**Stuart R. Hameroff, MD**

**CV short: SEPTEMBER 20, 2022**

**Position title**

Emeritus Professor, Anesthesiology

Emeritus Professor, Psychology

Director, Co-Founder, Center for Consciousness Studies

Attending Anesthesiologist, Banner-University Medical Center

University of Arizona, Tucson, Arizona

|  |  |  |  |
| --- | --- | --- | --- |
| **Education/Training**  **Institution and Location** | **Degree** | **Years** | **Field of Study** |
| University of Pittsburgh Pittsburgh, PA | B.S. | 1965-69 | Chemistry, Physics Mathematics |
| Hahnemann Medical College Philadelphia, PA | M.D. | 1969-73 | Medicine |
| Internship, Tucson Medical Center  Tucson, AZ  Residency  Residency |  | 1973-74 | Integrated |

Residency in Anesthesiology

University of Arizona Medical Center 1975-77 Anesthesiology

Tucson, AZ

**Employment**

**1977-present** Attending Physician/Anesthesiologist, Department of Anesthesiology, University Hospital, University Medical Center, University Physicians Inc., University of Arizona, Health Sciences Center, UAHN, Banner-University Medical Center, The University of Arizona, Tucson, Arizona

**1977-1978** Instructor, Anesthesiology, University of Arizona, College of Medicine, Tucson, Arizona

**1978-1984** Assistant Professor, Anesthesiology

**1979** Certified by the American Board of Anesthesiology

**1979-1985** Director, Pain Clinic/Pain Service, University Medical Center

**1984 -1995** Associate Professor with Tenure, Anesthesiology

**1994** Joint Appointment, Associate Professor, Department of Psychology

**1995** Professor, Department of Anesthesiology, College of Medicine

**1995** Professor, Department of Psychology, University of Arizona

**1999** Co-Founder, Associate Director, Center for Consciousness Studies, The University of Arizona

**2003-present** Emeritus Professor, Anesthesiology and Psychology, The University of Arizona

**2004-present** Director, Center for Consciousness Studies, The University of Arizona

**Biosketch – Stuart Hameroff**

**September 19, 2022**

Stuart Hameroff MD is Emeritus Professor of Anesthesiology & Psychology, Director of the Center for Consciousness Studies, and attending anesthesiologist at Banner-University Medical Centers, all at the University of Arizona in Tucson.

Hameroff grew up in Cleveland, Ohio, and attended the University of Pittsburgh, studying chemistry, physics, mathematics and philosophy of mind.  At Hahnemann Medical College in Philadelphia

in the early 1970s, he spent time in a cancer research lab studying cell division/mitosis becoming interested in how mitotic spindles, composed of cylindrical protein lattice polymers called microtubules, were able to very precisely separate and move chromosomes in a delicate dance. Comparing the microtubule lattice to Boolean computer matrices, Hameroff began to develop an idea that microtubules were computer-like sources of biological intelligence, and possibly consciousness.

After medical school, Hameroff trained in the department of anesthesiology at the University of Arizona Medical Center in Tucson. He was recruited and mentored by the department’s

founding chair Burnell Brown Jr, MD, PhD, who told him that understanding how anesthesia works was the key to understanding consciousness. And he handed him a paper showing anesthetics affected microtubules. Hameroff began residency in the department of anesthesiology in 1975, and joined the faculty in 1977, a position he still holds as emeritus professor and practicing anesthesiologist at (now) Banner-University Medical Centers.

Over his 47 years in the department Hameroff has pursued research in chronic pain, high frequency ventilation and transcranial ultrasound (TUS) as a clinical tool addressing microtubule resonances to treat mental and cognitive disorders. But his main interest has been related to microtubules, anesthesia and consciousness.

In the 1980s Hameroff collaborated with physicists to develop models of information processing in microtubules based on ‘cellular automata’ (‘microtubule automata’) able to interact with membrane and synaptic activities.  Applied to microtubules in brain neurons, the approach theoretically increased

brain information processing capacity enormously. But it didn’t begin to explain the nature, or origin of consciousness.

In 2001 Hameroff read ‘The emperor’s new mind’ by Roger Penrose which proposed that consciousness

stemmed from collapse (quantum state reduction) of the quantum wavefunction due to an objective

threshold related to gravity (objective reduction, ‘OR’), and that the brain must contain some form

of quantum computer which would organize or orchestrate these OR quantum events.

Hameroff suggested to Penrose that microtubules inside brain neurons might be the biological quantum computers he was looking for. Penrose agreed, and the two teamed up to develop the ‘Orchestrated objective reduction’, ‘Orch OR’ theory of consciousness which connects brain activity to quantum state reductions at the most basic level of the universe - fundamental spacetime geometry – where Penrose had proposed Platonic information could influence conscious choices and perceptions.

Orch OR has been viewed skeptically by scientists and philosophers because technological quantum computers require extremely cold temperatures to avoid thermal “decoherence”, and the brain is a warm 37.6 degrees Centigrade. But recent experiments which are part of the Templeton World Charity Foundation (TWCF) program “Accelerating Research in Consciousness” have demonstrated quantum effects in microtubules at ambient temperatures. Experiments in Greg Scholes’ lab at Princeton, and in Aristide Dogariu’s lab at Central Florida show that quantum optical effects in microtubules are dampened by anesthetics which selectively block consciousness.  The Open Science Foundation (‘OSF’) registration for the project is here <https://osf.io/zqnjd/>, and the first paper submitted to a top journal and is posted here on the BioArXiV <https://arxiv.org/abs/2208.10628>

In 1994, with University of Arizona colleagues Al Kaszniak in Psychology, Alwyn Scott in Mathematics, Jim Laukes in Extended University, and subsequently David Chalmers in Philosophy and Stuart Hameroff started an interdisciplinary, international conference series ‘The Science of Consciousness’ (‘TSC’).  Held in even-numbered years in Tucson, and odd-numbered years elsewhere around the world, the 29th annual TSC was held in April 2022 in Tucson. The 2023 conference will be held in Taormina, Sicily co-organized with Riccardo Manzotti and colleagues.

In 1998, with Kaszniak and Scott, and a 1.4-million-dollar grant from the Fetzer Institute,

Hameroff co-founded the University of Arizona Center for Consciousness Studies (CCS), served as associate director, and succeeded Kaszniak and then Chalmers, as director in 2004. With Abi Behar-Montefiore as assistant director and conference manager, CCS has subsisted since 2004 and in 2018 moved administratively to the College of Social and Behavioral Sciences. University of Arizona Regents Professor Tom Bever has acted as CCS Co-Director and, with support from the Eugene Jhong Family Foundation, has developed an educational curriculum for which Hameroff will teach a course ‘Introduction to the science of consciousness’ as he transitions from clinical work to research and education. CCS Associate Directors include psychologist Jay Sanguinetti, an authority in non-invasive brain modulation including transcranial ultrasound, and another Regents professor, planetary scientist Dante Lauretta who studies astrobiology and the origin of life and consciousness. Abi Behar-Montefiore continues as CCS stalwart Assistant Director and conference manager.

Hameroff has written or edited 6 books, and several hundred scientific articles and book chapters, lectured on 6 continents, appeared in the film ‘WhattheBleep?’ and numerous TV shows about consciousness on BBC, PBS, Discovery, OWN, National Geographic, and History Channel.

**Books Authored or Edited**

|  |
| --- |
| Satsangi P, Hameroff SR, Sahni V, Dua P (2018) **Consciousness: Integrating**  **Eastern and Western Perspectives**, New Age Books |

Hameroff SR, Kaszniak AW & Chalmers D. (Eds.) **(1999).** **Toward a Science of Consciousness III:** The Third Tucson Discussions and Debates. Cambridge, MA: MIT Press/Bradford Books.

Hameroff SR, Kaszniak AW & Scott AC. (Eds.) **(1998).** **Toward a Science of Consciousness II:** The Second Tucson Discussions and Debates. Cambridge, MA: MIT Press/Bradford Books.

Hameroff SR, Kaszniak AW & Scott AC. (Eds.) (**1996). Toward a Science of Consciousness: The First** **Tucson Discussions and Debates.** Cambridge, MA: MIT Press/Bradford Books.

Koruga DL, Hameroff SR, Withers J, Loutfy R, & Sundareshan M. (Eds.) **(1993).** **Fullerene C60 – History, Physics, Nanobiology, Nanotechnology**. Amsterdam: Elsevier-North Holland, Amsterdam - Elsevier Science Ltd; First Edition (May 1, 1993) ISBN-13: 978-0444898333. ISBN-10: 0444898336

Hameroff SR. (1987).**Ultimate Computing: Biomolecular Consciousness and NanoTechnology.** Amsterdam: Elsevier-North Holland. eBook: 978-0-444-60009-7

**Book Chapters and Proceedings**

Hameroff S **(2021)** **Orch OR and the quantum biology of consciousness In: Quantum mechanics and consciousness,** Edited by Shan Gao, Oxford University Press, in press.

Hameroff S **(2021)** **Consciousness and Orch OR – Penrose, Bohm, Darwin, Freud and Chomsky,** In **Unfolding the Big Picture. Essays in Honour of Paavo Pylkkänen,** P. Limnell & T Vaden eds. Philosophical Studies from the University of Helsinki (2021).

Craddock, T.J., Kurian P., Tuszynski J.A., & Hameroff S.R. **(2019)** **Quantum Processes in Neurophotonics and the Origin of the Brain's Spatiotemporal Hierarchy.** In R.R. Alfano & L. Shi (Eds.), Neurophotonics and Biomedical Spectroscopy. (189-213). Elsevier. [abstract](http://sciencedirect.com/science/article/pii/B9780323480673000093?via%3Dihub)

Hameroff, S., & Penrose R. **(2016).** “**Consciousness in the Universe: An Updated Review of the ‘Orch OR’** **Theory.”** In R. Poznanski, J.A. Tuszynski, & T.E. Feinberg, (Eds.), The Biophysics of Consciousness: A Foundational Approach. (517-599; Chap. 14). Singapore: World Scientific. [abstract](http://anesth.medicine.arizona.edu/sites/default/files/hameroff-penrose_updated_review_of_orch_or_2016_b2237_ch-14_revised-2-3.pdf)

Craddock, T., Hameroff, S., Tuszynski, J.A. **(2016).** **“The "Quantum Underground": Where Life and** **Consciousness Originate.”** In R. Poznanski, J.A.Tuszynski, T.E. Feinberg, (Eds.), The Biophysics of Consciousness – Foundational Approaches. (Chap. 13). Singapore: World Scientific.

