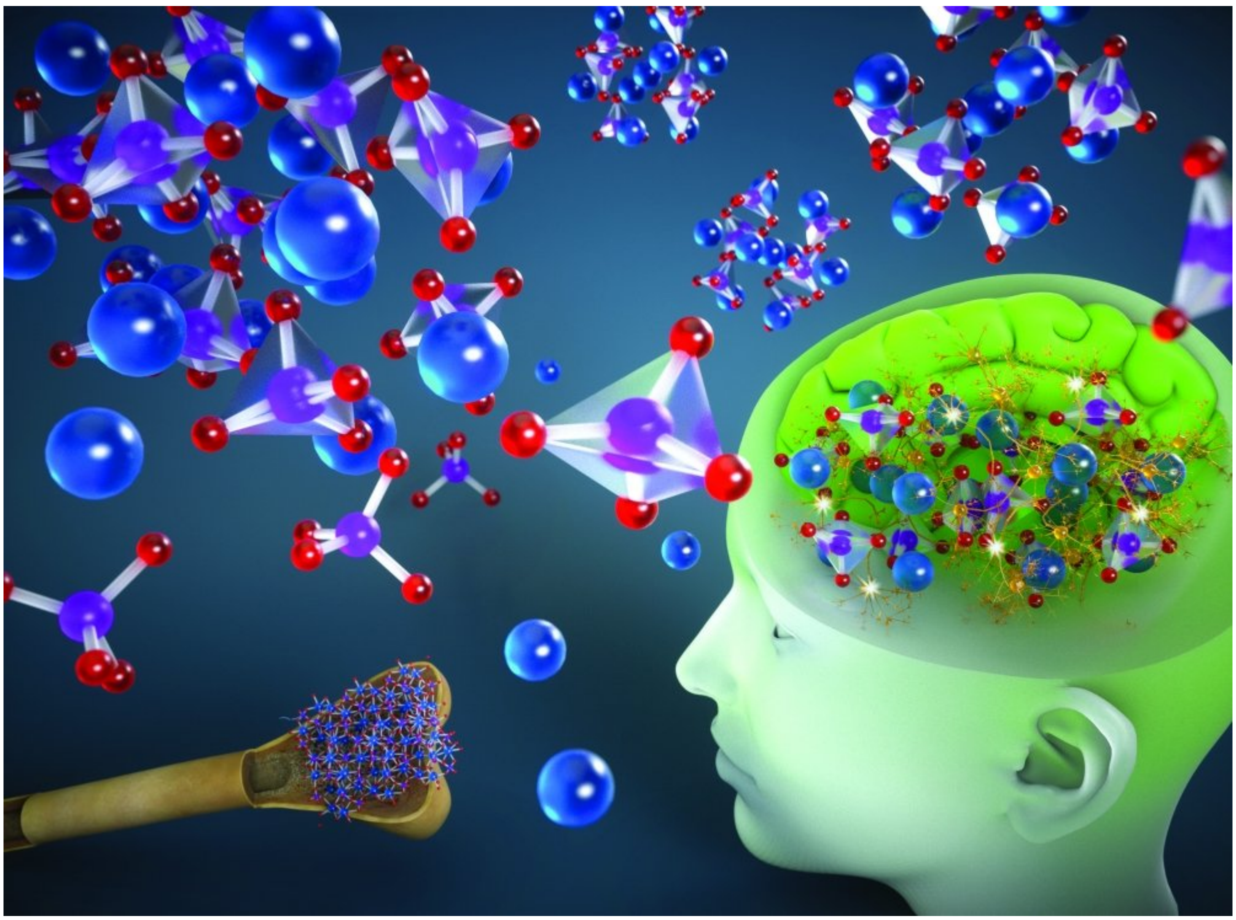
Are we quantum computers? International collaboration will investigate the brain's potential for quantum computation

March 27 2018, by Sonia Fernandez



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Much has been made of quantum computing processes using ultracold atoms and ions, superconducting junctions and defects in diamonds, but could we be performing them in our own brains?

It's a question UC Santa Barbara theoretical physicist Matthew Fisher has been asking for years. Now, as scientific director of the new Quantum Brain Project (QuBrain), he is seeking to put this inquiry through rigorous experimental tests.

"Might we, ourselves, be quantum computers, rather than just clever robots who are designing and building quantum computers?" Fisher asks.

Some functions the brain performs continue to elude neuroscience—the substrate that "holds" very long-term memories and how it operates, for example. Quantum mechanics, which deals with the behavior of nature at atomic and subatomic levels, may be able to unlock some clues. And that in turn could have major implications on many levels, from quantum computing and materials sciences to biology, mental health and even what it is to be human.

