On the science of conscious brains.

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A YouTube lecture is available and an iTunes U podcast. We are working to produce an ongoing series of classroom materials on human psychology and its neural foundations.

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I hope you enjoy these newsletters.

BJB Conscious Brain Letter 1(1). The biology of consciousness.

1. The conscious brain.

To the best of our knowledge, consciousness depends upon brains, and brains are biological organs. In a boxing match a blow to the jaw often leads to a loss of consciousness, but the same impact to the torso does not. More specifically, scientists have long thought that human consciousness depends upon two large brain structures, the cortex and the thalamus. The daily cycle of waking, dreaming and sleep depends on distinctive global rhythm generators in the thalamus and cortex. (Www.baars-gage.com, Chapter 8)

While deep brain nuclei control the daily sleep-waking cycle, the specific contents of conscious vision, like the sight of a coffee cup, are directly supported by known regions of the cortex and corresponding nuclei in the thalamus. Cortex and its satellites underlie speech and hearing, vision, hearing and touch, the ability to make decisions and to control our voluntary muscles.

In contrast, medical students have long learned that the two large lobes of the cerebellum, hanging from the rear of the cortex, can be damaged in humans without impairing consciousness significantly. Since the cerebellum has nearly the same numbers of neurons as cortex, the question therefore becomes: How it is that cortex supports conscious contents? Why not the cerebellum? (Figure 1).

(Note: Other animals may not be as cortico-centric as humans seem to be.)

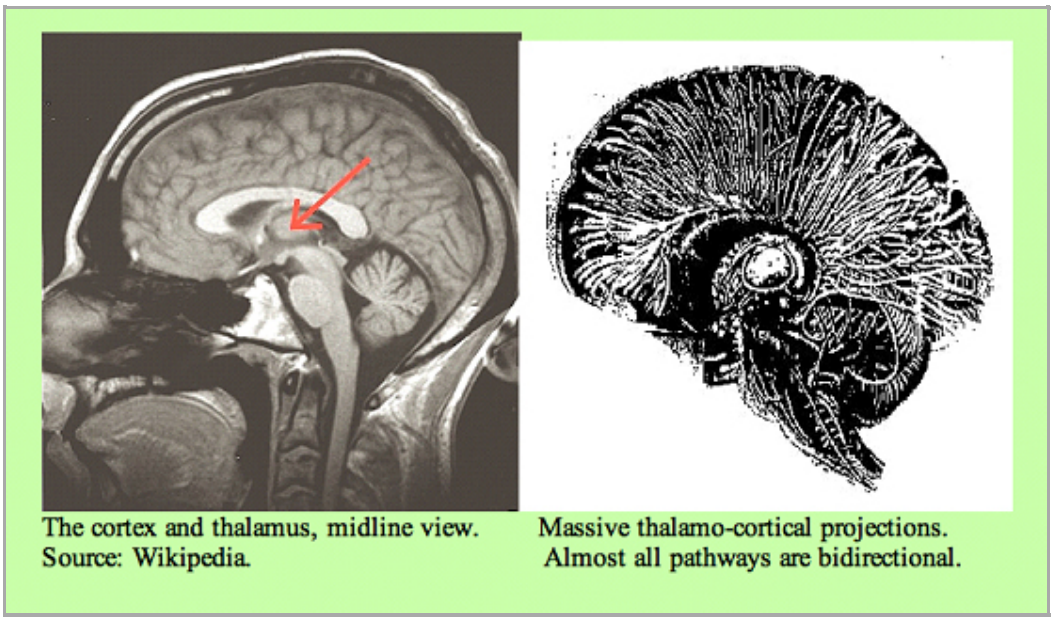
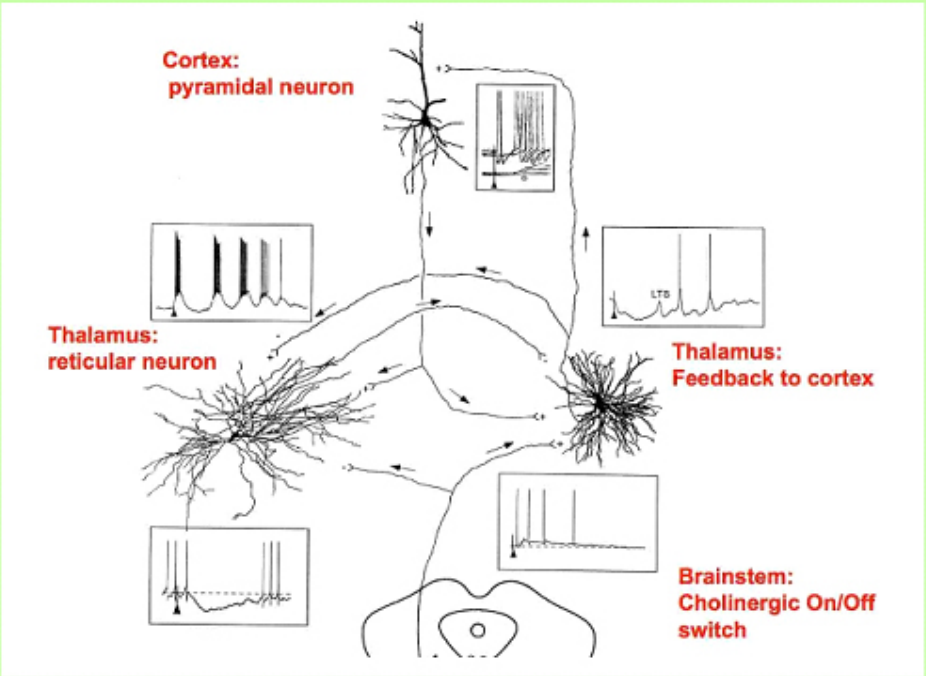


