

Interview for Insight, an Australian magazine sponsored by the Center for Human Development

Question 1. You are an anesthesiologist at the University Medical Center, Professor in the Departments of Anesthesiology and Psychology, and Director of the Center for Consciousness Studies at the University of Arizona in Tucson. How did you become interested in quantum consciousness?

It's a bit of a roundabout story.

I first became interested in the problem of consciousness as an undergraduate, studying chemistry and physics. Later, while in medical school I worked in a lab studying cancer cells and became fascinated by the mechanism of cell division or mitosis, in which chromosomes are precisely separated into equal pairs. The elegant spatiotemporal dance of the chromosomes is orchestrated by wispy filaments called microtubules. It seemed to me there was some kind of intelligence, possibly consciousness guiding these precise activities. It turned out that these microtubules are responsible for movement, growth and function inside all our cells, including formation and maintenance of synapses in our nerve cells.

Microtubules are the main component of the cell cytoskeleton, providing bone-like support. But I began to think they were also the nervous system within the cell. The structure of microtubules, like a hollow ear of corn, was similar to computer switching circuits, in which individual kernels - proteins called tubulins - could play the role of bit states.

So for 20 years I worked on models and simulations of microtubule information processing inside the brain's neurons.

Most views maintain that consciousness is an emergent property of computation *among* the brain's neurons connected by synapses, that neurons and synapses function like relatively simple bits, or on-off switches. I thought that neurons were far more complex, that computation extended *inside* cells to the level of microtubules.

Think about single cell organisms like *paramecium*. They are able to swim around, find food and mates, learn and have sex. They have no synaptic connections - they are single cells and use their microtubules as sensors, propellers and information processing devices. So if single cell organisms can use their microtubules to be so clever, neurons should be able to use their microtubules to be far more than simple on-off switches.

Molecular-level computation in microtubules would increase the potential information capacity in the brain tremendously. Artificial intelligence people trying to emulate the brain didn't like that idea because increasing the computational capacity of the brain pushes the goal of brain equivalence in computers a half-century or so into the future.

But then someone said "OK, say you are correct, and information processing relevant to consciousness does extend downward to the level of microtubules inside cells. How would that explain consciousness? How would that account for feelings, emotions, the smell of a rose, the pain of a toothache?"

I had to admit they were right. There was a huge difference between consciousness and computation. That's when I read a book by Roger Penrose called *'The emperor's new mind'* which introduced the concept of consciousness based on quantum effects.

Question 2. Can you define what you mean by Quantum Consciousness?

Well first one must attempt to define quantum. Literally, quantum means the smallest unit of anything, but quantum theory is far more encompassing.

Basically the world seems to be described by two distinct sets of laws. In our everyday world - called the classical world - Newton's laws of motion, Maxwell's equations of electromagnetism and a few others pretty much explain everything. But at small scales - and the boundary between large and small is part of the problem - strange quantum laws reign.

In the quantum world, particles can be in two or more states or locations simultaneously, literally "beside themselves," or smeared out like waves. This is called quantum superposition of multiple possibilities.

Also, particles which become separated can remain somehow interconnected, so that perturbation of one affects the other instantaneously, even over great distances. This is called quantum entanglement.

And multiple particles can condense into one unified entity. This is called quantum coherence.

Entanglement and coherence are bizarre, but as far as weirdness goes, superposition takes the cake. How can something be in different places at the same time? And why don't we see superpositions in the classical world? Everything we observe is in a single, definite place.

Early experiments seemed to show that conscious observation caused superpositions to collapse to definite states, that consciousness "collapsed the wave function". Maybe you've heard the story of Schrodinger's cat in superposition of being both dead and alive until observed by a conscious human. So one interpretation is that the conscious observer causes superpositions to reduce or collapse to classical states. But this places consciousness outside physics.

Another view is that each superposition branches off to form another universe, resulting in an infinite number of universes. This is the multiple worlds view. There are also the view of David Bohm, and the idea of decoherence - that interaction with the classical environment erodes the quantum superposition. But none of these are satisfactory for various reasons.

Nonetheless the bizarre features are used in quantum information technology. For example in quantum computers, information can be represented not only as bits of 1 or 0, but also as quantum superpositions of both 1 AND 0. These are called quantum bits or qubits. The qubits communicate by entanglement and perform incredibly efficient computation. Eventually the qubits collapse, or reduce to classical bits as the solution. So multiple possibilities collapse, or reduce to definite states.

But the mysteries persist. Why do quantum states collapse or reduce to classical states. Why don't we see quantum superpositions in our classical world?

In *The emperor's new mind* Roger Penrose put forth another idea. He started out by considering how particles can actually be in superposition, and suggested that the universe itself separated at its most basic level. The basic level is called fundamental spacetime geometry, and it exists at the incredibly tiny Planck scale, 25 orders of magnitude smaller than atoms. This basic level is theoretically described through quantum gravity, or string theory, but we don't really understand it except to know that it exists.

