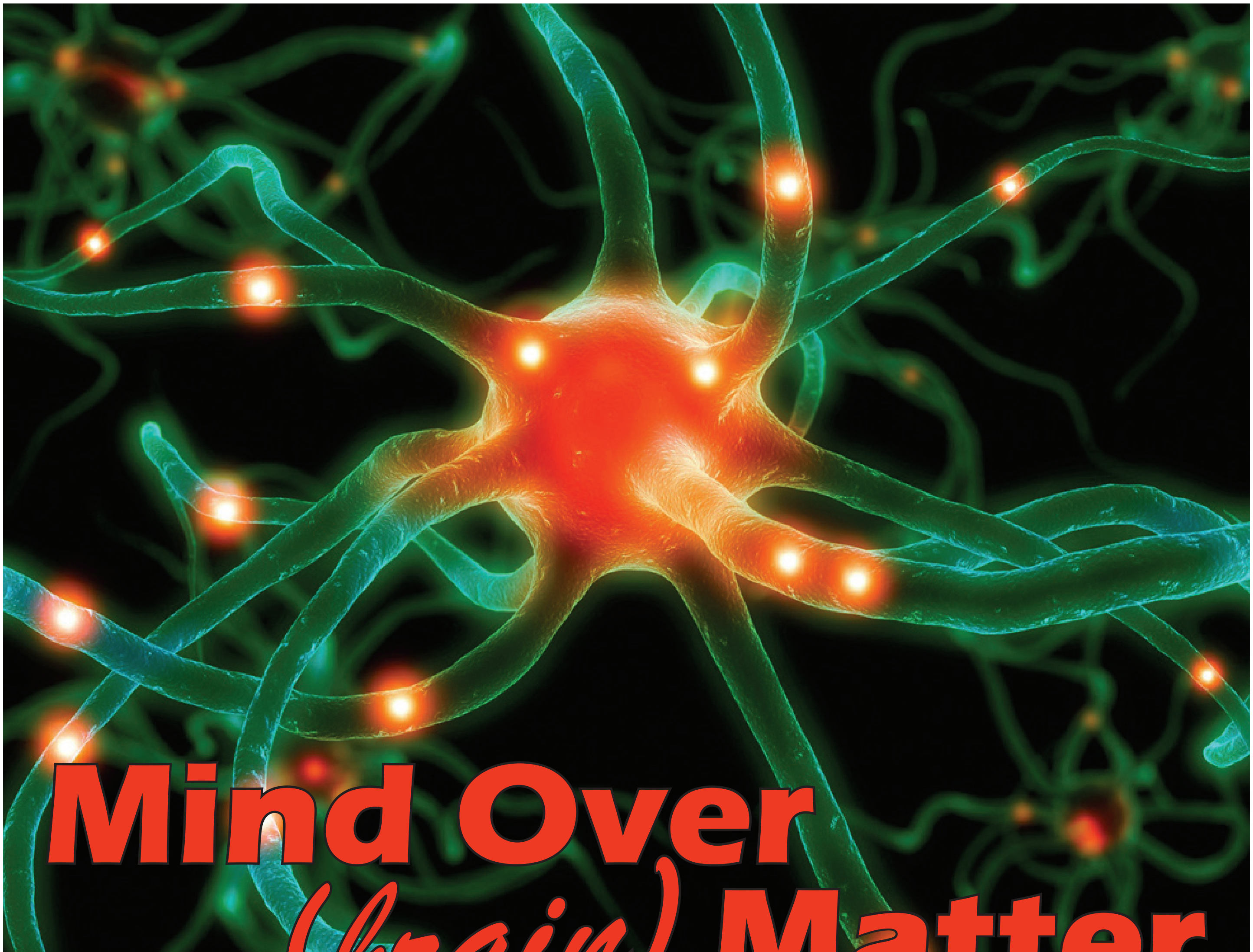

Mind Over (brain) Matter

Scientists study secret to consciousness

By Brian VanderWerf

Long before the philosopher Descartes boldly declared, "I think, therefore I am," scientists, philosophers and mystics shared a serious problem, and more than three centuries later, the problem persists.

