In 1948 there were seven thousand people in Grinnell, Iowa, including more than one who didn't dare take a drink in his own house without pulling the shades down first. It was against the law to sell liquor in Grinnell, but it was perfectly legal to drink it at home. So it wasn't that. It wasn't even that someone might look in through the window and disapprove. God knew Grinnell had more than its share of White Ribbon teetotalers, but by 1948 alcohol was hardly the mark of Cain it had once been. No, those timid souls with their fingers through the shade loops inside the white frame houses on Main Street and Park Street were thinking of something else altogether.

They happened to live on land originally owned by the Congregational minister who had founded the town in 1854, Josiah Grinnell. Josiah Grinnell had sold off lots with covenants, in perpetuity, stating that anyone who allowed alcohol to be drunk on his property forfeited ownership. *In perpetuity!*In perpetuity was forever, and 1948 was not even a hundred years later. In 1948 there were people walking around Grinnell who had known Josiah Grinnell personally. They were getting old; Grinnell had died in 1891; but they were still walking around. So... why take a chance!

The plain truth was, Grinnell had Middle West written all over it. It was squarely in the middle of Iowa's Midland corn belt, where people on the farms said "crawdad" instead of crayfish and "barn lot" instead of barnyard. Grinnell had been one of many Protestant religious communities established in the mid-nineteenth century after Iowa became a state and settlers from the East headed for the farmlands. The streets were lined with white clapboard houses and elm trees, like a New England village. And today, in 1948, the hard-scrubbed Octagon Soap smell of nineteenth century Protestantism still permeated the houses and Main Street as well. That was no small part of what people in the East thought of when they heard the term "Middle West. " For thirty years writers such as Sherwood Anderson, Sinclair Lewis, and Carl Van Vechten had been prompting the most delicious sniggers with their portraits of the churchy, narrow minded Middle West. The Iowa painter Grant Wood was thinking of farms like the ones around Grinnell when he did his famous painting *American Gothic.*Easterners recognized the grim, juiceless couple in Wood's picture right away. There were John Calvin's and John Knox's rectitude reigning in the sticks.

In the fall of 1948 Harry Truman picked out Grinnell as one of the stops on his whistle-stop campaign tour, one of the hamlets where he could reach out to the little people, the average Americans of the heartland, the people untouched by the sophisticated opinion-makers of New York and Washington. Speaking from the rear platform of his railroad car, Truman said he would never forget Grinnell, because it was Grinnell College, the little Congregational academy over on Park Street, that had given him his first honorary degree. The President's fond recollection didn't cut much ice, as it turned out. The town had voted Republican in every presidential election since the first time Abraham Lincoln ran, in 1860, and wasn't about to change for Harry Truman.

On the face of it, there you had Grinnell Iowa, in 1948: a piece of mid-nineteenth century American history frozen solid in the middle of the twentieth. It was one of the last towns in America that people back east would have figured to become the starting point of a bolt into the future that would create the very substructure, the electronic grid, of life in the year 2000 and beyond.

On the other hand, it wouldn't have surprised Josiah Grinnell in the slightest.

It was in the summer of 1948 that Grant Gale, a forty-five-year-old physics professor at Grinnell College, ran across an item in the newspaper concerning a former classmate of his at the University of Wisconsin named John Bardeen. Bardeen's father had been dean of medicine at Wisconsin, and Gale's wife Harriet's father had been dean of the engineering school, and so Bardeen and Harriet had grown up as fellow faculty brats, as the phrase went. Both Gale and Bardeen had majored in electrical engineering. Eventually Bardeen had taught physics at the University of Minnesota and had then left the academic world to work for Bell Laboratories, the telephone company's main research center, in Murray Hill, New Jersey. And now, according to the item, Bardeen and another engineer at Bell, Walter Brattain, had invented a novel little device they called a transistor.

It was only an item, however: the invention of the transistor in 1948 did not create headlines. The transistor apparently performed the same function as the vacuum tube, which was an essential component of telephone relay systems and radios. Like the vacuum tube, the transistor could isolate a specific electrical signal, such as a radio wave, and amplify it. But the transistor did not require glass tubing, a vacuum, a plate, or a cathode. It was nothing more than two minute gold wires leading to a piece of processed germanium less than a sixteenth of an inch long. Germanium, an element found in coal, was an insulator, not a conductor. But if the germanium was contaminated with impurities, it became a "semiconductor." A vacuum tube was also a semiconductor; the vacuum itself, like the germanium, was an insulator. But as every owner of a portable radio knew, vacuum tubes drew a lot of current, required a warm-up interval before they would work, and then got very hot. A transistor eliminated all these problems and, on top of that, was about fifty times smaller than a vacuum tube.  
 

So far, however, it was impossible to mass-produce transistors, partly because the gold wires had to be made by hand and attached by hand two thousandths of an inch apart. But that was the telephone company's problem. Grant Gale wasn't interested in any present or future applications of the transistor in terms of products. He hoped the transistor might offer a way to study the flow of electrons through a solid (the germanium), a subject physicists had speculated about for decades. He thought it would be terrific to get some transistors for his physics department at Grinnell. So he wrote to Bardeen at Bell Laboratories. Just to make sure his request didn't get lost in the shuffle, he also wrote to the president of Bell Laboratories, Oliver Buckley. Buckley was from Sloane, Iowa, and happened to be a Grinnell graduate. So by the fall of 1948 Gale had obtained two of the first transistors ever made, and he presented the first academic instruction in solid-state electronics available anywhere in the world, for the benefit of the eighteen students majoring in physics at Grinnell College.

One of Grant Gale's senior physics majors was a local boy named Robert Noyce, whom Gale had known for years. Bob and his brothers, Donald, Gaylord, and Ralph, lived just down Park Street and used to rake leaves, mow the lawn, baby-sit, and do other chores for the Gales. Lately Grant Gale had done more than his share of agonizing over Bob Noyce. Like his brothers, Bob was a bright student, but he had just been thrown out of school for a semester, and it had taken every bit of credit Gale had in the local favor bank, not only with other faculty members but also with the sheriff, to keep the boy from being expelled for good and stigmatized with a felony conviction.

Bob Noyce's father, Ralph Sr. was a Congregational minister. Not only that, both of his grandfathers were Congregational ministers. But that hadn't helped at all. In an odd way, after the thing happened, the boy's clerical lineage had boomeranged on him. People were going around saying, "Well, what do you expect from a preacher's son?" It was as if people in Grinnell unconsciously agreed with Sherwood Anderson that underneath the righteousness the midwestern Protestant preachers urged upon them, and which they themselves professed to uphold, lived demons of weakness, perversion, and hypocrisy that would break loose sooner or later.

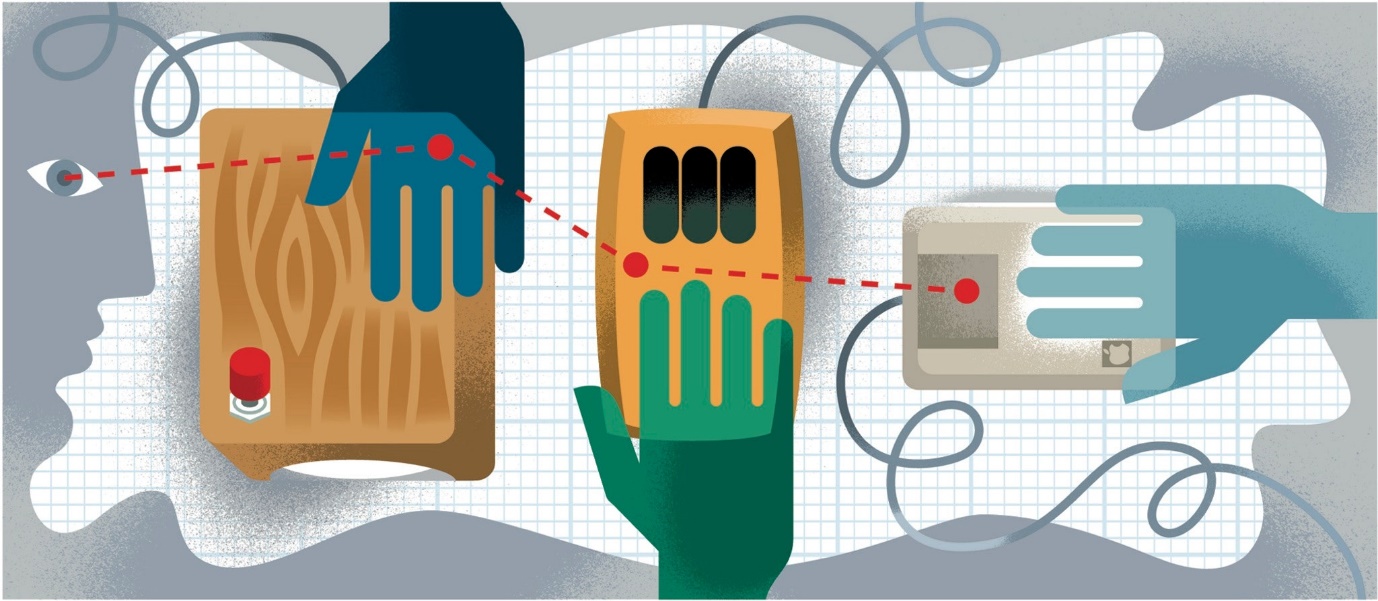
No one denied that the Noyce boys were polite and proper in all outward appearances. They were all members of the Boy Scouts. They went to Sunday School and the main Sunday service at the First Congregational Church and were active in the church youth groups. They were pumped full of Congregationalism until it was spilling over. Their father, although a minister, was not the minister of the First Congregational Church. He was the associate superintendent of the Iowa Conference of Congregational Churches, whose headquarters were at the college. The original purpose of the college had been to provide a good academic Congregational education, and many of the graduates became teachers. The Conference was a coordinating council rather than a governing body, since a prime tenet of the Congregational Church embedded in its name, was that each congregation was autonomous. Congregationalists rejected the very idea of a church hierarchy. A Congregational minister was not supposed to be a father or even a shepherd, but, rather, a teacher. Each member of the congregation was supposed to internalize the moral precepts of the church and be his own priest dealing directly with God. So the job of secretary of the Iowa Conference of Congregational Churches was anything but a position of power. It didn't pay much, either.

The Noyces didn't own their own house. They lived in a two-story white clapboard house that was owned by the church at Park Street and Tenth Avenue, at the college.

Not having your own house didn't carry the social onus in Grinnell that it did in the East. There was no upper crust in Grinnell. There were no top people who kept the social score in such matters. Congregationalists rejected the idea of a social hierarchy as fiercely as they did the idea of a religious hierarchy. The Congregationalists, like the Presbyterians, Methodists, Baptists, and United Brethren, were Dissenting Protestants. They were direct offshoots of the Separatists, who had split off from the Church of England in the sixteenth and seventeenth centuries and settled New England. At bottom, their doctrine of the autonomous congregation was derived from their hatred of the British system of class and status, with its endless gradations, topped off by the Court and the aristocracy. Even as late as 1948 the typical small town of the Middle West, like Grinnell, had nothing approaching a country club set. There were subtle differences in status in Grinnell, as in any other place, and it was better to be rich than poor, but there were only two obvious social ranks: those who were devout, educated, and hardworking, and those who weren't. Genteel poverty did not doom one socially in Grinnell. Ostentation did. The Noyce boys worked at odd jobs to earn their pocket money. That was socially correct as well as useful. To have devoted the same time to taking tennis lessons or riding lessons would have been a gaffe in Grinnell.

Donald, the oldest of the four boys, had done brilliantly at the college and had just received his Ph.D. in chemistry at Columbia University and was about to join the faculty of the University of California at Berkeley. Gaylord, the second oldest, was teaching school in Turkey. Bob, who was a year younger than Gaylord, had done so well in science at Grinnell High School that Grant Gale had invited him to take the freshman physics course at the college during his high school senior year. He became one of Gale's star students and most tireless laboratory workers from that time on. Despite his apparent passion for the scientific grind, Bob Noyce turned out to be that much-vaunted creature, the well-rounded student. He was a trim, muscular boy, five feet eight, with thick dark brown hair, a strong jawline, and a long, broad nose that gave him a rugged appearance. He was the star diver on the college swimming team and won the Midwest Conference championship in 1947. He sang in choral groups, played the oboe, and was an actor with the college dramatic society. He also acted in a radio drama workshop at the college, along with his friend Peter Hackes and some others who were interested in broadcasting, and was the leading man in a soap opera that was broadcast over station WOI in Ames, Iowa.

n late 1979, a twenty-four-year-old entrepreneur paid a visit to a research center in Silicon Valley called Xerox parc. He was the co-founder of a small computer startup down the road, in Cupertino. His name was Steve Jobs.



*The mouse was conceived by the computer scientist Douglas Engelbart, developed by Xerox PARC, and made marketable by Apple.*Illustration by PAUL ROGERS

Xerox parc was the innovation arm of the Xerox Corporation. It was, and remains, on Coyote Hill Road, in Palo Alto, nestled in the foothills on the edge of town, in a long, low concrete building, with enormous terraces looking out over the jewels of Silicon Valley. To the northwest was Stanford University’s Hoover Tower. To the north was Hewlett-Packard’s sprawling campus. All around were scores of the other chip designers, software firms, venture capitalists, and hardware-makers. A visitor to parc, taking in that view, could easily imagine that it was the computer world’s castle, lording over the valley below—and, at the time, this wasn’t far from the truth. In 1970, Xerox had assembled the world’s greatest computer engineers and programmers, and for the next ten years they had an unparalleled run of innovation and invention. If you were obsessed with the future in the seventies, you were obsessed with Xerox parc—which was why the young Steve Jobs had driven to Coyote Hill Road.

Apple was already one of the hottest tech firms in the country. Everyone in the Valley wanted a piece of it. So Jobs proposed a deal: he would allow Xerox to buy a hundred thousand shares of his company for a million dollars—its highly anticipated I.P.O. was just a year away—if parc would “open its kimono.” A lot of haggling ensued. Jobs was the fox, after all, and parc was the henhouse. What would he be allowed to see? What wouldn’t he be allowed to see? Some at parc thought that the whole idea was lunacy, but, in the end, Xerox went ahead with it. One parc scientist recalls Jobs as “rambunctious”—a fresh-cheeked, caffeinated version of today’s austere digital emperor. He was given a couple of tours, and he ended up standing in front of a Xerox Alto, parc’s prized personal computer.