Hameroff, S. **(2016).** **“The Quantum Origin of Life – How the brain evolved to feel good.”** In M. Tabeyranc & F. J. Ayala (Eds.), On Human Nature: Biology, Psychology, Ethics, Politics, and Religion. Academic Press. Elsevier. (2017).

Satsangi, P.S., Hameroff, S. & Sahni, V. **(2016)** “**Does Consciousness Guide the Universe?”** In Satsangi, P.S., Hameroff, S., (Eds.), Consciousness: Integrating Eastern and Western Perspectives. (351-373; Sec. 2) New Age Books.

Ebner, M., & Hameroff, S. **(2015) “Modeling Figure/Ground Separation with a ‘Mobile Zone’ of Laterally-Connected Spiking Neurons.**” In Irena Roterman-Konieczna, (Ed.), Simulationin Medicine: Preclinical and Clinical Approach. Berlin: de Gruyter.

Alfonseca, A, Ortega, M de la Cruz, Hameroff, S.R. & Lahoz-Beltra, R. **(2015)** **“A Model of Quantum-von Neumann Hybrid Cellular Automata: Principles and simulation of quantum coherent superposition and decoherence in cytoskeletal microtubules.**” In Quantum Information and Computation. (22-36). Rinton Press.

Sanguinetti, J.L., Smith E., Allen, John J.B., Hameroff, S. **(2014)** **“Human Brain Stimulation with Transcranial Ultrasound: Potential Applications for Mental Health.”** In Bioelectromagnetic and Subtle Energy Medicine. (355-360; 2nd edition). CRC Press.

Hameroff, S. **(2014) “Consciousness, Free Will and Quantum Brain Biology –The ‘Orch OR’ Theory.**” In A. Corradini, U. Meixner, (Eds.), Quantum Physics Meets the Philosophy of Mind.(99-134).Berlin: De Gruyter.

Hameroff, S., Pylkkanen, P., & Gennaro, R. **(2014) 'HOT to DOT’ – A ‘Deeper order thought’ theory of** **consciousness.”** In D. Chopra, (Ed.), Brain, Mind, Cosmos: The Nature of Our Existence and the Universe*.*  (Chapter 15; Series Book 1), Sages and Scientists (Amazon Digital Services, Inc). [Kindle Ed]

Hameroff, S.R. **(2007)** **“That’s Life’ – The geometry of pi electron resonance clouds**.” In D. Abbot, P. Davies & A.K. Pati, (Eds.). Quantum aspects of life. Biology. Imperial College Press.

Hameroff, Stuart **(2007) “Consciousness, Neurobiology and Quantum Mechanics: The Case for Connection.”** In: The Emerging Physics of Consciousness, edited by Jack Tuszynski Springer-Verlag, (2007). [pdf.link](http://quantumconsciousness.org/sites/default/files/2007%20Hameroff_Case%20for%20a%20Connection%20in%20Tuszynski%20ed%20The%20Emerging%20Physics%20of%20Consciousness.pdf)

Hameroff, S. & Tuszynski, J. (**2004** June**) “Quantum states in proteins and protein assemblies.”** Proceedings of SPIE, Conference on Fluctuationa and Noise, Canary Islands.

Hameroff, S.R., & Tuszynski, J. **(2003)** **“Search for quantum and classical modes of information processing** **in microtubules: Implications for the living state.”** In Franco Musumeci & Mae-Wan Ho (Eds.), *Bioenergetic organization in living systems*. Singapore: World Scientific.

Hameroff, S.R. **(2003)** “**Time, consciousness and quantum events in fundamental spacetime geometry.”** In R. Buccheri & M. Saniga (Eds.), The nature of time: Physics, geometry and perception: Proceedings of a NATO Advanced Research Workshop. [Link](file:///Users/abimontefiore/Downloads/Hameroff%20S,%20Nato%20Advanced%20Research%20Workshop%202002.pdf)

Hameroff, S.R. **(2003)** **“Consciousness, Whitehead and quantum computation in the brain:** **Panprotopsychism meets the physics of fundamental spacetime geometry.”** In M. Weber, (Ed.), *Whitehead Process Network Compendium*.

Hameroff, S.R., & Woolf N.J. **(2002)** “**Quantum consciousness: A cortical neural circuit.”** In Naoyuki Osaka, (Ed.), Neural Basis of Consciousness.(167-200)Amsterdam: John Benjamins.

Hameroff, S. **(2001)** “**Biological feasibility of quantum approaches to consciousness - The Penrose-Hameroff “Orch OR” model.”** In Philip van Looke, (Ed.), The Physical Nature of Consciousness. (1-61). John Benjamins.

Hameroff, Stuart. **(2001)** [**Consciousness, The Brain and Spacetime Geometry.**](http://quantum.webhost.uits.arizona.edu/prod/sites/default/files/cajal.pdf)[From the *Annals of the New York Academy of Sciences*, Special issue: Cajal and consciousness, Scientific Approaches to Consciousness on the Centennial of Ramon y Cajal's Textura,  Marijuan P., eds, Volume 929;](http://quantum.webhost.uits.arizona.edu/prod/sites/default/files/cajal.pdf) 74-104. [link](https://www.scribd.com/document/364482289/Cajal-and-Consciousness-Scientific-Approaches-to-Consciousness-on-the-Centennial-of-Ramon-y-Cajal-s-Textura-2001)

Hameroff, S.R. **(1999)** “**Anesthesia.”** In J. Brockman (Ed.), Greatest inventions of the past 2000 years. (94-98). Simon and Schuster.

Hameroff, S.R. **(1998)** **“Funda-Mental geometry: The Penrose-Hameroff “Orch OR” model of consciousness.”** In Huggett N.S.A., Mason L.J., Tod K.P., Tsou S.T., & Woodhouse N.M.J. (Eds.), The Geometric Universe -Science, geometry and the work of Roger Penrose. (135-160).

Hameroff, S.R. **(1998)** **“Did Consciousness Cause the Cambrian Evolutionary Explosion?”** In Hameroff, S.R, Kaszniak A.W., & Scott, A.C., (Eds.), Toward a Science of Consciousness II - The Second TucsonDiscussions and Debates. (421-437). Cambridge, MA: MIT Press.

Hameroff, S., Scott, A. **(1998)** **"A Sonoran Afternoon" -** Discussion on the relevance of quantum theory to consciousness.” In Hameroff, S.R., Kaszniak, A.W. & Scott, A.C., (Eds.), (635-643). Toward a Science of Consciousness II - The Second Tucson Discussions and Debates, Cambridge, MA: MIT Press.

Hameroff, S. **(1998)** “**More neural than thou (A reply to Patricia Churchland),”** In Hameroff, S.R., Kaszniak, A.W. & Scott, A.C., (Eds.), (197-213). Toward a Science of Consciousness II - The Second Tucson Discussions and Debates,Cambridge, MA: MIT Press.

Hameroff, S. **(1997) “Consciousness Studies: An overview.”** In Taddei-Ferretti, C., Musio, C., (Eds.), (3-13). Neuronal and psychological aspects of consciousness. Series on Biophysics and Biocybernetics. (Vol. 8)-Biocybernetics. World Scientific.

Hameroff, S. **(1997) “Quantum computing in microtubules: The Penrose-Hameroff Orch OR Model.”** In Taddei-Ferretti, C., Musio, C., (Eds.), (479-506). Neuronal and psychological aspects of consciousness, Series on Biophysics and Biocybernetics Vol 8 - Biocybernetics. World Scientific.

Hameroff, S.R. **(1997) “Quantum computing in microtubules: an intra-neural correlate of consciousness?”** In Cognitive Studies: Bulletin of the Japanese Cognitive Science Society. 4(3): 67-92).

Boswell, M.V., Hameroff, S.R., **(1996) “Theoretical mechanisms of general anesthesia.**” In V.J. Collins (Ed.), *Principles of Anesthesiology*, 3rd Edition, Volume 3: The Physiologic and Pharmacologic Basis of Anesthesia, Philadelphia: Lea and Feiberger.

Hameroff, S.R. **(1996)** **“Cytoplasmic Gel States and Ordered Water: Possible Roles** in Biological Quantum Coherence.” *Proceedings* - 2nd Annual Advanced Water Sciences Symposium, Dallas, TX.

Hameroff, S., Penrose, R., **(1996)** **“Orchestrated reduction of quantum coherence in brain microtubules: a** **model for consciousness.”** In S. Hameroff, A. Kaszniak & A. Scott., (Eds.), (507-540). Toward a Science of Consciousness - The First Tucson Discussions and Debates. Cambridge, MA: MIT Press. [A Model for Consciousness 1996.pdf](http://quantumconsciousness.org/sites/default/files/1996%20Orchestrated%20Objective%20Reduction%20of%20Quantum%20Coherence%20in%20Brain%20Microtubules%20-%20A%20Model%20For%20Consciousness.pdf)

Louria, D., Hameroff, S., **(1996)** **“Computer simulation of anesthetic binding in protein hydrophobic** **pockets.”** In S. Hameroff, A. Kaszniak & A. Scott., (Eds.), Toward a Science of Consciousness – The First Tucson Discussions and Debates. Cambridge, MA: MIT Press.

Hameroff, S., Penrose, R., **(1996) “Conscious events as orchestrated space-time selections**.” In D. Chalmers & J. Shear (Eds.), Explaining consciousness - the “hard problem” of conscious experience.

Hameroff, S., Penrose, R., **(1995)** **“Orchestrated reduction of quantum coherence in brain microtubules: a** **model for consciousness?”** In J. King and K. Pribram (Eds.), Scales in Conscious Experience, Is the brain too important to be left to specialists to study? Mahway, NJ: Lawrence Erlbaum. (243-274).

Hameroff, S.R., Polson, J.S., Watt, R.C. **(1994)** **“Monitoring Anesthetic Depth.”** In C. Blitt, Churchill Livingstone (Eds.), *Monitoring in Anesthesia and Critical Care Medicine-* 3rd ed. (491-507).

Samsonovich A, Scott, A, Hameroff SR. **(1992) Acousto-conformational phase transitions in the cytoskeleton, adaptive resonance networks with nonlinear synapses and trainable intraneuronal pattern recognition.** Proceedings 1992 IJCNN International and Joint Conference on Neural Networks. 7-11 June, 1:565–569.

