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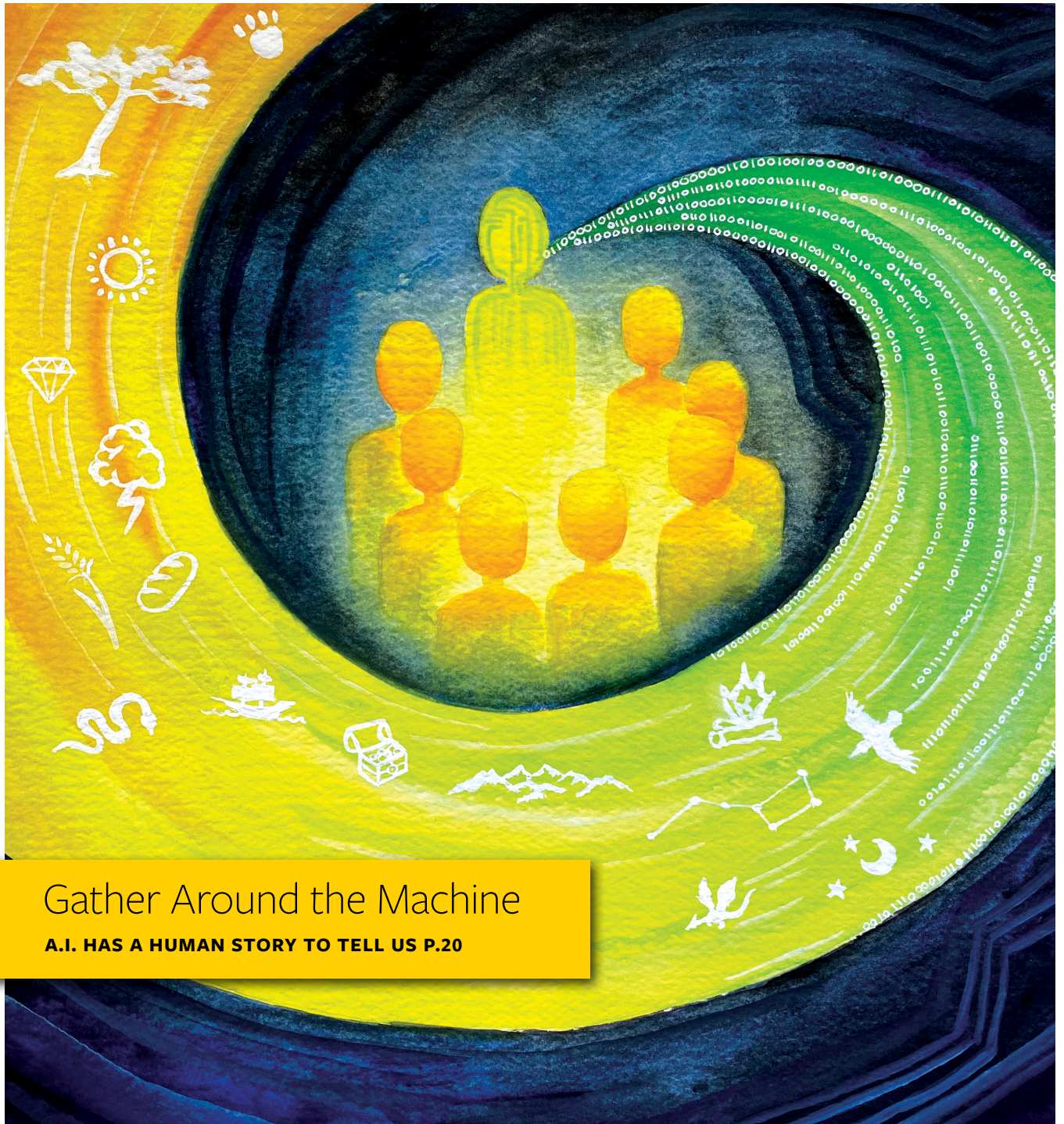
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Our Stories

BY KEVIN BERGER

W

E TELL OURSELVES STORIES in order to live.” It’s Joan Didion’s most famous line, the opening sentence of her essay, “The White Album,” an ominous narrative of California in the 1960s, fraudtly etched with images of the Doors, Black Panthers, and Manson Family murders. “We live entirely, especially if we are writers, by the imposition of a narrative line upon disparate images, by the ‘ideas’ with which we have learned to freeze the shifting phantasmagoria which is our actual experience,” Didion wrote.

Neuroscience has immortalized Didion’s observation in the language of biology. In his article, “Our Brains Tell Stories So We Can Live,” a play on Didion’s line featured in this print edition of *Nautilus*, neurologist Robert A. Burton explains how evolution shaped our brains to produce narratives to guide us through a chaotic world. “We are hardwired to need stories,” Burton tells us.

In our cover story, “The Storytelling Computer,” M.R. O’Connor offers the insight that evolution wired stories into our brains to guide us through the chaos by fixing successive images of the physical landscape in our minds. O’Connor shows us that, yes, neuroscientists can explain this in terms of special place neurons, but long before them, Native Americans knew the way through the world was marked by nature’s features. O’Connor then meets computer scientist Patrick Henry Winston, who claims that if artificial intelligence is ever going to rise above being a simulacrum of the human brain, it’s going to need to do that most quintessential human thing: Tell stories.

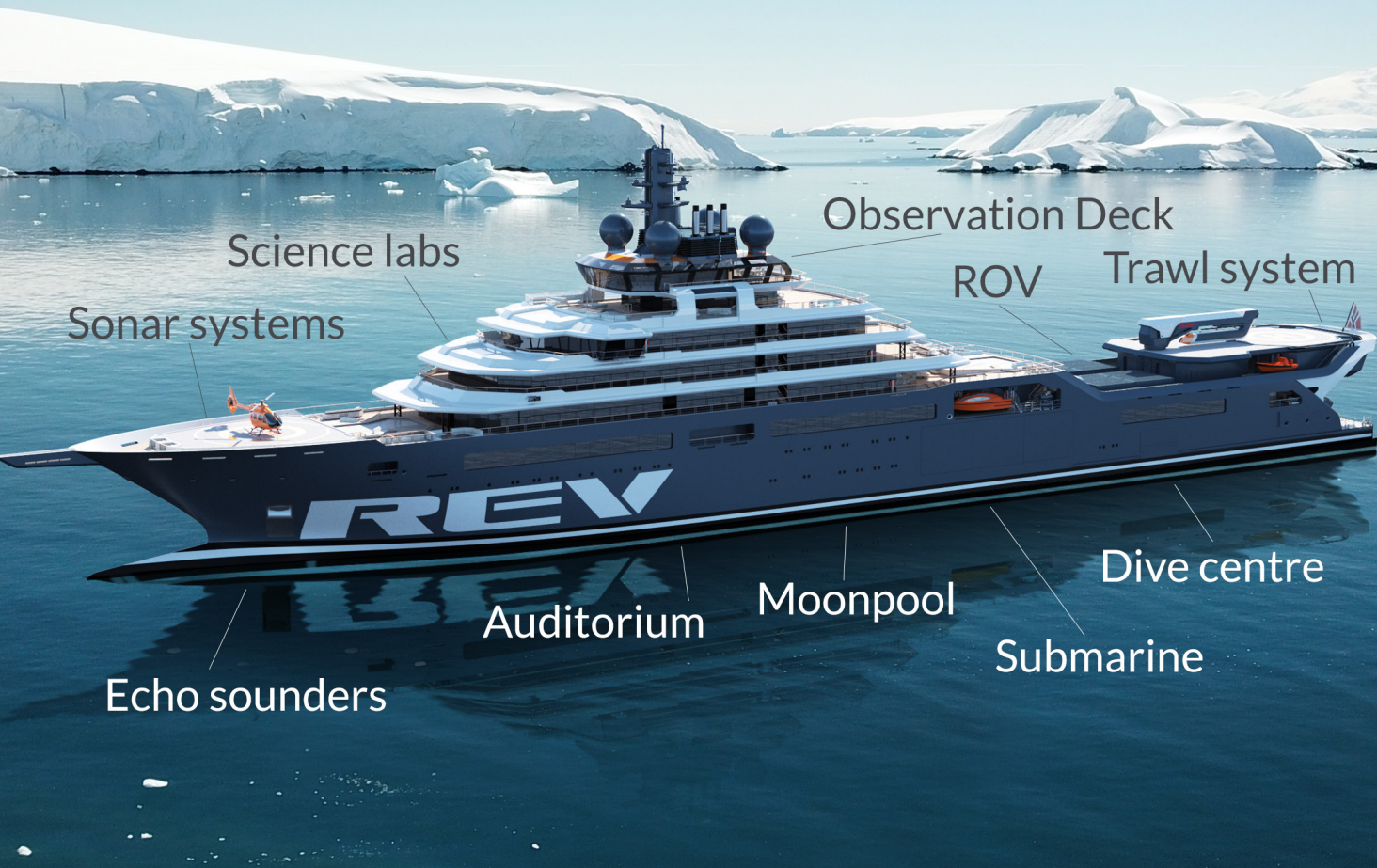
Stories, of course, need language, and David Adger, a professor of linguistics at Queen Mary University of London, explains why in “This Simple Structure Unites All Human Languages.” Adger delves into the evolutionary rise of language and how its universal structure mirrors the self-similarity seen in nature, such as rivers that branch into streams and rivulets, each branch similar to the branch that preceded it. Language is also the engine of imagination, Adger says. Through infinite sentences, language allows us to “create new ways of thinking,” Adger tells me in an interview. “Then our individual worlds can be distinct.”

Science too depends on language, not just communicating ideas, but, as Adger says, creating meaning where none existed before. The language of science has to be amazingly creative to present the intricacies of nature. That’s always been our mission and it just got a boost. The acquisition of *Nautilus* by the super-fan investment group NautilusNext has been completed. Led by CEO Nicholas White, NautilusNext will keep our creativity charged.

So pull up a chair. When *Nautilus* arrives, it’s storytime.

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Readers Respond

Comments and letters about stories from print issue 27.

“ARE ANIMAL EXPERIMENTS JUSTIFIED?”

Thank you for this careful article. It has increased my understanding of animal-based research, but it has not quieted my distress over it. I got rather caught up in the section about researchers “loving” animals, having pets, and so on. You do this research because you can, not out of any other directive that I can see. To me, it is not comfortable. I can kill, if I must. I can help a young hawk recovering from an early illness hone his hunting skills before release by buying and releasing rats for him. But to use a creature to learn how to extend a human’s life? Not for me.

—Sallie F. Reynolds

“YES, DETERMINISTS, THERE IS FREE WILL”

I think the author avoided a clear answer to the determinism question—the meteorology example is a bad one. If we accept the world is deterministic (which it may not be, of course), then *in principle* we could forecast weather (and anything else) just by knowing the full system state at one point in time. The fact that we use probabilities in weather description stems from both the practical impossibility of knowing the system fully and, at a higher level, from the chaotic-like nature of flow equations—but there’s a reason we call it “deterministic chaos.” One must not mistake our inability to make accurate predictions for absence of

determinism. The important point is that, *in principle*, a deterministic world allows for prediction of future states, even if that prediction is not feasible *in practice*. That is, after all, the very definition of determinism.

—Paulo Martel

“WECHAT IS WATCHING”

It’s like 1984, except everyone volunteers to put Big Brother into their lives, no threats or force necessary. Social credit sounds like a credit score with criminal past included. I don’t get the concept of naming and shaming people that have a low score. Is there some intimation that violence or prejudice against low scores is OK? We are probably going to get there in the West someday. The question is how fiercely we defend our rights and data as the solution is being developed. “Not very” has been the answer so far.

—Mark Manning

Very nice article. Regarding the social credit system and similar schemes elsewhere, sharing all this data globally is an alternative approach that has not been investigated enough. See some of David Brin’s articles on “global transparency,” i.e. the total lack of privacy. Brin posits that so long as all the information is publicly available, citizens may make use of it to exert counter-pressures on governments and others. For instance, suppose that all the social credit and

WeChat data on a corrupt local official is available to everyone. Perhaps a citizen campaign might change such behavior? But of course the right to “due process” disappears in such scenarios, so we need to have vigorous and frank discussions on how feedbacks to the feedback (i.e. keeping public-data-enabled social responses civil) can be structured.

—Clement Kent



Nautilus welcomes reader responses. Please email letters@nautil.us. All letters are subject to editing.

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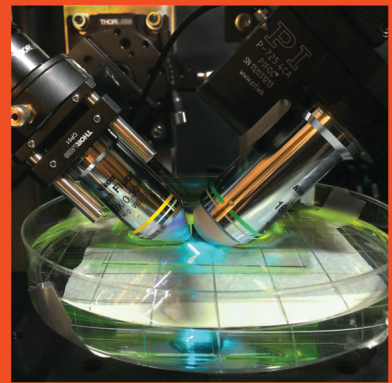
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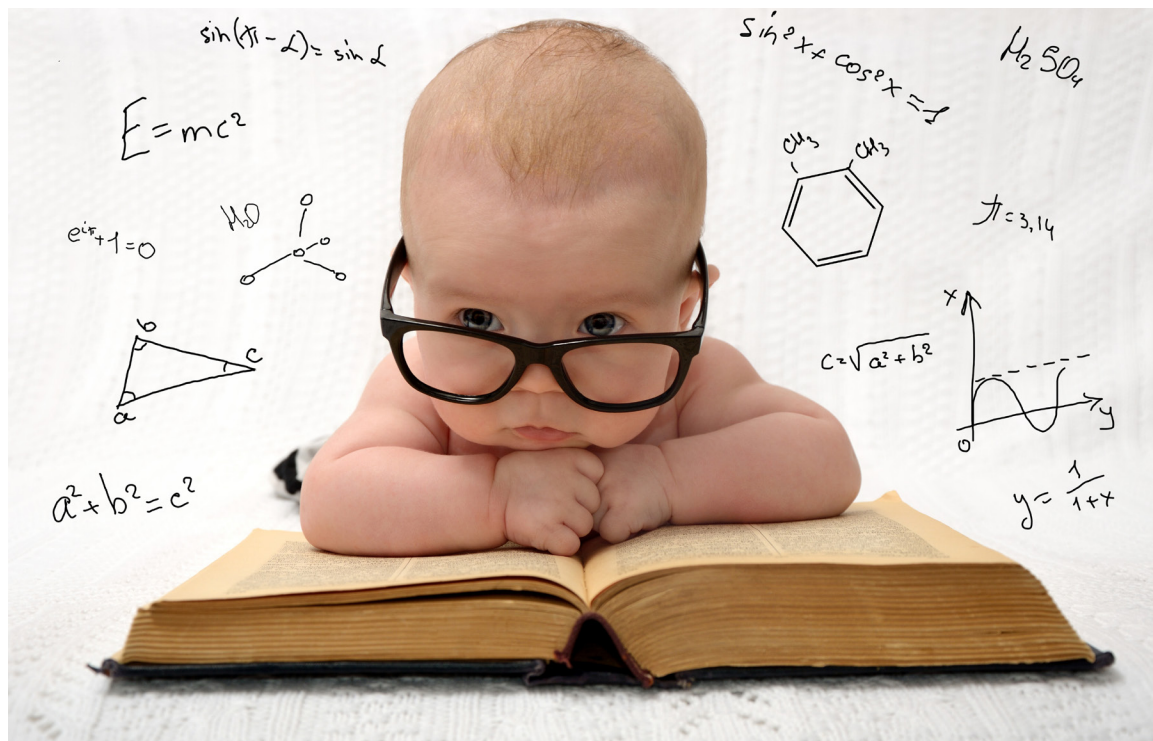
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Preludes



PHYSICS

The Strange Physics of How Babies Talk

LIKE ALL NEW PARENTS, I must sound like a kook when I babble along with my 9-month-old daughter. That's okay: It delights her. I sometimes ask her what she might mean as she offers some apparently affirming utterance and looks at me with her big blue eyes: *Oh, you like it when daddy lifts you? Ah, you're thankful for a new diaper?* Her vocalizations—the squeals and *whoas* and *yah-wahs*—can have surprising verve and a kind of ecological significance. My daughter's noises, scientists say, “catalyze” me to produce “simplified, more easily learnable language.”

My daughter is now regularly saying “mama.” My wife has taken this to mean the baby wants her attention. So I felt a little disheartened after reading a 2017

paper in which Charles Yang, a computer scientist who studies language acquisition, wrote that these vocalizations are nothing more than “rhythmic repetitions of nonsense syllables.” (Sorry, Danielle!) This lack of “semantic content” is nothing to be bummed about, though, for “babbling merges linguistic units (phonemes and syllables) to create combinatorial structures,” the bread and butter of language learning.

The puzzle of how language can be so learnable has had me, of late, utterly perplexed. Babies are helpless. I can see how, with some instruction, a *child* can pick up on a new idea or skill, like shoe-tying—they can understand what you're saying and mimic movements. Yet my daughter will be obeying grammar reliably and

effortlessly, if a bit crudely, before she's tying her own shoes. It's a wonder babies learn anything, let alone a language.

All human languages have an "inaudible and invisible hierarchical structure" that, when we're children, we impose on sound sequences we hear, writes linguist David Adger. "We hear sounds or see signs, but our minds think syntax." Which is why infants can learn any language. There's something deeply hidden in the mind that recognizes syntax as if it were as apparent as a face. "The full scale of linguistic complexity in a toddler's grammar still eludes linguistic scientists and engineers alike, despite decades of intensive research."

Perhaps it's no surprise, then, that physicists are now chiming in. In a paper published in March 2019, theoretical physicist Eric DeGiuli argues that a language—or specifically a "context-free grammar," which almost all languages share—can be treated as a physical object that children interact with as they hear words and sentences. In a context-free grammar, sentences have tree-like graphical structures: "The bear walked into the cave" can be broken down into a noun and verb phrase—"the bear" and "walked into the cave," respectively—and each of those elements breaks down into more elementary units, like nouns and verbs. You might call these the tree's leaves.

This gave me the absurd image of a baby flying through a forest. The "surface" of a language that babies "touch" are all the possible configurations of words into sentences, both meaningful and meaningless.

It's fair to say that something has "crystallized" in the mind of a child able to talk.

"Each grammar defines probabilities for sentences," DeGiuli writes. In English, certain words, coming one after another, are more likely than others to make grammatical sense. DeGiuli says that the ones that do make sense get assigned, in the baby's mind, greater weight.

Surprisingly, which phrases are assigned that weight has to do with "temperature." Not literal temperature, as in hot and cold, but a measure akin to temperature. For DeGiuli, hot is associated with randomness

while cold is more deterministic, not unlike how high temperature in a room is due to the quick and chaotic movement of atoms.

In an article about the paper, science writer Philip Ball likens this process to the freezing of water. He goes on to say that DeGiuli thinks "something like this switch may explain why, at a certain stage of development, a child learns very quickly how to construct grammatical sentences."

The idea that language locks in place, as water does when it's chilled, is a weird, attractive idea. It's fair to say that something has "crystallized" in the mind of a child able to talk. How exactly that happens, though, is difficult to say. As I play with my daughter and listen to her form proto-words, I sympathize with Yang and his colleagues: "The growth of language is nothing short of a miracle."

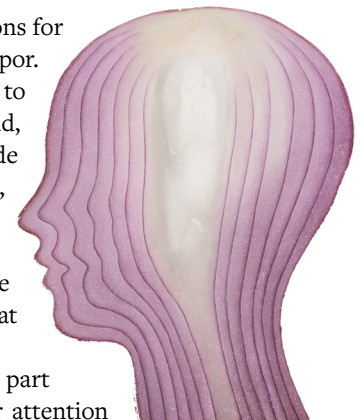
—Brian Gallagher

PSYCHOLOGY

Daydreams Shape Your Sense of Self

YOU ARE AT HOME, cutting onions for dinner, and tear up from the vapor. Your mother, teaching you how to cut onions when you were a child, pops into your mind: Guide the blade against the knuckles of your free hand, curling your fingertips inward to protect them from the blade. Absorbed by the scene, you begin to think about how one day, if you have kids, you might pass that tip on to them.

Most people spend a considerable part of their waking lives daydreaming, their attention



constantly fluttering from the task at hand to the thoughts, images, and memories moving through consciousness. Why is daydreaming so prevalent?

The more I studied daydreams, the less clear their role seemed to be. I began with the observation that the majority of daydreams involve the self in one form or another. In our daydreams, fleeting or detailed, we are the main characters. We are self-centered beings—not in any pejorative sense—and the content of our daydreams reflects this. Self-related elements in consciousness—including beliefs, values, memories, and goals—are much easier to access than self-unrelated knowledge. In other words, information related to the self is more interesting or noticeable than most other things. So, what may make daydreaming important is that it provides a way for the brain to process self-related information to update our life story.

Storytelling is deeply ingrained in humans, whether it is through writing, music, visual art, or face-to-face conversation. People tell stories about themselves, to themselves, on a daily basis. These self-related stories allow people to make sense of who they are and build their narrative identity—their sense of continuity through time. People need to connect who they believe they are to ongoing experiences.

I hypothesized that daydreams with a clear theme that flowed like a story and linked elements of the story back to the self (to create meaning) would be beneficial for narrative processing. That is, I believed that the relatively

The more I studied daydreams, the less clear their role seemed to be.

spontaneous stories that take place within daydreams would help people update their concept of self with new and relevant information. I collected a large number of daydreams and coded them for story-like elements and for other important features: emotional intensity, specificity, presence of the self, presence of other people, timeframe (past, present, future, short term, long term), and realism (versus fantasy).

The results belied my hypothesis. Daydreams, I found, do not form perfectly crafted narratives like in a novel—or even like little stories you might tell a friend over dinner. Instead, daydreams seem to adopt certain elements of stories while also combining information in a fairly random fashion. They were most often structured in four ways, depending on whether they were highly emotional or highly realistic, and whether they related to a specific event or reflected broadly on a person's goals, identity, and life.

Interestingly, only one category—daydreams that were realistic and specific—were related to the self-concept, and none of the categories helped people update their self-concept. This suggests that daydreaming may not include the conscious and thoughtful analysis that narrative processing needs. Having a story-like daydream may

be more like looking at one's reflection in rippling water than in a mirror. It disrupts the clarity of the self-concept by bringing new narratives into conscious awareness. But for these narratives to be integrated into clear and stable evaluations of self, a deeper analysis may need to occur, such as sharing personal narratives with another person or keeping a journal.

Certain daydreams reflect what is important to a person; what worries them, who they care about, and what they love and aspire to do. They're made up of pieces of who we are. When these pieces reflect real life and flow like stories, we pay attention, we look, we become aware.

I recently daydreamed that I was standing in front of my new undergraduate students, introducing myself. The chalkboard was dusty, and the afternoon light shone through the window. My students were quiet for the most part, on their phones or computers. I felt slightly nervous and embarrassed that I couldn't get everyone's attention. Later, I realized that I was worried about making a good first impression. The subtle mix of these emotions in my daydream reinforced my identity as an instructor. I knew I was excited for the new school year to start.

—Eve Blouin-Hudon

GENETICS

How to Collapse the Distinction Between Art and Biology

LANGUAGE,” THE BEAT WRITER William S. Burroughs supposedly once exclaimed, “is a virus from outer space.” Burroughs was making a metaphorical extrapolation about the ways in which words, phrases, idioms, sentences, lines, and narratives can seemingly rewire our brains; how literature has the power to reprogram a mind just as a virus can alter the DNA of its host. Such a concept holds that more than just a simple means of expressing and communicating ideas, language is its own potent agent, a force that actually has the ability to shape the world, often in ways that we’re unconscious of and with an almost autonomous sense of itself.

As with something biological, language is capable of infecting, of propagating and spreading, of indelibly marking its host. In 1970’s *The Electronic Revolution*, Burroughs writes that “I have frequently spoken of word and image as viruses or as acting as viruses, and this is not an allegorical comparison.”

For Canadian poet Christian Bök the contention that language is a virus is very much not allegorical. In 2011 he announced a new experiment called *Xenotext* in which, with the assistance of a laboratory at the University of Calgary, he proposed to encode the words of his poem into the genetics of a bacterium called *Deinococcus radiodurans*. Bök proposed that the letters that composed a conventional sonnet could be translated into the nucleotide triplets that compose the basic units of genetic code, which could then be inserted into the bacterium’s DNA, so that in a literal way the word could become flesh.

First experimenting on the easier to use (but far less durable) *E.coli*, the *Xenotext* project has been a multi-year experiment whose first volume only saw publication in 2015, at a cost so far of \$110,000.

The poem is created by inserting DNA coded with a poem into *Deinococcus radiodurans*. Then when the cell transcribes its DNA into RNA, it writes a response, which can be read using a cipher the poet developed. Appropriately enough, the response sonnets in Bök’s cycle are titled “Orpheus” and “Eurydice” after the



Greek mythological poet who descended to Hades to resurrect his wife, with the former written in DNA and the latter by the resultant RNA.

