it raged in Baltimore in 1800 (1,197 deaths); and it occurred in several minor epidemics in Boston, Charleston, and New Orleans. The fever also chased the government from Philadelphia and disrupted commerce for months at a time. Yellow fever was the most serious natural problem that the early United States faced.

While the virus known as SARS-CoV-2 first crossed over from bats to humans in 2019, the specter of a global pandemic had haunted the world for years. The global community narrowly avoided wasting pandemics in 1997 with avian influenza, in 2002 and 2003 with severe acute respiratory syndrome (SARS), and again in 2009 and 2010 with H1N1 influenza. All were highly contagious viral diseases that spread easily through respiratory secretions.

Public health agencies around the world sounded the alarm and many, such as the Centers for Disease Control in the United States, crafted plans for a global pandemic. But governments were reluctant to allocate money and attention to prepare for something that seemed more like a nightmare from the past than an actual possibility.

Americans then and now were surprised by disease when perhaps they shouldn't have been. To use a technical term, the diseases caught us with our pants down. They exposed gaps in our awareness of health risks, and they revealed a certain degree of hubris. In the heady aftermath of the Revolutionary War and in our era of modern technological marvels, Americans overestimated their control over the forces of nature.

Benjamin Rush, the most celebrated doctor in the early United States, believed that the American Revolution had ushered in a golden age, not only in politics, but in health as well. "All the doors and windows of the temple of nature have been thrown open by . . . the late American revolution," he wrote in a 1789 manual for young physicians.

When the fever came to Philadelphia in 1793, Rush remained in the city for the duration, treating the sick with a "therapy" involving massive bloodlettings. Writing to his wife, a far humbler Rush praised God for his own preservation and remarked, "What a bitter thing must *sin* be to deserve even such a punishment as a destroying pestilence."

Both outbreaks also disproportionately affected the poor and marginalized. The effects of COVID-19 have mirrored racial and economic disparities in the United States—throughout the pandemic, racial minorities and economically disadvantaged have been much more likely to get the disease and to die from it. According to one estimate, the 65 million Americans who receive Medicaid assistance have been more than four times more likely to die from complications of COVID-19. This is because impoverished Americans often lack access to healthcare, they are more likely to work in crowded workplaces without recourse to remote options, and they tend to have pre-existing health conditions at higher frequencies.

Very similar disparities existed in the early republic. The printer Mathew Carey wrote a popular account of the 1793 epidemic in which he estimated that seven-eighths of those who died were poor. Carey implausibly blamed bad hygiene and loose morals.

Richard Allen and Absalom Jones, leading figures in Philadelphia's Black community, came much closer to the mark in their *Narrative of the Proceedings of the Black People, during the Late Awful Calamity* (1794). Written in reply to Carey, who accused Black nurses of theft and profiteering, the *Narrative* emphasized the heroism of Black volunteers and called attention to a simple truth: unlike the wealthy and middling classes who fled the city at the first sign of disease, the poor had no choice but to remain. They also tended to live in the more densely populated waterfront, right where newly arrived mosquitoes hungrily swarmed. Finally, then as now, access to healthcare cost money, which meant that impoverished victims of yellow fever could not avail themselves of the nursing care that was, and still is, the best way to treat yellow fever.

Both outbreaks also produced controversy—lots of it.

When yellow fever first struck, the nation's doctors quickly divided into two schools of thought about its cause and prevention. One group, the localists, believed that yellow fever arose from the pestilential miasmas that emanated from dirt, decay, excrement, and all the other foul things that cities had to offer. They suggested that sanitary reform—essentially cleaning cities and supplying fresh drinking water—would solve the problem.

The other group, the contagionists, argued that yellow fever was imported by commercial vessels. They believed that quarantines and the regulation of trade would eradicate yellow fever from the ports. The acrimonious debate lasted for years, enveloping the public in a bitter feud that fractured trust in the medical community and exacerbated tensions in the young nation.

As it turns out, both sides were partially correct. Since *A. aegypti* prefers to breed in small, artificial containers of water—such as the rain barrels used to collect water in the 18th century—yellow fever was linked to urban conditions, as the localists insisted. At the same time, *A. aegypti* was a non-native species, and it died in the frosty mid-Atlantic winters; so the mosquitoes did have to be reimported each year before yellow fever could occur, as the contagionists claimed.

While doctors of our time have achieved something close to unanimity on questions about the cause and prevention of COVID-19, that hasn't kept Americans from forming their own ideas and debating them fiercely in the vast marketplace of ideas. Most everything about the disease has been doggedly contested, from where it originated (The Wuhan wet market or the Wuhan Institute of Virology? From bats? Pangolins? From shadowy government organizations? The deep state?) to what we should do about it (Shut down? Stay open? Wear masks? Take ivermectin? Get vaccines?).

The existence of such debates isn't particularly remarkable, but the fact that these debates fell clearly along political lines is.

In the time of COVID-19, Democrats have favored stiff lockdown measures, mask mandates, and universal vaccinations; they have openly celebrated the authority of science, encouraging others to do so as well. Republicans have been more critical of the lockdown's severity, they have been more receptive to vaccine skepticism, and they have shown greater reluctance to believe the "experts."

Pundits have posited many explanations for this disparity: the parties' conflicting ideas about personal "liberty," their different attitudes toward the roles of the state and science in daily life, their contrasting perceptions of the trustworthiness of news reporting and other sources of information, the economic costs of the shutdown, the president's personal disdain for scientists and scientific knowledge, and the fact that the pandemic started during an unusually important and divisive election year.

Absalom Jones, portrait by Raphaelle Peale, 1810.

Richard Allen, lithograph by Albert Newsam, ca. 1850.

In the 1790s, opinions about yellow fever also mapped strongly onto the political landscape, which was then polarized by the two political parties, the Federalists, whose informal leader was Alexander Hamilton, and the Republicans, whose informal leader was Thomas Jefferson. Those who have seen *Hamilton* may remember the basic tenets of the parties.

Federalists promoted a strong central government, whose institutions, such as the Bank of the United States, would take an active role in shaping a mighty manufacturing economy. In terms of foreign policy, they called for an alliance with Great Britain against France, mainly because the French Revolution was unfolding at the same time, and with the guillotine, the regicide, and all, things seemed to have gotten radically out of hand.

The Republicans favored a small government that would oversee a simple and virtuous agrarian republic. The Republicans feared that cities stimulated vice and corruption, and so they wanted to keep them few and small. In foreign affairs, they favored cooperation with France, their erstwhile ally in the Revolutionary War.

What *Hamilton* doesn't mention is that Federalists overwhelmingly tended to be contagionists and Republicans tended overwhelmingly to be localists. If we look at the implication of the medical theories, it isn't hard to see why.

For the Federalists, quarantine measures fortuitously benefited both their domestic and foreign policy agendas. By limiting foreign trade, quarantine would protect the domestic manufacturing industry from foreign competition. Blaming foreign sources of contagion also happily exonerated cities from charges of unhealthfulness; this was important because manufacturing happens in cities. It also proved a convenient excuse for barring entry of the "radical" French and Haitian refugees, who were fleeing from the horrors of the French and Haitian revolutions. This same fear of outside French influence led the Federalists to pass the infamous Alien and Sedition Acts in 1798!

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American Fevers, American Plagues

> "Federalists and Republicans saw in yellow fever exactly what they wanted to see. And it is certainly true in our time that many have embraced beliefs about COVID-19 that suited their own economic and political ends."

Republicans drew as much self-interest from the localist doctrine. For one, localism confirmed Republican suspicions that cities were indeed unhealthy places. Far better to farm in the salubrious air of the countryside. As Jefferson bluntly put it in a letter to Rush, "Yellow fever will discourage the growth of great cities in our nation, & I view great cities as pestilential to the morals, the health and the liberties of man."

Localist sanitary reform would also leave foreign trade intact; thus, cheaply produced manufactured goods from abroad would continue to discourage domestic manufacturers. As for the refugees, Republicans were split. While many welcomed French and Haitian revolutionaries, slaveholders such as Jefferson didn't want anyone talking too loudly of liberty.

The utilitarian philosopher John Stuart Mill once wrote, "Men who have been much taught . . . do not see, in the facts they are called upon to deal with, what is really there, but what they have been taught to expect." Federalists and Republicans saw in yellow fever exactly what they wanted to see. And it is certainly true in our time that many have embraced beliefs about COVID-19 that suited their own economic and political ends.

The obliviousness to the real threat of disease, the disproportionate impact it had on the poor, and the way politics influenced the public's understanding of disease—all are key features of the COVID-19 pandemic that were anticipated by yellow fever more than 200 years before.

Of course, those looking for differences will find them too. We are fortunate to have a medical and scientific community that agrees on the principles of disease cause and transmission, and we are fortunate to have moved on from therapeutic systems that involve draining blood.

But another difference should give us pause. While self-interested rationalization may have steered Federalists and Republicans to contagionism and localism respectively, at least they subscribed to sound theories that were supported by medical and scientific knowledge. For all our medical advantages, in our own time one partisan group has openly denied scientific knowledge and vilified its creators. That's a precedent we all might come to lament. D

Thomas Apel is the author of Feverish Bodies, Enlightened Minds: Science and the Yellow Fever Controversy in the Early American Republic *(2016). He was a 2016–2017 fellow at the Institute.*

This unattributed political cartoon is based on newspaper accounts from 1820 and lampoons the New York Board of Health for mistaking a man's drunken condition for yellow fever.

How History Keeps Ignoring James Barry

After 150 years of scrutiny, scholars still misrepresent the doctor's life.

BY REBECCA ORTENBERG

In 1865 a celebrated British army surgeon died of dysentery. There was nothing strange about the death—dysentery was a common killer. Instead, it was the scandal that followed that rocked British society.

According to reports, the surgeon, James Barry, had not been all that he had seemed. While washing the doctor's body after his death, a charwoman discovered that he was, in her words, "a perfect female." The *Manchester Guardian* responded to this news with gusto: "Were not the truth capable of being vouched for by official authority, the narration would certainly be deemed absolutely incredible." Some of Barry's acquaintances reacted with shock; others claimed to have always suspected Barry was not a man. Two years later, none other than Charles Dickens wrote that it was "a mystery still" as to how the good doctor had fooled so many people for so long.

More recent writers have taken a different view of Barry's so-called deception—now it is seen as the "exquisite subterfuge" of an ambitious woman ahead of her time. Today we're much more inclined to celebrate women who broke barriers, and we even relish the thought of a woman outwitting the sexist establishment that looked down on her. Some historians have called Barry the first woman to become a qualified doctor in the United Kingdom and have placed Barry in the same category as other daring women who had donned men's clothes to seek their fortunes and serve their countries.

As tempting as this narrative may be, what if it is still fundamentally misrepresenting James Barry's life and identity?

Barry was most likely born Margaret Ann Bulkley in Cork, Ireland, in 1789. The Bulkleys ran a successful grocery business, but the eldest child, Jeremiah, liked to spend lavishly to impress his rich friends. By 1806 he had bankrupted the family and landed himself in prison. Their luck changed later that year after Barry's uncle died and left the family a surprise inheritance. With the help of this newfound wealth, in 1809 Barry and his mother set off for Edinburgh. In the early 19th century, Edinburgh was the place to be for anyone wishing to study medicine—the university there was considered the finest medical school in the United Kingdom and one of the best in the world. In Edinburgh, Barry could begin a new life. He enrolled in medical school, and after graduating and passing his examinations for the Royal College of Surgeons, he joined the army. His career lasted 50 years and was spent in outposts across the British Empire, from South Africa, to the Caribbean, to Canada, and nearly everywhere in between.

Slight of stature and known for a love of flamboyant clothes and stylish wigs, Barry's dapper appearance belied a toughness and a hard-nosed, often belligerent dedication to his job. (He was known also to carry a rapier.) He had a habit of infuriating people in power in his quest to improve sanitation and medical care in the communities he served. As the medical inspector in Cape Town, South Africa, he cracked down on quack-medicine hawkers, worked to improve access to clean water for rich and poor alike, and drew up strict rules for the humane treatment of patients at a local leper colony. He also performed one of the first documented cesarean sections in which both mother and infant survived.

Barry took this same crusading spirit to other outposts of the British Empire. While stationed in Canada, he demanded that the living conditions and diets for soldiers be improved and that all ranks have access to recreational facilities and libraries. He had a reputation for shouting, swearing, and insulting those who got in the way of what he saw as necessary reforms, shocking even Florence Nightingale with his brutish nature. As one observer later put it, "Although it is quite certain that for these 'interfering ways' many of the senior officers disliked Barry, there must be still many officers and a great many of the ex-rank and file who remember [him] with gratitude."

By 1859 the 70-year-old Barry's health was failing. He returned to England, where, over his objections, the medical board forced him to retire. He died a few years later, leaving behind a remarkable professional legacy and a simple request: that his body remain unexamined after his death and that he be buried in the clothes he was wearing when he died. Had that request been followed, Barry likely would be dimly remembered today for his crusading medical work. Instead, people have spent the last century and a half hypothesizing about his gender—speculation based not on how he lived, but on the nature of his body when he died.

Today we might call Barry a trans man: someone who was assigned female at birth but who identified as a man and transitioned their name and appearance to align with that understanding of themselves. Barry could not have used the word *trans* to describe himself—it was first used in this context in 1974—but his story has many elements that transgender people today might find familiar. As historian David Obermayer observed, "My experiences allow me to see a kinship with Barry's identity and his struggle, particularly at the end of his life, to make sure that identity was respected."

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Yet most historical accounts still refer to Barry as female, placing him in a category much beloved in the popular imagination: that of the woman who dresses as a man to chase fortune or love. It's a very old, sometimes apocryphal, tradition that includes 6th-century Chinese legend (and modern-day Disney hero) Mulan as well as the protagonists of "Sweet Polly Oliver" and other broadside ballads from 16th- to 19th-century Britain. In these traditional songs and their modern interpretations, women dress as men to join their true loves at sea or on the battlefield. Historians, such as Peter Boag and Catherine Baker, have pointed out that, in reality, women who cross-dressed probably had more practical reasons for doing so. For example, a woman might have dressed as a man in the 19th-century American West to travel safely, or in 17th-century England to support her family after her husband's death.

Eighteenth-century botanist Jeanne Baret combined these romantic and pragmatic motivations. In the 1760s, her lover and fellow botanist, Philibert de Commerson, was given a job as a plant collector on a scientific sailing expedition. The pair quickly decided that Baret should join him as his "assistant," a move that would allow them to stay together and give Baret an opportunity to pursue her scientific passion. She bound her chest in linen, donned breeches, and joined the ship's crew as a man named Jean. Over the next two years she circumnavigated the globe in disguise, collecting botanical samples all the while. Most notably, she was the first European to discover the bright pink bougainvillea in Brazil, which she named after the captain of the ship, Louis Antoine de Bougainville. The ruse was eventually discovered, though, and the couple were left in the French colony of Mauritius, where they married. Baret went back to living as a woman for the rest of her life.

Like Baret, many of those assigned female at birth who later dressed as men did so for a short time only. They returned to their lives as women when they could support themselves again, were no longer in physical danger, or could be reunited with their loved ones. In these instances, historians usually lack a clear

Portrait of James Barry, artist and date unknown.

basis for judging how a person might have self-identified. Some of these "cross-dressers" may have, in fact, been trans in the contemporary sense, even if they did not spend the majority of their lives living as men. Others may have unquestionably identified as women, seeing their cross-dressing as merely a short-term solution to a serious problem.

Presented with only the vague sketch of a person's life and no record of their thoughts or emotions, diligent historians grapple with which pronouns and gender categories to bestow on people who can't be asked how they identified. "I tried to choose terms that conformed to what I reasoned the person I was writing about would have wanted," writes Boag in his exploration of cross-dressing in the American West. Boag ultimately found that he had to do "what all historians do at some point or another, taking a leap of faith and hoping the evidence is there to support one's landing."

In sharp contrast, though, Barry's story presents no such ambiguity. The very last mention of Margaret Bulkley in the historical record appears in a letter Barry wrote to the Bulkley family solicitor shortly after settling in Edinburgh; though the letter was signed James Barry, the solicitor wrote "Miss Bulkley" on the envelope, as if reminding himself that Barry and Bulkley were the same person. Barry never returned to his previous name and never presented as a woman again, living both publicly and privately as a man, signing his letters as a gentleman, and using male pronouns to describe himself. In his medical school thesis he tellingly wrote, "Do not consider whether what I say is a young man speaking, but whether my discussion with you is that of a man of understanding."