Watt RC, Navabi MJ, Scipione PJ, Hameroff SR, Maslana ES. **(1990)** Neural **Network Estimation of Anesthetic** **Level Using Eeg Spectral Signatures**. Engineering in Medicine and Biology Society, 1990. Proceedings of the Twelfth Annual International Conference of the IEEE. 1-4 Nov 1990; 12:5: 2017-2018. [link](https://ieeexplore.ieee.org/abstract/document/692136)

Hameroff, SR, Vernetta LA, Lee YC, Sarid D, Watt RC, **(1990)** **Atomic Resolution of Cytoskeletal Protein by** **Scanning Tunneling Microscopy.** Proceedings of the Twelfth Annual International Conference of the IEEE*,* 1-4 Nov. 1990; 1724-1724.  [link](https://ieeexplore.ieee.org/document/691983)

[Navabi MJ, Watt RC, Mylrea KC, Hameroff SR. **(1990) Classification of CO2 Waveforms Using Artificial Neural**](http://ieeexplore.ieee.org/xpl/articleDetails.jsp?reload=true&amp;arnumber=691836) [**Networks**. Engineering in Medicine and Biology Society.](http://ieeexplore.ieee.org/xpl/articleDetails.jsp?reload=true&amp;arnumber=691836) Proceedings of the Twelfth Annual International Conference of the IEEE. 1-4 Nov 1990; 1455-1456. [link](https://ieeexplore.ieee.org/document/691836?reload=true&arnumber=691836)

Hameroff SR, Navabi MJ, Watt RC, Mylrea KC. **(1990)** **Smart Alarms in Anesthesia Heart Rate and ECG** **Monitoring and Event Recognition Using Neural Network and Algorithmic Methods**. Engineering in Medicine and Biology Society. Proceedings of the Twelfth Annual International Conference of the IEEE*.* 1- 4 Nov 1990; 2000-2001.  [link](https://ieeexplore.ieee.org/document/692128)

Hameroff SR, Karampurwala H, Rasmussen S. **(1990) Adaptive behavior in sub-neural microtubule automata.** Proceedings of the Twelfth Annual International Conference of the IEEE, 17-21 June 1990; 3:715-720.

Hameroff, S., Karampurwala, H., & Rasmussen, S., (Eds.), **(1990)** June; 17-21; 3:715-720). **“Adaptive behavior in sub-neural microtubule automata**.” IJCNN International Joint Conference on Neural Networks, IEEE Publisher.

Hameroff S, Simic-Krstic Y, Koruga, D, Kelley M, McCuskey R, Krasovich M, Schneiker C. **(1989) Scanning tunneling microscopy of microtubules**. Engineering in Medicine and Biology Society, Images of the Twenty-First Century. Proceedings of the Annual International Conference of the IEEE Engineering in Medicine andBiology Society. 9-12 November 1989. 4:1350-1351. [link](https://avs.scitation.org/doi/abs/10.1116/1.576164)

Rasmussen S, Karampurwala H, Vaidyanath R, Hameroff S. **(1989) Emergent computation in microtubule model networks.** Engineering in Medicine and Biology Society. Images of the Twenty-First Century. Proceedings of the Annual International Conference of the IEEE Engineeringin 9-12 Nov 1989. 4:1368-1369. [link](https://ieeexplore.ieee.org/document/96244)

Watt RC, Ehlers KC, Scipione PJ, Maslana ES, Hameroff SR. **(1989)** Dimensional **analysis of the** **electroencephalogram during general anesthesia.** Engineering in Medicine and Biology Society, 1989. Images of the Twenty-First Century. Proceedings of the Annual International Conference of the IEEE Engineering. 9-12 Nov 1989; 6:1881-1882. [link](https://ieeexplore.ieee.org/document/96503)

Hameroff, S., Rasmussen, S., & Mansson, B. **(1988**) “Molecular automata in microtubules: basic **computational logic of the living state.”** In C. Langton, (Ed.), (521-553). Artificial Life: SFI Studies in the Science of Complexity. New York: Addison-Wesley.

**Peer-Reviewed Publications - selection**

# Kalra AP, Benny A, Travis SM, Zizzi EA, Morales-Sanchez A, Oblinsky DG, Craddock TJA, Hameroff SR, MacIver MB, Tuszynski, Petry S, Penrose R, Scholes GD. **Electronic Energy Migration in Microtubules**, Submitted Aug 22, 2022 Now at:

# <https://arxiv.org/abs/2208.10628>

###### Hameroff, S (2022) **Consciousness, Cognition and the Neuronal Cytoskeleton – A New Paradigm Needed in Neuroscience**. Front. Mol. Neurosci. <https://doi.org/10.3389/fnmol.2022.869935>

Aminpour M, Hameroff S, Tuszynski J (2022) **How COVID-19 Hijacks the Cytoskeleton: Therapeutic Implications** Life (Basel) 12(6):814. doi: 10.3390/life12060814. PMID: 35743845; PMCID: PMC9225596.

###### Hameroff, Stuart (2020) **‘Orch OR’ is the most complete, and most easily falsifiable theory of consciousness,** Cognitive Neuroscience,; Pub online: 24 Nov <https://www.tandfonline.com/doi/full/10.1080/17588928.2020.1839037>

Sanguinetti JL, Hameroff S, Smith EEE, Sato T, Daft CMW, Tyler WJ, Allen JJB. **Transcranial focused ultrasound to the right prefrontal cortex improves mood and alters functional connectivity in humans** Frontiers in Human Neuroscience, **2020;** 14:52 <https://www.frontiersin.org/article/10.3389/fnhum.2020.00052>

Hameroff S, Muotri Alysson R. (**2020**) **Testing for consciousness in cerebral**

**organoids,** Trends in Cell and Molecular Biology 15:43-57

Hameroff, Stuart. **Consciousness and quantum state reduction – Which comes first**? Activitas Nervosa Superior, April **2019**; 61:31-40. [link](file:///Users/abimontefiore/Downloads/Hameroff%20-%20Cons%20and%20Quantum%20State%20Reduction%20Apr%202019%20.pdf)

Hameroff, SR. Editorial. “**Anesthetic action and ‘quantum consciousness’: A match made in olive oil.”** Anesthesiology, **2018;** 8(129):228-231. [link](http://anesthesiology.pubs.asahq.org/article.aspx?articleid=2682839)

Craddock JAT, Kurian P, Preto J, Sahu K, Hameroff SR, Klobukowski M, Tuszynski JA**. Anesthetic alterations of collective terahertz oscillations in tubulin correlate with clinical potency: Implications for anesthetic action and post-operative cognitive dysfunction."** Nature, Scientific Reports, **2017;** Vol. 7 (1): 9877;1-12. <https://www.nature.com/articles/s41598-017-09992-7>

Hameroff, SR. **“Change the Music: Psychotherapy and Brain Vibrations.”** The Neuropsychotherapist, April **2016**; Vol 4, 4, 31-35. [pdf](http://consciousness.arizona.edu/documents/neuropsychotherapist-2.pdf)

Craddock, JA, Hameroff SR, Ayoub AT, Klobukowski M, and Tuszynski JA. **Anesthetics act in quantum channels in brain microtubules to prevent consciousness.”** Current Topics in Medicinal Chemistry, **2015;** 3/1, Vol 15:6, 523-533. [link](https://www.ncbi.nlm.nih.gov/pubmed/25714379)

Craddock, J.A. Travis, Friesen D, Mane J, Hameroff SR, and Tuszynski JA. “**The Feasibility of Coherent Energy Transfer in Microtubules.”** Journal of the Royal Society Interface, **2014;** Nov 6; 11(100).  [link](https://royalsocietypublishing.org/doi/full/10.1098/rsif.2014.0677)

Hameroff, SR, Craddock TJ, Tuszynski JA **“Quantum effects in the understanding of consciousness**.” Journal Integr Neurosci.; **2014.** 13(2):229-52  [link](https://www.ncbi.nlm.nih.gov/pubmed/25012711)

Hameroff, S. Comment. L Turin et al, Proc. Nat. Acad. Sci., **“Electron spin changes during general anesthesia in Drosophila.”** Chemistry World Review. **2014;** August 11-2. [link](http://pnas.org/content/early/2014/08/06/1404387111)

[**Hameroff, S., and Penrose R. “Consciousness in the universe: A review of the 'Orch OR' theory.”** Phys Life Rev,](http://www.ncbi.nlm.nih.gov/pubmed/24070914) 2014; [Mar 11(1):39-78.](http://www.ncbi.nlm.nih.gov/pubmed/24070914) [Sci Direct](http://quantumconsciousness.org/sites/default/files/Hameroff%20Penrose%20-%20Consciousness%20in%20the%20Universe-A%20Review%20of%20the%20Orch%20OR%20Theory%20-%202013%20-%20Physics%20of%20Life%20Reviews.pdf)   [Elsevier](https://phys.org/news/2014-01-discovery-quantum-vibrations-microtubules-corroborates.html)

[Hameroff S., and Penrose R. “**Reply to Seven Commentaries on “Consciousness in the Universe: Review of the**](http://www.sciencedirect.com/science/article/pii/S1571064513001905) [‘**Orch OR’ theory".** Physics of Life Reviews, 2014; 11:94–100.](http://www.sciencedirect.com/science/article/pii/S1571064513001905) [link](http://sciencedirect.com/science/article/pii/S1571064513001905)

[Hameroff S., Penrose R. **“Reply to Criticism of the 'Orch OR qubit' - Orchestrated objective reduction is**](http://www.sciencedirect.com/science/article/pii/S1571064513001917)[**scientifically justified**.” Physics of Life Reviews, **2014;**11(1):104-112.](http://www.sciencedirect.com/science/article/pii/S1571064513001917) [link](http://sciencedirect.com/science/article/pii/S1571064513001917)

Hameroff S**. “Consciousness, Microtubules and ‘Orch-OR’: A ‘Space-time’ Odyssey.”**  Journal of Consciousness Studies, Imprint Academic. **2014;** Vol. and 21, 3-4, pp 126-153. [link](https://www.ingentaconnect.com/content/imp/jcs/2014/00000021/f0020003/art00008)

Hameroff S. **“Quantum walks in brain microtubules-a biomolecular basis for quantum cognition?”** Top Cogn Sci, **2014;** Jan; 6(1):91-7. [link](https://www.ncbi.nlm.nih.gov/pubmed/24259348)

[Hameroff, SR. **Quantum mathematical cognition requires quantum brain biology: the "Orch OR"**](http://www.ncbi.nlm.nih.gov/pubmed/23673035) [**theory**.  Behav Brain Sci, **2013;** June; 36(3):287-90.](http://www.ncbi.nlm.nih.gov/pubmed/23673035) [link](https://www.ncbi.nlm.nih.gov/pubmed/23673035)