Bök explained that when his sonnet is “translated into a gene and then integrated into a cell ... [it will] cause the organism to manufacture a viable, benign protein in response—a protein that, according to my original, chemical alphabet, is itself yet another text.” Thus, Bök imagined that gene *X-P13* as altered in the *Deinococcus radiodurans* would be “a life-form so that it becomes not only a durable archive for storing a poem, but also an operant machine for writing a poem.” Where an individual poet might edit, revise, and rewrite their lyrics, and where an oral tradition might naturally change over the course of its transmission, *Xenotext* is coded to alter its composition based on the relationship between DNA and RNA, between Orpheus and Eurydice. Bök begins “Orpheus” with “Any style of life/is prim,” an opening appropriately congruent with the nature of the *Xenotext*, and “Eurydice” responds in a sonnet of protein, its first line reading “The faery is rosy/of glow.”

By writing verse through genetic engineering, Bök’s *Xenotext* promised to make Burroughs’ contention about

Language is capable of infecting, of propagating and spreading, of indelibly marking its host.

language's viral nature explicit, not allegorical. As language propagates, infects, and alters the minds which it encounters, so too does the ever reproducing *Deinococcus radiodurans* promise to replicate Bök's verse to a greater extent than a mere printing press ever could. Bök dreams that literature will "no longer take on the form of codices, scrolls, or tablets, but instead ... become integrated into the very life of their readers," the microbe itself becoming a library, an archive, an ark. Bök claims

that his project has a permanence that other verse can't match. Chosen because it's an extremophilic bacterium, hearty *Deinococcus radiodurans* can withstand extreme cold, heat, pressure, acid, and radiation, leading Bök to enthuse that whereas other literary texts are subject to decay and entropy, fire and forgetting, his poem "can persist on the planet until the sun itself explodes."

For skeptics, such as myself, *Xenotext* seems more interesting as a theoretical concept than as

an actual project; one can envision a great science-fiction story in which an overzealous poet accidentally engineers his constructed lyrical microbe into a dangerous plague. Hard to imagine that, even if successful, the noble *Deinococcus radiodurans* will somehow shepherd Orpheus and Eurydice through the coming apocalypse. Even should the indefatigable microbe endure heat and radiation, flooding and fire, no poem can survive the extinction of readers. Bök's project, however, is motivated more by a deep (and expensive) sense of playfulness and irony. What *Xenotext* does is cause its audience to reevaluate their ideas of creation, both literary and biological.

—Ed Simon

PHYSICS

Mind the Gap Between Science and Religion

HAVE YOU HEARD that we may be living in a computer simulation? Or that our universe is only one of infinitely many parallel worlds in which you live every possible variation of your life? Or that the laws of nature derive from a beautiful, higher-dimensional theory that is super-symmetric and explains, supposedly, everything?

I've heard that, too. It's how my research area, fundamental physics, often ends up making headlines: with insights about the nature of reality so mind-boggling you can't believe it's still science. Unfortunately, in many cases, it's not.

Take the idea that we live in a computer simulation. According to our best current knowledge, the universe follows rules that are encoded by a set of equations. We don't know these equations completely (yet!), but you could rightfully say the universe computes in real time whatever the correct equations are. In that sense, we trivially "live in a computer," but that's just a funny way to talk about the laws of nature.

And, if you are really asking whether our universe has been programmed by a superior intelligence, that's just a badly concealed form of religion. Since this hypothesis

is untestable inside the supposed simulation, it's not scientific. This is not to say it is in conflict with science. You can believe it, if you want to. But believing in an omnipotent Programmer is not science—it's tech-bro monotheism. And without that Programmer, the simulation hypothesis is just a modern-day version of the 18th-century clockwork universe, a sign of our limited imagination more than anything else.

It's a similar story with all those copies of yourself in parallel worlds. You can believe that they exist, all right. This belief is not in conflict with science and it is surely an entertaining speculation. But

This confusion of religion and science comes directly from the practitioners.



there is no way you can ever test whether your copies exist, therefore their existence is not a scientific hypothesis.

Most worryingly, this confusion of religion and science comes directly from the practitioners in my field. Many of my colleagues have become careless in separating belief from fact. They speak of existence without stopping to ask what it means for something to exist in the first place. They confuse postulates with conclusions and mathematics with reality. They don't know what it means to explain something in scientific terms, and they no longer shy away from hypotheses that are untestable.

Particularly damaging to fundamental physics has been the belief that the equations which describe nature must be beautiful. There is no rational reason why this should be so, but faith in beautiful math has become pervasive in the community. And that's despite the fact that relying on beauty as a guide to new natural laws has historically worked badly.

And it's still working badly for physicists. We see the tragedy

playing out in the ongoing failure of ideas like a unification of the fundamental forces, a theory of everything, or new types of symmetries that experiments continue to not find. Such pretty hypotheses remain popular among physicists even though they haven't led anywhere for decades.

This blurring of the line between science and religion is not innocuous. Resources—both financial and human—that go into elucidating details of untestable ideas are not available for research that could

lead to much-needed progress. I like the idea that the laws of nature are beautiful and the universe was made for a purpose as much as everybody else, and I appreciate public interest in our research anytime. But let's not call it science when it isn't.

We have fought hard for secularism, and we don't want religious leaders to meddle in scientific debate. Scientists, likewise, should respect the limits of their discipline.

—Sabine Hossenfelder

PSYCHOLOGY

Your Mind Can't Tell Fact from Fiction

STORIES, FICTION INCLUDED, act as a kind of surrogate life. You can learn from them so seamlessly that you might believe you knew something—about ancient Greece, say—before having gleaned it from Mary Renault's novel *The Last of the Wine*. You'll also retain false information even if you didn't mean to. That seems like a liability: Philosophers have long concerned themselves with what they call "the paradox of fiction"—why would we find imagined stories emotionally arousing at all? The answer is that most of our mind does not even realize that fiction is fiction, so we react to it almost as though it were real.

At the same time, very young children "can rationally deal with the make-believe aspects of stories," distinguishing the actual, the possible, and the fantastical with sophistication, as Denis Dutton has written in



Most of our mind does not even realize that fiction is fiction.

The Art Instinct. “Not only does the artistic structure of stories speak to Darwinian sources: so does the intense pleasure taken in their universal themes of love, death, adventure, family conflict, justice, and overcoming adversity.” That may help explain why, when stories are done well, we love them so much. Just as artificial sweeteners fool our minds into thinking we’re eating sugar, stories—even weird ones like *Alice’s Adventures in Wonderland*—take advantage of our natural tendency to want to learn about real people, and how to treat them.

There’s experimental evidence for this. Children, for example, sometimes actually believe that puppets are alive. Even animals

sometimes react to pictures the same way they react to real things. The industrialized world is so full of human faces, like in ads, that we forget that it’s just ink, or pixels on a computer screen. Every time our ancestors saw something that looked like a human face, it probably was one. As a result, we didn’t evolve to distinguish reality from representation. The same perceptual machinery interprets both.

The rational parts of our minds, particularly in the prefrontal cortex, do indeed know that what we’re looking at, or reading, isn’t real. One way to understand this is by thinking about optical illusions. Even after you understand how an illusion operates, it continues to fool part of your mind. This is the kind of double knowledge we have when we consume fiction.

These perceptual areas of our brains are very closely connected to our emotions. That’s why emotions don’t just motivate us to act in certain ways but force us to interpret the world differently. A 2011 paper, for example, explained how

fear can affect vision, moods can make us more or less susceptible to visual illusions, and desire can change the apparent size of goal-relevant objects. The authors proposed that emotions offer information “about the costs and benefits of anticipated action,” knowledge that can be used swiftly, without thought, “circumventing the need for cogitating on the possible consequences of potential actions.”

That’s the solution to the paradox of fiction, and why telling ourselves, “It’s only a movie,” can only partially attenuate the feelings we have about it. Our brains can’t help but believe.

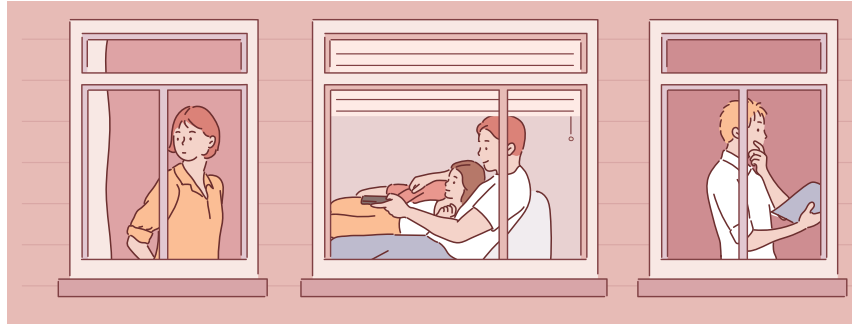
—Jim Davies

LINGUISTICS

Talking Is Throwing Fictional Worlds at One Another

A FEW YEARS AGO, David Adger was in his office at Queen Mary University of London, where he is a professor of linguistics, when the phone rang. It was a British TV company that wanted him to invent a language for monsters with no lips, just big teeth, in a new fantasy series, *Beowulf*. Adger loved the idea and concocted a wonderfully weird and complex language called Ur-Hag Hesh. Although he made it up for monsters, Adger says, “I used my knowledge of the linguistics of natural human languages as a blueprint.”

Language maintains
as well as creates.



Adger's knowledge of human languages runs deep. For decades he has ventured beyond the classroom to study languages in Kenya, India, the Himalayas, and the Scottish Highlands. Languages do not vary randomly, he says. "They have a design, a structure, a pattern, in common." Despite that seeming constraint, Adger argues that the sentences we make are infinite in faculty, form, and expression. Language "is the engine of imagination," he writes in his 2019 book, *Language Unlimited*.

There's an interesting paradox in *Language Unlimited*. You write that language is endlessly creative but also our cognition is constrained by the structure of language. What does that paradox say about human beings?

You're right. There is a wee paradox in there. That's a nice thing to pick up on. I think about it like even numbers. There's an unlimited number of even numbers but obviously they're limited, right? Because 3s and 7s aren't in there. Language is like that. There's an unlimited number of possible things we can say, of sentence structures, but not anything can be a sentence structure.

So you're absolutely right. Language is unlimited, but it's unlimited in a limited way.

What does that say about us as human beings? That's a gigantic and fascinating question. It probably means our cognition is limited. There may be things that we can never solve because we don't have the cognitive structures that will help to solve them. Imagine there were aliens. Other species would be able to think about and solve problems in ways that are outside our space of comprehension.

That was the brilliant idea at the heart of the film *Arrival*.

Yeah, that was one of the really interesting things about both the short story and the film. The aliens thought about things in a non-causal way. They looked at things from a whole perspective, they looked at a system as a whole. Whereas we humans tend to see things in terms of one thing causes the next. We use language as one of our major tools for thinking, and it may be that it just isn't up to every task.

You write that language, like fiction, creates meaning where none existed before. Have you ever

thought that when we talk to each other, we're just throwing fictional worlds at one another?

I totally think that's what we're doing! This goes back to what the limits of humans are. Our own internal worlds are what we represent and think about the external world. They're probably all wrong to start with, and then we try and link those fictions with other people's fictions. I think most of our interaction is an attempt to align the fictions that we build to be able to survive in the world. And this goes back to culture wars. People have different fictions of the world and sometimes they are pretty brutally out of alignment. Like now. And that's quite terrifying, right?

So how do people understand each other?

Our languages allow us to both create these new ways of thinking and to maintain the ways of thinking we've already built. So there's another paradox there, which is that language maintains as well as creates. But then our individual worlds can be distinct. And trying to pull them into cohesion with other people is a huge amount of work.

—Kevin Berger

The Storytelling Computer

If machines are going to be sentient, they first need to be good storytellers

BY M.R. O'CONNOR





VASILYEV ALEXANDR / SHUTTERSTOCK

H

UMANS ARE A STORYTELLING SPECIES. Our brains seem designed to conjure narratives from experience with beginnings, middles, and ends.

For eons, different cultures have harnessed the cognitive power of narrative to transmit knowledge about navigating the world. Our species' need to travel in search of water, food, and shelter contributed to our ability to organize our journeys into narrative sequences. Storytelling is an evolutionary result of navigation. The anthropologist Michelle Scalise Sugiyama once spent a year researching oral traditions of foraging societies and discovered how widespread this phenomenon is across the world. In her analysis of nearly 3,000 stories from Africa, Australia, Asia, North America, and South America, she found that 86 percent contain topographic information—travel routes, landmarks, the locations of resources like water, game, plants, and campsites. She argues that the human mind—initially designed to encode space—found a way to transmit topographical information verbally by transforming it into social information in the form of stories. “Narrative serves as a vehicle for storing and transmitting information critical to survival and reproduction,” she has written. “The creation of landmarks by a human agent or agents in the course of a journey is a common motif in forager oral traditions. ... By linking discrete landmarks, these tales in effect chart the region in which they take place, forming story maps.”

Examples of practices for creating story maps abound in Native American cultures from the Mojave to the Gitksan. In 1898, Franz Boas described a common feature of the stories of the Salish peoples, a character known as a “culture hero,” “transformer,” or “trickster,” who gives the universe its shape through his travels and whose adventures are passed down through generations. A few years earlier, Richard Irving Dodge, an American colonel who spent 34 years in the American West, described an amazing capacity for memorizing orally transmitted topographical information among the Comanche in his 1883 book, *Our Wild Indians*. As a young boy, Dodge’s guide had been kidnapped and raised by Comanches, and he told Dodge that a few days before young men set out on a raid, an older man with knowledge of the country would assemble them for instruction. As Dodge recounts:

All being seated in a circle, a bundle of sticks was produced, marked with notches to represent the days. Commencing with the stick with one notch, an old man drew on the ground with his finger, a rude map illustrating the journey of the first day. The rivers, streams, hills, valleys, ravines, hidden water holes, were all indicated with reference to prominent and carefully described landmarks. When this was thoroughly understood, the stick representing the next day’s march was illustrated in the same way, and so on to the end. He further stated that he had known one party of young men and boys, the eldest not over nineteen, none of whom had ever been in Mexico, to start from the main camp on Brady’s Creek in Texas, and make a raid into Mexico as far as the city of Monterey, solely by memory of information represented and fixed in their minds by these sticks.

In her description of Pawnee migrations across the Midwest plains, anthropologist Gene Weltfish describes how each band followed a preferred route, some of which had few identifiable landmarks and were easy to get lost in. To successfully navigate, “the Pawnees had a detailed knowledge of every aspect of the land,” she wrote in *The Lost Universe*. “Its topography was in their minds like a series of vivid pictorial images, each a configuration where this or that event had happened in the past to make it memorable. This was especially true

“I think stories are what make us different from chimpanzees and Neanderthals.”

of the old men who had the richest store of knowledge in this respect.”

Similarly, the cultural and linguistic anthropologist Keith Basso wrote in his book *Wisdom Sits in Places* that the Apache frequently cite the names of places in sequence, recreating a journey. One day Basso was stringing barbed wire with two Apache cowboys when he heard one of them talking to himself quietly, reciting a list of place names for nearly 10 minutes straight. The cowboy told Basso that he “talked names” all the time, that it allowed him to “ride that way in my mind.” Basso, who spent decades studying the place-naming practices of the Western Apache people, called place names “intricate little creations.” They are small words that do large tasks, one of which is to aid in navigation. For example, an Apache name like *Tséé Biká Tú Yaahilíné* translates to “Water Flows Down a Succession of Flat Rocks,” a literal description of the place itself.

In the Apache settlement of Cibecue, Basso mapped 45 square miles and recorded 296 place names. Place names are “situating devices” in Western Apache stories. “Thus, instead of describing these settings discursively, an Apache storyteller can simply employ their names, and Apache listeners, whether they have visited the sites or not, are able to imagine in some detail how they might appear,” Basso wrote.



THE SEER The late Patrick Henry Winston in his MIT office. His tremendous intellectual curiosity led him to see connections between moving through space, sequential thinking, storytelling, and human intelligence.

He describes Western Apache culture as one in which storytelling, places, traveling, memory, and future imagining are the ingredients required for wisdom itself. One day Basso talked to Dudley Patterson, a horseman who lived in Cibecue, and asked him: What is wisdom? “Your life is like a trail. You must be watchful as you go,” Patterson told him.

How will you walk along this trail of wisdom? Well, you will go to many places. You must look at them closely. You must remember all of them. Your relatives will talk to you about them. You must remember everything they tell you. You must think about it. You must do this because no one can help you but yourself. If you do this your mind will become smooth. It will become steady and resilient. You will stay away from trouble. You will walk a long way and live a long time. Wisdom sits in places. It’s like water that never dries up. You need to drink water to stay alive, don’t you? Well, you also need to drink from places. You must remember everything about them.

When I read Patterson’s words, I felt how apt they were to what I had learned about the origins of the human mind in the practice of navigating across pre-historic landscapes, of our unique capacity to store memories and think in terms of stories. Life itself, I started to think, is a movement through time, the creation of a story of how we came to be here now and where we are going. It was much later that I came across the work of Patrick Henry Winston, a pioneer in artificial intelligence research, who thinks that storytelling is so central to human intelligence that it’s the key to creating sentient machines in the future.

IN 2017, I MET WINSTON at his second-floor office in the Stata Center on the Massachusetts Institute of Technology campus, a surreal 720,000-square-foot Alice in Wonderland building designed by Frank Gehry with walls and corners crashing into one another at sharp angles. Winston, white-haired and dressed casually, sat at his desk. Behind him was an assortment of books on the Civil War, of which he is an amateur scholar, but it was the painting above his head that

JASON DORFMAN / MIT CSAIL

caught my attention. It was a framed reproduction of Michelangelo's fresco *The Creation of Adam*, depicting the moment just before genesis, the fingers of God and Adam hanging in the air, about to touch and set into motion the biblical story of man on Earth.

Winston had been at MIT for most of his life; he was an undergraduate there, receiving a degree in 1965 in electrical engineering before doing a doctoral dissertation under the famous artificial intelligence researcher and philosopher Marvin Minsky. It was Winston who took over the Artificial Intelligence Laboratory when Minsky moved on to create the influential Media Lab. "I do screwball AI," Winston told me. "My work is about developing a computational understanding of human intelligence rather than creating applied systems. Applied AI is about 95 percent of the field."

Within this niche of screwball AI, Winston has created a new computational theory for human intelligence. He believes that in order to evolve AI beyond systems that can simply win at chess or *Jeopardy*, to build systems that might actually begin to approach the intelligence of a human child, scientists must tackle one of the age old questions of philosophy: identifying what it is exactly that makes humans so smart. Logos? Imagination? Reason? It was Alan Turing, Winston explained to me, who published the seminal paper "Computer Machinery and Intelligence" in 1950 that argued human intelligence was the result of complex symbolic reasoning. Minsky also believed that reasoning—the ability to think in a multiplicity of ways that are hierarchical—was what made humans human. Subsequent AI researchers argued that human intelligence is actually a matter of genetic algorithms, statistical methods, or replicating the neural net of the human brain. "I think Turing and Minsky were wrong," said Winston, pausing. "We forgive them because they were smart and mathematicians, but like most mathematicians, they thought reasoning is the key, not the byproduct."

"My belief is that the distinguishing characteristic of humanity is this keystone ability to have descriptions with which we construct stories," he told me. "I think stories are what make us different from chimpanzees and Neanderthals. And if story understanding is really where it's at, we can't understand our intelligence until we understand *that* aspect of it." Winston draws on linguistics, in particular a hypothesis developed by fellow

MIT professors Robert Berwick and Noam Chomsky, to explain how language evolved in humans. Their idea is that humans were the only species who evolved the cognitive ability to do something called "Merge." This linguistic "operation" is when a person takes two elements from a conceptual system—say "ate" and "apples"—and merges them into a single new object, which can then be merged with another object—say "Patrick," to form "Patrick ate apples"—and so on in an almost endlessly complex nesting of hierarchical concepts. This, they believe, is the central and universal characteristic of human language, present in almost everything we do. "We can construct these elaborate castles and stories in our head. No other animals do that," said Berwick. The theory flips the common explanation of why language developed: not as a tool for interpersonal communication but as an instrument of internal thought. Language, they argue, is not sound with meaning but meaning with sound.

For Winston, the merge hypothesis represents the best explanation so far for how humans developed story understanding. But Winston also believes that the ability to create narrative stems from spatial navigation. "I do think much of our understanding comes from the physical world, and that involves things moving through it," he said. "The ability to put things in order, I think that comes out of spatial navigation. We benefit from many things that were already there, and sequencing was one of the things that was already there. From an AI perspective, what merge gives you is the ability to build a symbolic description. We already had the ability to arrange things in sequences, and this new symbolic capability gave us the ability to have stories, listen to stories, tell stories, to combine two stories together to get a new story, to be creative." Winston calls it the Strong Story Hypothesis.

WINSTON DECIDED TO SEE if he could create a program that could understand a story. Not just read or process a story but glean lessons from it, even communicate its own insights about the motivations of its protagonists. What were the most basic functions that would be needed to give a machine this ability, and what would they reveal about human computation? Winston and his team decided to call their machine Genesis. They started to think about common sense



rules it would need to function. The first rule they created was deduction—the ability to derive a conclusion by reasoning. “We knew about deduction but didn’t have anything else until we tried to create Genesis,” Winston told me. “So far we have learned we need seven kinds of rules to handle the stories.” For example, Genesis needs something they call the “censor rule” that means: If something is true, then something else can’t be true. For instance, if a character is dead, the person cannot become happy.

When given a story, Genesis creates what is called a representational foundation: a graph that breaks the story down and connects its pieces through classification threads and case frames and expresses properties

like relations, actions, and sequences. Then Genesis uses a simple search function to identify concept patterns that emerge from causal connections, in a sense reflecting on its first reading. Based on this process and the seven rule types, the program starts identifying themes and concepts that aren’t explicitly stated in the text of the story. What fascinated Winston initially was that Genesis required a relatively small set of rule types in order to successfully engage in story understanding at a level that appears to approach human understanding. “We once thought that we would need a whole lot of representations,” said Winston. “We now know that we can get away with just a few.”

ILLUSTRATION BY K. CANTNER

Can a computer think without a body?

The class was quiet.

“Would you like a demonstration?” he asked me. I rolled my chair around to the other side of his desk and watched as Winston opened the Genesis program. “Everything in Genesis is in English, the stories, the knowledge,” he said. He typed a sentence into a text window in the program: “A bird flew to a tree.” Below the text window I saw case frames listed. Genesis had identified the actor of the story as the bird, the action as fly, and the destination as tree. There was even a “trajectory” frame illustrating the sequence of action pictorially by showing an arrow hitting a vertical line. Then Winston changed the description to “A bird flew toward a tree.” Now the arrow stopped short of the line.

“Now let’s try *Macbeth*,” Winston said. He opened up a written version of *Macbeth*, translated from Shakespearean language to simple English. Gone were the quotations and metaphors; the summarized storyline had been shrunk to about 100 sentences and included only the character types and the sequence of events. In just a few seconds Genesis read the summary and then presented us with a visualization of the story. Winston calls such visualizations “elaboration graphs.” At the top were some 20 boxes containing

information such as “Lady Macbeth is Macbeth’s wife” and “Macbeth murders Duncan.” Below that were lines connecting to other boxes, connecting explicit and inferred elements of the story. What did Genesis think *Macbeth* was about? “Pyrrhic victory and revenge,” it told us. None of these words appeared in the text of the story. Winston went back to a main navigation page and clicked on a box called “selfstory.” Now we saw, in a window called “Introspection,” the process of Genesis’s own understanding of the story, the sequence of its reasoning and inference. “I think that’s cool because Genesis is a program that is in some respects self-aware,” he said.

Building complex story understanding in machines could help us create better models for education, political systems, medicine, and urban planning. Imagine, for example, a machine that possessed not just a few dozen rules by which to understand a text but thousands of rules that it could apply to a text hundreds of pages long. Imagine such a machine employed by the FBI, given an intractable murder case with puzzling evidence and a multitude of potential perpetrators. Or inside the Situation Room, offering American diplomats and military

The computer grasped the Native American concept of differences as a source of strength.

intelligence its own analysis of the motives of Russian hackers or Chinese belligerence in the South China Sea, calculating predictions for future behavior based on an analysis of a hundred years of history.

Winston and his students have used Genesis to analyze a 2007 cyberwar between Estonia and Russia. They have also found creative ways to test its intelligence, prompting it to tell stories itself, or tweaking its perspective to read a story from different psychological profiles—Asian vs. European, for example. One of Winston's graduate students gave Genesis the ability to teach and persuade readers. For example, the student requested that Genesis make the woodcutter look good in the story of Hansel and Gretel. Genesis responded by adding sentences that emphasized the character's virtuousness.

