November 2004: Vol 1: The quest for consciousness: An interview with Christof Koch by Thomas Zoëga Ramsøy

RAMSOY:
Dear Prof. Koch, in your new book entitled "The Quest for Consciousness"1 you both write an autobiography of your own and Francis Crick's scientific ideas and studies of consciousness, but you also give a comprehensive introduction to the science of visual perception and awareness. Could you please explain the basic assumptions you have proposed about consciousness?

KOCH:
1. Francis Crick and I take consciousness seriously, as a brute fact that needs to be explained. The first-person perspective, feelings, qualia, awareness, phenomenal experiences are real phenomena that arise out of certain privileged brain processes. They make up the landscape of conscious life.

2. We put aside the question at the heart of the mind-body problem---why does phenomenal experience feel like anything? For now, scientists should focus on the search for the minimal neuronal mechanisms jointly sufficient for any one specific conscious experience, the neuronal correlates of consciousness (NCC). While it remains an open question whether discovering and characterizing the NCC will be sufficient to understand the structure, function, and origin of consciousness it is a necessary step.

3. The NCC have one, or more, functions, such as planning. That is, summarizing the current state of affairs in the world and the body and presenting this concise summary to a system that contemplates diverse courses of action open to the organism. It follows as a corollary that thinking about philosophical zombies is sterile.

4. While the NCC are embedded within the brain, not all of the brain's myriad of neurons and regions contribute equally. Some will be much more important than others. Thus, our emphasis on local, particular properties of neurons rather than on more global, holistic aspects. In particular, Crick and I have argued that the firing activity of both retinal neurons and of cells in the primary visual cortex (V1) is not part of the NCC. The retina and V1 are important for many aspects of normal seeing, but the representational content of conscious visual perception does not arise from activities in these structures. This is an eminently testable hypothesis (with much supporting evidence). This shows that in regard to consciousness, true progress is possible.

RAMSØY:
But if your focus is on local processes in neurons, do you not run the risk of missing crucial events at a global scale? Consciousness might be, as some claim (e.g. Baars [2-4], Dehaene and Naccache[5], and Tononi and Edelman [6]), a global event in distributed parts of the brain. Specifically, how does such an approach relate to such global theories of consciousness in the brain?

KOCH:
The same question could also be asked about the molecular mechanisms underlying heredity. There is a loose parallel between the NCC and genes. Heredity is a property of an individual cell, much as consciousness is a property of an individual brain. One could easily argue that the mechanisms underlying inheritance of acquired properties involve the entire cell and are therefore necessarily global. Ribosomes, for instance, the machinery necessary for the synthesis of proteins from mRNA,are found throughout the cell. So, too, are many of the proteins they manufacture, such as the ionic channels that are anchored in the neuronal membrane. Incapacitating the various forms of RNA polymerase (the enzymes responsible for synthesizing the different kinds of RNA) blocks all protein synthesis globally, much as gas anesthesia knocks out a patient. Any one gene, however, encoded via its associated string of nucleic acids along the DNA molecule in the nucleus, transcribes into one or a few specific RNA molecules that are ultimately translated into proteins. This highly localized aspect of the genetic information is seemingly at odds with the fact that the synthesis or the expression of that protein occurs at many distinct locations in the cell. I believe it is likely that consciousness will also be based on such local and highly specific mechanisms, which is not to say that global properties of the brain don't play some role.

For now, scientists should focus on the search for the minimal neuronal mechanisms jointly sufficient for any one specific conscious expeience, the neuronal correlates of consciousness (NCC).

Note that by local I don't mean to imply spatial locality but that the NCC depend critically on very specific properties. An example of this may be loops of cortical pyramidal cells that are located in the highly level visual cortex (IT) and in prefrontal cortex and that are reciprocally connected by powerful excitatory synapses close to the cell body. Once activity in this loop exceeds a threshold, it may maintain itself in a reverberatory state for quite some time, and may be crucial factor for the NCC.

RAMSØY:
That should mean that it is possible to pinpoint areas of the brain that have (or not have) the potential to be part of the NCC? As you mention, V1 is not likely to have such properties. But is there a general picture? Does consciousness rely on a fixed set of modules or areas of the brain?

KOCH:
The honest answer is, of course, that we don't know. It is plausible that by dint of constant training, cortical regions previously inaccessible to consciousness will become accessible in the sense that the neuronal coalitions that constitute the NCC will now extend into these regions. This would explain how, as people mature, they can learn to introspect (know thyself) or to experience the world in a new way. At the level of

individual neurons, there is likely to be a great deal of flexibility in which neurons partake in what coalition to generate a conscious percept.

Ultimately, however, any such plasticity will be limited by the architecture and extent of the axons of projection neurons. There is now evidence from patients in the persistent vegetative state that primary auditory (A1) and primary somatosensory cortices (S1) are insufficient for sensory consciousness. That is, maybe all primary sensory cortical regions are off limit to the NCC. Francis and I think this will also hold for many regions in the frontal lobes.

RAMSØY:
The 'normal' activity of neurons in primary sensory regions in vegetative and comatose states certainly point to these areas as non-essential to the NCC. But you have gone further than that: you claim that V1, for example, is not part of the NCC due to it's connectivity, and especially since it is not directly connected to the frontal cortex (your 1995 article with Francis Crick [7]). But judging from what you just said, then this would only go for certain parts of the frontal lobes?