Yet many historians, including multiple biographers, still assert that Barry was a woman who tricked everyone. This emphasis on the gender Barry was assigned at birth and fascination with his so-called subterfuge parallel the ways trans people are often discussed outside of history books. The idea that a trans person isn't really who they say they are is built into a lot of anti-trans rhetoric, both subtly and unsubtly. It shows up in popular film representations, where trans women are still depicted as unstable murderers, men in dresses, or as a shocking punchline. When people advocate for so-called bathroom bills that would force trans people to use the restroom that matches the gender they were assigned at birth, or when organizations argue that trans men suffer from "internalized misogyny," they are essentially claiming that trans people are lying about who they are.

This perspective on trans identity isn't just offensive—it literally gets people killed. Cisgender men who have attacked and killed trans people will often claim that they were provoked into doing so by the realization that the victim, usually a trans woman of color, was "lying" about their gender. While such murderous acts may make a historian's speculation seem of little consequence, both stem from a fundamental rejection of a trans person's clearly stated identity. Whether the response is a criminal act, a cruel joke, or—in the case of so many historians who have written about Barry—a condescending dismissal, these claims of subterfuge and trickery show an unwillingness to imagine trans people as *people* and fully worthy of respect.

For his entire adult life, James Barry gave no indication that he was anything other than a man. Let's take him at his word. D

Rebecca Ortenberg was the social media editor at the Science History Institute.

ESCAPE FROM NAZI TERROR


Herr ~~Frau~~ ~~Fräulein~~ Dr. Bredig

erhält die Erlaubnis, nach Ablegung der Prüfung ein Kraftfahrzeug mit Antrieb durch Verbrennungsmaschinen ~~Elektromotoren~~ ~~Dampfmaschinen~~

der Klasse 1 zu führen.

Berlin, den 20. Jan. 1937

Der Polizeipräsident

Nach bestandener Prüfung ausgehändigt.

Berlin, den 27. Jan. 1937.

Der amtlich anerkannte Sachverständige:

Liste Nr. 155/37. 0092

Gebührenfrei — 2,50 RM.

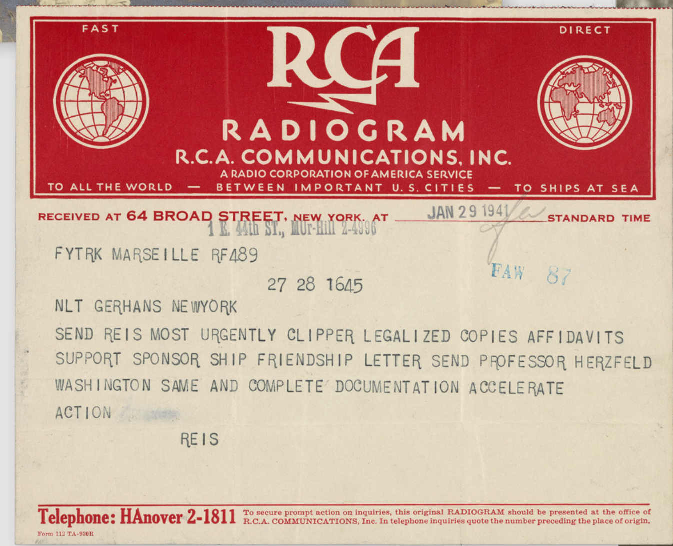
Geb.-Buch Nr. 950

Eigenhändige Namensunterschrift des Inhabers:

Dr. M. A. Bredig

BY
PATRICK H.
SHEA

CHEMIST **MAX BREDIG**'S RACE TO SAVE FAMILY AND FRIENDS FROM CATASTROPHE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R.C.A. COMMUNICATIONS, INC.

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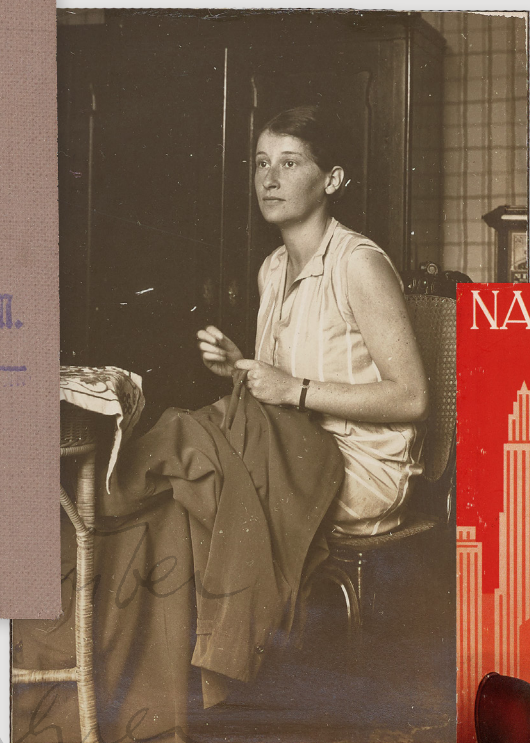

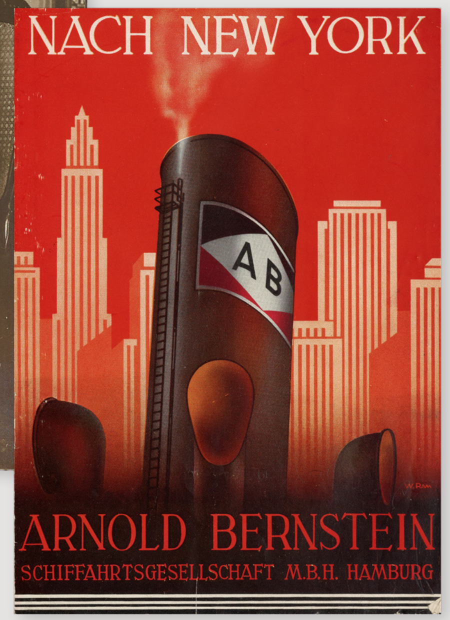

Praise from Fritz Haber was high praise indeed. So people listened when the man who won a Nobel Prize for turning air into fertilizer wrote, "Max Albert Bredig rates among the most intelligent and best-trained young colleagues I have met. Not easily will anyone be found who surpasses him in industry and thoroughness, good will and professional interest."

The 24-year-old's path into the German chemical industry seemed already paved, following that of his father, Georg Bredig, a well-known professor and scholar of physical chemistry who himself had trained under some of Europe's greatest chemists. Georg provided Max with the foundational knowledge to be an outstanding physical chemist, but it was in Berlin, under the tutelage of Haber, that Max engaged with the world's most renowned scientists, including Albert Einstein, Max Planck, Erwin Schrödinger, and Eugene Wigner. In late-1920s Germany, Max's future seemed bright indeed.

Max Bredig was born in 1902 and raised alongside his younger sister, Marianne, in Karlsruhe, where his father served as the director of the Institute of Physical Chemistry at the Technical University of Karlsruhe. Showing an early aptitude for physical chemistry, Max began his training under his father at the university. Georg went out of his way to avoid any appearance of nepotism as his son's instructor, even refusing him an assistantship despite his qualifications. Max earned the equivalent of a master's degree in 1925 from Karlsruhe and received his doctorate in 1926 under the direction of Haber, a friend and colleague of his father's, at the Kaiser Wilhelm Institute in Berlin.

The physical chemistry department at the University of Heidelberg, 1906.

Armed with Haber's recommendation, Max obtained employment as a research chemist at the Bavarian Nitrogen Works. These were halcyon days for Max, who oversaw the company's X-ray and optical division and spent his free time sailing, hiking, and playing the piano. But Max's good fortune began to turn once the National Socialists seized power in 1933. He, like all Germans of Jewish heritage, increasingly became the target of antisemitic attacks. In the short term, Max's position at the Bavarian Nitrogen Works was secure, but others close to him were hurt, including his father, who was forced into an early retirement after the Nazi government banned Jews from teaching at German universities.

Each day seemed to bring a new indignity, as the Nazi regime continued to strip away rights from German Jews until only their citizenship remained. Then the Nuremberg Laws of 1935 took that away.

At the Bavarian Nitrogen Works, Max's colleagues warned him that the firm would soon be aryanized and that he would lose his job. Max took the warnings seriously and prepared to flee Germany. He asked his father to join him in emigrating, but Georg refused, still hoping for a return to the Germany he had loved. Nonetheless, he encouraged his son to leave.

Max fled in 1937, travelling first to Sweden, and then to England, before finally arriving at the University of Michigan's Department of Chemical and Metallurgical Engineering, where he had been offered a fellowship. Having landed safely, his thoughts now turned to those left behind. He corresponded frequently with his father and sister and encouraged them to leave Germany and join him in the United States. Both Georg and Marianne were reluctant to leave. Marianne had just married and was raising three stepchildren. She was also unwilling to leave her father behind. "My biggest worry these days is dad," she wrote Max. "Although he is healthy, he is very sad, and of a sadness that is difficult to cure. . . . I do not want to separate from him."

But then came *Kristallnacht*, a pogrom that hit the city of Karlsruhe particularly hard. Georg, his son-in-law Viktor Homburger, and about 500 other Jews in the city were arrested, beaten, and publicly humiliated. Viktor's family bank was ransacked and later confiscated by the state. Although Georg was released the following day, Viktor was sent to the recently opened Dachau concentration camp, where he was imprisoned for six weeks and released only after proving his intention to emigrate.

After Kristallnacht, it was no longer a question of whether to leave Germany, only how to leave. Viktor and his family were in line to get American visas, but with so many people trying to immigrate, it would be years before their turn came. Certain that conditions in Germany would worsen, Marianne insisted her three stepsons be sent out of Germany as quickly as possible. Peter, Wolfgang, and Walter, ages 10, 12, and 14, respectively, travelled to England as part of the *Kindertransport*, in which 10,000 Jewish children were taken in by families across the United Kingdom.

The events of Kristallnacht also convinced Georg to leave Germany. He made it to the Netherlands in 1939, but it was then up to Max to get him across the Atlantic. Max set out to secure his father a teaching position at an American university—only with that in hand could Georg obtain a coveted visa. Princeton University responded with a pro forma position of research associate, with a salary that was to be funded entirely by Max. Georg, thrilled and relieved to receive the appointment, replied to Princeton's president with a short and succinct telegram: "Highly honored. Accept. Coming as soon as possible." He arrived in the United States just months later.

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Bredig family photograph, ca. 1910. *From left to right, back row,* Georg Bredig, a relative identified as Frau Dombrowsky, Rosa Bredig. *Front row,* Max and Marianne Bredig.

Max also labored to bring Marianne and Viktor to the United States, although this task proved far more challenging. In October 1940, the couple, along with 11,000 other Jews from the Baden region of Germany, were forcibly deported to Vichy France. They were brought by train to Lyon, and then sent to the Gurs internment camp, built years earlier for refugees of the Spanish Civil War.

The French running the camp were not nearly as cruel as their Nazi counterparts, but they had no means to help the 11,000 people in desperate need of food, water, and clothing. At first the camp was only loosely a prison—individuals were permitted to leave for the day to obtain food and other essentials. Marianne used this time to visit Viktor, who was kept in a separate camp for men, and to send letters to Max, who was working to secure immigration visas.

The archives at the Science History Institute hold many letters written by Marianne while she was interned at Gurs. "As long as the sun shines, it is bearable here," one early letter reads. "If it rains and gets cold, it is quite terrible. What people here are suffering cannot be expressed. The poverty is unbelievably huge." She continued,

> We could relieve a lot of the suffering of the people of Gurs if we could organize a sponsorship for people who receive no outside help. This kind of help is not just a question of money but more of taking on the responsibility. It is a question of empathy, of participating in the suffering of your fellow humans in the battle against apathy of the heart. We know of what many do for their relatives that are left behind. In addition, thousands should help unknown thousands.

Max was able to arrange shipments of food and clothing to the camp. He wired cash payments to a contact in Portugal, who would in turn send shipments of nonrationed dry goods to Gurs. Money was also sent to bribe local officials and anyone else who could assist in securing Marianne and Viktor's release.

Eventually Max did secure the visas, transit permits, and transport necessary to rescue his sister and brother-in-law from the camp. In a letter announcing his success, Viktor wrote,

> I cannot find words to express my gratitude for all you have done for us these last 7 months. Without your generous help dear Max, we would have never been able to escape the big misery in which we found ourselves. Our situation has often been very desperate, and the indescribably generous and huge help that you have given us has helped us to survive this most difficult time in our lives.

Viktor and Marianne were among the lucky ones. Of the 11,000 Jews evacuated from Baden and sent to Gurs, only about 1,000 were released. Approximately 1,000 others would die in their first winter; most of the remaining 9,000 were sent to extermination camps in Poland and never heard from again.

With his family safe, Max pressed on, working to get Jewish colleagues out of Europe. He had several successes, such as chemists Alfred Reis and Fritz Hochwald, but despite his best efforts, Max could not save everyone.

In 1938 Max's former colleague Alfred Schnell married Eva Jolowicz, a primary school teacher from Homburg. The two then fled Nazi Germany to escape the persecution of Jews and took up residency in The Hague. When Germany invaded the Netherlands, life again became increasingly difficult. In 1943 they were ordered to report to a Nazi transit camp, but instead they went into hiding.

Their search for a suitable hiding place brought them to Otto Veening, a pastor and member of the Dutch resistance movement. Veening had created a network of hiding places in the countryside for Jews and young Dutch men who wished to avoid slave labor in German factories. With his assistance, Alfred and Eva were placed on a farm in Oldebroek, about 40 miles east of Amsterdam, with a widow named Hendrikje Blaauw-Flier.

While in hiding they sent short messages to Max through the Red Cross. Often writing in code and using aliases to protect their identities, these letters were their only lifeline to the outside world.

In autumn 1944 Max lost contact with the Schnells. According to eyewitness accounts, the Schnells were arrested by the Germans during a raid of the surrounding area. The couple were found in their hideout under a haystack and taken to a nearby town for interrogation. They were to be kept overnight and transported the following morning to Poland. But that night a pair of Dutch Nazis took Eva and Alfred from their cells, along with four other prisoners. They were taken to a park and told to dig six holes. When Eva protested, she was shot. The rest were murdered immediately after.

Max learned of the Schnells' fate from a letter he received just after the war. Wim Wesseldy, who had been in hiding on a farm in the same area, gives a detailed description of the Schnells' last 18 months and tells of the friendship he forged with the couple. The following is a small portion of that letter.

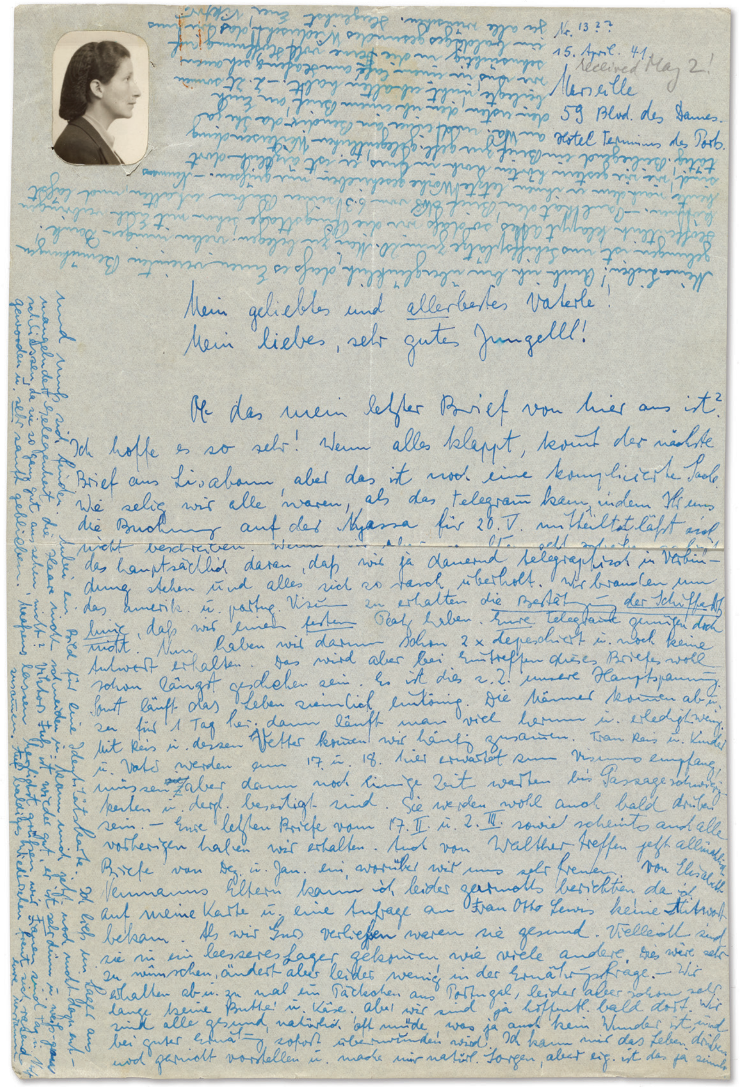
> I am a 24-year-old student in Theology at the Univ. of Utrecht. On the 5th of May 1943 the Germans ordered all Dutch male students who had refused to sign a declaration of loyalty to the Nazi regime, to go to Germany for slave labor. Out of 16,000 students, 11,000 did not go, but hid themselves (or dived as we called it).