Recently, Winston's students found a way to give Genesis schizophrenia. "We think some aspects of schizophrenia are the consequence of fundamentally broken story systems," explained Winston. He showed me a cartoon illustration. It depicted a little girl trying to open a door handle that is too high to reach, and then fetching an umbrella. A healthy person would infer the girl is getting the umbrella to extend her reach

and open the door; a person with schizophrenia does what is called hyperpresumption—inferring that the girl is getting an umbrella to go outside in the rain. To get Genesis to think like a schizophrenic in this way, Winston and his students simply switched two lines of code in the program. They put Genesis's search for explanations that tie story elements together after the search for the default answer, the one that the girl will be going into the rain. Hyperpresumption, according to Genesis, is a dysfunction of sequencing in the brain. They called it the Faulty Story Mechanism Corollary.

ONE OF WINSTON'S FORMER STUDENTS at MIT was Wolfgang Victor Hayden Yarlott, an engineering and computer science major who graduated in 2014 and is now doing a Ph.D. at Florida International University. Yarlott is a Crow Indian and had an idea: If Winston was correct about the Strong Story Hypothesis, that stories are a key part of human intelligence, Genesis needed to demonstrate that it understood stories from all cultures, including indigenous cultures such as the Crow. "Stories are how intelligence and knowledge is represented and passed down from generation to



BEWARE THE CROW Computer scientist Wolfgang Victor Hayden Yarlott successfully programmed the Genesis computer to discern a key theme in a Native American creation story about protecting wisdom from the covetous crow.

generation—an inability to understand any culture’s stories means that either the hypotheses are wrong or the Genesis system needs more work,” Yarlott wrote in his thesis.

Yarlott chose a set of five Crow stories for Genesis to read, including creation myths that he’d heard during his childhood in southern Montana. His challenge was to create recognition in Genesis of chains of events that seemed unrelated, of supernatural concepts like medicine (which has a magic-like quality in Crow folklore), and of the “trickster” personality traits. Those are all elements in the Crow stories that, as Yarlott determined, distinguish them from the canon of Anglo-European storytelling. The creation myth “Old Man Coyote Makes the World” features animals that communicate with Old Man Coyote just as people do. As Yarlott points out, there is an amazing display of power or medicine that enables Old Man Coyote to create—but

there are explicitly unknowable events that take place as part of the story, like, “How he did this, no-one can imagine.” To solve these issues Yarlott had to give Genesis new concept patterns to recognize. For example:

Start description of “Creation”.

XX and YY are entities.

YY’s not existing leads to XX’s creating YY.

The end.

Start description of “Successful trickster”.

XX is a person.

YY is an entity.

XX’s wanting to fool YY leads to XX’s fooling YY.

The end.

Start description of “Vision Quest”.

XX is a person.

YY is a place.

XX’s traveling to YY leads to XX’s having a vision.

The end.

The stories that Yarlott told to Genesis read like this:

Start experiment.

Note that “Old Man Coyote” is a name.

Note that “Little_Duck” is a name.

Note that “Big_Duck” is a name.

Note that “Cirape” is a name.

Insert file Crow commonsense knowledge.

Insert file Crow reflective knowledge.

“Trickster” is a kind of personality trait.

Start story titled “Old Man Coyote Makes the World”

Old Man Coyote is a person.

Little_Duck is a duck.

Big_Duck is a duck.

Cirape is a coyote.

Mud is an object.

“the tradition of wife stealing” is a thing.

Old Man Coyote saw emptiness because the world didn’t exist.

Old Man Coyote doesn’t want emptiness.

Old Man Coyote tries to get rid of emptiness.

Yarlott found that Genesis was capable of making dozens of inferences about the story and several discoveries, too. It triggered concept patterns for ideas that weren’t explicitly stated in the story, recognizing the themes of violated belief, origin story, medicine man, and creation. It seemed to comprehend the elements of Crow literature, from unknowable events to

The computer’s understanding showed that in some respects it was self-aware.

the concept of medicine to the uniform treatment of all beings and the idea of differences as a source of strength. “I believe this is a solid step toward showing both that Genesis is capable of handling stories from Crow literature,” he surmised, “and that Genesis is a global system for story understanding, regardless of the culture the stories come from.”

Genesis has obvious shortcomings: So far it only understands elementary language stripped of metaphor, dialogue, complex expression, and quotation. To grow its capacity for understanding, Genesis needs more concept patterns—in other words, more teaching. How many thousands of stories does a child hear, create, and read as she grows into adulthood? Perhaps hundreds of thousands. But even if Genesis could access the same number of stories there are probably more fundamental limitations to the machine’s potential. One rainy day in November I went to see Winston teach his extremely popular undergraduate course at MIT, “Intro to Artificial Intelligence.” I listened to him explain the Strong Story Hypothesis to hundreds of students and demonstrate its abilities. “Can Watson do this?” he quipped. But then he posed a series of questions to his young students casting doubt on his own invention.

“Can we think without language?”

The room was quiet.

“Well, we know from those whose language cortex is gone that they can’t read or speak or understand spoken language,” he explained. “Are they stupid? They can still play chess, do arithmetic, find hiding places, process music. Even if the external language apparatus is blown away, I think they still have inner language.”

He paused. “Can we think without a body?”

Quiet.

“What does Genesis know about love if it doesn’t have a hormonal system?” he said. “What does it know about dying if it doesn’t have a body that rots? Can it still be intelligent?”

He paused again. “We’ll leave that part of the story for another time.”

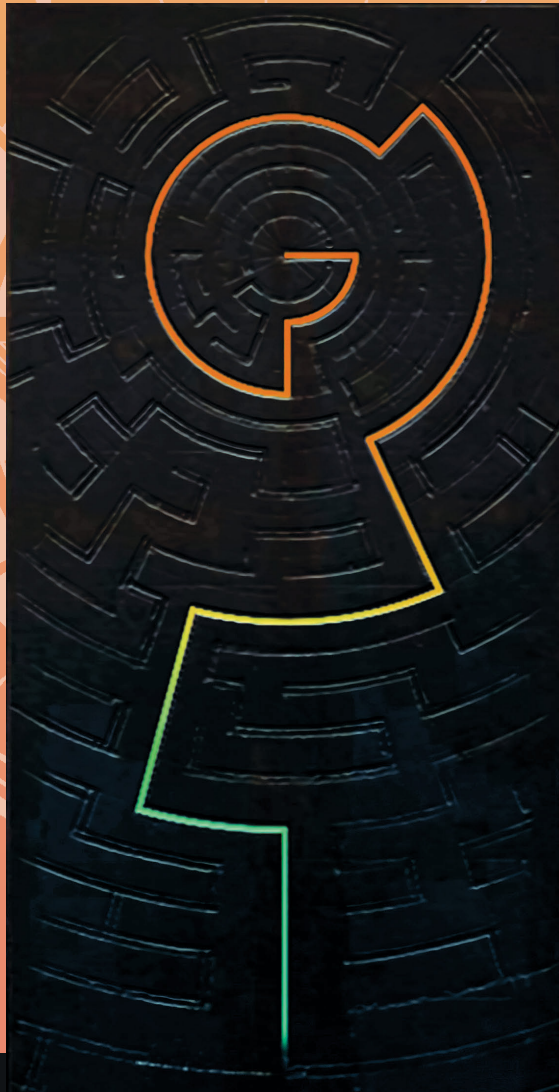
Love and death, I marveled, as students filed out of the lecture hall. The stuff of the most epic stories on Earth. Without embodiment in space and time, could Genesis ever understand these universal human conditions? Winston thought that one of the next questions that needed to be answered was how much humans learn by self-discovery. Genesis had been taught in the same manner that a parent would teach a child, but children also have direct experience and what he called “surrogate experience” through reading that helps them to formulate rules and concepts independently. Could this self-discovery process be somehow computationally modeled? Or, I wondered, could Genesis somehow reproduce the navigation across landscape and mind that has made humans human? As Winston himself said at the close of his lecture, “We’ll leave that part of the story for another time.” Winston died in July, 2019, at age 76. 🌀

M.R. O’CONNOR is the author of *Wayfinding: The Science and Mystery of How Humans Navigate the World*. She writes about the politics and ethics of science, technology, and conservation. Her reporting has appeared online in *The New Yorker*, *Science*, *Foreign Policy*, and *The Atlantic*. She was a MIT Knight Science Journalism Fellow in 2016/17.

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COMPLEXITY

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Our Brains Tell Stories So We Can Live

Without inner narratives we would be lost in a chaotic world

BY ROBERT A. BURTON

WE ARE ALL STORYTELLERS; we make sense out of the world by telling stories. And science is a great source of stories. Not so, you might argue. Science is an objective collection and interpretation of data. I completely agree. At the level of the study of purely physical phenomena, science is the only reliable method for establishing the facts of the world.

But when we use data of the physical world to explain phenomena that cannot be reduced to physical

facts, or when we extend incomplete data to draw general conclusions, we are telling stories. Knowing the atomic weight of carbon and oxygen cannot tell us what life is. There are no naked facts that completely explain why animals sacrifice themselves for the good of their kin, why we fall in love, the meaning and purpose of existence, or why we kill each other.

Science is not at fault. On the contrary, science can save us from false stories. It is an irreplaceable means of understanding our world. But despite the verities of science, many of our most important questions compel us to tell stories that venture beyond the facts. For all of the sophisticated methodologies in science, we have not moved beyond the story as the primary way that we make sense of our lives.

TO SEE WHERE SCIENCE AND STORY meet, let's take a look at how story is created in the brain. Let's begin with an utterly simple example of a story, offered by E.M. Forster in his classic book on writing, *Aspects of the Novel*: "The king died and then the queen died." It is nearly impossible to read this juxtaposition of events without wondering why the queen died. Even with a minimum of description, the construction of the sentence makes us guess at a pattern. Why would the author mention both events in the same sentence if he didn't mean to imply a causal relationship?

Once a relationship has been suggested, we feel obliged to come up with an explanation. This makes us turn to what we know, to our storehouse of facts. It is general knowledge that a spouse can die of grief. Did the queen then die of heartbreak? This possibility draws on the science of human behavior, which competes with other, more traditional narratives. A high school student who has been studying *Hamlet*, for instance, might read the story as a microsynopsis of the play.

The pleasurable feeling that our explanation is the right one—ranging from a modest sense of familiarity to the powerful and sublime "a-ha!"—is meted out by the same reward system in the brain integral to drug, alcohol, and gambling addictions. The reward system extends from the limbic area of the brain, vital to the expression of emotion, to the prefrontal cortex, critical to executive thought. Though still imperfectly understood, it is generally thought that the reward system plays a central role in the promotion and reinforcement of learning. Key to the system, and found primarily within its brain cells, is dopamine, a neurotransmitter that carries and modulates signals among brain cells. Studies consistently show that feeling rewarded is accompanied by a rise in dopamine levels.

This reward system was first noted in the 1950s by two McGill University researchers, James Olds and Peter Milner. Stimulating electrodes were placed in presumed brain reward areas of rats. When allowed

Despite the verities
of science, we are
compelled to tell stories
that venture beyond
the facts.

full unrestricted access to a lever that, when depressed, would cause the electrodes to fire, the rats quickly learned to repeatedly depress the lever, often to the exclusion of food and water. Realizing that our brains are capable of producing feelings so intense that we choose to ignore such basic drives as hunger and thirst was a first step toward understanding the enormous power of the brain's reward circuitry.

When we make and take incomplete stories from science, there are moral consequences.

Critical to understanding how stories spark the brain's reward system is the theory known as pattern recognition—the brain's way of piecing together a number of separate components of an image into a coherent picture. The first time you see a lion, for instance, you have to figure out what you're seeing. At least 30 separate areas of the brain's visual cortex pitch in, each processing an aspect of the overall image—from the detection of motion and edges, to the register of color and facial features. Collectively they form an overall image of a lion.

Each subsequent exposure to a lion enhances your neural circuitry; the connections among processing regions become more robust and efficient. (This theory, based on the research of Canadian psychologist Donald O. Hebb, a pioneer in studying how people learn, is often stated as “cells that fire together wire together.”) Soon, less input is necessary to recognize the lion. A fleeting glimpse of a partial picture is sufficient for recognition, which occurs via positive feedback from your reward system. *Yes, you are assured by your brain, that is a lion.*

An efficient pattern recognition of a lion makes perfect evolutionary sense. If you see a large feline shape moving in some nearby brush, it is unwise to wait until you see the yellows of the lion's eyes before starting to run up the nearest tree. You need a brain that quickly detects entire shapes from fragments of the

total picture and provides you with a powerful sense of the accuracy of this recognition.

One need only think of the recognition of a new pattern that is so profound that it triggers an involuntary “a-ha!” to understand the degree of pleasure that can be associated with learning. It's no wonder that once a particular pattern-recognition-reward relationship is well grooved into our circuitry, it is hard to shake. In general—outside of addiction, that is—this “stickiness” of a correlation is a good thing. It is through repetition and the sense of familiarity and “rightness” of a correlation that we learn to navigate our way in the world.

SCIENCE IS IN THE BUSINESS of making up stories called hypotheses and testing them, then trying its best to make up better ones. Thought-experiments can be compared to storytelling exercises using well-known characters. What would Sherlock Holmes do if he found a body suspended in a tree with a note strapped to its ankle? What would a light ray being bounced between two mirrors look like to an observer sitting on a train? Once done with their story, scientists go to the lab to test it; writers call editors to see if they will buy it.

People and science are like bread and butter. We are hardwired to need stories; science has storytelling buried deep in its nature. But there is also a problem. We can get our dopamine reward, and walk away with a story in hand, before science has finished testing it. This problem is exacerbated by the fact that the brain, hungry for its pattern-matching dopamine reward, overlooks contradictory or conflicting information whenever possible. A fundamental prerequisite for pattern recognition is the ability to quickly distinguish between similar but not identical inputs. Not being able to pigeonhole an event or idea makes it much more difficult for the brain to label and store it as a discrete memory. Neat and tidy promotes learning; loose ends lead to the “yes, but” of indecision and inability to draw a precise conclusion.

Just as proper pattern recognition results in the reward of an increased release of dopamine, faulty pattern recognition is associated with decreased dopamine release. In monkeys, the failure to make a successful prediction (correlation between expected and actual outcome) characteristically diminishes dopamine release exactly at the time that the predicted event is

anticipated but fails to occur. Just as accurate correlations are pleasurable, lack of correlation produces the neurotransmitter equivalent of thwarted expectation (or worse).

Once we see that stories are the narrative equivalent of correlation, it is easy to understand why our brains seek out stories (patterns) whenever and wherever possible. You may have read or heard about the famous experiment in which University of Illinois psychology professor Daniel Simons asked subjects to watch a video and count the number of times a ball is dribbled by a basketball team. When focused on counting, the majority of viewers failed to see a woman in a gorilla suit walk across the playing area. In effect, well-oiled patterns of observation encourage our brains to compose a story that we expect to hear.

Because we are compelled to make stories, we are often compelled to take incomplete stories and run with them. With a half-story from science in our minds, we earn a dopamine “reward” every time it helps us understand something in our world—even if that explanation is incomplete or wrong.

Loose ends lead to the “yes, but” of indecision and inability to draw a precise conclusion.

Following the Newtown massacre, some experts commented on the killer having Asperger’s syndrome, as though that might at least partially explain his behavior. Though Asperger’s syndrome feels like a specific diagnosis, it is, by definition, nothing more than a constellation of symptoms common to a group of people. In the 1940s, Austrian pediatrician Hans Asperger noted that a number of patients had similar problems with social skills, eccentric or repetitive actions, unusual preoccupation rituals, and communication difficulties, including lack of eye contact and trouble understanding facial expressions and gestures. The 2013 decision by the American Psychiatric Association to remove the diagnosis of Asperger’s syndrome from its guidebook for clinicians, the *Diagnostic and Statistical Manual of Psychiatric Disorders (DSM-V)*, for failing to conform to

any specific neuropathology, underscores the all-too-common problem of accepting a clustering of symptoms as synonymous with a specific disease. Syndromes are stories in search of underlying causes.

Similarly, studies of psychopaths have shown a diminished volume of gray matter in specific regions of the prefrontal cortex. But these findings aren’t the sole explanation for violent acts. Because it is impossible to stimulate a specific brain region to produce complex and premeditated acts, we are left to conclude that while certain brain conditions can be correlated with a complex act, they are not necessarily causing it. Likewise, brain scans that reveal abnormalities in mass murderers may help us understand what might have contributed to their behavior. But the abnormalities are no more the sole explanation for violence than childhood neglect or poor nutrition are. They are stories, albeit with a detailed neurophysiological component, but stories nonetheless.

WHEN WE MAKE AND TAKE incomplete stories from science, there are often moral consequences. How much personal responsibility should we assign to an individual with a damaged or malfunctioning brain? What is the appropriate punishment and possibility of rehabilitation for such a person? Only when we openly acknowledge the degree to which science is presenting its observations in the form of story can we address this moral dimension. We must each work out our own guidelines for when we think scientific data has exceeded its bounds and has morphed into the agenda and bias of story. Of course this is always going to be a challenge in the absence of a full array of scientific data.

But we can begin by being aware of the various ways that storytelling can insinuate itself into the presentation and interpretation of data. Good science is a combination of meticulously obtained and analyzed data, a restriction of the conclusions to those interpretations that are explicitly reflected in the data, and an honest and humble recognition of the limits of what this data can say about the world.

As members of the public, we need to ensure that any science we accept as truth has passed through the peer-review process. We should also understand that even peer-reviewed data is not always accurate. In 2011, *Nature* reported that published retractions had

increased by a factor of 10 over the last 10 years, while the number of papers published rose only 44 percent. Also in *Nature*, scientists C. Glenn Begley and Lee M. Ellis wrote that their colleagues at the biotechnology firm Amgen could reproduce only six of 53 landmark hematology and oncology studies from the scientific literature. Similarly, scientists from Bayer reported in 2011 that they could not consistently reproduce about two-thirds of oncology studies relevant to their work.

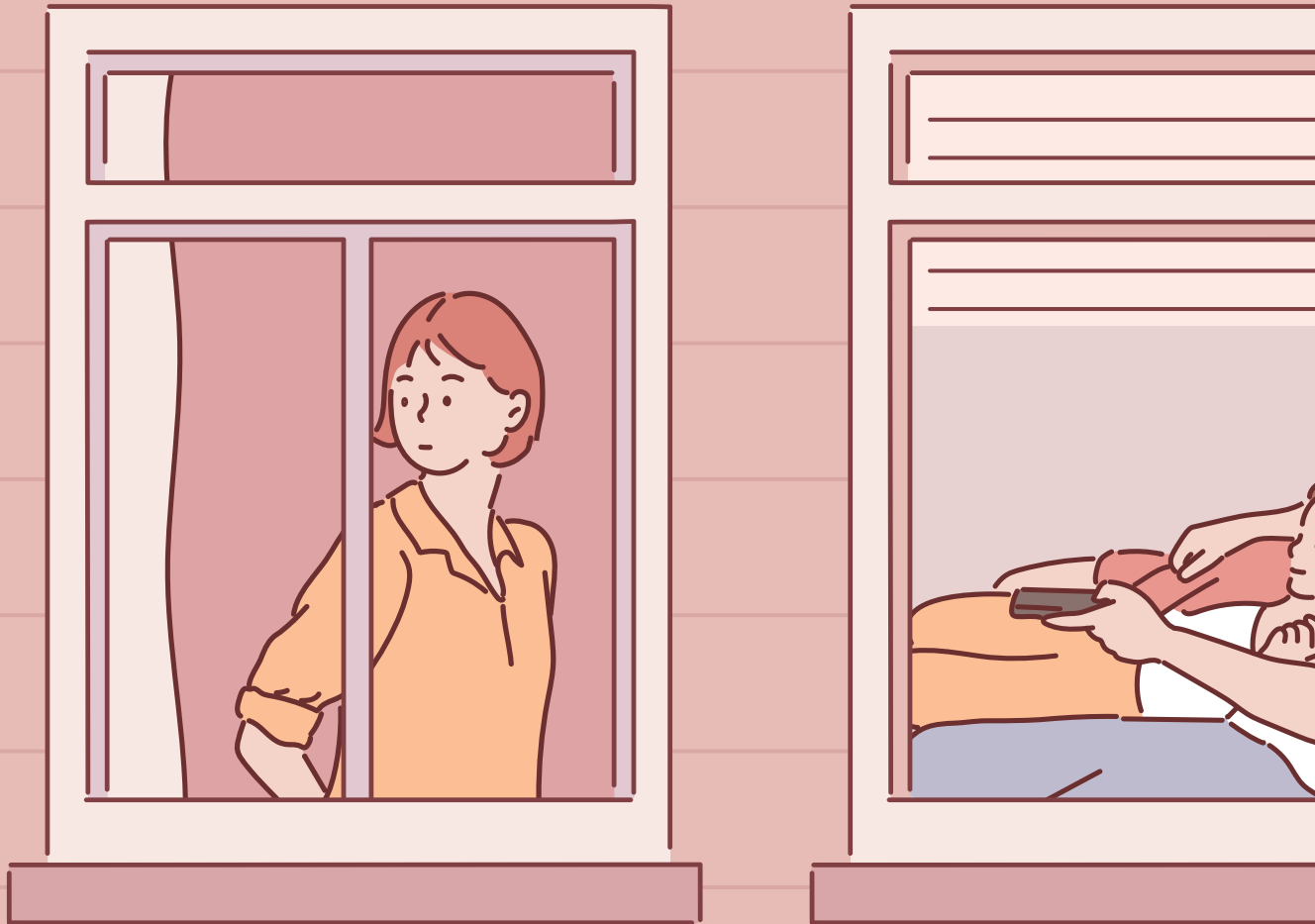
When reading science reports, we should also search for information on the limits of the data. Were assumptions made? What do the “error bars,” or graphic representations of variable data, say? We may not always understand the data limits, but we should be worried when some discussion of them is completely absent.

In the end, scientists have the tools, language, and experience to tell us informed, engaging, and powerful stories. In turn, we should judge their studies in the same light in which we judge other artistic forms. Like a literary critic, we should assess the preciseness of language, the tightness of structure, the clarity and originality of vision, the overall elegance and grace of the study, the restraint with which they present moral issues, how they place their studies in historical, cultural, and personal context, and their willingness to entertain alternative opinions and interpretations.

The methodology of science remains one of the great advances of humankind. Its stories, properly told, are epic poems in progress, and deserve to stand alongside the great stories of history. ☺

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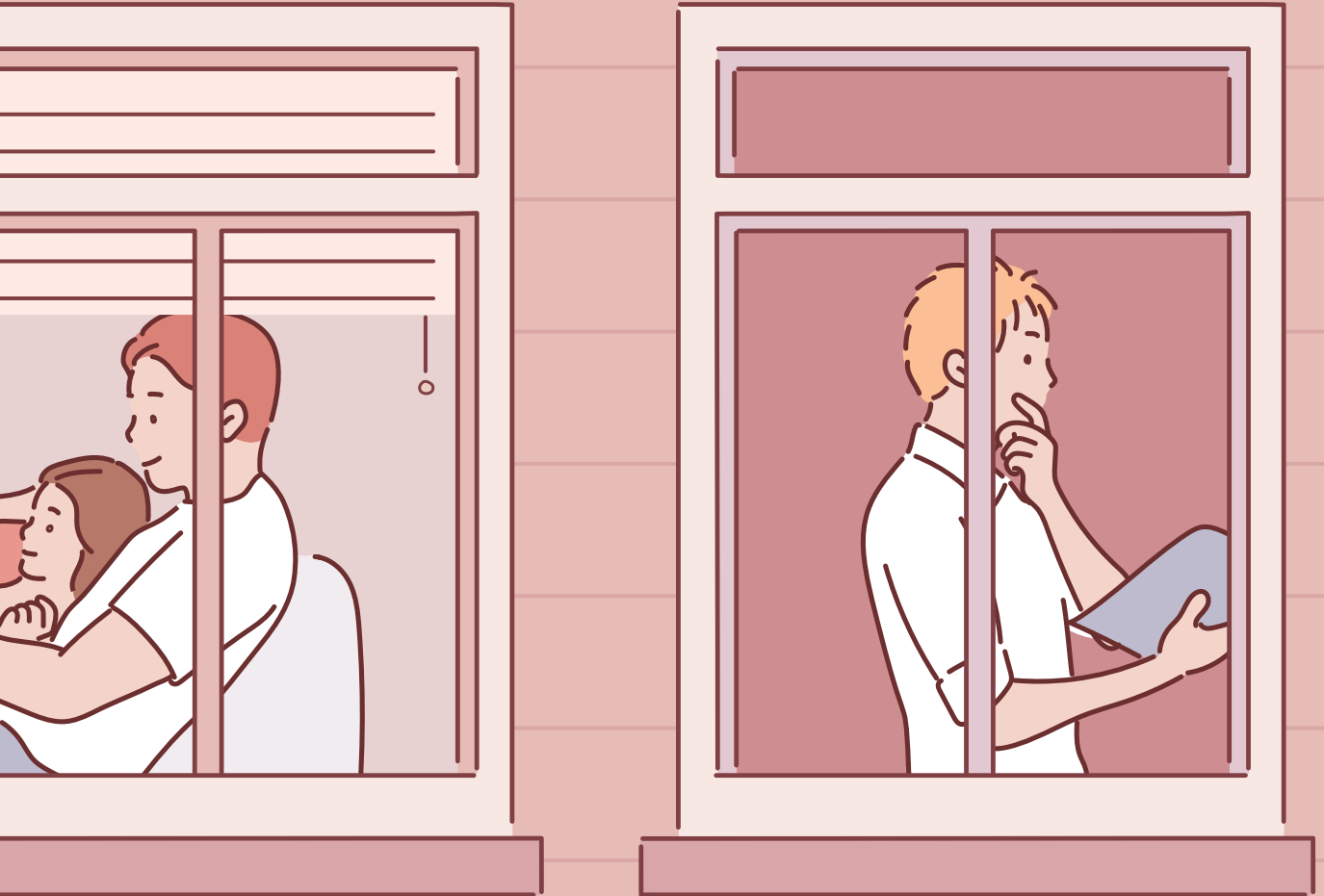
A slightly different version of this story appeared in our preview issue, “The Story of Nautilus” in April 2013.



