How Much Can We Know?

The reach of the scientific method is constrained by the limitations of our tools and the intrinsic impenetrability of some of nature's deepest questions

By Marcelo Gleiser

"WHAT WE OBSERVE IS NOT NATURE IN ITSELF but nature exposed to our method of questioning," wrote German physicist Werner Heisenberg, who was the first to fathom the uncertainty inherent in quantum physics. To those who think of science as a direct path to the truth about the world, this quote must be surprising, perhaps even upsetting. Is Heisenberg saying that our scientific theories are contingent on us as observers? If he is, and we take him seriously, does this mean that what we call scientific truth is nothing but a big illusion?

People will quickly counterstrike with something like: Why do airplanes fly or antibiotics work? Why are we able to build machines that process information with such amazing efficiency? Surely, such inventions and so many others are based on laws of nature that function independently of us. There is order in the universe, and science gradually uncovers this order.

No question about it: There is order in the universe, and much of science is about finding patterns of behavior—from quarks to mammals to galaxies—that we translate into general laws. We strip away unnecessary complications and focus on what is essential, the core properties of the system we are studying. We then build a descriptive narrative of how the system behaves, which, in the best cases, is also predictive.

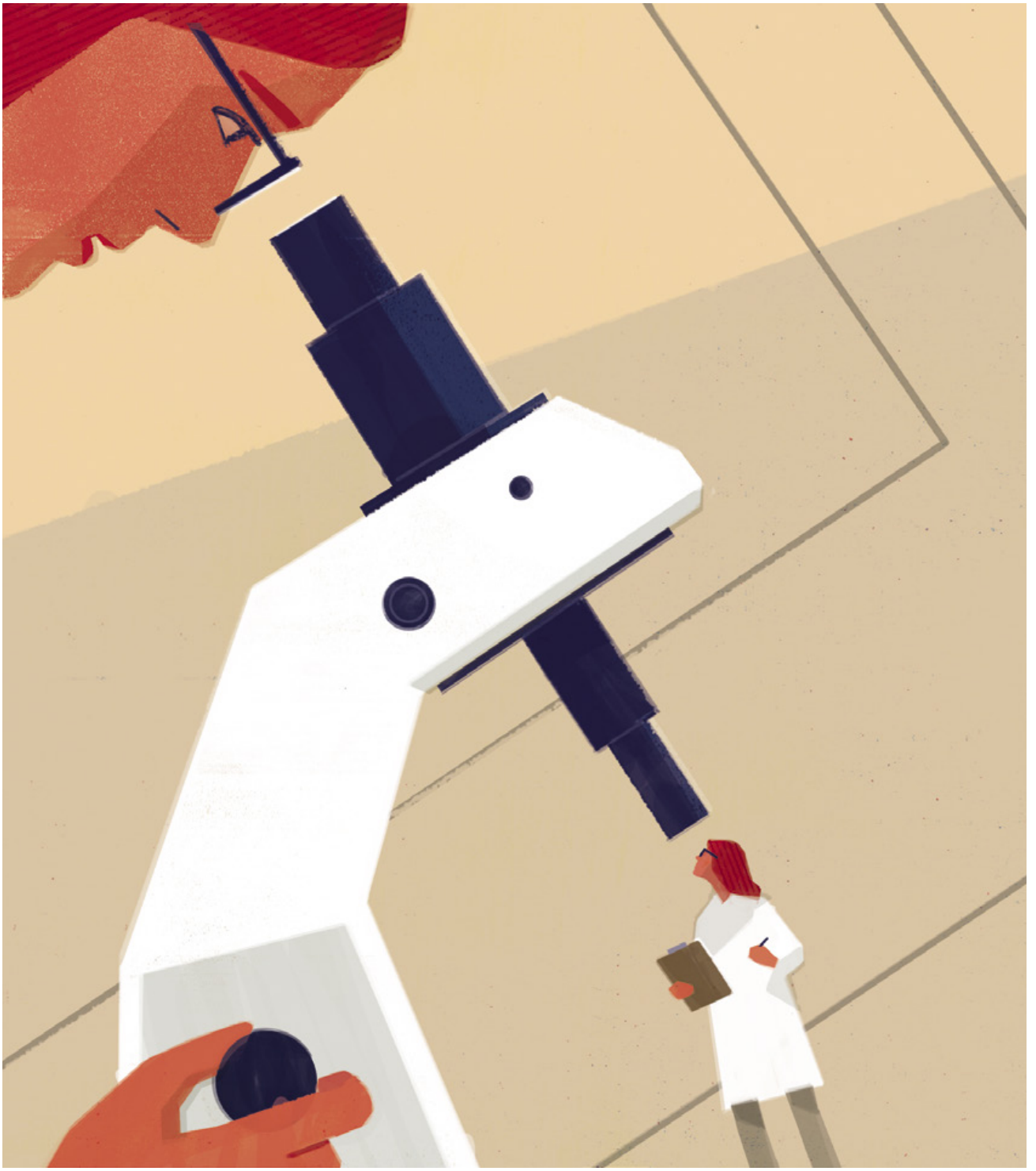
Often overlooked in the excitement of research is that the methodology of science requires interaction with the system we are studying. We observe its behavior, measure its properties, and build mathematical or conceptual models to understand it better. And to do this, we need tools that extend into realms beyond our sensorial reach: the very small, the very fast, the very distant and the virtually inaccessible, such as what is inside the brain or buried in the earth's core. What we observe is not nature itself but nature as discerned through data we collect from machines. In consequence, the scientific worldview depends on the information we can acquire through our instruments. And given that our tools are limited, our view of the world is necessarily myopic. We can see only so far into the nature of things, and our ever shifting scientific worldview reflects this fundamental limitation on how we perceive reality.

