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Review

# Consciousness, biology and quantum hypotheses

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**Abstract**

Natural phenomena are reducible to quantum events in principle, but quantum mechanics does not always provide the best level of analysis. The many-body problem, chaotic avalanches, materials properties, biological organisms, and weather systems are better addressed at higher levels.

Animals are highly organized, goal-directed, adaptive, selectionist, information-preserving, functionally redundant, multicellular, quasi-autonomous, highly mobile, reproducing, dissipative systems that conserve many fundamental features over remarkably long periods of time at the species level. Animal brains consist of massive, layered networks of specialized signaling cells with 10,000 communication points per cell, and interacting up to 1000 Hz. Neurons begin to divide and differentiate very early in gestation, and continue to develop until middle age.

Waking brains operate far from thermodynamic equilibrium under delicate homeostatic control, making them extremely sensitive to a range of physical and chemical stimuli, highly adaptive, and able to produce a remarkable range of goal-relevant actions.

Consciousness is "a difference that makes a difference" at the level of massive neuronal interactions in the most parallel-interactive anatomical structure of the mammalian brain, the cortico-thalamic (C-T) system. Other brain structures are not established to result in direct conscious experiences, at least in humans. However, indirect extra-cortical influences on the C-T system are pervasive. Learning, brain plasticity and major life adaptations may require conscious cognition.

While brains evolved over hundreds of millions of years, and individual brains grow over months, years and decades, conscious events appear to have a duty cycle of ∼100 ms, fading after a few seconds. They can of course be refreshed by inner rehearsal, re-visualization, or attending to recurrent stimulus sources.

These very distinctive brain events are needed when animals seek out and cope with new, unpredictable and highly valued life events, such as evading predators, gathering critical information, seeking mates and hunting prey. Attentional selection of conscious events can be observed behaviorally in animals showing coordinated receptor orienting, flexible responding, alertness, emotional reactions, seeking, motivation and curiosity, as well as behavioral surprise and cortical and autonomic arousal. Brain events corresponding to attentional selection are prominent and widespread. Attention generally results in conscious experiences, which may be needed to recruit widespread processing resources in the brain.

Many neuronal processes never become conscious, such as the balance system of the inner ear. An air traveler may "see" the passenger cabin tilt downward as the plane tilts to descend for a landing. That visual experience occurs even at night, when the traveler has no external frame of spatial reference. The passenger's body tilt with respect to gravity is detected unconsciously via the hair cells of the vestibular canals, which act as liquid accelerometers. However, that sensory activity is not experienced directly.

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It only becomes conscious via vision and the body senses. The vestibular sense is therefore quite different from visual perception, which “reports” accurately to a conscious field of experience, so that we can point accurately to a bright star on a dark night. Vestibular input is also precise but unconscious.

Conscious cognition is therefore a distinct kind of brain event. Many of its features are well established, and must be accounted for by any adequate theory. No non-biological examples are known.

Penrose and Hameroff have proposed that consciousness may be viewed as a fundamental problem in quantum physics. Specifically, their ‘orchestrated objective reduction’ (Orch-OR) hypothesis posits that conscious states arise from quantum computations in the microtubules of neurons. However, a number of microtubule-associated proteins are found in both plant and animal cells (like neurons) and plants are not generally considered to be conscious.

Current quantum-level proposals do not explain the prominent empirical features of consciousness. Notably, they do not distinguish between closely matched conscious and unconscious brain events, as cognitive-biological theories must. About half of the human brain does not support conscious contents directly, yet neurons in these “unconscious” brain regions contain large numbers of microtubules.

QM phenomena are famously observer-dependent, but to the best of our knowledge it has not been shown that they require a *conscious* observer, as opposed to a particle detector. Conscious humans cannot detect quantum events “as such” without the aid of special instrumentation. Instead, we categorize the wavelengths of light into conscious sensory events that neglect their quantum mechanical properties.

In science the burden of proof is on the proposer, and this burden has not yet been met by quantum-level proposals. While in the future we may discover quantum effects that bear distinctively on conscious cognition ‘as such,’ we do not have such evidence today.


*Keywords:* Consciousness; Cognitive neuroscience; Quantum hypothesis; Philosophy of mind; Global workspace theory; Thalamocortical

## 1. Introduction

The human brain supports a variety of structures and processes that are allow us to compare “conscious version unconscious” information processing. These two kinds of brain events are strikingly different, but they interact seamlessly. Most obviously, we have the capacity to report conscious brain events, sometimes with remarkably accuracy; no such capacity exists for the half of the brain (very roughly) that does not yield direct conscious events. However, there is now a sizable body of brain and behavioral evidence that differentiates reliably between conscious and unconscious aspects of the brain [11].

Conscious events are commonly assessed by accurate reports of sensory stimuli and basic cognitive tasks, while unconscious ones are inferred when there is strong evidence for neuronal information processing without reportability [1]. While accurate report has long been used in sensory psychophysics and a variety of medical conditions (like coma and seizures), researchers constantly seek better measures. Significant progress toward better brain indices has been made in recent years [23].

Some of the most useful evidence compares closely matched conscious and unconscious brain phenomena. Binocular rivalry is one well-studied technique to compare optically identical retinal stimuli that cannot be fused into a single, consistent, conscious percept. Thus one of the two inconsistent input streams is unconscious at any given moment. At least a dozen other experimental paradigms allow for such comparisons. Theoretical ideas are therefore strongly constrained by a growing body of evidence.

A variety of brain measures converge on the conclusion that the cerebral cortex and its major input hub, the thalamus, are strongly implicated in specific conscious experiences. Damage to the thalamus and cortex impairs conscious functions, sometimes as a state (e.g., deep sleep and coma), and sometimes in specific conscious contents (blindsight, hemineglect, cortical color blindness). Thus, very small lesions in the color area of the visual cortex (area V3/V4) may abolish the conscious perception of red objects, but not their unconscious identification [31]. Similarly, damage to the first cortical map of the visual pathway (area V1) blocks conscious vision, but not unconscious or “near-unconscious” vision. Thus we see the remarkable condition of ‘blindsight,’ in which patients deny having visual experiences at all, but can still walk through a hallway without bumping into scattered chairs and tables.

Many structures outside of the human cortex and thalamus do not support moment-to-moment conscious contents, though they constantly interact with cortex. Generations of medical students have learned that the two large cerebellar