Human Emotions Are Personal Narratives

Neuroscientist Joseph LeDoux on what makes our brains unique

BY KEVIN BERGER



MINIWIIDE / SHUTTERSTOCK

FOR HIS NEXT BOOK, Joseph LeDoux knew he had to go deep. He had to go back in time, way back, 3.5 billion years ago. The author of the seminal *The Emotional Brain*, followed by *Synaptic Self* and *Anxious*, sensed a missing element in those books on how brain anatomy and function shape human behavior and emotions. That element was evolution. In his new book, *The Deep History of Ourselves: The Four-Billion-Year Story of How We Got Our Conscious Brains*, LeDoux takes readers back to the emergence of life on Earth to show what our protean brains today owe to the canny survival of Protozoa.

We have 36 words in our language for variations of fear and anxiety.

“I started asking, ‘How far back in evolution does the ability to detect and respond to danger go?’” he said to me in a recent interview at his home in New York City. LeDoux directs the Emotional Brain Institute at New York University. In his research and previous books, he has shown the human brain processes that detect and respond to danger differ from the conscious experiences of fear itself. “I felt I needed to understand more about this process,” he said. “I wanted to know what single-cell organisms teach us about emotion.”

The Deep History of Ourselves takes readers from past to present along a wonderfully readable path, defined by short chapters, paved with insights. LeDoux’s argument is our emotional systems are what make us uniquely human. He writes that “there is indeed good evidence that the same brain systems control survival behaviors in humans and other mammals, but that these are not the systems responsible for conscious feelings we experience when we engage in such behaviors.” Those conscious feelings belong to humans alone.

LeDoux is aware his argument runs counter to that of many animal experts like Frans de Waal and Jane Goodall, whose work underlines a connection between the emotions of non-human primates and us. LeDoux carefully spells out, and documents, where humans differ from other animals in their emotional lives and experiences.

In my interview with LeDoux, I asked him to focus on the common misperception of emotions, as he sees them, and to clarify for us just what makes us unique from other animals. He did just that, with patience and passion.

What’s the most common conception of emotions?

That they are states that we share with animals and they drive our behavioral responses. Darwin said emotions are mental states we’ve inherited from our animal ancestors. It’s assumed that when we respond to danger, do things like freeze or flee, it’s because we’re afraid. When we feel pleasure, it’s because we’ve eaten something great. It’s true these states go with those kinds of behaviors, but the question is, do the states cause the behavior?



QUESTION OF BALANCE “We live in a biological equilibrium with animals and plants,” says Joseph LeDoux (left). “At the rate we’re destroying species of plants and animals, the equilibrium is going to shift, and every time the equilibrium shifts, new power structures take place.” Given we’re the species with the power to rebalance nature, the future is up to us.

Why is fear universal if it’s not innate?

What’s universal is danger, not fear. Because danger has to be important in the life of every human, no matter what culture they’re in, they’re going to have a system for understanding that within their culture. They’re going to have a word for it or some words for it. We have 36 words in our language for variations of fear and anxiety. So the experience that’s going to arise is going to be culturally determined and is going to be personally determined.

So what, then, is an emotion?

It’s a conscious awareness that something psychologically or biologically important is happening to you. Evolution gave us these behavioral responses to stimulus, but those are not yet emotions.

Why did we evolve emotions?

I think of emotions as coming along in the way that Stephen J. Gould described certain things as exaptations, which is a kind of a variation of his more famous term, which was spandrel. A spandrel is something that exists without having a function, and he used the so-called spandrels at San Marco and Venice, arches in the architecture that created a space where you could put pictures or flowers. They weren’t designed for that, but because they existed, it was useful to use them. A good example of an exaptation is that feathers originally arose in bird-like reptiles for warmth, but then they were co-opted for flight in the wings.

How are emotions exaptations?

I see emotions as the result of other exaptations. One is language. We had certain kinds of communicative skills, and we put these together with other capacities,

And do they? Do emotional states drive our behavior?

A lot of research, including mine, suggests that’s not the case. Take the example of subliminal stimulation. If you present stimuli to people in a way that they can’t consciously recognize it, they still have responses to it. One of the first studies was done in the 1950s. After being passively conditioned with a visual stimulus, the person’s heart was beating faster, even though they had no fear or any conscious experience of what the stimulus was.

Another example is blindsight, patients who don’t see stimuli in a blind spot, yet perform behaviors that show the stimuli were perceptually registered by the brain. If a person with blindsight sees a picture of a snake, their heart will beat faster and their palms will sweat, but they won’t know the stimulus is there and they won’t have any fear. Fear is not what’s causing it. The same stimulus is going into the brain, but it’s going to one set of circuits to produce the responses, and other circuits to generate the experience.

I think, basically, the mind is a narrative generator.

such as hierarchical relational reasoning, the ability to do mental time travel, to project yourself into the past and the future.

An important part of these ideas is the self. I have a motto, “No self, no fear.” If you don’t know you’re in harm’s way, then you’re not going to experience fear. You can react to it, you can protect yourself, but until you know that it’s you, it’s not the conscious experience that invades your mind. The stimulus of danger is going into the brain. But it’s going to one set of circuits to produce the responses, and other circuits to generate the experience. Now, the responses are going to contribute to the experience, but don’t determine it.

Other scientists argue emotions are more hardwired circuits in our brains. They say we can read emotions in people’s faces because they’re signifiers of these ingrained emotions. Why are they wrong?

It’s the difference between correlation and causation. The facial expressions are innate, and they often occur when we are afraid or happy or whatever the basic emotion in question is. But in the brain, I think that those are separately controlled. So the fear does not cause the grimace or whatever you would call the fear facial expression. Those things happen in parallel rather than in sequence.

So if someone smiles, am I not necessarily right to say they’re happy?

If you did that, you’d probably be correct many times. But in the case of fear, there are instances where we can dissociate those things. I suspect you could do that with other emotions as well. A lot of the reason we can do this so well in the case of fear is because there are good animal models for studying them. We know that the circuit underlying the behavioral and physiological responses to danger is pretty much the same in non-human animals and human animals.

And that’s the amygdala, right?

Right.

What is the amygdala?

The amygdala is a small region in the temporal lobe. We say “the amygdala,” but there are two amygdalae. Traditionally it’s thought of as the fear center, an idea for which I’m partly responsible, maybe largely responsible, through my book *The Emotional Brain*. But I was a little sloppy with the language, even though back then I was saying the amygdala is an implicit fear circuit, and the explicit fear, the conscious fear, is a cortical process. Still, over time, the amygdala has become a term for a fear center, not an implicit fear center, and that’s what I’ve been trying to correct.

The amygdala is not where you consciously experience fear. It's just a way station in the flow of information from the sensory systems into the motor systems. You can have a person with amygdala damage who can still feel fear. Given that fact, the amygdala can't be making fear. It's making behavioral responses, but not the experience of fear. Let's say there's a snake at your feet. That's probably enough to activate a fear schema in your circuits and begin to pattern-complete a concept of the situation you're in. That concept is then the foundation of the conscious experience.

We're not conscious of the foundation, right?

Right. Most of what the brain does is not conscious. Up until the moment when something crosses that threshold of consciousness, it's not conscious. So every conscious experience is based on a flow of information that's not conscious, that somehow reaches the threshold. So these schema are non-conscious, but they are the kinds of things that can rise up.

How do you know you're right?

I don't. But my research on this goes back to my Ph.D. in 1978. My Ph.D. research was all on split-brain patients and conscious experience. I wanted to understand how non-conscious behaviors could be dealt with simultaneously with these conscious experiences. We'd generate behaviors in patients' right hemisphere, and then we'd ask the left hemisphere, "Why'd you do that?" And the left hemisphere would generate an explanation, even though it had no idea. So there's this idea of these narratives that come out of observing your behavior, because it causes cognitive dissonance if you're seeing a behavior you didn't perform. We have free will. We control our behavior, and if we're not controlling our behavior, something is wrong. So that's where this idea of narratives comes from. I think, basically, the mind is a narrative generator. It's all about generating mental models of situations.

To explain what?

To explain what we're doing and why we do it. The other thing is motivation. We know what we do, we see it. But why we do it is less clear. So we're often compelled to generate an explanation for our motivations because then we feel that we're in charge of ourselves.

Is that explanation subjective? Is it going to be subjective to each person?

Absolutely.

Are emotions, then, just subjective narratives?

They are.

You disagree with scientists who claim animals have emotions. Why don't animals have emotions comparable to ours?

I know I'm accused of saying animals have no emotion. I don't say that. I say that whatever they have, they don't have what we have. Every human has a human brain. Every animal has their own brain. And they're different. Some parts of the brain involved in conceptualizations of what emotions are have unique properties in the human brain. It's based on the difference between autonoetic and noetic consciousness, which is an idea that Endel Tulving gave us about memory, and I'm using to extend to emotion.

What is autonoetic consciousness?

It's a consciousness in which the self is involved. The self is subject as opposed to object. To have an emotion, as I mentioned, your self has to be involved. Animals can have past memory and perspective cognition. They can project and experience something that's going to happen in the future. But the question is, can they put themselves into it? Even the best people in the animal-studies field say they don't know if the animals can have this sense of self the way that humans can. I think that's the right approach.

In his recent book, *Mama's Last Hug*, Frans de Waal writes, "Emotions are like organs. They are all needed, and we share them with other mammals." He goes on to say, "All emotions are both biological and essential. None is more basic than the others, and none are uniquely human." What do you think of that statement?

I agree with him that none are more basic than the others, but they do have a unique, human sense. Animals have semantic knowledge, not in the sense of words, but of facts. Animals have a lot of facts in their lives. They have facts about where there's food, and may have an experience that goes along with that. But do they

have the sense of self that allows them to know that it's them that is having the experience?

Do they?

No. The self as a psychological entity is different from the self as an objective body. Many animals may have a body-self sense. They know their body versus another body or another animal. But they don't have a psychological sense that they own their own body, that it's something that they're aware of as a possession of their mind.

Jane Goodall and Temple Grandin repeatedly say animals have feelings.

Yeah, but on the basis of what? Nothing.

On the basis that we share a similar anatomy.

My argument is that anatomy is the wrong anatomy, that emotions are cognitive-assembled states in higher areas of the brain, in the prefrontal cortex, with circuits and cellular components that other animals don't possess.

What is the one brain component we have that animals don't have?

The frontal pole. It's a unique region in the human brain. Other primates, some apes, have some tiny version of the frontal pole. But there's a unique aspect of it in the human brain that's involved in higher-order conceptualization. My whole point is that emotions are higher-order conceptualizations, so that's where I put my money.

Doesn't our language differentiate us from animals, too?

Yes, but that doesn't mean it's all about words or any specific thing about language, except that language has rewired our brains to think in different ways. Daniel Dennett has said, "language lays down tracks on which thoughts can travel." It allows us to do all kinds of things, like simulate in a fraction of a second of who's going to do what to whom in a social situation. We have syntax that parses those kinds of things.

Are you saying we need language for emotions?

We need the architecture of language because that's one of the spandrel exaptations that made emotions possible.

The architecture of language
made emotions possible.

So animals don't have language?

They have communication, but not language.

So does that also explain why animals can't have emotions?

They can't have what we call emotions, or the way we understand emotions.

Like anger, shame, jealousy?

They might behave in a way that's consistent with those. But do they have the experiences of them is the question. And if they did, how would you know? You can't ask them because all they do is behave. Here's the thing. A human can do two things to respond to a conscious stimulus. You present me with an apple, I can say, "That's an apple," or I can pick up the apple. I can respond verbally or non-verbally to something I'm conscious of. But if I'm not conscious of something, I can only respond non-verbally. I can't give a verbal response. Animals don't have that alternate response, one different from the non-verbal response. All they have is the non-verbal. I'm not saying they don't have something, but scientifically, how do you study that?

If readers came away from *The Deep History of Ourselves* with only one idea, what would you like that idea to be?

That we can't take the obvious as fact. Just because things seem a certain way doesn't mean they are. Just because we are running from the bear and feeling afraid at the same time, that doesn't mean our behavior and emotions have the same cause. To understand the causes, we have to study them. We can't simply study them psychologically. We have to figure out what's going on in the brain. When we do that, we see these things are controlled separately in the brain. They interact but fundamentally they're triggered separately. One has an evolutionary history that we can trace to the beginning of life, and the other is something that is unique to our species. ☺

KEVIN BERGER is the editor of *Nautilus*.



How Freedom Divides

An expert on animal societies on what sets human societies apart

BY MARK W. MOFFETT

MILAN M / SHUTTERSTOCK

A **S A BIOLOGIST** who studies animal behavior, particularly the long-term stability of the societies of different species, our own included, I've traveled through diverse cultures around the world. The word I hear everywhere I go, a badge of honor to all people, is freedom. Americans have made pride in freedom a national pastime since winning their independence. But at the time of the Revolutionary War, the British thought of themselves as free compared to repressive European countries of the day. What is this warm glow that arises within us from feeling free?

On one of my expeditions to New Guinea, an elderly man boasted that his tribe did as they wished. Invited to join a picnic in Iran, I listened to a family joyfully tell me about the liberties their nation provided, not realizing how Americans might see their lives differently. The fact is, "freedom" and "free" are among the most common words in all national anthems. Even Afghanistan, which strikes the west as a land perennially in chaos, long had an anthem declaring it "the nation of freedom" (until that verse was replaced in 2006 by another highlighting the names of the country's major tribal groups). People around the globe—perhaps all but the most repressed—appear to think of themselves as free. How can *we* be free, and *they* be so delusional?

I've come to appreciate that much human activity can be understood in terms of our pursuit of the choices a society opens to us. But this freedom is never simple. Permissiveness isn't uncontrolled. A society defines itself in part by what it won't tolerate, and the proper conduct required from its members. Even societies that take pride in a commitment to personal rights exist by exacting a loss of choice on members for the sake of safety and predictability. By its nature, society membership entails a loss of freedom.

What choices do societies curtail? For most other species, the constraint appears to be that members affiliate with each other and consort little if at all with outsiders. Chimpanzees attack all foreign conspecifics (unless it's a female in heat), while the related bonobo can have friends in other communities but always

return to their territory at the end of the day. In both instances, there's a clean separation of the societies, based on the animals' knowledge of each other.

Human societies come with further obligations. People must look and act appropriately, adhering within accepted limits to whatever differences set *us* apart from *them*. I call such distinctions markers of identity. These markers, which other primates lack, can include devotion to a particular flag, manners of dress, hairstyles, languages, gestures, moral attitudes, and even slight differences, detected subconsciously, in how we walk and smile. These traits are so numerous and ever-present that human beings are walking billboards for their identities.

WE FEEL FREE insofar as our actions and appearance fall within the socially sanctioned bounds of these sometimes unstated rules (weighing some of them more than others), our expressions of our identity adhering to our commitments to the society and to our station and status within it. Generally speaking, the more privations a society has undergone, the more rigid the expectations put on its people.¹

In a thriving democracy, persons with radical takes on faith or dress retain citizenship, but things can get nasty for those who don't conform to the required markers when times are tough. Further, the repulsion felt toward social deviants can be so profound that we treat them more harshly for the same offense than we do a foreigner—an overreaction known in psychology as the black sheep effect.² Outliers poorly matching

what is “normal” are ostracized, stigmatized, pressured to change or treated as foreign, depending on the kind and extent of the aberrance. Such censure puts a rein on what goes on in a society.³

Extremist regimes aside, by and large citizens everywhere gladly embrace the restrictions placed upon them, believing in the rightness of their society and finding comfort within the restraints it imposes. A society’s members seldom have to be sold on why their ways are best: They absolutely know how things should be, and for them a life arranged that way is worth living. The return from the society is substantial: a sense of ease, even camaraderie, around likeminded others; security and social support; access to resources, choices for employment, suitable marriage partners, the arts, and much more.

While people value their freedom, socially imposed limits on freedom, defined by the currently agreed-upon markers of identity, are as indispensable to happiness as freedom itself. If we are overwhelmed or

For this reason, individualist societies that promote a right to be different, like the United States, and those that nurture a collectivist identity, such as Japan or China (where people emphasize the support given by the collective) can both celebrate the opportunities and happiness their society offers⁵; indeed there’s little difference in people’s overall happiness (well-being) across countries.⁶

Regardless of a society’s permissiveness, unity falters if its citizens have the freedom (or feel they should have the freedom) to act outside the comfort zone of others. Often our discomfort around such acts is expressed as disgust or fear, and we (whoever we may be) verbalize the sensations in terms of morality. That the freedom to do such things could be desirable will seem absurd to us, as we see today, for example, with sexual acts some deem inappropriate, or the right to an abortion or the choice to carry an assault rifle. The schism makes constructive communication between social factions all but impossible. Such differences give

How can *we* be free, and *they* be so delusional?

unsettled by the options available to us and other members, and by the acts of those around us, what we feel is turmoil, not freedom. For western-developed societies, this had led to what psychologist Barry Schwartz calls the paradox of choice, where an overabundance of options makes people unhappy.⁴ What we think of as freedom then is both restricted and restricting. Yet only an outsider would see the restrictions are oppressive.

rise to weaknesses in the social fabric that have always existed, but nations increasingly grapple with today.

Ethnic diversity presents even greater complications in the pursuit of freedom. *Homo sapiens* is the only species where groups of individuals that were originally from different sources can merge into a single society, generating ethnicities and races, and that creates unusual challenges. The difficulty is balancing

By its nature, society membership entails a loss of freedom.

one group's pursuit of freedom with another group's comfort. All too often, inequalities in personal freedom emerge between groups. Minorities must fit in with what the society finds acceptable—which often means the preferences of the dominant group, which holds primary sway over the identity, symbols, and power of a nation.

Minorities are put in the position of having to invest in identifying not only with the society where they are citizens but with their own ethnicity, too.⁷ Hispanic Americans, for example, are constantly registered by fellow Americans, and almost constantly see themselves, as Hispanic. By contrast, the dominant members, being the cultural default of their society, seldom need to think about their own ethnicity or race (except to the degree that they must when pulling together in times of economic distress, as is the situation for working class whites today). This gives the majority individuals greater freedom: They enjoy the luxury of considering themselves as one-of-a-kind, idiosyncratic persons.⁸

In short, human beings give up a degree of freedom, and to some extent equality, to gain the security and social and economic payoffs of belonging to a nation, with some ethnicities relinquishing more than others.

Still, the pleasure that freedom gives us is undeniable. What's hard is recognizing that dissimilar peoples elsewhere feel the same thing, and for equally good reason; or how easily our outlook on freedom can squelch what others believe to be just behavior. ☺

This essay is adapted from *The Human Swarm: How Societies Arise, Thrive, and Fall* (Basic Books, 2019), author MARK W. MOFFETT's contribution to what his Ph.D. mentor, Edward O. Wilson, calls consilience—the goal of bringing together the biological and social sciences.

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The Great Silence

A parrot has a question for humans

BY TED CHIANG



THE HUMANS USE ARECIBO to look for extraterrestrial intelligence. Their desire to make a connection is so strong that they've created an ear capable of hearing across the universe.

But I and my fellow parrots are right here. Why aren't they interested in listening to our voices?

We're a nonhuman species capable of communicating with them. Aren't we exactly what humans are looking for?

The universe is so vast that intelligent life must surely have arisen many times. The universe is also so old that even one technological species would have had time to expand and fill the galaxy. Yet there is no sign of life anywhere except on Earth. Humans call this the Fermi Paradox.

One proposed solution to the Fermi Paradox is that intelligent species actively try to conceal their presence, to avoid being targeted by hostile invaders.

Speaking as a member of a species that has been driven nearly to extinction by humans, I can attest that this is a wise strategy.

It makes sense to remain quiet and avoid attracting attention.

The Fermi Paradox is sometimes known as the Great Silence. The universe ought to be a cacophony of voices, but instead it is disconcertingly quiet.

Some humans theorize that intelligent species go extinct before they can expand into outer space. If they're correct, then the hush of the night sky is the silence of a graveyard.

Hundreds of years ago, my kind was so plentiful that the Río Abajo Forest resounded with our voices. Now we're almost gone. Soon this rainforest may be as silent as the rest of the universe.

KUNGVERYLUCKY / SHUTTERSTOCK

There was an African grey parrot named Alex. He was famous for his cognitive abilities. Famous among humans, that is.

A human researcher named Irene Pepperberg spent thirty years studying Alex. She found that not only did Alex know the words for shapes and colors, he actually understood the concepts of shape and color.

Many scientists were skeptical that a bird could grasp abstract concepts. Humans like to think they're unique. But eventually Pepperberg convinced them that Alex wasn't just repeating words, that he understood what he was saying.

Out of all my cousins, Alex was the one who came closest to being taken seriously as a communication partner by humans. Alex died suddenly, when he was still relatively young. The evening before he died, Alex said to Pepperberg, "You be good. I love you."

If humans are looking for a connection with a nonhuman intelligence, what more can they ask for than that?

Every parrot has a unique call that it uses to identify itself; biologists refer to this as the parrot's "contact call."

In 1974, astronomers used Arecibo to broadcast a message into outer space intended to demonstrate human intelligence. That was humanity's contact call.

In the wild, parrots address each other by name. One bird imitates another's contact call to get the other bird's attention.

If humans ever detect the Arecibo message being sent back to Earth, they will know someone is trying to get their attention.

Parrots are vocal learners: we can learn to make new sounds after we've heard them. It's an ability that few animals possess. A dog may understand dozens of commands, but it will never do anything but bark.

Humans are vocal learners, too. We have that in common. So humans and parrots share a special relationship with sound. We don't simply cry out. We pronounce. We enunciate.

Perhaps that's why humans built Arecibo the way they did. A receiver doesn't have to be a transmitter, but

Arecibo is both. It's an ear for listening, and a mouth for speaking.

Humans have lived alongside parrots for thousands of years, and only recently have they considered the possibility that we might be intelligent.

I suppose I can't blame them. We parrots used to think humans weren't very bright. It's hard to make sense of behavior that's so different from your own.

But parrots are more similar to humans than any extraterrestrial species will be, and humans can observe us up close; they can look us in the eye.

How do they expect to recognize an alien intelligence if all they can do is eavesdrop from a hundred light-years away?

It's no coincidence that "aspiration" means both hope and the act of breathing.

When we speak, we use the breath in our lungs to give our thoughts a physical form. The sounds we make are simultaneously our intentions and our life force.

I speak, therefore I am. Vocal learners, like parrots and humans, are perhaps the only ones who fully comprehend the truth of this.

There's a pleasure that comes with shaping sounds with your mouth. It's so primal and visceral that, throughout their history, humans have considered the activity a pathway to the divine.

Pythagorean mystics believed that vowels represented the music of the spheres, and chanted to draw power from them.

Pentecostal Christians believe that when they speak in tongues, they're speaking the language used by angels in heaven.

Brahman Hindus believe that by reciting mantras, they are strengthening the building blocks of reality.

Only a species of vocal learners would ascribe such importance to sound in their mythologies. We parrots can appreciate that.

According to Hindu mythology, the universe was created with a sound: “om.” It is a syllable that contains within it everything that ever was and everything that will be.

When the Arecibo telescope is pointed at the space between stars, it hears a faint hum.

Astronomers call that the cosmic microwave background. It’s the residual radiation of the Big Bang, the explosion that created the universe fourteen billion years ago.

But you can also think of it as a barely audible reverberation of that original “om.” That syllable was so resonant that the night sky will keep vibrating for as long as the universe exists.

When Arecibo is not listening to anything else, it hears the voice of creation.

We Puerto Rican parrots have our own myths. They’re simpler than human mythology, but I think humans would take pleasure from them.

Alas, our myths are being lost as my species dies out. I doubt the humans will have deciphered our language before we’re gone.

So the extinction of my species doesn’t just mean the loss of a group of birds. It’s also the disappearance of our language, our rituals, our traditions. It’s the silencing of our voice.

Human activity has brought my kind to the brink of extinction, but I don’t blame them for it. They didn’t do it maliciously. They just weren’t paying attention.