He describes how he came to meet Alfred and Eva and writes about their living conditions:

> They had an underground hiding space under a haystack at the back of the barn. They slept in it every night. It was about 2 meters long and 2 meters wide and about 1½ meters high. The floor and walls were thickly covered with straw, while two cleverly camouflaged stove pipes were used for ventilation. Eva and Fred called it their castle and were very happy with this room of their own.

He continued:

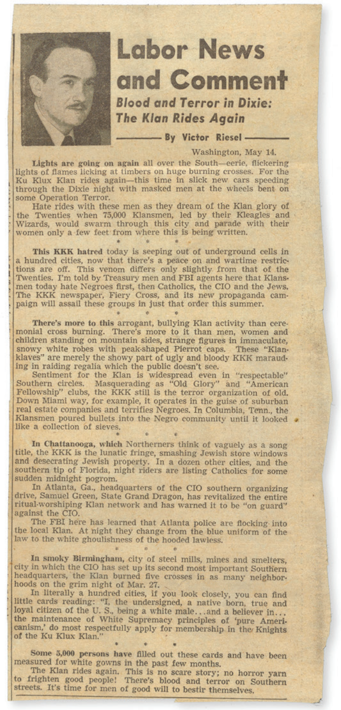
> It was always a pleasure to visit them, for their happiness with one another radiated and caused a sphere of joy around them. They could [cast] a glance at one another in a way which made you feel something of the perfect unity in which they lived together. A unity which made all words superfluous. Their greatest fear was that they should ever be separated. It has not happened.



A letter from Marianne Homburger, written after her release from Gurs internment camp, April 1941.

> Eventually, I came to spend nearly every evening with them and we became very good friends. They helped me a great deal with their friendship at a time when I had many difficulties. Often, we imagined how we should visit one another and stay with each other when peace and normal life, for which they were longing so much, should have returned. Our dreams will never come true.
>
> Frequently, I am likely to ask, why they had to die, who so rightly deserved to have lived to see better times. I do not know the answer. The only thing I know, from experience, is that God loves me even when he seems to be chastising me. Rest assured that Eva and Fred will live forever in my memory. I am grateful that I have known them.

In 2001 a monument was unveiled honoring the six people murdered on the evening of October 3, 1944. A nearby primary school has adopted the monument, which is located in the park where the six were murdered. Students take care of the monument's upkeep and take part in a memorial ceremony each year.



Labor News and Comment
Blood and Terror in Dixie: The Klan Rides Again

By Victor Riesel

Washington, May 14.

Lights are going on again all over the South—eerie, flickering lights of flames licking at timbers on huge burning crosses. For the Ku Klux Klan rides again—this time in slick new cars speeding through the Dixie night with masked men at the wheels bent on some Operation Terror.

Hate rides with these men as they dream of the Klan glory of the Twenties when 75,000 Klansmen, led by their Kleagles and Wizards, would swarm through this city and parade with their women only a few feet from where this is being written.

* * *

This KKK hatred today is seeping out of underground cells in a hundred cities, now that there's a peace on and wartime restrictions are off. This venom differs only slightly from that of the Twenties. I'm told by Treasury men and FBI agents here that Klansmen today hate Negroes first, then Catholics, the CIO and the Jews. The KKK newspaper, Fiery Cross, and its new propaganda campaign will assail these groups in just that order this summer.

* * *

There's more to this arrogant, bullying Klan activity than ceremonial cross burning. There's more to it than men, women and children standing on mountain sides, strange figures in immaculate, snowy white robes with peak-shaped Pierrot caps. These "Klan-klaves" are merely the showy part of ugly and bloody KKK marauding in raiding regalia which the public doesn't see.

Sentiment for the Klan is widespread even in "respectable" Southern circles. Masquerading as "Old Glory" and "American Fellowship" clubs, the KKK still is the terror organization of old. Down Miami way, for example, it operates in the guise of suburban real estate companies and terrifies Negroes. In Columbia, Tenn., the Klansmen poured bullets into the Negro community until it looked like a collection of sieves.

* * *

In Chattanooga, which Northerners think of vaguely as a song title, the KKK is the lunatic fringe, smashing Jewish store windows and desecrating Jewish property. In a dozen other cities, and the southern tip of Florida, night riders are listing Catholics for some sudden midnight pogrom.

In Atlanta, Ga., headquarters of the CIO southern organizing drive, Samuel Green, State Grand Dragon, has revitalized the entire ritual-worshiping Klan network and has warned it to be "on guard" against the CIO.

The FBI here has learned that Atlanta police are flocking into the local Klan. At night they change from the blue uniform of the law to the white ghoulishness of the hooded lawless.

* * *

In smoky Birmingham, city of steel mills, mines and smelters, city in which the CIO has set up its second most important Southern headquarters, the Klan burned five crosses in as many neighborhoods on the grim night of Mar. 27.

In literally a hundred cities, if you look closely, you can find little cards reading: "I, the undersigned, a native born, true and loyal citizen of the U. S., being a white male... and a believer in... the maintenance of White Supremacy principles of 'pure Americanism,' do most respectfully apply for membership in the Knights of the Ku Klux Klan."

* * *

Some 5,000 persons have filled out these cards and have been measured for white gowns in the past few months.

The Klan rides again. This is no scare story; no horror yarn to frighten good people! There's blood and terror on Southern streets. It's time for men of good will to bestir themselves.

LEFT Souvenir postcard of Wilson Dam, Bredig's potential workplace in Alabama. **RIGHT** Newspaper clipping of columnist Victor Riesel's warning of growing Ku Klux Klan violence in the South, May 14, 1946.

Such losses affected Max deeply. After the war he made a point of identifying former colleagues sympathetic to the Nazi regime. Of Wolfgang Ostwald—the son of his father's mentor—he wrote,

> At no moment in history has it been more important for us to be able to discern wisely merit and guilt. There were and still are scientists, even in Germany, who, though unable to leave their country or to protest effectively the crimes of their Nazi masters, silently kept their faith in a final restoration of human dignity. Wolfgang Ostwald unfortunately was not one of them.

Max would go on to scorn invitations from German universities and scientific societies that sought to welcome back German Jewish scientists after the war.

He also leveled a disdainful eye on the injustices in his adoptive country. In 1946 Bredig was offered a job with the Tennessee Valley Authority (TVA) in Florence, Alabama. He was wary. After meeting Bertha Klenova, a fellow European immigrant employed by the TVA, he wrote to her with questions about the cultural climate in Alabama and about antisemitism within the TVA and surrounding area. Klenova's response was withering:

> Very poor. You have to carry your torch within you. You fare best when you discuss your work and . . . the weather. You have never heard of a Negro problem. You do not see things that are not pleasant.

Accompanying the letter was a newspaper clipping headlined, "Blood and Terror in Dixie: The Klan Rides Again." The story describes, among other things, how the KKK smashed the windows of a Jewish store and desecrated Jewish property. It's little surprise Max declined the TVA's offer.

Max and his wife, Lydia, who he married in 1944, had one son, George. In 1946 Max was hired by Eugene Wigner, an old Berlin colleague who had become the director of research and development at Oak Ridge National Laboratory. Max worked at Oak Ridge until his retirement in 1967 but stayed on as a consultant until his death, on November 21, 1977.

Today Max is remembered as a first-rate scientist. He published approximately 100 scientific papers and is probably best known in the field for his work on the interaction of molten metallic halides with their metals. The mineral bredigite, $Ca_7Mg(SiO_4)_4$, was named in his honor for the work he did studying it. To this day, the Max Bredig Award is given out by the Electrochemical Society.

Still, few people know about the work Max undertook during the war. He rarely spoke of the hardships he and his family endured during the Nazi regime or his efforts to save family, friends, and strangers. Whether it was an unwillingness to relive painful memories or just personal modesty, even some members of his family never knew of Max's wartime activities until after his death, when the contents of his archive surfaced. We now know that Max made the lives of others his personal responsibility and did so with no thought of praise or thanks but merely because it was the right thing to do. D

Patrick H. Shea is chief curator of archives and manuscripts at the Institute.

THE MURKY ETHICS OF WASTEWATER SURVEILLANCE

By monitoring sewage, scientists can track disease outbreaks in near real time. But will the technology leave long-term privacy risks in its wake?

By Meir Rinde

William Heath's *Monster Soup Commonly Called Thames Water, Being a Correct Representation of That Precious Stuff Doled Out to Us*, ca. 1828.

PHILADELPHIA MUSEUM OF ART

In October 2020, during some of the worst days of the COVID-19 pandemic, colleges across the country were scrambling to keep their students healthy and their doors open. At Colorado College, a liberal arts school in Colorado Springs, math professor Andrea Bruder did her part by slipping on a biohazard suit and crawling through a tunnel below a freshman dorm.

Squatting in the dark, cramped space, Bruder held a plastic ladle and a to-go coffee cup near an open sewer pipe, waiting for someone to flush.

"You just pray that someone goes to the bathroom?" asked an NPR reporter who accompanied her into the tunnel.

"I just wait and listen for somebody to flush, yeah," Bruder responded with a slight laugh. After 20 minutes, they heard a toilet's soft roar echo down the pipe.

"It was a very good flush, and now it takes a little while to get there," she said. "And here's some TP," she added, noting fragments of toilet paper as the sample trickled out.

The collected liquid was taken to a lab, where testing showed it did not contain traces of the coronavirus. But similar operations at other schools found evidence of infection. At the University of Arizona, a positive wastewater result in August 2020 led the school to test all 311 residents of a dormitory. Officials found two asymptomatic, infected students, who were quickly quarantined.

Testing wastewater is less expensive and invasive than swabbing thousands of students' noses and analyzing all those samples individually. It can also be done almost continuously. As of late 2020 at least five dozen colleges had set up sewage-testing programs.

Hundreds of local governments and sewer authorities also embraced testing, and the Centers for Disease Control created a National Wastewater Surveillance System to collect and publish data on COVID-19 levels across the country. The agency is now planning to expand the program to monitor influenza, respiratory syncytial virus, foodborne illnesses, monkeypox, and the infectious fungus *Candida auris*.

"We've launched a new revolution in the way that we monitor infectious diseases," Emory University microbiologist Marlene Wolfe told the Association of American Medical Colleges. Wolfe helped design an early COVID-19 wastewater testing program in the San Francisco Bay Area.

Sewage surveillance has seen unprecedented growth in a very short period. The field is undergoing a rapid transformation from a "fringe science," in the words of one researcher, to a mainstay of public health and a multibillion-dollar industry.

Yet it hardly came out of nowhere. Wastewater-based epidemiology, or WBE, has a long history that has repeatedly demonstrated the technology's usefulness, as well as its potential perils. From early on, scientists have understood the simultaneous benefits and harms that could follow from tracing disease organisms in wastewater back to asymptomatic carriers. Its history is dotted with examples.

Christopher Reimer, a graduate student at the University of British Columbia who studies the history of WBE, unearthed a 1959 typhoid investigation in British Columbia that tracked the bacteria to open roadside drains, and eventually a 59-year-old woman.

While the work helped stem the spread of a killer disease, her life was practically ruined. She was barred from her food-handling work, apparently badgered into having her gall bladder removed, and publicly

Collecting a wastewater sample from a dorm's sewer line at the University of Arizona, August 2020.

CHENEY ORR/BLOOMBERG VIA GETTY IMAGES

embarrassed. The researchers who tracked her down noted "the devastating effect on the carrier of the publicity which her state evokes . . . From being a quiet and respected citizen she becomes a social pariah."

As WBE expands and scientists develop increasingly sophisticated analytical methods, concerns have only intensified about potential infringements on the privacy and autonomy of people whose waste is being surveilled.

Scientists have used wastewater data to track patterns of drug use, to see how much coffee and alcohol a neighborhood's residents drink, and to show the variety of ethnic ancestries in a city by analyzing DNA. In Australia, law enforcement agencies examine sewage to see whether crackdowns on fentanyl and methamphetamine trafficking have affected consumption rates. In the Chinese city of Zhongshan, police reportedly used wastewater analysis to hunt down and arrest a manufacturer of illegal drugs.

WBE is virtually unregulated, leaving it unclear what rights people have over their sewage and how others use it. Could landlords evict tenants whose sewer lines test positive for illicit drugs? Could companies coerce workers identified as drug users to rat out their colleagues?

Wastewater analysis is a powerful tool for protecting public health. But a vocal group of scientists, legal analysts, and privacy experts warn against allowing it to quietly become ubiquitous without sufficient oversight, much as other surveillance technologies, such as facial recognition and Internet tracking, have done or threaten to do. They say it is critical that governments establish guidelines on avoiding unnecessary harms, ensuring appropriate use of data, and consulting with affected communities.

"The thing that's quite scary to us about wastewater surveillance is that, because it's kind of icky, there's stigma and taboo, and it's not talked about a lot," said geographer Mohammed Rafi Arefin, a member of the Biosecurities and Urban Governance Research Collective, along with Reimer and others.

Arefin predicts that, without reforms, "we'll see a slow creep of the technology into our everyday lives and into how we are governed. You won't really know what's gone wrong until it's pretty established as a normal, regularized tool of public health."

AN INADVERTENT DISCOVERY

Sewage systems are key public health tools and as such have been deeply intertwined with scientists' efforts to understand infectious disease. In the mid-19th century, Robert Koch, Louis Pasteur, and others began identifying specific microorganisms that cause diseases such as cholera and anthrax. Sewer engineers soon took notice.

The Lawrence Experiment Station north of Boston was established in 1887 to improve nascent sewage treatment technologies. There biologist Edwin Jordan cultured water samples on beef-jelly, bouillon, boiled potato, and milk to find bacterial indicators of water quality.

"If certain species are found to be characteristic of sewage, and are never found in uncontaminated sources, then the presence of these typical 'sewage-bacteria' in any given water supply will indicate undoubted pollution," he wrote. Some of the bacteria he identified had never been described before.

Typhoid researchers were among the first to try to use wastewater analysis to stop epidemics. Typhoid fever ravaged Great Britain through the 19th century, killing thousands every year. By the 1920s sanitation improvements had reduced annual deaths to hundreds. But the disease persisted, and scientists struggled to determine why.

Perhaps, they wondered, people who had experienced mild or asymptomatic infections were serving as unwitting long-term carriers of the Salmonella bacteria that cause the illness.

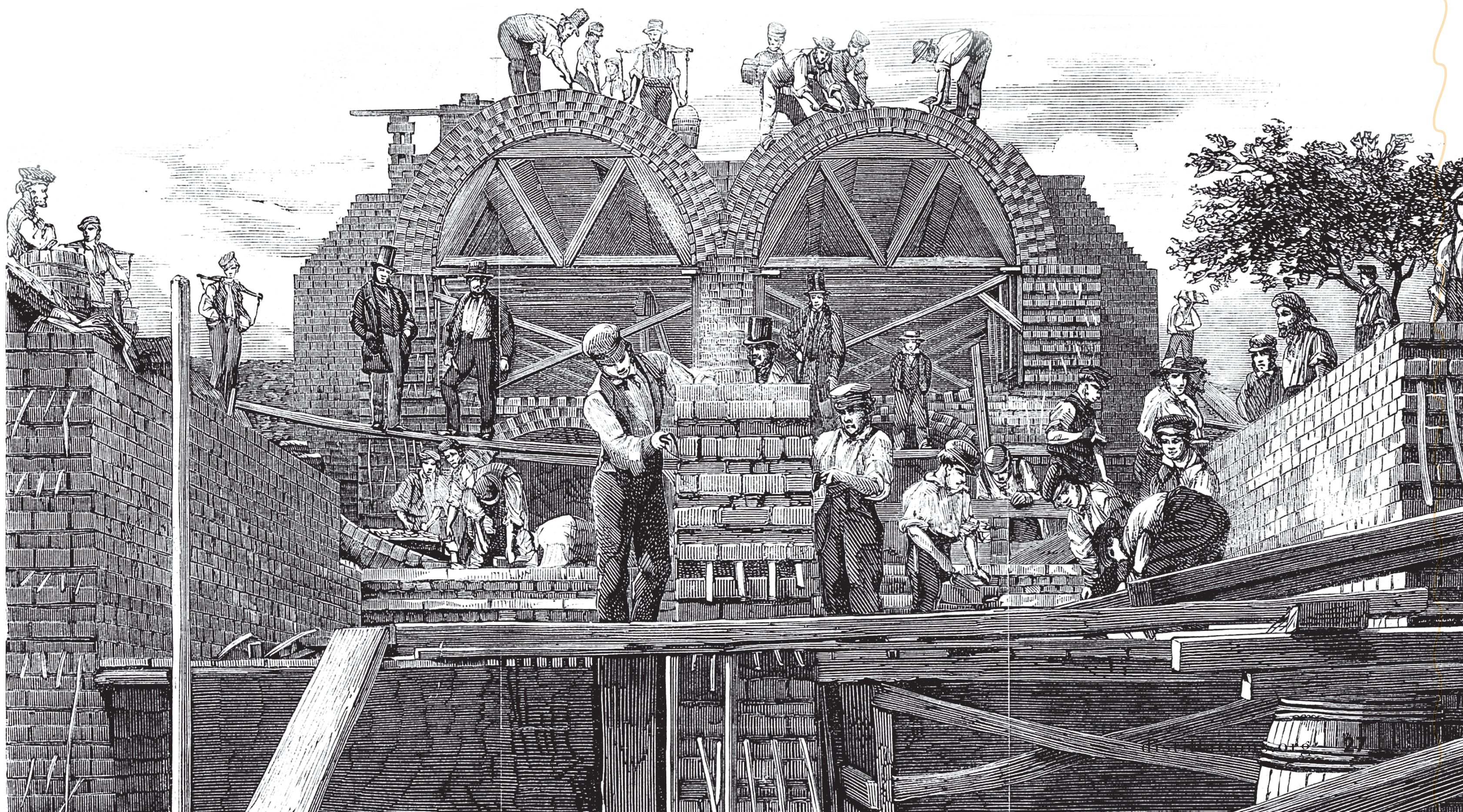
But confirming infections in apparently healthy people was a painstaking process. Investigators had to trace each person's potential disease contacts, and repeatedly collect and analyze the subject's urine and feces. Despite the effort, studies turned up very few hidden carriers.