Hameroff, S.  ***Comment on***: A Tale of Two Fields: “Dissipation of ‘dark energy’ by cortex in knowledge [retrieval” by Capolupo, Freeman and Vitiello. Phys Life Rev. **2013;** March; 10(1):95-6; discussion 112-6.](http://www.ncbi.nlm.nih.gov/pubmed/23375127) [link](https://www.ncbi.nlm.nih.gov/pubmed/23375127)

Hameroff, SR, Sanguinetti JL, Duffield C, Raman U, Ghosh S, Parker S, Amos QD, and

Allen JJB. **“Transcranial ultrasound (‘TUS’) - an optimal non-invasive brain-machine**

**interface via microtubules?”** Soc. for Neuroscience, [Brain Stimulation Journal, **2013;** Nov 14](http://www.brainstimjrnl.com/article/S1935-861X%2812%2900084-8/abstract) [link](https://www.brainstimjrnl.com/article/S1935-861X(12)00084-8/fulltext)

[Hameroff, S, Trakas M, Duffield C, Annabi E, Gerace MB, Boyle P, Lucas A, Amos Q, Buadu A, and Badal JJ.](http://www.ncbi.nlm.nih.gov/pubmed/22664271) rev **“**[**Transcranial ultrasound (TUS) effects on mental states: a pilot study.”** Brain Stimul, 2013 May; 6(3):409-15.](http://www.ncbi.nlm.nih.gov/pubmed/22664271) online [link](https://www.brainstimjrnl.com/article/S1935-861X(12)00084-8/fulltext)

Hameroff, S. **“How quantum brain biology can rescue conscious free will.”**Front Integr Neurosci, **2012;** 6:93, 12 October.   [link](https://www.ncbi.nlm.nih.gov/pubmed/23091452)

Hameroff, S. **“Quantum brain biology complements neuronal assembly approaches to consciousness.”** ***Comment*** on Baars and Edelman, “Consciousness, biology and quantum hypotheses.” Phys Life Rev. **2012;** Sept; 9(3):303-5; discussion 306-307. [link](https://www.ncbi.nlm.nih.gov/pubmed/22795934)

Craddock TJA, Tuszynski JA, Hameroff S, **Cytoskeletal signaling: Is synaptic memory encoded in microtubule lattices by CaMKII phosphorylation?,** PLoS Comp Biol **2012;** 8(3): e10024212011 [link](https://journals.plos.org/ploscompbiol/article?id=10.1371/journal.pcbi.1002421)

Craddock, TJ, St George M, Freedman H, Barakat KH, Damaraju S, Hameroff S, & Tuszynski JA. **“**[**Computational predictions of volatile anesthetic interactions with the microtubule cytoskeleton: implications**](http://www.ncbi.nlm.nih.gov/pubmed/22761654)[**for side effects of general anesthesi**](http://www.ncbi.nlm.nih.gov/pubmed/22761654)[**a.”**](http://ncbi.nlm.nih.gov/pubmed/22761654(opens%20in%20a%20new%20tab))[PLoS One. 7(6) **2012**.](http://www.ncbi.nlm.nih.gov/pubmed/22761654) [link](https://www.ncbi.nlm.nih.gov/pubmed/22761654)

[Craddock, TJ, Tuszynski JA, Chopra D, Casey N, Goldstein LE, Hameroff SR, & Tanzi RE. **“The** **zinc**](http://www.ncbi.nlm.nih.gov/pubmed/22457776) [**dyshomeostasis hypothesis of Alzheimer’s disease.” PLoS One 2012;7(3): e33552,**](http://www.ncbi.nlm.nih.gov/pubmed/22457776)[2012.](http://ncbi.nlm.nih.gov/pubmed/22457776) [link](https://www.ncbi.nlm.nih.gov/pubmed/22457776)

[Ebner, M, and Hameroff S. **“Lateral information processing by spiking neurons: a theoretical model of the neural**](http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3199212/)[**correlate of consciousness.” Comput Intell Neurosci, 2011; Oct 23.**](http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3199212/) [link](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3199212/)

[Hameroff SR, Craddock TJ, and Tuszynski JA. **"Memory bytes" - molecular match for CaMKII**](http://www.ncbi.nlm.nih.gov/pubmed/21064217) [**phosphorylation encoding of microtubule lattices.**” J Integr Neurosci, **2010;** Sep;9(3):253-67.](http://www.ncbi.nlm.nih.gov/pubmed/21064217) [link](https://www.ncbi.nlm.nih.gov/pubmed/21064217)

[Hameroff S. **“The "conscious pilot"-dendritic synchrony moves through the brain to mediate**](http://www.ncbi.nlm.nih.gov/pubmed/19669425)[**consciousness.**” J Biol Phys, **2010;** Jan;36(1):71-93.](http://www.ncbi.nlm.nih.gov/pubmed/19669425) [link](https://www.ncbi.nlm.nih.gov/pubmed/19669425)

Hameroff, Stuart. **“The Good, the Bad and the Octopus.”** Journal of Consciousness Studies, Volume 14, Number 8, **2007**; pp. 105-109(5). [pdf](https://www.quantum-mind.org/content/good-bad-octopus)

[Hameroff](http://www.ncbi.nlm.nih.gov/pubmed/21635328), [S.R. **“The Brain Is Both**](http://www.ncbi.nlm.nih.gov/pubmed/21635328)[**Neurocomputer**](http://www.ncbi.nlm.nih.gov/pubmed/21635328)[**and Quantum Computer.**](http://www.ncbi.nlm.nih.gov/pubmed/21635328)” [Cogn](http://www.ncbi.nlm.nih.gov/pubmed/21635328) [Sci, **2007**; Nov](http://www.ncbi.nlm.nih.gov/pubmed/21635328) [12;31(6):1035-45.](http://www.ncbi.nlm.nih.gov/pubmed/21635328) [link](https://www.ncbi.nlm.nih.gov/pubmed/21635328)

[Hameroff, SR. **"The entwined mysteries of anesthesia and consciousness: Is there a common underlying mechanism?"** Anesthesiology](http://anesthesiology.pubs.asahq.org/Article.aspx?articleid=1931238) **2006**; [105(2):400–412.](http://anesthesiology.pubs.asahq.org/Article.aspx?articleid=1931238) [link](http://anesthesiology.pubs.asahq.org/Article.aspx?articleid=1931238)

Hameroff [SR. **A new theory of the origin of cancer: quantum coherent entanglement, centrioles, mitosis,**](http://www.ncbi.nlm.nih.gov/pubmed/15527951)[**and differentiation.**](http://www.ncbi.nlm.nih.gov/pubmed/15527951) Biosystems. **2004;** Nov; 77(1-3):119-36. [link](https://www.sciencedirect.com/science/article/pii/S0303264704000619)

Hagan, S, Hameroff, SR, and Tuszynski, JA. “**Quantum Computation in Brain Microtubules?”** Decoherence and Biological Feasibility, Physical Reviews E**2002;**65:061901. [link](https://www.semanticscholar.org/paper/Quantum-computation-in-brain-microtubules%3A-and-Hagan-Hameroff/b7ce1aada9fcfb57538c537a37daf39a8981ef88)

Hameroff, S, Nip, A, Porter, M, and Tuszynski, J. **“Conduction pathways in microtubules, biological** quantum computation, and consciousness.” BioSystems, **2002;** 64: 149-168. [link](https://www.ncbi.nlm.nih.gov/pubmed/11755497?dopt=Abstract)

Woolf, N.J., Hameroff, S. **“A quantum approach to visual consciousness**.” *Trends in Cognitive Sciences*, **2001;** 5(11): 472-478. [link](http://quantum.webhost.uits.arizona.edu/prod/sites/default/files/Woolf_Nancy%20and%20Hameroff_Stuart%20A%20Quantum%20Approach%20to%20Visual%20Consciousness_2001.pdf#overlay-context=content/orch-or-theory)

Hameroff, S. **Anesthesia: the “other side” of consciousness** (**Commentary** on the papers of E. Roy John and colleagues). Consciousness and Cognition, **2001;** 10: 217-229.

Hameroff, S. [**To the brink of enlightenment?** **(Review** of “The quantum brain” by Jeffrey Satinover)](http://www.dana.org/Cerebrum/2001/To_the_Brink_of_Enlightenment/) Cerebrum – The Dana Forum on Brain Science 3(2), Spring **2001**;  [link](http://www.dana.org/Cerebrum/2001/To_the_Brink_of_Enlightenment/)

Hameroff, S.R. **The neuron doctrine is an insult to neuron**s (**Commentary** on target article "The neuron doctrine" by Gold and Stoljar) Behavioral and Brain Sciences, **1999;** 22(5):838-839.

Hameroff, S.R. **Quantum computation in brain microtubules?** The Penrose-Hameroff “Orch OR" model of consciousness. Philosophical Transactions Royal Society London, **1998;** (A)356:1869-1896. [link](https://royalsocietypublishing.org/doi/10.1098/rsta.1998.0254)

Hameroff, S.R. **Anesthesia, consciousness and hydrophobic pockets-a unitary quantum hypothesis of anesthetic action**. Toxicology Letters, **1998;** 100/101:31-39. [link](https://www.sciencedirect.com/science/article/pii/S0378427498001623)

Hameroff, S.R**. Funda-Mentality: Is the conscious mind subtly linked to a basic level of the universe?** Trends in Cognitive Science, **1998;** 2(4):119-127. [link](http://quantumconsciousness.org/sites/default/files/1998 Funda-Mentality_Is the Conscious Mind Subtly Linked to a Basic Level of the Universe 1998.pdf)

Hameroff, S. **Reply** to Spier and Thomas from Stuart Hameroff, Trends in Cognitive Science, Vol 2, 4, 1 Apr **1998;** pp. 125-126. [link](https://www.sciencedirect.com/science/article/abs/pii/S1364661398011590)

Hameroff, S. **Quantum vitalism.** Advances: The Journal of Mind-Body Health **1997;** 13(4):13-22.

Hameroff, SR. **“Quantum computing in microtubules: an intra-neural correlate of** **consciousness?”**Cognitive Studies: Bulletin of the JapaneseCognitive Science Society,**1997;** 4(3):67-92.