An engineer named Larry Tesler conducted the demonstration. He moved the cursor across the screen with the aid of a “mouse.” Directing a conventional computer, in those days, meant typing in a command on the keyboard. Tesler just clicked on one of the icons on the screen. He opened and closed “windows,” deftly moving from one task to another. He wrote on an elegant word-processing program, and exchanged e-mails with other people at parc, on the world’s first Ethernet network. Jobs had come with one of his software engineers, Bill Atkinson, and Atkinson moved in as close as he could, his nose almost touching the screen. “Jobs was pacing around the room, acting up the whole time,” Tesler recalled. “He was very excited. Then, when he began seeing the things I could do onscreen, he watched for about a minute and started jumping around the room, shouting, ‘Why aren’t you doing anything with this? This is the greatest thing. This is revolutionary!’ ”

Xerox began selling a successor to the Alto in 1981. It was slow and underpowered—and Xerox ultimately withdrew from personal computers altogether. Jobs, meanwhile, raced back to Apple, and demanded that the team working on the company’s next generation of personal computers change course. He wanted menus on the screen. He wanted windows. He wanted a mouse. The result was the Macintosh, perhaps the most famous product in the history of Silicon Valley.

“If Xerox had known what it had and had taken advantage of its real opportunities,” Jobs said, years later, “it could have been as big as I.B.M. plus Microsoft plus Xerox combined—and the largest high-technology company in the world.”

This is the legend of Xerox parc. Jobs is the Biblical Jacob and Xerox is Esau, squandering his birthright for a pittance. In the past thirty years, the legend has been vindicated by history. Xerox, once the darling of the American high-technology community, slipped from its former dominance. Apple is now ascendant, and the demonstration in that room in Palo Alto has come to symbolize the vision and ruthlessness that separate true innovators from also-rans. As with all legends, however, the truth is a bit more complicated.

After Jobs returned from parc, he met with a man named Dean Hovey, who was one of the founders of the industrial-design firm that would become known as ideo. “Jobs went to Xerox parc on a Wednesday or a Thursday, and I saw him on the Friday afternoon,” Hovey recalled. “I had a series of ideas that I wanted to bounce off him, and I barely got two words out of my mouth when he said, ‘No, no, no, you’ve got to do a mouse.’ I was, like, ‘What’s a mouse?’ I didn’t have a clue. So he explains it, and he says, ‘You know, [the Xerox mouse] is a mouse that cost three hundred dollars to build and it breaks within two weeks. Here’s your design spec: Our mouse needs to be manufacturable for less than fifteen bucks. It needs to not fail for a couple of years, and I want to be able to use it on Formica and my bluejeans.’ From that meeting, I went to Walgreens, which is still there, at the corner of Grant and El Camino in Mountain View, and I wandered around and bought all the underarm deodorants that I could find, because they had that ball in them. I bought a butter dish. That was the beginnings of the mouse.”

I spoke with Hovey in a ramshackle building in downtown Palo Alto, where his firm had started out. He had asked the current tenant if he could borrow his old office for the morning, just for the fun of telling the story of the Apple mouse in the place where it was invented. The room was the size of someone’s bedroom. It looked as if it had last been painted in the Coolidge Administration. Hovey, who is lean and healthy in a Northern California yoga-and-yogurt sort of way, sat uncomfortably at a rickety desk in a corner of the room. “Our first machine shop was literally out on the roof,” he said, pointing out the window to a little narrow strip of rooftop, covered in green outdoor carpeting. “We didn’t tell the planning commission. We went and got that clear corrugated stuff and put it across the top for a roof. We got out through the window.”

He had brought a big plastic bag full of the artifacts of that moment: diagrams scribbled on lined paper, dozens of differently sized plastic mouse shells, a spool of guitar wire, a tiny set of wheels from a toy train set, and the metal lid from a jar of Ralph’s preserves. He turned the lid over. It was filled with a waxlike substance, the middle of which had a round indentation, in the shape of a small ball. “It’s epoxy casting resin,” he said. “You pour it, and then I put Vaseline on a smooth steel ball, and set it in the resin, and it hardens around it.” He tucked the steel ball underneath the lid and rolled it around the tabletop. “It’s a kind of mouse.”

VIDEO FROM THE NEW YORKER

**[Lisa Brennan-Jobs on the Shadow of Steve Jobs](https://www.newyorker.com/video/watch/the-new-yorker-interview-lisa-brennan-jobs-on-the-shadow-of-steve-jobs" \t "_blank)**

The hard part was that the roller ball needed to be connected to the housing of the mouse, so that it didn’t fall out, and so that it could transmit information about its movements to the cursor on the screen. But if the friction created by those connections was greater than the friction between the tabletop and the roller ball, the mouse would skip. And the more the mouse was used the more dust it would pick up off the tabletop, and the more it would skip. The Xerox parc mouse was an elaborate affair, with an array of ball bearings supporting the roller ball. But there was too much friction on the top of the ball, and it couldn’t deal with dust and grime.

At first, Hovey set to work with various arrangements of ball bearings, but nothing quite worked. “This was the ‘aha’ moment,” Hovey said, placing his fingers loosely around the sides of the ball, so that they barely touched its surface. “So the ball’s sitting here. And it rolls. I attribute that not to the table but to the oldness of the building. The floor’s not level. So I started playing with it, and that’s when I realized: I *want* it to roll. I don’t want it to be supported by all kinds of ball bearings. I want to just barely touch it.”

The trick was to connect the ball to the rest of the mouse at the two points where there was the least friction—right where his fingertips had been, dead center on either side of the ball. “If it’s right at midpoint, there’s no force causing it to rotate. So it rolls.”

Hovey estimated their consulting fee at thirty-five dollars an hour; the whole project cost perhaps a hundred thousand dollars. “I originally pitched Apple on doing this mostly for royalties, as opposed to a consulting job,” he recalled. “I said, ‘I’m thinking fifty cents apiece,’ because I was thinking that they’d sell fifty thousand, maybe a hundred thousand of them.” He burst out laughing, because of how far off his estimates ended up being. “Steve’s pretty savvy. He said no. Maybe if I’d asked for a nickel, I would have been fine.”

Here is the first complicating fact about the Jobs visit. In the legend of Xerox parc, Jobs stole the personal computer from Xerox. But the striking thing about Jobs’s instructions to Hovey is that he didn’t want to reproduce what he saw at parc. “You know, there were disputes around the number of buttons—three buttons, two buttons, one-button mouse,” Hovey went on. “The mouse at Xerox had three buttons. But we came around to the fact that learning to mouse is a feat in and of itself, and to make it as simple as possible, with just one button, was pretty important.”

So was what Jobs took from Xerox the idea of the mouse? Not quite, because Xerox never owned the idea of the mouse. The parc researchers got it from the computer scientist Douglas Engelbart, at Stanford Research Institute, fifteen minutes away on the other side of the university campus. Engelbart dreamed up the idea of moving the cursor around the screen with a stand-alone mechanical “animal” back in the mid- nineteen-sixties. His mouse was a bulky, rectangular affair, with what looked like steel roller-skate wheels. If you lined up Engelbart’s mouse, Xerox’s mouse, and Apple’s mouse, you would not see the serial reproduction of an object. You would see the evolution of a concept.

The same is true of the graphical user interface that so captured Jobs’s imagination. Xerox parc’s innovation had been to replace the traditional computer command line with onscreen icons. But when you clicked on an icon you got a pop-up menu: this was the intermediary between the user’s intention and the computer’s response. Jobs’s software team took the graphical interface a giant step further. It emphasized “direct manipulation.” If you wanted to make a window bigger, you just pulled on its corner and made it bigger; if you wanted to move a window across the screen, you just grabbed it and moved it. The Apple designers also invented the menu bar, the pull-down menu, and the trash can—all features that radically simplified the original Xerox parc idea.

**A Moveable Feast**

Outside Magazine, October 1990

Have I ever told you about how I invented the electronic book?  A love song to the Kindle, from a time long before the Kindle.

The helicopter was costing about $600 an hour and the dollars weren't mine and we looked to be overweight, so there came a moment outside the hangar when small, ruthless decisions had to be made.  Andy called it triage.  Andy is young and tough and deranged by love for his work, inured to going weeks at a time in wet, bloody socks on a diet of crackers and canned fish.  That is to say, he's a tropical ecologist.

The dollars in question belonged to him and his wife, Deb, doctoral students financing a wildly ambitious program of fieldwork in the highlands of Papua New Guinea from a handful of finite grants.  The helicopter was a little four-seater Hughes.  It could handle 450 kilograms, the pilot had told us.  On a series of trips to Andy and Deb's camp, it had moved hundred of kilos of rice, cases of beef-flavored crackers, cases of canned mackerel, cases of navy biscuit whatever that is, cases of corned meat loaf and some other suspicious canned substance labeled "lamb flaps," cases of cooking oil, cans of lard and or margarine, boxes full of beans and noodles and tomato paste and lentils and coffee and Milo and powdered milk, as well as two cassowary chicks in woven cages.  The cassowaries, large flightless birds of a species endemic to New Guinea, were intended for strictly experimental purposes, though the local people consider them good eating.  And now on this trip the helicopter would move us.  Four hundred and fifty kilos, period, inclusive of passengers and personal baggage and the breakfast we'd eaten that morning and any mud on our shoes.  It would be lifting us through bad weather, across 60 kilometers of razorback ridges, into a zone of roadless rainforest.  We gazed again at our modest but impossible pile of gear.  Which bits, in a pinch, were dispensable?

 The alternatives to triage were that I might ante up another 600 bucks myself or, still less appealing, that we might ballast ourselves to an unscheduled landing in the treetops.  All right, I said.  All right.  We'll leave my camera behind.  Both lenses.  The whole box.  Good, Andy said, that's a start.

 Well, this lump, I said, is just my sleeping bag.  Oh, you won't need that, we've got blankets, said Deb.  I carry a first-aid kit, I admitted guiltily.  Leave it, said Andy, there's plenty of medicine at the camp.  Mmmf, mmfffmmm, OK, this here is a filter pump for potable water, note how small, how compact, very handy item.  Totally unnecessary, said Deb, the stream is fine.  Sigh.  Reluctantly I removed from my pack a jar of oat-bran tablets.  And a plastic canteen.  And an emergency ration of dried apricots.  And then I stopped.

Do you have any books? asked Andy.

Books?  I put on my most vacant face.  Hey, look, maybe the clouds are opening.  Gee, it's already quarter past ten.  By the way, I'm skinnier than I look in this shirt.  What, oh, books?

Books, Andy said.  Won't need them.  We've got books galore out there.

I'd heard that one before.  Dick Francis, Robert Ludlum, Tom Robbins, and Principles of Dispersal in Higher Plants.  Many of the brightest people I know are ecologists, but generally they have no better idea of what constitutes good literature than I do of what constitutes multiple linear regression.  Dear God, I thought, no.  Not my books.

Ostentatiously I lightened my pack by the weight of two paperbacks.  Discreetly I kept a third.  It was a novel, The Silence of the Lambs, by Thomas Harris, of which I had read only the first chapter.  Not a great book, not a serious book, but skillful and engrossing.  And everyone has his own final, non-negotiable limit.  There's just so far a person is willing to go merely for the sake of avoiding a helicopter crash in the jungle.

I had reached my final, nonnegotiable limit.  One book.  I would read it slowly, read it twice.  I would surrender it when they pried off my cold, dead fingers.  Crank up the machine, I thought, and let's flly.

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Of course, it's not a dilemma unique to helicopters or to tropical forest.  It's inherent in travel itself.  Suitcases are too small, bookstores are scarce and mediocre, everything at the newsstand is in Portuguese or German or Malagasy, you've already reread all the best parts (for instance, Samuel) of the Gideon's Bible, and on the shelves of those charming and otherwise percipient folk you happen to be visiting sit Reader's Digest condensations, Pearl Buck, Sidney Sheldon, John D. MacDonald, The Exorcist, Agatha Christie, romances of the torn bodice school, Louis L'Amour, Carlos Castaneda, Douglas Adams, and the great starchy dumplings of James Michener.  Part of the essence of travel is relinquishing full control over the texture and path of your own life--and one aspect of that relinquishment is a chronic shortage of decent reading.

You can't plan your way around this dilemma.  But you try.  You fatten your luggage with a half-dozen paperbacks, books you intend to read and other fallbacks you might read, the lesser works of authors whose masterpieces you know, neglected classics for which you've never found time.  Over the weeks of your journey, you ration these treasures carefully and finish them all.  Then suddenly there's an unforeseen three-day delay at some Mongolian railway hotel while workers with small shovels pretend to be trying to clear an avalanche off the tracks.  Or you're stuck on an atoll because of a bad number-three engine, with parts to be sent in from Guam.  Or the monsoon arrived early, the river fords are impassable, the forest trails are flowing mud, and you have no option but to sit on a bamboo veranda murdering hours of your life.  Or a bag gets lost, say, and your last previous stash of rainy-day volumes is lost with it.  You can't plan for these things.  If you do supply yourself with a generous margin of books, then the delays and the rain don't happen, and you have built up your shoulder muscles and made the trip seem longer and harder by schlepping 30 pounds of superfluous paper halfway around the world.  In which case:  Next time you pack less, and then come the rain and delays.  It's not a problem that can be eluded by foresight.  You're out there, and you just have to live off the land.

You scan those bookshelves at airports and in hotels and guest cottages for the orange spine of anything published by Penguin.  Many of these Penguins you don't want to read, but still it's a useful heuristic.  You develop a grateful devotion to the handful of writers who, despite being hugely popular and widely available, also produce consistently fine work:  John le Carré, for instance.  And you reread your favorite among the hallowed standards, and reread them again, as often as luck offers them; by this method you come to memorize certain parts of The Sun Also Rises and All the King's Men.  Finally, in capitulation, you read things that otherwise you wouldn't.  Which is how you acquire your informed distaste for Dick Francis and Tom Robbins and Michener.  Do you have any other forms of recourse?

Well, there does happen to be one ingenious invention designed to cope with this problem.  But unfortunately it's not yet available in stores.

It's also not yet available in catalogs or warehouses or the R&D lab at Sony.  Even the prototype remains unbuilt.  Remember you heard it here, because this little gizmo is a surfboard-length out in front of even the breaking crest of microelectronic news.  My wife and I only invented it three weeks ago, over the dinner table, on the evening before I left for New Guinea.  We call it The Moveable Feast Compact Electronic Library.

