THE DISCOVER INTERVIEW

ROGER PENROSE

One of the greatest thinkers in physics seeks the core of consciousness and rails against the fundamental failings of quantum theory.

BY **SUSAN KRUGLINSKI** PHOTOGRAPHY BY **OLIVER CHANARIN**

Roger Penrose could easily be excused for having a big ego. A theorist whose name will be forever linked with such giants as Hawking and Einstein, Penrose has made fundamental contributions to physics, mathematics, and geometry. He reinterpreted general relativity to prove that black holes can form from dying stars. He invented twistor theory—a novel way to look at the structure of space-time—and so led us to a deeper understanding of the nature of gravity. He discovered a remarkable family of geometric forms that came to be known as Penrose tiles. He even moonlighted as a brain researcher, coming up with a provocative theory that consciousness arises from quantum-mechanical processes. And he wrote a series of incredibly readable, best-selling science books to boot.

And yet the 78-year-old Penrose—now an emeritus professor at the Mathematical Institute, University of Oxford—seems to live the humble life of a researcher just getting started in his career. His small office is cramped with the belongings of the six other professors with whom he shares it, and at the end of the day you might find him rushing off to pick up his 9-year-old son from school. With the curiosity of a man still trying to make a name for himself, he cranks away on fundamental, wide-ranging questions: How did the universe begin? Are there higher dimensions of space and time? Does the current front-running theory in theoretical physics, string theory, actually make sense?

Because he has lived a lifetime of complicated calculations, though, Penrose has quite a bit more perspective than the average starting scientist. To get to the bottom of it all, he insists, physicists must force themselves to grapple with the greatest riddle of them all: the relationship between the rules that govern fundamental particles and the rules that govern the big things—like us—that those particles make up. In his powwow with DISCOVER contributing editor Susan Kruglinksi, Penrose did not flinch from questioning the central tenets of modern physics, including string theory and quantum mechanics. Physicists will never come to grips with the grand theories of the universe, Penrose holds, until they see past the blinding distractions of today's half-baked theories to the deepest layer of the reality in which we live.

You come from a colorful family of overachievers, don't you?
My older brother is a distinguished theoretical physicist, a fellow of the Royal Society. My younger brother ended up the British chess champion 10 times, a record. My father came from a Quaker family. His father was a professional artist who did portraits—very traditional, a lot of religious subjects. The family was very strict. I don't think we were even allowed to read novels, certainly not on Sundays. My father was one of four brothers, all of whom were very good artists. One of them became well known in the art world, Sir Roland. He was cofounder of the Institute of Contemporary Arts in London. My father himself was a human geneticist who was recognized for demonstrating that older mothers tend to get more Down syndrome children, but he had lots of scientific interests.

How did your father influence your thinking?
The important thing about my father was that there wasn't any boundary between his work and what he did for fun. That rubbed off on me. He would make puzzles and toys for his children and grandchildren. He used to have a little shed out back where he cut things from wood with his little pedal saw. I remember he once made a slide rule with about 12 different slides, with various characters that we could combine in complicated ways. Later in his life he spent a lot of time making wooden models that reproduced themselves—what people now refer to as artificial life. These were simple devices that, when linked together, would cause other bits to link together in the same way. He sat in his woodshed and cut these things out of wood in great, huge numbers.

So I assume your father helped spark your discovery of Penrose tiles, repeating shapes that fit together to form a solid surface with pentagonal symmetry.
It was silly in a way. I remember asking him—I was around 9 years old—about whether you could fit regular hexagons together and make it round like a sphere. And he said, "No, no, you can't do that, but you can do it with pentagons," which was a surprise to me. He showed me how to make polyhedra, and so I got started on that.

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Are Penrose tiles useful or just beautiful?
My interest in the tiles has to do with the idea of a universe controlled by very simple forces, even though we see complications all over the place. The tilings follow conventional rules to make complicated patterns. It was an attempt to see how the complicated could be satisfied by very simple rules that reflect what we see in the world.

The artist M. C. Escher was influenced by your geometric inventions. What was the story there?
In my second year as a graduate student at Cambridge, I attended the International Congress of Mathematicians in Amsterdam. I remember seeing one of the lecturers there I knew quite well, and he had this catalog. On the front of it was the Escher picture *Day and Night,* the one with birds going in opposite directions. The scenery is nighttime on one side and daytime on the other. I remember being intrigued by this, and I asked him where he got it. He said, "Oh, well, there's an exhibition you might be interested in of some artist called Escher." So I went and was very taken by these very weird and wonderful things that I'd never seen anything like. I decided to try and draw some impossible scenes myself and came up with this thing that's referred to as a tri-bar. It's a triangle that looks like a three-dimensional object, but actually it's impossible for it to be three-dimensional. I showed it to my father and he worked out some impossible buildings and things. Then we published an article in the *British Journal of Psychology* on this stuff and acknowledged Escher.