Hameroff, Stuart R. & Penrose, Roger**. Conscious events as orchestrated space-time selections**. Journal of Consciousness Studies **1996;** 3(1):36-53.  [link](http://quantumconsciousness.org/sites/default/files/1996%20Hameroff_Penrose%20Conscious%20Events%20as%20Orchestrated%20Space%20Time%20Selections%20JCS%201996.pdf)

Hameroff, S.R. Penrose R. **Orchestrated reduction of quantum coherence in brain microtubules: A model** **for consciousness?** Mathematics and Computers in Simulation, **1996;** 40:453-480. [link](https://www.sciencedirect.com/science/article/abs/pii/0378475496804769?via%3Dihub)

Lahoz-Beltra, R, Hameroff, S.R, Dayhoff, J.E., Shellie K.C., Mangan R.L., and Capoyleas V**. On the area of** **the intersection of disks in the plane.** Computational Geometry, Volume 6, Number 6, November **1996;** pp. 393- 396(4).

Lahoz-Beltra, R, Hameroff, S.R., and Dayhoff, J.E**. Connection weights based on molecular mechanisms** **in Aplysia neuron synapses,** Neurocomputing, Vol 11, 2, 1 June **1996;** pp. 179-202.

Penrose R, Hameroff SR.  **What Gaps?** **Reply** to Grush and Churchland. Journal of Consciousness Studies, **1995;** 2(2):99-112. [PhilPapers](https://philpapers.org/rec/PENWGR)

Hameroff SR, Penrose R. **Orchestrated reduction of quantum coherence in brain microtubules: a model** **for consciousness?** Neural Network World, **1995;** 5:793-804. [link](https://www.scopus.com/record/display.uri?eid=2-s2.0-0029180357&origin=inward&txGid=0d6fa827ef1baa9f3721abb93e58cfa1)

Tuszynski JA, Hameroff SR, Sataric MV, Trpisová B, and Nip MLA. **Ferroelectric behavior in microtubule dipole lattices: implications for information processing, signaling and assembly/disassembly**. Journal of Theoretical Biology, **1995;** 174:371-380. [link](https://www.sciencedirect.com/science/article/pii/S0022519385701051)

Jibu, M., Hagan, S., Pribram, K., Hameroff, S.R., and Yasue, K. **Quantum optical coherence in cytoskeletal** **microtubules: implications for brain function.** BioSystems, **1994;** 32:195-209.  [link](https://www.ncbi.nlm.nih.gov/pubmed/7919117)

Hameroff SR. **“Quantum coherence in microtubules: A neural basis for emergent consciousness?”** Journal of Consciousness Studies, **1994;** 1(1):91-118. [link](https://pdfs.semanticscholar.org/8cca/d4d7d9e9a813cfdcd694d3ab36f1c941e9dc.pdf)

Dayhoff JE, Hameroff SR, Swenberg CE, Lahoz-Beltra R. **Cytoskeletal involvement in neuronal learning: a review.** Eur Biophys J, **1994;** 23:79-93. [link](https://www.academia.edu/18387580/Cytoskeletal_involvement_in_neuronal_learning_a_review)

Koruga D, Simic-Krstic J, Trifunovic M, Jankovic S, Hameroff S, Withers JC, Loutfy RO.  **“Imaging** **fullerene C60 with atomic resolution using a scanning tunneling microscope.”** Fullerene Sci Tech, **1993;** 1(1):93-100.

Hameroff SR, Dayhoff JE, Lahoz-Beltra R, Samsonovich AV, Rasmussen S.  **Conformational automata in** **the cytoskeleton: Models for molecular computation.** IEEE Computer, Nov. **1992;** 25(11):30-39. [link](https://arizona.pure.elsevier.com/en/publications/models-for-molecular-computation-conformational-automata-in-the-c)

Hameroff S, Dayhoff J, Koruga D.  **Cytoskeletal conformational automata: intra-neuronal support of** **neural networks.** Systems, Man and Cybernetics. IEEE International Conference on 18-21 Oct **1992;** 1:84-88.

Dayhoff JE, Hameroff SR, Lahoz-Beltra R, Swenberg C. **Intracellular mechanisms in neuronal learning:** **adaptive models.** Neural Networks. International Joint Conference on IJCNN, 7-11 June **1992.**

Dayhoff JE, Hameroff SR, Swenberg C, Lahoz-Beltra R, Samsonovich A. **Biological learning with** **cytoskeletal signaling Neural Networks.** International Joint Conference on IJCNN. **1992;** 7-11 June 2:45-50.

Hotani H, Lahoz-Beltra R, Combs B, Hameroff SR, Rasmussen S. **Microtubule dynamics, liposomes and** **artificial cells: in vitro observation and cellular automata simulation of microtubule assembly/disassembly and membrane morphogenesis.** Nanobiology, **1992;** 1(1):61-74.

Samsonovich A, Scott A, Hameroff SR.  **Acousto-conformational transitions in cytoskeletal microtubules: implications for intracellular information processing.** Nanobiology, **1992;** 1:457-468.

Vernetti LA, Nowlin CLA, Hameroff SR, Gandolfi AJ, Lee, YC, Sarid D**. Scanning tunneling microscopy resolution of surface features on cytokeratin protein is enhanced by prolonged exposure of protein to cold temperatures.** Journal of Vacuum Science & Technology B: Microelectronics and Nanometer Structures. March **1991.**

Navabi M, Watt RC, Miller K, Mylrea K, Hameroff SR. **Integrated monitoring SMART alarms can recognize critical events and reduce false alarms**. J Clin Mon, **1991;** 16(4):295-306.

Hameroff SR, Simic-Krstic Y, Vernetti L, Lee YC, Sarid D, Wiedmann J, Elings V, Kjoller K, McCuskey R.  **STM of cytoskeletal proteins: Microtubules and intermediate filaments**. J Vac Sci A, **1990;** 8(1):687- 691.

Rasmussen S, Karampurwala H, Vaidyanath R, Jensen K, Hameroff S.  **Computational connectionism within neurons: a model of cytoskeletal automata subserving neural networks**. Physica D, **1990**; 42:428-449.

Hameroff SR, Simic-Krstic Y Jovana, Kelley Murray F, Voelker Mark A, He Jackson D, Dereniak EL, McCuskey Robert S, Schneiker Conrad W. **Scanning tunneling microscopy of biopolymers: Conditions for microtubule stabilization**, Journal of Vacuum Science & Technology A: Vacuum, Surfaces, and Films, July, **1989.**

Simic-Krstic Y, Kelley M, Schneiker C, Krasovich M, McCuskey R, Koruga D, Hameroff S.  **Direct** **observation of microtubules with the scanning tunneling microscope.** FASEB Journal, **1989;** 3:2184-2188. [link](https://www.ncbi.nlm.nih.gov/pubmed/?term=Direct+observation+of+microtubules+with+the+scanning+tunneling+microscope.)

Watt RC, Hameroff SR. **Phase space electroencephalography (EEG): a new mode of intraoperative EEG** **analysis.** Int. J. Clin. Monit. Comput. **1988;** 5, 3–13.  [link](https://www.ncbi.nlm.nih.gov/pubmed/3351372)

Voelker MA, Hameroff SR, He JD, Dereniak EL, McCuskey RS, Schneiker CW, Chvapil TA, Bell L S, Weiss LB. **STM imaging of molecular collagen and phospholipid membranes**. Journal of Microscopy, **1988;** 152, 2, 1:557- 566(10) [link](https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1365-2818.1988.tb01421.x)

Schneiker Conrad, Hameroff Stuart, Voelker Mark, He Jackson, Dereniak Eustace, McCuskey Robert.  **Scanning tunnelling engineering**, Journal of Microscopy, Volume 152, Number 2, 1 November **1988;** 585-596(12).  [link](https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1365-2818.1988.tb01424.x)

Hameroff SR, Smith SA, Watt RC. **Automaton model of dynamic organization in microtubules**. Annals of the New York Academy of Sciences, **1986**; 446:949-952.  [link](https://www.ncbi.nlm.nih.gov/pubmed/3460465)

Pierce PA, Mylrea KC, Watt RC, Hameroff SR, Cork RV, Calkins JM**.** [**Effects of pulse duration on neuromuscular blockade monitoring: implications for supramaximal stimulation.**](http://www.ncbi.nlm.nih.gov/pubmed/3489078) J Clin Monit. **1986;** Jul;2(3):169-73. [link](https://www.ncbi.nlm.nih.gov/pubmed/3489078)

Mylrea, KC, Hameroff SR, Calkins JM, Blitt CD, Humphrey LL**.** [**Evaluation of peripheral nerve stimulators and relationship to possible errors in assessing neuromuscular blockade.**](http://www.ncbi.nlm.nih.gov/pubmed/6324617) Anesthesiology, **1984;**  May;60(5):464-6.  [link](https://www.ncbi.nlm.nih.gov/pubmed/6324617)

Smith S, Watt RC, Hameroff SR. **Cellular automata in cytoskeletal lattice proteins.** Physica D, **1984;** 10: l68-l74. [link](https://www.sciencedirect.com/science/article/pii/0167278984902598?via%3Dihub)

Fukui T, Hameroff SR, Gandolfi AJ.  **Alpha-l-acid glycoprotein and beta-endorphin alterations in chronic pain patients.** Anesthesiology, **1984;** 60:494-496. [link](https://www.ncbi.nlm.nih.gov/pubmed/6324618)

Hameroff SR, Weiss JL, Leman JC, Cork RC, Watts KS, Crago, BR, Neuman CP, Womble JR, Davis TP. **Doxepin's effects on chronic pain and depression: a controlled study**. J Clin Psychiatry, **1984;** 45 (3 sec 2):47-52. [link](https://www.ncbi.nlm.nih.gov/pubmed/6321454)

Cork RC, Weiss JL, Hameroff SR, Bentley J. **Fentanyl preloading for rapid sequence induction of anesthesia.** Anesthesia and Analgesia; **1984;** 63:60-64. [link](https://www.ncbi.nlm.nih.gov/pubmed/6318605)

Misiaszek J, Cork RC, Hameroff SR, Finley JF. **The effect of electroconvulsive therapy on plasma beta-endorphin.** Biological Psychiatry **1984;** l9:45l-455. [link](https://www.ncbi.nlm.nih.gov/pubmed/6326868)

Quan SF, Calkins JM, Waterson CK, Conahan TJ, Hameroff SR, Otto CW. **Airway movement in dogs** **during high-frequency jet ventilation**. Crit Care Med. **1984;** May;12(5):452-6. [link](https://www.ncbi.nlm.nih.gov/pubmed/6370601)

Otto CW, Quan SF, Calkins JM, Waterson CK, Hameroff SR. **Mean Airway pressure and hemodynamic** **effects**, Anesthesiology. **1984;** Jan;60(1)74-5. [link](https://www.ncbi.nlm.nih.gov/pubmed/6691600)

Hameroff SR**.** [**Opiate receptor pharmacology: mixed agonist/antagonist narcotics**](http://www.ncbi.nlm.nih.gov/pubmed/6136392). Contemp Anesth Pract. **1983;** 7:27-43. Review. [link](https://www.ncbi.nlm.nih.gov/pubmed/6136392)

Otto CW, Quan SF, Conahan TJ, Calkins JM, Waterson CK, Hameroff SR. **Hemodynamic effects of high** **frequency jet ventilation.** Anesthesia and Analgesia **1983;** 62:(3) 298-304.