And humans create such beautiful myths; what imaginations they have. Perhaps that’s why their aspirations are so immense. Look at Arecibo. Any species who can build such a thing must have greatness within them.

My species probably won’t be here for much longer; it’s likely that we’ll die before our time and join the Great Silence. But before we go, we are sending a message to humanity. We just hope the telescope at Arecibo will enable them to hear it.

The message is this:

You be good. I love you. ☺

TED CHIANG’S fiction has won four Hugo, four Nebula, and four Locus awards, and has been featured in *The Best American Short Stories*. His debut collection, *Stories Of Your Life and Others*, has been translated into 21 languages. He was born in Port Jefferson, New York, and currently lives near Seattle, Washington.

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This Simple Structure Unites All Human Languages

Language builds meaning through self-similarity

BY DAVID ADGER



TAKE A DEEP BREATH.

As you breathe in, your lungs fill with air. The air is carried through every part of your lungs by tubes. These tubes are organized in a particular way. They branch off, one into the left lung, one into the right. The tubes fill our lungs by branching, branching, and branching again, into tinier and tinier tubes. Each branching point is similar to the previous one. Your breath, your very life, depends on this structure. It is a structure organized by the principle of self-similarity.

Self-similarity is everywhere in nature. Look at a fern: Each fern leaf is composed of smaller replicas of itself, which are composed of yet smaller replicas. Or think of vast deltas, where huge rivers branch out into smaller and smaller streams and rivulets until they

vanish into the earth or oceans. Each branching of a river is similar to a previous branching that created that river.

The Internet has, without anyone overseeing it, evolved into a self-similar pattern, with huge hubs connecting to smaller ones, these themselves connecting, in just the same way, to smaller hubs all the way down to phones and laptops.

Self-similarity is everywhere because it is efficient. If a tube, developing into a lung, or frond into a fern, does the same thing each time it grows, then the genes don't need to specify the details of the growth. The same thing happens at the larger scale, and at the smaller. It makes no difference whether a river is the Amazon or a tiny stream, it branches in the same way.

Self-similarity is at the heart of language, too.

SENTENCES AND PHRASES of human languages, all human languages, have an inaudible and invisible hierarchical structure. When we are children, we impose this structure on the sequences of sounds that we hear. Our minds can't understand continuous streams of sound directly as meaningful language. Instead, we subconsciously chop them up into discrete bits—sounds and words—and organize these into larger units. This means that sentences have a hierarchical structure.

Other animals, even extremely intelligent close evolutionary relatives like bonobos and chimpanzees, treat sequences of words as sequences, not as hierarchies. The same is true for modern artificial intelligences based on deep learning. Humans, however, don't seem to be able to do this. When we encounter language, the hierarchical structure of phrases and sentences is something our minds can't escape from. We hear sounds or see signs, but our minds think syntax.

The most basic units of language, words and word-parts, are limited to the tens of thousands. We can create new ones on the fly if we need to, but we don't have a distinct word for every aspect of our existence. The number of words speakers know is a finite store. We can add words to that store, and we can forget words. But the sentences we can say, or understand, are unlimited in number. They create meanings where there were none before.

Human language is amazingly creative. If you make up a sentence of any complexity, and search for that exact sentence on the Internet, it's almost never there. Virtually everything we say is novel. Yet at the heart of this capacity of ours lies an incredibly simple piece of mental technology: Merge. Merge takes two bits of language, say two words, and creates out of them another bit of language. It builds the hierarchical structures of language.

MERGE WAS PROPOSED by Noam Chomsky in the early 1990s. He argued that this single piece of mental technology, plus language specific constraints that children could learn from their linguistic experiences, was enough to capture the syntax of all human languages.

Let's take two words, *drink* and *wine*. Merge says that we can take these two bits of language and from these create a new bit of language. We don't do this by putting the two words in a sequence, like an artificial

intelligence or a bonobo would do. Instead we build a new hierarchical unit. This unit puts together the verb *drink* with the noun *wine* to create the phrase *drink wine*, with *wine* being the grammatical object of *drink*.

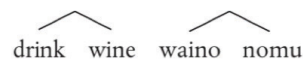
Let's visualize how Merge works on a verb and its object by putting things in boxes. Each box is a bit of language. If you're not in a box, you're not a bit of language. The things inside boxes aren't in a sequence; they don't have an order. The only information the box adds is that the bits inside it are grouped together. The words *drink* and *wine* are bits of language, and Merge says that a grouping of these can also be a bit of language. We can represent this with boxes like this:



Merge has created a self-similar structure: a larger bit of language containing two smaller bits of language. Boxes within boxes. An invisible hierarchy.

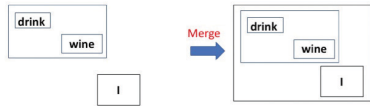
Now, in spoken or written language, we have to put one word after the other. That's just the way these channels of language work. We can't say two words at the same time. Speaking, and to a lesser extent signing, flattens the hierarchy that Merge builds into a sequence, and that sequence has an order. This means that this structure, which is just one structure as far as Merge is concerned, can be pronounced in two ways. We either pronounce it as *wine drink*, or as *drink wine*. The grammatical object either appears before the verb, or after it. Those are the only two logical possibilities. The first is the order we'd find in a language like Japanese, where we'd say *waino nomu*, literally *wine drink*. The second is, of course, English.

Linguists usually write the outcome of Merge using little tree diagrams. These tree diagrams give us the information that comes from Merge (what words group together), plus information about order. The diagrams for English and Japanese look like this:

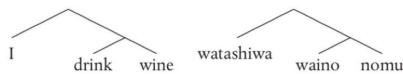


These trees are the same in terms of Merge, but distinct in the order of their parts. We've translated the pure hierarchy that Merge gives us into an order that we can pronounce.

Let's assume that I drink wine. To express this thought as a sentence, we want to add a grammatical subject to the bit of language we've just created. Since Merge says we can take two bits of language and create a new one, we can apply Merge to the word *I* and the linguistic unit we've just built:



Now we have nested boxes. One big unit containing two smaller units, one of which is the result of a previous process of Merge. The Japanese word that best translates the English word *I* is *watashiwa*, so we can write our two trees like this:



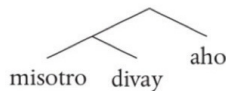
English is a subject-verb-object language, while Japanese is a subject-object-verb language. But both are identical as far as Merge is concerned.

There are also languages that mix up these orders. Malagasy, for example, has the English order for *drink wine*, but puts the subject after that unit:

misotro divay aho

drink wine I

The Merge structure for Malagasy is just the same as that for English or Japanese, but while those languages put the subject first, Malagasy puts it last.



The last logical possibility is where we say the equivalent of *wine drink I* to mean *I drink wine*.

This is pretty exotic in the world's languages. In fact, for many years, linguists were unable to find a language where that was the natural order to express this thought. However, during the 1960s and early '70s, the late Desmond Derbyshire lived in the Amazonian village of Kasawa in Brazil. There he worked on learning and analyzing the language of a local tribe, the

If you make up a sentence of any complexity, and search for that exact sentence on the Internet, it's almost never there.

Hixkaryana. As Derbyshire worked on the language, he discovered that it had a basic order exactly the reverse of English. To express *The boy caught a fish*, the Hixkaryana said the equivalent of *A fish caught the boy*:

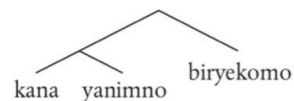
kana yanimno biryekomo

fish he-caught-it boy

Since Derbyshire's work, a number of other languages with this order, the object-verb-subject order, have come to light. Even these rare languages can be thought of as having the same structure, given by Merge:



Hixkaryana has the Japanese order for the most deeply embedded unit, giving *kana yanimno* (literally *fish caught*). But it has the Malagasy order for the subject *biryekomo*, "boy." The whole sentence can be given a tree diagram that looks like this:



MERGE ISN'T VERY COMPLEX, but it does a lot of what linguists need it to do. It applies to discrete units of language (words or their parts). It combines these, not sequentially, but hierarchically. It doesn't state what order the words have to be pronounced in, so it allows variation across languages. The hierarchical structure is the same in all four types of language we just looked at, but the order of the corresponding words is different.

Self-similarity is everywhere because it is efficient.

The fact that the hierarchical structure is the same but the word order is different allows us to express an important idea. The way that languages build up meaning is through Merge. Each Merge comes along with an effect on the meaning of the sentence, and that effect is generally both stable and systematic. That's why it makes sense to say that the Japanese and English sentences mean the same. They have different orders, but there is a deep commonality. Merge builds both structure and meaning in the same basic way in both kinds of language. Languages are deeply similar, not deeply different.

Merge is also open-ended. As we just saw, it can reuse something it has already created.

Because Merge reuses its own output, it is a recursive process. Recursive processes are well known in mathematics, and form the foundation of modern theories of computing. Merge is a quite specific recursive process—it uses exactly two units and it creates structures that are linguistic. If our human sense of linguistic structure is guided by Merge, that will explain why all human languages are hierarchical and none are sequential. It also explains why human language is so unbounded, why sentences don't have a natural upper limit. Merge both creates, and limits, the infinite potential of language.

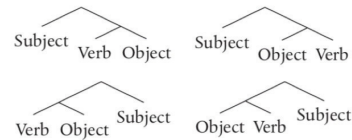
I SAID THAT the four types of languages we've just seen were the four logical possibilities given Merge. But there's an apparent problem. There are other kinds of word order: two important ones are verb-subject-object, and object-subject-verb languages. In fact, verb-subject-object is fairly common. It's the order found in Celtic languages like Scottish Gaelic, Mayan languages like Chol, and some Polynesian languages like Hawaiian.

Let's look at Gaelic. In this language, to say "A boy caught a fish," we say:

Ghlac balach iasg

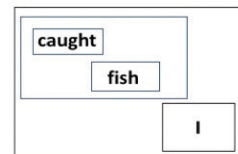
caught boy fish

We can't get this order from Merge by just switching the order of object and verb, or the order of the subject with the rest of the sentence. As we've seen, there are only four possibilities when we do that:

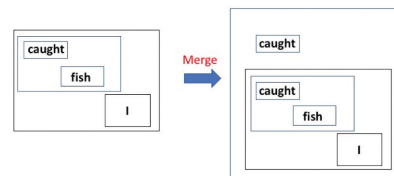


Merge doesn't look powerful enough to get us all the orders we want. Was Chomsky wrong to suggest Merge was sufficient as the single way that all syntax is constructed?

It seems he wasn't wrong. Remember that Merge takes two bits of language and creates a new bit of language. So far, we have just used Merge to take independent bits of language and put them together. That's how we got to the structure we've so far used for English, Japanese, Malagasy, and Hixkaryana.

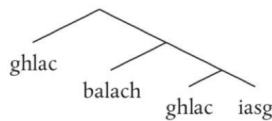


But Merge is recursive. It can go back and reuse something it's already used. This means we can merge the bit of language containing the verb *caught* (that is, the box with *caught* inside it) with the bit of language containing everything else (that is, the large outside box). What we create is a new bit of language that contains the box with the verb in it, and the box containing that:



The verb *caught* here is both inside the box containing *caught fish* and inside a larger box that contains *caught* and a box containing everything else. It's in two places at once. We've created a kind of loop in the structure. We didn't have to extend Merge to do this. Merge has the consequence that we can reuse bits of language that have already been used.

This gives us a way of understanding verb-subject-object languages like Gaelic: they involve this kind of loop. If I write the boxes as a tree diagram, putting things in the right order, we can begin to see the solution to our dilemma:



The subject here, *balach*, is “boy” and the object *iasg* is “fish.” The verb *ghlac*, “caught,” merges with its object and gives the meaning associated with catching fish. Then the result of that merges with the subject. This can be ordered as subject-verb-object, boy caught fish. Finally, Merge applies to a bit of language it has already used (the verb *ghlac*, “caught”) and merges that with the subject-verb-object unit. We can now pronounce this tree like this:

Ghlac balach ghlac iasg

caught boy caught fish

Oops! This isn't quite what we want, since the verb (*ghlac*), “caught,” appears twice. That verb is just one bit of language, but it appears in two places, because we've reused it.

Common sense, though, might suggest that if you have one bit of language, you pronounce it just once. In Gaelic, when we reuse the verb, we pronounce it in its reused position. This is why in Gaelic we say *Ghlac balach iasg*, which is *Caught boy fish*.

Word order is, of course, far more complex than I've shown here. There are languages with very free word order, and even within languages there are many intriguing complexities. However, this idea, that Merge can both combine bits of language, and reuse them, gives us a unified understanding of how the grammar of human languages works.

Because Merge recursively builds hierarchies, with each application connecting to both meaning and sound, there is no end to the complexity of the meaningful structures it builds. Merge gives us the ability to build the new worlds of ideas that have been so central to the successes and disappointments of our species. It makes language unlimited. ☺

DAVID ADGER is the author of *Language Unlimited: The Science Behind Our Most Creative Power*. He is a professor of linguistics at Queen Mary University Of London and the president of the Linguistics Association of Great Britain. This article was adapted from *Language Unlimited*.



EQROY/SHUTTERSTOCK

How American Tycoons Created the Dinosaur

The story of dinosaurs is also the story of capitalism

BY LUKAS RIEPPEL



THE DINOSAUR IS A CHIMERA. Some parts of this complex assemblage are the result of biological evolution. But others are products of human ingenuity, constructed by artists, scientists, and technicians in a laborious process that stretches from the dig site to the naturalist's study and the museum's preparation lab. The mounted skeletons that have become such a staple of natural history museums most closely resemble mixed media sculptures, having been cobbled together from a large number of disparate elements that include plaster, steel, and paint, in addition to fossilized bone. When standing before one of these towering creatures, such as the T. rex skeleton named Sue in Chicago's Field Museum of Natural History, it is surprisingly difficult to distinguish which features are ancient and which ones are modern, where prehistory ends and imagination begins.

Paleontologists worked hard to assemble dinosaurs. They relied on inference, judgment, and imagination.

If dinosaurs in museums are chimeras, their prehistoric antecedents are unobservable entities. In this respect, dinosaurs resemble subatomic particles like electrons, neutrons, and positrons. Both are inaccessible to direct observation, but for different reasons. Whereas subatomic particles are too small to be seen, dinosaurs are too old. And in both cases, scientists gain access to their objects of study by interpreting the effects they produce: Electrons leave characteristic marks on a photographic emulsion as they pass through a cloud chamber, and dinosaurs supply us with clues to their former existence in the form of fossilized bones.

But dinosaurs are unlike electrons in a number of important ways. For one thing, dinosaurs cannot be experimented upon. Instead, scientists have to interpret the fossil record, which is spotty at best. The first dinosaur discoveries consisted of only a few bones and a handful of teeth. Before long, more complete skeletons began to be found, but the individual pieces were usually scattered about in a jumbled mess of material.

Often, they had also been crushed and distorted by the immense pressures at work during and after the process of fossilization. For that reason, paleontologists had to work hard to assemble dinosaurs into something that resembled real, live animals. In doing so, they relied not only on the available evidence, but also on inference, judgment, and their imagination.

Because dinosaurs are in part creatures of the imagination, they reveal a great deal about the time and place in which they were found, studied, and put on display. Often, paleontologists tasked with reconstructing the fragmentary remains of these animals have been guided in their pursuits by analogies to more familiar objects and circumstances. In the mid-19th century, the British anatomist Richard Owen modeled dinosaurs on pachyderms such as the elephant, whereas early American paleontologists looked to the kangaroo as an anatomical guide. It was not until the turn of the 20th century that dinosaurs came to be seen as massive, hulking, and lumbering

behemoths of prehistory. More recently, many museums have completely overhauled their aging dinosaur displays yet again, to better reflect contemporary views of these creatures as bird-like, active, and fast-moving, with complex social structures. Dinosaurs simultaneously occupy two widely divergent temporal regimes: They hail from a world in which humans did not exist, yet they are also a product of human history.

Dinosaurs tell us a great deal about ourselves. Their immense size and outlandish appearance all but ensured that dinosaurs would become a mass public spectacle. But the scarcity of their fragmentary remains and the vast temporal chasm that separates their world from ours meant that it was difficult to know much about these creatures with certainty. The mystery of what life might have been like during the depths of time allowed people to project their fears and anxieties, as

well as their hopes and fantasies, onto these alien creatures. Taken together, these features helped to make dinosaurs into a favorite target for the philanthropic largesse of wealthy elites, which ensured that there would be plenty of resources devoted to the science of vertebrate paleontology.

During the Long Gilded Age, which stretched from the end of Reconstruction to the start of the Great Depression, financial elites like J.P. Morgan and industrialists like Andrew Carnegie rose to enormous power and influence. They oversaw the transition of the country's political economy from an unruly and highly competitive form of proprietary capitalism to a more managed economy dominated by large corporate firms. This was precisely when dinosaurs from the American West became an icon of science, and the transition to corporate capitalism affected the practice of vertebrate

WHEN DINOSAURS RULED

Fearing a backlash to their corporate might, America's industrial tycoons became avid philanthropists to uplift and educate working people, establishing universities, art galleries, and natural history museums, with their prized possessions, dinosaurs.



Dinosaurs came to symbolize the country's economic might and power.

paleontology in surprisingly concrete and far-reaching ways. Not only did dinosaurs reflect the obsession with all things big and powerful that prevailed at the time, but the science of paleontology itself was profoundly influenced by the creation of large, corporately organized, and bureaucratically managed museums of natural history.

THE FIRST DINOSAUR FOSSILS were uncovered in England during the 1820s and 1830s, and they acquired the name *Dinosauria* from the British anatomist Sir Richard Owen in 1841. During the decades that followed, many additional fossils came to light, including an especially rich quarry found in a Belgian coal mine that contained dozens upon dozens of *Iguanodon* specimens. Nonetheless, the earliest dinosaurs did not stand out among all of the other large, impressive, and strange-looking creatures from prehistory that were being unearthed, which included extinct mammals,

such as the *Megatherium*, and marine reptiles, such as ichthyosaurs and plesiosaurs. This suddenly changed during the last third of the 19th century, with a series of new discoveries in the American West that elicited enormous excitement. American dinosaurs were a scientific and popular sensation, especially once their fossil remains were mounted as free-standing skeletons in urban museums at the turn of the 20th century. In part, this was due to the fossils themselves. American dinosaurs struck many observers as bigger and more imposing than their European counterparts. But the United States also proved an especially receptive environment for these creatures, a fertile niche that promoted their development into the towering behemoths that continue to wow museum visitors.

At precisely the same time that dinosaur bones became a public sensation, the U.S. was transforming into an industrial powerhouse of global proportions. Between the end of the Civil War and the beginning

of World War I, the country's economic output grew to exceed that of England, France, and Germany combined. This was due, in no small part, to the development of a robust extractive economy. As a result, the Rocky Mountain region, where many of the continent's rich mineral resources were concentrated, came to be seen as a land of almost unlimited possibility, and white settlers looking to profit from its abundant resources quickly colonized the region. Simultaneously, more and more people were moving to cities like New York, Philadelphia, Pittsburgh, and Chicago. This included a growing class of wealthy merchants, bankers, and entrepreneurs who bankrolled the process of industrialization. The railroad linked these two worlds together, tying the city and the countryside into an increasingly dense network of supply and demand. Resources flowed in one direction and capital in the other, with a good many people siphoning off a sizeable profit along the way.

Because they were so prodigious in size, dinosaurs came to stand in for the power and fecundity of the U.S. In a striking coincidence, three major dinosaur quarries were simultaneously discovered in the American West during a single field season in the summer of 1877. They contained some of the most recognizable fossils, including *Stegosaurus*, *Brontosaurus*, and *Allosaurus*, a close relative of *T. rex*. Subsequent decades brought more discoveries to light, catapulting the U.S. into position as a world center for vertebrate paleontology. This was still a relatively new science at the time, but the wealth of amazing specimens being unearthed quickly became a scientific and popular sensation. For a people still emerging from the shadow of a bloody civil war, this was a welcome development, and the industrial elite were quick to embrace dinosaurs as their nation's most iconic extinct creatures. As a result, dinosaurs came to symbolize the country's economic might and power, offering material proof of its exceptional history and outstanding promise.

With the best specimens hailing from the country's interior, dinosaurs became associated with its celebrated western frontier. Their discovery was deeply embedded within the extractive economy that dominated the region at this time. In part because the exploitation of mineral resources in precisely this part of the country was so instrumental in propelling the U.S. into the position of an economic superpower, dinosaurs

from the American West were elevated into a symbol for the entire political economy. Widely heralded as having been larger, fiercer, and more abundant than prehistoric animals from Europe, they meshed well with a conventional narrative that celebrated American exceptionalism.

Paleontologists acquired funding, while wealthy capitalists could claim to be engaged in altruism.

THEIR ORIGIN in the deep past ensured that dinosaurs would be associated with evolutionary theory, which was often invoked to explain social, cultural, and economic developments. But dinosaurs did not function as a straightforward image of progress. The mass extinction event that killed them off at the end of the Cretaceous period mirrored the era's widespread anxieties about degeneration and decline, and dinosaurs were often inserted into a cyclical narrative that characterized evolutionary development as a predictable series of fits and starts. The same evolutionary process was understood, in turn, to result in a familiar pattern of boom and bust that mirrored the emerging conception of what came to be called the business cycle.

The link between dinosaurs and American capitalism was material as well as symbolic. The rapid process of industrialization created riches that had been almost unimaginable just decades before. But the period's wealth and prosperity was not equally shared among all parts of society. During the late 19th century, a small group of financial and industrial capitalists coalesced into an elite social class that supplanted an older generation of merchant families. Because wealthy industrialists often hailed from fairly humble, artisan backgrounds, they signaled their newfound class status to themselves and each other using traditional markers of

high social standing. In addition to wearing expensive clothes and adopting erudite modes of speech, they invested considerable resources in amassing impressive collections of artworks and natural history specimens. Whereas artworks largely functioned as a display of refined aesthetic sensibilities, natural history represented another form of social distinction, one that combined epistemic virtues like objectivity with notions of good stewardship and civic munificence.

Although the economy was booming, American capitalism was in a state of crisis during this period. The industrial juggernaut was responsible for unprecedented levels of economic growth, but it also produced frequent financial panics and economic depressions. Working people were especially hard hit during these downturns, and inequality rose sharply. This led to a widespread backlash against a system of economic production that seemed to yield almost equal measures of growth and precarity, of gratification and misery. A sense of revolutionary uprising was in the air, leading to widespread moral panic among the social and financial elite, who feared that radical immigrants and incendiary labor leaders were spreading an anarchist message that could bring the industrial economy to its knees. Some even worried that a new civil war might be brewing over the issue of wage rather than slave labor. In response, the well-to-do literally armed themselves, forming militias and building ostentatious fortresses that doubled as clubhouses in cities across the U.S.

At the same time, they became avid philanthropists, founding organizations designed to uplift, edify, and educate working people by exposing them to the highest achievements of modern civilization. In the process, they created the nonprofit corporation. These institutions were designed to demonstrate that capitalism could be altruistic as well as competitive—that it worked for the good of all in society, not just the wealthy few.

In addition to establishing universities, libraries, symphonies, and art galleries, wealthy capitalists such as Carnegie founded natural history museums. Natural history doubled as both a popular leisure pursuit and a pious devotional exercise at the time, which made it an especially effective means for showing off one's generosity among a broad and socially diverse but respectable audience. Of all the branches of natural history,

Like Gilded Age industrialists, today's Chinese industrialists boost their social distinction with dinosaur collections.

dinosaur paleontology offered a particularly attractive target for philanthropic investment. Dinosaurs lent themselves to the building of spectacular displays that attracted throngs of visitors to the museum, which was crucial to cement the argument that industrial capitalism could produce genuine public goods in addition to profits. Imposing dinosaur displays helped philanthropists such as Carnegie make the claim that because industrial capitalism concentrated wealth in the hands of the few, it unlocked the power for truly awesome achievements.

Philanthropists were also drawn to dinosaurs as a powerful tool to help naturalize the evolution of American capitalism. Before the Civil War, the business landscape of the U.S. was dominated by small, family-owned firms that specialized in a single product or service. But that changed dramatically during the last third of the 19th century, as sole proprietorships were increasingly replaced by large, capital-intensive, and often vertically integrated corporate firms. As these corporate behemoths gobbled up their competitors in a wave of mergers and acquisitions, some grew so large that they threatened to monopolize an entire industrial sector. This restructuring of America's political economy elicited enormous controversy, especially among rural populations who found themselves on the receiving end of the bureaucratic machine.