Edinburgh University bacteriologists R. S. Begbie and H. J. Gibson decided to try something new—a quicker, less invasive, and, perhaps, less icky approach. Taking up recently invented methods of capturing and identifying bacteria, they tested wastewater for Salmonella in multiple sewer lines with the goal of identifying neighborhoods whose denizens were unknowingly excreting the pathogen. They pulled 58 samples from Edinburgh's main sewers, incubated them, dyed them, and induced various biochemical reactions to identify bacterial strains.

Their experiment didn't really succeed; it turned out chronic disease carriers weren't producing the "massive discharge" of bacilli needed to detect typhoid. The scientists concluded they had only found Salmonella from people who were actively symptomatic or recently recovered.

But Begbie and Gibson's study revealed something unexpected—they inadvertently found evidence of socioeconomic disparities in the neighborhoods studied. Residents of a "congested tenement area" produced far more bacteria than people living in a "residential suburban area of modern construction," they observed in a 1930 paper. "In an upper-class residential district the habits of the people are such that spread from such foci does not arise."

A sewer improvement project in east London, 1859, from the *Illustrated London News*, after a photograph by F. Thompson.



WELLCOME COLLECTION

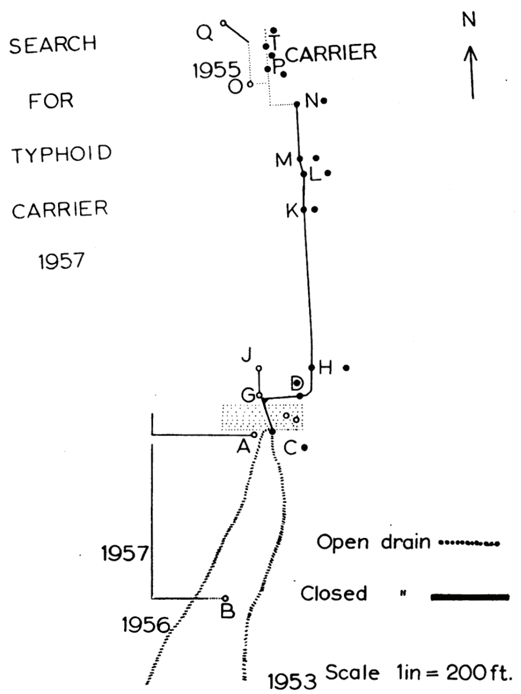


Fig. 1.—Map of residential area (streets not shown). Key: Homes of patients indicated by date of occurrence, e.g. 1953. School area stippled with ravine to south. Sampling points indicated by letters adjoining a black dot if *S. typhi* isolated and an open circle if negative.

Fig. 2.—Open ditch adjoining home of carrier near sampling point P in dry weather.

Figures from "Typhoid Fever: Where There's a Case, There's a Carrier," *Canadian Medical Association Journal*, February 1959.

NATIONAL LIBRARY OF MEDICINE

Like many future wastewater researchers, the bacteriologists showed no concern for the social ramifications of culling human data from sewage.

One of the few scientists to note the ethical challenges associated with WBE from early on was Brendan Moore, a public health official in southwest England who invented the "Moore swab," a method for collecting sewer bacteria that remains in use to this day.

In the 1940s he tried his invention in a small seaside resort town that had seen a series of infections from paratyphoid, another disease caused by Salmonella. The bacteria was isolated and eventually traced back to the house of an ice cream van driver. The man's wife turned out to be a chronic carrier who had both contaminated the ice cream and directly infected other people.

Moore then took his method to a larger town, where he discovered previously unsuspected infections in several households. Yet despite its obvious usefulness, he cautioned against using his new technique to identify or contact infected people unless it was truly necessary.

"Experience showed . . . that except in the presence of an outbreak, it was probably unwise to pursue infection back to the individual carrier," Moore wrote in 1948. As he noted elsewhere, "We are left with the problem of whether the methods are of any value, and, if so, when they should be applied. These are matters for discussion and experience."

Moore's concerns were unusual and remained of little interest to most scientists, who perhaps were more focused on simply understanding whether wastewater had any role in spreading other diseases. Clarifying that question was no small task.

Polio outbreaks had struck Philadelphia, New Haven, Charleston, and other American cities in the 1930s. Frustrated local health officials called in epidemiologists to look for evidence the virus was being transmitted through sewage. But the task was slow and even more onerous than isolating typhoid.

The work required a large supply of monkeys, which were both scarce and costly at $6 to $8 apiece. Researchers would inject the animals with samples of wastewater, wait a few weeks for them to get sick, then remove their brains and spinal cords to examine the tissue under a microscope for telltale lesions.

Polio, the scientists determined, was not spreading through wastewater. But they did find that viral loads in sewage correlated with known infections: more infected people equaled more virus in sewer water. Because 99% of polio cases show few or no symptoms, health officials recognized that wastewater monitoring could give them a jump on outbreaks and help them respond before many people fell ill—particularly if they could speed up the process of detection. In the decades that followed, advances in cell culture methods allowed researchers to detect viruses in samples more quickly, without waiting weeks for monkeys to get sick.

In the 1980s wastewater-based epidemiology and biological research generally were revolutionized with the arrival of polymerase chain reaction (PCR) analysis of DNA, which allowed near real-time monitoring of polio and other diseases. Sewage surveillance has been a lifesaver in the years since. In 2013 and 2014 Israel detected a "silent" polio outbreak and launched a vaccination campaign before anyone suffered paralysis. In 2022 New York State began tracking polio in sewage water as it fought a scattering of infections in several counties around New York City.

FUNCTION CREEP

While wastewater analysis was gradually perfected, essentially no thought was given to legal or ethical frameworks for its use.

Christopher Reimer, the University of British Columbia researcher, reviewed sewage studies from the 1950s to 1970s and found only brief allusions to ethical concerns. At most, researchers offered brief comments, as in the 1959 typhoid investigation, focusing only on the privacy of individuals identified as disease carriers. He found that they mostly eschewed discussion of broader societal impacts.

"I saw a discomfort from the scientists, like, 'Oh, there's probably some things we should be cautious about in doing this work.' It's usually two sentences, maybe a paragraph," Reimer said in an interview. "'We did this cool stuff, maybe we should think about it,' and then moving forward like nothing happened."

Yet research by Reimer, Arefin, and their colleague Carolyn Prouse has turned up more instances where targeted wastewater analysis has been used in ethically dubious and potentially troubling ways.

In 1962, for example, a Yale epidemiologist tested the sewage of incarcerated teenage girls in Middletown, Connecticut, without their knowledge and consent, to observe how a polio vaccination campaign affected the viral population in the sewers.

"Who would have been advocating for them or concerned about data justice, and the maybe unethical sampling of biological information? Not many people," Arefin said.

In 1973 the South African government and gold mining companies set up a cholera surveillance system to ensure the stability of their pool of cheap immigrant laborers; the program's health officers monitored sewage from the workers' barracks and subjected some new recruits to invasive rectal swabs.

"The people who were doing this testing were the same people who were giving them housing, who were giving them transport, who were giving them everything," Reimer said. In the context of the camp's stark power imbalances, subjecting the workers to treatment based on WBE was ethically questionable, he said.

Arefin described wastewater surveillance as a "roaming technology." Historically it pops up suddenly when needed and then disappears again, rather than becoming an established practice with built-up norms and controls. With WBE on an unprecedented upswing, now is the time to properly investigate and regulate the field, he said.

"When these kinds of technologies get rolled out in crises, as a quick fix to a problem, they often go with little public debate or ethical oversight," he said. "If these technologies prove successful, they most likely will stay with us throughout the future and expand their scope and analysis."

Arefin noted that wastewater surveillance sometimes includes "near-source" sample collection that can narrowly point to the location of a disease carrier. That could be a sewer pipe from a single building as opposed to a main sewer or sewage treatment plant. But because WBE studies do not involve medical treatment of patients and their findings are not considered traceable back to individuals, they do not trigger standard biomedical ethics reviews that examine the potential benefits and harms of the work and can require changes to study protocols.

Formal concerns about ethics and privacy of WBE only began to surface in the early 2000s as the scope of the United States' long War on Drugs expanded into unexpected scientific domains.

In 2001 EPA chief of environmental chemistry Christian Daughton called for "non-intrusive drug monitoring" at sewage treatment facilities to better understand the impact of illicit drugs on plants and animals.

ERNEST COLE FAMILY TRUST/MAGNUM

Workers holding identification papers at a South African mining camp, ca. 1960s. Photograph by Ernest Cole.

Molecular biologist Emanuel Wyler holding a wastewater sample at the Max Delbrück Center for Molecular Medicine in Berlin, August 2022.

BERND VON JUTRCZENKA/PICTURE-ALLIANCE/DPA/AP IMAGES

The EPA tested the program in 2004. Two years later Jennifer Field, an environmental chemist at Oregon State University, launched a "community urinalysis" program that analyzed water from a city's sewage treatment plant and revealed all the illicit drugs its population was ingesting.

But by the time Field's project got going, her stated objective had changed. Rather than environmental protection, she pitched the program as a way to assess the growing problem of methamphetamine use in her state. That got the attention of *Popular Science*, the *New York Times*, and the Office of National Drug Control Policy, as well as civil rights lawyers and academics who study privacy.

"The possible application of community urinalysis techniques to an individual home's wastewater frightens civil libertarians," Christopher Hering wrote in a 2009 law review article, one of the first explorations of potential harms from sewage surveillance.

Hering, a law student at the University of Arizona at the time, reviewed questions such as who legally owns wastewater and whether sample collection should require a search warrant. He argued that a positive drug test of a neighborhood sewer could lead to responses that impact many innocent people, such as invasive door-to-door questioning by police.

Hering concluded that new laws and regulations were needed to govern so-called community urinalysis.

"As wastewater testing proliferates, courts, policymakers, and attorneys will need to grapple with its implications on privacy," he wrote. "If none of these institutions act . . . citizens will be left at the mercy of advancing technology."

A PIVOT TO COVID-19

By the 2010s, more WBE proponents were actively casting about for reasons to set up large-scale sewage surveillance.

Researchers at MIT proposed analyzing sewage to head off epidemics, then spun off a company called Biobot Analytics with the goal of monitoring patterns of opioid abuse. Arizona State University environmental engineer Rolf Halden, a longtime WBE advocate, measured opioid levels in Tempe, got an NIH grant to track flu outbreaks, and launched a project to monitor use of toxic chemicals nationwide.

Officials in Louisville, Kentucky, joined Halden's opioid-tracking program after overdose deaths surged in 2016 and they realized they had underestimated the crisis. "Even our most aggressive estimates fell short of the reality. We needed a new source of data to be able to respond better, and earlier," Grace Simrall, Louisville's chief of civic innovation and technology, told *Scientific American*.

A smattering of scientists and academics started to plumb the legal and ethical implications of widespread surveillance. But then the pandemic hit.

Biobot, Halden's lab, and many other groups rapidly pivoted to COVID-19 detection. WBE proliferated as governments, schools, prisons, hospitals, and businesses scrambled to work around shortages of clinical tests, map the spread of the virus, isolate new variants, and in some cases identify infected people.

In August 2020 the CDC created the National Wastewater Surveillance System. The *Washington Post* counted testing efforts at more than 170 wastewater facilities across 37 states, as well as programs in Singapore, China, Spain, Canada, New Zealand, Britain, and the Netherlands. By late 2022 the number of survey sites had reached more than 3,500 in 70 countries.

The new prominence of wastewater testing brought a surge of interest in potential uses of the technology and accompanying ethical challenges.

Halden co-authored a paper that called for guidelines on respecting the autonomy of research subjects, doing no harm, preventing discrimination, proper use of data, and other basic principles. Engineers, social scientists, and law professors published a stream of articles on similar topics: "The Datafication of Wastewater"; "COVID-19 Sewage Testing as a Police Surveillance Infrastructure"; and "Truth from the sewage: Are we flushing privacy down the drain?"

Some of the more advanced efforts to set rules for wastewater surveillance are underway in Canada, where environmental scientist Steve Hrudey has raised the alarm about highly targeted sewer surveillance. Hrudey heads a Canadian Water Network panel that published ethics guidance for wastewater surveillance for COVID-19 in June 2021.

Workers examine a sewer in a Hong Kong neighborhood after a COVID-19 outbreak in the area, January 2021.

ANTHONY KWAN/GETTY IMAGES

"The ethical issues that should guide environmental scientists and engineers in performing wastewater surveillance for SARS-CoV-2 must address the general goals of considering the common good, equity, respect for persons and good governance," the panel wrote. "There is a need for an open dialogue that will reveal valid concerns for individual interests potentially in conflict with surveillance that is intended to serve the well-being of the population."

Arefin said he's less concerned about isolated instances of surveillance than the potential for various actors to quietly use real-time wastewater data to their financial advantage or to insinuate as-yet-unknown impingements on human rights.

Insurance companies could increase premiums or withhold coverage based on health data extracted from sewage. If a prison measures high levels of illegal drugs, it could conceivably ban family visits in an effort to stop drugs from getting in, harming all the prisoners and depriving them of a basic privilege to see their relatives, he said.

Many of the ethics discussions focus on the tendency for new surveillance and policing technologies to affect marginalized communities the most. Begbie and Gibson's experiment showed how easily socioeconomic disparities can be detected in sewage, and the midcentury studies Arefin and Reimer uncovered repeatedly used WBE data from poor or powerless individuals in troubling ways.

Claire Duvallet, a data scientist at Biobot Analytics, argued in a blog post that data from sewage can be used to measure and protect the health of whole communities, including people whose needs are often overlooked or who do not have access to healthcare. At the same time, she recognized wastewater epidemiology as "a potential tool of oppression." Like Arefin, she raised concerns about health insurers, who could argue that "objective" sewage-based metrics justify higher premiums in less healthy neighborhoods, thus reinforcing existing inequities. Employers could cite low COVID-19 levels in the sewers to justify unsafe return-to-work policies and overrule workers' fears, she said.

"At its best, wastewater epidemiology will provide additional concrete evidence to motivate change and actionable metrics to quantify improvements. At worst, it will be deployed thoughtlessly and in ways that further entrench existing disparities," Duvallet wrote.

She concluded that it is up to WBE technology leaders and entrepreneurs to prevent the worst outcomes from its wider deployment. Yet Arefin and Reimer say the engineers who design and operate wastewater-analysis technology typically have no experience with privacy or data security issues, making it critical to establish systems of transparent, interdisciplinary oversight with community involvement.

"We're not against wastewater surveillance. We just think it needs to be subject to principles like data justice, and real community oversight and input," Arefin said. "Surveillance has immense risks, but also—especially in a public health crisis—some real benefits, and it's about ensuring that calculation is not just left up to scientists and public health officials." D

Meir Rinde is a reporter at WHYY in Philadelphia.