Figure 1. To the best of our knowledge, the brain basis of conscious experiences. The thalamocortical system is switched from waking to sleep and REM dreams by means of basal brain nuclei. Each state enables hundreds of changes in the expression of neuronal genes.

2. Brain rhythms.

Whether you and I are conscious seems to depend entirely on a particular oscillatory regime of the thalamus and cortex. While observable rhythms of (conscious) waking and (unconscious) sleep have been known for many years, the rhythm generators of sleep, waking and dreaming have only been worked out in the last decade or two by a number of distinguished scientists, including a Canadian group directed by Mircea Steriade and Alain Destexhe. (Figure 2).

Figure 2.



The brain's "rhythm pump" for waking consciousness, sleep and dreaming.

From B.J. Baars & N.M.Gage (2010) *Cognition, Brain & Consciousness: An Introduction to Cognitive Neuroscience.* Elsevier, Inc./Academic Press. Figure 8.6. Copyright, Elsevier, Inc., with permission.

Based on: A. Destexhe, D. Contreras & M. Steriade (1999) Cortically-induced coherence of thalamically-generated oscillations. *Neuroscience, 92* (2), 427-443.

Using implanted electrodes in human and animals, we can now see fast inter-regional signals zipping back and forth during waking and dreaming, compared to much more local and stop-and-go signal traffic in sleep and other unconscious states.

The high, regular delta waves of unconscious sleep reflect billions of neurons firing and pausing in unison every second or so. Epileptic seizures show the same massive stop-and-go activity in large parts of the cortex. Unconscious states often have this widespread stop-and-go character.

In contrast, during conscious states, signal traffic flows much more freely in the hubs and highways of the brain, in what Gerald Edelman and Giulio Tononi have called "the dynamic core." Individual conscious experiences seem to reflect moment-to-moment signaling in this dynamic core. (Baars & Gage, 2010)

3. Consciousness has an evolutionary history.

A few decades ago the Princeton psychologist Julian Jaynes speculated that consciousness is a recent phenomenon — just a few thousand years old. Jaynes thought so based on a difference between the language of Homer's Illiad and the Odyssey. In the Odyssey, he claimed, the voices of the gods are perceived to come from the outside world. In the Illiad, on the other hand, the gods are thought to speak inside of the heroes' heads.