It's the size and weight of one Gideon's Bible.  It runs on a rechargeable battery.  No traveler should be without one.

The MFCEL is so simple, I'm surprised someone else didn't think of it.  The book-like hardware contains just ten pagelike flaps, thin but sturdy, each of which is (on both sides) a backlit liquid-crystal display screen.  (Don't ask me how that works.  Engineering details are not my province.  Fiber optics, says my wife, whose province they aren't also.)  On the spine of this thing are two switches.  One turns it on.  The other is a two-way control:

Advance/Reverse.  Inside the back cover, where a library slip would go, is stored a packet of several dozen 64-megabit chips.  Each chip holds the entire text of a good book.  You choose a chip, fit the chip into a slot, and presto:  "All happy families are alike but an unhappy family is unhappy after its own fashion" et cetera, displaying on those crystal pages.  You read, turn a page, read, turn a page--because the physical act of turning pages is a sacred part of the reading experience that can never be replaced by electronic scrolling.  You read to page 20 and then press Advance, which automatically gives you the next 20.  You return to the front and begin reading them.

It fits in a briefcase.  It fits in a purse, in a daypack, in the side pocket of a Banana Republic vest.  With an adapter, it can be recharged anyplace.  It's probably bad for your eyes, but it might save your brain.  Also it glows with its own radiance, obviating the need for a headlamp when you're confined for 12-hour nights in a tent.  Within one of these little babies you can carry the Harvard Classics.  Better still, you can carry the best of Thomas Mann, Ford Maddox Ford, Bertrand Russell, Charles Darwin, Flaubert, Arthur Koestler, and Gabriel Garcia Márquez, as well as the complete works of Flannery O'Connor and Ray Carver.  On a single lonely journey you can have with you all of Graham Greene; think of the solace.  The only serious flaw of The Moveable Feast Compact Electronic Library is that, so far, it doesn't exist.

Now here comes a reckless admission.  The MFCEL hasn't been patented.  Truth is, I don't care so much about getting rich.  I just want to be able to read when I travel.  Somebody please build it.

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Andy Mack and Deb Wright-Mack have created their research camp in the New Guinea forest, a nine-hour hike from the nearest grass airstrip, and stocked it by helicopter with all manner of tools and amenities that you wouldn't expect in a biologists' bivouac.  But then it isn't a bivouac.  They call it Crater Mountain Biological Research Station and hope it might become something permanent.  They have built with their own hands--from raw logs and ax-hewn planks cut from them by their New Guinean assistants--a large house that can supply work space and dry shelter and hot food and running water and kerosene lighting and intermittent (depending upon the gasoline generator) electricity and peace of mind to a small handful of busy scientists.  In the process, they have caused minimal disruption to the forest around them, and the forest around them is spectacular.  They intend to stay at least a few years, maybe longer, and they welcome other biologists to consider joining them.  They have also been known to welcome a journalist.  What surprised me most about this triumph of logistics and provisioning was not the stainless steel kitchen sink, nor the plastic lawnchairs on which you can sit at dusk and watch white cockatoos cruising above distant treetops, nor the computer, nor the fluorescent-lit Formica worktable, nor the dissecting scope and soldering iron with which Deb manufactures tiny transmitters for radio-tracking, nor the cheerful sight of a bottle of Jim Beam, nor the daunting supply of wheatmeal crackers and lamb flaps, nor even the fact that I was offered a log bed on which lay an actual mattress.  What surprised me most was that Andy and Deb did have books galore, good books as well as the other kind, including quite a few in which even a persnickety snot like myself could find himself interested.

They had The Selfish Gene by Dawkins and The Growth of Biological Thought by Mayr and Ontogeny and Phylogeny by Gould and Adaptation and Natural Selection by Williams.  They had The Painted Bird by Kosinski and Our Man in Havana by Greene and The New Men by Snow and Crime and Punishment and some Greek plays and a volume containing "The Kreutzer Sonata" plus other short novels by Tolstoy.  They had, if I recall correctly, some Didion and some Bellow.  They had much more.  Under their sheet-metal roof, on their rough plank shelves, a day's march from the nearest flush toilet, they had not just a pile of junk reading but a smallish, humidity-warped, admirably diverse library.  Now they also have a copy of The Silence of the Lambs.

When I'd finished that bizarre novel, early on during my visit, I turned to something from the shelves--a book that I felt due to reread and that would certainly keep me occupied for more than few kerosene-lit evenings.  I opened Anna Karenina to "All happy families are alike but an unhappy family" et cetera, and suddenly Papua New Guinea was Russia.

When the time finally came for me to make that nine-hour hike downriver to the grass airstrip, I had barely gotten past the chapter in which Levin and Anna's brother go snipe-hunting.  I said grateful good-byes to Andy and Deb and Leo Tolstoy.  But you'll need something to read, said Deb, while you wait for the plane.  That was true, yet I didn't have the heart to ask for Anna Karenina; I knew it was much too precious right there where I'd found it.  Let me take something that's dispensable, I said.  They sent me off with Dick Francis.

Two days later, by foot and Cessna, I had reached the town of Goroka and was holed up at a little hotel run by Lutheran missionaries, while I waited for my international flight.  Like a junkie needing a fix, I nervously prowled the local newsstands and the Goroka public library.  By now I had reclaimed the rest of my gear, including the two paperbacks that hadn't made it aboard the helicopter.  But how far would those two have to be stretched?  What if my flight were delayed?  At the newsstands, no luck.  At the library I found Michener, Leon Uris, M\*A\*S\*H Goes to Las Vegas, an autobiography by Groucho Marx that (unlike Harpo's amazing autobiography) looked slapdash and unrewarding, and my favorite Raymond Chandler novel, The Long Good-bye, which I'd already read three times.  I took the Chandler as a fallback.  Then I picked carefully over the shelves at the Lutheran hotel, finding religious tracts in German, a Bible in New Guinea Pidgin, a three-year-old copy of Time magazine, and something I swear to God titled Clarence, the TV Dog.  In fairness to the Lutherans I'll admit there were quite a few others, but none that fit my needs.  Wait, though.  What's this?  My hand went to a thin black paperback sandwiched inconspicuously on a lower shelf.  I saw the name Hemingway, and I snatched it.

Next morning before dawn, with a cup of instant coffee scrounged from the kitchen while the Lutherans slept, I settled into this wonderful thin book.  "If you are lucky enough to have lived in Paris as a young man, then wherever you go for the rest of your life, it stays with you, for Paris is a moveable feast."  I had only read it once or twice before.

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[LIFE AFTER WARMING](https://nymag.com/intelligencer/tags/life-after-warming/) FEB. 4, 2019

**The Cautious Case for Climate Optimism**

Believing in a comfortable future for our planet probably means some giant carbon-sucking machines.

*By*[*David Wallace-Wells*](https://nymag.com/author/david-wallace-wells/)*Photo illustration by*[*Joe Darrow*](https://nymag.com/author/joe-darrow/)

Photo-Illustration: Joe Darrow/Sven Schabbach/Getty Images



Adapted from [*The Uninhabitable Earth*](https://www.amazon.com/Uninhabitable-Earth-Life-After-Warming/dp/0525576703?ots=1&slotNum=0&imprToken=74bd5d1b-86a5-2757-32a&tag=nymagcom-20&linkCode=w50), by David Wallace-Wells, to be published on February 19 by Tim Duggan Books, an imprint of Penguin Random House LLC. Copyright © 2019 by David Wallace-Wells.

**It’s not too late.** In fact, it never will be. Whatever you may have read over the past year — as extreme weather brought a global heat wave and [unprecedented wildfires](http://nymag.com/intelligencer/2018/11/the-california-fires-and-the-threat-of-climate-change.html) burned through 1.6 million California acres and newspaper headlines declared, “Climate Change Is Here” — global warming is not binary. It is not a matter of “yes” or “no,” not a question of “fucked” or “not.” Instead, it is a problem that gets worse over time the longer we produce greenhouse gas, and can be made better if we choose to stop. Which means that no matter how hot it gets, no matter how fully climate change transforms the planet and the way we live on it, it will always be the case that the next decade could contain more warming, and more suffering, or less warming and less suffering. Just how much is up to us, and always will be.

**My Week In *New York***

*A week-in-review newsletter from the people who make*New York *Magazine*.

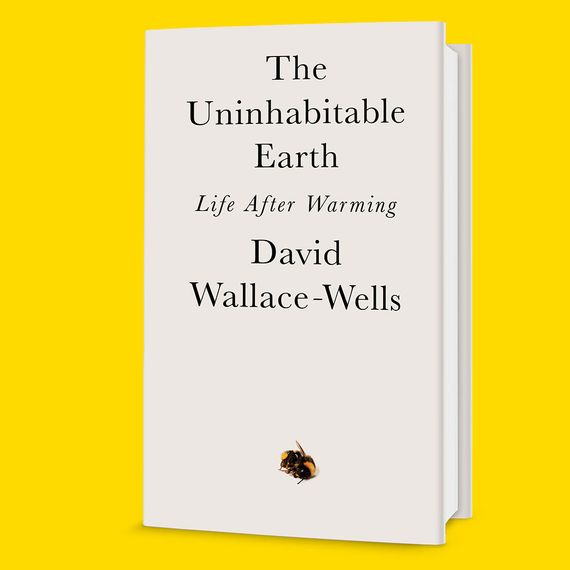
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A century and a half after the greenhouse effect was first identified, and a few decades since climate denial and misinformation began muddying our sense of what scientists do know, we are left with a set of predictions that can appear falsifiable — about global temperatures and sea-level rise and even hurricane frequency and wildfire volume. And there are, it is true, feedback loops in the climate system that we do not yet perfectly understand and dynamic processes that remain mysterious. But to the extent that we live today under clouds of uncertainty about the future of climate change, those clouds are, overwhelmingly, not projections of collective ignorance about the natural world but of blindness about the human one, and they can be dispersed by human action. The question of how bad things will get is not, actually, a test of the science; it is a bet on human activity. How much will we do to forestall disaster and how quickly?

These are the disconcerting, contradictory lessons of global warming, which counsels both human humility and human grandiosity, each drawn from the same perception of peril. There’s a name for those who hold the fate of the world in their hands, as we do — gods. But for the moment, at least, many of us seem inclined to run from that responsibility rather than embrace it. Or even admit we see it, though it sits in front of us as plainly as a steering wheel. That climate change is all-enveloping means that it targets us all and that we must all share in the responsibility so we do not all share in the suffering — at least not share in so suffocatingly much of it.

[[](https://www.amazon.com/Uninhabitable-Earth-Life-After-Warming/dp/0525576703?ots=1&slotNum=1&imprToken=74bd5d1b-86a5-2757-32a&tag=nymagcom-20&linkCode=w50)](https://www.amazon.com/Uninhabitable-Earth-Life-After-Warming/dp/0525576703?ots=1&slotNum=1&imprToken=74bd5d1b-86a5-2757-32a&tag=nymagcom-20&linkCode=w50)

**Since I first began** [writing about climate](http://nymag.com/intelligencer/2017/07/climate-change-earth-too-hot-for-humans.html) a few years ago, I’ve been asked often whether I see any reason for optimism. The thing is, I am optimistic. But optimism is always a matter of perspective, and mine is this: No one wants to believe disaster is coming, but those who look, do. At about two degrees Celsius of warming, just one degree north of where we are today, some of the planet’s ice sheets are expected to begin their collapse, eventually bringing, over centuries, perhaps as much as 50 feet of sea-level rise. In the meantime, major cities in the equatorial band of the planet will become unlivable. There will be, it has been estimated, 32 times as many extreme heat waves in India, and even in the northern latitudes, heat waves will kill thousands each summer. Given only conventional methods of decarbonization (replacing dirty-energy sources like coal and oil with clean ones like wind and solar), this is probably our best-case scenario. It is also what is called — so often nowadays the phrase numbs the lips — “catastrophic warming.” A representative from the Marshall Islands spoke for many of the world’s island nations when he used another word to describe the meaning of two degrees: *genocide.*

You do not need to contemplate worst-case scenarios to be alarmed; this best-case scenario is alarming enough. Two degrees would be terrible, but it’s better than three, at which point Southern Europe would be in permanent drought, African droughts would last five years on average, and the areas burned annually by wildfires in the United States could quadruple, or worse, from last year’s million-plus acres. And three degrees is much better than four, at which point six natural disasters could strike a single community simultaneously; the number of climate refugees, already in the millions, could grow tenfold, or 20-fold, or more; and, globally, damages from warming could reach $600 trillion — about double all the wealth that exists in the world today. We are on track for more warming still — just above four degrees by 2100, the U.N. estimates. So if optimism is always a matter of perspective, the possibility of four degrees shapes mine.

It is unlikely, I think, that we reach four degrees this century. But this is what it would take to stay under two: a comprehensively decarbonized economy, a perfectly renewable energy system, a reimagined system of agriculture, perhaps even a planet without meat-eaters. We also need overhauls of the world’s transportation systems and infrastructure. Every year the average American emits enough carbon to melt 10,000 tons of ice in the Antarctic ice sheets — enough to add 10,000 cubic meters of water to the ocean. Every minute, we each add five gallons.

If the task of reversing all that seems incomprehensibly big, it is. The scale of the technological transformation required dwarfs every technological revolution ever engineered in human history, including electricity and telecommunications and even the invention of agriculture 10,000 years ago. By definition, it dwarfs them, because it contains all of them — every single sector needs to be rebuilt from the foundation, since every single one breathes on carbon like it’s a ventilator. In October, the [U.N.’s Intergovernmental Panel on Climate Change warned](http://nymag.com/intelligencer/2018/10/un-says-climate-genocide-coming-but-its-worse-than-that.html) that the world has only a dozen years to halve its carbon emissions to safely avoid two degrees of warming and all those “catastrophic” impacts.

Is it possible? The short answer is, technically speaking, maybe — though just maybe. But speaking practically, and politically, is another matter.

Let’s consider the tools at hand. First: a [carbon tax](http://nymag.com/intelligencer/2018/10/a-carbon-tax-cant-solve-climate-change-but-we-should-do-it.html). The very same day the IPCC [released](https://report.ipcc.ch/sr15/pdf/sr15_spm_final.pdf) its “Doomsday” report, the Nobel Prize in economics was awarded to William Nordhaus, who pioneered the economic study of climate change and is known today primarily for having championed the idea of carbon pricing. The premise is simple: Legislate a high enough cost on the stuff and the market will respond by producing less, then eventually none, of it. It is also an appealing proposition to those who don’t want to see the economy truly upended; to those who trust that market forces will deliver the outcomes they are predicted to; to those who believe that the world would trust action on climate only if it came for free or, better yet, with economic benefits; and to those who believe that action would otherwise involve, invariably, a trade-off — that climate action of any meaningful scale would be expensive, probably too expensive for any growth-minded country to countenance.