The Rise and Fall of Polywater

What happens when an earth-shattering discovery runs up against the scientifically impossible?

BY AINISSA RAMIREZ

In a backwater Soviet laboratory in the early 1960s, Nikolai Fedyakin toiled away at his research. Fedyakin worked at the technological institute in Kostroma, an old city on the Volga River 200 miles northeast of Moscow. Some would say this bygone hub of the linen industry was charming, others that it was primitive. In many ways this quiet, unadorned corner of the Soviet Union was the perfect setting for the unremarkable research Fedyakin pursued. While other Russian scientists propelled cosmonauts into space, Fedyakin studied water.

Fedyakin was probing an old theory. Back in the 19th century William Thomson, better known today as Lord Kelvin, found that individual water droplets evaporate faster than water in a bowl. Kelvin also noticed water in a glass tube evaporates even more slowly. He surmised that the curvature of the water's surface affected how quickly it evaporated. To test Kelvin's theory Fedyakin carefully placed drops of purified water in containers of different shapes. In one experiment he condensed water vapor in a glass tube the diameter of a human hair, sealed it, and stored it upright. When he examined the contents of the tube a few weeks later, he saw something strange. Under the microscope the column of liquid was divided into two parts, separated like vinegar and oil.

Why would water split into two parts, Fedyakin wondered, and did these parts behave in the same way? After repeating his experiments several times under clean laboratory conditions, Fedyakin managed to create a sample size smaller than the equivalent of a drop of dew. His observations were limited by the resolution of his microscope, but he could see enough to realize the liquid at the bottom of the glass tube was denser than ordinary water. Fedyakin published his results in a Russian scientific journal in hopes that others would also find his water curious. Only one man did.

Boris Deryagin was the internationally renowned director of the Institute of Physical Chemistry in Moscow. A tall man with a perpetually pained expression, he had already reached the most rarefied level of Soviet science and was now seeking a research problem that could thrust him into the orbit of a Nobel Prize. The strange water found by an unknown chemist in a forgotten part of Russia was possibly just the boost he needed.

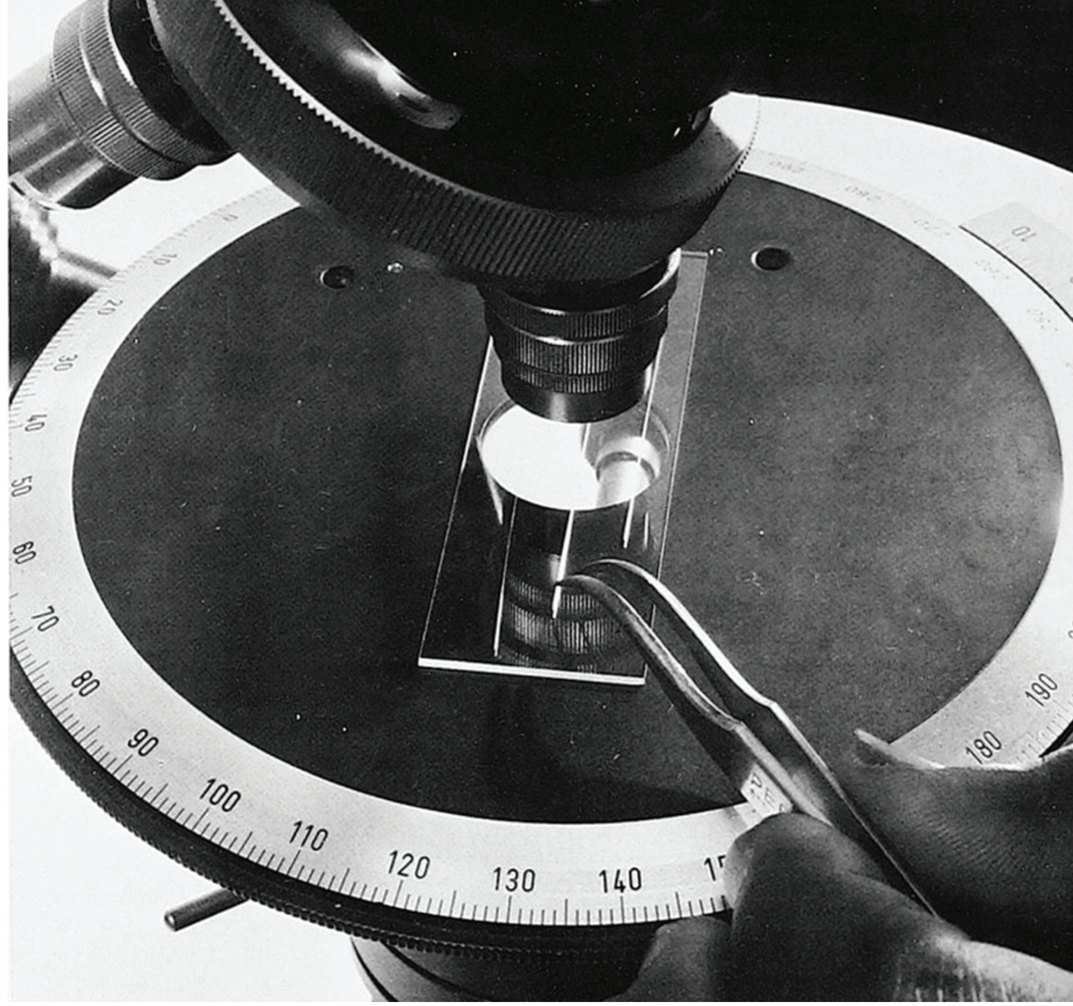
Soviet chemist Boris Deryagin peering into a microscope in his lab, undated.

SUBSTANTIA/BARRY NINHAM

Deryagin struck up a collaboration with Fedyakin and then steadily absorbed the research of the little-known scientist into his own work. Deryagin's team confirmed the substance at the bottom of the glass tube was denser and thicker than ordinary water. They also discovered that compared with ordinary water it froze at a far lower temperature (–40°F) and boiled at a much higher one (near 400°F). Using an optical microscope the researchers could also see this new type of water expanded more than ordinary water when heated and bent light differently. With every new observation Deryagin grew more convinced that this "modified water," as he called it, was the most thermodynamically stable form of water, meaning any water coming into contact with the modified water would eventually become modified as well. But Deryagin needed more evidence to prove the water's newness and strangeness. Once he had that proof, he could catch the attention of scientists outside the Soviet Union.

In 1966, after nearly four years of work, Deryagin got his wish after Soviet authorities permitted him to speak at a conference at the University of Nottingham in England. Most of the conference's talks elicited contentious debate, but when Deryagin finished speaking, only a few polite questions were asked. His talk, dryly titled "Effects of Lyophile Surfaces on the Properties of Boundary Liquid Films," was too vague to draw any of the interest usually generated by a scientific breakthrough. The attention he desired, the questions he expected, and the crowds he hoped for never came. Only one British scientist expressed interest in his work: Brian Pethica, the director of the Unilever Research Laboratory in Cheshire, England.

Pethica went back to his group's laboratory and followed Deryagin's directions for creating modified water. Three years later Pethica and his team confirmed Deryagin's findings. But they too were unable to determine the fluid's chemical makeup apart from the hydrogen combined with oxygen found in ordinary water: the amount of the modified water was below what their instruments could detect. However, using the same tools as the Soviets, they verified the liquid expanded more than ordinary water and found it had a thick, gel-like consistency. They made a cautious guess that this new substance was created by silicates leaching from the glass tube. But they also had their doubts about this theory, as Deryagin had created the water using quartz tubes in which leaching was unlikely. Despite their misgivings they gave the odd liquid a new name—anomalous water—and published a paper about it in *Nature*, a science journal with a strong international reputation, which alerted American scientists to the discovery.



A sample of polywater being examined under a microscope at the National Bureau of Standards, 1969.

NIST ARCHIVES

As Americans devoured the details of this possibly stunning breakthrough, Deryagin finally began to see his Nobel dreams materialize. J. D. Bernal, one of Britain's most celebrated scientists, told Deryagin that "this is the most important physical-chemical discovery of the century."

Many less-famous scientists doubted the reality of anomalous water, dismissing it in commentary sections of science periodicals. If anomalous water was the most stable form of water, said these doubters, then *all* water coming into contact with it should turn anomalous. For some the existence of anomalous water seemed impossible. For others there were data enough to ignite the imagination.

Chemicals, like humans, have unique fingerprints, and instruments called spectrometers can identify the elements and molecules from a chemical fingerprint, or spectrum. Yet success hinges on the size of the sample, where bigger is better. In published papers anomalous-water believers lamented there just wasn't enough of it, certainly not enough to identify its molecular makeup. Scientists measured what they could with the tiny amounts of anomalous water available, largely physical properties, such as boiling point, appearance, thermal expansion, and viscosity. These observations bolstered their conviction that anomalous water was real, but for every believer there were many more skeptics who loudly dismissed the results. The matter would only be settled by a definitive chemical analysis from a spectrometer sensitive enough to determine the fluid's chemical composition and structure.

That data arrived on June 27, 1969. A paper published in *Science*, a prestigious American scientific journal, provided the missing evidence for doubting scientists—definitive spectroscopic proof that this water was different. What made the data even more convincing was the person who led the team,

> “I regard the polymer as the most dangerous material on earth. . . .Treat it as the most deadly virus until its safety is established.”

Ellis Lippincott of the University of Maryland, a well-known chemist and an expert in spectroscopy who had built one of the two best spectrometers in the country. Working with polymer chemists from the National Bureau of Standards, Robert Stromberg and Warren Grant, Lippincott showed the liquid’s spectrum was “not . . . of any known substance.” When the scientists tried to chemically analyze the liquid, they found trace quantities of silicon and sodium, in amounts too small to be considered significant. Using the data from these spectrometers the researchers also took a stab at explaining what made the liquid unique: the molecules of H_2O, they suggested, were arranged in a honeycomb-shaped network, making a polymer of water. They dubbed it polywater.

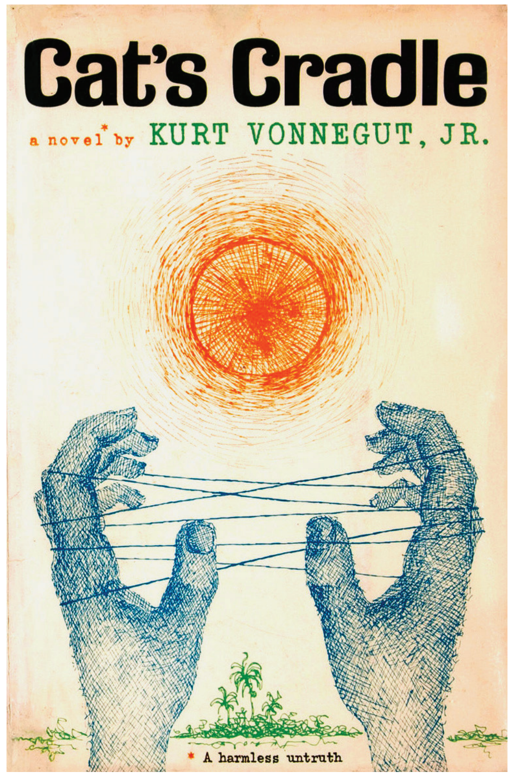
Scientists—even the most skeptical—took notice. Polywater also caught the attention of the press and public, some of whom were reminded of Kurt Vonnegut’s monstrous ice-nine from the novel *Cat’s Cradle*, published a few years earlier. Ice-nine froze whatever liquid H_2O it touched, from lakes and rivers to blood and sweat. Like an infection, might the real-life weird water also change any water it came into contact with? And what if polywater were flushed down the toilet? Could it transform ordinary water in a treatment plant, water people might then drink? Physicist Frank Donahoe was also alarmed and vehement about polywater’s threat. “I regard the polymer as the most dangerous material on earth,” he wrote in *Nature* in October 1969. “Treat it as the most deadly virus until its safety is established.”

Once the press picked up the polywater story, Stromberg started receiving letters, lots of them. “People were writing me that I am destroying the world,” he said.

Polywater’s Soviet origins didn’t help matters. By 1969 the CIA was monitoring polywater research by its Cold War rival, and the *Wall Street Journal* reported the Pentagon was “bankrolling efforts to push U.S. polywater technology ahead of the Soviet Union’s.”

By 1970 everyone had questions about polywater, and a scientific conference in Bethlehem, Pennsylvania, was advertised to have the answers.

LEFT Dust jacket for the first edition of Kurt Vonnegut’s *Cat’s Cradle* (1963), designed by Ben Feder. **RIGHT** National Bureau of Standards researchers Robert Stromberg (*left*) and Warren Grant with printouts of the proposed molecular structure of polywater.



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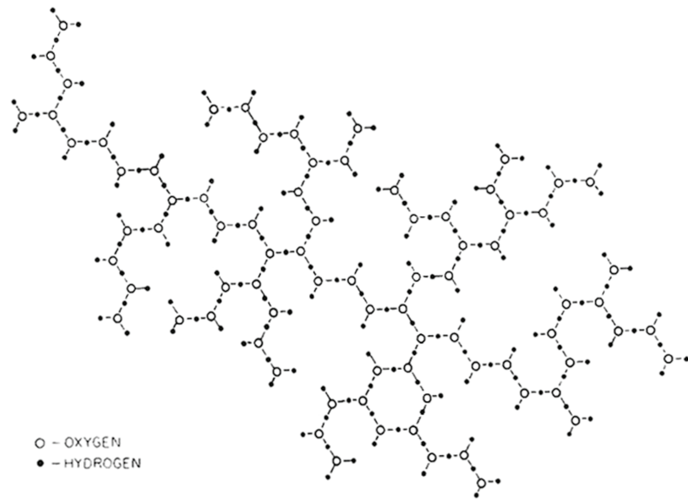
The Rise and Fall of Polywater



Molecular structure of polywater with branched polymer chains, as proposed by University of Maryland researcher Ellis Lippincott and Stromberg and Grant at the National Bureau of Standards, 1969.

Press conference at the American Chemical Society’s symposium at Lehigh University, 1970. *From left:* Albert Zettlemoyer, Lehigh University provost and vice present (and future ACS president); Boris Deryagin; Denis Rousseau of Bell Labs; Frederick Fowkes, chair of Lehigh’s chemistry department.

In April 1970 the American Chemical Society held a symposium at Lehigh University, in the steel town of Bethlehem. An entire session focused on water, including anomalous water. A news conference was scheduled to follow. Reporters and the 300 attendees all wanted to better understand the nature of polywater. Passions were high among both skeptics and believers: a fight was simmering.

Deryagin, the godfather of polywater, had the honor of giving the opening talk. After his presentation he was pummeled with questions. One audience member asked about evidence of impurities found in polywater by other labs. “I can’t be responsible for the results that are bad and not by us,” Deryagin replied. If the impurities are present in their equipment, he said, they will turn up in the anomalous water, too.

But Lippincott, the adoptive American father of polywater, said impurities were a problem in his lab and he had had difficulty repeating his earlier findings. Stromberg supported Lippincott’s defection. “With the evidence we had, we started out believing that water forms a polymer,” he said. “New evidence casts serious doubt.”

Denis Rousseau, a 29-year-old postdoctoral scientist at Bell Labs in Murray Hill, New Jersey, was one of the more vocal and passionate disbelievers. He told the heavyweights around him that in working with chemists skilled in detecting trace amounts of compounds, they found the “polywater samples show the material to be highly contaminated.” Results showed “high concentrations of sodium, potassium, carbon, oxygen, and chloride” as well as other compounds. Rousseau was confident impurities were at play in polywater: in one experiment in which he aimed a laser at a sample of polywater, the polywater burned and turned dark brown, a sign the sample contained more than just H_2O molecules in a new configuration. “I do not believe there is sufficient evidence to justify a polymer of water,” he said. Deryagin remained unswayed.

Scientists from all over the world had traveled to the Lehigh Valley for an answer, but they left frustrated. The status quo returned as polywater’s supporters got back to the business of making a sample large enough to test, while its skeptics continued to denounce the whole thing as drivel.

Rousseau was determined to prove the nonexistence of polywater, and to make his point he went to the gym, where he believed he could get to the source of the impurities. After an intense game of handball Rousseau wrung out the perspiration from his T-shirt and put a sample of it into his spectrometer. The machine spat out the chemical spectrum, which matched that of an earlier sample of polywater. In January 1971 *Science* published a paper with Rousseau’s findings. In it he wrote that each person, like the *Peanuts* character Pigpen, is surrounded by a fog containing a fine mist of that person’s essence. This mist, or aerosol, when it landed on the inside of a glass tube containing a microscopic amount of water, created the fluid with the odd behavior. Polywater turned out to be 1% inspiration and 99% perspiration. Put another way, polywater was merely dirty water.