Each of us may be aware that we in fact exist, but how exactly does the mass of gray matter between our ears produce something as incredible as consciousness itself?

Now, one physician, whose research has led him to explore the origins of consciousness, believes he has solved the mystery.

Like the helical DNA that determines our physical appearance, he believes that microtubules, which are tiny helical protein structures in the brain, are responsible for creating consciousness.

Dr. Stuart Hameroff, an anesthesiologist and emeritus professor at the University of Arizona, has been working on the problem of explaining consciousness since the 1970s. His fascination with consciousness began while watching cancer cells divide through a microscope during medical school. What he saw were tiny biological machines within the cell that seemed to "know" exactly what to do.

"The centrioles send out these spindles, which are microtubules. They grab the chromosomes and pull them apart perfectly. There's an incredible ballet that seems to be organized," he recalls.

For those who believe a complex collection of neurons within a brain is necessary for decision-making and consciousness, Hameroff reminds us, "A single celled paramecium swims around. It finds food. It finds a mate. It has sex. It can learn. It can avoid predators. It can avoid obstacles. It's one cell. It does it with microtubules."

Aptly named, microtubules appear as hollow tubes under the most powerful microscopes. In fact, they are so tiny that four million could fit within a single human hair. And while the functions of microtubules are impressive, in order to understand how they might be responsible for the wonder of consciousness, we must take a brief tour of how the brain processes information.

BRAIN AS MAINFRAME

It is often helpful to think of the brain as a computer. The computer you are looking at right now processes information very simply. In a mathematical calculation, two numbers are sent to the computer coded as ones and zeros. Each one or zero is called a bit. Computer processors are designed to perform operations on the bits, such as adding them together. The answer to the calculation becomes the output.

Many people believe the brain operates in the same way. Neurons in the brain act like the processors. They receive information from our sense organs, like our eyes and ears, as well as from several other neighboring neurons. The messages can say fire or not fire – one or zero. If enough messages tell the neuron to fire, it sends out an electrical signal. The message gets relayed to other neurons and, in the end, the body produces a response.

This chain of events does a great job of explaining how cognition, or information processing occurs in the brain. Your eyes receive the image of red lights from the car ahead of you, that message is relayed to the brain and then to motor neurons controlling your foot, and you hit the brake. But this model of a bundle of neurons sending out electrical spikes does a poor job of explaining why you chose to take the freeway today, or how you are aware of that fact that there even is a "you" at all.

As Hameroff says, "As far as the easy problems go, neuronal computation is okay, but consciousness is missing in action."

Many in the scientific community, however, believe explaining consciousness is not really a problem at all. They argue that consciousness is a natural product that emerges when brains reach a critical level of complexity. They point to the stock market as an example of another type of emergent phenomenon.

The stock market does not tell investors what the prices ought to be for certain stocks. Yet, collective decision making takes place among individuals, prices are determined, and they tend to follow patterns despite the lack of centralized control.

Hameroff is unabashedly opposed to this view of consciousness. "The emergence of consciousness from complex computation is a hand waving argument – although, it's the mainstream argument."

NEITHER DETERMINATE NOR RANDOM BE?

During the 1990s, mathematician-physicist Roger Penrose was considering the problem of explaining consciousness in terms of computers. He made a major distinction between the way consciousness and computers function. The difference, he says, is that computers follow algorithms that are deterministic. They follow strict protocols that give the same answers every time. In essence, computers are designed to perform the complete opposite of random decision-making.

Human consciousness, on the other hand, is neither predictable nor completely random. As Penrose saw it, it was non-computable.

What Penrose needed was a way to describe how the brain makes decisions that are non-computable – choosing to take the freeway today – and why the experience of perceiving red lights and sitting in traffic seems so real and universal to each of us.

For Penrose, the way to solve the problem of explaining consciousness was to view the brain as a quantum computer.