Over the past several years, there has been a raft of papers showing that the intuitive terms of that bargain are backward: Faster action on climate will save or gain the world enormous amounts of money ($26 trillion in potential growth by just 2030, according to one estimate; those $600 trillion in damages avoided by the end of the century, according to another). But the labor involved in such a transformation makes it seem burdensome anyway, and so the hope of the market solving the problem on its own — with the help of just a little incentive-setting — has prevailed, at least among a certain set.

In January, 45 economists described by [Bloomberg](https://www.bloomberg.com/news/articles/2019-01-17/from-greenspan-to-yellen-economic-brain-trust-backs-carbon-tax) as both “an all-star lineup” and the world’s “economic brain trust” united behind the cause of a gradually increasing carbon tax, though they did not name their starting price, which is a crucial variable. For his part, Nordhaus has identified pricing for an “optimal” scenario: between $35 and $229 per ton of CO2, a tax that, by his own estimate, could result in 3.5 degrees Celsius of warming by 2100. That is 1.5 degrees warmer than that island-nation “genocide.”

A carbon tax is hypothetical for Americans, which may be one reason they tend to be optimistic about it. But there are already, today, many places with existing carbon pricing — South Korea, Japan, the E.U. None of their emissions are declining fast enough to meet a goal of two degrees, according to the carbon-watchdog site [Climate Action Tracker](https://climateactiontracker.org/). It is conceivable, even probable, that at much higher levels of taxation, the impact would be clearer. But as Jay Inslee, the governor of bright-green Washington State, which tried and failed to enact such a tax in 2018, recently [put it](https://www.nbcnews.com/politics/2020-election/defeated-twice-top-climate-change-crusader-has-wake-call-some-n957691), “To actually get carbon savings, you have to jack up the price so high that it becomes politically untenable.”

The longer we wait, the steeper the declines will have to be. If the world as a whole had begun decarbonization in the year 2000, when Al Gore collected half a million more votes in the presidential election than George W. Bush, emissions would have had to fall by 3 percent per year to achieve climate stability at two degrees; if we begin now, we will have to cut them by 10 percent each year; if we wait another decade, the cuts will be enormous, 30 percent per year, to even hope for warming levels below “genocide.” Last year, Nordhaus’s own nephew Ted wrote in [*Foreign Affairs*](https://www.foreignaffairs.com/articles/world/2018-03-07/truth-about-two-degree-target) that the dream of keeping the world under two degrees of warming, under any approach, was simply naïve.

**The carbon tax** is the solution favored by business. On the left, another possible approach has emerged: massive public investment and public works, both directed toward replacing dirty energy sources with clean ones and producing, along the way, an entirely renewable economy. In other words, the [Green New Deal](http://nymag.com/intelligencer/2018/12/what-is-the-green-new-deal-explained-revolution.html).

The term may seem like a response to our very present tense of climate panic, but it has bounced around for a while. It was used by Van Jones, Obama’s green-jobs adviser, in 2008 and formed the centerpiece of Jill Stein’s 2012 and 2016 campaigns, not that too many people took note. This year, under that same banner, Alexandria Ocasio-Cortez has rallied an astonishing level of political and policy energy around it — Cory Booker and Kamala Harris and Elizabeth Warren have already endorsed the plan, and many of their fellow aspiring nominees will surely follow. Their endorsements were for only a set of goals, as the proposal was still being hammered into legislation when they attached their support. The initial concept offered only one extremely ambitious goal — decarbonizing the American economy entirely by 2030 — and a number of other commitments that have excited many on the left whose political priorities may not be so climate-focused. That is: to use the economic stimulus of green-energy investment “to virtually eliminate poverty in the United States and to make prosperity, wealth, and economic security available to everyone participating in the transformation.”

These proposals are worthy, invigorating, and — believe it or not — popular. I’m all for them. Unfortunately, they are also, on their own, not enough. As a strategy of avoiding that same threshold of two degrees of warming, the investments of a Green New Deal are what logicians call “necessary but insufficient.”

This is not a reflection of the modesty of the legislation, which is not at all modest — in fact, it is perhaps the most ambitious bill put forward in congress in three quarters of a century. It is simply a reflection of the scale of the challenge. In its report, the IPCC compared the transformation required to stay safely below two degrees to the mobilization of World War II. That mobilization was unprecedented in human history and has never been matched since. That time, there was a draft, a nationalization of industry, widespread rationing: The entire American nation turned single-mindedly toward the relevant threat, as did the entire Russian nation — and the two of them, almost inconceivably, in retrospect, allied. That is the kind of mobilization the sober-minded scientists of the world believe is necessary today — to get to half of our current emissions by 2030. Is it possible? Well, just about anything is possible, as the total mobilization of the nation in World War II shows you. But it recently took New York City 45 years to build three new stops on a single subway line.

And if such a Green New Deal transformation within the U.S. were possible, it would affect only one country in the world, a country producing only 15 percent of global emissions. This is the second reason the Green New Deal is, on its own, insufficient. Last year, China was responsible for more than a quarter of emissions — and that figure does not account for any of the massive infrastructure projects the country is undertaking across Asia and Africa as part of its “Belt and Road” initiative to remake highways and ports and airports throughout those continents. If the cement industry were a country, it would be the world’s third-largest emitter, and China is now pouring more concrete in a span of three years than the United States poured during the entire 20th century.

# Forty years of the internet: how the world changed for ever

In October 1969, a student typed 'LO' on a computer - and the internet was born



Internet business cables in California. Photograph: Bob Sacha/Corbis



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Fri 23 Oct 2009 08.00 BST

**T**owards the end of the summer of 1969 – a few weeks after the moon landings, a few days after Woodstock, and a month before the first broadcast of Monty Python's Flying Circus – a large grey metal box was delivered to the office of Leonard Kleinrock, a professor at the University of California in Los Angeles. It was the same size and shape as a household refrigerator, and outwardly, at least, it had about as much charm. But Kleinrock was thrilled: a photograph from the time shows him standing beside it, in requisite late-60s brown tie and brown trousers, beaming like a proud father.

Had he tried to explain his excitement to anyone but his closest colleagues, they probably wouldn't have understood. The few outsiders who knew of the box's existence couldn't even get its name right: it was an IMP, or "interface message processor", but the year before, when a Boston company had won the contract to build it, its local senator, Ted Kennedy, sent a telegram praising its ecumenical spirit in creating the first "interfaith message processor". Needless to say, though, the box that arrived outside Kleinrock's office wasn't a machine capable of fostering understanding among the great religions of the world. It was much more important than that.

It's impossible to say for certain when the internet began, mainly because nobody can agree on what, precisely, the internet is. (This is only partly a philosophical question: it is also a matter of egos, since several of the people who made key contributions are anxious to claim the credit.) But 29 October 1969 – 40 years ago next week – has a strong claim for being, as Kleinrock puts it today, "the day the infant internet uttered its first words". At 10.30pm, as Kleinrock's fellow professors and students crowded around, a computer was connected to the IMP, which made contact with a second IMP, attached to a second computer, several hundred miles away at the Stanford Research Institute, and an undergraduate named Charley Kline tapped out a message. Samuel Morse, sending the first telegraph message 125 years previously, chose the portentous phrase: "What hath God wrought?" But Kline's task was to log in remotely from LA to the Stanford machine, and there was no opportunity for portentousness: his instructions were to type the command LOGIN.

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To say that the rest is history is the emptiest of cliches – but trying to express the magnitude of what began that day, and what has happened in the decades since, is an undertaking that quickly exposes the limits of language. It's interesting to compare how much has changed in computing and the internet since 1969 with, say, how much has changed in world politics. Consider even the briefest summary of how much has happened on the global stage since 1969: the Vietnam war ended; the cold war escalated then declined; the Berlin Wall fell; communism collapsed; Islamic fundamentalism surged. And yet nothing has quite the power to make people in their 30s, 40s or 50s feel very old indeed as reflecting upon the growth of the internet and the world wide web. Twelve years after Charley Kline's first message on the Arpanet, as it was then known, there were still only 213 computers on the network; but 14 years after that, 16 million people were online, and email was beginning to change the world; the first really usable web browser wasn't launched until 1993, but by 1995 we had Amazon, by 1998 Google, and by 2001, Wikipedia, at which point there were 513 million people online. Today the figure is more like 1.7 billion.

Unless you are 15 years old or younger, you have lived through the dotcom bubble and bust, the birth of Friends Reunited and Craigslist and eBay and Facebook and [Twitter](https://www.theguardian.com/technology/twitter), blogging, the browser wars, Google Earth, filesharing controversies, the transformation of the record industry, political campaigning, activism and campaigning, the media, publishing, consumer banking, the pornography industry, travel agencies, dating and retail; and unless you're a specialist, you've probably only been following the most attention-grabbing developments. Here's one of countless statistics that are liable to induce feelings akin to vertigo: on New Year's Day 1994 – only yesterday, in other words – there were an estimated 623 websites. In total. On the whole internet. "This isn't a matter of ego or crowing," says Steve Crocker, who was present that day at UCLA in 1969, "but there has not been, in the entire history of mankind, anything that has changed so dramatically as computer communications, in terms of the rate of change."

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Looking back now, Kleinrock and Crocker are both struck by how, as young computer scientists, they were simultaneously aware that they were involved in something momentous and, at the same time, merely addressing a fairly mundane technical problem. On the one hand, they were there because of the Russian Sputnik satellite launch, in 1957, which panicked the American defence establishment, prompting Eisenhower to channel millions of dollars into scientific research, and establishing Arpa, the Advanced Research Projects Agency, to try to win the arms technology race. The idea was "that we would not get surprised again," said Robert Taylor, the Arpa scientist who secured the money for the Arpanet, persuading the agency's head to give him a million dollars that had been earmarked for ballistic missile research. With another pioneer of the early internet, JCR Licklider, Taylor co-wrote the paper, "The Computer As A Communication Device", which hinted at what was to come. "In a few years, men will be able to communicate more effectively through a machine than face to face," they declared. "That is rather a startling thing to say, but it is our conclusion."

On the other hand, the breakthrough accomplished that night in 1969 was a decidedly down-to-earth one. The Arpanet was not, in itself, intended as some kind of secret weapon to put the Soviets in their place: it was simply a way to enable researchers to access computers remotely, because computers were still vast and expensive, and the scientists needed a way to share resources. (The notion that the network was designed so that it would survive a nuclear attack is an urban myth, though some of those involved sometimes used that argument to obtain funding.) The technical problem solved by the IMPs wasn't very exciting, either. It was already possible to link computers by telephone lines, but it was glacially slow, and every computer in the network had to be connected, by a dedicated line, to every other computer, which meant you couldn't connect more than a handful of machines without everything becoming monstrously complex and costly. The solution, called "packet switching" – which owed its existence to the work of a British physicist, Donald Davies – involved breaking data down into blocks that could be routed around any part of the network that happened to be free, before getting reassembled at the other end.

"I thought this was important, but I didn't really think it was as challenging as what I thought of as the 'real research'," says Crocker, a genial Californian, now 65, who went on to play a key role in the expansion of the internet. "I was particularly fascinated, in those days, by artificial intelligence, and by trying to understand how people think. I thought that was a much more substantial and respectable research topic than merely connecting up a few machines. That was certainly useful, but it wasn't art."

Still, Kleinrock recalls a tangible sense of excitement that night as Kline sat down at the SDS Sigma 7 computer, connected to the IMP, and at the same time made telephone contact with his opposite number at Stanford. As his colleagues watched, he typed the letter L, to begin the word LOGIN.

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"Have you got the L?" he asked, down the phone line. "Got the L," the voice at Stanford responded.

Kline typed an O. "Have you got the O?"

"Got the O," Stanford replied.

Kline typed a G, at which point the system crashed, and the connection was lost. The G didn't make it through, which meant that, quite by accident, the first message ever transmitted across the nascent internet turned out, after all, to be fittingly biblical:

"LO."

**Frenzied visions of a global conscious brain**

One of the most intriguing things about the growth of the internet is this: to a select group of technological thinkers, the surprise wasn't how quickly it spread across the world, remaking business, culture and politics – but that it took so long to get off the ground. Even when computers were mainly run on punch-cards and paper tape, there were whispers that it was inevitable that they would one day work collectively, in a network, rather than individually. (Tracing the origins of online culture even further back is some people's idea of an entertaining game: there are those who will tell you that the Talmud, the book of Jewish law, contains a form of hypertext, the linking-and-clicking structure at the heart of the web.) In 1945, the American presidential science adviser, Vannevar Bush, was already imagining the "memex", a device in which "an individual stores all his books, records, and communications", which would be linked to each other by "a mesh of associative trails", like weblinks. Others had frenzied visions of the world's machines turning into a kind of conscious brain. And in 1946, an astonishingly complete vision of the future appeared in the magazine Astounding Science Fiction. In a story entitled A Logic Named Joe, the author Murray Leinster envisioned a world in which every home was equipped with a tabletop box that he called a "logic":

"You got a logic in your house. It looks like a vision receiver used to, only it's got keys instead of dials and you punch the keys for what you wanna get . . . you punch 'Sally Hancock's Phone' an' the screen blinks an' sputters an' you're hooked up with the logic in her house an' if somebody answers you got a vision-phone connection. But besides that, if you punch for the weather forecast [or] who was mistress of the White House durin' Garfield's administration . . . that comes on the screen too. The relays in the tank do it. The tank is a big buildin' full of all the facts in creation . . . hooked in with all the other tanks all over the country . . . The only thing it won't do is tell you exactly what your wife meant when she said, 'Oh, you think so, do you?' in that peculiar kinda voice "

Despite all these predictions, though, the arrival of the internet in the shape we know it today was never a matter of inevitability. It was a crucial idiosyncracy of the Arpanet that its funding came from the American defence establishment – but that the millions ended up on university campuses, with researchers who embraced an anti-establishment ethic, and who in many cases were committedly leftwing; one computer scientist took great pleasure in wearing an anti-Vietnam badge to a briefing at the Pentagon. Instead of smothering their research in the utmost secrecy – as you might expect of a cold war project aimed at winning a technological battle against Moscow – they made public every step of their thinking, in documents known as Requests For Comments.