Finally polywater’s adherents lost their faith. Scientists got back to work left undone while polywater had consumed them along with millions of research dollars. It was all water under the bridge now. Two years later even the stubborn Deryagin conceded. “These experiments do not support the hypothesis of anomalous or polymeric water,” he said. D

Ainissa Ramirez is a materials scientist and the author of The Alchemy of Us.

Bacteriophages and the Fight Against Cholera in Cold War Afghanistan

Could a Soviet-era therapy offer a new defense against antibiotic-resistant superbugs?

BY MIRIAM F. LIPTON

Kabul's central hospital was already filled with 600 of the city's sickest cholera patients when Zinaida Plankina arrived in August 1960. The Afghan government had sought out the Soviet epidemiologist and her team of experts based on her earlier success in stemming a cholera outbreak in East Pakistan (present-day Bangladesh). Plankina's tools of choice were bacteria-destroying viruses known as bacteriophages, and her group arrived with enough of them to treat every cholera patient in Afghanistan.

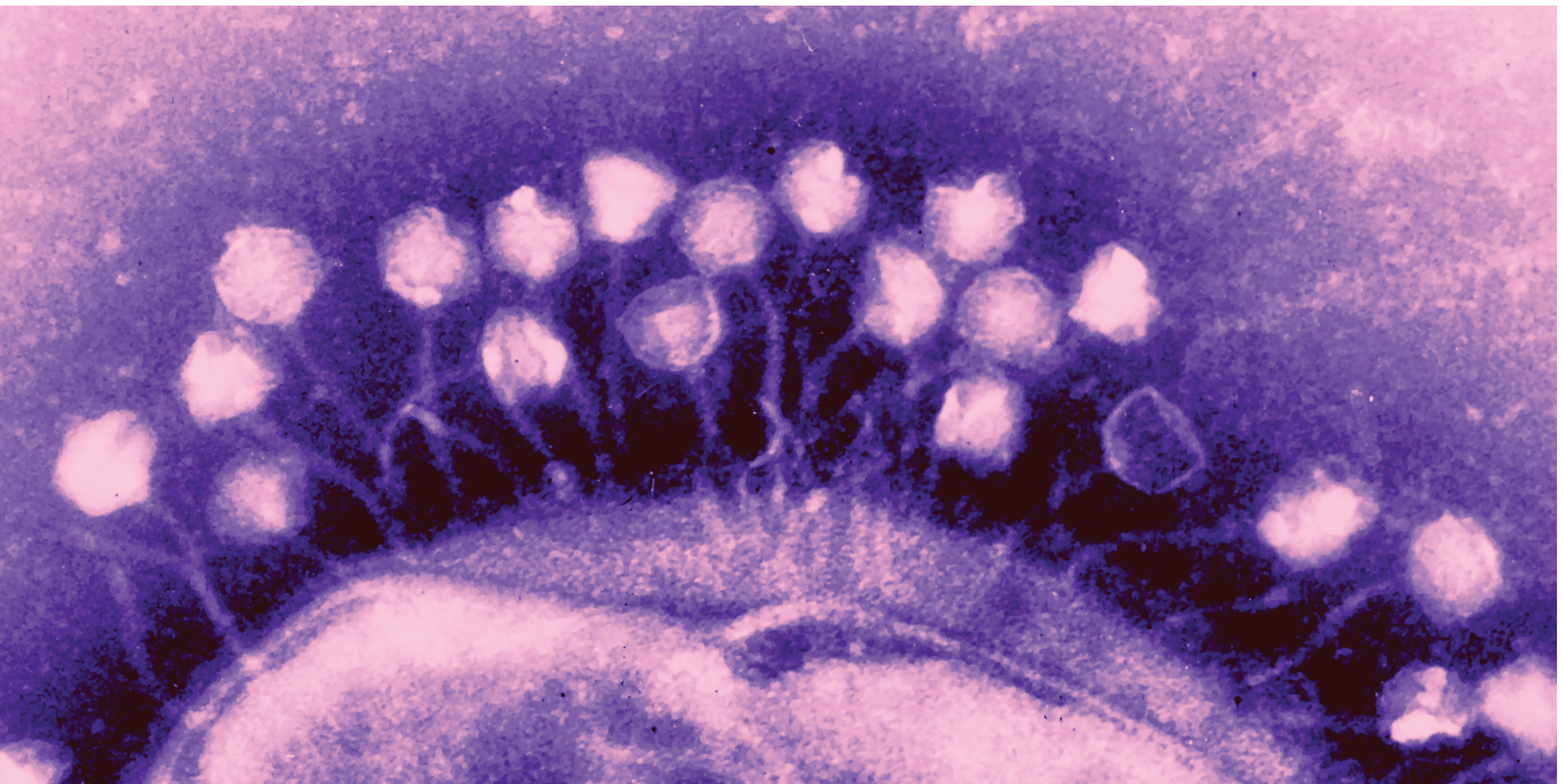
Shortly after landing, Plankina and her colleagues met with the lead doctors at the Aliabad General Hospital for what she thought would be a planning session on how to best administer the bacteriophages. Instead the Afghan doctors told her they would not be using them. The treatments would interfere, they said, with the American-supplied antibiotics already in use at the hospital. Plankina and her bacteriophages were unwelcome.

The epidemiologist unwittingly had found herself caught in a dispute that had less to do with science than politics. The struggle between those who supported antibiotics and those who relied on bacteriophages was a Cold War skirmish, with doctors and patients in Afghanistan caught between the warring cultural and political traditions of the United States and Soviet Union.

Afghanistan had a complicated relationship with both superpowers during the Cold War.

GRAHAM BEARDS/WIKIMEDIA COMMONS

Colorized transmission electron micrograph of bacteriophages attacking a bacterium.



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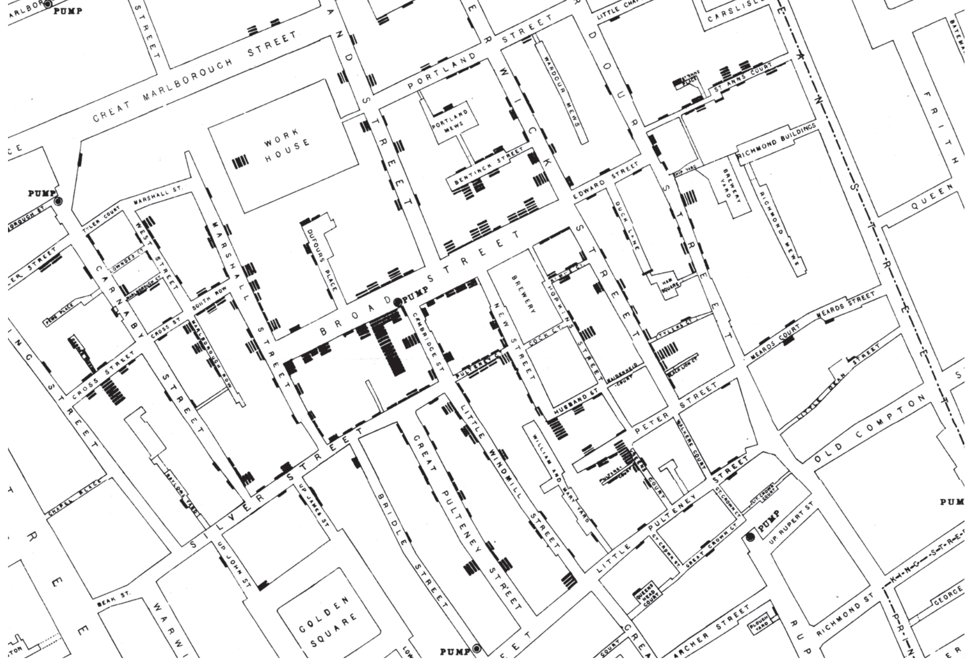
Britain's departure from the Indian subcontinent in 1947 left a political void in the region. Afghanistan's prime minister at the time, Shah Mahmud Khan, made clear his intention to align with the United States, seeing it as a natural ally and successor to Britain. But the United States had little interest in Afghanistan and instead pursued an alliance with Pakistan, a neighbor and political foe of Afghanistan. By the 1950s the U.S. government had established relations with Pakistan, which eroded American relations with Afghanistan.

The Soviets, on the other hand, shared a border with Afghanistan, giving them a vested interest in shoring up the political stability of their poorer neighbor. From 1955 to 1979, Soviet leaders sent the ailing, landlocked nation aid worth more than $9.3 billion today. The Soviets' foreign aid was also a way to show the world that Soviet Communism was not only exportable but successful. If the Soviet project in Afghanistan succeeded, they would be one step closer to winning the Cold War's zero-sum game.

But when Plankina arrived in 1960, Afghanistan's political alliance with the Soviet Union had yet to be cemented. There was still a lingering desire to align with the United States among the country's elites. Afghan doctors were among those who wanted U.S. support, including antibiotics, miracle drugs then experiencing a "golden age" of discovery.



Detail of a map from London doctor John Snow's investigation of an 1854 cholera outbreak, which he traced back to a contaminated drinking water pump.

Cholera is a highly contagious and often fatal diarrheal disease that is caused by the *Vibrio cholerae* bacterium. The disease had ravaged communities for centuries, but outbreaks remained small and isolated until the growth of international trade networks led to the first cholera pandemic in 1817, which began in India and spread as far as Russia. Thirty-eight years later British physician John Snow famously showed that cholera spread through contaminated water. Sanitation measures based on Snow's discovery slowed transmission of the disease, but these improvements were of little help to those already sick.

In the next century powerful tools to fight bacterial diseases emerged.

Sulfa drugs arrived in the 1930s, followed by penicillin during World War II. These antibiotics could cure people, not just treat symptoms. By the time of the 1960 outbreak in Kabul, numerous antibiotics were being used to treat a variety of bacterial infections, including cholera. Partially as a result, the average life expectancy for Americans had increased by more than four years since World War II.

But antibiotics' benefits were not shared equally. Going back to World War II, the U.S. government strategically limited access to the drugs. While antibiotic production boomed during the war, the U.S. military withheld them from their Soviet allies until the fighting was nearly over.

In response, Soviet scientists pursued therapies based on bacteriophages, continuing research that had been going for more than a decade. After the war the Soviet Union remained devoted to bacteriophage development, so much so that in 1953 it created regulations solidifying their status as the main treatment for bacterial infections and built research centers throughout the country to provide a steady supply of medicine.

But while the Soviets were early and eager adopters of bacteriophage therapies, they were not the first to isolate these remarkable viruses.

Soon after the start of World War I, British bacteriologist Frederick Twort realized that soldiers who were shot or otherwise sustained open wounds and then spent extended time in ponds or other bodies of water tended to fare better than those who fell on dry land. Intrigued by this phenomenon, he began to sample water from these sources and soon isolated a perplexing substance. Twort published his findings in *The Lancet* in 1915, describing the substance as made up of "ultra-microscopic viruses." But Twort hedged his bets and suggested it could just as easily be "a minute bacterium" or an amoeba of some sort.

Twort's failure to fully comprehend his findings was fortuitous for Félix d'Hérelle, a restless, adventure-seeking French microbiologist who set out to understand Twort's discovery as well as the mechanism by which it healed wounded soldiers. Working at the Pasteur Institute in Paris, d'Hérelle soon determined that the mysterious agents were parasitic viruses, which he named bacteriophages (*phage* is Latin for "to eat"). In short order d'Hérelle published his findings on these bacteria eaters.

French bacteriologist Félix d'Hérelle, ca. 1905.

The world seemed poised to accept not only bacteriophages but a new approach to medicine, one that could cure the previously incurable. Bacteriophages became a part of the zeitgeist. Author Sinclair Lewis's 1925 novel, *Arrowsmith*, about a doctor who uses bacteriophages to save people on a tropical island from a plague outbreak, won the Pulitzer Prize for Fiction the following year. D'Hérelle launched a short-lived bacteriophage laboratory in Paris and traveled the world—accepting awards and supporting bacteriophage programs targeting dysentery, plague, and cholera—and held a professorship at Yale University for five years. By the 1930s bacteriophage processing plants were opening across the globe, including in the United States, France, and Brazil.

By that time d'Hérelle, like many intellectuals, had become disillusioned with political turmoil that had lingered in France since the end of World War I. The Soviet Union, with its message of unity and equality for all, seemed a better place for the abiding critic of capitalism, a place where he and other scientists could safely express their ideas. When a former colleague, Soviet bacteriologist George Eliava, offered d'Hérelle a job helping build a bacteriophage center at Eliava's Institute of Bacteriology in Tbilisi, Georgia, the Frenchman jumped at the chance.

Eliava's brainchild was planned as a sprawling, 17-hectare, world-class facility. The plans were personally approved by Stalin and included residences for both Eliava and d'Hérelle, laboratories, clinics, and even a vivarium, all with French motifs.

But toward the end of 1935, the political atmosphere shifted. Lavrentiy Beria—first secretary of the Georgian Communist Party, close Stalin ally, and childhood rival of Eliava—refused to provide more funds for the laboratory. Soon after, d'Hérelle and his wife boarded an Italian ship from Georgia's port city of Batumi, under the pretense of needing to complete work at the Pasteur Institute. They never returned. In a harsh twist of fate, Eliava was murdered on Beria's orders in 1937 during Stalin's Great Purge.

D'Hérelle continued to work on bacteriophages, but never gained the recognition he sought. He was nominated for a Nobel Prize several times but was never chosen. His scientific methods were repeatedly attacked, and he was placed under house arrest in Vichy France. He died in 1949, just as the golden age of antibiotics was beginning.

Georgian microbiologist George Eliava, undated.

WIKIMEDIA COMMONS

Despite these losses, Soviet bacteriophage research thrived. Several research centers opened across the Soviet Union, including Eliava's lab, which was completed in the late 1930s. The laboratory in Tbilisi, now named the Eliava Institute, is still producing bacteriophages for the citizens of Georgia and surrounding countries.

An effective bacteriophage treatment for cholera remained elusive until 1954, when Soviet researcher Aleksandr Grigorevich Nikonov at the Rostov-on-Don Anti-Plague Research Institute finally succeeded. Nikonov's success required meticulous trial-and-error experiments on cholera-infected guinea pigs as well as the development of new growth mediums for bacteriophages, which included such ingredients as "bile, the contents of the small intestine and fragments of the small intestine in Tyrode's solution."

In 1958, when an outbreak of cholera struck a city in a remote part of East Pakistan, the Soviets seized the opportunity to show the world that their bacteriophages were at the very least as potent as their rival's antibiotics. In a matter of weeks the Soviet contingent had treated everyone in the city; not a single person showed signs of recurrence.

While armed with a proven cholera treatment, the outbreak Plankina and her colleagues encountered in 1960 was particularly daunting. Cholera was a common problem in Afghanistan—the country had experienced several outbreaks in the previous 40 years—but modern transportation had expanded the disease's reach and ramped up the pace of its spread. Plankina also recognized that some traditions were contributing to the spread. Irrigation ditches were used as a place to wash corpses and a source of water for rinsing the mouth. The Kabul outbreak was later traced back to a woman who drank from an irrigation ditch, where, further upstream, mourners had washed the linens of a cholera patient from Jalalabad.

Doctors at Aliabad General Hospital initially tried to isolate the sick, which proved ineffective; it was simply too difficult to isolate people quickly enough to blunt the spread. And the American antibiotic they were using, oxytetracycline, was only about 50% effective.

Faced with a growing number of cases, the hospital's doctors began testing and quarantining anyone who had come into contact with a positive case. But they were too late. The outbreak surged and overwhelmed the staff's capacity to test patients. By the time Plankina arrived in August 1960 all of Aliabad General's 600 beds were full, the cholera patients crowded close together but without the proper isolation measures that would prevent further spread within the hospital.

On October 2 a patient on the neurological ward of another hospital died of a diarrheal disease. A hospital worker who cleaned the body and a cook who fed the patient also became ill. By October 6, 12 patients in different parts of the hospital came down with the same symptoms, which were similar to those of cholera. Because these patients were scattered throughout the hospital and not contained within the cholera ward, the overwhelmed Afghan doctors failed to recognize the cases as cholera.

When Plankina heard about the mysterious bout of gastroenteritis, she seized the opportunity to test those patients for cholera.

"The world seemed poised to accept not only bacteriophages but a new approach to medicine, one that could cure the previously incurable."

After the patients, including two who were comatose, tested positive, Plankina secretly treated them with bacteriophages. By the next day these patients had improved so rapidly that the Afghan doctors abandoned their antibiotics and switched to Plankina's bacteriophage injections. Locals reportedly dubbed the treatment "holy water."

