A Neurophysiological Approach to Consciousness: Integrating Molecular, Cellular and System Level Information

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Consciousness is basically a biological problem, the greatest of biology today, but with philosophical consequences. How do the dynamically interacting electrical impulse patterns in sets of neuronal networks, forming brains, cause consciousness? We are approaching this problem along different routes and at different complexity levels.

At the system level we ask which brain structures are critical for creating consciousness. This problem is approached by testing how influential consciousness theories apply to the known fine structure of evolutionary different brain types. Our analysis suggests that avian and mammalian brains share functional features in spite of being structurally different, bringing reptilian brains into focus as the evolutionary first conscious structure.

At the cellular level we ask how the impulse patterns critically change when a brain goes into an unconscious state. This problem is approached by analysing the surprisingly little understood mechanisms of general anaesthesia. The received view is that general anaesthetics mainly affect a class of membrane bound proteins, ligand-gated channels. Our analysis shows that general anaesthetics also modify voltage-gated ion channels, and that such modifications can contribute to general anaesthesia by determining the firing pattern of the neurons.

How the density of voltage-gated channels affect the firing pattern in detail is analyzed by studying a cortical model neuron. The calculations show that the oscillatory activity can be separated into several distinct channel-density dependent firing patterns. This suggests that certain general anaesthetics can contribute to general anaesthesia by inducing a switch from firing frequencies associated with conscious states to frequencies associated with sleep or unconscious states.

The validity of these results is being tested by analysing the activity of cortical neurons of a mouse strain, in which a channel type has been genetically eliminated. The results suggest that the eliminated ion channel type is involved in sculpturing the impulse patterns and in general anaesthesia.