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Deliberately or not, they helped encourage a vibrant culture of hobbyists on the fringes of academia – students and rank amateurs who built their own electronic bulletin-board systems and eventually FidoNet, a network to connect them to each other. An argument can be made that these unofficial tinkerings did as much to create the public internet as did the Arpanet. Well into the 90s, by the time the Arpanet had been replaced by NSFNet, a larger government-funded network, it was still the official position that only academic researchers, and those affiliated to them, were supposed to use the network. It was the hobbyists, making unofficial connections into the main system, who first opened the internet up to allcomers.

What made all of this possible, on a technical level, was simultaneously the dullest-sounding and most crucial development since Kleinrock's first message. This was the software known as TCP/IP, which made it possible for networks to connect to other networks, creating a "network of networks", capable of expanding virtually infinitely – which is another way of defining what the internet is. It's for this reason that the inventors of TCP/IP, Vint Cerf and Bob Kahn, are contenders for the title of fathers of the internet, although Kleinrock, understandably, disagrees. "Let me use an analogy," he says. "You would certainly not credit the birth of aviation to the invention of the jet engine. The Wright Brothers launched aviation. Jet engines greatly improved things."

The spread of the internet across the Atlantic, through academia and eventually to the public, is a tale too intricate to recount here, though it bears mentioning that British Telecom and the British government didn't really want the internet at all: along with other European governments, they were in favour of a different networking technology, Open Systems Interconnect. Nevertheless, by July 1992, an Essex-born businessman named Cliff Stanford had opened Demon [Internet](https://www.theguardian.com/technology/internet), Britain's first commercial internet service provider. Officially, the public still wasn't meant to be connecting to the internet. "But it was never a real problem," Stanford says today. "The people trying to enforce that weren't working very hard to make it happen, and the people working to do the opposite were working much harder." The French consulate in London was an early customer, paying Demon £10 a month instead of thousands of pounds to lease a private line to Paris from BT.

After a year or so, Demon had between 2,000 and 3,000 users, but they weren't always clear why they had signed up: it was as if they had sensed the direction of the future, in some inchoate fashion, but hadn't thought things through any further than that. "The question we always got was: 'OK, I'm connected – what do I do now?'" Stanford recalls. "It was one of the most common questions on our support line. We would answer with 'Well, what do you want to do? Do you want to send an email?' 'Well, I don't know anyone with an email address.' People got connected, but they didn't know what was meant to happen next."

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Fortunately, a couple of years previously, a British scientist based at Cern, the physics laboratory outside Geneva, had begun to answer that question, and by 1993 his answer was beginning to be known to the general public. What happened next was the web.

**The birth of the web**

I sent my first email in 1994, not long after arriving at university, from a small, under-ventilated computer room that smelt strongly of sweat. Email had been in existence for decades by then – the @ symbol was introduced in 1971, and the first message, according to the programmer who sent it, Ray Tomlinson, was "something like QWERTYUIOP". (The test messages, Tomlinson has said, "were entirely forgettable, and I have, therefore, forgotten them".) But according to an unscientific poll of friends, family and colleagues, 1994 seems fairly typical: I was neither an early adopter nor a late one. A couple of years later I got my first mobile phone, which came with two batteries: a very large one, for normal use, and an extremely large one, for those occasions on which you might actually want a few hours of power. By the time I arrived at the Guardian, email was in use, but only as an add-on to the internal messaging system, operated via chunky beige terminals with green-on-black screens. It took for ever to find the @ symbol on the keyboard, and I don't remember anything like an inbox, a sent-mail folder, or attachments. I am 34 years old, but sometimes I feel like Methuselah.

I have no recollection of when I first used the world wide web, though it was almost certainly when people still called it the world wide web, or even W3, perhaps in the same breath as the phrase "information superhighway", made popular by Al Gore. (Or "infobahn": did any of us really, ever, call the internet the "infobahn"?) For most of us, though, the web is in effect synonymous with the internet, even if we grasp that in technical terms that's inaccurate: the web is simply a system that sits on top of the internet, making it greatly easier to navigate the information there, and to use it as a medium of sharing and communication. But the distinction rarely seems relevant in everyday life now, which is why its inventor, Tim Berners-Lee, has his own legitimate claim to be the progenitor of the internet as we know it. The first ever website was his own, at CERN: info.cern.ch.

The idea that a network of computers might enable a specific new way of thinking about information, instead of just allowing people to access the data on each other's terminals, had been around for as long as the idea of the network itself: it's there in Vannevar Bush's memex, and Murray Leinster's logics. But the grandest expression of it was Project Xanadu, launched in 1960 by the American philosopher Ted Nelson, who imagined – and started to build – a vast repository for every piece of writing in existence, with everything connected to everything else according to a principle he called "transclusion". It was also, presciently, intended as a method for handling many of the problems that would come to plague the media in the age of the internet, automatically channelling small royalties back to the authors of anything that was linked. Xanadu was a mind-spinning vision – and at least according to an unflattering portrayal by Wired magazine in 1995, over which Nelson threatened to sue, led those attempting to create it into a rabbit-hole of confusion, backbiting and "heart-slashing despair". Nelson continues to develop Xanadu today, arguing that it is a vastly superior alternative to the web. "WE FIGHT ON," the Xanadu website declares, sounding rather beleaguered, not least since the declaration is made on a website.

Web browsers crossed the border into mainstream use far more rapidly than had been the case with the internet itself: Mosaic launched in 1993 and Netscape followed soon after, though it was an embarrassingly long time before Microsoft realised the commercial necessity of getting involved at all. Amazon and eBay were online by 1995. And in 1998 came Google, offering a powerful new way to search the proliferating mass of information on the web. Until not too long before Google, it had been common for search or directory websites to boast about how much of the web's information they had indexed – the relic of a brief period, hilarious in hindsight, when a user might genuinely have hoped to check all the webpages that mentioned a given subject. Google, and others, saw that the key to the web's future would be helping users exclude almost everything on any given topic, restricting search results to the most relevant pages.

Without most of us quite noticing when it happened, the web went from being a strange new curiosity to a background condition of everyday life: I have no memory of there being an intermediate stage, when, say, half the information I needed on a particular topic could be found online, while the other half still required visits to libraries. "I remember the first time I saw a web address on the side of a truck, and I thought, huh, OK, something's happening here," says Spike Ilacqua, who years beforehand had helped found The World, the first commercial internet service provider in the US. Finally, he stopped telling acquaintances that he worked in "computers", and started to say that he worked on "the internet", and nobody thought that was strange.

It is absurd – though also unavoidable here – to compact the whole of what happened from then onwards into a few sentences: the dotcom boom, the historically unprecedented dotcom bust, the growing "digital divide", and then the hugely significant flourishing, over the last seven years, of what became known as Web 2.0. It is only this latter period that has revealed the true capacity of the web for "generativity", for the publishing of blogs by anyone who could type, for podcasting and video-sharing, for the undermining of totalitarian regimes, for the use of sites such as Twitter and Facebook to create (and ruin) friendships, spread fashions and rumours, or organise political resistance. But you almost certainly know all this: it's part of what these days, in many parts of the world, we call "just being alive".

The most confounding thing of all is that in a few years' time, all this stupendous change will probably seem like not very much change at all. As Crocker points out, when you're dealing with exponential growth, the distance from A to B looks huge until you get to point C, whereupon the distance between A and B looks like almost nothing; when you get to point D, the distance between B and C looks similarly tiny. One day, presumably, everything that has happened in the last 40 years will look like early throat-clearings — mere preparations for whatever the internet is destined to become. We will be the equivalents of the late-60s computer engineers, in their horn-rimmed glasses, brown suits, and brown ties, strange, period-costume characters populating some dimly remembered past.

Will you remember when the web was something you accessed primarily via a computer? Will you remember when there were places you couldn't get a wireless connection? Will you remember when "being on the web" was still a distinct concept, something that described only a part of your life, instead of permeating all of it? Will you remember Google?

# The Science of Why We Don’t Believe Science

## How our brains fool us on climate, creationism, and the vaccine-autism link.

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**Illustration: Jonathon Rosen**

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**“A MAN WITH A CONVICTION** is a hard man to change. Tell him you disagree and he turns away. Show him facts or figures and he questions your sources. Appeal to logic and he fails to see your point.” So wrote the celebrated Stanford University psychologist [Leon Festinger](https://motherjones.com/wp-content/uploads/lfestinger.pdf) (PDF), in a passage that might have been referring to climate change denial—the persistent rejection, on the part of so many Americans today, of what we know about global warming and its human causes. But it was too early for that—this was the 1950s—and Festinger was actually describing a [famous case study](http://www.powells.com/biblio/61-9781617202803-1) in psychology.

Festinger and several of his colleagues had infiltrated the Seekers, a small Chicago-area cult whose members thought they were communicating with aliens—including one, “Sananda,” who they believed was the astral incarnation of Jesus Christ. The group was led by Dorothy Martin, a Dianetics devotee who transcribed the interstellar messages through automatic writing.

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Through her, the aliens had given the precise date of an Earth-rending cataclysm: December 21, 1954. Some of Martin’s followers quit their jobs and sold their property, expecting to be rescued by a flying saucer when the continent split asunder and a new sea swallowed much of the United States. The disciples even went so far as to remove brassieres and rip zippers out of their trousers—the metal, they believed, would pose a danger on the spacecraft.

Festinger and his team were with the cult when the prophecy failed. First, the “boys upstairs” (as the aliens were sometimes called) did not show up and rescue the Seekers. Then December 21 arrived without incident. It was the moment Festinger had been waiting for: How would people so emotionally invested in a belief system react, now that it had been soundly refuted?

[](http://motherjones.com/environment/2011/04/history-of-climategate)**Read also:**[**the truth about Climategate**](http://motherjones.com/environment/2011/04/field-guide-climate-change-skeptics)**.**At first, the group struggled for an explanation. But then rationalization set in. A new message arrived, announcing that they’d all been spared at the last minute. Festinger summarized the extraterrestrials’ new pronouncement: “The little group, sitting all night long, had spread so much light that God had saved the world from destruction.” Their willingness to believe in the prophecy had saved Earth from the prophecy!

From that day forward, the Seekers, previously shy of the press and indifferent toward evangelizing, began to proselytize. “Their sense of urgency was enormous,” wrote Festinger. The devastation of all they had believed had made them even more certain of their beliefs.

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In the annals of denial, it doesn’t get much more extreme than the Seekers. They lost their jobs, the press mocked them, and there were efforts to keep them away from impressionable young minds. But while Martin’s space cult might lie at on the far end of the spectrum of human self-delusion, there’s plenty to go around. And since Festinger’s day, an array of new discoveries in psychology and neuroscience has further demonstrated how our preexisting beliefs, far more than any new facts, can skew our thoughts and even color what we consider our most dispassionate and logical conclusions. This tendency toward so-called “[motivated reasoning](http://www.ncbi.nlm.nih.gov/pubmed/2270237)” helps explain why we find groups so polarized over matters where the evidence is so unequivocal: climate change, vaccines, “death panels,” the birthplace and [religion of the president](http://www-personal.umich.edu/~bnyhan/obama-muslim.pdf) (PDF), and much else. It would seem that expecting people to be convinced by the facts flies in the face of, you know, the facts.

The theory of motivated reasoning builds on a [key insight of modern neuroscience](https://motherjones.com/wp-content/uploads/descartes.pdf) (PDF): Reasoning is actually suffused with emotion (or what researchers often call “affect”). Not only are the two inseparable, but our positive or negative feelings about people, things, and ideas arise much more rapidly than our conscious thoughts, in a matter of milliseconds—fast enough to detect with an EEG device, but long before we’re aware of it. That shouldn’t be surprising: Evolution required us to react very quickly to stimuli in our environment. It’s a “basic human survival skill,” explains political scientist [Arthur Lupia](http://www-personal.umich.edu/~lupia/) of the University of Michigan. We push threatening information away; we pull friendly information close. We apply fight-or-flight reflexes not only to predators, but to data itself.

We apply fight-or-flight reflexes not only to predators, but to data itself.

We’re not driven only by emotions, of course—we also reason, deliberate. But reasoning comes later, works slower—and even then, it doesn’t take place in an emotional vacuum. Rather, our quick-fire emotions can set us on a course of thinking that’s highly biased, especially on topics we care a great deal about.

Consider a person who has heard about a scientific discovery that deeply challenges her belief in divine creation—a new hominid, say, that confirms our evolutionary origins. What happens next, explains political scientist [Charles Taber](http://www.stonybrook.edu/polsci/ctaber/) of Stony Brook University, is a subconscious negative response to the new information—and that response, in turn, guides the type of memories and associations formed in the conscious mind. “They retrieve thoughts that are consistent with their previous beliefs,” says Taber, “and that will lead them to build an argument and challenge what they’re hearing.”

In other words, when we think we’re reasoning, we may instead be rationalizing. Or to use an analogy offered by University of Virginia psychologist [Jonathan Haidt](http://people.virginia.edu/~jdh6n/): We may think we’re being scientists, but [we’re actually being lawyers](https://motherjones.com/wp-content/uploads/emotional_dog_and_rational_tail.pdf) (PDF). Our “reasoning” is a means to a predetermined end—winning our “case”—and is shot through with biases. They include “confirmation bias,” in which we give greater heed to evidence and arguments that bolster our beliefs, and “disconfirmation bias,” in which we expend disproportionate energy trying to debunk or refute views and arguments that we find uncongenial.

That’s a lot of jargon, but we all understand these mechanisms when it comes to interpersonal relationships. If I don’t want to believe that my spouse is being unfaithful, or that my child is a bully, I can go to great lengths to explain away behavior that seems obvious to everybody else—everybody who isn’t too emotionally invested to accept it, anyway. That’s not to suggest that we aren’t also motivated to perceive the world accurately—we are. Or that we never change our minds—we do. It’s just that we have other important goals besides accuracy—including identity affirmation and protecting one’s sense of self—and often those make us highly resistant to changing our beliefs when the facts say we should.

Modern science originated from an attempt to weed out such subjective lapses—what that great 17th century theorist of the scientific method, Francis Bacon, dubbed the “idols of the mind.” Even if individual researchers are prone to falling in love with their own theories, the broader processes of peer review and institutionalized skepticism are designed to ensure that, eventually, the best ideas prevail.