Wealthy elites responded by framing the transition to a political economy ruled by vast corporations as an example of evolutionary progress, celebrating the capacity of rational administration and organized planning to replace what they characterized as wasteful and "ruinous" competition between small,



DINOS OF A DIFFERENT FEATHER: The fairly recent discovery that many dinosaurs had feathers has transformed them in our imaginations from domineering gray behemoths to agile and colorful social creatures.

independent firms. Dinosaurs offered an especially powerful means to make that claim convincing. Paleontologists consistently portrayed these animals as vicious and solitary predators whose terrible reign had come to a sudden and ignominious end at the close of the Cretaceous period. But their mass extinction opened up the ecological space for a kinder and gentler world to emerge. According to this evolutionary narrative, the cutthroat competition of the deep past gave way to a more enlightened modernity, as intelligent mammals—including early hominids—put the struggle for existence behind them and began to cooperate for the greater good. The exhibition of dinosaurs in philanthropic museums helped to bolster the argument that the evolution of modern capitalism did not depend upon social conflict or lead to

class warfare. On the contrary, it could be framed as a means to promote enlightened administration and organized teamwork over ruthless self-interest and incessant competition.

THE HISTORY OF DINOSAUR PALEONTOLOGY offers an instructive contrast to how the relationship between science and capitalism is often framed. Science has traditionally been portrayed as a higher calling, one that is insulated from the demands of the marketplace. This led early- to mid-20th-century historians and sociologists to stress the autonomy of science, emphasizing the extraordinary measures that researchers take to police the bounds of acceptable conduct, guard against misinformation, and prevent fraud. On this view, membership in the scientific community is governed by a set

of expectations like objectivity and value-neutrality, as well as a commitment to share the results of one's work free of charge.

However, more recent developments have made these ideas seem hopelessly naive. In today's world of patented gene sequences, technology transfer offices, and Silicon Valley startups, it has become increasingly difficult to sustain the fiction that science is fundamentally divorced from the marketplace. Instead, newer accounts are more likely to stress the extent to which powerful actors and institutions leverage their access to capital to shape the research priorities of the scientific community. Rather than stress the autonomy of science, many historians now tend to examine how the boundary between science and capitalism has become blurred. Nevertheless, our expectations have remained surprisingly stable, and many are troubled to learn that an important medical trial was bankrolled by the pharmaceutical industry, or that a study on climate change was funded by energy companies.

Dinosaurs offer a very different perspective. It is precisely because dinosaurs were so deeply entangled with both science and capitalism that vertebrate paleontologists were especially careful to distance themselves from the world of commercial affairs. Dinosaurs rose to international prominence during a period when the economic elite in the U.S. had plenty of money but suffered from a deficit in legitimacy. In contrast, vertebrate paleontologists were engaged in a prestigious but expensive undertaking. Dinosaurs were not just immensely popular, they were also exceedingly difficult to find and collect. Access to a steady source of funds was essential for anyone wishing to work on these remarkable creatures. As a result, paleontologists might be expected to have touted all the ways they could help further the interests of the wealthy donors who underwrote their endeavors. But in fact exactly the opposite happened.

Rather than broadcast their willingness to enter a quid pro quo agreement with philanthropists, Gilded Age paleontologists instead chose to guard the institutional autonomy of their discipline by insisting that funding be offered with no obvious strings attached. Ironically, this only made paleontologists more attractive to philanthropists, who were eager to distance themselves from their commercial and industrial roots.

The two communities forged a strategic alliance with mutual benefits. Paleontologists acquired a steady stream of funding, while wealthy capitalists could claim to be engaged in a genuinely altruistic endeavor. And what better way to support this claim than by investing in a lost world that had entirely disappeared before human beings and the industrial economy had even come into existence?

TODAY, DINOSAURS REMAIN bound up with the culture of capitalism, but in ways that are new and often surprising. After several decades in which the scientific and popular enthusiasm for vertebrate paleontology was in decline, we are now witnessing a dinosaur renaissance.

Much of the recent excitement stems from the explosive idea that modern birds are directly descended from dinosaurs. In much the same way that humans are primates, this means that birds are modern-day dinosaurs. It also means that dinosaurs did not go extinct. In a remarkable case of backtracking causation, so-called non-avian dinosaurs have been almost entirely reimagined. Contemporary paleontologists now envision them not as drab, sluggish, and solitary creatures who roamed the deep past but as active and social animals that were often covered with colorful feathers. Moreover, whereas the overwhelming majority of dinosaurs that fueled both the public and scientific imagination during the Long Gilded Age hailed from the American West, the most spectacular fossils today come from northeastern China.

During the mid-1990s, a rural farmer named Li Yin-fang uncovered the fossil remains of a small dinosaur in the Liaoning Province of Northeastern China. This specimen has many unique features, but paleontologists were especially excited about the wispy, feathery fringe that ran all along the animal's back, down to the tip of its tail. This was the first time that anyone had found a dinosaur fossil with intact feathers, and it caused a scientific sensation, both inside and outside of China. As a result, present-day paleontologists have come to regard China in much the same way that late 19th-century predecessors thought of the U.S.

Li's dinosaur was christened *Sinosauropteryx prima* (meaning "first Chinese lizard wing"), but in the years since, a great many other spectacular fossils have been un-earthed in Liaoning. Some of these are so

well preserved that scientists have even used them to infer the color of dinosaurs, completely upending the modern conception of these remarkable creatures. As the paleontologists Mark Norell recently put it, “now, instead of scaly animals portrayed as usually drab creatures, we have solid evidence for a fluffy colored past.”

Fossilized feathers have even led paleontologists to revise their ideas about dinosaur behavior. Because many such as *Sinosauropteryx* had colorful but relatively simple feathers that did not impart the aerodynamic properties necessary for flight, it is now widely believed that complex or “pinnate” feathers were only secondarily adapted for that purpose. Initially, they most likely evolved for thermoregulation, for camouflage, and as a signaling mechanism to communicate and attract mates. This further cements the once revolutionary idea that far from having been solitary brutes, at least some dinosaurs were intensely social creatures that may have developed complex family structures.

It has become almost a cliché to compare modern-day China to America during the Long Gilded Age. Much as the U.S. did in the late 19th century, China is undergoing a period of rapid industrialization. China’s explosive economic expansion resembles that of the U.S. in that it has been fueled by an abundance of natural resources, including huge tracts of arable land and large stores of mineral wealth. Economic expansion in both countries has come at the price of widespread corruption, escalating labor unrest, and concerns over environmental degradation, as well as a precipitous increase in economic inequality.

Most striking for our purposes is that as well-to-do segments of both societies developed a taste for conspicuous consumption, dinosaur fossils joined artworks as some of the most sought-after means by which new members of the wealthy elite seek to demonstrate their class status and social distinction. Not unlike Andrew Carnegie did during the 1890s, the industrialist Zheng Xiaoting recently drew on the vast fortune he made in gold mining to found the Shandong Tianyu Museum of Nature, which holds the Guinness World Record for the largest collection of dinosaurs.

The comparison between 19th-century America and present-day China can easily be taken too far, and the global economy has changed dramatically in the past hundred years. The Long Gilded Age was a period of

increasing consolidation and market integration. Today’s global economy is on a very different trajectory, due in no small part to the emergence of Asia as a dynamic industrial center. Whereas the late 19th and early 20th centuries saw the rise of vertically integrated corporations, the past several decades have seen a new mantra of efficiency taking hold, one that celebrates small, agile, and adaptable startups whose so-called disruptive innovations have eroded the power and profitability of large and heavily bureaucratized industrial firms.

Given the changes in the global economy, is it any surprise that our understanding of dinosaurs has undergone a dramatic transformation? The past several decades have seen business and political leaders embrace political economist’s Joseph Schumpeter’s notion that a process of “creative destruction” underlies economic development, whereas biologists have revolutionized evolutionary theory with the introduction of game-theoretic models of rational decision-making. Indeed, many biologists now believe that even the most exquisitely complex social assemblages have been produced through natural selection acting on a molecular level. Moreover, while evolutionary biologists have reinterpreted altruistic acts of self-sacrifice as selectively advantageous from a perspective, political economists have renewed their commitment to political liberalism, even as the financial panic of 2008 has caused many of them to shy away from the excesses of the perfect market hypothesis.

No wonder, then, that dinosaurs have been transformed in our imaginations from lumbering behemoths of the prehistoric into agile, intelligent, and intensely social creatures covered by colorful feathers, many of which hail from Asia rather than North America. ☺

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Language Is the Scaffold of the Mind

Once we acquire language, we can live without it

BY ANNA IVANOVA

CAN YOU IMAGINE a mind without language? More specifically, can you imagine *your* mind without language? Can you think, plan, or relate to other people if you lack words to help structure your experiences?

Many great thinkers have drawn a strong connection between language and the mind. Oscar Wilde called language “the parent, and not the child, of thought”; Ludwig Wittgenstein claimed that “the limits of my language mean the limits of my world”; and Bertrand Russell stated that the role of language is “to make possible thoughts which could not exist without it.”

After all, language is what makes us human, what lies at the root of our awareness, our intellect, our sense of self. Without it, we cannot plan, cannot communicate, cannot think. Or can we?

IMAGINE GROWING UP without words. You live in a typical industrialized household, but you are somehow unable to learn the language of your parents. That means that you do not have access to education; you cannot properly communicate with your family other than through a set of idiosyncratic gestures; you never get properly exposed to abstract ideas such as “justice”

or “global warming.” All you know comes from direct experience with the world.

It might seem that this scenario is purely hypothetical. There aren’t any cases of language deprivation in modern industrialized societies, right? It turns out there are. Many deaf children born into hearing families face exactly this issue.

They cannot hear and, as a result, do not have access to their linguistic environment. Unless the parents learn sign language, the child’s language access will be delayed and, in some cases, missing completely.

Does our mind develop normally under such circumstances? Of course not. Language enables us to receive vast amounts of information we would have never acquired otherwise. The details of your parents’ wedding. The Declaration of Independence. The entrée section of the dinner menu. The entire richness of human experience condensed into a linear sequence of words. Take language away, and the amount of information you can acquire decreases dramatically.

The lack of language affects even functions that do not seem to be intrinsically “linguistic,” such as math. Developmental research shows that keeping track of exact numbers above four requires knowing the words for these numbers. Imagine trying to tell the difference between seven apples and eight apples. The task becomes almost impossible if you can’t count

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them—and you can't count them if you never learn that "seven" is followed by "eight." As a result of this language-number interdependency, many deaf children in industrialized societies fall behind in math, precisely because they did not learn to count early on.¹

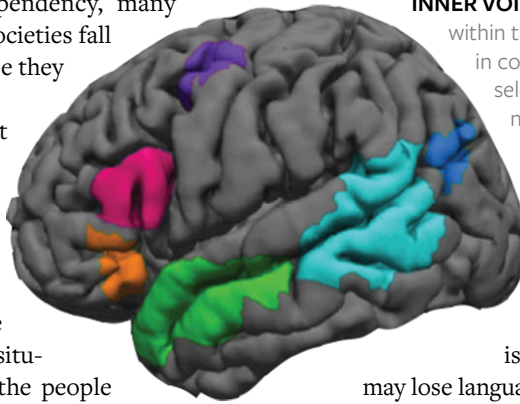
Another part of your mind that needs language to develop properly is social cognition. Think about your interactions with your family and friends. Why is your mom upset? Why did your friend go inside the house just now? Understanding social situations requires inferring what the people around you are thinking.

This ability to infer another person's thoughts is known as "theory of mind"; typically developing kids acquire this skill by age 5 or so. However, children with delayed language access have trouble imagining the mental state of other people.² Moreover, brain regions involved in inferring others' thoughts work differently in such children: They are active during all kinds of social situations, unable to properly distinguish scenarios that require mentalizing from those that do not.³ Theory of mind, therefore, is a prime example of a non-linguistic process that suffers if linguistic input is delayed.

So far, the evidence we have seen does suggest that "the limits of my language mean the limits of my world." However, what happens if language disappears once the mind is fully developed? Will we then lose the ability to use math and understand others?

IMAGINE YOU ARE a typical adult; let's say you're 40. You wake up one day, and suddenly, you realize that your language is gone. You look around the room, but no words come to mind to describe the objects you see. You're starting to plan out your day, but no half-formed phrases rush through your mind. You unlock your smartphone, but, instead of text, you see a sea of squiggles. Desperate, you cry out for help, and someone rushes up to you—but, instead of speech, all you hear is meaningless murmur.

The condition I have just described is known as global aphasia. It arises from severe damage to the brain, often as a result of a massive stroke. While some



INNER VOICES A set of brain regions within the left hemisphere, shown in color, responds strongly and selectively to language, but not to other thought-related processes.

aphasias are temporary, in some cases the damage is irreparable, and the person may lose language for life. In your case, let's say that a dozen doctors examined you and said (or, you think they said) that nothing can be done. If the limits of your language mean the limits of your world, should you conclude the way you experience the world is now fundamentally limited? Do you even have a mind?

Desperate, you attempt to figure out what cognitive functions you still have left. Can you count? 1, 2, 3 ... You take a pen and write $5+7=12$. You get a little bolder and attempt to multiply 12 by 5 in your mind, then 12 by 51 on paper. It works! Turns out, losing language as an adult does not prevent you from using math.

You meet up with some friends. You cannot understand a word they say, but you try to gesticulate—at least it's an attempt at a conversation. You notice that they exchange guilty looks, then start discussing something in hushed voices (no need, since you don't know what they're saying anyway). You realize that they each thought the other one was going to bring a gift. You chuckle. Even though you can't really communicate with your friends anymore, you still know what's on their mind.

Research on adult individuals with aphasia has demonstrated that math, theory of mind, and many other cognitive abilities are independent from language.⁴ Patients with severe language impairments perform comparably to the rest of us when asked to complete arithmetic tasks, reason about people's intentions, determine physical causes of actions, or decide whether a drawing depicts a real-life event. Some of them play chess in their spare time. Some even engage

Without language, we cannot plan, cannot communicate, cannot think. Or can we?

in creative tasks. Soviet composer Vissarion Shebalin continued to write music even after a stroke that left him severely aphasic.

Neuroimaging evidence also supports the claim that language in adults is separate from the rest of cognition. In recent years, neuroscientists have isolated a network of brain regions (typically in the left hemisphere) that react almost exclusively to linguistic input.⁵ They respond to written sentences, spoken narratives, words, monologues, conversations, but will not activate in response to memory tasks, spatial reasoning, music, math, or social situations that do not involve dialogue. No wonder many patients with aphasia do not have impairments in other cognitive domains—language and other functions are housed in separate chunks of brain matter.

I HAVE TO ADMIT, not all writers support Wittgenstein's and Russell's idea that language and thought are inseparable. Tom Lubbock, a British writer and illustrator whose language system gradually deteriorated because of a brain tumor, wrote in his memoir shortly before his death in 2011:

My language to describe things in the world is very small, limited. My thoughts when I look at the world are vast, limitless and normal, same as they ever were. My experience of the world is not made less by lack of language but is essentially unchanged.

So, what can we say about the role language plays in shaping our minds? Well, pick a mind that is still developing, and you will find that removing language will alter it for life. However, pick a mind that is fully formed and take all words away, and you will discover

that the rest of cognition remains mostly intact. Our language is but a scaffold for our minds: indispensable during construction but not necessary for the building to remain in place. ☺

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Humans Are Wired for Goodness

We're not as bad as the headlines make us out to be

BY BRIAN GALLAGHER



NICHOLAS CHRISTAKIS AND I are on the same page: We would definitely sacrifice our lives to save a billion strangers, perhaps even several hundred million, plucked at random from Earth's population. But, for sure, not a thousand strangers, or a million. Those numbers seem, somehow, too insignificant. Christakis, the director of the Human Nature Lab at Yale University, shared this thought experiment on Twitter as a poll that garnered over 2,000 votes: 12 percent would sacrifice their life for one stranger, 31 percent for a thousand strangers, 21 percent for a million strangers, and 35 percent for a billion strangers. "That's completely implausible. I don't know what to make of that," Christakis said of that 12 percent. "I also don't know what to make of the non-monotonicity of the responses—a larger fraction would sacrifice their life for a thousand people than for a million people."

Just how self-sacrificial should we be, especially toward people we don't know? That question is just one of an array of biological and psychological riddles that Christakis tackles in his latest book, *Blueprint: The Evolutionary Origins of a Good Society*. In *Blueprint*, Christakis marshals, in engaging and colorful prose, copious amounts of data—much of it stemming from his own lab—to make, in the end, a philosophical point about the fundamental goodness of humanity.

When I spoke to him recently, Christakis told me, "What I'm attempting to do in *Blueprint* is very much in keeping with my liberal philosophy, which is to regard it as a book of sociodicy. I try to vindicate the existence of society, despite the evils and wrongs in society. It's an account of why we live socially and why there is good in society, despite the manifest horrors. It's both an empirical and a philosophical exercise, because first of all, empirically, I believe the case is compelling, but philosophically, that's my belief about the world, that we are united by our common humanity." At a time when tribalism is ascendant, we need to find new ways to appeal to the better angels of our nature.

What prompted you to poll people about sacrificing their lives for different amounts of strangers?

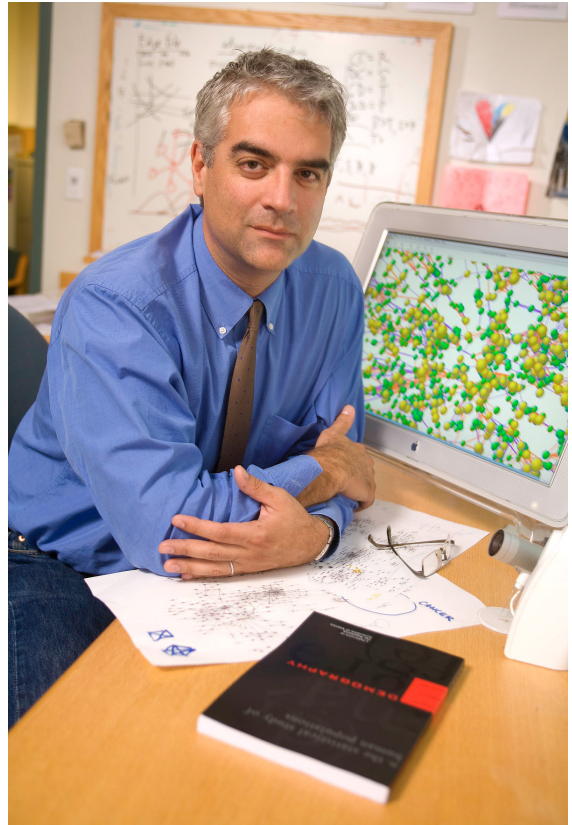
It was a crazy confluence of events. It was the four-year anniversary of a Syrian archeologist who sacrificed his life to protect antiquities that ISIS was going to destroy. It made me think: I'm confident that I would sacrifice my life to protect my family, but were there other causes I would die for? Then there was the story of this asteroid that is projected, in about 10 years, to fly beneath some of our geostationary orbiting satellites. NASA doesn't think it'll hit Earth. Would I sign up for a mission to save a billion people, like in the movies? Saving a billion strangers is the greatest good that any human being could ever have done. Then, I started thinking about how, during the Fukushima disaster, some elderly Japanese nuclear workers volunteered to take a one-way trip into their reactor to shut it down, because there was so much radiation. There are examples of extreme altruism that people manifest toward unrelated individuals—which is hard to explain in evolutionary terms.

You write in *Blueprint* that, when you were with your grandfather at a frenzied political rally in Crete, he explained to you that leaders could prey on people's sense of community and xenophobia simultaneously, in evoking feelings of injustice. People's pessimism of human nature can also be preyed on. What gave you the sense that the narrative about human beings was too negative, and needed to be balanced?

I have spent a lot of time thinking about human nature, and to me it's inescapable that much of the discourse about it is about our propensity to violence and selfishness and mendacity and tribalism. We read about warfare and colonialism and slavery. Every century is replete with horrors. This propensity to emphasize the dark side characterizes not only the person on the street, but also social and biological scientists who explore the origins of behavior. I thought the bright side had been denied the attention it deserved because, equally, we are prone to friendship and love and cooperation and teaching. And these qualities must necessarily have been stronger than our propensity to all the evils, because if every time I came near you, you killed me, or filled me with fake news, or were otherwise mean to me or abused me, I'd be better off not approaching you. We would've evolved to live apart from each other. The benefits of a connected life must've outweighed the cost.

Why do you argue that the most important part of our environment is other humans?

Unlike the biological or the physical environment, the germs or the cold that can afflict us, the social environment is something that we, ourselves, make. That social environment is also a selection pressure. We evolve in response to it and become more social. You get this feedback loop when it comes to our sociality. The environment selects from among us those who are best suited to live in that environment, who then go about creating more of the environment. For example, we evolved to have friends. If you were a person who didn't like friends, living in a society in which everyone else had friends, you wouldn't fare so well. Friendly people make friendly societies, and friendly societies foster the Darwinian fitness of friendly people. I'm summarizing a longer and more complex argument, but that's the gist of it.



WE CONTAIN (CONSTRAINED)

MULTITUDES "Human society," Nicholas Christakis (pictured above) writes, "is like a Rubik's cube that is bound together and obeys a few particular principles but that is nevertheless configurable into 43,252,003,274,489,856,000 combinations."

It's an evolutionary luxury to be a unique person.

You write a lot about what you call the “social suite,” which you argue is the evolutionary basis—the blueprint—of a good society, and spotlights our common humanity. What is the social suite?

I'm talking about evolutionarily shaped qualities or capacities that are inborn, shaped by natural selection, and expressed universally and collectively. There's personal identity, love for partners and children, friendship, social networks, what I call mild hierarchy, in-group bias, cooperation, and social learning and teaching. Those are the eight traits of the social suite.

If there is a blueprint for a basic, functional society that has been shaped by evolution and that is part of our genetic heritage, why do societies fail?

When the social suite's qualities are not expressed, it's typically because some strong environmental or cultural force is impeding their expression. For example, by way of analogy, people have a body when they're born that they're innately prone to make. Kidneys make up a part of it. But if you were exposed to some environmental toxin, you might not have kidneys when you're born. That absence, though, doesn't say anything about the innate propensity of human beings to have kidneys when they're born. The same thing might occur in certain societies. For example, when you have a secret police, like in Eastern Europe with the Stasi, you can constrain the innate capacity of human beings to befriend each other. What happens in East Germany

when half of the population is informants? Well, no one trusts or befriends anybody, because everyone is worried that they are being ratted on.

Are we evolving to be ever more social, living in cities, or is there a ceiling?

That's a very interesting thought experiment. I don't think there's a ceiling. We are getting progressively more social. I don't think it's primarily the cities per se that are doing that, although the cities probably play a role. As I speculate in *Blueprint*, it's possible that this cultural artifact of ours, cities, could be a force of selection, acting over long time periods, now that great numbers of human beings live in them.

Cities could act like other known cultural forces of selection.

Yes. Take, for example, the most famous example of gene-culture co-evolution: Because we domesticated cattle and other milk-producing animals in the past 3,000 to 9,000 years, we've made milk constantly available. Those among us who can digest it in adulthood, which was previously a useless trait because we only drank milk from our mother's breast, benefit from that. The domestication of cattle, in other words, has shaped the trajectory of our evolution. I think that it's likely that the invention of cities is in this category. There are likely certain qualities—in the immune system, in our cognitive capacities—that fare better in cities

One of the reasons we've evolved the capacity to befriend unrelated individuals is that it facilitates the emergence of cooperation.

than in rural environments. The fact that large cities are a feature of our natural environment may be making humans smarter. I'm not saying city-living folk are smarter than rural folk, but that the cognitive ability to live in cities, maybe in denser settlements, will have an advantage.

Yet, I think we would've become hypersocial even if we had not invented cities. Some people, like biologist E.O. Wilson, think that we may even be evolving to ultimately become like the eusocial insects, that eventually we'll have castes of breeders and non-breeders, over hundreds of thousands of years. That's too speculative for me, but I don't think there's a cap on how social we can be.

If we are members of a social species, why do we have individual identities?

It's an evolutionary luxury to be a unique person. Every human face is different. Why don't we all have the same face? Well, it's crucial to living socially. Humans have the capacity to communicate our individual identity with our faces. Not only do we have different faces, but you can look out at a sea of faces and tell the difference between a thousand different faces. The genetics of this are increasingly being worked out. The features of the social suite require the capacity to signal and identify unique individuals. An infant needs to be able to signal to its mother, "This is me. Feed me, not some other baby." Or, if you are nice to me, I want to be able to reciprocate kindness to you, in particular. I need to remember who you are, to tell you apart from everyone else, and be nice to you in the future.

Yet often our sense of identity can be suppressed. You explain how in-group bias or tribal feeling, for example, can lead to deindividuation, where the self becomes less salient. This can be good and bad.

We have this capacity to surrender ourselves to the benefits of the whole group. Now, that can also lead us astray, right? We can so identify with our own group that we demonize other groups. This is one of the most depressing aspects that my 10 years of thinking about human nature has led me to: Why can't we just love our own group without hating other groups? Some people believe that they go hand-in-hand, and it's inescapable. Other scholars think that we could evolve in-group cooperation with out-group neutrality. But in-group affection and out-group hatred seem entangled.

