

THE FREE WILL THEOREM

Mathematicians at Princeton say they've come up with an unassailable theorem that proves elementary particles have 'free will.' Needless to say, 'it makes philosophers' hair stand on end.'

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TWO HIGH-POWERED PRINCETON MATHEMATICIANS spend their days kicking around ideas pretty much as they choose. For the past 10 years, they have been chipping away at one in particular -- the notion of free will.

They work whenever they please -- an hour in the morning until one runs off to his daily tennis game at noon, and then an hour after lunch, with discussions continuing during the age-old ritual of 3 o'clock tea in the common room of the university's mathematics department.

One afternoon about seven months ago, these mathematical free agents, John Conway and Simon Kochen, achieved some results worth crowing about.

They claim they have proved that if humans have free will, then elementary particles possess free will as well. And, they suggest, this probably explains why humans have free will in the first place.

"I think it is remarkable that we can prove anything at a mathematical level of precision and exactness about this nebulous concept of free will," Dr. Conway says. "But, you know, that's what we've done. Our proof is unassailable."

What makes it unassailable, in part, is that they have tackled this scientific quandary via the airtight method of a mathematical theorem.

According to Dr. Conway, "There is a great advantage of stating it as a theorem" -- a theorem being a truth successfully demonstrated through a logical chain of reasoning. "You can't disagree with the theorem. If you disagree with the theorem's conclusion, you have to disagree with one of its premises."

And the free will theorem, as they call it, depends primarily on three premises, or axioms, with which it's hard to disagree.

"The results of the first two axioms are predicted by quantum mechanics," Dr. Conway says. "And, you know, every prediction of quantum mechanics has proved to be true. So you are on a losing bet if you disbelieve them."

The third axiom is confirmed by Albert Einstein's special relativity theory, which has also proved to be remarkably accurate.

But before the mention of quantum mechanics causes your brain to depower, take heart in the fact that neither Dr. Conway nor Dr. Kochen understands it either.

("If you meet someone who tells you they understand quantum mechanics, then you've met a good liar," Dr. Conway says.)

In fact, this is part of what makes their free will theorem unique: It does not require the reader to really understand any theory. "It makes a simple assertion directly about the world," Dr. Conway says.

(Dr. Conway and Dr. Kochen point out that what they have done is not completely new -- their theorem refines work done by Dr. Kochen and Ernest Specker in 1965, and follows in a line started by Albert Einstein, Boris Podolsky and Nathan Rosen in 1935, which was explored simultaneously in 1965 by John Bell.)

Quantum mechanics, to attempt to define it, is a mathematical machine, a tool, which provides predictions on the behaviour of subatomic particles, predictions that are in the form of reliable statistics or probabilities.

Where it falls short, however, is telling us anything more precise.

Take, for instance, a lump of radium. Quantum mechanics can tell you its half-life, the period of time in which half of it will decay. It cannot tell you when any individual atom will decay.

"It looks like the decay is happening for no reason," says Princeton philosopher John Burgess, who attended the first public presentation of the free will theorem last November at the university.

"Essentially everything quantum mechanics says is like that. . . . A lot of people were unhappy with the thought that the world could be so random. They hoped that there was something hidden away inside that was actually making it happen, but we just couldn't see it -- like every individual atom had a little alarm clock and when the alarm went off, that's when it decayed."

The notion of a hidden alarm clock is properly called hidden variable theory. It proposes, like Isaac Newton's classical mechanics, that if we only knew every possible force affecting the world and all its particles, then we would be able to predict their predetermined paths.

If we knew how these supposed hidden variables controlled physics, it would describe a universe governed by laws of cause and effect, rather than by chance.

The theorem of Dr. Conway and Dr. Kochen is the latest in a long line of arguments against hidden variable theory. It implies that physics cannot be explained by adding hidden variables.

"Almost all physicists already disbelieve in the existence of hidden variables," Dr. Conway says. "This is because they believe quantum mechanics is a complete theory, the most thoroughly tested of all physical theories, and because all attempts to go beyond quantum mechanics have failed."

In order to prove their theorem, the mathematicians employed three axioms about the physical world: the spin axiom, the twin axiom and the fin axiom.

They also made the crucial assumption that the scientist doing the experiment has free will. (Only a little free will is needed, enough to make basic decisions about the experiment.)

In the experiment, the scientist sends a "spin 1 particle" through an "electrical Stern-Gerlach apparatus" that can be oriented in 33 specified directions. The experimenter needs free will merely to choose three of these 33 directions to investigate. The particle responds with a 0 or 1 to each direction.

"We can prove that the particle's answer is not determined ahead of time," Dr. Conway says. "So each is a free-will decision -- if the experimenter has free will, so do the particles."