Scientific evidence is highly susceptible to misinterpretation. Giving ideologues scientific data that’s relevant to their beliefs is like unleashing them in the motivated-reasoning equivalent of a candy store.

Our individual responses to the conclusions that science reaches, however, are quite another matter. Ironically, in part because researchers employ so much nuance and strive to disclose all remaining sources of uncertainty, scientific evidence is highly susceptible to selective reading and misinterpretation. Giving ideologues or partisans scientific data that’s relevant to their beliefs is like unleashing them in the motivated-reasoning equivalent of a candy store.

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Sure enough, a large number of psychological studies have shown that people respond to scientific or technical evidence in ways that justify their preexisting beliefs. In [a classic 1979 experiment](http://synapse.princeton.edu/~sam/lord_ross_lepper79_JPSP_biased-assimilation-and-attitude-polarization.pdf) (PDF), pro- and anti-death penalty advocates were exposed to descriptions of two fake scientific studies: one supporting and one undermining the notion that capital punishment deters violent crime and, in particular, murder. They were also shown detailed methodological critiques of the fake studies—and in a scientific sense, neither study was stronger than the other. Yet in each case, advocates more heavily criticized the study whose conclusions disagreed with their own, while describing the study that was more ideologically congenial as more “convincing.”

Since then, similar results have been found for how people respond to “evidence” about affirmative action, gun control, the [accuracy of gay stereotypes](http://psp.sagepub.com/content/23/6/636.abstract), and much else. Even when study subjects are explicitly instructed to be unbiased and even-handed about the evidence, they often fail.

And it’s not just that people twist or selectively read scientific evidence to support their preexisting views. According to research by Yale Law School professor [Dan Kahan](http://www.law.yale.edu/faculty/DKahan.htm) and his colleagues, people’s deep-seated views about morality, and about the way society should be ordered, strongly predict whom they consider to be a legitimate scientific expert in the first place—and thus where they consider “scientific consensus” to lie on contested issues.

In [Kahan’s research](https://motherjones.com/wp-content/uploads/kahan_paper_cultural_cognition_of_scientific_consesus.pdf) (PDF), individuals are classified, based on their cultural values, as either “individualists” or “communitarians,” and as either “hierarchical” or “egalitarian” in outlook. (Somewhat oversimplifying, you can think of hierarchical individualists as akin to conservative Republicans, and egalitarian communitarians as liberal Democrats.) In one study, subjects in the different groups were asked to help a close friend determine the risks associated with climate change, sequestering nuclear waste, or concealed carry laws: “The friend tells you that he or she is planning to read a book about the issue but would like to get your opinion on whether the author seems like a knowledgeable and trustworthy expert.” A subject was then presented with the résumé of a fake expert “depicted as a member of the National Academy of Sciences who had earned a Ph.D. in a pertinent field from one elite university and who was now on the faculty of another.” The subject was then shown a book excerpt by that “expert,” in which the risk of the issue at hand was portrayed as high or low, well-founded or speculative. The results were stark: When the scientist’s position stated that global warming is real and human-caused, for instance, only 23 percent of hierarchical individualists agreed the person was a “trustworthy and knowledgeable expert.” Yet 88 percent of egalitarian communitarians accepted the same scientist’s expertise. Similar divides were observed on whether nuclear waste can be safely stored underground and whether letting people carry guns deters crime. (The alliances did not always hold. In [another study](http://digitalcommons.law.yale.edu/cgi/viewcontent.cgi?article=1095&context=fss_papers) (PDF), hierarchs and communitarians were in favor of laws that would compel the mentally ill to accept treatment, whereas individualists and egalitarians were opposed.)

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Head-on attempts to persuade can sometimes trigger a backfire effect, where people not only fail to change their minds when confronted with the facts—they may hold their wrong views more tenaciously than ever.

In other words, people rejected the validity of a scientific source because its conclusion contradicted their deeply held views—and thus the relative risks inherent in each scenario. A hierarchal individualist finds it difficult to believe that the things he prizes ([commerce, industry, a man’s freedom to possess a gun to defend his family](http://digitalcommons.law.yale.edu/cgi/viewcontent.cgi?article=1095&context=fss_papers)) (PDF) could lead to outcomes deleterious to society. Whereas egalitarian communitarians tend to think that the free market causes harm, that patriarchal families mess up kids, and that people can’t handle their guns. The study subjects weren’t “anti-science”—not in their own minds, anyway. It’s just that “science” was whatever they wanted it to be. “We’ve come to a misadventure, a bad situation where diverse citizens, who rely on diverse systems of cultural certification, are in conflict,” [says Kahan](http://seagrant.oregonstate.edu/blogs/communicatingclimate/transcripts/Episode_10b_Dan_Kahan.html).

And that undercuts the standard notion that the way to persuade people is via evidence and argument. In fact, head-on attempts to persuade can sometimes trigger a backfire effect, where people not only fail to change their minds when confronted with the facts—they may hold their wrong views more tenaciously than ever.

Take, for instance, the question of whether Saddam Hussein possessed hidden weapons of mass destruction just before the US invasion of Iraq in 2003. When political scientists Brendan Nyhan and Jason Reifler [showed subjects fake newspaper articles](http://www-personal.umich.edu/~bnyhan/nyhan-reifler.pdf) (PDF) in which this was first suggested (in a 2004 quote from President Bush) and then refuted (with the findings of the Bush-commissioned Iraq Survey Group report, which found no evidence of active WMD programs in pre-invasion Iraq), they found that conservatives were more likely than before to believe the claim. (The researchers also tested how liberals responded when shown that Bush did not actually “ban” embryonic stem-cell research. Liberals weren’t particularly amenable to persuasion, either, but no backfire effect was observed.)

Another study gives some inkling of what may be going through people’s minds when they resist persuasion. Northwestern University sociologist [Monica Prasad](http://www.sociology.northwestern.edu/faculty/prasad/home.html) and her colleagues wanted to test whether they could dislodge the notion that Saddam Hussein and Al Qaeda were secretly collaborating among those most likely to believe it—Republican partisans from highly GOP-friendly counties. So the researchers set up [a study](http://sociology.buffalo.edu/documents/hoffmansocinquiryarticle_000.pdf) (PDF) in which they discussed the topic with some of these Republicans in person. They would cite the findings of the 9/11 Commission, as well as a statement in which George W. Bush himself denied his administration had “said the 9/11 attacks were orchestrated between Saddam and Al Qaeda.”

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One study showed that not even Bush’s own words could change the minds of Bush voters who believed there was an Iraq-Al Qaeda link.

As it turned out, not even Bush’s own words could change the minds of these Bush voters—just 1 of the 49 partisans who originally believed the Iraq-Al Qaeda claim changed his or her mind. Far more common was resisting the correction in a variety of ways, either by coming up with counterarguments or by simply being unmovable:

**Interviewer:** [T]he September 11 Commission found no link between Saddam and 9/11, and this is what President Bush said. Do you have any comments on either of those?

**Respondent:** Well, I bet they say that the Commission didn’t have any proof of it but I guess we still can have our opinions and feel that way even though they say that.

The same types of responses are already being documented on divisive topics facing the current administration. Take the “Ground Zero mosque.” Using information from the political myth-busting site [FactCheck.org](http://www.factcheck.org/), a team at Ohio State [presented subjects](http://www.comm.ohio-state.edu/kgarrett/FactcheckMosqueRumors.pdf) (PDF) with a detailed rebuttal to the claim that “Feisal Abdul Rauf, the Imam backing the proposed Islamic cultural center and mosque, is a terrorist-sympathizer.” Yet among those who were aware of the rumor and believed it, fewer than a third changed their minds.

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A key question—and one that’s difficult to answer—is how “irrational” all this is. On the one hand, it doesn’t make sense to discard an entire belief system, built up over a lifetime, because of some new snippet of information. “It is quite possible to say, ‘I reached this pro-capital-punishment decision based on real information that I arrived at over my life,'” explains Stanford social psychologist [Jon Krosnick](http://communication.stanford.edu/faculty/krosnick/). Indeed, there’s a sense in which science denial could be considered keenly “rational.” In certain conservative communities, explains Yale’s Kahan, “People who say, ‘I think there’s something to climate change,’ that’s going to mark them out as a certain kind of person, and their life is going to go less well.”

This may help explain a curious pattern Nyhan and his colleagues found when they [tried to test the fallacy](http://www-personal.umich.edu/~bnyhan/obama-muslim.pdf) (PDF) that President Obama is a Muslim. When a nonwhite researcher was administering their study, research subjects were amenable to changing their minds about the president’s religion and updating incorrect views. But when only white researchers were present, GOP survey subjects in particular were more likely to believe the Obama Muslim myth than before. The subjects were using “social desirabililty” to tailor their beliefs (or stated beliefs, anyway) to whoever was listening.

Which leads us to the media. When people grow polarized over a body of evidence, or a resolvable matter of fact, the cause may be some form of biased reasoning, but they could also be receiving skewed information to begin with—or a complicated combination of both. In the Ground Zero mosque case, for instance, [a follow-up study](http://www.comm.ohio-state.edu/kgarrett/MediaMosqueRumors.pdf) (PDF) showed that survey respondents who watched Fox News were more likely to believe the Rauf rumor and three related ones—and they believed them more strongly than non-Fox watchers.

Okay, so people gravitate toward information that confirms what they believe, and they select sources that deliver it. Same as it ever was, right? Maybe, but the problem is arguably growing more acute, given the way we now consume information—through the Facebook links of friends, or tweets that lack nuance or context, or “[narrowcast](http://en.wikipedia.org/wiki/Narrowcasting)” and often highly ideological media that have relatively small, like-minded audiences. Those basic human survival skills of ours, says Michigan’s Arthur Lupia, are “not well-adapted to our information age.”

A predictor of whether you accept the science of global warming? Whether you’re a Republican or a Democrat.

If you wanted to show how and why fact is ditched in favor of motivated reasoning, you could find no better test case than climate change. After all, it’s an issue where you have highly technical information on one hand and very strong beliefs on the other. And sure enough, one key predictor of whether you accept the science of global warming is whether you’re a Republican or a Democrat. The two groups have been growing more divided in their views about the topic, even as the science becomes more unequivocal.

So perhaps it should come as no surprise that more education doesn’t budge Republican views. On the contrary: In [a 2008 Pew survey](http://people-press.org/report/417/a-deeper-partisan-divide-over-global-warming), for instance, only 19 percent of college-educated Republicans agreed that the planet is warming due to human actions, versus 31 percent of non-college educated Republicans. In other words, a higher education correlated with an increased likelihood of denying the science on the issue. Meanwhile, among Democrats and independents, more education correlated with greater acceptance of the science.

Other studies have shown a similar effect: Republicans who think they understand the global warming issue best are least concerned about it; and among Republicans and those with higher levels of distrust of science in general, learning more about the issue doesn’t increase one’s concern about it. What’s going on here? Well, according to Charles Taber and Milton Lodge of Stony Brook, one insidious aspect of motivated reasoning is that political sophisticates are prone to be more biased than those who know less about the issues. “People who have a dislike of some policy—for example, abortion—if they’re unsophisticated they can just reject it out of hand,” says Lodge. “But if they’re sophisticated, they can go one step further and start coming up with counterarguments.” These individuals are just as emotionally driven and biased as the rest of us, but they’re able to generate more and better reasons to explain why they’re right—and so their minds become harder to change.

That may be why the selectively quoted emails of Climategate were so quickly and easily seized upon by partisans as evidence of scandal. Cherry-picking is precisely the sort of behavior you would expect motivated reasoners to engage in to bolster their views—and whatever you may think about Climategate, the emails were a rich trove of new information upon which to impose one’s ideology.

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Climategate had a substantial impact on public opinion, according to [Anthony Leiserowitz](http://environment.yale.edu/profile/leiserowitz/), director of the [Yale Project on Climate Change Communication](http://environment.yale.edu/climate/). It contributed to an overall drop in public concern about climate change and a significant loss of trust in scientists. But—as we should expect by now—these declines were concentrated among particular groups of Americans: Republicans, conservatives, and those with “individualistic” values. Liberals and those with “egalitarian” values didn’t lose much trust in climate science or scientists at all. “In some ways, Climategate was like a Rorschach test,” Leiserowitz says, “with different groups interpreting ambiguous facts in very different ways.”

Is there a case study of science denial that largely occupies the political left? Yes: the claim that childhood vaccines are causing an epidemic of autism.

So is there a case study of science denial that largely occupies the political left? Yes: the claim that childhood vaccines are causing an epidemic of autism. Its most famous proponents are an environmentalist ([Robert F. Kennedy Jr.](http://www.huffingtonpost.com/robert-f-kennedy-jr-and-david-kirby/vaccine-court-autism-deba_b_169673.html)) and numerous Hollywood celebrities (most notably [Jenny McCarthy](http://www.huffingtonpost.com/jenny-mccarthy/vaccine-autism-debate_b_806857.html) and Jim Carrey). The Huffington Post gives a very large megaphone to denialists. And [Seth Mnookin](http://sethmnookin.com/), author of the new book [The Panic Virus](http://www.powells.com/biblio/1-9781439158647-0), notes that if you want to find vaccine deniers, all you need to do is go hang out at Whole Foods.

Vaccine denial has all the hallmarks of a belief system that’s not amenable to refutation. Over the past decade, the assertion that childhood vaccines are driving autism rates [has been undermined](http://discovermagazine.com/2009/jun/06-why-does-vaccine-autism-controversy-live-on/article_print) by multiple epidemiological studies—as well as the simple fact that autism rates continue to rise, even though the alleged offending agent in vaccines (a mercury-based preservative called thimerosal) has long since been removed.

Yet the true believers persist—critiquing each new study that challenges their views, and even rallying to the defense of vaccine-autism researcher Andrew Wakefield, after [his 1998 Lancet paper](http://www.thelancet.com/journals/lancet/article/PIIS0140673697110960/fulltext)—which originated the current vaccine scare—was retracted and he subsequently [lost his license](http://www.gmc-uk.org/Wakefield_SPM_and_SANCTION.pdf_32595267.pdf) (PDF) to practice medicine. But then, why should we be surprised? Vaccine deniers created their own partisan media, such as the website Age of Autism, that instantly blast out critiques and counterarguments whenever any new development casts further doubt on anti-vaccine views.

It all raises the question: Do left and right differ in any meaningful way when it comes to biases in processing information, or are we all equally susceptible?