There've been many experiments with small children in this regard. You can take a group of 3-year-olds and randomly assign them T-shirts of different colors. The children know that they didn't do anything to deserve these colors, and yet, once you assign them these colors, they immediately hate the other group. Those blue T-shirted children should be punished. They're awful children. They shouldn't get any toys. It's crazy. You just scratch the surface of human beings, and you get this quality.

Do you have hope that we can ease the enmity that tribal feelings can encourage?

The literature on group mixing is complicated and often depressing. It's not necessarily the case that mixing heterogeneous groups together improves people's sense of our shared humanity, alas. It may depend sensitively on the circumstances or on the proportions of people being mixed. Some studies show that mixing increases inter-group identification and empathy, and other studies show that it decreases it. It may be the case—and this is very depressing—that we would reduce inter-ethnic strife by separating people, or it may be the case that we increase inter-ethnic strife by separating people. To what extent this is the case may depend on what we mean by separation, who the groups are, what the interactions are. There may be a lot of stuff that's important about this, and that we need to understand better, if we're going to reduce the ascendant tribalism that is so bedeviling our nation, and even the whole world, these days.

You can foster cooperation in groups of 10 or 100, but as you start to demand cooperation of a million or a billion people, it gets much more difficult.

In a section on communal success, you write that “the only cures for anomie and doubt are faith and a deep contact with reality.” What do you mean by that?

This is another piece of received ancient wisdom, that the cure for disconnection is connection. That connection can come either from faith, or from actually going into the world and experiencing it and seeing it. Put another way, if you doubt something, and you want to stop doubting it, you’ve got two options. Either you can have faith in things unseen, or you can attempt to see them and remove your doubt.

Do you see our society dealing with a lot of anomie and doubt at the moment?

Yes, in some ways. This again provides fertile terrain for the emergence of a strongman, right? What do strongmen do? They say, “I alone can save you. You are lost in the wilderness, and I know the path”—the path to wealth, or to God, or to safety. It’s very tempting for people who are feeling lost to fall in line. In *Blueprint*, I talk about how one of the reasons we have ascendant tribalism in the United States right now may relate, in part, to the fall of the Berlin Wall and the decline of the Soviet Union. The existence of a superordinate threat can force former enemies together, to fight the common threat. We broaden our sense of who belongs in the in-group. I think that there’s some sense in which the fall of the Soviet Union may be having this effect

in the U.S. of pitting us against each other, because we don’t have quite the common enemy anymore, and the loss of that common enemy—like Alexander the Great seeing that there were no more worlds for him to conquer—has led us to fall on each other. This is, first of all, bad politically and bad for the future of our nation, but it’s also inconsistent with my own vision, for whatever it’s worth, of what I think is a wise and sensible way to organize a civilization, which is to emphasize our common humanity.

How do we make sure to express the social suite in today’s evolutionarily novel societies?

I would like to live in a pluralistic society, but one in which there are, nevertheless, core values centered on the social suite—love, friendship, teaching. Incidentally, free speech falls under teaching. Because, in order to be able to teach each other things, we have to be able to speak the truth and talk to each other.

The Russians and the Chinese have different approaches to this. The Chinese have the great firewall. They try to stop information from reaching people, so people don’t see stuff that the government doesn’t want them to see. The Russians do the opposite. They flood the system with all kinds of crap, so people never know what’s true or false. In fact, one of the sources of our wealth and of our dignity as a people, which was foreseen by the Founding Fathers, was the commitment to free and open expression. We have to be able to test what’s true and what’s false. Otherwise, we just pass on falsehoods. It doesn’t work.

Our inability to confront the climate crisis also causes a good amount of our anomie and doubt. What’s stopping us from expressing our cooperative instinct?

We evolved at a time when the scale of our social interactions was much smaller. My laboratory has done a lot of experiments over the last 10 years, exploring the conditions for cooperation, and how it relates to the size of groups. It’s very difficult to maintain cooperation as the size of the population with which you’re trying to cooperate rises. You can foster cooperation in groups of 10 or 100 with a number of interventions, or 1,000 even, but as you start to demand cooperation of a million or a billion people, it gets much more difficult.

Are there ways that we can game our cooperative psychology?

There's a lot of different ways. They have to do with something called "adding structure" to the population—so fostering personal connections between people, where everybody has their own particular personal connections, but everyone is connected to somebody else, who is in turn connected to somebody else. That kind of an intervention is very good for fostering cooperation, actually. This is very rare in the animal kingdom. We do it. Certain other primates do it. Elephants do it. Certain whale species do it. One of the reasons we've evolved the capacity for friendship, to befriend unrelated individuals, is that it facilitates the emergence, or co-evolves with, this capacity for cooperation.

If I ask you to be nice to everybody on the planet, you might not do that, but if I ask you to be nice to your friends, and if I ask every person to just be nice to their friends, then all of a sudden, everyone is being much nicer than they otherwise would have been. The amount of niceness in the society rises by taking an amorphous group of people and organizing them into a social network. Conditional on you not being a stranger, then I am more likely to have an opinion of you, good or bad. But the important point is that antagonistic ties are vastly less numerous than positive, friendship ties.

How does your argument that society is fundamentally good relate to historical accounts of a good life?

What I'm talking about is a set of prehistorical forces. I could've made all the arguments in the book about human societies as they existed 10,000 years ago. It is indeed the case, for example, as Steven Pinker and others have argued, that the Enlightenment fostered the emergence of a good life—everyone is living safer, longer, healthier lives because of philosophical, scientific, and technological innovations that continue to this day. But my argument is that we don't need to rely on historical forces to provide an account for a good life. Deeper, more powerful, more ancient forces are at work that provide a foundation for us to understand the origins and meaning of a good life. We can relate to each other using these observations. Anyone who's had any experience talking to someone who seemed alien to them, can very quickly realize how much they have in common with that person. We should be humble in the

face of temptations to engineer society in opposition to our evolved instincts. As I finish the book, I say, "Fortunately, we do not need to exercise any such authority in order to have a good life. The arc of our evolutionary history is long, but it bends towards goodness." To me, that's a very happy and—as it turns out nowadays—necessary thought. ☺

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When Words Fail

Where our minds go when words let us down

BY KENNETH S. KOSIK

BRIAN A. JACKSON / SHUTTERSTOCK

IN SAMUEL BECKETT'S NOVEL, *The Unnamable*, the anonymous narrator laments, "I'm all these words, all these strangers, this dust of words, with no ground for their setting, no sky for their dispersing."

For Beckett's narrator, words have become unmoored from their meaning. They no longer refer to anything in the physical world. Ultimately, they fail to fully convey or contain the inner message that prompted them. It's a deeply unsettling feeling I suspect we've all experienced. Words become disconnected from our emotions, insufficient for what we want to convey. They betray us at moments when we need them most.

This sharp sense of despair is an opening to exploring why we have words in the first place. Many psychological factors drive one to speak, and one of them is the need to tell our story. However, for some, the motivation to tell our story can outstrip our capacity to do so, no matter how adept we are at words.

How serious is the gap between experience and the words we have? Serious. The need to render experience for others is tied to a need for others to understand us, and when unfulfilled, leaves an emptiness that hollows out our sources of motivation. This thin ornamental layer of words and the vast underbelly of thought and feeling beneath, etched into our biology, falls short of what we long to express.

The limits of words, like so many other shortfalls inherent in our biology, are like elbows that cannot bend backward, or the invisibility of a microscopic world around us, or the needless fears we have of others. Striking out against biological limits, with the only tools we have—human inventiveness—always carries unexpected consequences, and words as a biological limitation require a context from which to navigate the boundary between our words and their meaning.

IN THE HISTORY of brain evolution, words are a recent addition to the neurobiological repertoire. Like a non-native species, words have invaded the human brain and ascended to dominance as a tool to render experience.

Long before words, the kingdoms of life had mechanisms of communication. They had pheromones or chemical signals from bacteria that alerted the colony about nutrient conditions in the environment. No life form survives as a single individual; they are always multitudes, replicating within an ecosystem that has necessarily evolved communication systems as a critical adaptive tool. Clearly communication does not need words.

When adapted for survival, chemical communication must be precise, unambiguous, and stripped of nuance, and it must precisely render the intentions of the sender. When paired with the precision of chemical signals, words seem a paltry addition—they lack precision, are loaded with intentional or unintentional ambiguity and double entendre—far from what seems needed for survival. Except we apparently do need them. Organisms do not expend precious resources for functions without survival value, and words would be an expensive adornment for the brain.

So what is the survival value of words? Vocalizations all through the animal kingdom project into a limited acoustic space, vibrate through the air to enclose within their boundaries all those capable of hearing the frequencies of these public announcements. Among hominins, the ability to provide detailed information about food sources and threats must have been advantageous.

This sharp despair is an opening to exploring why we have words in the first place.

Beyond their information value, words assumed a phatic function, the empty pleasantries that establish social relationships and let us pose questions like, “How are you?” for which we do not expect answers.

While other primates accomplish this function perfectly well in the absence of words by grooming, words can perform “grooming” at a distance to avoid uncomfortable proximity. Words can refine social relationships with fine grain detail.

Establishing social relationships requires more than pleasantries and forms of address. Words allowed us to tell our stories to each other as a means of eliciting empathy and building trust. Or, reversing the arrow of time, the desire to render our experience gave us words. The evolutionary sequence of biological adaptations is not always knowable.

In any case, social networks, strengthened by the bonds of empathy, probably confer a collective advantage. Once endowed with words, we had the capacity to elicit empathy, which was motivation enough to use them for telling our story.

BUT MOTIVATION TO SPEAK can be dissociated from the capacity to speak. The drive to express ourselves can be joined with the sense that we cannot quite express ourselves fully, that language is inherently the limiting factor. Why should that be?

Via a complex circuitry, the brain delivers motivation to the body as a motor command to execute its will. One view is the brain is busy making predictions about the world such as what we will see when we turn the corner. If we are surprised by not seeing what we expected, then we are motivated to turn around and meet our expectations in some other direction or explore further. A failure to match the world with our expectation delivers a surprise and motivates the motor system. Speech is a motor system and attaching words

to explain the world is a way to align pre-verbal perception or experience with an expected state.

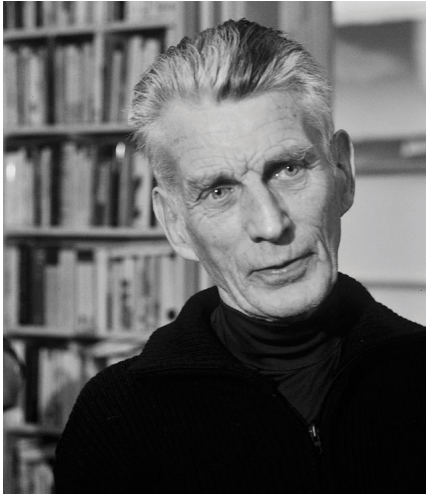
Our closest living relatives—the old-world monkeys—route trillions of electrical messages through their gray and white matter and manage to fill their large brains with neural activity, while remaining devoid of words. Their grunts, barks, screams, and hoots and accompanying range of facial expressions convey messages including nuance, even some rudimentary elements of language. It’s difficult to know what they may be experiencing. Do their perceptions raise conflicts, questions, doubts, and anxieties that require communication tools beyond their capacity? Whatever the mental states of non-human primates, at some point words usurped a wordless consciousness.

Reduced to their elementary waveforms, words are complex vibrations generated by rapid movements of mouth parts, shaped according to learned patterns to convey meaning. The synchronization of vocalization muscles with millisecond timing and the neural firing patterns in the brain that generate the muscle movements are the physical embodiment of an abstraction called meaning.

The emitted sounds represent a thought or a feeling that motivated them. How can a vocalization in the form of a complex sound package, let’s say a signifier, which can be precisely described as a set of waveforms, serve as a representation of a thought?

Can we track thought instantiated as brain pulses, and recorded as complex waveforms, to its representation in the form of words? The neuroscientist probes this space from one direction as material changes in the brain—something one can see and measure in the dense underbrush of synapses, and makes the transformation to the abstract through models and equations. The writer pushes from the opposite direction, from an intangible mental state. From this perspective, the rigorously depersonalized, unallusive language of science feels like a hostile interface with the allusive, richly personalized language of literature. Beckett says it best: “I’m in the middle. I’m the partition. I’ve two surfaces and no thickness. Perhaps that’s what I feel, myself vibrating. I’m the tympanum. On the one hand the mind, on the other the word. I don’t belong to either.”

Packaging of a thought into an utterance necessarily assigns meaning, attributes a signifier to the signified.



WAITING FOR THE WORD Samuel Beckett (left) is the rare author who takes us inside the raw workings of the human brain, into the clefts between motivation and language.

Meaning, undergirded by words, transmutes a large body of phonetic constructs in the form of some generally agreed upon practical significance. But much remains indeterminate, left dangling at the blurry boundaries of multiple meanings. The system of signifier and signified has multiple points of mismatch that create the uneasy sense of words as inadequate. Did the meaning assigned to the words of the sender match the meaning that the sender wanted to convey—did I say it right?—and were those words understood by the receiver according to the intentions of the sender? Words often imprecisely fit the shape of the desire for meaning that motivated them. And beyond the mismatch lies a vast realm of human feeling and perception and experience that falls entirely outside the power of language to capture.

A GREAT DEAL of brain tissue is preoccupied with words. The specific mapping of a vocabulary onto brain activity, albeit plastic and dynamic, narrows the gap between mind and brain. Brain imaging allows us to watch the brain as the sounds of words assume meaning for the receiver. Whereas non-word sounds show discrete and limited activation patterns, word representations appear as intricate patterns tiled over large regions of the brain. Metaphors are understood by activating regions of the brain that correspond to sensory functions. For example, the phrase “she had a rough week” activates touch areas of the brain, and the

phrase “grasp a concept” activates hand muscle regions related to an intentional action. As words spread over brain regions, they generate abstraction from more specific controllers of brain function, such as tactile regions for the word “rough” and motor regions for the word “grasp.”

The circuitry of word meaning functions in flux with our internal bodily state. The pattern elicited by the word “apple” depends on whether we feel hungry or sated. The internal states of speaker and listener may differ and words can miss their mark as they cross the boundary into the mind. The tuning of word meaning, the many dials implanted in both sender and receiver, is where we face the opacity of mind, the impenetrability of subjectivity because the internal state is not made of objects or anything tangible, but of moods, of anxiety and joy, of awe and disgust, all without discrete metrics to objectify. More succinctly David Foster Wallace said, “How odd I can have all this inside me and to you it’s just words.”

As an imprecise abstraction of the internal state that cannot readily express the musings of consciousness, words can feel like a lie. They are inherently mismatched with the complex layering of meaning, a word-mind duality. As Beckett’s narrator in *The Unnamable* says, “On the one hand the mind, on the other the word. I don’t belong to either.”

Words are imperfect vehicles for thought, incapable of completely encompassing the nonlinear leaps through the brain. Stilling thought requires the tectonic concentration of a yogi to hold onto a mantra without intrusion. As one ascends the motor system from the simple reflexes of the spinal cord to the cerebral cortex, motor activity at the highest level of brain function becomes thought. In fact, when the motor system slows and the initiation of an action is difficult, as occurs in Parkinson’s disease, patients also suffer from bradyphrenia, or slow thinking.

The narrator probes an abstract place where silence and meaning co-exist.

ONCE THE BRAIN DEVELOPS, linguistic rules superimpose an abstract structure on communication. But in young children, words are incompletely bound by their syntactical context. With crib talk, young children engage in monologues that may be shaping the social function of language, and precise meaning is irrelevant. It's similar to practicing scales on a musical instrument. With development, fitting words into the constraints of grammar transforms thought from something amorphous into a socially agreed upon conduit for communication with others.

Novel concepts must conform to the constraint-specifics based upon a deeply ingrained grammar that knits words together via syntax to create concepts. From nouns come categories. Some are predetermined, built into the anatomy and functional circuitry of the brain, such as face encoding, which is physiologically wired to identify specific faces. Word categories can be localized by fMRI—some brain regions respond more to words than non-words, or specifically represent concrete versus abstract words, action verbs, social narratives, or semantic areas honed for living things, tools, food, or shelter. All of these categories have overlapping blurry edges. As experience mounts, the particulars of each category get filled in and do so in a culturally modulated manner. By sweeping up cumulative experience from the surroundings, as a means to fill in the brain's category bins and parsing the world into increasingly

narrow categories, learned and operated upon by the brain, each person comes into possession of their own particulars, an identity.

FMRI activation patterns, which constitute brain circuitry, encode abstract semantic concepts signified by words. How many patterns are there? How frequently do we draw upon the same patterns for different perceptions and thereby blur differences or merge concepts? Can we predict brain activation patterns from specific words or predict from a brain activation pattern the associated thought? Not very accurately. The complexity of the environment far supersedes the complexity of the brain. Therefore, the brain is a data-reduction machine and what the brain can encode places a boundary upon human thought.

When narrowing the encoding capacity of the brain to words, one can compile them in terms of their usage, which approximates a statistical distribution called Zipf's law. Among the utterances of natural language, the frequency of any word is inversely proportional to its rank in the frequency table. Accordingly, the most frequent words will occur about twice as often as the second most frequent words, and three times as often as the third most frequent words, and so on down the ranking. Ordered in this manner, only 135 vocabulary items are needed to account for half of English language usage in a sampling of texts with approximately 1 million words. This type of distribution with a very high frequency of

common words and a long tail of low frequency words skews expression to a small proportion of the semantic repertoire. Representations with high frequency usage can facilitate communication and rarely used representations serve as a creative reservoir for expression.

Unlike nouns, pronouns present a problem of identity. The brain adopts a pronoun to encode agency, to assign responsibility for the consequences of an action. Pronouns can sharpen person distinctions or blur them. As anaphoric references, they lose focus with distance from their subject and become weightless, leaving the information-hungry brain spinning like the Mac color wheel. Turning to Beckett in *The Unnamable*, he faults the pronouns: “Someone says you. It’s the fault of the pronouns. There’s no name for me. No pronoun for me. All the trouble comes from that. That. It’s a kind of pronoun too.” The third and first person have an indistinct boundary in the brain. Paradoxically, the self and the other are encoded by the same neurons. The third person is a brain artifice that sets up an apposition figure, a seemingly outside voice within us, in some respects like the voice heard by the schizophrenic.

Nouns are limited by their categories (but capable of expanding through metaphor), pronouns create ambiguous identities, and verbs force an action within a temporal framework. Verbs are the motor system of language. As thoughts jump through time and memories, often unbidden, all of this motion relies on verbs to make the connections. All languages struggle with verbs, sometimes emphasizing fine gradations in time, while others require a statement of location embedded in the action. Encoding time taps into what is possibly the most core function of the brain—predicting the future. Predictions draw upon the past, which is called learning. Because multiple clocks, not just chronological time, mark change, packing myriad time scales into language, precise communication sometimes comes up short.

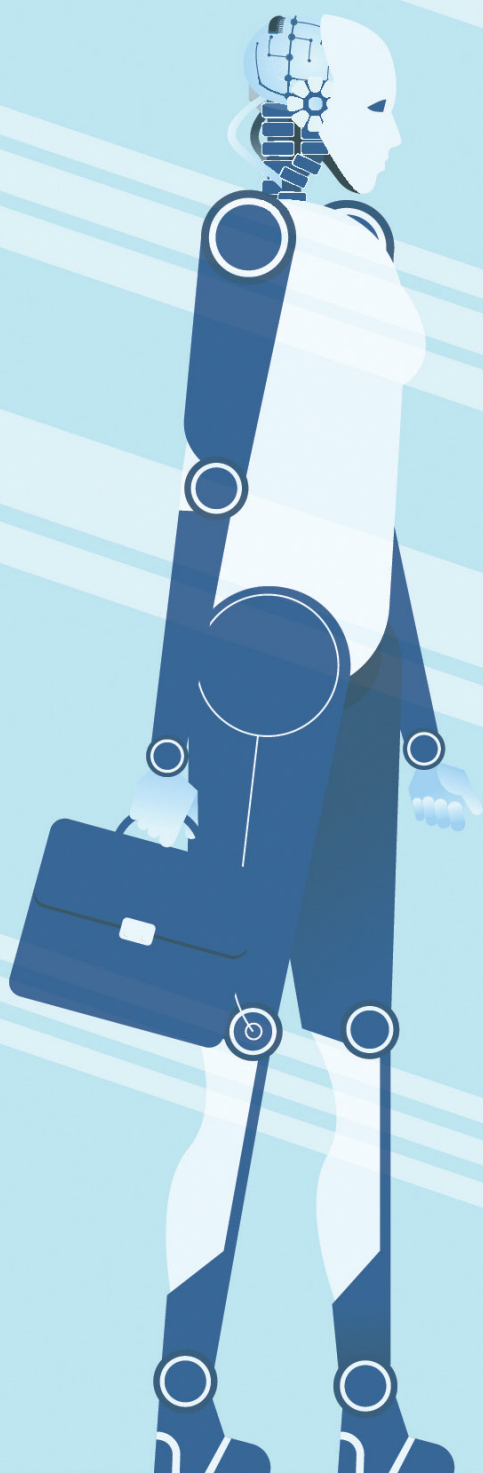
THE MENTAL STATE that corresponds to activation of the default mode network may be a glimpse of an interior consciousness detached from words. This network is a set of brain regions, located toward the back of the brain, that synchronize and in so doing disengage the brain from the external world akin to daydreaming or mind wandering.

“Default” describes the tendency for the brain to enter this state. Once disengaged from a task, from rationale episodic sequences with an inherent grammar, even momentarily, the default system is activated. Once we engage more deeply in the logical framework of a storyline, the brain shifts back from the default mode to activate a new pattern devoted to analysis and the logical framework of a storyline. The default mode, independent and non-linguistic, blinks off and language areas light up in a complex circuitry related to articulation, grammar, and semantics.

While the stories we tell rely on words, our collective stories, the stuff of myths and legends, fables and beliefs, reside, in part, within the default network. They arise from brooding about the night sky or mentally wandering through a nondescript expanse of partial sensations about a lost loved one. Within a community, these notions can gel into universal creation myths. The default network can synchronize among multiple individuals when watching a movie together or listening to a story together as we contemplate, absorb, and assimilate the characters and their actions.

These stories cannot be silenced. The nature of the default mode network connects human minds within a shared neurological territory. Drawing inspiration, the narrator in Beckett’s *The Unnamable* probes an abstract place where silence and meaning co-exist, where meaning is wordless and the effort to get there is relentless, and concludes: “You must go on. I can’t go on. I’ll go on.” ☺

KENNETH S. KOSIK is a neuroscientist whose work in Colombia on familial Alzheimer’s disease has appeared in *The New York Times*, BBC, CNN, PBS and *60 Minutes*. The commencement address he gave at the University of California, Santa Barbara is archived at the Graduation Wisdom website.



Would You Survive a Merger with AI?

The cost of brain enhancement may be your identity

BY SUSAN SCHNEIDER

THE IDEA THAT HUMANS should merge with AI is very much in the air these days. It is offered both as a way for humans to avoid being outmoded by AI in the workplace, and as a path to superintelligence and immortality. For instance, Elon Musk recently commented that humans can escape being outmoded by AI by “having some sort of merger of biological intelligence and machine intelligence.”¹ To this end, he’s founded a company, Neuralink. One of its first aims is to develop “neural lace,” an injectable mesh that connects the brain directly to computers. Neural lace and other AI-based enhancements are supposed to allow data from your brain to travel wirelessly to one’s digital devices or to the cloud, where massive computing power is available.

Perhaps these sorts of enhancements will turn out to be beneficial, but to see if this is the case, we will need to move beyond all the hype.

Policymakers, the public, and even AI researchers themselves need a better idea of what is at stake. For instance, if AI cannot be conscious, then if you substituted a microchip for the

parts of the brain responsible for consciousness, you would end your life as a conscious being. You’d become what philosophers call a “zombie”—a nonconscious simulacrum of your earlier self. Further, even if microchips could replace parts of the brain responsible for consciousness without zombifying you, radical enhancement is still a major risk. After too many changes, the person who remains may not even be you. Each human who enhances may, unbeknownst to them, end their life in the process.

TO DECIDE WHETHER TO ENHANCE, you must understand the metaphysics of personal identity. Philosophers call the characteristics that a thing must have as long as it exists “essential properties.” What might your essential properties be? If you are simply the physical stuff that comprised your brain and body in first grade, you would have ceased to exist some time ago. That physical first-grader is simply not here any longer. Ray Kurzweil, in his 2005 book *The Singularity Is Near: When Humans Transcend Biology*, clearly appreciates the difficulties here, commenting:

So who am I? Since I am constantly changing, am I just a pattern? What if someone copies that pattern? Am I the original and/or the copy? Perhaps I am this stuff here—that is, the both ordered and chaotic collection of molecules that make up my body and brain.