So Roger was saying that superpositions were separations at this basic level, like in the multiple worlds view. But instead of branching off to form a new universe – as multiple worlds proponents believe - Roger said the superposition/separations, or bubbles in the fine structure of reality were unstable and would spontaneously reduce at a specific time to definite states. This reduction was due to an objective factor intrinsic to spacetime geometry. So his theory is called objective reduction.

But the most amazing feature of Roger's suggestions was that fundamental spacetime geometry contains Platonic values like mathematical truth, ethical and aesthetic values, and the rudiments of consciousness. The Greek philosopher Plato had described an abstract world of absolute truth and pure form, but Penrose was saying it physically existed in the fine structure of the universe. The raw components of goodness, beauty and feelings are irreducible components of reality, embedded as patterns or configurations of fundamental spacetime geometry! Moreover, when objective reductions occur, these Platonic values influence the choice of particular classical states.

The final point was that objective reduction IS consciousness, that quantum computation mediated by objective reduction occurs in the brain. Pre-conscious, or sub-conscious processes are quantum superpositions whose reduction due to spacetime geometry IS consciousness. When you look at dreams and various subconscious or altered states, they resemble quantum information – multiple coexisting possibilities, deep interconnected meaning, and timelessness: the quantum subconscious.

That's a lot of ideas in a few sentences, and I recommend Roger's books. But he was basically suggesting that consciousness is a form of quantum computation, that multiple pre-conscious or dream-like subconscious quantum superpositions collapse/reduce at each instant of consciousness, that particular conscious perceptions and choices are influenced by Platonic values embedded deep in the universe. In other words, consciousness involves brain processes

connected to the most basic level of reality. Consciousness is a process on the edge between the quantum and classical worlds.

Question 3. Who are some of the people who influenced your study of consciousness?

Well obviously Roger Penrose is one. When I read “*Emperor*” it seemed Roger might have the mechanism for consciousness but he didn’t have the structure. He suggested that maybe neurons existed in superpositions of both firing and not firing, that neurons were the qubits. I thought that microtubules might be his quantum computers, with tubulin proteins the qubits. He had the mechanism and I had the structure. So I contacted him and we developed a model of consciousness based on quantum computation in microtubules within the brain’s neurons. The quantum computations are orchestrated by feedback from synapses, so our model is called orchestrated objective reduction, or Orch OR. The conscious events occur roughly 40 times per second, consistent with known brain physiology.

I’ve also been influenced by Karl Pribram who suggested that consciousness may in some sense be holographic, Sir John Eccles who proposed a quantum mechanism in the brain, as well as colleagues with whom I worked on microtubule information processing like Steen Rasmussen, Jack Tuszynski, Scott Hagan, Nancy Woolf, quantum philosopher Paavo Pylkkanen, experimental physicist Dick Bierman and others. Also philosophers Alfred North Whitehead, who described pan-experientialism – the idea that protoconsciousness exists everywhere - and “occasions of experience”, and Abner Shimony who compared Whitehead’s occasions to quantum state reductions. Also two Australians - philosopher David Chalmers and physicist Paul Davies - have been important to my work. And I have been influenced by many whose ideas I think are completely wrong, those who believe that consciousness is computation and see no need for quantum effects, like Daniel Dennett, Patricia Churchland, Christof Koch, the late Francis Crick and others. It’s always fun to spar with materialists..

Question 4. Most recently, people may be familiar with your role in the movie "What the Bleep do We Know?" What was your experience of being involved with the film? Do you think it will open the door for more awareness of the science of quantum physics for the general public?

I think Bleep introduced the connection between quantum physics and consciousness but didn’t develop it very much. It planted the seed, whetted an appetite, and hinted at connections to spirituality. I don’t think the general public was quite ready for a thorough exposition of the topic. But as brain=mind=computer proponents continue to fail and flail, and quantum computers come on line, quantum consciousness will become more popular. The quantum ideas are testable, so eventually we will come close to an answer.

Being in the film has been fun, I must admit. It ran for 6 months here in Tucson and many people recognize me.

Question 5. You have hosted Quantum Mind conferences in Tucson, the latest in March 2003. What is the result of these conferences from the point of view of the presenters and the participants?

Our main interdisciplinary conferences “Toward a Science of Consciousness” have been organized by our Center for Consciousness Studies every other year since 1994, the next one being April 4-8, 2006. We have had two focused conferences on the quantum approach - Quantum Mind – in 1999 and 2003, and will have another in 2007. Relevant information is on our website consciousness.arizona.edu.