There are some clear differences. Science denial today is considerably more prominent on the political right—once you survey climate and related environmental issues, anti-evolutionism, attacks on reproductive health science by the Christian right, and stem-cell and biomedical matters. More tellingly, anti-vaccine positions are virtually nonexistent among Democratic officeholders today—whereas anti-climate-science views are becoming monolithic among Republican elected officials.

Some researchers have suggested that there are psychological differences between the left and the right that might impact responses to new information—that conservatives are more rigid and authoritarian, and liberals more tolerant of ambiguity. Psychologist John Jost of New York University has further argued that conservatives are “system justifiers”: They engage in motivated reasoning to defend the status quo.

This is a contested area, however, because as soon as one tries to psychoanalyze inherent political differences, a battery of counterarguments emerges: What about dogmatic and militant communists? What about how the parties have differed through history? After all, the most canonical case of ideologically driven science denial is probably the rejection of genetics in the Soviet Union, where researchers disagreeing with the anti-Mendelian scientist (and Stalin stooge) Trofim Lysenko were executed, and genetics itself was denounced as a “bourgeois” science and officially banned.

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The upshot: All we can currently bank on is the fact that we all have blinders in some situations. The question then becomes: What can be done to counteract human nature itself?

We all have blinders in some situations. The question then becomes: What can be done to counteract human nature?

Given the power of our prior beliefs to skew how we respond to new information, one thing is becoming clear: If you want someone to accept new evidence, make sure to present it to them in a context that doesn’t trigger a defensive, emotional reaction.

This theory is gaining traction in part because of Kahan’s work at Yale. In [one study](http://www.scribd.com/doc/3446682/The-Second-National-Risk-and-Culture-Study-Making-Sense-of-and-Making-Progress-In-The-American-Culture-War-of-Fact), he and his colleagues packaged the basic science of climate change into fake newspaper articles bearing two very different headlines—”Scientific Panel Recommends Anti-Pollution Solution to Global Warming” and “Scientific Panel Recommends Nuclear Solution to Global Warming”—and then tested how citizens with different values responded. Sure enough, the latter framing made hierarchical individualists much more open to accepting the fact that humans are causing global warming. Kahan infers that the effect occurred because the science had been written into an alternative narrative that appealed to their pro-industry worldview.

You can follow the logic to its conclusion: Conservatives are more likely to embrace climate science if it comes to them via a business or religious leader, who can set the issue in the context of different values than those from which environmentalists or scientists often argue. Doing so is, effectively, to signal a détente in what Kahan has called a “culture war of fact.” In other words, paradoxically, you don’t lead with the facts in order to convince. You lead with the values—so as to give the facts a fighting chance.

# The World’s Most Efficient Languages

How much do you really need to say to put a sentence together?

By [John McWhorter](https://www.theatlantic.com/author/john-mcwhorter/)



Runners in front of Brandenburg Gate at the start of the 35th Berlin marathon (Pawel Kopczynski / Reuters)

JUNE 29, 2016

SHARE

Just as fish presumably don’t know they’re wet, many English speakers don’t know that the way their language works is just one of endless ways it could have come out. It’s easy to think that what one’s native language puts words to, and how, reflects the fundamentals of reality.

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But languages are strikingly different in the level of detail they require a speaker to provide in order to put a sentence together. In English, for example, here’s a simple sentence that comes to my mind for rather specific reasons related to having small children: “The father said ‘Come here!’” This statement specifies that there is a father, that he conducted the action of speaking in the past, and that he indicated the child should approach him at the location “here.” What else would a language need to do?

Well, for a German speaker, more. In “*Der Vater sagte ‘Komm her!’”*, although it just seems like a variation on the English sentence, more is happening. *“Der,”*the word for “the,” is a choice among other possibilities: It’s the one used for masculine nouns only. If the sentence were about a mother, it would have to use the feminine *die*, or if about a girl, the neuter *das* (for reasons unnecessary to broach here!). The word for “said,” *sagte*, is marked with a suffix for the third-person singular; if it were “*you* said,” then it would be *sagtest*—in English, those forms don’t vary in the past tense. Then, *her* for “here” means “to here”: In German one must become what feels to an English speaker rather Shakespearean and say “hither” when that’s what is meant. “Here” in the sense of just sitting “here” is a different word, *hier*.

## RECOMMENDED READING

### [**The World’s Most Musical Languages**](https://www.theatlantic.com/international/archive/2015/11/tonal-languages-linguistics-mandarin/415701/)

* [](https://www.theatlantic.com/international/archive/2021/07/uyghur-chronicles/619446/)

### [**One by One, My Friends Were Sent to the Camps**](https://www.theatlantic.com/international/archive/2021/07/uyghur-chronicles/619446/)

[TAHIR HAMUT IZGIL](https://www.theatlantic.com/author/tahir-hamut-izgil/)

* [](https://www.theatlantic.com/international/archive/2021/07/euro-2020-england-patriotism/619382/)

### [**What Euro 2020 Has Revealed About Englishness**](https://www.theatlantic.com/international/archive/2021/07/euro-2020-england-patriotism/619382/)

[YASMEEN SERHAN](https://www.theatlantic.com/author/yasmeen-serhan/)

This German sentence, then, requires you to pay more attention to the genders of people and things, to whether it’s me, you, her, him, us, y’all, or them driving the action. It also requires specifying not just where someone is but whether that person is moving closer or farther away. German is, overall, busier than English, and yet Germans feel their way of putting things is as normal as English speakers feel their way is.

Other languages occupy still other places on the linguistic axis of “busyness,” from prolix to laconic, and it’s surprising what a language can do without. In Mandarin Chinese, a way of saying “The father said ‘Come here!’” is “*Fùqīn shuō ‘Guò lái zhè lǐ!’”* Just as in English, there is no marker for the father’s gender, nor does the form of the word *shuō* for “said*”* indicate whether the speaker is me, you, or him. The word for “here,” *zhè lǐ*, can mean either “right here” or “to here,” just like in English. But Mandarin is even more telegraphic. There is no definite article like “the.” The word for “said” lacks not only a suffix for person, but is also not marked for tense; it just means “say.” It is assumed that context will indicate that this event happened in the past. Much of learning Mandarin involves getting a sense of how much one can *not* say in an acceptable sentence.

Moreover, anyone who has sampled Chinese, or Persian, or Finnish, knows that a language can get along just fine with the same word for “he” and “she.”[\*](https://www.theatlantic.com/international/archive/2016/06/complex-languages/489389/#Correction) And whereas Mandarin *can*mark tense but often doesn’t, in the Maybrat language of New Guinea, there’s pretty much no way to mark it at all**—**context takes care of it and no one bats an eye.

If there were a prize for the busiest language, then a language like Kabardian, also known as Circassian and spoken in the Caucasus, would win. In the simple sentence “The men saw me,” the word for “saw” is *sǝq’ayǝƛaaɣwǝaɣhaś* (pronounced roughly “suck-a-LAGH-a-HESH”**).**This seems like a majestic monster of a word, and yet despite its air of “supercalifragilisticexpealidocious,” the word for “saw” is every bit as ordinary for Kabardian-speakers as English-speakers’ “saw” is for them. It’s just that Kabardian-speakers have to pack so much more into their version. In *sǝq’ayǝƛaaɣwǝaɣhaś*, other than the part meaning “see,” there is a bit that reiterates that it’s me who was seen, even though the sentence would include a separate word for “me” elsewhere. Then there are other bits that show that the seeing was most significant to “me” rather than to the men or anyone else; that the seeing was done by more than one person (despite the sentence spelling out elsewhere that it was plural “men” who did the seeing); that this event did not happen in the present; that on top of this, the event happened specifically in the past rather than the future; and finally a bit indicating that the speaker really means what he’s saying.

Is a Kabardian shopkeeper in the Caucasus more exquisitely attuned to the nuances of experience than a Riau Indonesian-speaking fisherman in Sumatra?

The prize for most economical language could go to certain colloquial dialects of Indonesian that are [rarely written](https://www.amazon.com/Austronesian-Languages-Madagascar-Routledge-Language/dp/0415681537/ref=sr_1_1?s=books&ie=UTF8&qid=1466519301&sr=1-1&keywords=austronesian+routledge) but represent the daily reality of Indonesian in millions of mouths. For example, in the Riau dialect spoken in Sumatra, *ayam* means chicken and *makan* means eat, but “*Ayam makan”* doesn’t mean only “The chicken is eating.” Depending on context, “*Ayam makan”* can mean the “chickens are eating,” “a chicken is eating,” “the chicken is eating,” “the chicken will be eating,” “the chicken eats,” “the chicken has eaten,” “someone is eating the chicken,” “someone is eating for the chicken,” “someone is eating with the chicken,” “the chicken that is eating,” “where the chicken is eating,” and “when the chicken is eating.” If chickens and eating are *à propos*, the assumption is that everybody in the conversation knows what’s what. Thus for a wide variety of situations the equivalent of “chicken eat” will do—and does.

So does the contrast between Riau Indonesian’s “chicken eat” and Kabardian’s “they saw me and it affected me, not now, and I really mean it” mean that each language gives its speakers a different way of looking at the world? It’s an intriguing idea, first formulated by anthropologist and linguist Edward Sapir and amateur linguist (and fire inspector!) Benjamin Whorf. If it were correct, an English-speaker would generally think about the past more than a Chinese-speaker would, while Germans would think more about movement than Americans or Brits.

Experiments have [shown](http://www.casasanto.com/papers/Casasanto_2004_CogSci_TimeEstimation.pdf) that this is often true to a faint, flickering degree a psychologist can detect in the artifice of experimental conditions. But does this mean a different way of experiencing life? Is a Kabardian shopkeeper in the Caucasus more exquisitely attuned to the nuances of experience than a Riau Indonesian-speaking fisherman in Sumatra? If that Kabardian shopkeeper’s jam-packed verbs mean that he vibrates in tune to the jots and tittles of life, then doesn’t one have to say that the Riau Indonesian speaker, whose grammar directs his attention to so few details, is something of a limp string on the guitar? We would run into similarly hopeless comparisons around the world. The Zulu speaker would be hypervigilant given the complexities of his language, the Samoan speaker inattentive given the less obsessively complicated nature of hers.

If thought and culture aren’t why some languages pile it on while others take it light, then what is the reason? Part of the answer is unsatisfying but powerful: chance. Time and repetition wear words out, and what wears away is often a nugget of meaning. This happens in some languages more than others. Think of the French song “*Alouette*, *gentille alouette* …” (“lark, nice lark”) in which one sings “ahh-loo-eh-*tuh.*” In running speech the word has long been pronounced just “ah-loo-ett” with no -*uh* at the end. That *–uh* in the song today is a leftover from the way the word actually was once pronounced normally, and it indicated the word’s feminine gender to the listener. Today, beyond marginal contexts like that song, only the final *e* in the spelling of *alouette*indicates its gender; hearing it in a sentence we’d have to rely on the definite article *la* alone to know that the word is feminine.

Even if languages’ differences in busyness can’t be taken as windows on psychological alertness, the differences remain awesome.

In a language where final sounds take the accent, such sounds tend to hold on longer because they are so loud and clear—you’re less likely to mumble it and people listening are more likely to hear it. In Hebrew, “Thank you very much,” is “*Toda raba*,” pronounced “toe-DAH rah-BAH.” The sounds at the end of the word mark gender in Hebrew, too, and they aren’t going anywhere anytime soon because they are enunciated with force.

When a language seems especially telegraphic, usually another factor has come into play: Enough adults learned it at a certain stage in its history that, given the difficulty of learning a new language after childhood, it became a kind of stripped-down “schoolroom” version of itself. Because all languages, are, to some extent, busier than they need to be, this streamlining leaves the language thoroughly complex and nuanced, just lighter on the bric-a-brac that so many languages pant under. Even today, Indonesian is a first language to only [one in four of its speakers](http://bps.go.id/index.php/publikasi/14); the language has been used for many centuries as a lingua franca in a vast region, imposed on speakers of several hundred languages. This means that while other languages can be like overgrown lawns, Indonesian’s grammar has been regularly mowed, such that especially the colloquial forms are tidier. Lots of adult learning over long periods of time is also why, for example, the colloquial forms of Arabic like Egyptian and Moroccan are somewhat less elaborated than Modern Standard Arabic—they were imposed on new people as Islam spread after the seventh century.

In contrast, one cannot help suspecting that not too many adults have been tackling the likes of *sǝq’ayǝƛaaɣwǝaɣhaś*. Kabardian has been left to its own devices, and my, has it hoarded a lot of them. This is, as languages go, normal, even if Kabardian is rather extreme. By contrast, only a few languages have been taken up as vehicles of empire and imposed on millions of unsuspecting and underqualified adults. Long-dominant Mandarin, then, is less “busy” than Cantonese and Taiwanese, which have been imposed on fewer people. English came out the way it did because Vikings, who in the first millennium forged something of an empire of their own in northern and western Europe, imposed themselves on the Old English of the people they invaded and, as it were, mowed it. German, meanwhile, stayed “normal.”

Even if languages’ differences in busyness can’t be taken as windows on psychological alertness, the differences remain awesome. In a Native American language of California called Atsugewi (now extinct), if a tree was burned and we found the ashes in a creek afterward, we would have said that soot *w’oqhputíc’ta* into the creek. *W’oqhputíc’ta* is a conglomeration of bits that mean “it moved like dirt, in a falling fashion, into liquid, and for real.” In English, we would just say “flowed.”

**S**ometimes it seems surprising that science functions at all. In 2005, medical science was shaken by a paper with the provocative title “Why most published research findings are false.”**1** Written by John Ioannidis, a professor of medicine at Stanford University, it didn’t actually show that any particular result was wrong. Instead, it showed that the statistics of reported positive findings was not consistent with how often one should *expect* to find them. As Ioannidis concluded more recently, “many published research findings are false or exaggerated, and an estimated 85 percent of research resources are wasted.”**2**

It’s likely that some researchers are consciously cherry-picking data to get their work published. And some of the problems surely lie with journal publication policies. But the problems of false findings often begin with researchers unwittingly fooling themselves: they fall prey to cognitive biases, common modes of thinking that lure us toward wrong but convenient or attractive conclusions. “Seeing the reproducibility rates in psychology and other empirical science, we can safely say that something is not working out the way it should,” says Susann Fiedler, a behavioral economist at the Max Planck Institute for Research on Collective Goods in Bonn, Germany. “Cognitive biases might be one reason for that.”