Quan SF, Otto CW, Calkins JC, Hameroff SR, Conahan TJ, Waterson CK.  **High-frequency ventilation—a** **promising new method of ventilation.** Heart Lung, **1983;** Mar;12(2):152-5. [link](https://www.ncbi.nlm.nih.gov/pubmed/6337981)

Hameroff SR, Watt RC. **Do anesthetics act by altering electron mobility**? Anesthesia and Analgesia, **1983;** 62:936-940. [link](https://www.ncbi.nlm.nih.gov/pubmed/6614526)

Davis TP, Veggeberg SK, Hameroff SR, & Watts KL. **Sensitive and quantitative determination of plasma doxepin and desmethyldoxepin in chronic pain patients by gas chromatography and mass** **spectrometry.** J Chromatogr. **1983;** Apr 8;273(2):436-41.100. [link](https://www.ncbi.nlm.nih.gov/pubmed/6863457)

Hameroff SR, Otto CW, Kanel J, Weinstein PR, Blitt CD. **Acute cardiovascular effects of dimethyl sulfoxide.** Ann N Y Acad Sci. **1983;** 411:94-9.  [link](https://www.ncbi.nlm.nih.gov/pubmed/6576725)

Calkins JM, Waterson CK, Hameroff SR. **Jet pulse characteristics in high frequency ventilation.** Anesthesia and Analgesia; **1982;** 6l:293-300. [link](https://www.ncbi.nlm.nih.gov/pubmed/6802031)

Hameroff SR, Watt RC. **Information processing in microtubules.** J Theor Biol, **1982;** 98:549-56l. [link](file:///Users/abimontefiore/Downloads/informationprocessing_hameroff_1982.pdf)

Hameroff, S. R.; Watt, R. C.; Borel, J. D.; Carlson, G.  **General anesthetics directly inhibit electron mobility: Dipole dispersion theory of anesthetic action**. Physiol. Chem. Phys., **1982;**14, 183–187. [link](https://arizona.pure.elsevier.com/en/publications/general-anesthetics-directly-inhibit-electron-mobility-dipole-dis)

Hameroff SR, Waterson CK, Calkins JM, Kanel JS. **High frequency alternating lung ventilation.** Anesthesiology; **1981;** 54:237-239. [link](https://www.ncbi.nlm.nih.gov/pubmed/6781383)

Hameroff SR, Carlson GC, Brown, Jr BR. **Ilioinguinal** pain syndrome. Pain, **1981;** l0:253-257  [link](https://www.ncbi.nlm.nih.gov/pubmed/7267142)

Hameroff SR, Crago BR, Blitt CD, Womble J, Kanel JS. **Comparison of bupivacaine, etidocaine, saline for trigger-point therapy.** Anesthesia and Analgesia **1981**; 60:752-755.

Blitt CD, Carlson GL, Rolling GD, Hameroff SR, Otto CW. **A comparative evaluation of pretreatment with** **nondepolarizing neuromuscular blockers prior to the administration of succinylcholine.** Anesthesiology. **1981;**Dec;55(6):687-9. [link](http://www.ncbi.nlm.nih.gov/pubmed/6458224)

Hameroff SR, Otto CW, Kanel J, Weinstein PR, Blitt CD. **Acute cardiovascular** [**effects of dimethyl sulfoxide.**](http://www.ncbi.nlm.nih.gov/pubmed/7318458) Crit Car Med.**1981;**Dec;9(12):855-7. [link](https://www.ncbi.nlm.nih.gov/pubmed/7318458)

Bentley JV, Hameroff SR. **Diffuse reflex sympathetic dystroph**y. Anesthesiology, **1980**; 53:256-257.

Stiffel P, Hameroff SR. Blitt CD and Cork R. **Variability in assessment of neuromuscular blockade.** Anesthesiology, **1980;** 52:436-437. [link](https://arizona.pure.elsevier.com/en/publications/variability-in-assessment-of-neuromuscular-blockade)

Reynolds AF Jr, Hameroff SR. Blitt CD, Roberts WL. **Spinal subdural epiarachnoid hematoma: a complication of a novel epidural blood patch technique**. Anesth Analg. **1980;** Sep;59(9):702-3. [link](https://www.ncbi.nlm.nih.gov/pubmed/7191232)

Stiffel P, Hameroff SR. **A modified technique for transtracheal anesthesia**. Anesthesiology, **1979;** 5l: 274-275.

Chvapil M, Hameroff SR. O'Dea K, Peacock EE**. Local anesthetics and wound healing**. Journal of Surgical Research, **1979;** 27:367-37l.

Hameroff SR. Ch’i: A neural hologram? **Microtubules, bioholography and acupuncture**. American Journal of Chinese Medicine, **1974;** 2(2):163-170. [link](file:///Users/abimontefiore/Downloads/chi_hameroff_1974.pdf)

**Grants/Awards**

2021 Alvin J. Clark Foundation for Science & Roger Penrose conference

2021 Mani Bhaumik for Science & Roger Penrose conference

2021 Eugene Zhong Family Foundation - CCS Educational grant (Tom Bever) $75,000

2020 Templeton World Charity Foundation – Experiments to test Orch OR theory

(through University of Alberta) $230,000

2020 Fetzer Institute – The Science of Consciousness Online conference $50,000

2020 Templeton World Charity Foundation – Testing Orch OR Quantum Theory of Consciousness

– conference 40,000

2020 Fetzer Institute – Testing Orch OR Theory of Consciousness $18,500

2020 Vielight – The Science of Consciousness Online conference $5,000

2020 Crowdfundng (Jay Sanguinetti) Transcranial ultrasound $68,000

2020 Alvin J. Clark Foundation – The Science of Consciousness Online Conference $10,550

2020 Eugene Zhong Family Foundation - CCS Educational grant (Tom Bever) $45,000

2020 Dennis Balson – TSC Conference $3,000

2020 Facilitating mindfulness training - TUS– with Jay Sanguinetti, Shinzen Young, J Allen,

Stuart Hameroff $68,000 – crowdfunding

2020 Sonication enhanced mindfulness acquisition, Atlantic Foundation, with Jay Sanguinetti,

S. Young $50,000

2019 Anonymous – TSC 2020 Conference $10,000

2019 Default mode network ultrasonic neuromodulation, Atlantic Foundation with J. Sanguinetti,

JA Allen $150,000

2019 Interlaken TSC Sponsors Alvin Clark and Mani Bhaumik $20,000

2018 Penrose Institute – Treating mental and cognitive disorders with Transcranial Ultrasound

(TUS), Penrose Foundation, CCS, S. Hameroff and J. Sanguinetti $150,000

2018 Univ. of Michigan CCS (George Mashour) – TSC Conference - $45,000

2018 Ron Gruber – TSC Conference - $500

2018 Alvin J. Clark Foundation – TSC Conference - $10,000

2018 Dennis Balson – TSC Conference $1500

2017 Mani Bhaumik – TSC Conference $10,000

2017 Alvin Clark – TSC Conference $10,000

2016 Center for Consciousness Science, U Michigan –TSC Conference Co-Sponsor $40,000

2016 Alvin J. Clark Foundation – TSC Conference - $10,000

2016 Dennis Balson – TSC Conference $1000

2016 Ron Gruber - TSC-Conference $500

2016 YeTaDel Foundation – TSC Conference $1000

2016 Mani Bhaumik – TSC Conference $10,000

2014 Mani Bhaumik - Toward a Science of Consciousness TSC-20th Anniversary

Conference Penrose Prize $10,000

2014 YeTaDel Foundation – TSC Conference $2500

2013-4 Transcranial ultrasound for mood enhancement, Thync/Neurotrek, with JA Allen,

J. Sanguinetti, Hameroff $89,998

2012 Monroe Institute – TSC Conference $5000

2012 David Benjamin Publishing– TSC Conference $1000

2011 Elata Inc – TSC Conference – $1000

2011 Chapman University – TSC Conference $2000

2011 Rustum Roy Award, Chopra Foundation $75,000

2011 Institute of Noetic Sciences, TUS Pilot Study $5,000

2011 USAF-AFOSR - 2011 TSC-Stockholm Conference, European Office; Asian Office of

Aerospace R&D $23,000

2009 Anonymous – TSC Conference $10,000

2009 Neti Neti – TSC Conference $10,000

2007 YeTaDeL Foundation Award for Quantum Approaches to Consciousness – TSC

Conference $13,5000

2003 Samueli Foundation Award for 2003 Quantum Mind conference $20,000

1998- Fetzer Institute Award to establish the Center for Consciousness Studies at the University

2001 of Arizona $1.4 million

1990-9 National Science Foundation (NSF) Nonlinear dynamics: Solitons in biomolecules (Co-PI

Alwyn Scott) $40,000

1982 Pfizer-Roerig Pharmaceuticals: Effects of the antidepressant doxepin in chronic pain $30,000

1996-2014 Woodward White Independent Survey, US Pacific Region, Best Doctors in America,

*(Neuroanesthesia)*

**Presentations, Press, Podcasts, Film**

Short list - see below Long list – see PDF

**Podcasts from Brian Keating, UC San Diego 2022**

Sir Roger Penrose & Stuart Hameroff: What is Consciousness? Part 1

<https://www.youtube.com/watch?v=DaXkyxTZB58>

# Sir Roger Penrose & Stuart Hameroff: Collapsing a theory of quantum consciousness? Part 2

<https://www.youtube.com/watch?v=OoDi856wLPM>

Penrose, Sir Roger and Hameroff, Stuart. Presentation. Consciousness and the Physics of the Brain.  [**The Qualcomm Institute**](https://www.youtube.com/channel/UCXtSt_iCM8XMy0Z-B2w9LSg)**.** Sanford Consortium for Regenerative Medicine - Roth Auditorium - La Jolla, CA. **January 10, 2020.** <https://www.youtube.com/watch?v=xGbgDf4HCHU>

Hameroff, S. Presentation.Anesthesia, Consciousness, Bohm and Penrose (EmQM17), **University of London, UK** – posted Oct 2020 - Emergent Quantum Mechanics **October 26-28, 2017** –Towards Ontology of Quantum Mechanics and the Conscious Agent, David Bohm Centennial Symposium, 4th International Symposium on Quantum Mechanics based on a “Deeper Level Theory”, Sponsored by Fetzer Franklin Fund.