Escher saw the article and was inspired by it?
He used two things from the article. One was the tri-bar, used in his lithograph called *Waterfall.* Another was the impossible staircase, which my father had worked on and designed. Escher used it in *Ascending and Descending,* with monks going round and round the stairs. I met Escher once, and I gave him some tiles that will make a repeating pattern, but not until you've got 12 of them fitted together. He did this, and then he wrote to me and asked me how it was done—what was it based on? So I showed him a kind of bird shape that did this, and he incorporated it into what I believe is the last picture he ever produced, called *Ghosts.*

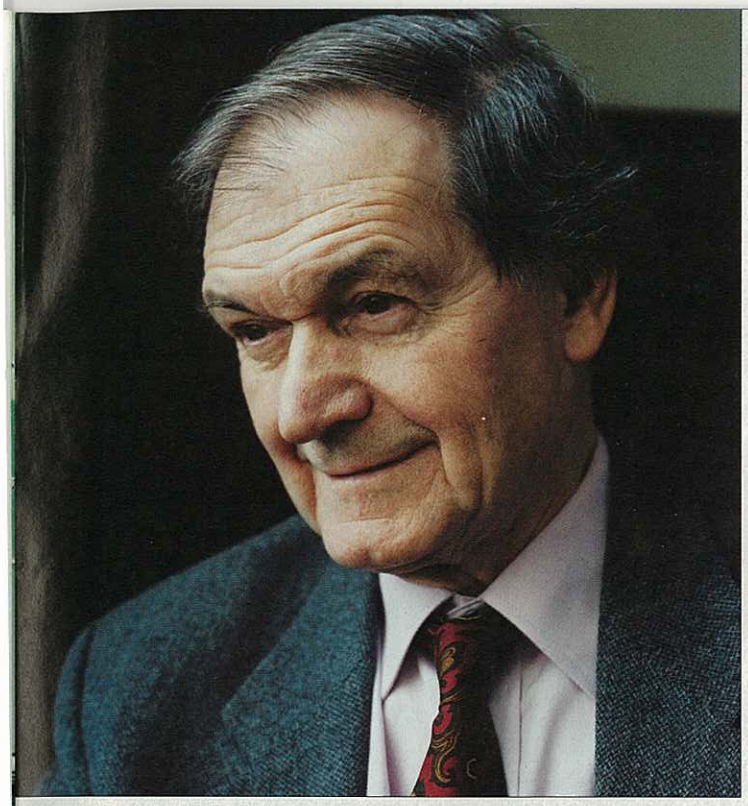
Is it true that you were bad at math as a kid?
I was unbelievably slow. I lived in Canada for a while, for about six years, during the war. When I was 8, sitting in class, we had to do this mental arithmetic very fast, or what seemed to me very fast. I always got lost. And the teacher, who didn't like me very much, moved me down a class. There was one rather insightful teacher who decided, after I'd done so badly on these tests, that he would have timeless tests. You could just take as long as you'd like. We all had the same test. I was allowed to take the entire next period to continue, which was a play period. Everyone was always out and enjoying themselves, and I was struggling away to do these tests. And even then sometimes it would stretch into the period beyond that. So I was at least twice as slow as anybody else. Eventually I would do very well. You see, if I could do it that way, I would get very high marks.

You have called the real-world implications of quantum physics nonsensical. What is your objection?
Quantum mechanics is an incredible theory that explains all sorts of things that couldn't be explained before, starting with the stability of atoms. But when you accept the weirdness of quantum mechanics [in the macro world], you have to give up the idea of space-time as we know it from Einstein. The greatest weirdness here is that it doesn't make sense. If you follow the rules, you come up with something that just isn't right.

In quantum mechanics an object can exist in many states at once, which sounds crazy. The quantum description of the world seems completely contrary to the world as we experience it.
It doesn't make any sense, and there is a simple reason. You see, the mathematics of quantum mechanics has two parts to it. One is the evolution of a quantum system, which is described extremely precisely and accurately by the Schrödinger equation. That equation tells you this: If you know what the state of the system is now, you can calculate what it will be doing 10 minutes from now. However, there is the second part of quantum mechanics—the thing that happens when you want to make a measurement. Instead of getting a single answer, you use the equation to work out the probabilities of certain outcomes. The results don't say, "This is what the world is doing." Instead, they just describe the probability of its doing any one thing. The equation should describe the world in a completely deterministic way, but it doesn't.

Erwin Schrödinger, who created that equation, was considered a genius. Surely he appreciated that conflict.
Schrödinger was as aware of this as anybody. He talks about his hypothetical cat and says, more or less, "Okay, if you believe what my equation says, you must believe that this cat is dead and alive at the same time." He says, "That's obviously nonsense, because it's not like that. Therefore, my equation can't be right for a cat. So there must be some other factor involved." [Schrödinger invented a famous thought experiment in which a cat is placed inside a box that contains a vial of poison; the poison is released only if a single radioactive atom decays. Since the decay of that atom is a quantum that cannot be known until it is observed, quantum theory says that the cat is both alive and dead until the box is opened so that an observer can peer inside.]