Psychologist Brian Nosek of the University of Virginia says that the most common and problematic bias in science is “motivated reasoning”: We interpret observations to fit a particular idea. Psychologists have shown that “most of our reasoning is in fact rationalization,” he says. In other words, we have already made the decision about what to do or to think, and our “explanation” of our reasoning is really a justification for doing what we wanted to do—or to believe—anyway. Science is of course meant to be more objective and skeptical than everyday thought—but how much is it, really?

*I was aware of biases in humans at large, but when I first “learned” that they also apply to scientists, I was somewhat amazed, even though it is so obvious.*

Whereas the falsification model of the scientific method championed by philosopher Karl Popper posits that the scientist looks for ways to test and falsify her theories—to ask “How am I wrong?”—Nosek says that scientists usually ask instead “How am I right?” (or equally, to ask “How are *you*wrong?”). When facts come up that suggest we might, in fact, not be right after all, we are inclined to dismiss them as irrelevant, if not indeed mistaken. The now infamous “cold fusion” episode in the late 1980s, instigated by the electrochemists Martin Fleischmann and Stanley Pons, was full of such ad hoc brush-offs. For example, when it was pointed out to Fleischmann and Pons that their energy spectrum of the gamma rays from their claimed fusion reaction had its spike at the wrong energy, they simply moved it, muttering something ambiguous about calibration.

[](https://nautil.us/issue/24/Error/how-the-biggest-fabricator-in-science-got-caught)

[**ALSO IN SCIENCE PRACTICE**](https://nautil.us/term/f/Science%20Practice)

#### [**How the Biggest Fabricator in Science Got Caught**](https://nautil.us/issue/24/Error/how-the-biggest-fabricator-in-science-got-caught)

By Adam Marcus & Ivan Oransky

In April of 2000, the journal Anesthesia & Analgesia published a letter to its editor from Peter Kranke and two colleagues that was fairly dripping with sarcasm. The trio of academic anesthesiologists took aim at an article published by a...[**READ MORE**](https://nautil.us/issue/24/Error/how-the-biggest-fabricator-in-science-got-caught)

Statistics may seem to offer respite from bias through strength in numbers, but they are just as fraught. Chris Hartgerink of Tilburg University in the Netherlands works on the influence of “human factors” in the collection of statistics. He points out that researchers often attribute false certainty to contingent statistics. “Researchers, like people generally, are bad at thinking about probabilities,” he says. While some results are sure to be false negatives—that is, results that appear incorrectly to rule something out—Hartgerink says he has never read a paper that concludes as much about its findings. His recent research shows that as many as two in three psychology papers reporting non-significant results may be overlooking false negatives.**3**

Given that science has uncovered a dizzying variety of cognitive biases, the relative neglect of their consequences within science itself is peculiar. “I was aware of biases in humans at large,” says Hartgerink, “but when I first ‘learned’ that they also apply to scientists, I was somewhat amazed, even though it is so obvious.”

**CAN YOU BELIEVE IT?:** In 1989, Martin Fleischmann and Stanley Pons claimed to have produced a fusion reaction at room temperature in a test tube (mockup shown above). When it was pointed out to them that the energy spectrum of the gamma rays emanating from their claimed reaction had its spike at the wrong energy, they simply moved the spike.George Frey/Getty Images

**A**common response to this situation is to argue that, even if individual scientists might fool themselves, others have no hesitation in critiquing their ideas or their results, and so it all comes out in the wash: Science as a communal activity is self-correcting. Sometimes this is true—but it doesn’t necessarily happen as quickly or smoothly as we might like to believe.

Nosek thinks that peer review might sometimes actively hinder clear and swift testing of scientific claims. He points out that, when in 2011 a team of physicists in Italy [reported evidence of neutrinos](http://nautil.us/issue/24/error/the-data-that-threatened-to-break-physics) that apparently moved faster than light (in violation of Einstein’s theory of special relativity), this astonishing claim was made,**4** examined, and refuted**5, 6** very quickly thanks to high-energy physicists’ efficient system of distributing preprints of papers through an open-access repository. If that testing had relied on the usual peer-reviewed channels, it could have taken years.

Similarly when researchers suggested in *Science* in 2010 that arsenic might substitute for phosphorus in the DNA of some microbe—a claim that would have rewritten the fundamental chemical principles of life—one of the researchers who conducted follow-up studies to try to replicate the findings felt it important to document her on-going results on an open-source blog. This was in contrast to the original research team, who were criticized for failing to report any subsequent evidence in support of their controversial claim.**7**

Peer review seems to be a more fallible instrument—especially in areas such as medicine and psychology—than is often appreciated, as the emerging “[crisis of replicability](http://nautil.us/issue/24/error/how-the-biggest-fabricator-in-science-got-caught)” attests. Medical reporter Ivan Oransky and science editor Adam Marcus, who run the service Retraction Watch, put it this way: “When science works as designed, subsequent findings augment, alter or completely undermine earlier research … The problem is that in science—or, more accurately, scientific publishing—this process seldom works as directed … Much, if not most, of what gets published today in a scientific journal is only somewhat likely to hold up if another lab tries the experiment again, and, chances are, maybe not even that.”**8**

One of the reasons the science literature gets skewed is that journals are much more likely to publish positive than negative results: It’s easier to say something is true than to say it’s wrong. Journal referees might be inclined to reject negative results as too boring, and researchers currently get little credit or status, from funders or departments, from such findings. “If you do 20 experiments, one of them is likely to have a publishable result,” Oransky and Marcus write. “But only publishing that result doesn’t make your findings valid. In fact it’s quite the opposite.”**9**

*“Like many graduate students, my idealism about how science works was shattered when I took research methods.”*

Oransky believes that, while all of the incentives in science reinforce confirmation biases, the exigencies of publication are among the most problematic. “To get tenure, grants, and recognition, scientists need to publish frequently in major journals,” he says. “That encourages positive and ‘breakthrough’ findings, since the latter are what earn citations and impact factor. So it’s not terribly surprising that scientists fool themselves into seeing perfect groundbreaking results among their experimental findings.”

Nosek agrees, saying one of the strongest distorting influences is the reward systems that confer kudos, tenure, and funding. “To advance my career I need to get published as frequently as possible in the highest-profile publications as possible. That means I must produce articles that are more likely to get published.” These, he says, are ones that report positive results (“I have discovered …”, not “I have disproved …”), original results (never “We confirm previous findings that …”), and clean results (“We show that …”, not “It is not clear how to interpret these results”). But “most of what happens in the lab doesn’t look like that”, says Nosek—instead, it’s mush. “How do I get from mush to beautiful results?” he asks. “I could be patient, or get lucky—or I could take the easiest way, making often unconscious decisions about which data I select and how I analyze them, so that a clean story emerges. But in that case, I am sure to be biased in my reasoning.”

**THE UTOPIAN:** Brian Nosek is in pursuit of a scientific utopia, in which science is rid of motivated reasoning and confirmation bias.Courtesy of Brian Nosek

Not only can poor data and wrong ideas survive, but good ideas can be suppressed through motivated reasoning and career pressures. The suggestions by geneticist Barbara McClintock in the 1940s and ’50s that some DNA sequences can “jump” around chromosomes, and by biochemist Stanley Prusiner in the 1980s that proteins called prions can fold up into entirely the wrong shape and that the misfolding can be transmitted from one protein to another, went so much against prevailing orthodoxy that both researchers were derided mercilessly—until they were proved right and won Nobel prizes. Skepticism about bold claims is always warranted, but looking back we can see that sometimes it comes more from an inability to escape the biases of the prevailing picture than from genuine doubts about the quality of the evidence. The examples of McClintock and Prusiner illustrate that science does self-correct when the weight of the evidence demands it, says Nosek, but “we don’t know about the examples in which a similar insight was made but was dismissed outright and never pursued.”

Scientists have some awareness of this, to be sure. Many sympathize with philosopher Thomas Kuhn’s theory that science undergoes abrupt paradigm shifts in which the prevailing wisdom in the entire field is undermined and a wholly new picture emerges. Between such shifts, we see only “normal science” that fits the general consensus—until a build-up of anomalies creates enough pressure to burst through the walls into a new paradigm. The classic example was the emergence of quantum physics at the start of the 20th century; the 18th-century notion of phlogiston in chemistry—a supposed “principle of combustion,” overturned by Lavoisier’s oxygen theory—also fits the model. A famous quotation attributed to Max Planck suggests another means by which such preconceptions in science are surmounted: “Science advances one funeral at a time.” New ideas break through only when the old guard dies.

**T**he role of bias in science became clear to Nosek as a graduate student in psychology. “Like many graduate students, my idealism about how science works was shattered when I took research methods”, he says. “In that class, we read lots of papers that were old even then—articles from the 1950s through the 1970s—articles about publication bias, low-powered research designs, lack of replication, underreporting of methodology in published articles, lack of access to original data, and bias against null results.”

Nosek has since devoted himself to making science work better.**10** He is convinced that the process and progress of science would be smoothed by bringing these biases to light—which means making research more transparent in its methods, assumptions, and interpretations. “Fighting these issues isn’t easy, because they are cultural challenges—and no one person can change a culture,” he says. “So I started with the issue that I could control: the power of my research designs.”

Surprisingly, Nosek thinks that one of the most effective solutions to cognitive bias in science could come from the discipline that has weathered some of the heaviest criticism recently for its error-prone and self-deluding ways: pharmacology. It is precisely because these problems are so manifest in the pharmaceutical industry that this community is, in Nosek’s view, way ahead of the rest of science in dealing with them. For example, because of the known tendency of drug companies and their collaborators to report positive results of trials and to soft-pedal negative ones, it is now a legal requirement in the Unites States for all clinical trials to be entered in a registry before they begin. This obliges the researchers to report the results whatever they say.

Nosek has instituted a similar pre-registration scheme for research called the [Open Science Framework](http://osf.io/)(OSF). He had planned it for many years, but it really took off when former software developer Jeff Spies joined his lab in 2009-2010 and took it on as a dissertation project. “Lots of people got involved and it became a much bigger thing pretty quickly,” says Nosek. “We started a website for the OSF, and a community—and funders—gathered around it.” Nosek and Spies cofounded the [Center for Open Science](http://cos.io/" \t "_blank) in Charlottesville in 2013, which now administers the OSF and is able to offer its services for free.

The idea, says Nosek, is that researchers “write down in advance what their study is for and what they think will happen.” Then when they do their experiments, they agree to be bound to analyzing the results strictly within the confines of that original plan. It sounds utterly elementary, like the kind of thing we teach children about how to do science. And indeed it is—but it is rarely what happens. Instead, as Fiedler testifies, the analysis gets made on the basis of all kinds of unstated and usually unconscious assumptions about what would or wouldn’t be seen. Nosek says that researchers who have used the OSF have often been amazed at how, by the time they come to look at their results, the project has diverged from the original aims they’d stated.

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Fiedler has used the service and says that not only does it keep the research honest but it makes it run more smoothly. “Pre-registration at the OSF forces me to think through all the details upfront, and the project, as well as some of the writing, is already done before I even start collecting the data,” she says. “Having this awareness helps me to separate which results I trust and which ones I trust less.” And not just her: Making the whole process transparent “gives every other researcher the chance to judge if this result is worth their valuable research time.”

Stating your aims is also a good way of checking that you know what they are, says Hartgerink, who is also an OSF user. “Once we decided to do this, we noticed that explicating the hypotheses was difficult in itself”—an indication that they hadn’t actually been formulated clearly enough. “Pre-registration is technically a must if you want to test hypotheses,” he concludes. Fiedler says that for the past year she and all of her Ph.D. students have used the OSF scheme. “I have learned so much by doing it that I can only recommend it to everyone in our line of work,” she avers.

The distinction between OSF and business as usual is considerable, says Hartgerink. Since most researchers write their manuscripts only after having conducted the study, hypotheses are not written down explicitly before. “This results in more favorable formulations of the hypothesis once results are known.” Psychologist Ernest O’Boyle of the University of Iowa and his coworkers have dubbed this bias to make the retrospective presentation of results more beautiful the “Chrysalis effect.” One consequence, Hartgerink says, is that it is common to present unexpected results as expected. “Ask anyone in the general public whether it is OK to do that, and they will say it is not. Yet this has been the common thing to do in science for a long time.”

Often, this shift in hypotheses and goals just happens, without intention and even without recognition. “Within the sometimes long process of designing an experiment, collecting the data, analyzing it, and presenting the results to our scientific colleagues, our way of looking at a question and the corresponding results evolves,” says Fiedler. “Along the way we might forget about the original tests that failed, and present our new insights as answering different questions based on the same data.” This approach to science has a lot of value, she says: It’s important to discover unforeseen connections. But not only does this shift the goalposts of the research, it can also lead researchers to “put too much trust in maybe spurious effects.” OSF forces researchers to leave their goalposts where they are.



But if you elect to constrain yourself to a narrow set of objectives before you’ve even done the experiments, don’t you close off potentially fertile avenues that you couldn’t have foreseen? Maybe, says Nosek, but “learning from the data” is not the way to reach reliable conclusions. “At present we mix up exploratory and confirmatory research,” he says. “One basic fact that is always getting forgotten is that you can’t generate hypotheses *and* test them with the same data.” If you find an interesting new lead, you should follow that up separately, not somehow tell yourself that this is what the experiment was about all along.

Fiedler disputes the accusation that pre-registration will kill creativity and freedom. “It’s not something everybody always has to do,” she says, and exploratory research that collects data without a definite agenda of hypothesis testing still has an important place. But we need to keep the distinctions in view.

The major obstacle, Hartgerink thinks, is education: Researchers are simply not advised to do things this way. But they had better be. “If younger researchers do not start applying these techniques now,” he says, “they might find themselves on the backbenches in 10 years, because it is becoming the norm to do your research in a reproducible, transparent, and open manner.”

Ultimately, Nosek has his eyes on a “scientific utopia,” in which science becomes a much more efficient means of knowledge accumulation. Nobody claims that OSF will be the panacea that gets us there, however. As Oransky says, “One of the larger issues is getting scientists to stop fooling themselves. This requires elimination of motivated reasoning and confirmation bias, and I haven’t seen any good solutions for that.” So along with OSF, Nosek believes the necessary restructuring includes open-access publication, and open and continuous peer review. We can’t get rid of our biases, perhaps, but we can soften their siren call. As Nosek and his colleague, psychologist Yoav Bar-Anan of Ben-Gurion University in Israel, have said, “The critical barriers to change are not technical or financial; they are social. Although scientists guard the status quo, they also have the power to change it.”