Consciousness, the Brain, and Spacetime Geometry

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David Salvetti

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Astrosiesta

Stuart Hameroff

- Anesthesiologist and professor at the University of Arizona (Department of Anesthesiology and Psychology)
- He is now the director of the Center for Consciousness Studies at the University of Arizona

What is consciousness?

- A century ago it was showed the brain to be a large group of individual neuronal cells that communicate by synapses
- The brain is commonly viewed as a hierarchical system, comprising layers of organization with bottom-up, as well as top-down feedback
- Neuronal interactions are seen as the bottom level, with consciousness emerging as a novel property at an upper level of the hierarchy, for example, coherent 40-Hz oscillations
- Consciousness “emerges” as a novel property of complex interactions among relatively simple neurons

Beyond conventional approaches

- Conventional approaches:
  - Emergent property of complex interactions among individual neurons
- These approaches fail to address enigmatic features of consciousness:
  1. Why other emergent phenomena are not conscious
  2. What critical threshold or level of complexity produces consciousness

=> Need to examine the phenomenon of consciousness from a different point of view

Non-computability in conscious thought processes

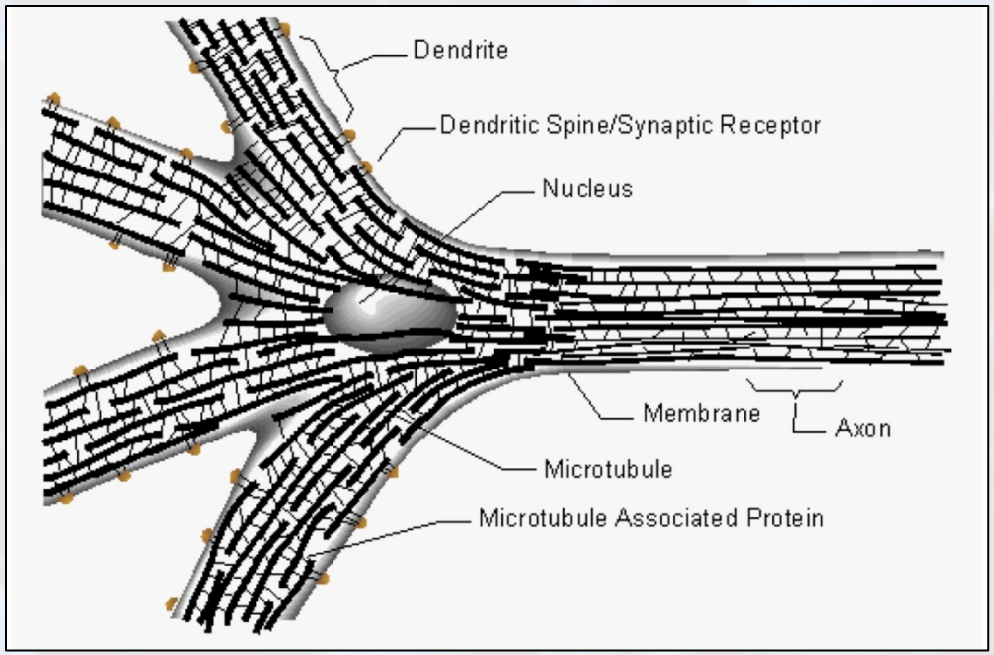
- In 1931, Kurt Gödel proved that any effectively generated theory capable of expressing elementary arithmetic cannot be both consistent and complete
- In 1989 Penrose argued that while a formal proof system cannot prove its own incompleteness, Gödel-type results are provable by human mathematicians. The brain could perform functions that no computer could perform, known as "non-computable" functions
- If correct, the Penrose's argument creates a need to understand the physical basis of non-computational behavior in the brain. Most physical laws are computable, and therefore described by algorithms. However, the nature of quantum collapse is not known making it a candidate for a non-computable process

Objective Reduction: "OR"

- Existing ideas on wave function collapse might only apply to situations where the quanta are the subject of measurement
- If quanta remain isolated, these quanta may be subject to a different form of wave function collapse
- **Quantum gravity approach**: each quantum superposition has its own piece of specetime curvature
- Limit to the size of this spacetime blister: **$E=\hbar/T$**
- Beyond this value the system becomes unstable, and collapses in a "non-computable" way so as to choose just one of the possible locations for the particle: Objective Reduction (OR)
- Where and how could such quantum processes be implemented in the brain?
- A particular quantum computation may occur in the brain

Microtubules

- Only large collections of particles acting coherently in a single macroscopic quantum state could sustain isolation and support coherent superposition in a time frame brief enough to be relevant to our consciousness
- Hameroff and Penrose nominated a quantum computational OR process with the requisite characteristics to be occuring in cytoskeletal microtubules



Microtubules (MTs)

1) hollow cylindrical polymers of individual proteins known as tubulin;
2) interconnected by linking proteins (MAPs) to other MTs to form cytoskeleton lattice network;
3) help mantain and regulate synaptic strenghts responsable for learning and cognitive functions;
4) collective Frohlich excitations of tubulin subunits support computation and information processing

The Orch-OR model (I)