The proof is where the spin, twin and fin axioms come in.

The spin axiom states that if these three directions are perpendicular, then the particle's responses must be 011, 101 or 110 -- that is, the answer always consists of two 1's and one 0.

"But the question is, and this is the thing that in the end turns out to be a free-will decision, which is the zero?" Dr. Conway says.

Dr. Kochen and Dr. Specker determined that it is impossible for the particle to have decided ahead of time a fixed answer for each particular direction.

"To use the word 'decided' is an anthropomorphic way of saying things, which shouldn't be taken to mean that the particle consciously decides what to do," Dr.

Conway says, "just that whatever the particle does do is not determined ahead of time."

Dr. Conway and Dr. Kochen prove this with their characteristic mathematical sleight of hand.

"Think of a ball of wool with 33 knitting needles running through it in certain cleverly chosen directions," Dr. Conway says.

"And you're trying to make some of the needles black and some of them white in such a way that whenever three of them are perpendicular, there are two black [corresponding to the 1's] and one white [corresponding to the 0]. The reason the particle's response cannot depend only on the direction is that this purely geometric puzzle turns out to have no solution. You simply can't do it."

It might seem possible, then, that the particle's answers are influenced, if not only by direction, then by the combination of three directions queried.

"Why can't the particle decide its answers according to previous questions?" Conway asks.

Here, the twin axiom applies. "The twin axiom is rather clever," he says. The twin axiom asserts that you can produce two twinned particles and separate them as far as you like -- say one particle on Earth and another on Mars. It then asserts that if you ask them about the same three directions -- but in any order -- you'll get the same three answers.

To prove that the previous answers can't influence the next, we must preclude the possibility that those twinned particles are somehow communicating their answers to one another.

That's where the fin axiom comes in. "It basically says you can't transmit information faster than the speed of light," Dr. Conway says. "We call it fin, because there is some finite bound."

The impact of the fin axiom is that it prevents the twinned particles from conspiring, communicating their response to one another, because they do not have enough time, and the experimenter's spontaneous free-will choice means that he can make up his mind about which three directions to measure only at the last moment.

So the twin and fin and spin axioms have been used by Dr. Conway and Dr. Kochen to "prune down" these possible influences on the particle, and they use

similar arguments to eliminate other potential influences.

And, with that, the free will theorem is a fait accompli.

The only outstanding uncertainty, perhaps, is proving that free will exists in the first place. "It is impossible to prove that we have free will," Dr. Conway says. "But everybody tends to believe it.

"It is a consistent point of view to assume that the whole world is determined," he says. "We might be in a movie of what happened before, and in the movie everything has already been determined. That possibility can always exist. Like solipsism, it is perhaps a ridiculous position, but it is one that can never be disproved."

When Dr. Conway first presented their "unassailable theorem" to a group of philosophers and mathematicians at Princeton, it was met with mixed reviews.

Philip Anderson, a 1977 Nobel laureate in physics, told The Daily Princetonian: "[The theorem] may cause me to rethink some things that I've basically known all along."

However, Dr. Burgess, who has an interdisciplinary PhD. in math and philosophy, wasn't so enthusiastic. "The way he [Dr. Conway] was talking about free will makes philosophers' hair stand on end."

Hans Halvorson, a Princeton philosopher who specializes in quantum theory, said: "In fact, what it seems is that [they] proved indeterminism -- that the future is not fixed by the past. There are good arguments that free will and indeterminism don't have a lot to do with one another. There are old arguments going back to Immanuel Kant that you can have free will in a completely deterministic world. It's called compatibilism."

"I expected this," Dr. Conway says. "I deliberately and tendentiously and provocatively used the term free will for the particles, for the very good reason that the theorem itself shows it to be the same property that has always been called 'free will' for people.

"I think that's a good thing to do, to tell people they are the same. People don't like the idea, and they never have, of equating a human property with a non-human one. However, I think it would be silly to have our theorem say that 'if people have free will, then particles have indeterminacy.' "

"There is no essential difference," Dr. Kochen says. "We're not talking about free

will as a moral decision, about good and evil, or whether or not you should divorce your wife. If the experimenter's choice is to be called free will, I don't see why one may not use 'free will' for the same property of the particle."

"The world is a wonderful, willful place," Dr. Conway says, getting a bit philosophical himself. "Where does free will come from? Well, we're made of particles. So probably, somehow, our own free will is derived from that of the particles we're made of. . . ."

"The theorem renders it extremely plausible that somewhere in our brains there is a way of distilling the willfulness of the universe. We obtain our free will, I believe, from the willfulness we have proved is all over the world."

Siobhan Roberts is a Toronto writer whose biography of geometer Donald Coxeter will be published next year by Penguin.