If the brain were to operate as a quantum computer it would be governed by the principles of quantum mechanics, which can allow all sorts of bizarre behavior. One consequence of quantum mechanics is that things that are very small can actually exist temporarily in two places at the same time until an outside influence forces the object to "choose" one position or another.

The key, he wrote, was that "choice" is not completely random in the quantum brain. The decision is influenced by information that is embedded in the fundamental levels of the universe.

Sound far-fetched? Maybe no harder to grasp than most quantum physics. Certain universal constants – having the same value throughout the universe – have everything to do with why the universe looks like it does.

In Penrose's view, we are all accessing the same information with our quantum computing brains.

As Hameroff puts it, "What underlines both matter and mind is space-time geometry. Matter comes out of it, why not snips of consciousness? Embedded in the universe are precursors of conscious experience, which form a palette. Our brains take a dab of this and a dab of that and you have a beautiful masterpiece. If you didn't have a quantum process that could access [the universal precursors of conscious experience] we would be like robots. We would have complex behavior without inner experience."

The only thing missing is how the brain actually does it.

A QUANTUM FOR YOUR THOUGHTS

After reading a book by Penrose, Hameroff believed microtubules fulfilled all the requirements for a consciousness generating quantum computer. He contacted Penrose, and the two soon began a collaboration, looking into the concept of "Quantum Consciousness."

Hameroff recalls, "In 1972 it was discovered that neurons are full of microtubules. To me ... the microtubule structure looked like a switching network."

It turns out the microtubule switching network is made from a protein called tubulin. When many tubulin molecules get together, they form cylinders with helical patterns of proteins that are involved in many functions of every cell, including neurons.

The nature of the tubulin molecule is that it has at least two distinct conformational shapes that it can adopt. Penrose and Hameroff view these conformations as bit states, just like the ones and zeros in a classical computer. Except, their view is that the classical bit states are chosen by quantum computations within the protein itself.

How might microtubules function in a neuron? Hameroff explains, "Input comes in. [The cell] goes into the quantum phase. It does all the quantum calculations... The output is a particular set of states of the tubulin." And with that output, "Now you're back in classical mode. [The tubulin] triggers spikes and changes in [neurons]." In their view, the neuron's accepting input and firing in output mark the classical, non-quantum phase of brain activity, and the computation – decision-making – is carried out during the quantum phase.

MICROTUBULES AND ANESTHESIA

As an anesthesiologist, Hameroff uses drugs in order to temporarily suspend consciousness for patients before surgery. One way in which anesthesiologists can determine the patients' level of consciousness, is by looking at changes in their brainwaves.

According to Hameroff, one type of brainwave, called the 40 Hertz, is the best marker of consciousness. "It goes away under anesthesia."

If microtubules are involved in producing consciousness, they need to be able to explain the 40 Hertz brainwave, so named because it beats with a frequency of 40 times per second in all of us.

In Penrose and Hameroff's model, the time it takes for a quantum computer to make a "decision" decreases as the mass of the system gets larger. They calculated that for a quantum system to make a "decision" 40 times every second, the mass of microtubules in roughly 100,000 neurons would need to be calculating together. It turns out that their number is right in line with the number of neurons that scientists believe are active in our brains at any given time, Hameroff says.

Of course, theoretical calculations such as this are not conclusive, and there are serious objections by scientists to the explanation of consciousness put forward by Penrose and Hameroff. One critique is that the quantum systems like Penrose and Hameroff describe can only be created in the laboratory by isolating the system from the environment, which would not duplicate the way life is at sub-sub-microscopic levels in the brain.

There is also a problem with science's understanding of how anesthesia itself works. For Penrose and Hameroff to be right, anesthetic drugs need to affect the microtubules in some way. It is well known that inhaled anesthetics interact with proteins on the surface of cells, but so far it has not been shown that they exert their effect on microtubules, either directly or indirectly.

When asked what it would mean if it was shown that inhaled anesthetics also act on microtubules to produce unconsciousness, he replies, "It would be huge." And so he and Penrose push on ever-deeper and, they hope, ever-closer to that tantalizing source of consciousness itself.