The results of the general conferences have been to bring together philosophers, neuroscientists, psychologists, physicists and experientialists – those who engage in first person explorations of consciousness by various means. The Quantum Mind conferences have served to sharpen the arguments, develop testable predictions for experiments and deal with issues like decoherence – how can delicate quantum effects occur at warm brain temperatures. More and more evidence suggests that the brain has evolved mechanisms to avoid decoherence.

Question 6. Since all cells have microtubules, are all cells conscious?

I hear this question a lot, like why isn't my toe conscious? Or why isn't some other anatomical feature conscious?

Applying Roger's formula to reach objective reduction, larger superpositions reach threshold faster; smaller superpositions require a long time. Meanwhile, decoherence – erosion of the quantum state by interaction with environment – must be avoided.

To reach threshold for consciousness in a brief enough time to be useful and relevant to brain processes, for example 1/40 of a second, requires superposition of microtubule in about 100,000 neurons. A single cell could have a conscious moment but it would have to maintain superposition and avoid decoherence for close to an hour, which is unlikely. And even then the intensity – which is proportional to the amount of superposition – would be very small. Any superposition can in principle have a conscious moment. For example, an electron which avoided decoherence and remained in superposition for ten million years would have a conscious moment, but it would be very dull. The brain is special.

But on the other hand, large scale superpositions can occur in cosmology, for example in the cores of neutron stars, or in the early universe. An Italian astrophysicist Paola Zizzi has calculated that during the inflationary period of the Big Bang the universe was in superposition of multiple possible universes, and that it reached threshold for objective reduction to end inflation. At that instant, according to Paola, the universe had a cosmic conscious moment, choosing the universe we have today. Moreover our consciousness is a literal microcosm of that universal conscious moment, what some people call the “Big Wow”.

Question 7. How does your work on the cellular level of quantum consciousness apply to the larger fields of study in medicine, technology, communications, spirituality; and our culture in general?

Well, in medicine the possible quantum mechanisms in microtubules may be relevant in several areas. I mentioned cell division, or mitosis and cancer. It appears that defects in the mitosis process itself, rather than genetic mutations, may be responsible for malignancy. That raises the question of how the precision required for mitosis is accomplished normally. In a recent paper in the journal *Biosystems*, I suggested that quantum coherence and entanglement via quantum photons between microtubules in mitosis may be necessary for normal mitosis. This suggests that certain forms of optical laser therapy may be useful in cancer and other diseases. Also, defective brain microtubules are the root of the problem in Alzheimer's disease.

If consciousness is a quantum process, the door is open for nonlocal effects between and among people via entanglement. This may occur at a subconscious level but have profound effects nonetheless. So called paranormal phenomena may be explained. Alex Wendt, a sociologist at Ohio State University is writing a book about the implications of quantum consciousness on culture, society and politics.

Regarding spirituality, the notion of an omnipresent entity of Platonic truth, ethics and aesthetics which interconnects every living being and can guide our actions and perceptions is as good an explanation as I've heard. We're talking about the universe itself at its most basic, fundamental level. Wherever you go, there it is. Critics will say that the energy is too weak to affect biological entities, but I think we can show how the connection occurs. Roger avoids discussions of spirituality, but I think his Platonic universe may be what we've been looking for.

Question 8. Is there a difference between "living" and "consciousness?"

People used to think that life involved a special force or field, presumably electromagnetic. But that idea, called "vitalism", was dispelled by reductionist science. Life became defined by its functional properties - reproduction, growth, evolution, metabolism, responsive behavior etc. But self-organizing computer programs and other systems fit those criteria which also fail to account for the unity of living systems. I think life involves states of quantum coherence and superposition. Paul Davies also thinks life involves quantum effects at scales above those normally occurring in non-living systems. Health is the optimal state of life – well tuned quantum coherence.

But to be conscious, such superpositions must persist to reach the Penrose threshold for objective reduction, and that requires a large superposition and isolation mechanisms to avoid decoherence. So yes, there is a difference.

Question 9. How does the function of the brain relate to consciousness?

I think the brain evolved to best access and communicate with proto-conscious, fundamental spacetime geometry which has existed at least since the Big Bang, or Big Wow.

Some Hindu and idealist philosophers would say that consciousness creates reality, that consciousness is “all there is”. The interpretation of quantum mechanics in which consciousness causes collapse of the wave function also suggests that consciousness creates reality by causing superpositions to reduce to particular classical reality. A theme in Whatthebleep was that we can shape our reality by, for example planning our day. So these are three views that consciousness creates reality in decreasing degrees of literal meaning.

Others would say that the brain is a kind of receiver for cosmic consciousness, while others believe the brain is more like a computer, simply recording reality and generating consciousness from computation.

I think there is some truth to all these ideas, but that consciousness is a process on the edge between the quantum and classical worlds. So the brain is like a bridge between the two worlds. The subconscious dream world is quantum, and the conversion process from quantum to classical is consciousness.