But fully formed language is now believed to date back some 50,000 to 100,000 years, and as for consciousness, at least sensory consciousness seems to be much, much more ancient. Hemispheric lateralization such as we find in language can be observed in guinea pigs and song birds. The hoped-for "language gene" of FOXP2 is known to exist in alligators. Human cognitive faculties are spun off from much more ancient adaptations.

Humans are not the sole possessors of the core thalamocortical brain. We share it with all mammals, going back to the earliest ones some 200 million years ago.

The characteristic rhythm pumps of the T-C (thalamocortical) system are therefore shared with cats and dogs, with mice and the duck-billed platypus — and perhaps earlier. In the words of Edelman and Tononi, from a brain point of view we may be living in "a universe of consciousness." If true, that idea throws an extraordinary new light on the biosphere.

That is not to say that tree shrews have "higher level consciousness" (Edelman, 1989), which is heavily dependent on language, executive and social functions, the brain bases of human culture. Other mammals share our sensorimotor cortex and thalamus, but relatively smaller frontal lobes.

Nonetheless, primates like macaques are routinely studied for insights into human visual consciousness, because our visual brains seem so similar. We will look at this scientific literature in a forthcoming issue.

Like other major life functions, consciousness has an evolutionary history.

4. Consciousness in other species.

Philosophers like Gilbert Ryle and Ludwig Wittgenstein warned that we can't even be sure that other humans are conscious, but these basic biological links suggest otherwise. If all humans share the same basic brain anatomy, physiology, and behavioral functions, chances are that you and I are not lone conscious beings in a solipsistic universe. Nor is it likely that consciousness is "epiphenomenal" — that it has no biological or psychological function at all. After all, how many bodily functions play no biological role? The Darwinian answer has to be: probably none. Without survival and reproductive benefits no major function can last.

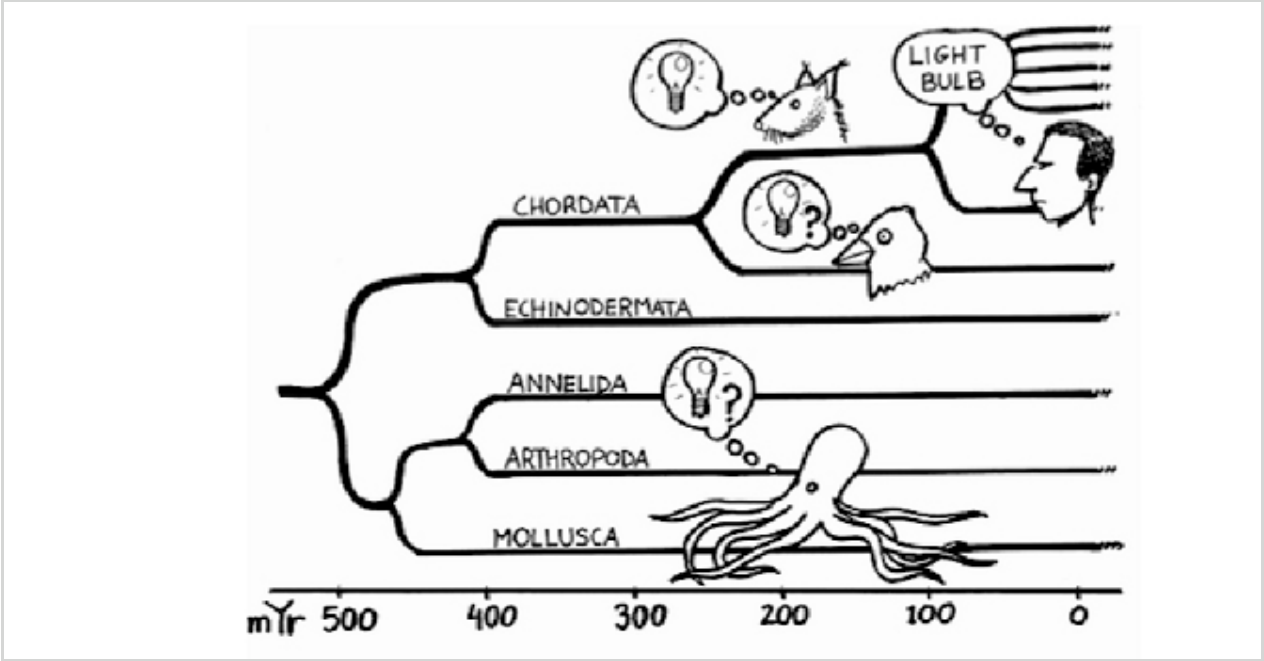
Traditionally we have been warned not to generalize lightly from humans to other species. That is still an important caution to keep in mind. But it has been relaxed somewhat with major advances in the genetic code. We can begin to read the genetic code for neurons and their many roles in evolution, and if a set of genes are similar, their phenotypic expression is also likely to be similar. While Darwin was already convinced about striking similarities among mammalian emotions, we are now beginning to add the DNA code for structures like the thalamus and cortex, and for biological states like sleep, waking, and dreams. The transition between sleep and waking is now known to alter gene expression in hundreds of DNA locations.