KOCH:
Yes, most certainly. We explicitly discuss the question of which regions of the frontal lobes are directly involved in consciousness and which one not in a long article published in Neuro-Psychoanalysis [8]. The frontal lobes account for a very large fraction of all brain tissue. Neuroanatomists distinguish 40 different regions here with a very complex interconnectivity. It is not yet clear whether the same sort ofneuroanatomical rules that give rise to the observed Felleman-Van Essen hierarchy [9-11] in the visual cortex at the back of the brain are applicable to the front of the brain. However, there is no doubt that given the observed heterogeneity in cortical regions, the essential neuronal coalitions that underlie one or the other conscious percept or memory will only be found in some of these regions but not in others. The latter ones make up what we call the Unconscious Homunculus, the parts of the brain that are involved in high-level, cognitive functions and decisions but that are not consciously accessible.

RAMSØY:
Some of these high-level functions normally ascribed to the frontal cortex, or parts of it, are processes such as working memory, social reasoning and motor planning. But you assert that some of these very intelligent processes can obviously work below the level of consciousness. This contradicts our everyday experience of agency and control of our own actions, wouldn't you say?

KOCH:
Well, yes, but we knew that at least since Benjamin Libet's seminal experiments on the readiness potential that can appear many hundreds of milliseconds before the subject became aware of wanting to initiate the action on the surface of her brain (and can be picked up by EEG electrodes). Something in her brain made the decision to lift the arm or whatever else the voluntary action consisted of and this decision was only later communicated to the stages of the brain accessible to conscious perception of agency or authorship.

Immanuel Kant had argued two centuries earlier against the possibility of a physical event occurring without a prior, physical cause that is, against the idea of a truly free will. Every scientist knows perfectly well that whenever something happens somewhere at sometime, this event has to caused by something else (or a combination of other factors; the universe is causally closed as the philosophers like to say).

Yet, of course, I perfectly well feel that I am in charge, that it is me, Christof, that decided to type this text on my laptop. That is, from a psychological point of view, my actions are not predetermined (in general, and excluding things like rage, intoxication etc). The question is what are the neuronal correlates of this conscious feeling of agency, of being in charge? What are the computational algorithms that underlying its outputs and what are the sources of information this module uses (prior intentions, sensory-motor feedback, efference copy signals and so on)? All of these are experimentally accessible questions.

The successful conclusion of my quest, identifying and understand the neuronal correlates of all aspects of consciousness, is bound to have significant consequences for ethics. They may give rise to a new conception of what it is to be human, a view that might radically contradict the traditional images that men and women have made of themselves throughout the ages.

RAMSØY:
This also points to the function of consciousness. In the free will discussion, one could ask why we should have a sense of agency at all, if it is really an after-the-fact phenomenon. Actions, if they are indeed selected and executed without our awareness, would function just the same. What function do you think that the sense of agency plays? And would you say that the sense of agency is thus an illusion of free will?

KOCH:
It is important to point out that this tension between the causal closedness of the universe---nothing from outside the universe can cause anything within it to happen---and the perceived freedom of action is a major, unresolved empirical and theoretical problem. One solution is to argue that all agency is illusory. While under laboratory condition, it can be shown that some free acts are influenced---in an unconscious manner---by previous ones, the assumed illusory nature of free will simply does not accord with our everyday experience in which I choose one course of action over another. As John Searle has remarked somewhere, I don't go to a restaurant, look at the menu, and then tell the waiter "I'm a determinist, I'll just wait and see what I order."

For those who believe that free will does not exist, the perception of agency must carry some evolutionary function. Dan Wegner has suggested that it gives the system a sense of purpose, that it will act in the world on the belief that its action can influence events. Think of the difference between an optimist, who thinks that by acting he can make a difference in the world, and a pessimist, who thinks that all is lost and nothing really makes a difference. Who will shape the future more? Surely the optimist, because he tries, even if half of the time the outcome is negative. And so it may be with the sense of freedom of action.

During the course of this online interview, Francis Crick died. He was a close personal friend and mentor to me for the past 16 years, a period during which we had an ongoing and intense, almost daily, dialogue concerning the nature of consciousness and its seat in the brain. Francis was the living incarnation of what it is to be a scholar: brilliant, rational, dispassionate, and always willing to revise his own opinions and views in light of the actions of a universe that never ceased to astonish him. He was editing a manuscript on his death bed, a scientist until the bitter end. The paper concerned itself with the possible involvement of the claustrum---a sheet like structure hidden away between the inner surface of the neocortex and the basal ganglia---in globally coordinating neural activity. Francis concludes by listing those experiments that need to be done, ending with a call to arms that could be his epitaph "What could be more important (than understanding the brain basis of consciousness)? So why wait?"

Please refer to http://www.sci-con.org/articles/20041102.html for a review of "The Quest for Consciousness" by Stuart Hameroff.

Brief Bio:
Prof. Christof Koch is the author of more than three hundred scientific papers and journal articles, and several books. He studies the biophysics of computation, and the neuronal basis of visual perception, attention, and consciousness. Together with his long-time collaborator, Francis Crick, he has pioneered the scientific study of consciousness. Prof. Koch is now head of Koch Laboratory at California Institute of Technology.