

Consciousness: The flipside of anaesthesia

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The search for a description of how anaesthesia works and, in particular, the search for molecular mechanisms has been greatly hindered by our general ignorance of how the brain, and in particular, consciousness, actually functions. Descriptions of general anaesthesia focus almost exclusively on molecular level explanations and neglect the higher-level functions of the brain, to a greater or lesser extent.

- What do we remove when we anaesthetize someone?
- What are we fiddling with?
- Are we just keeping them still and insensible whilst a knife wielding ego works on them?

Each day at work, anaesthetists practice their art, rendering patients oblivious to the pain and trauma of surgery, and afterwards reversing this state. The advances possible led Hameroff to state that anaesthesia was perhaps the greatest invention of the last 2000 years.¹ And yet we inject these drugs, deliver these vapours without a clear idea of what we are actually removing and returning.

Research into consciousness and the development of anaesthesia as a field have progressed in parallel with little interaction. Traditionally the realm of philosophers, consciousness research has become a mainstream topic involving multidisciplinary teams of neuroscientists, philosophers, biologists, physicists, psychologists and other interested parties. Anaesthetists have generally concerned themselves with the practicalities of keeping patients unconscious for surgery without taking a very active interest in the study of consciousness, though this appears to be changing.

Consciousness – A difficult definition

The word consciousness is used in a huge number of situations, flexibly, and without a great degree of precision. It takes in awareness, self-awareness, awake, experience and many other meanings.

Searle has offered a common sense definition: “Consciousness consists of inner, qualitative, subjective states and processes of sentience or awareness.”² Three principle meanings can be distinguished.³ Consciousness as the waking state, as experience and as mind. From an anaesthetists’ perspective, the first meaning is most familiar. The dimensions of consciousness, anaesthesia, sleep and coma are present here. The second meaning takes in the fact that we are always conscious of something. Consciousness as mind, the third mean-

ing, is synonymous with awareness, or mindfulness.

Consciousness is not restricted to the human species, and investigation of both primates, other mammals and non-mammalian species have uncovered evidence of behaviours consistent with consciousness.⁴

Explaining consciousness

Descartes’ famous separation of existence into material and spiritual planes, with the spiritual one beyond the reach of science, has plagued progress in this field for many years. Only recently has it become acceptable to study consciousness neurobiologically, and attempt its explanation scientifically.

*Penrose offers four different options regarding consciousness.*⁵

- A – All thinking is computation; in particular, feelings of conscious awareness are evoked merely by the carrying out of appropriate computations
This is compatible with the strong artificial intelligence model where, given enough computing power, consciousness in computers will occur.
- B – Awareness is a feature of the brain’s physical action; and whereas any physical action can be simulated computationally, computational simulation cannot by itself evoke awareness.
This option includes “perfect” simulation of consciousness, without it actually occurring in machines.
- C – Appropriate physical action of the brain evokes awareness, but the physical action cannot even be properly simulated computationally.
Here, a requirement is set for the discovery of new physical or computational laws, before understanding of consciousness can occur.
- D – Awareness cannot be explained by physical, computational or any other scientific terms.
This option negates the possibility of any scientific description of consciousness, and includes religious or spiritual approaches.

Options A, B and C are compatible with a scientific description of consciousness.

What should a theory of consciousness be able to explain⁶

1. Range of conscious contents
2. Widespread brain effects
3. Informative conscious contents
4. Rapid adaptivity and fleetingness
5. Internal consistency
6. Limited capacity and seriality
7. Sensory binding
8. Self attribution
9. Accurate reportability
10. Subjectivity
11. Focus-Fringe structure
12. Consciousness facilitates learning
13. Stability of conscious contents
14. Allocentricity
15. Consciousness is useful for voluntary decision making
16. Involvement of the thalamocortical core

The list is long, and I will focus on five aspects in particular.

The range of experiences, memories, and contents is vast, and any theory needs to be able to explain this. Consciousness is rapidly adaptive and fleeting in its nature. The ability to switch attention from one focus to another is crucial, particularly if one views consciousness as survival tool that hu-

mans excel at. The problem of sensory binding is extensively investigated and debated, and asks how discrete sensory modalities are synthesized into a coherent perception. Subjectivity of consciousness is obvious to all of us, and forms a difficult barrier to explanation that has had some philosophers denying that consciousness is truly explicable in a scientific sense.⁷ The thalamocortical area has emerged as a crucial area of interest, given its' relay station placement in the CNS. It serves as a link between many neural systems, and much research, particularly lesion analysis, has identified it as crucial to maintaining consciousness. As most of us have seen in neurosurgery, a surprising amount of cortical damage can be done, without grossly affecting consciousness. However, a minute stroke, in midbrain or brainstem areas involving the reticular nuclei can result in coma or persistent vegetative states.⁸

Dynamic Core Hypothesis – Edelman and Tononi

The thalamocortical area serves as a link between perception and memory, and allows the creating of functional clusters of interacting neurons to be generated, a process of integration. Highlighted is the importance of re-entrant circuits in this process – “ongoing, recursive, highly parallel signaling within and among brain areas.”⁹

Additionally the system needs to have a minimum level of complexity in order to provide a sufficiently large repertoire of behaviours and actions, something present in this area and the brain in general.

In essence, groups of neurons that function as units, and interact between each other on a timescale of hundreds of milliseconds, based in the thalamocortical area, give rise to the conscious experience. Affect these neurons, however you will, and you affect consciousness.

