Forget the multiverse. In the pluriverse, we create reality together

A radical idea that resolves many quantum paradoxes suggests there is no objective view of reality. How can the cosmos be stitched together from interlocking perspectives?

J R Eyerman/The LIFE Picture Collection/Shutterstock

What is now? The nature of the ever-changing present moment has always fascinated me, because there is a paradox at its heart. From a personal perspective, the present is everything: it is the only time we can ever act or choose; the only thing we can ever experience or know. What did you have for breakfast? Where do you hope to go tomorrow? Even our memories and plans are forged in the present; we can only experience them *now*.

And yet, the conventional view of physics is that now, as we usually think of it, doesn't actually exist at all. In Albert Einstein's theory of relativity, all time points are equal: any event can be already done or yet to occur, from different points of view. There is no cosmic unfolding through which reality comes to be.

A new place for consciousness in our understanding of the universe

This raises a problem for us as thinking, feeling humans. If now is an illusion, then we cannot intervene in that moment to affect the future, because all events and times already exist. There is no gateway through which our in-the-moment thoughts or desires can reach out and change anything. By getting rid of now from the universe, we have lost a key part of ourselves.

In writing my book, *In Search of Now*, I wanted to know if

there is another way. Can we reconcile scientific evidence with a cosmos that includes us and the choices we make? The answer, I found, was yes. But only if we are prepared to radically rethink what reality is and who we are. "The world is such that you cannot separate yourself from it," says Michel Bitbol, a philosopher of physics at the École Normale Superieure in Paris.

Quantum paradoxes

To see how, let's start with a classic thought experiment, suggested in the 1970s by renowned physicist John Wheeler. It is beautifully simple, in principle at least, yet it is a vivid demonstration that the universe – and time – may work very differently from how we often assume.

Wheeler's set-up is a variant of the famous double-slit experiment of quantum physics, in which an experimenter's choice of what to measure determines what they find. Photons are fired at a screen with two slits in it. If physicists don't observe which route a photon takes, it seems to behave like a wave, spread across both slits. If they do observe, it acts as a particle, passing through just one slit.

This is strange enough: a mysterious switch from fuzziness to certainty at just the moment we look (quantum physicists call this "collapse"). But Wheeler raised the stakes. He asked what would happen if physicists didn't decide whether to

check a photon's route until after it had already completed its journey. In the decades since, researchers have repeatedly found just what Wheeler predicted in his delayed-choice experiment: the decision still affects the photon's path.

Variations on the famous double-slit experiment mess with our understanding of time and causality

CHRISTIAN KOCH, MICROCHEMICALS/SCIENCE PHOTO LIBRARY

Wheeler described this as "a strange inversion of the normal order of time", as if our choices aren't just influencing the present, but also the past. Physicists have tried to make sense of it, along with other quantum paradoxes, in ingenious ways: suggesting branching realities in which all

possibilities already exist in a vast multiverse, or proposing an unseen guiding influence, or so-called pilot wave, that can instantaneously link different parts of reality. But for Wheeler, the lesson of quantum mechanics was simply that our reality doesn't exist separately from us. We can't pin down a particle until we look, because what's beyond us isn't definite things, but potential. By choosing the question, we shape what kind of answer we get.

It follows, reasoned Wheeler, that if a phenomenon doesn't exist until we measure it, then what appears to us must be not just its present, but its past as well. He suggested that our whole universe – near and far, past and predicted future – is continually brought into being now, moment by moment, through the answers to questions we ask. If we asked different questions, or asked them in a different order, we would get a different result. Wheeler epitomised this concept as "it from bit": the particles we perceive derive from "information" that we help to create.

Wheeler's insights led to the highly successful field of quantum information, which now underpins technologies ranging from quantum computing to cryptography. But as it exploded, quantum physicist Christopher Fuchs at the University of Massachusetts Boston, previously a student of Wheeler's, felt frustrated by this new direction. His peers spoke about information like "a new fluid in the world", he

says. Fuchs felt this was missing Wheeler's key point: that there is no answer until we ask the question.

> *Nature is being hammered out as we speak*

Fuchs wanted to focus on the experimenter, so, from the 1990s, he pioneered his own interpretation of quantum physics, later dubbed QBism (pronounced cubism). What does it mean for reality to say that the outcome of a measurement is inseparable from the measuring itself? Fuchs and his colleagues have spent years reformulating the equations of quantum mechanics, rewriting them from a first-person point of view.

To do it, they used a Bayesian approach to probability. This is a method for making sense of the world from the inside: instead of making statements about "how things are", you continually update your predictions for future events according to what you have experienced in the past. "Probabilities are not things out in the world, but rather measures of what somebody knows," says Fuchs. Along with his fellow QBists, Fuchs found it is perfectly possible to express the relationships of quantum mechanics in this way. And when they did, something fascinating happened.

How a quantum innovation may quash the idea of the multiverse

At the core of quantum mechanics is an equation called the Born rule, formulated by physicist Max Born in 1926. It is usually interpreted as providing objective probabilities for different physical outcomes, depending on a particle's quantum state. You plug in everything you know about an entity, such as a photon, and the Born rule tells you how likely you are, when you measure it, to get a particular result. But in QBism, the rewritten rule isn't telling us about objects in the outside world. It becomes a method for connecting purely personal probabilities – beliefs – in different experiments.