When it comes to conscious waking, the thalamocortical system is shared among mammals. The oscillatory regimes of waking and sleeping are also widely shared: Conscious waking is a fast-changing state with large numbers of phase-locked oscillations zipping back and forth, while sleep involves regular, global halting in the flow of signal traffic. During conscious waking animals engage in adaptive, purposeful behavior. Sleep makes us vulnerable to predation, so we retreat into the relative safety of trees, caves, and human settlements.

Neurobiologists now suggest that the brains of birds are much closer to mammals than they have been thought to be. Specifically the "pallium" in birds seems to be homologous to cortex in mammals. That raises the question: Are they also conscious? Irene Pepperberg's famous African Grey parrot Alex certainly seems to suggest so.

A biological view of conscious (and unconscious) brains reveals a trove of new insights. And unanswered questions, of course.

Figure 3.



A sketch of the possible evolution of consciousness, from D.B. Edelman et al (2004). The gross brain anatomy of large-brained cephalopods is strikingly different from mammals, but their problem-solving capacities may resemble that of some birds and primates.

(From: Edelman, D. B., Baars, B. J., & Seth, A. K. (2004). Identifying the hallmarks of consciousness in non-mammalian species. Consciousness and Cognition.)

5. Subjectivity and Occam's razor.

Can we attribute subjectivity to other animals? Do monkeys and kitty cats have a point of view on a world of conscious objects, events and scenes? Is it like something to be a bat?

During seven decades of behavioristic dominance Occam's Razor was often wielded against that notion. (About 1920 to 1990). If behavior could be explained without consciousness, it was argued, there is no reason to postulate any more "entities" than are strictly needed. Occam's Razor lopped off subjectivity.

Today, a vast body of evidence indicates that consciousness is a brute biological fact. It occurs in highly predictable ways in certain kinds of brains, under well-studied conditions. Conscious brains have numerous established properties (e.g. Baars, 1988; Edelman, 1989; Seth et al, 2005). The same is true for unconscious brain states and processes. Occam's Razor cannot be used to lop off a brute fact. Facts are what we are trying to understand.

Figure 4. Occam's razor, not Occam's Axe.

Careful how you wield that razor!

It has now become ethically required for scientists to describe their laboratory animals as "conscious." Along with a vast body of evidence, the scientific presumption has swung toward consciousness in animals like ourselves. That swing of opinion may turn out to be wrong, but it reflects a great weight of evidence. Arguments against animal consciousness should be fully informed about that body of behavioral and neurobiological evidence. Animal consciousness is no longer based upon speculation or abstract philosophy.

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