Just think of biology before and after the microscope or gene sequencing, or of astronomy before and after the telescope, or of particle physics before and after colliders or fast electronics. Now, as in the 17th century, the theories we build and the worldviews we construct change as our tools of exploration transform. This trend is the trademark of science.

Sometimes people take this statement about the limitation of scientific knowledge as being defeatist: "If we can't get to the bottom of things, why bother?" This kind of response is misplaced. There is nothing defeatist in understanding the limitations of the scientific approach to knowledge. Science remains our best methodology to build consensus about the workings of nature. What should change is a sense of scientific triumphalism—the belief that no question is beyond the reach of scientific discourse.

There are clear unknowables in science—reasonable questions that, unless currently accepted laws of nature are violated, we cannot find answers to. One example is the multiverse: the conjecture that our universe is but one among a multitude of others, each potentially with a different set of laws of nature. Other universes lie outside our causal horizon, meaning that we cannot receive or send signals to them. Any evidence for their existence would be circumstantial: for example, scars in the radiation permeating space because of a past collision with a neighboring universe.

Other examples of unknowables can be conflated into three questions about origins: of the universe, of life and of the mind. Scientific accounts of the origin of the universe are incomplete because they must rely on a conceptual framework to even begin to work: energy conservation, relativity, quantum physics, for instance. Why does the universe operate under these laws and not others?



Similarly, unless we can prove that only one or very few biochemical pathways exist from nonlife to life, we cannot know for sure how life originated on Earth. For consciousness, the problem is the jump from the material to the subjective—for example, from firing neurons to the experience of pain or the color red. Perhaps some kind of rudimentary consciousness could emerge in a sufficiently complex machine. But how could we tell? How do we establish—as opposed to conjecture—that something is conscious?

Paradoxically, it is through our consciousness that we make sense of the world, even if only imperfectly. Can we fully understand something of which we are a part? Like the mythic snake that bites its own tail, we are stuck within a circle that begins and ends with our lived experience of the world. We cannot detach our descriptions of reality from how we experience reality. This is the playing field where the game of science unfolds, and if we play by the rules we can see only so much of what lies beyond. SA

Marcelo Gleiser is Appleton Professor of Natural Philosophy and a professor of physics and astronomy at Dartmouth College. He has authored several books, including *The Island of Knowledge: The Limits of Science and the Search for Meaning* (2014). In 2019 he was awarded the Templeton Prize.