In other words, argues Fuchs, the probabilities of quantum physics don't relate to anything external to us. Rather than a flashlight revealing what's beyond, quantum physics is more like a manual or "handbook", he says, that an individual can use to predict what outcome they are likely to experience if they take a particular action. Someone else, with another pattern of experiences and beliefs, could come to an entirely different conclusion.

QBism tells us that reality is more like a jazz improvisation than a static brick of space-time

zerocreatives/DEEPOL/plainpicture.com

It might sound extreme to suggest quantum physics is a guide to personal experience, not objective reality. But one big reason for taking QBism seriously is that recasting quantum states as states of belief essentially dissolves all the quantum weirdness. Why does a quantum state "collapse" when a physicist makes a measurement? In QBism, the physicist simply experiences an outcome, which causes her to immediately change her future beliefs.

Or take the knotty Wigner's friend paradox, suggested by physicist Eugene Wigner. In the usual way of describing this scenario, Wigner's friend measures a particle while Wigner

stands outside the lab, oblivious to the result. The two participants observe different – mutually exclusive – quantum states, implying physical reality is somehow two opposing things at the same time. But if quantum states are personal beliefs, the clash makes perfect sense. Similarly, with Wheeler's delayed-choice experiment, no strange back-in-time effects are needed because there's no particle "out there" to change. Every measurement – even if it relates to what we think of as the past – is an experience for a particular individual that becomes true for them at the time they get the result.

QBism has been remorselessly dismissed and criticised – accused of being meaningless or confused, or for claiming reality doesn't exist. But zoom out from particles for a second to think about what you actually experience, every day: planting a tree, casting a vote, picking up a book, checking on a friend. Is it so strange to say that our choices and actions can shape what happens? Or that what's true for each of us depends on the questions we ask?

A living community of nows

In fact, neuroscientists are reaching some similar conclusions regarding how we perceive our environment more generally. The conventional, bottom-up view of perception is that we experience what's out in the world. You see a mug on the desk in front of you because light travels

from the mug to your eyes. The signals are relayed to your brain and used to form an image of a mug. But growing evidence suggests we don't experience the outside world directly, but as a personal and continually updated model, or prediction.

This is an increasingly popular framework called predictive coding. Advocates argue that the brain takes a probabilistic – Bayesian – approach, updating what it believes about the world whenever new sensory information comes in. The things we perceive – mugs, cats, sofas – are the brain's "best guesses", says Anil Seth, a neuroscientist at the University of Sussex, UK, dependent on our personal history and beliefs. "We will never see things as they really, really are," he says. "It's hard to know what that would even mean." Remember the dress that broke the internet in 2015, which some people saw as blue and black, while others were convinced it was white and gold? It was a dramatic demonstration that when we each look at the world, we can see very different things. Well, if Fuchs is right, quantum physics is telling us something very similar. It isn't an objective window onto the universe beyond, but a souped-up approach to experience. Even a photon or atom is a personal prediction, inseparable from our point of view.

There is a key difference, though. Like most physicists, neuroscientists tend to assume that, although we are

experiencing different takes on the world, there is still some solid, true landscape lying beyond our perception. The probabilistic models of the world inside our heads – that is, our conscious experience – are a “controlled hallucination”, as Seth puts it. We are still essentially living in an illusion, unable to reach the real world.

QBism flips the refrain that our perceptions are hallucinations. What if physical reality is the hallucination?

Camerique/Getty Images

But if there were no solid landscape beyond, then it might change the meaning of predictive coding entirely. Fuchs's big innovation is to say there is no transcendent truth; nothing exists from a "God's eye" perspective, regardless of the individual ways we look. Rather than treating our personal worlds as hallucinations or models of the physical world, what if our experiences are components of a different kind of reality, with causative powers of their own? Whereas Wheeler saw a universe made of information, Fuchs talks in terms of actions and outcomes. "If you don't take the action, you have a different universe than if you do take an action," says Fuchs. "And if you do take an action, it depends on which kind of action you take."

This is the pluriverse, a dynamic tapestry of interacting perspectives that Fuchs describes as "a living community of nows". Rather than consisting of pre-existing, standalone things, this pluriverse is made up of patterns of experiences, continually brought into being through choices and actions. It includes all the features of our personal worlds that influence what we perceive and how we act: not just the atoms and fields of physics, but every illogical belief and unrepeatable experience, from clicking particle detectors and monsters under the bed to crunching autumn leaves.

What 350 different theories of consciousness reveal about reality

Bitbol says that QBism offers a fascinating "twist" on reality. Einstein's general theory of relativity describes reality as a four-dimensional block universe: a static brick of space-time within which any occurrence can be in the past or future relative to another, but there is no global unfolding or change. Instead of this monolithic block, the pluriverse is like a jazz improvisation, or wild forest, or jubilant crowd: an unruly, ever-evolving joint project with no master plan and the freedom to forge its own future. "It's continual creation," says Fuchs. "Nature is being hammered out as we speak."