Between October and December 1960 Plankina and her colleagues inoculated 1,600 hospital employees with bacteriophages. Through that winter the Afghan minister of public health corralled foreign aid from the World Health Organization (WHO) and persuaded scientific teams from France and Czechoslovakia to come help Plankina and her colleagues inoculate people in Kabul and its environs. The international team used more than 550 liters of the cholera bacteriophage to treat more than 27,000 people, some living in villages that are among the world's highest and most precarious to reach. Not one person treated with bacteriophages became ill with cholera in three years of follow-up surveillance.

Despite the remarkable success of this medical mission, just one English-language article on Plankina's work exists, published by the WHO. She and her colleagues returned to the Soviet Union much as they had come, with little fanfare. She was still Soviet, after all, and her science was still seen as *other* by the Afghans and members of the WHO delegation.

Why did no enterprising or ambitious American researcher adopt such a compelling treatment? It's likely the English-speaking world never knew of her efforts. The teams that helped distribute the bacteriophages were French, who had a bacteriophage connection through d'Hérelle, and Czech, who were then in the Soviet sphere of influence.

When it comes to U.S. bacteriophage research, there has been little growth in the 60 years since Plankina set out on her Afghan mission. But that might change as doctors face an increasingly alarming but long-recognized problem.

Soon after antibiotics were discovered, signs of bacterial resistance began to emerge. Scientists, such as future Nobel laureate Selman Waksman, realized as early as 1945 that bacteria were becoming resistant to penicillin.

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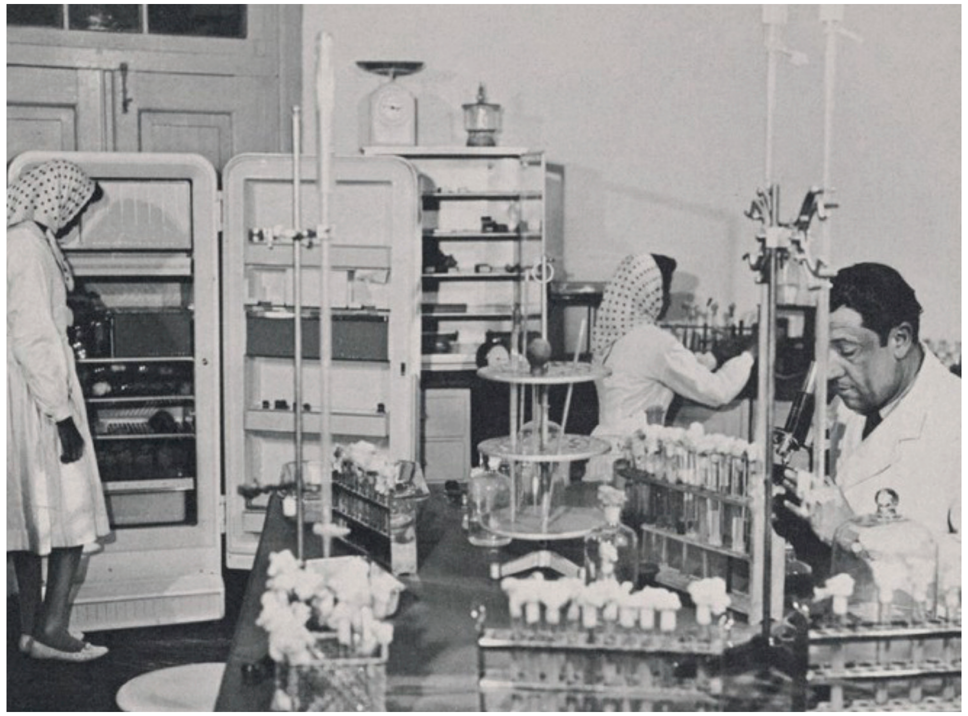
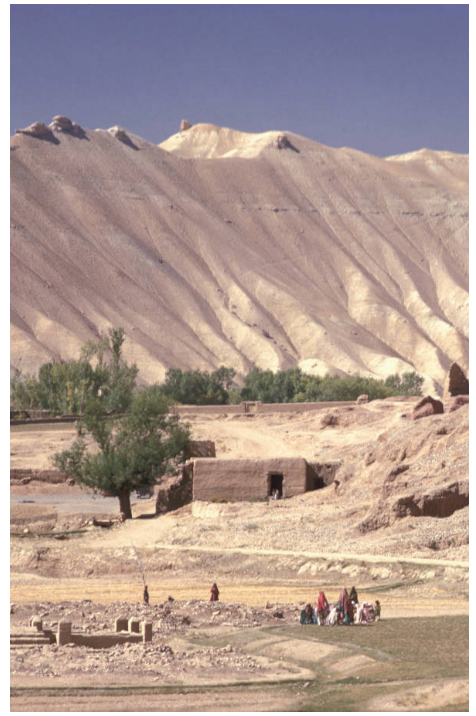


An Afghan vaccine research lab, ca. 1960, from *Afghanistan: Ancient Land with Modern Ways*, 1961.



Afghan village in the Hindu Kush mountains, ca. 1969.

“Why did no enterprising or ambitious American researcher adopt such a compelling treatment?”

Two years later Waksman’s bacteria showed resistance to streptomycin. Newer, so-called broad-spectrum antibiotics would be needed to overcome the growing resistance, but bacteria showed signs of resistance to these newer drugs almost immediately. Waksman even saw signs of resistance to streptomycin while conducting efficacy studies on experimental guinea pigs.

Belgian microbiologist Maurice Welsch became convinced that resistance was unavoidable and in 1952 told the WHO as much. Pharmaceutical companies responded by introducing fixed-dose, combination antibiotics to overcome rising bacterial resistance. These drugs combined two, sometimes three, antibiotics in one pill, but were banned in the 1960s due to increasing bacterial resistance.

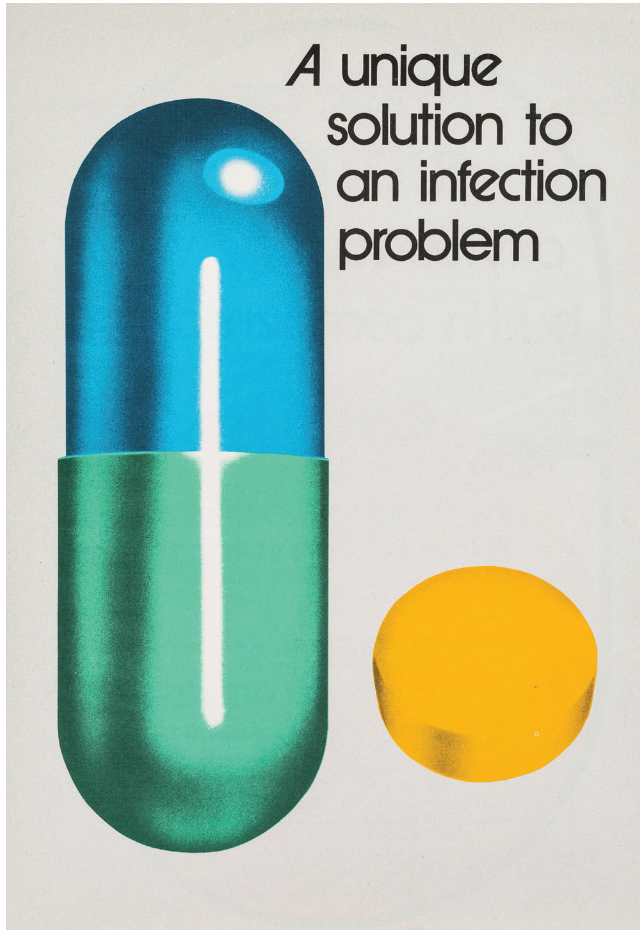
Oxytetracycline, the antibiotic used in Kabul in 1960, belonged to the broad-spectrum family. This pale-yellow drug was developed in 1952 by Pfizer scientists, the first antibiotic to be produced entirely by a pharmaceutical company. The company branded it Terramycin because it was found in soil samples and proved successful in treating a variety of bacterial infections.

Despite growing antibiotic resistance, bacteriophage treatments never took off in the antibiotic-dominated West. Historians have speculated that because antibiotics held so much promise in the early years of their development, scientists struggled to understand the inevitability of resistance for all antibiotics. Certainly, these researchers had a reason to be optimistic. Scientists were creating antibiotics at a rapid rate, and when resistance was recognized, new antibiotics, such as vancomycin, were made, often in the belief that no bacteria would ever develop resistance to them.

This boundless support for antibiotics and their promise was buttressed by the Cold War and its effects on American and Soviet science. The conflict influenced scientific fields on both sides of the political divide. For example, Soviet scientists promoted their own form of genetics, which relied heavily on theories championed by Trofim Lysenko, primarily because it was not Western.

Why did no enterprising or ambitious American researcher adopt such a compelling treatment?

Americans felt similarly disdainful of Soviet medicine. In a CIA report from 1951, analysts examining the state of Soviet medicine concluded that it was of the “simplest old-fashioned type.” The Cold War’s influence on this kind of analysis is apparent.



Advertisement for the broad-spectrum antibiotic oxytetracycline, ca. 1979.

WELLCOME COLLECTION

While there’s no clear evidence the CIA buried knowledge of the Soviets’ success with bacteriophages, American scientists’ unwavering pursuit of antibiotics and their abandonment of bacteriophages aligned with similar Cold War policies, which favored the adoption of homegrown science. (The Soviets, it’s worth noting, did develop their own antibiotic, called gramicidin-S, although a lack of resources and other factors prevented them from developing other antibiotics.)

A Cold War hangover may be partially to blame for Americans’ enduring reluctance to pursue phage therapies, but money might be a more important factor: bacteriophages, as naturally occurring organisms, cannot be patented.

Phage therapies are effectively banned in the United States and in most other Western countries. However, rising antibiotic resistance has at least some Americans taking another look at the viruses’ potential.

A notable example is a team of doctors at the University of California, San Diego, who in 2016 successfully lobbied the FDA for emergency use authorization for bacteriophages to treat Tom Patterson, a professor of psychiatry at the school, after he became infected with *Acinetobacter baumannii*—a life-threatening, multi-drug-resistant bacteria—during a trip to Egypt in late 2015.

Bacteriophage researchers Nina Chanishvili (*left*) and Ketino Porchidze at the Eliava Institute in Tbilisi, Georgia, June 2005.

VANO SHLAMOV/AFP VIA GETTY IMAGES

The treatment’s remarkable effect mirrored those seen with Plankina’s patients more than 50 years earlier. After receiving the bacteriophages intravenously, Patterson came out of his monthslong coma within three days. He returned to work, fully recovered, shortly thereafter. This success, along with a few others, prompted several researchers to launch the school’s Center for Innovative Phage Applications and Therapeutics in 2018 to combat antibiotic-resistant diseases.

The San Diego lab is an outlier. Many U.S. researchers doubt the efficacy of bacteriophages, and there is some evidence supporting such skepticism. Recent research, for example, has found that the body can quickly shed bacteriophages. In such cases bacteriophages do not spend enough time in the body to destroy bacteria, rendering the treatments useless.

Yet Georgian scientists have successfully treated patients with bacteriophages since the 1930s. Any suggestion that they are ineffective runs counter to decades of their own research and clinical experience. Today patients can buy ready-made bacteriophages for specific bacteria, such as staphylococci, and can receive a tailor-made bacteriophage cocktail within three days for other, more complex bacterial infections. The phage therapies made by the Eliava Institute’s doctors today have not changed much since the 1930s. For them the treatments simply work.

This was the case for Alfred Gertler, a Canadian who in 2001 became the first Westerner treated with bacteriophages in Georgia. A year earlier he had read an article in the *New York Times Magazine* about bacteriophages. The article highlighted their absence in the West, despite the Georgian scientists’ success in using them to treat bacterial infections, such as the *Staphylococcus* bacteria that had long ravaged Gertler’s foot and continued to do so even after nearly four years of antibiotic treatments.

Gertler knew he would soon lose his foot and viewed phage therapy as a last-ditch chance to avoid amputation. He soon discovered bacteriophages were not an approved treatment in the West. So in early 2001 he spent nearly all his savings to fly to Tbilisi and begin treatment.

After two weeks of treatments at the Eliava Institute, Gertler was cured and walked out of the hospital. Despite this success just a handful of Westerners have been treated in Georgia since. D

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Mouse Heaven or Mouse Hell?

Biologist John Calhoun's rodent experiments gripped a society consumed by fears of overpopulation.

BY SAM KEAN

Officially, the colony was called the Mortality-Inhibiting Environment for Mice. Unofficially, it was called mouse heaven. Biologist John Calhoun built the colony at the National Institute of Mental Health in Maryland in 1968. It was a large pen—a 4½-foot cube—with everything a mouse could ever desire: plenty of food and water; a perfect climate; reams of paper to make cozy nests; and 256 separate apartments, accessible via mesh tubes bolted to the walls. Calhoun also screened the mice to eliminate disease. Free from predators and other worries, a mouse could theoretically live to an extraordinarily old age there, without a single worry.

But the thing is, this wasn't Calhoun's first rodent utopia. This was the 25th iteration. And by this point he knew how quickly mouse heaven could deteriorate into mouse hell.

John Calhoun grew up in Tennessee, the son of a high school principal and an artist, and was an avid birder when young. After earning his PhD in zoology, he joined the Rodent Ecology Project in Baltimore in 1946, whose purpose was to eliminate rodent pests in cities. The project had limited success, partly because no one could figure out what aspects of rodent behavior, lifestyle, or biology to target. Calhoun set up his first utopia, involving Norway rats, in the woods behind his house to monitor rodents over time and figure out what factors drove their population growth.

Eventually Calhoun grew fascinated with the rodent behavior for its own sake and began crafting ever more elaborate and carefully controlled environments. It wasn't just the behavior of rats that interested him. Architects and civil engineers at the time were having vigorous debates about how to build better cities, and Calhoun imagined urban design might be studied in rodents first and then extrapolated to human beings.

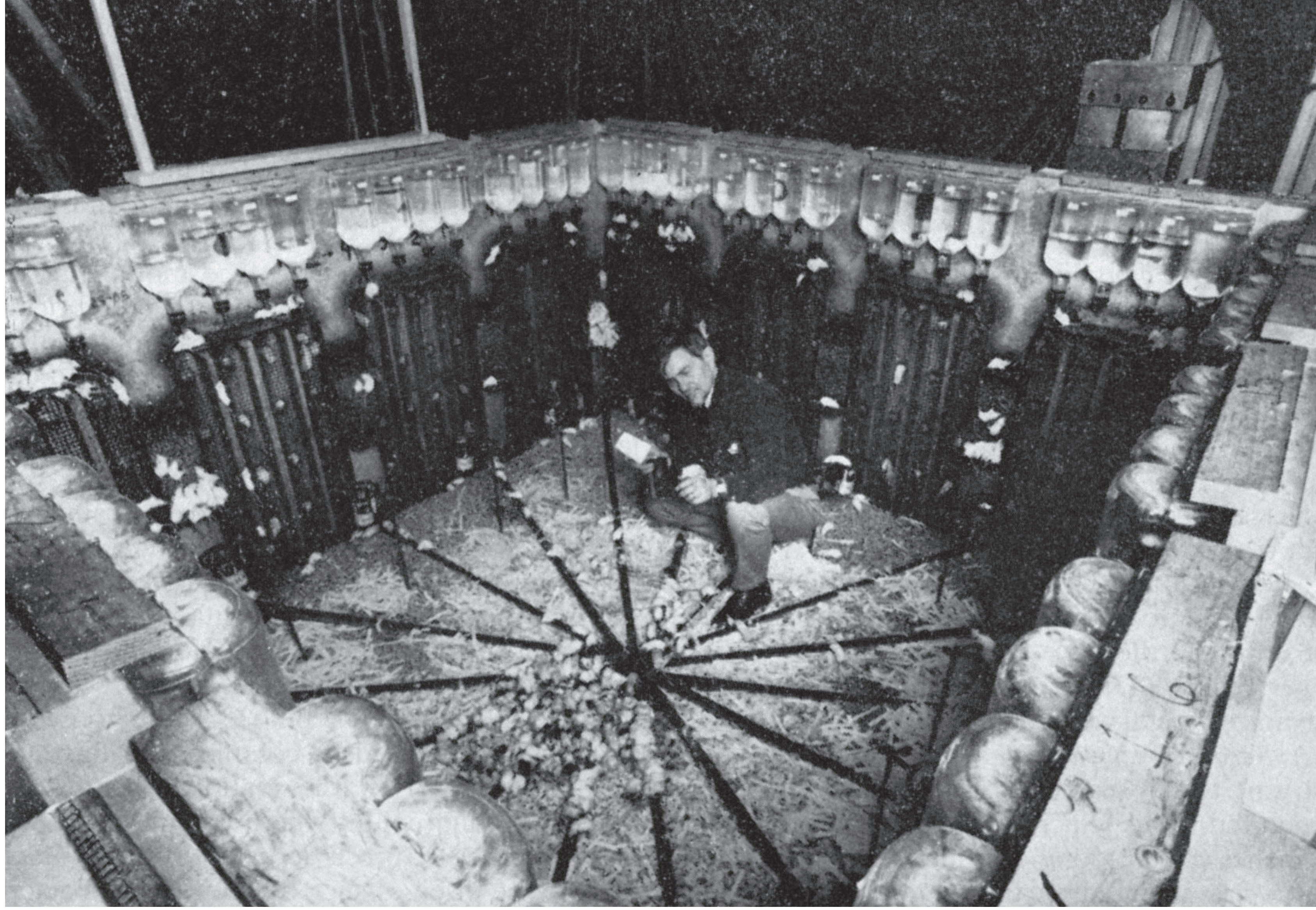
Calhoun's most famous utopia, number 25, began in July 1968, when he introduced eight albino mice into the 4½-foot cube. Following an adjustment period, the first pups were born 3½ months later, and the population doubled every 55 days afterward. Eventually this torrid growth slowed, but the population continued to climb, peaking at 2,200 mice during the 19th month.