So Schrödinger himself never believed that the cat analogy reflected the nature of reality?
Oh yes, I think he was pointing this out. I mean, look at three of the biggest figures in quantum mechanics, Schrödinger, Einstein, and Paul Dirac. They were all quantum skeptics in a sense. Dirac is the one whom people find most surprising, because he set up the whole foundation, the general framework of quantum mechanics. People think of him as this hard-liner, but he was very cautious in what he said. When he was asked, "What's the answer to the measurement problem?" his response was, "Quantum mechanics



is a provisional theory. Why should I look for an answer in quantum mechanics?" He didn't believe that it was true. But he didn't say this out loud much.

Yet the analogy of Schrödinger's cat is always presented as a strange reality that we have to accept. Doesn't the concept drive many of today's ideas about theoretical physics?
That's right. People don't want to change the Schrödinger equation, leading them to what's called the "many worlds" interpretation of quantum mechanics.

That interpretation says that all probabilities are playing out somewhere in parallel universes?
It says OK, the cat is somehow alive and dead at the same time. To look at that cat, you must become a superposition [two states existing at the same time] of you seeing the live cat and you seeing the dead cat. Of course, we don't seem to experience that, so the physicists have to say, well, somehow your consciousness takes one route or the other route without your knowing it. You're led to a completely crazy point of view. You're led into this "many worlds" stuff, which has no relationship to what we actually perceive.

The idea of parallel universes—many worlds—is a very human-centered idea, as if everything has to be understood from the perspective of what we can detect with our five senses.
The trouble is, what can you do with it? Nothing. You want a physical theory that describes the world that we see around us. That's what physics has always been: Explain what the world that we see does, and why or how it does it. Many worlds quantum mechanics doesn't do that. Either you accept it and try to make sense of it, which is what a lot of people do, or, like me, you say no—that's beyond the limits of what quantum mechanics can tell us. Which is, surprisingly, a very uncommon position to take. My own view is that quantum mechanics is not exactly right, and I think there's a lot of evidence for that. It's just not direct experimental evidence within the scope of current experiments.

In general, the ideas in theoretical physics seem increasingly fantastical. Take string theory. All that talk about 11 dimensions or our universe's existing on a giant membrane seems surreal.
You're absolutely right. And in a certain sense, I blame quantum mechanics, because people say, "Well, quantum mechanics is so nonintuitive; if you believe that, you can believe anything that's nonintuitive." But, you see, quantum mechanics has a lot of experimental support, so you've got to go along with a lot of it. Whereas string theory has no experimental support.

I understand you are setting out this critique of quantum mechanics in your new book.
The book is called *Fashion, Faith and Fantasy in the New Physics of the Universe.* Each of those words stands for a major theoretical physics idea. The fashion is string theory; the fantasy has to do with various cosmological schemes, mainly inflationary cosmology [which suggests that the universe inflated exponentially within a small fraction of a second after the Big Bang]. Big fish, those things are. It's almost sacrilegious to attack them. And the other one, even more sacrilegious, is quantum mechanics at all levels—so that's the faith. People somehow got the view that you really can't question it.

A few years ago you suggested that gravity is what separates the classical world from the quantum one. Are there enough people out there putting quantum mechanics to this kind of test?
No, although it's sort of encouraging that there are people working on it at all. It used to be thought of as a sort of crackpot, fringe activity that people could do when they were old and retired. Well, I *am* old and retired! But it's not regarded as a central, as a mainstream activity, which is a shame.

After Newton, and again after Einstein, the way people thought about the world shifted. When the puzzle of quantum mechanics is solved, will there be another revolution in thinking?
It's hard to make predictions. Ernst Rutherford said his model of the atom [which led to nuclear physics and the atomic bomb] would never be of any use. But yes, I would be pretty sure that it will have a huge influence. There are things like how quantum mechanics could be used in biology. It will eventually make a huge difference, probably in all sorts of unimaginable ways.

In your book *The Emperor's New Mind,* you posited that consciousness emerges from quantum physical actions within the cells of the brain. Two decades later, do you stand by that?
In my view the conscious brain does not act according to classical physics. It doesn't even act according to conventional quantum mechanics. It acts according to a theory we don't yet have. This is being a bit big-headed, but I think it's a little bit like William Harvey's discovery of the circulation of blood. He worked out that it had to circulate, but the veins and arteries just peter out, so how could the blood get through from one to the other? And he said, "Well, it must be tiny little tubes there, and we can't see them, but they must be there." Nobody believed it for some time. So I'm still hoping to find something like that—some structure that preserves coherence, because I believe it ought to be there.

When physicists finally understand the core of quantum physics, what do you think the theory will look like?
I think it will be beautiful.