This vision is part of a group of quantum interpretations in which what exists depends on our perspective. "QBism takes the most radical possible way of implementing that", with no logical reason why we should agree on anything, says Matthew Leifer, a physicist who specialises in quantum foundations at Chapman University in Irvine, California. Although Leifer sees QBism as unnecessarily extreme, he accepts that "it's a coherent and consistent place to be".

Intriguingly, QBism has a lot in common with a revolutionary philosophy of mind called enactivism, which argues that living things – whales, plants, bacteria, even humans – are deeply entwined with the worlds they perceive. For an enactivist, there are no pre-existing environments on one side, or standalone organisms on the other. Instead, both emerge through the dynamic process of perception itself.

Here, the internal models described by predictive processing are better thought of as recipes for taking action. All of this leads enactivists, too, towards the conclusion that our perceptions aren't representations or hallucinations, but inseparable from reality itself – as are the perceptions of all living things. Ezequiel Di Paolo, a cognitive scientist and enactivist philosopher at Ikerbasque, the Basque Foundation for Science in Bilbao, Spain, describes existence as "an ever-changing moment of creation", in which we are all carving out both ourselves and our worlds.

Whales and other living beings may take part in creating reality through their beliefs

Franco Banfi/naturepl.com

Both fields promise a living, open-ended cosmos, based on

novelty and freedom. As appealing as that might sound, if there is no solid landscape beyond, what connects all the perspectives? How is this different from saying that we are each living in our own bubble, with reality all in our minds?

In QBism, nothing is set in stone for you – not even what we think of as the past – until you pick an action. But there is one thing, one hard-and-fast rule, that applies to everyone. This is the QBists' reinterpretation of the Born rule, which defines how your flow of predictions must connect together overall. "Quantum probabilities aren't freewheeling," says Fuchs. "They're all tied together." If you nudge one belief, then you must adjust another somewhere else. The details are up for grabs, but there are limits constraining the underlying structure of what you can experience. The rule in some sense "exceeds us", adds Bitbol, even while we cannot extract ourselves from the picture.

For this reason, Fuchs strongly denies that QBism means reality is all in our minds. What exists in any moment encompasses the interlocking beliefs and perspectives, but also the statistical framework that ties them all together. This pluriverse is a very different kind of external reality as it is made up of other perspectives that we can only ever "bump into", says Fuchs. We can influence each other, or be surprised or thwarted by events, but we can never truly understand someone else's perspective, force them to see

things in a particular way or know for sure what they will do next.

Building shared realities

"People are literally experiencing different worlds," agrees Di Paolo. "But, of course, that doesn't mean we cannot share." We are all forging a path within an evolving "meshwork" of possibility. When we interact and communicate, we can bring our perspectives closer together. And through this process, we can build shared realities, whether they are cultural myths and stories or the rigorous universe of physics.

In this view, science becomes another kind of shared perspective. This conflicts with conventional notions of science, which have always strived for an objective God's-eye view of reality. "That has been the dream of science," says Di Paolo. But if you take away all perspective, "then you wouldn't be able to say anything meaningful". From scientific models of cells and molecules to supernovae and black holes, he argues, our understanding of the universe isn't a pre-existing, external landscape, but a particularly rigorous and far-reaching guide to experience. Perhaps it is physical reality that is the hallucination.

Fuchs and his colleagues are now collaborating with enactivists to see if they can inform each other further:

whereas the enactivists have thought more deeply about what perception means and how we interact, the QBists can offer a mathematical treatment of how those predictions and probabilities tie together. The aim, ultimately, is to develop a new world view for science that avoids the trap of dividing the world into mechanistic particles on one side versus pointless bubbles of consciousness on the other.

[No space, no time, no particles: A radical vision of quantum reality]

[If we admit that quantum numbers are the true essence of reality – not particles, space or time – then a surprising and beautiful new vision of reality opens up to us]

Somewhere in between those extremes sit the agents who take part in creating the pluriverse. That includes physicists carrying out quantum experiments, but more broadly, all humans are engaging in perception: predicting and acting, shaping our own worlds. That doesn't mean we are the only ones, of course. Enactivists extend this to all life forms – even a plant turning towards the sun or a bacterium swimming up a chemical gradient. But could other structures or processes be understood as having a perspective: choosing actions and responding to the results? Intriguingly, researchers are finding that even simple networks of biomolecules appear to display some degree of agency, aspiring towards their own goals. Fuchs, for one, says he hopes to flesh out his approach to cover not just conscious human measurements, but all kinds of agency, to understand better what it means for our experiences to form "part of the stuff of the world".

And this brings us back to the idea of now. The QBists and enactivists are reaching for a reality that wasn't created in one long-ago big bang and then left to run. It is continually coming into existence, as Wheeler once suggested, in "billions upon billions" of tiny creative flashes that are sounding out all around us. It is a vision in which we aren't simply observing reality; we are immersed within it. Through our choices and actions, moment by moment, we influence what exists – and what comes next.