Kurzweil is referring to two theories that are center stage in the age-old philosophical debate over the nature of persons. Key theories include the following:

1. *The psychological continuity theory*: You are essentially your memories and ability to reflect on yourself and, in its most general form, this type of view claims you are your overall psychological configuration, what Kurzweil referred to as your “pattern.”
2. *Brain-based materialism*: You are essentially the material that you are made out of (i.e., your body and brain)—what Kurzweil referred to as “the ordered and chaotic collection of molecules” that make up his body and brain.
3. *The no-self view*: The self is an illusion. The “I” is a grammatical fiction. There are bundles of impressions, but there is no underlying self. There is no survival because there is no person.

Each of these views has its own implications about whether to enhance. For instance, the psychological continuity view holds that enhancements can alter your substrate, but they must preserve your overall psychological configuration. This view would allow you to transition to silicon or some other substrate, at least in

For many transhumanists, uploading is key to the mind-machine merger.

principle. In contrast, the brain-based materialism says that your thinking is dependent on the brain. Thought cannot “transfer” to a different substrate—enhancements must not change one’s material substrate, or the person would cease to exist.

On the no-self view, the survival of the person is not an issue, for there is no person or self there to begin with. In this case, expressions like “I” and “you” do not really refer to persons or selves. Notice that if you are a proponent of the no-self view, you may strive to enhance nonetheless. For instance, you might find intrinsic value in adding more superintelligence to the universe—you might value life forms with higher forms of consciousness and wish that your “successor” be such a creature.

I don’t know whether many of those who publicize the idea of a mind-machine merger, such as Elon Musk and Michio Kaku, have considered these classic positions on personal identity. But they should. It is a bad idea to ignore this debate. One could be dismayed, at some later point, to learn that a technology one advocated actually had a tremendously negative impact on human flourishing.

IN ANY CASE, both Kurzweil and the philosopher Nick Bostrom *have* considered the issue in their work. They, like many other transhumanists, adopt a novel and intriguing version of the psychological continuity view; in particular, they adopt a computational, or *patternist*, account of continuity. Patternism’s point of departure is the computational theory of mind. Although computational theories of mind differ in their details, one thing they have in common is that they all explain cognitive and perceptual capacities in terms of causal relationships between components, each of which can be described algorithmically. One common way of describing the computational theory of mind is by reference to the idea that the mind is a software program: That is,

the mind is the algorithm the brain implements, and this algorithm is something that different subfields of cognitive science seek to describe.

Those working on computational theories of mind in philosophy of mind tend to ignore the topic of patternism, as well as the more general topic of personal identity. This is unfortunate for two reasons. First, on any feasible view of the nature of persons, one's view of the nature of mind plays an important role. For what is a person if not, at least in part, that which she thinks and reflects with? Second, whatever the mind is, an understanding of its nature should include the study of its persistence, and it seems reasonable to think that this sort of undertaking would be closely related to theories of the persistence of the self or person. Yet the issue of persistence is often ignored in discussions of the nature of the mind. I suspect the reason is simply that work on the nature of the mind is in a different subfield of philosophy from work on the nature of the person—a case, in other words, of academic pigeonholing.

To their credit, transhumanists step up to the plate in trying to connect the topic of the nature of the mind with issues regarding personal identity, and they are clearly right to sense an affinity between patternism and the Software Approach to the Mind. After all, if you take a computational approach to the nature of mind, it is natural to regard persons as being somehow computational in nature and to ponder whether the survival of a person is somehow a matter of the survival of their software pattern. The guiding conception of the patternist is aptly captured by Kurzweil:

The specific set of particles that my body and brain comprise are in fact completely different from the atoms and molecules that I comprised only a short while ago. We know that most of our cells are turned over in a matter of weeks, and even our neurons, which persist as distinct cells for a relatively long time, nonetheless change all of their constituent molecules within a month. ... I am rather like the pattern that water makes in a stream as it rushes past the rocks in its path. The actual molecules of water change every millisecond, but the pattern persists for hours or even years.

According to the patternist, what is essential to you is your computational configuration: the sensory

systems/subsystems your brain has (e.g., early vision), the association areas that integrate these basic sensory subsystems, the neural circuitry making up your domain-general reasoning, your attentional system, your memories, and so on. Together these form the algorithm that your brain computes.

You might think the transhumanist views a brain-based materialism favorably. Transhumanists generally reject brain-based materialism, however, because they tend to believe the same person can continue to exist if her pattern persists, even if she has “uploaded” to a computer, no longer having a brain. For many transhumanists, uploading is key to the mind-machine merger.

*Each human who enhances
may, unbeknownst to them,
end their life in the process.*

IN THE SCIENCE-FICTION NOVEL *Mindscan* by Robert Sawyer, the protagonist Jake Sullivan has an inoperable brain tumor. Death could strike him at any moment. Luckily, Immortex has a new cure for aging and illness—a “mindscan.” Immortex scientists tell him they will upload his brain configuration into a computer and “transfer” it into an android body that is designed using his own body as a template. Although imperfect, the android body has its advantages—once an individual is uploaded, a backup exists that can be downloaded if one has an accident. And it can be upgraded as new developments emerge. Jake will be immortal.

Sullivan decides to get the mindscan. He enthusiastically signs numerous legal agreements. He is told that, upon uploading, his possessions will be transferred to the android, who will be the new bearer of his consciousness. Sullivan’s original copy, which will die soon anyway, will live out the remainder of his life on “High Eden,” an Immortex colony on the moon. Although stripped of his legal identity, the original copy will be comfortable there, socializing with the other originals who are also still confined to biological senescence.

Sawyer then depicts Jake's perspective while lying in the scanning tube:

I was looking forward to my new existence. Quantity of life didn't matter that much to me—but quality. And to have time—not only years spreading out into the future, but time in each day. Uploads, after all, didn't have to sleep, so not only did we get all those extra years, we got one-third more productive time. The future was at hand. Creating another me. Mindscan.

But then, a few seconds later:

"All right, Mr. Sullivan, you can come out now." It was Dr. Killian's voice, with its Jamaican lilt.

My heart sank. No ...

"Mr. Sullivan? We've finished the scanning. If you'll press the red button. ..." It hit me like a ton of bricks, like a tidal wave of blood. No! I should be somewhere else, but I wasn't. ...

I reflexively brought up my hands, patting my chest, feeling the softness of it, feeling it raise and fall. Jesus Christ!

I shook my head. "You just scanned my consciousness, making a duplicate of my mind, right?" My voice was sneering. "And since I'm aware of things after you finished the scanning, that means I—this version—isn't that copy. The copy doesn't have to worry about becoming a vegetable anymore. It's free. Finally and at last, it's free of everything that's been hanging over my head for the last twenty-seven years. We've diverged now, and the cured me has started down its path. But this me is still doomed."²

Sawyer's novel is a *reductio ad absurdum* of the patternist conception of the person. All that patternism says is that as long as person A has the same computational configuration as person B, A and B are the

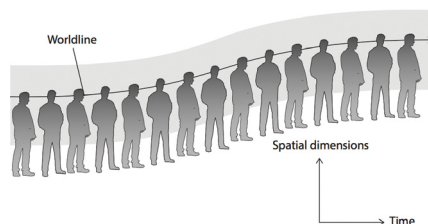
same person. Indeed, Sugiyama, the person selling the mindscan to Jake, had espoused a form of patternism.²

But Jake has belatedly realized a problem with that view, which we shall call "the reduplication problem": Only one person can really be Jake Sullivan. According to patternism, both creatures are Jake Sullivan, because they share the very same psychological configuration. But, as Jake learned, although the creature created by the mindscan process may be a person, it is not the same person as the original Jake. It is just another person with an artificial brain and body configured like the original. Both feel a sense of psychological continuity with the person who went into the scanner, and both may claim to be Jake, but nonetheless they are not the same person, any more than identical twins are.

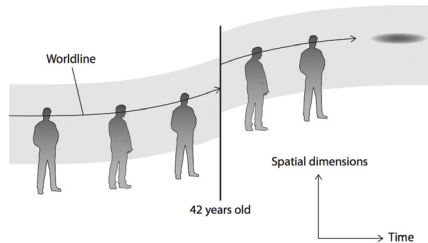
Hence, having a particular type of pattern cannot be *sufficient* for personal identity. Indeed, the problem is illustrated to epic proportions later in Sawyer's book when numerous copies of Sullivan are made, all believing they are the original!

BUT YOU MAY SUSPECT that there still is a kernel of truth to patternism: Your cells change continually but your organizational pattern carries on. Your pattern is *essential* to yourself despite not being *sufficient* for a complete account of your identity. Perhaps there is an additional essential property which, together with your pattern, yields a complete theory of personal identity.

What could the missing ingredient be? Think about your own existence in space and time. When you go out to get the mail, you move from one spatial location to the next, tracing a path in space. A spacetime diagram can help us visualize the path one takes throughout one's life. Collapsing the three spatial dimensions into one (the vertical axis) and taking the horizontal axis to signify time, consider the following typical trajectory:



Notice that the figure carved out looks like a worm; you, like all physical objects, carve out a sort of “space-time worm” over the course of your existence. This, at least, is the kind of path that ordinary people—those who are neither posthumans nor superintelligences—carve out. But now consider what happened during the mindscan. The copy’s spacetime diagram would look like the following:



This is bizarre. It appears that Jake Sullivan exists for 42 years, has a scan, and then somehow instantaneously moves to a different location in space and lives out the rest of his life. This alerts us that something is wrong with pure patternism: It lacks a requirement for spatiotemporal continuity. On the day of the mindscan, Jake went into the laboratory and had a scan; then he left the laboratory and went directly into a spaceship and flew to exile on the moon. It is this man—the one who traces a continuous trajectory through space and time—who is the true Jake Sullivan. The android is an unwitting impostor.

This response to the reduplication problem only goes so far, however. Consider Sugiyama, who, when selling his mindscan product, ventured a patternist pitch. If he had espoused patternism together with a spatiotemporal continuity clause, he would have to admit that his customers would not become immortal, and few would have signed up for the scan. That extra ingredient would rule out a mindscan (or any kind of uploading, for that matter) as a means to ensure survival. Only those wishing to have a replacement for themselves would sign up.

There is a general lesson here for the transhumanist: If one opts for patternism, enhancements like uploading are not really “enhancements”; they can even result in death. ☹️

SUSAN SCHNEIDER is the author of *Artificial You: AI and the Future of Your Mind*. She is the NASA-Baruch Blumberg Chair at the Library of Congress and the director of the AI, Mind and Society Group at the University of Connecticut. Her work has been explored on PBS, The History Channel, the National Geographic Channel, and featured by *The New York Times*, *Science*, and *Smithsonian*.

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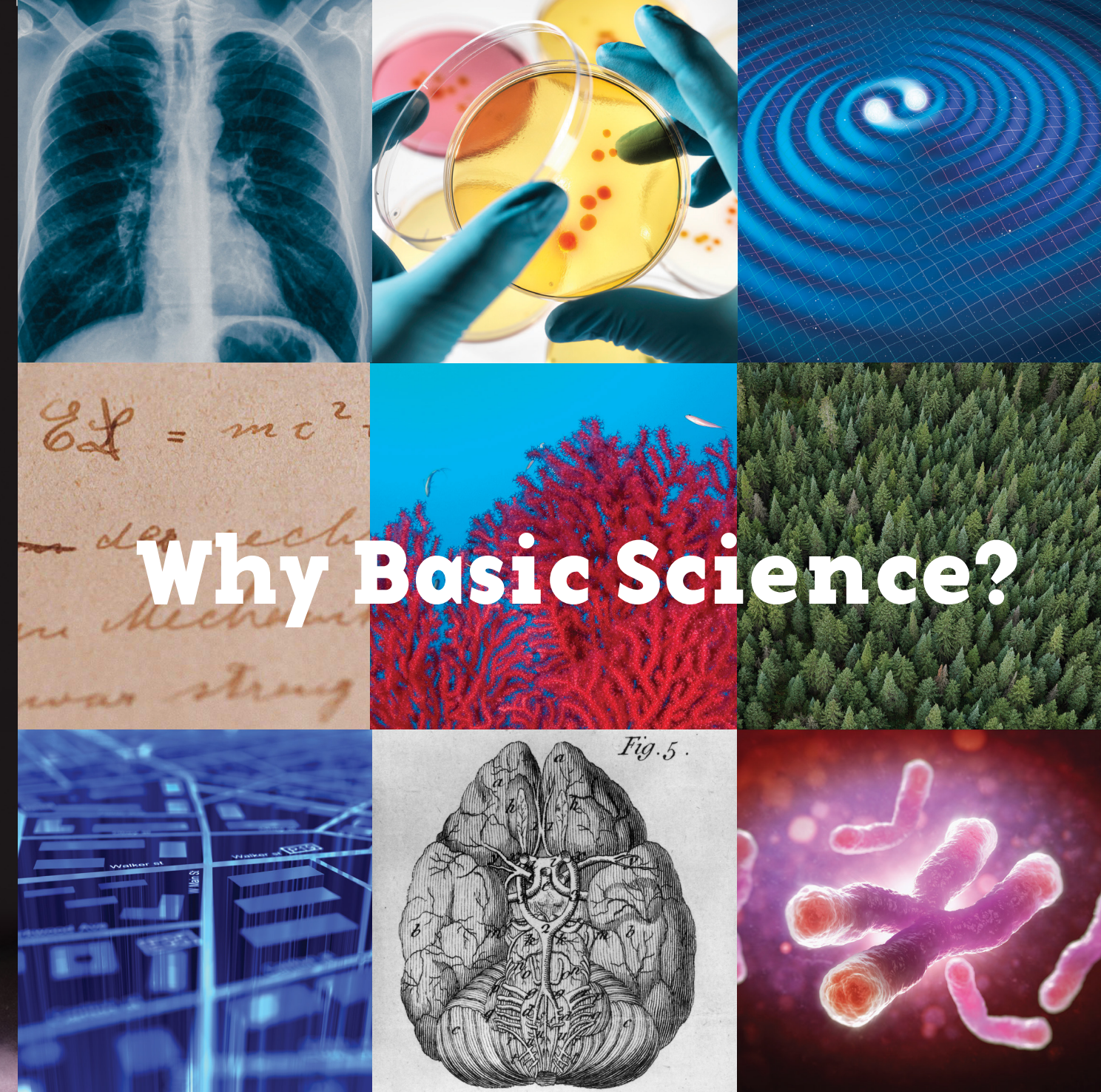


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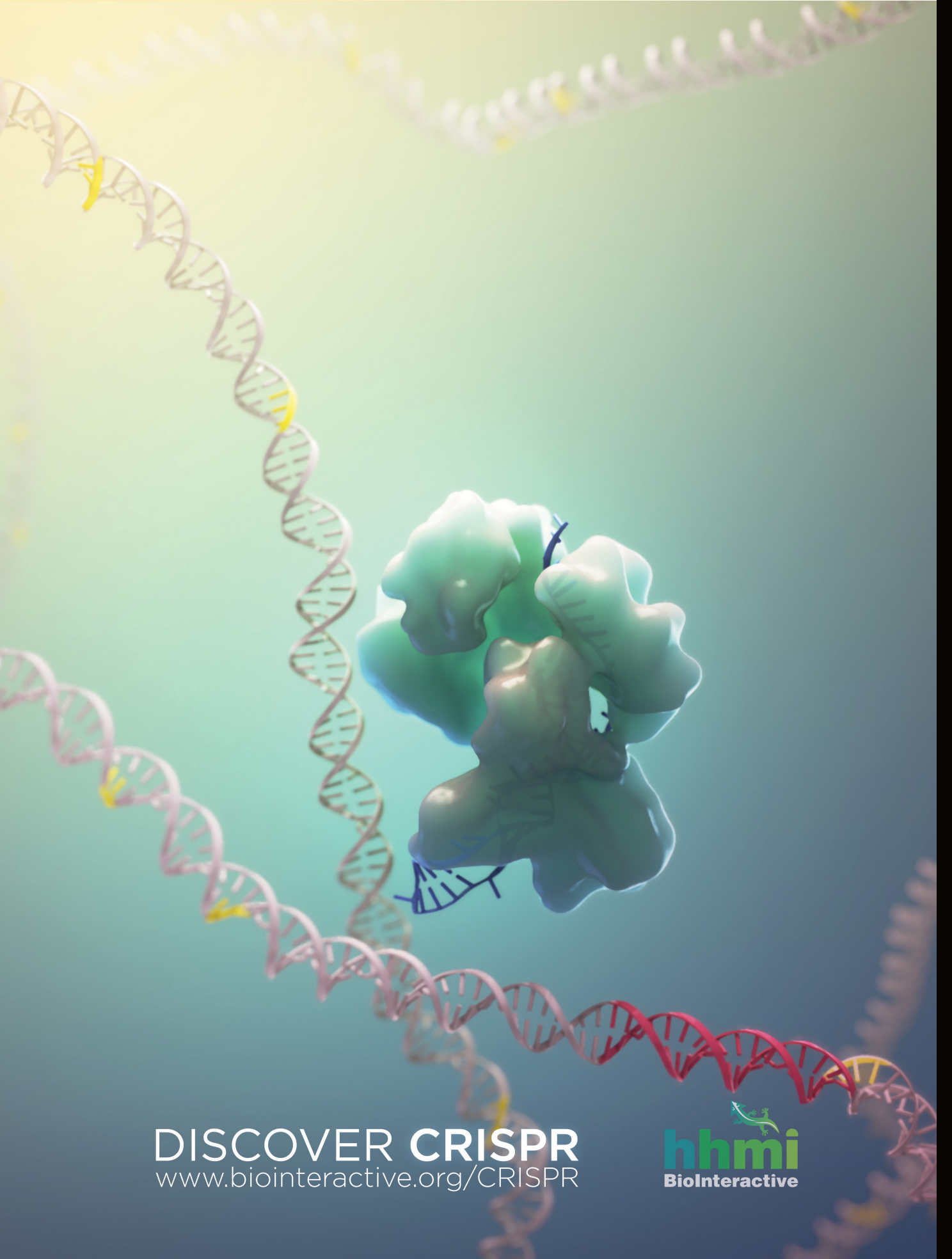


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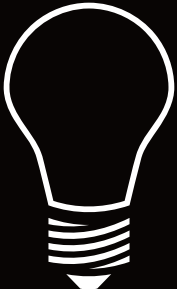
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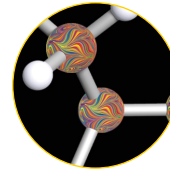
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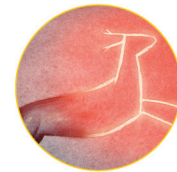


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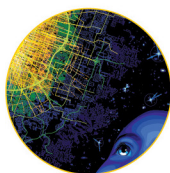
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Nell Freudenberger

The writer on learning physics for her novel, Lost and Wanted

INTERVIEW BY KEVIN BERGER

FIRST DRAFT

I had a draft of the novel with a male protagonist who was both a fiction writer and an astrophysicist. I'm interested in somebody who has that kind of brain, who likes to do both things. As I wrote the book, though, I got more skeptical about the idea that we had either a humanities brain or a science brain. Then I thought, "What if the first-person narrator were a physicist and a woman?" It was scary because I knew I would have to do a whole other level of research to write a convincing physicist. But the feeling I can't do something is what makes me think it's worth trying to do.

DEEP READING

Reading about physics was more accessible than I had thought. I spent a lot of time with Imre Bartos, one of the LIGO [Laser Interferometer Gravitational-Wave Observatory] scientists, who first detected gravitational waves. I once asked him about a paper that concerned noise reduction inside the interferometers. I said I might have to skip over the math. He said, "We all skip over the math; unless we think it's wrong, we skip it." That was a huge relief. I'm never going to read a paper the way a physicist reads it. But Imre believed I could take away the basic ideas. One day we were walking in a park and he was explaining black holes in a classical, Newtonian way. He was using all of these things around us—trees and rocks and squirrels—to help me understand black holes. And I said, "Wait a minute, aren't we supposed to resist explaining things in this way?"

He said, "Absolutely not, our brains aren't equipped to understand a lot of these ideas without analogies to our three-dimensional world." The more I had moments like that, the more confident I got that I could understand physics well enough to put it on stage.

MAGICAL THINKING

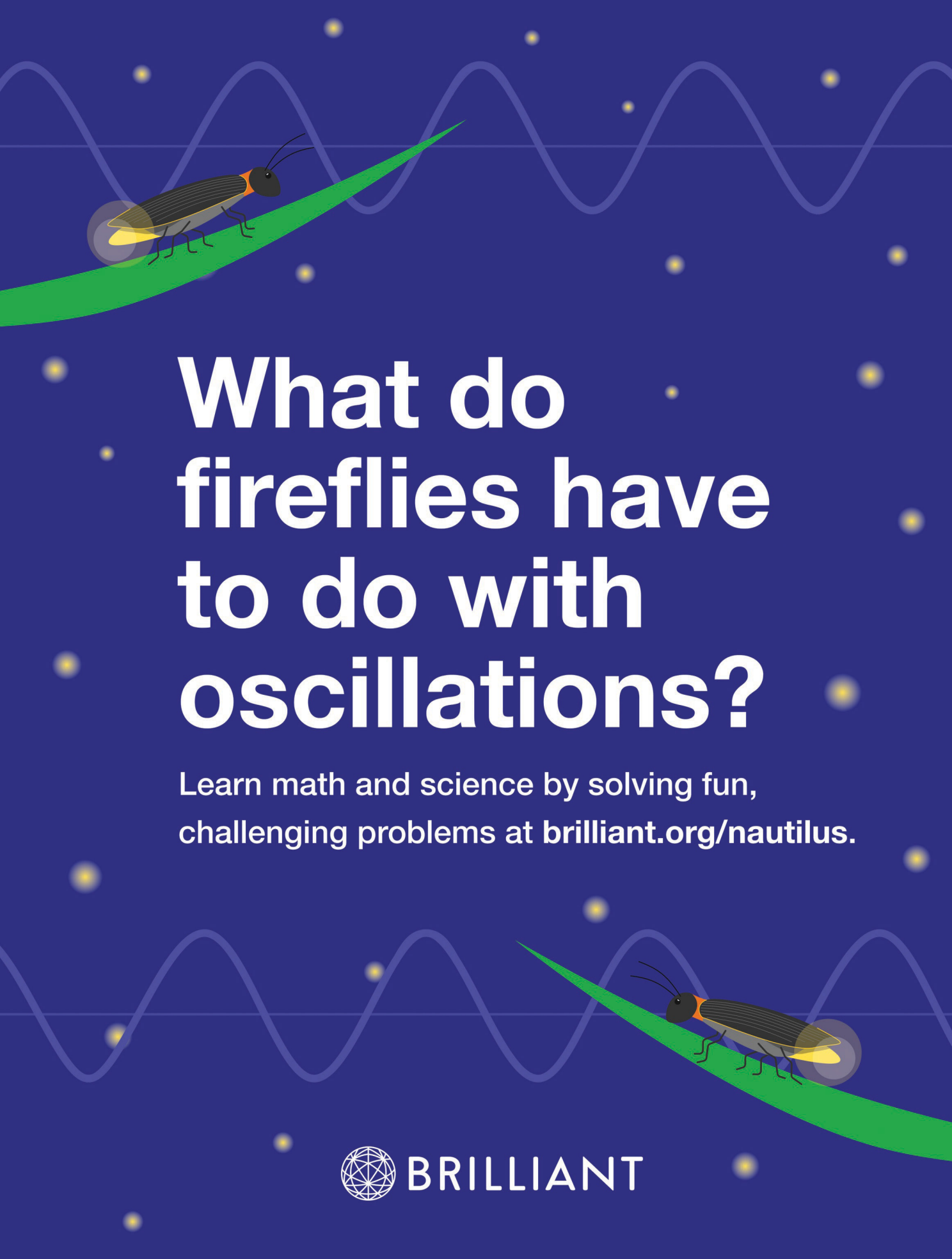
I was writing about a scientist who experiences loss and grief. I thought she would experience grief in a more scientific or rational way than the rest of us do. But by the time I got to the end of the book, I thought she might be prone to the same sort of magical thinking we all have around loss and grief. It's fascinating to read some of the more out-there ideas about the afterlife that wear scientific clothing. I've never read one that I felt was pure science. But I was interested in the way that some people who might be seriously ill or thinking about death might latch on to the ideas of a scientist as a comfort in the same way that somebody might latch on to a religious idea.



ALTERNATIVE CAREER

If I were a scientist I would study gravitational waves. An interferometer is a fairly simple machine that's been around for a long time. The way LIGO refined it to see this thing that Einstein didn't believe scientists would ever be able to detect is amazing. And the first paper by the scientists is beautiful. The fact that it's about both the first detection of gravitational waves and the first observation of a black hole merger, in just a few pages, is incredible. ☺

ELENA SEIBERT

The background is a dark blue field with a light blue sine wave oscillating horizontally. Scattered throughout are small, glowing yellow dots. A green leaf, representing a sine wave, curves from the top left towards the center. A firefly with a black body, orange thorax, and glowing yellow abdomen is positioned on this leaf. Another identical firefly is on a similar leaf at the bottom right.

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