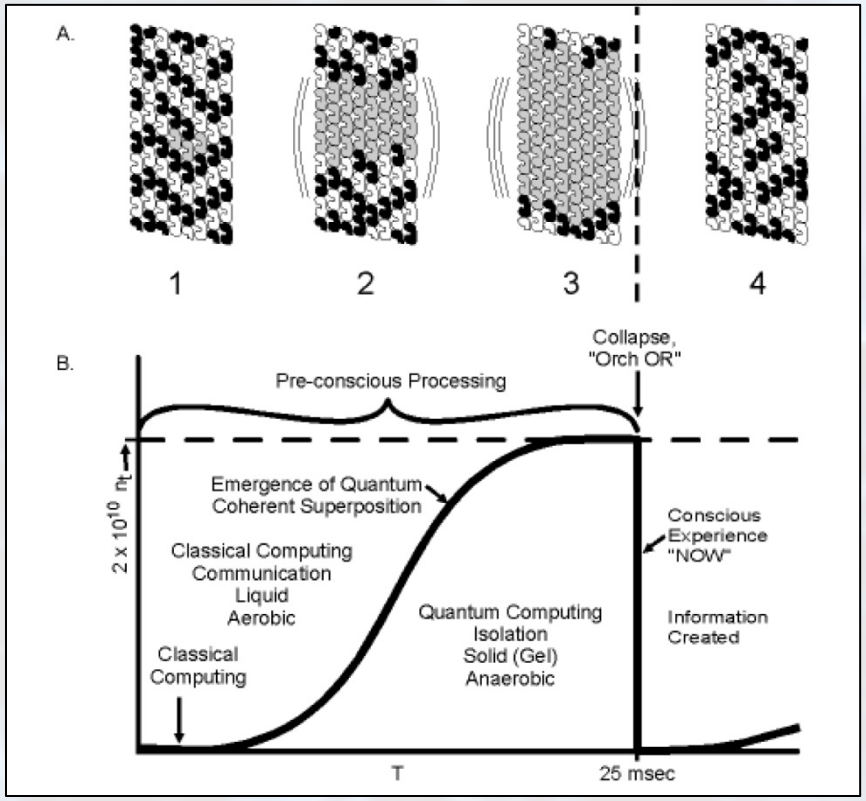
1) Quantum-superposed states develop in MT subunit proteins, remain coherent, and recruit more superposed tubulins until a mass-time-energy threshold is reached
2) Self-collapse (OR) abruptly occurs
3) MAPs can "tune" the quantum oscillations of the coherent superposed states; the OR is thus self-organized: "Orch OR"
4) Each Orch OR event selects MT subunit states which regulate synaptic/neural functions using classical signaling

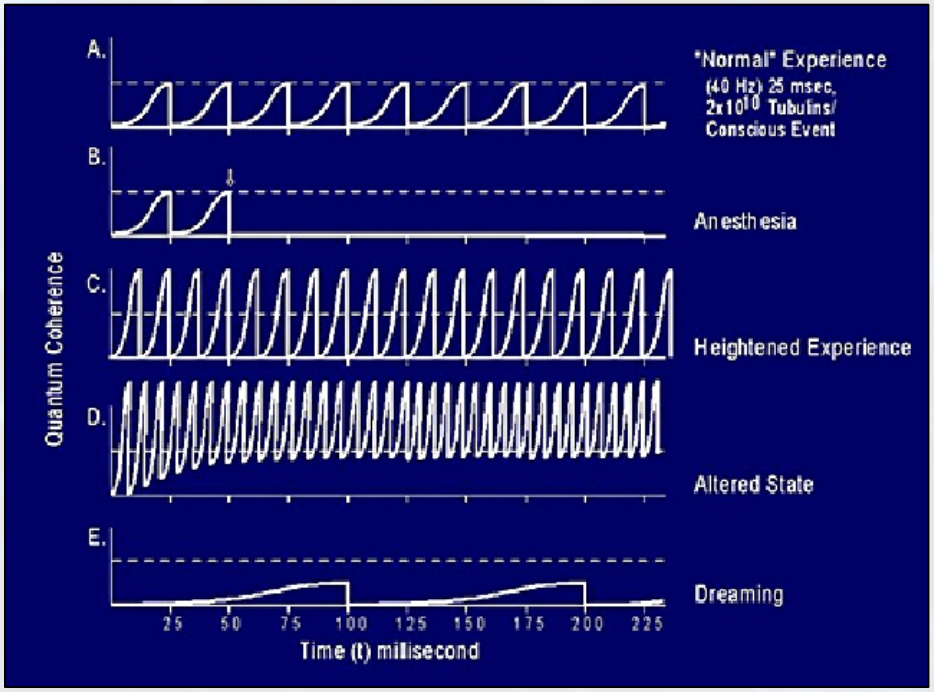
Pre-reduction phase => pre-conscious pocesses

Istantaneous OR => discrete conscious event

The Orch-OR model (II)

Orch OR events may be of variable intensity and duration pre-conscious processing. From E=h/T for a pre-conscious processing time of T=25 msec, E is roughly the superposition/separation of $2x10^{10}$ tubulins. Thus, millisecond events would involve roughly one billions neuron, 1% of brain capability.





Conclusions

- Consciousness is a sequence of discrete quantum events at the fundamental level of spacetime geometry
- Such events are connected to the brain via quantum processes in microtubules
- Orch OR model can explain the enigmatic features of consciousness
- **BUT** there are some problems in the model:
  - Brain enviroment is “warm, wet and noisy”;
  - Max Tegmark (Phys. Rev. E, 2000) calculated decoherence times of 10^{-13} sec by ions in the brain’s milieu;
  - Some predictions of the Orch OR model hase been falsified
  - OR theory has to be tested by experiments
  - The Penrose’s argument about the implications of Gödel's incompleteness theorem for computational theories of human intelligence has been widely criticized

<u>There is much work to be done!</u>

References

1. "Consciousness, the Brain, And Spacetime Geometry", *The Annals of the NewYork Academy of Sciences* special issue Cajal and consciousness
2. You can find other interesting publications on the website:

http://www.quantum-mind.org/publications.html