Illustration by Jessica Fortner

Ya Know?

Beyond the unknown unknowns is what's unknowable

By Steve Mirsky

In the 1954 World Series, Willie Mays of the New York Giants made what many consider the greatest catch in baseball history on a long fly ball to straightaway centerfield hit by Vic Wertz of the Cleveland Indians. Broadcaster Bob Costas talked about the catch for the Ken Burns documentary series *Baseball:* "It was more than just a great catch. It was a catch no one had ever seen before … it was a play that until that point was outside the realm of possibility in baseball." Mays in that moment thus expanded baseball into previously nonexistent territory, much like the universe expands—and not *into* anything, for there was nothing there before.

On the other hand, nah. Indians' pitcher Bob Feller, who watched the play from the dugout, followed Costas on the episode. "It was far from the best catch I've ever seen," he says. "It was a very good catch. We knew Willie had the ball all the way."

I thought of this sequence more than once when I attended a conference in 2019 at the New School's Center for Public Scholarship here in New York City billed as "Unknowability: How Do We Know What Cannot Be Known?" Filled with doubt, I felt fortunate to simply find the auditorium.

Discussing the unknown, Columbia University biologist Stuart Firestein cited what he called an apocryphal saying: "It's very hard to find a black cat in a dark room, especially when there is no cat." He continued, "I think this is exactly how science works and how it deals with the so-called unknowable. We stomp around in black rooms and eventually … we may find this critter or we may find some other critter entirely. But once having decided the room is either empty or full of a cat, we simply move on to the next dark room."

He also cited James Clerk Maxwell as having said, "'Thoroughly conscious ignorance is the prelude to every real advance in science.'" Firestein went on, "And so this is the kind of ignorance that I'm talking about, not the common usage of the word 'ignorance,' not stupidity or willful indifference to fact or logic—you know who I'm talking about. But rather this thoroughly conscious kind of ignorance that can be developed … The big question for me really is we've gained some knowledge, what does one do with that knowledge? And the purpose of that knowledge in my opinion is to create better ignorance, if you will. Because there's low-quality ignorance and high-quality ignorance … science, in my opinion, is the search for better ignorance." Presumably, as the quality of ignorance increases, so does the level of associated bliss.

After University of Cambridge mathematician John Barrow pointed out that "the unknown … is of course a vast, untapped field—rather like studying everything that is not a banana," he mentioned that beyond unknown unknowns lies the truly unknowable. "[Kurt] Gödel announced that … if you have a system that's got a finite number of axioms … and if it's complicated enough to include arithmetic … and if it's consistent … then there are statements of arithmetic which you can neither show to be true nor false using the rules and axioms of arithmetic."

Gödel's knack for deep insights led to a famous story about his U.S. citizenship interview. He allegedly cheerfully announced that he had discovered a way to apply the Constitution that would turn the U.S. into a dictatorship. (See above, "You know who I'm talking about.") Legend has it that his friend Einstein, on hand for the happy day, jumped in to change the subject.

Uncertainty and unknowability may feel discouraging. But Firestein thought they could be a source of optimism, as in the story of the condemned prisoner who convinces the king to give him a year's reprieve in return for the promise that the inmate will teach the monarch's horse to talk.

Another prisoner asks the saved man what possessed him to make such a crazy bargain. "The fellow says, 'A lot can happen in a year. The horse might die. The king might die. I might die. The horse might learn to talk.'" That last option may seem overly optimistic. But it certainly beats the alternative. SA

Steve Mirsky has been writing the Anti Gravity column since a typical tectonic plate was about 36 inches from its current location. He also hosts the *Scientific American* podcast Science Talk.

Illustration by Matt Collins