IS THE UNIVERSE DETERMINISTIC?

VLATKO VEDRAL

However you look at it, the answer seems to be "maybe"

WHEN I was a child I liked to ponder deep questions before falling asleep. One of my favourites was "Do we have free will?". Shifting my mind back and forth between the possibilities served me well – it was a good technique for falling asleep. Now I am a grown man I am lucky enough to have a job that involves deliberating over questions like this. So what does a man of science have to say about free will?

Most of us in the west are certain that we have free will, though how we reach that conclusion, and even what we mean by it, is far from clear. If we define free will in everyday terms – as the capacity that allows us to control our actions – the answer would seem to come down to one of two possibilities: "Yes, we do have free will", or "No, we don't". Both, however, quickly lead us into contradictions.

Suppose you answer with "yes". How would you demonstrate the validity of this statement? You would need to act in a way that would not be predetermined by anything. But how can this ever be, when whatever you do can be traced back to some cause?

Say you decide to prove your free will by acting out of character: having an introverted personality, you decide to start a conversation with a complete stranger on the street, for instance. The very fact that you have decided to act contrary to your usual predisposition seems itself to be fully predetermined by the fact that you wanted to act out of character to prove your free will. The very act of trying to prove free will adds to the evidence that you have none.

It appears that since we can never demonstrate free will we are forced to conclude that we do not have it. But this does not necessarily follow either – and feels completely contrary to the whole of human psychology. We reward people for doing good deeds and punish them for bad ones. This would seem to be completely misconceived if humans did indeed not have any free will. How can you punish someone for doing something when they are not free to do otherwise? Is our whole moral and judicial system based on an illusion?

This just cannot be the case – or at least it is impossible to live with. Can nothing good that I do be attributed to me? Is it all predetermined by my genes or my history or my parents or social order or the rest of the universe? It seems that we have no choice but to believe in free will.

We have now come full circle, from free will to no free will and back to free will again. Different strands of religion, which have also argued for both "yes" and "no" answers, don't help much. Eastern religions have come up with the notion of karma, according to which all your actions will lead to consequences in the interconnected universe. This has a deterministic ring to it, but then according to a number of eastern religions you can change your karma by acting differently. So it is up to you to change things, and you have free will to do so. In the west, in the Catholic version of Christianity, everyone is similarly predetermined by original sin, but can also use free will to do good deeds and end up in heaven: born to lose, but live to win. Most religions are about morality, and it would seem that assuming humans have free will is an essential part of that.

Science, on the other hand, seems to have its roots firmly set in the deterministic traditions. The main question for a physicist is: if I do so and so to such and such a system, how will it behave as a result of my actions? Physics is all about studying causes and their effects, so the deterministic link between cause and effect would seem to be of paramount importance. But is it?

Physics studies properties and laws of interaction of matter and energy. The ancient Greeks, especially philosophers such as Democritus and Leucippus, came up with the notion that everything in the world can be explained as collisions of the indivisible constituents of matter called atoms. This is identical in spirit, if not in form, to classical Newtonian physics and seems to leave no room for free will.

Newton imagined the universe to be like a giant clockwork machine running according to his immutable laws of motion. Not only is there no place for free will in Newton's universe, but even God plays a passive and marginal role. He is responsible only for setting the initial conditions. From then on the universe evolves deterministically without his intervention. Even when Newtonian gravity failed and Einstein replaced it with general relativity, nothing changed as far as determinism was concerned. ▶

PAUL BLOW

MARTIN REES

I hope that in 50 years we will know the answer to this challenging question: are the laws of physics unique and was our big bang the only one? Theoretical horizons have recently expanded astonishingly. According to some speculations the number of distinct varieties of space – each the arena for a universe with its own laws – could exceed the total number of atoms in all the galaxies we see. Most space-times would be sterile or stillborn, but among this cornucopia there could still be immense numbers that allow big bangs that "fly" – allowing the emergence of the rich complexity that leads to atoms, stars, planets, biospheres and brains able to contemplate their origins. So do we live in the aftermath of one big bang among many, just as our solar system is merely one of many planetary systems in our galaxy?

Martin Rees is Astronomer Royal and professor of cosmology and astrophysics at the University of Cambridge

IGOR ALEKSANDER

Talk of a scientific understanding of consciousness still evokes more sucking in of air than most other subjects. Sceptics are fond of saying that a "factor X" that cannot even be imagined at the moment is required. I would argue the opposite: it is here, and it will be commonplace by 2056.

Factor X is a recognition that the brain, despite being the most complex machine on Earth, is nonetheless a machine, and an informational one at that. The notion that information has a physical basis, like the wind, is itself less than 50 years old. Those involved in the rapid development of computation now have the power to understand the brain-machine in a way that was not possible through classical sciences. They are beginning to formalise the many elements of what we call consciousness.

Igor Aleksander is emeritus professor of neural systems engineering at Imperial College London

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BERNARD WOOD

Nearly all we know about human evolution before 2 million years ago comes from the Great Rift Valley and a few caves in southern Africa. The first breakthrough will be the discovery of rocks in west, north and central Africa that are the right age – between 8 and 2 million years old – containing fossils of mammals, including our ancestors. The second breakthrough will be in the fine details of how evolution works. By 2056 we will not only know how we differ from chimpanzees, but also how we came to differ. Developmental biologists will be able to explain how the brains, heads, teeth and limbs of our extinct ancestors came to be the way they were.