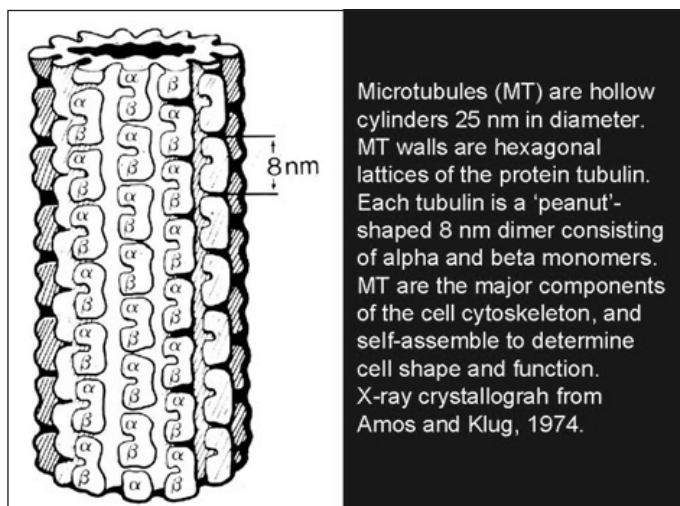
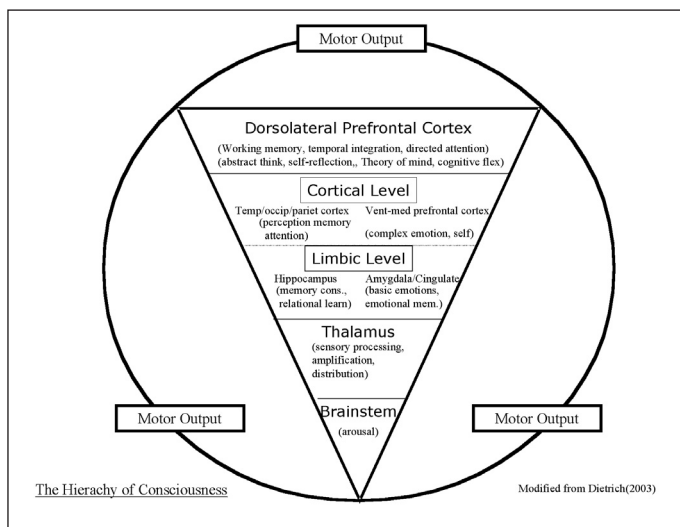
Penrose-Hameroff Quantum Computation in Microtubules

Much interest has been shown in the potentially vast increases in computational power theoretically available through the use of quantum computation. In addition, the property whereby collections of particles can blend together in a unified quantum state of real world size (Bose Einstein condensates, and lasers as examples) has been invoked to explain conscious states. Do specific quantum mechanical processes have a role in the generation of consciousness and anaesthesia? Penrose and Hameroff have advanced a theory based on these ideas.^{1,10}

Tubulin subunits in the microtubules composing the cytoskeleton are theorised to be able to switch conformational states via London dispersion forces, and, because of the quantum nature of these forces, the subunits can act as quantum q-bits in a distributed array of cytoskeletal proteins throughout the cell. Gap junctions may even be able to allow intercellular propagation of these quantum processes.

Functional macroscopic quantum states in the brain may be able to explain some of the enigmatic features of consciousness but suffer from some serious physical problems including rapid decoherence at body temperature.

The theoretic attraction of quantum computation and macroscopic quantum properties in the brain is real, but do we really need to invoke these sorts of explanations at this stage?



Anaesthesia and Consciousness

During the past ten years, progress in understanding how the brain functions has been rapid. This has been facilitated by several powerful technologies including functional MRI, computer-assisted EEG analysis and PET scanning. These technologies are beginning to be applied to the anaesthetised state and give us clues as to how anaesthetics work. Variations in the localization of agents are being shown, and, tied to knowledge of receptor density data, suggest differing actions for agents currently considered similar.¹¹

The integrated function of the brain involves complex interactions between consciousness, memory, emotion, cognition and perception. Anaesthetics have diverse effects on these aspects of brain functioning, and detailed knowledge of these interactions would open new avenues for research and improve anaesthesia.

Many theories of consciousness have been put forward, and many have quietly vanished. The current neurobiological approach is beginning to show promise, and once we have a clearer understanding of consciousness and its function, the mystery of how anaesthesia occurs will be solved.

References

1. *Hameroff S: Anesthesia: the "other side" of consciousness. Conscious.Cogn 2001; 10: 217-29.*
2. *Searle JR: Consciousness. Annu.Rev.Neurosci. 2000; 23: 557-78.*
3. *Zeman A: Consciousness. Brain 2001; 124: 1263-89.*
4. *Edelman DB, Baars BJ, Seth AK: Identifying hallmarks of consciousness in non-mammalian species. Conscious.Cogn 2005.*
5. *Penrose R: Shadows of the Mind. London, Vintage, 1995.*
6. *Seth AK, Baars BJ: Neural Darwinism and consciousness. Conscious.Cogn 2005.*
7. *Nagel T: "What is it like to be a bat?". Philosophical Review 1974; 83.*
8. *Dietrich A: Functional neuroanatomy of altered states of consciousness: the transient hypofrontality hypothesis. Conscious.Cogn 2003; 12: 231-56.*
9. *Tononi G, Edelman GM: Consciousness and complexity. Science 1998; 282: 1846-51.*
10. *Hameroff S, Nip A, Porter M, Tuszynski J: Conduction pathways in microtubules, biological quantum computation, and consciousness. Biosystems 2002; 64: 149-68.*
11. *Alkire MT, Haier RJ: Correlating in vivo anaesthetic effects with ex vivo receptor density data supports a GABAergic mechanism of action for propofol, but not for isoflurane. Br.J.Anaesth. 2001; 86: 618-26.* 