> "Universe 25 ended a half century ago, but it continues to fascinate people today—especially as a gloomy metaphor for human society."

That robust growth masked some serious problems, however. In the wild, infant mortality among mice is high, as most juveniles get eaten by predators or perish of disease or cold. In mouse utopia, juveniles rarely died. As a result, there were far more youngsters than normal, which introduced several difficulties.

Rodents have social hierarchies, with dominant alpha males controlling harems of females. Alphas establish dominance by fighting—wrestling and biting any challengers. Normally a mouse that loses a fight will scurry off to some distant nook to start over elsewhere.

But in mouse utopia, the losing mice couldn't escape. Calhoun called them "dropouts." And because so few juveniles died, huge hordes of dropouts would gather in the center of the pen. They were full of cuts and ugly scars, and every so often huge brawls would break out—vicious free-for-alls of biting and clawing that served no obvious purpose. It was just senseless violence. (In earlier utopias involving rats, some dropouts turned to cannibalism.)



John Calhoun crouching inside Universe 25, his famous mouse-behavior experiment, February 1970.

YOICHI R. OKAMOTO/NATIONAL LIBRARY OF MEDICINE

Alpha males struggled, too. They kept their harems in private apartments, which they had to defend from challengers. But given how many mice survived to adulthood, there were always a dozen hotshots ready to fight. The alphas soon grew exhausted, and some stopped defending their apartments altogether.

As a result, apartments with nursing females were regularly invaded by rogue males. The mothers fought back, but often to the detriment of their young. Many stressed-out mothers booted their pups from the nest early, before the pups were ready. A few even attacked their own young amid the violence or abandoned them while fleeing to different apartments, leaving the pups to die of neglect.

Eventually other deviant behavior emerged. Mice who had been raised improperly or kicked out of the nest early often failed to develop healthy social bonds, and therefore struggled in adulthood with social interactions. Maladjusted females began isolating themselves like hermits in empty apartments—unusual behavior among mice. Maladjusted males, meanwhile, took to grooming all day—preening and licking themselves hour after hour. Calhoun called them "the beautiful ones." And yet, even while obsessing over their appearance, these males had zero interest in courting females, zero interest in sex.

Intriguingly, Calhoun had noticed in earlier utopias that such maladjusted behavior could spread like a contagion from mouse to mouse. He dubbed this phenomenon "the behavioral sink."

Between the lack of sex, which lowered the birth rate, and inability to raise pups properly, which sharply increased infant mortality, the population of Universe 25 began to plummet. By the 21st month, newborn pups rarely survived more than a few days. Soon, new births stopped altogether. Older mice lingered for a while—hiding like hermits or grooming all day—but eventually they died out as well. By spring 1973, less than five years after the experiment started, the population had crashed from 2,200 to 0. Mouse heaven had gone extinct.

Universe 25 ended a half century ago, but it continues to fascinate people today—especially as a gloomy metaphor for human society. Calhoun actively encouraged such speculation, once writing, "I shall largely speak of mice, but my thoughts are on man." As early as 1968, journalist Tom Wolfe titled an essay about New York "O Rotten Gotham—Sliding Down into the Behavioral Sink." Oddly, though, none of the prognosticators could agree on the main lesson of Universe 25.

The first people to fret over Universe 25 were environmentalists. The same year the study began, biologist Paul Ehrlich published *The Population Bomb*, an alarmist book predicting imminent starvation and population crashes due to overpopulation on Earth. Pop culture picked up on this theme in movies, such as *Soylent Green*, where humans in crowded cities are culled and turned into food slurry. Overall, the idea of dangerous overcrowding was in the air, and some sociologists explicitly drew on Calhoun's work, writing: "We . . . take the animal studies as a serious model for human populations." The message was stark: *Curb population growth—or else*.

More recently scholars saw similarities to the Industrial Revolution and the rise of modern urban society. The 19th and 20th centuries saw population booms across the world, largely due to drops in infant mortality—similar to what the mice experienced. Recently, however, human birth rates have dropped sharply in many developed countries—often below replacement levels—and young people in those places have reportedly lost interest in sex. The parallels to Universe 25 seem spooky.

Behavioral biologists have echoed the eugenics movement in blaming the strange behaviors of the mice on a lack of natural selection, which in their view culls those they consider weak and unfit to breed. This lack of culling resulted in supposed "mutational meltdowns" that led to widespread mouse stupidity and aberrant behavior. (The researchers argued that the brain is especially susceptible to mutations because it's so intricate and because so many of our genes influence brain function.)

Extrapolating from this work, some political agitators warn that humankind will face a similar decline. Women are supposedly falling into Calhoun's behavioral sink by learning "maladaptive behaviors," such as choosing not to have children, which "destroy[s] their own genetic interests." Other critics agonize over the supposed loss of traditional gender roles, leaving effete males and hyperaggressive females, or they deplore the undermining of religions and their imperatives to "be fruitful and multiply." In tandem, such changes will lead to the "decline of the West."

Advertising poster for 1973 thriller *Soylent Green*.

Still others have cast Universe 25's collapse as a parable illustrating the dangers of socialist welfare states, which, they argue, provide material goods but remove healthy challenges from people's lives, challenges that build character and promote "personal growth." Another school of thought viewed Universe 25 as a warning about "the city [as] a perversion of nature." As sociologists Claude Fischer and Mark Baldassare put it, "A red-eyed, sharp-fanged obsession about urban life stalks contemporary thought."

Most critics who've fretted over Calhoun's work cluster on the conservative end of the political spectrum, but self-styled progressives have weighed in as well. Advocates for birth control repeatedly invoked Calhoun's mice as a cautionary tale about how runaway population growth destroys family life. More recent interpretations see the mice collapse in terms of one-percenters and wealth inequality; they blame the social dysfunction on a few aggressive males hoarding precious resources (e.g., desirable apartments). In this view, said one critic, "Universe 25 had a fair distribution problem" above all.

Given these wildly varying (even contradictory) readings, it's hard to escape the suspicion that personal and political views, rather than objective inquiry, are driving these critics' outlooks. And indeed, a closer look at the interpretations severely undermines them.

When forecasting population crashes among human beings, *Population Bomb*–type environmentalists invariably predicted that overcrowding would lead to widespread shortages of food and other goods. That's actually the *opposite* of what Universe 25 was like. The mice there had all the goods they wanted. This also undermines arguments about unfair resource distribution.

Perhaps, then, it was the lack of struggles and challenges that led to dysfunction, as welfare critics claimed. Except that the spiral of dysfunction began when hordes of "dropout" mice *lost* challenges to alpha males, couldn't escape elsewhere, and began brawling in the middle of the pen. The alpha males in turn grew weary after too many challenges from youngsters. Indeed, most mice faced competition far in excess of what they would encounter in the wild.

CINEMATERIAL

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The appearance of the sexless "beautiful ones" does seem decadent and echoes the reported loss of interest in sex among young people in developed countries. Except that a closer look at the survey data indicates that such worries might be overblown. And any comparison between human birth rates and Universe 25 birth rates is complicated by the fact that the mouse rates dropped partly due to infant neglect and spikes in infant mortality—the opposite of the situation in the developed world.

Then there are the warnings about the mutational meltdown and the decline of intelligence. Aside from echoing the darkest rhetoric of the eugenics movement, this interpretation runs aground on several points. The hermit females and preening, asexual males certainly acted oddly—but in doing so, they avoided the vicious, violent free-for-alls that beset earlier generations. This hardly seems dumb. Moreover, some of Calhoun's research actually saw rodents getting *smarter* during experiments.

This evidence came from an earlier utopia involving rats. In that setup, dropout rats began digging new burrows into the dirt floor of their pen. Digging produces loose dirt to clear away, and most rats laboriously carried the loose dirt outside the tunnel bit by bit, to dump it there. It's necessary but tedious work.

But some of the dropout rats did something different. Instead of carrying dirt out bit by bit, they packed it all into a ball and rolled it out the tunnel in one trip. An enthused Calhoun compared this innovation to humankind inventing the wheel. And it happened only because the rats were isolated from the main group and didn't learn the dominant method of digging. By normal rat standards, this was deviant behavior. It was also a creative breakthrough. Overall, then, Calhoun argued that social strife can sometimes push creatures to become smarter, not dumber.

(Incidentally, after Universe 25's collapse, Calhoun began building new utopias to encourage creative behavior by keeping mice physically *and* mentally nourished. This research, in turn, inspired a children's book named after Calhoun's workplace—*Mrs. Frisby and the Rats of NIMH*, wherein a group of rats escape from a colony designed to stimulate their intelligence.)

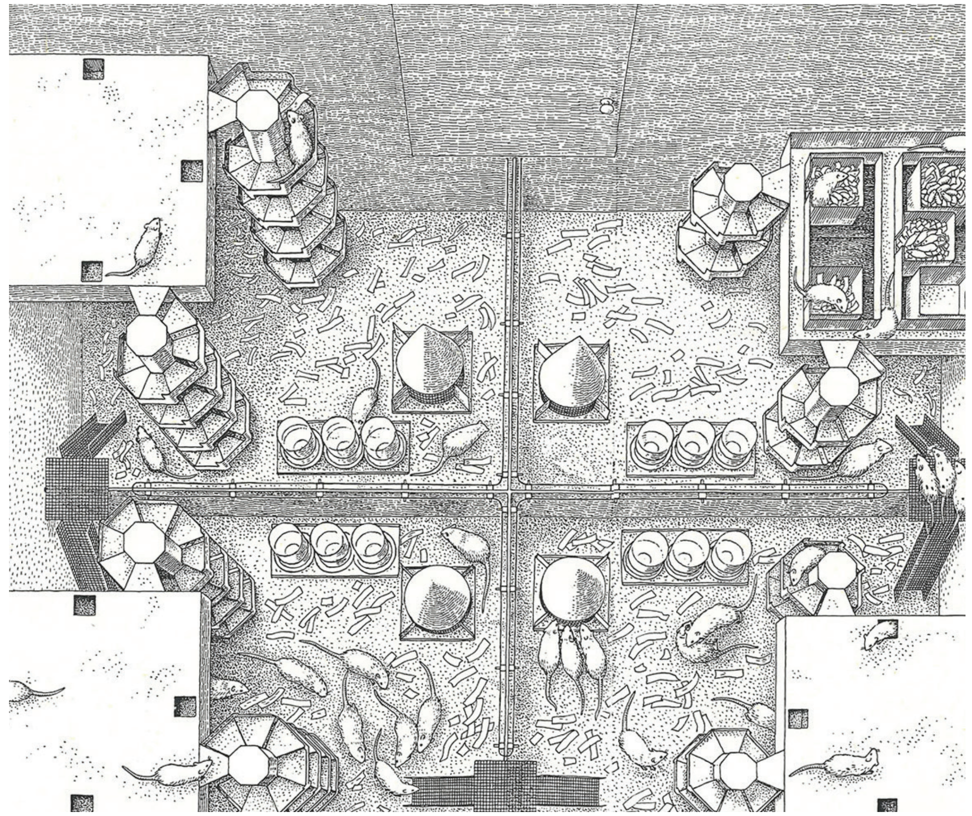
So if all these interpretations of Universe 25 miss the mark, what lesson can we draw from the experiment?

Calhoun's big takeaway involved status. Again, the males who lost the fights for dominance couldn't leave to start over elsewhere. As he saw it, they were stuck in pathetic, humiliating roles and lacked a meaningful place in society. The same went for females when they couldn't nurse or raise pups properly. Both groups became depressed and angry, and began lashing out. In other words, because mice are social animals, they need meaningful social roles to feel fulfilled. Humans are social animals as well, and without a meaningful role, we too can become hostile and lash out.

Still, even this interpretation seems like a stretch. Humans have far more ways of finding meaning in life than pumping out children or dominating some little hierarchy. And while human beings and mice are indeed both social creatures, that common label papers over some major differences. Critics of Calhoun's work argued that population density among humans—a statistical measure—doesn't necessarily correlate with crowding—a feeling of psychological stress. In the words of one historian, "Through their intelligence, adaptability, and capacity to make the world around them, humans were capable of coping with *crowding*" in ways that mice simply are not.

Ultimately Calhoun's work functions like a Rorschach blot—people see what they want to see. It's worth remembering that not all lab experiments, especially contrived ones such as Universe 25, apply to the real world. In which case, perhaps the best lesson to learn here is a meta-lesson: that drawing lessons itself can be a dangerous thing. D

Sam Kean is a best-selling science author and host of the Disappearing Spoon *podcast.*



An illustration of one of Calhoun's early rat habitats from his 1962 *Scientific American* article, "Population Density and Social Pathology."

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High School Science

Most object labels tell us what something is. Why one in our collections tells us what something is not.

BY ROGER TURNER

A Kipp's apparatus from the Institute's collection, ca. 1880–1920.

SCIENCE HISTORY INSTITUTE

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If you explore our digital collections, you might come across an oddly shaped piece of glassware that was once a familiar object in chemistry laboratories. It's called a Kipp's apparatus and the Science History Institute has several of these instruments, including one on display in our museum in Philadelphia.

But another Kipp's apparatus in our collections has a better provenance—and a surprising label.

The Kipp's apparatus, also known as the Kipp generator, was invented by Petrus Jacobus Kipp in 1844. The tool was widely used in labs and educational demonstrations into the second half of the 20th century. In a family publication, you might say it looks a bit like a snowman. In less formal company, you'd agree that it would look more at home with 1960s hippies than 19th-century chemists.

This Kipp's apparatus was donated to the Institute by Jeremy Wolf, a chemistry teacher at Palisades High School in Kintnersville, Pennsylvania. A decade after he donated it, Wolf told an Institute curator the story behind the label.

Wolf received the apparatus from his grandmother, Margaret Murray, who had worked as a teacher in Wyomissing, Pennsylvania. She had received it from a student's parent, who Wolf believes purchased it from a medical supply company in Reading, Pennsylvania. (The glass apparatus was produced by Reading Scientific sometime in the late 1800s or early 1900s.) Murray asked her grandson if he'd like it for his classroom. She thought it might inspire the kids.

Wolf displayed the apparatus in a glass cabinet in the "independent science research team" room at Palisades High School. When kids asked about it, Wolf explained it was an historical piece of chemical equipment. It could be used for capturing hydrogen generated by reacting acids and metals.

One day the school principal walked in, perhaps to do a teaching evaluation. The principal noticed the Kipp's apparatus. "It kind of looks like something illicit," he told Wolf.

"Don't worry," Wolf replied. "It's not a bong."

Then a student sensibly suggested it needed a label. Wolf agreed. To his surprise, the students decided the appropriate label was not "Kipp's apparatus" but "This is not a bong."

Later, the principal decided that perhaps it should not be displayed.

Beyond inspiring student creativity, this Kipp's apparatus once served as a set decoration for the school's fall play. Wolf also tried to use it to capture hydrogen with his Advanced Placement chemistry students after the AP exam. But missing some connectors, this apparatus was leaky. It also requires a lot of strong acid to work effectively, so it was not a good fit for a high school science lab.

Finally, in the summer of 2012, Wolf decided to donate it to what was then named the Chemical Heritage Foundation (now the Science History Institute). As he rode the subway to CHF, the Kipp's apparatus peeked out of a cardboard box. A fellow rider noticed it and complimented Wolf: "That's a pretty cool bong!" CB

Roger Turner is the Institute's curator of instruments and artifacts.

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