Question 10. How does the brain convert the stimuli it receives from the senses - sight, sound, smell, touch, taste, and feeling - to consciousness? Are these stimuli communicating the "real" world?

It depends what you mean by real. You could say the “real world” is the quantum world, and that our perceived classical world is an artifact. But whichever is real, consciousness exists on the boundary between the two. The Kabbalah describes two worlds – a world of chaos and strife, and a world of wisdom and enlightenment – and declares that consciousness “dances on the edge” between the two worlds. I think this is right. The Platonic quantum world is the world of wisdom and enlightenment.

But as for how we feel and perceive sensations, this is called the ‘hard problem’ in the philosophy of mind. How does the brain produce what philosophers call ‘qualia’, the raw components of conscious experience? Why do we have an “inner life”?

There are basically two approaches. The conventional view is that the brain is a computer, and conscious experience comprised of qualia emerges as a novel property from complex computation, like weather patterns emerge from complex interactions among dust and gas. The alternative is that the precursors of conscious experience, qualia, are fundamental, irreducible components of reality, built into the universe like mass, spin or charge. They just are. Our brains then access and select certain patterns of qualia from fundamental spacetime geometry, like an artist chooses dabs of paint from a canvas to create a masterpiece. Quantum computations in microtubules connect the brain to the ‘funda-mental’ level.

Question 11. What have you learned about consciousness from your work with patients under anesthesia? Have you seen any correlation with near death or out of body experiences?

The anesthetic gases – when given at just the right concentration - erase consciousness while sparing other brain activities which continue during anesthesia. It turns out that the anesthetic gases act in the brain only by very weak quantum forces, forming no chemical bonds. They get into tiny regions inside various proteins including microtubules and prevent normally occurring quantum effects responsible for consciousness. This suggests that consciousness is a quantum phenomenon.

As far as near death experiences in surgery – we try and avoid them. But a few years ago two studies appeared in leading medical journals which documented several hundred patients who suffered cardiac arrest and were revived. Of these, about 17 percent had near death experiences, including so-called out of body experiences. When they asked the researchers how they could explain them, they said something like “Ask Penrose and Hameroff”.

BBC TV did a documentary about this called *The day I died* and I gave the following possibility. Normal consciousness is occurring at the level of spacetime geometry within the brain. When the blood flow and metabolic energy driving the microtubule quantum coherence is interrupted, the quantum information related to consciousness “leaks out” to spacetime geometry everywhere, hanging together by entanglement. When the quantum coherence resumes, the quantum information comprising the person’s sub-conscious and consciousness – the soul, perhaps – returns. Of course if the person is not revived, if they die, then maybe the quantum information remains in spacetime geometry as a kind of hologram.

Question 12. What can we gain by learning about quantum mechanics in relation to the brain and consciousness? Specifically, are there any practical exercises we can do to become "more conscious"?

We can understand ourselves – what/who we really are, and how we fit in the universe which I think is proto-conscious at its most basic level . Maybe we can come to a partial scientific understanding of God. For me, to think that God might be the universe itself at its most fundamental level is more awe-inspiring than any other description I have heard. It is far from the final answer, but might be revealing the next layer of truth. And it is consistent with many spiritual traditions, Buddhism and Hinduism in particular.

As far as being more conscious, I think that the approaches people presently take like meditation do just that. And there are two ways to explain why that occurs. Clearing the mind of unnecessary information and meditating on pure feelings has been shown to increase the coherent frequency of brain activity. That gives more conscious event per time, and greater intensity per event. External time slows down and consciousness is more intense.

Meditation and other forms of altered states also shift us more into the normally subconscious realm of quantum information, which includes our own feelings as well as the Platonic world, or what Jung called the collective unconscious. If we have suppressed bad feelings, we tend to avoid going there. So it is important to “clean the basement”, to bring to the surface and deal with suppressed traumas and bad feelings. Then merging the conscious and normally

unconscious can be wonderful, putting us more directly in touch with the Platonic wisdom and enlightenment.

Question 13. Is there any other aspect that you would like to cover? We thank you for your time and response to these questions.

You're quite welcome.

The idea that consciousness is a sequence of discrete quantum events suggests that it is important to be "in the moment", to not obsess about past or present. Obviously one needs to plan, and learn from the past, but when it comes right down to it, "Now" is all there is. Enjoy and appreciate it.

To be influenced by Platonic wisdom requires a receptive mindfulness, a need to resist rash reflexive actions and follow intuitive instincts. This has also been described as "following the way of the Tao", "surrendering to one's higher power", "divine guidance", or "May the force be with you." It's reassuring that there might be a scientific explanation.

Finally, science and spirituality may be compatible. Those who deny this may have too-limited views of one or the other.