<https://www.youtube.com/watch?v=xGbgDf4HCHU>

<https://emqm17.org/presentations/Stuart-Hameroff/>

* [**http://en.wikipedia.org/wiki/Stuart\_Hameroff**](http://en.wikipedia.org/wiki/Stuart_Hameroff)

Note: Hameroff, S **(2019).** The Microtubule Quantum Vibration Theory of Anesthetic Action, Invited update to Wikipedia page ‘Theories of General Anesthetic Action’

Hameroff, S. Presentation. Is Your Brain Really a Computer? Sand Conference, **2019.** <https://www.youtube.com/watch?v=mrdkNeXUfGg>

Hameroff, S. The Science of Consciousness. Presentation. Sand Conference **2019.**

<https://www.youtube.com/watch?v=JHg-mr4aqWk&t=162s>

Hameroff, S. What is Consciousness? Interview by Robert Lawrence Kuhn. **Closer to Truth,** **PBS** April**,** **2014**. <https://www.youtube.com/watch?v=UhAVbX3K5Q4>

# Hameroff, S Anesthetic action links consciousness to quantum vibrations. **CalTech.** **June 11,** **2018.** <https://www.youtube.com/watch?v=VG8_hlnFdWM>

Hameroff, S. Quantum Consciousness. Interview with Robert Wright. **The Wright Show.** Meaning of Life.tv. **June 2018** <https://www.youtube.com/watch/Rnx4vf9eeWE>

Hameroff, S. What is a theory of consciousness for? **Sand Conference, 2018.**

<https://www.youtube.com/watch?v=h89zweg_AuE>; Hameroff, S. A Brief History of the Study of Consciousness. **Sand Conference 2015.** <https://www.youtube.com/watch/hKAVgq99o_w>

Hameroff, S. Physics of free will. Interview by Robert Lawrence Kuhn. **Closer to Truth, PBS.** **April 2014.** <https://www.youtube.com/watch?v=ztGNznlowic>

Hameroff, S. How Do Human Brains Function?Interview by Robert Lawrence Kuhn. **Closer to Truth, PBS. April 2014.** <https://www.youtube.com/watch?v=cJtYElOI75k>

Hameroff, S. Microtubules and quantum consciousness. **GF 2045 Initiative. Global Future 2nd International Congress. June, 2013. Alice Tully Hall. Lincoln Center**.

<https://www.youtube.com/watch?v=R5DqX9vDcOM>

<https://phys.org/news/2013-08-world-itskov-futurists-convene-gf2045_1.html>

Hameroff, S. Consciousness is more than computation. Interview with Nikola Danaylov. **September 2013.** **Singularity Weblog.** <https://www.youtube.com/watch?v=YpUVot-4GPM>

Hameroff, S. Presentation. The Future of Consciousness. TEDx Tucson. **December 2012.** <https://www.youtube.com/watch?v=1d5RetvkkuQ>

Hameroff, S. How quantum brain biology can save the world TEDx Brussels **2010** <https://www.youtube.com/watch?v=iIyEjh6ef_8>

**Additional Links:**

* <http://en.wikipedia.org/wiki/Stuart_Hameroff>

Note: Hameroff, S **(2019).** The Microtubule Quantum Vibration Theory of Anesthetic Action, Invited update to Wikipedia page ‘Theories of General Anesthetic Action’

**Websites:**

* [www.hameroff.arizona.edu](http://www.hameroff.arizona.edu)
* [www.quantumconsciousness.org](http://www.quantumconsciousness.org/)
* [www.consciousness.arizona.edu](http://www.consciousness.arizona.edu/)

#### [YouTube - The Science of Consciousness - TSC Conferences - Videos](https://www.youtube.com/channel/UCoNDcpkKXg2UioJKxTZI-ZA/videos)

**Databases**

[**PUB MED NIH**](https://pubmed.ncbi.nlm.nih.gov/?term=Hameroff%5bAuthor%5d&cmd=DetailsSearch)

[**ScienceDirect.com**](https://www.sciencedirect.com/)

[**Frontiers**](https://loop.frontiersin.org/people/1638840/overview)

[**Google Scholar**](https://scholar.google.com/scholar?hl=en&as_sdt=0%2C3&q=stuart+hameroff&btnG=)

[**Wikipedia**](https://en.wikipedia.org/wiki/Stuart_Hameroff)

**CV, Bio Sketch, Publications & Media Lists**

[**Bio/CV**](https://live-azs-hameroff.pantheonsite.io/profile/bio)

**Websites | Databases**

**TSC Conferences, Quantum Mind**

1991 NATO Advanced Workshop: Coherence in Bioenergetic Systems - Tucson, Arizona

1994 Toward a Science of Consciousness (“TSC 1”) Apr 12-17 - Tucson, Arizona

1995 Toward a Science of Consciousness (“TSC 2”) Naples, Ischia, Italy (Chloe Taddei-Ferretti)

1996 Toward a Science of Consciousness (“TSC 3”) Apr 8-13 - Tucson, Arizona

1997 Toward a Science of Consciousness (“TSC 4”) Aug 18-24 - Elsinore, Denmark (Alwyn Scott)

1998 Toward a Science of Consciousness (“TSC 5”) Apr 27- May 2 - Tucson, Arizona

1999 Toward a Science of Consciousness (“TSC 6”) May 28 - Tokyo, Japan (Kunio Yasue, Mari Jibu)

1999 Quantum Mind 1 August - Flagstaff AZ

2000 Toward a Science of Consciousness (“TSC 7”) Apr 10-15 - Tucson, Arizona

2001 Toward a Science of Consciousness (“TSC 8”) Aug 6-11 - Skövde, Sweden (Paavo Pylkkanen)

2002 Toward a Science of Consciousness (“TSC 9”) Apr 8-12 - Tucson, Arizona

2003 Toward a Science of Consciousness (“TSC 10”) July 6-10 - Prague, Czech Republic (Ivan Havel)

2003 Quantum Mind 2 Mar 15-19 - Tucson, Arizona

2004 Toward a Science of Consciousness (“TSC 11”) Apr 7-11 - Tucson, Arizona

2005 Toward a Science of Consciousness (“TSC 12”) Aug 17-20 - Copenhagen, Denmark

(Morten Overgaard)

2006 Toward a Science of Consciousness (“TSC 13”) Apr 4-8 - Tucson, Arizona

2007 Quantum Mind 3 July 17-20 - Salzburg, Austria (Gustav Bernroider)

2007 Toward a Science of Consciousness (“TSC 14”) July 23-27 - Budapest, Hungary (George Kampis)

2008 Toward a Science of Consciousness (“TSC 15”) Apr 8-12 - Tucson, Arizona

2009 Toward a Science of Consciousness (“TSC 16”) June 11-14 - Hong Kong, China (Gino Yu)

2010 Toward a Science of Consciousness (“TSC 17”) Apr 12-17 - Tucson, Arizona

2011 Toward a Science of Consciousness (“TSC 18”) May 2-8 - Stockholm, Sweden (Christer Perfjell)

2012 Toward a Science of Consciousness (“TSC 19”) Apr 9-14 -Tucson, Arizona

2013 Toward a Science of Consciousness (“TSC 20”) Mar 3-9 - Agra, India (PS Satsangi, Vishal Sahni)

2014 Toward a Science of Consciousness (“TSC 21”) Apr 21-26 -Tucson, Arizona

2015 Toward a Science of Consciousness (“TSC 22”) June 9-13 - Helsinki, Finland (Paaavo Pylkkanen)

2016 The Science of Consciousness (“TSC 23”) Apr 25-30 - Tucson, Arizona

2017 The Science of Consciousness (“TSC 24”) June 5-10 - San Diego, California

2018 The Science of Consciousness (“TSC 25”) Apr 2-7 - Tucson, Arizona

2019 The Science of Consciousness (“TSC 26”) June 25-28 - Interlaken, Suisse

(Harald Atmanspacher)

2020 The Science of Consciousness (“TSC 27”) Sept 14-18 - Online

2021 Science and Roger Penrose (“TSC 28”) August 3-6 - Online

2022 The Science of Consciousness (“TSC 29”) April 18-23 - Tucson, Arizona

2023 The Science of Consciousness (“TSC 30”) TBA - Taormina, Sicily (Riccardo Manzotti)



#### **STUART HAMEROFF, MD**

#### **Anesthesiologist, Quantum Consciousness Theorist and Researcher**

##### ****Researcher into the nature of consciousness, the mechanism of anesthesia, and the quantum biology of microtubules****

##### ****Professor Emeritus, Departments of Anesthesiology and Psychology Banner-University Medical Center Director, The Center for Consciousness Studies, Colleges of Medicine, Science, and Social and Behavioral Sciences, The University of Arizona, Tucson, Arizona****

##### ****Curriculum Vitae CV -Sept 19, 2022****

Link to PDF

##### ****Press, Presentations, Podcasts - Long List – Sept 19, 2022****

Link to PDF

##### ****REVIEWER****

##### Anesthesiology, Anesthesia and Analgesia; Physica A; Medical Hypotheses; Bioessays; Trends in Cognitive Sciences (‘TICS’); Journal of Consciousness Studies; Progress in Biophysics and Molecular Biology; Bio-Algorithms and Med-Systems; Proceedings A Royal Societ,y, Nature Scientific Reports.

##### ****EDITORIAL BOARDS****

##### BioSystems; Journal of Consciousness Studies (Assoc. Editor)

##### ****PROFESSIONAL MEMBERSHIPS****

##### American Society of Anesthesiologists; Association of University Anesthesiologists; Society for Neuroscience; Association for the Scientific Study of Consciousness

##### ****From here on needs review****

##### ****RESEARCH INTERESTS****

##### Consciousness studies, microtubules, Penrose-Hameroff ‘Orch OR’ theory, quantum biology, molecular mechanisms of anesthetic action, multi-scale brain hierarchy, brain modulation with transcranial ultrasound.