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MICHAEL BENTON

Palaeontologists and taxonomists are thinking big. In 50 years we should have a good picture of the tree of life – including all living and extinct species. At the moment, we are tussling over the large-scale aspects of the tree: what are the closest relatives of dinosaurs, trilobites or ginkgos; where do slime moulds fit in the scheme of things? Once such questions have been answered then the finer twigs can be mapped.

At the same time as the tree is being built, the main branching points are being dated. This is controversial too, but our methods are improving and should be routine in 50 years.

Why bother? Well, until we have a near-complete tree of life, it is hard to understand large-scale patterns such as rates of evolution, mass extinctions and diversifications. It would be nice to know for sure whether the diversifications of flowering plants and of social insects are linked, whether the demise of the dinosaurs really opened the world to mammals, when and how life moved onto land, whether the Cambrian explosion was a real event, and when and how the major increases in biological complexity were achieved. We might even find out what lies at the very root of the tree.

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According to Einstein the universe actually exists all at once, and everything that has happened and will happen is already there in what we now call the "block universe". All the future instances of time are already laid out on a line in a four-dimensional block-like reality, as far as general relativity is concerned. Einstein is famously quoted as saying that any change with passage of time is merely "an illusion, albeit a persistent one". This is full determinism at its best.

Quantum physics, however, has changed this picture in the most dramatic way. In quantum physics the notion of chance enters at a fundamental level. When a quantum particle, such as a particle of light – a photon – encounters a piece of glass, such as your window, it seems to behave randomly. There is a chance that it will go through, but there is also a chance that it will be reflected. As far as we can tell there is nothing in the universe that determines which alternative will happen at any given time. The event of a photon being transmitted or reflected is, according to our best understanding of the laws of physics, a genuinely random event. The whole philosophy of one of the fathers of quantum theory, Niels Bohr, was founded on the assumption that the chance element is crucial to the nature of reality.

Einstein remained very much against this. Acknowledging randomness in quantum mechanics while having determinism in relativity would mean that these two pillars of physics can never be unified to describe the same reality. However, that's not the whole story. There is an interpretation of quantum mechanics according to which both determinism and randomness can be maintained in the quantum world. According to the "many worlds" interpretation of quantum mechanics, all the alternatives, such as the photon being transmitted or reflected, exist at the same time, in the same universe – but in different worlds. So in one world the photon goes through your window, while in another "parallel" world it is reflected.

In this picture we believe both worlds to be "entangled" in their simultaneous existence within an overarching universe. And you, the observer of the photon, are also entangled within these worlds: there is a copy of you in one world who observes the photon going straight through the window, and another copy of you in another world observing the reflection of the photon from the surface of the window. Both versions of you, according to this interpretation, exist simultaneously in the same universe.

This is, of course, fully deterministic: everything that can happen does in fact happen. What you cannot decide, however –

PAUL BIOW

and here is where the element of chance is fundamental – is which particular world you yourself will occupy: which "you" is you, and which "you" is a copy. This kind of logic has led some people to conclude that consciousness may be fundamental for quantum mechanics, though it is not a conclusion I agree with.

ACCORDING TO EINSTEIN, THE UNIVERSE EXISTS ALL AT ONCE, AND EVERYTHING THAT HAS HAPPENED AND WILL HAPPEN IS ALREADY THERE

In the end, however, it is clear that neither determinism nor randomness is good for free will. If nature is fundamentally random, then outcomes of our actions are also completely beyond our control: randomness is just as bad as determinism.

To have the kind of free will we would like involves walking a fine line between determinism and randomness. We must be able to freely make our actions, but they should then result in deterministic (that is, non-random) effects. For example, we may want to be free to send our kids to a school of our choice. But then we also want to believe that the laws of physics (and biology, sociology and so on) ensure that going to a good school is highly likely to lead to a better life. Having free will is pointless without a certain degree of determinism.

The same can be said about studying physics. I want to believe that the choice regarding which aspect of nature I want to study – whether I want to measure the position or velocity of a particle, for example – lies with me. But what I also want is some degree of deterministic behaviour in nature that would then permit me to infer laws of physics from any measurement that I choose to make. In fact, the only means we have for deducing the basic equations of quantum mechanics means that they are fully deterministic, just like those of Newtonian mechanics.

DETERMINISM AND RANDOMNESS ARE EQUALLY BAD FOR FREE WILL. TO HAVE THE KIND OF FREE WILL WE WANT INVOLVES WALKING A FINE LINE BETWEEN THE TWO

There is nothing mysterious or controversial about this, but look what happens when we apply this to ourselves. If we are all made up of atoms, and if atoms behave deterministically, then we too must be fully determined. We simply must share the same fate as the rest of the universe. When we look inside our brains, all we find are interconnected neurons, whose behaviour in turn is governed by their underlying molecular structure, which in turn is fully governed by the strict laws of quantum mechanics. Taking the argument to extremes, the laws of quantum mechanics ultimately determine how I deduce the laws of quantum mechanics, which appears to be a fully circular argument and therefore logically difficult to sustain.

"What proof is there that brutes are other than a superior race of marionettes," the biologist Thomas Henry Huxley asked more than a century ago, "which eat without pleasure, cry without pain, desire nothing, know nothing, and only simulate intelligence?" There is no proof as far as physics is concerned. Physics is simply unable to resolve the question of free will, although, if anything, it probably leans towards determinism.

The most honest position for a scientist on the question of free will is definitely agnostic: I simply do not know. What I do know is that when I was asked to write about free will as a physicist I found the idea so exciting that I had no choice but to agree to take it on. ●

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