The idea of quantum computing in our brains is not a new one. In fact, it has been making the rounds for a while with some scientists, as well as those with less scientific leanings. But Fisher, a world-renowned expert in the field of quantum mechanics, has identified a precise—and unique—set of biological components and key mechanisms that could provide the basis for quantum processing in the brain. With $1.2 million in grant funding over three years from the Heising-Simons Foundation, Fisher will launch the QuBrain collaboration at UCSB. Composed of an international team of leading scientists spanning quantum physics, molecular biology, biochemistry, colloid science and behavioral neuroscience, the project will seek explicit experimental evidence to answer whether we might in fact be quantum computers.

"We are extremely grateful to the Heising-Simons Foundation for the bold vision in granting this project at the very frontier of quantum- and neuroscience," said UC Santa Barbara Chancellor Henry T. Yang. "Professor Matthew Fisher is an exceptional quantum physicist as evidenced by the Oliver E. Buckley Prize he shared in 2015 for his research on quantum phase transitions. Now he is stepping out of his traditional theoretical research framework, assembling an international team of experts to develop an experimentally based research program that will determine if quantum processes exist in the brain. Their research could shed new light on how the brain works, which might lead to novel mental health treatment protocols. As such, we eagerly anticipate the results of QuBrain's collaborative research endeavors in the years to come."

"If the question of whether quantum processes take place in the brain is answered in the affirmative, it could revolutionize our understanding and treatment of brain function and human cognition," said Matt Helgeson, a UCSB professor of chemical engineering and associate director at QuBrain.

Biochemical Qubits

The hallmarks of quantum computers lie in the behaviors of the infinitesimal systems of atoms and ions, which can manifest "qubits" (e.g. "spins") that exhibit quantum entanglement. Multiple qubits can form networks that encode, store and transmit information, analogous to the digital bits in a conventional computer. In the quantum computers we are trying to build, these effects are generated and maintained in highly controlled and isolated environments and at low temperatures. So the warm, wet brain is not considered a conducive environment to exhibit quantum effects as they should be easily "washed out" by the thermal motion of atoms and molecules.

However, Fisher asserts that nuclear spins (at the core of the atom, rather than the surrounding electrons) provide an exception to the rule.

"Extremely well-isolated nuclear spins can store—and perhaps process—quantum information on human time scales of hours or longer," he said. Fisher posits that phosphorus atoms—one of the most abundant elements in the body—have the requisite nuclear spin that could serve as a biochemical qubit. One of the experimental thrusts of the collaboration will be to monitor the quantum properties of phosphorus atoms, particularly entanglement between two phosphorus nuclear spins when bonded together in a molecule undergoing biochemical processes.

Meanwhile, Helgeson and Alexej Jerschow, a professor of chemistry at New York University, will investigate the dynamics and nuclear spin of Posner molecules—spherically shaped calcium phosphate nano-clusters—and whether they have the ability to protect the nuclear spins of the phosphorus atom qubits, which could promote the storage of quantum information. They will also explore the potential for non-local quantum information processing that could be enabled by pair-binding and disassociation of Posner molecules.

Entangled Neurons

In another set of experiments, Tobias Fromme, a scientist at the Technical University of Munich, will study the potential contribution of mitochondria to entanglement and their quantum coupling to neurons. He will determine if these cellular organelles—responsible for functions such as metabolism and cell signaling—can transport Posner molecules within and between neurons via their tubular networks. Fusing and fissioning of mitochondria could allow for establishment of non-local intra- and intercellular quantum entanglement. Subsequent disassociation of Posner molecules could trigger release of calcium, correlated across the mitochondrial network, activating neurotransmitter release and subsequent synaptic firing across what would essentially be a quantum coupled network of neurons—a phenomena that Fromme will seek to emulate in vitro.

The possibility of cognitive nuclear-spin processing came to Fisher in part through studies performed in the 1980s that reported a remarkable lithium isotope dependence on the behavior of mother rats. Though given the same element, their behavior changed dramatically depending on the number of neutrons in the lithium nuclei. What to most people would be a negligible difference was to a quantum physicist like Fisher a fundamentally significant disparity, suggesting the importance of nuclear spins. Aaron Ettenberg, UCSB Distinguished Professor of Psychological & Brain Sciences, will lead investigations that seek to replicate and extend these lithium isotope experiments.

"However likely you judge Matthew Fisher's hypothesis, by testing it through QuBrain's collaborative research approach we will explore neuronal function with state-of-the-art technology from completely new angles and with enormous potential for discovery," said Fromme. Similarly, according to Helgeson, the research conducted by QuBrain has the potential for breakthroughs in the fields of biomaterials, biochemical catalysis, quantum entanglement in solution chemistry and mood disorders in humans, regardless of whether or not quantum processes indeed take place in the brain.

Provided by University of California - Santa Barbara