###### **Overview**

###### **The nature of consciousness remains deeply mysterious and profoundly important, with existential, medical and spiritual implications. We know what it is like to be conscious – to have awareness, a conscious ‘mind’, but who, or what, are ‘we’ who know such things? How is the subjective nature of phenomenal experience – our ‘inner life’ - to be explained in scientific terms? What consciousness is, and how it comes about remain unknown.**

###### **The general assumption in modern science and philosophy is that consciousness emerges from complex computation among simple brain neurons, computation whose currency is usually seen as axonal firings (‘spikes’) and synaptic transmissions. These occur at the neuronal surface membrane level, and spikes are often equated with information ‘bits’ in digital computing. But this approach fails to account for phenomenal conscious experience, and relegates consciousness to epiphenomenal illusion, occurring too late for real-time conscious control of our seemingly conscious actions.**

###### **Rather than a computer of neurons, an alternative possibility is that the brain is a multi-scale hierarchy, with self-similar information patterns resonating, interfering and undergoing quantum state reductions across multiple fractal-like levels of scale, resulting in consciousness being more like music than computation.**

###### **When did consciousness arise? The brain-as-computer view presumes consciousness ‘emerged’ during biological evolution, perhaps fairly recently. On the other hand, spiritual and contemplative traditions, and scientists and philosophers embracing panpsychism, and the ‘Orch OR’ theory (see below) may consider consciousness to be intrinsic, somehow ‘woven into the fabric of the universe’, having existed all along in the fine scale structure of reality, fundamental spacetime geometry, and somehow accessible to conscious organisms. In the panpsychist/Orch OR views, conscious precursors and Platonic forms preceded life, possibly prompting its origin and driving its evolution.**

###### **CONSCIOUSNESS AND ORCH OR**

###### **I became interested in consciousness as an undergraduate, and in medical school in the early 1970s worked in a cancer lab and studied mitotic cell division. The precise separation of chromosomes and formation of dividing daughter cells were performed by mitotic spindles and centrioles, composed of self-organizing protein polymers called microtubules. Fascinated by their apparent intelligence and purposeful behavior, I wondered whether the microtubule polymer lattice processed information as a molecular computer, to organize cellular activities. If so, could this be somehow relevant to consciousness?**

###### **Following medical school I trained in anesthesiology at the University of Arizona, mentored by the department founding chairman Burnell Brown. He convinced me the best way to understand consciousness was to understand how anesthetic gases selectively block it, sparing non-conscious brain activities. In my academic career I’ve researched anesthetic action, microtubules and consciousness, as well as high frequency jet ventilation, chronic pain therapies, neuromuscular blockade, brain monitoring during anesthesia and transcranial ultrasound brain therapy. With engineer and physicist colleagues I developed models of microtubule information processing at deeper, higher capacity levels within neurons, and in the 1980s challenged mainstream ideas in neuroscience and artificial intelligence (‘AI’).**

###### **But one day someone said: “OK, there’s all this information processing in microtubules going on inside neurons. How would that explain consciousness?” I had to admit I didn’t know, but fortunately he suggested I read ‘The emperor’s new mind’ by Roger Penrose (1989), which I did.**

###### **In it, Roger proposed ‘objective reduction’, ‘OR’ self-collapse of quantum superposition due to spacetime geometry, as a solution for both the quantum measurement problem and the ‘hard problem’ of conscious experience. It was audacious and brilliant. He was suggesting a ‘quantum’ mechanism for consciousness connected to the fine scale structure of the universe but needed a quantum computer in the brain able to modulate neuronal functions. To me, microtubules fit the bill perfectly, and Roger agreed when we met. In the mid 1990s we published the Penrose-Hameroff theory of ‘orchestrated objective reduction’ (‘Orch OR’) which suggests consciousness arises from quantum vibrations ‘orchestrated’ in microtubules inside brain neurons, orchestrated vibrations which are proposed to interfere, ‘collapse’ and resonate across scale, control neuronal firings, and generate consciousness.**

###### **Orch OR was viewed skeptically, as quantum technology requires extreme cold to avoid thermal decoherence. But evidence has now shown 1) functional quantum behavior in photosynthesis proteins in sunlight, 2) coherent vibrations in microtubules at ambient temperatures in a multiscale hierarchy spanning terahertz, gigahertz, megahertz, kilohertz and hertz frequencies, 3) anesthetic action on microtubules rather than membrane proteins.**

###### **Stuart Hameroff’s research pursued microtubule information processing and anesthetic action. In the mid-1990s he teamed with eminent British physicist and Nobel Laureate Sir Roger Penrose to develop a controversial quantum theory of consciousness (‘orchestrated objective reduction’, ‘Orch OR’) based on microtubule quantum computing. Harshly criticized initially, Orch OR is now supported by experimental results including anesthetic action. In 2017, with Sir Roger Penrose, James Tagg, Ivette Fuentes and Erik Viierre, Hameroff co-founded the Penrose Institute, intended to support research based on the various works of Sir Roger (cosmology, quantum mechanics, general relativity, black holes, geometry and consciousness).**

**TESTING ORCH OR**

**For Orch OR to be feasible, microtubules would need to sustain functional quantum states spatially and temporally. Microtubules are polymers of the protein tubulin, each of which has 86 ‘aromatic’ amino acid rings (tryptophan, phenylalanine and tyrosine) of delocalized ‘pi electron’ resonance clouds. These electron clouds form non-polar (water-aversive) regions inside tubulin which are friendly to quantum-optical effects like fluorescence, phosphorescence, van der Waals coupled dipole oscillations, delayed luminescence, and superradiance. These non-polar regions are also precisely where anesthetic gases bind and act by weak, quantum interactions to selectively block consciousness.**

**To test Orch OR we set out to 1) demonstrate quantum optical states in microtubules at physiological conditions. If demonstrated, we would then 2) test effects of general anesthetics upon the microtubule quantum optical states. Failure to find quantum effects in microtubules, or, if found, determination that they were not dampened by anesthetics, would effectively ‘falsify’ Orch OR (Hameroff, 2021).**

**With funding from the Templeton World Charity Foundation (‘TWCF’; $230,000 over 2 years) program in ‘Accelerating Research in Consciousness’, Stuart Hameroff and Sir Roger Penrose convened an experimental group including Jack Tuszynski (U Alberta), Greg Scholes and Aarat Kalra (Princeton), Aristide Dogariu (Central Florida), Travis Craddock (Nova SE), and M. Bruce MacIver (Stanford). Two sets of experiments were planned and have been performed over the past two years.**

**At Princeton, Greg Scholes and Aarat Kalra studied tryptophan fluorescence lifetimes (‘TFLs’) in tubulin, and microtubules. Laser-induced optical excitations propagate far further and persist far longer through microtubules than expected. Two different anesthetics (etomidate, and isoflurane) both significantly alter TFL excitation time and distance in microtubules (Lewton, 2022).**

**In Aristide Dogariu’s lab at the University of Central Florida, brief pulses of blue light shown on microtubules and tubulin proteins resulted in apparent ‘light-trapping’, and then re-emission in a process called delayed luminescence (‘DL’), apparently mediated by quantum ‘superradiance’ (Celardo et al., 2019). Tubulin units re-emitted half the light after hundreds of milliseconds, and microtubules re-emitted after more than a second. The experiments were repeated with anesthetics etomidate and isoflurane, and also a structurally related anti-convulsant (but non-anesthetic) drug. Both anesthetics, but not the anti-convulsant shortened the DL/superradiance time.**

**Superradiance and other quantum optical effects in microtubules support Orch OR and could be essential for consciousness. We are writing up both studies and planning further experiments with anesthetics in the gas phase to look for reversibility in superradiance inhibition and compare different anesthetic potencies with their known potencies in rendering humans and animals unconscious and unresponsive. If those sets of potencies match, superradiance in microtubules would be, at least, a presumptive correlate of consciousness.**

**A NEW PARADIGM IN NEUROSCIENCE**

**Increasing evidence suggests functional aspects of consciousness and cognition operate and extend in a scale-invariant hierarchy, both 1) upward from the level of neurons to larger and larger neuronal networks and networks of networks in the brain, but also 2) downward, inward, smaller, to deeper, faster quantum processes in cytoskeletal microtubules inside neurons.**

**For the past 9 years Anirban Bandyopadhyay’s group at National Institutes of Material Sciences, in Tsukuba, Japan has found excitation and resonance in microtubules in terahertz, gigahertz, megahertz, kilohertz and hertz frequency ranges. The excitations occur in self-similar patterns which repeat every ~3 orders of magnitude as ‘triplets of triplets’, i.e., three peaks, each composed of 3 peaks.**

**The biological quantum vibrations apparently originate in terahertz quantum (van der Waals) dipole oscillations in and among aromatic amino acid rings of tryptophan, phenylalanine and tyrosine within each tubulin. This is the medium in which anesthesia acts to prevent consciousness, possibly by dampening quantum terahertz dipole oscillations.**

###### **Anirban’s group has also shown that gigahertz and megahertz oscillations in dendritic-somatic microtubules regulate axonal firings and have detected gigahertz and megahertz from the scalp within the EEG, with self-similar ‘triplet-of-triplet’ patterns.**

###### **The brain should be viewed as a scale-invariant hierarchy, with 15 orders of magnitude of activities critical to consciousness and cognition extending inward, deeper, faster into microtubules inside neurons. And further still to fundamental spacetime geometry, according to Penrose OR.**

###### **Medically, research into therapies for mental and cognitive disorders should include testbeds for quantum optical effects in microtubules.**

###### **Quantum optical pharmacology laboratory, testing effects of potential drug molecules on microtubule superradiance, quantum optics and electronic cloud dipoles. Also effects of ultrasound, and terahertz radiation. In addition to microtubules, we will study organic molecules including polyaromatic hydrocarbons, and other molecules from extraterrestrial sources through collaborations with Dante Lauretta.**

###### **CCS pioneered brain ultrasound therapy. When Anirban discovered megahertz and other frequencies in microtubules, I wondered whether ultrasound (megahertz mechanical vibrations) into the brain may be beneficial. It turned out to be safe and painless in reasonable exposure, and we performed and published the first clinical trial of transcranial ultrasound (TUS) on chronic pain and mood (Hameroff et al, 2013). I later worked with Jay Sanguinetti and John Allen in psychology on TUS (Sanguinetti et al, 2020), and hope to continue and expand clinical trials of TUS, e.g., for dementia, TBI, depression, anxiety, PTSD and addiction**

##### ****CONTACT INFORMATION****

[**hameroff@u.arizona.edu**](mailto:hameroff@u.arizona.edu)

##### ****CENTER FOR CONSCIOUSNESS STUDIES****

[**center@arizona.edu**](mailto:center@arizona.edu)

Contact:

Abi Behar Montefiore – [center@arizona.edu](mailto:center@arizona.edu) – 520-247-5785

Conference Manager; Asst. Mgr. CCS