Remote Learning Module for 20 April 2020

Lecture Notes on *The Cerebral Code* – Chapters 1 & 2

Last class we finished up our examination of *Mind, Matter and Mathematics*, as Changeux and Connes each recapitulated their respective nominalist and realist positions on the nature and existence of mathematical objects, followed by a consideration of the implications each of these positions has for thinking about ethics. Today, as we turn our attention to William Calvin's *Cerebral Code*, we'll return to Changeux's evolutionary model for understanding brain development—the Darwinian Schema—with a consideration of the hypothesis that what Dennett called the Tower of Generate and Test applies not just to the evolution of species, nor just to the maturation of mammalian brains, but to the formation of conscious thoughts in ourselves.

* * *

— Prologue —

(1) We open with an overview of Calvin's project: to explain conscious thought as a Darwin Engine—an explanation that links thought, memory, creativity, consciousness, narrative, and dreaming. We've seen this hypothesis surface in Daniel Dennett's Tower of Generate and Test already, but here we'll move beyond the functionalist's promissory note to examine a neurophysiologist's empirical theory.

(2) Our first hint as to the methodology for advancing this theory comes from Carl Jung: dreaming goes on continuously in experience (at least among mammals), but we don't normally see it when we're awake, just as we don't see the stars in daylight because the sky is too bright. What Calvin supposes plays the role of the stars in Jung's metaphor are the *spatiotemporal firing patterns* among hexagonal arrays of cell assemblies in our brains: mosaics of electrical activity competing for territory in our association cortices. On Calvin's view, these patterns are nothing short of a cerebral code—a translation table for converting thought into action. The empirical units (the units of empirical *significance*) in this code are, on this model, 0.5 mm hexagonal circuits of activity.

(3) Generalized Darwinism: just as we saw in Jean-Pierre Changeux's developmental model, here we'll seek brain analogies to the Darwinian mechanisms that create higher-order complex systems in nature—brain analogies sufficient to subserve the thinking of "Popperian Creatures" (who are able to simulate possible courses of action before engaging with the external world). The character of any Darwinian explanation is quintessentially bottom-up, that is, without any hierarchical design principle in play. Among the several examples of the Darwinian Schema Calvin adduces throughout his text, we find the evolution of immune responses to infectious diseases; nothing could be more topical for us today, as I'm sure you have already considered before reaching the end of this sentence.

(4) Perhaps the most significant element among the six primary and five secondary factors in any generalization of Darwinian evolution beyond biological speciation is *population thinking*. Despite our egocentric predilections, we must be careful to remember that the unit of selection in biological evolution is the species, not the individual. As Calvin notes in the Prologue, since the advent of Darwin's account of speciation in in 1859, a host of other biological phenomena, once thought to be instances of individual learning and adaptation, have turned out to evolve by way of selective mechanisms operating on populations. Note well the example of antibody formation: once thought to be an instruction from an antigen, we now know that antibodies form up as a result of selection from among existing patterns in our immune systems.

* * *

— Chapter 1 —

The Representation Problem & the Copying Solution

(1) Our first problem is to answer the question: What is the unit of memory? The short answer, according to Calvin comes from an analogy: committees are likely to be irreducible to individuals. Unpacking the analogy: individual neurons are not enough: we'll need to look for patterns of activity among cell-assemblies (specifically, Donald Hebb's model). For memory, we'll also need to find out how to model the manner in which memories are stored and retrieved. For this purpose, Calvin introduces a metaphor that will guide us throughout his entire theoretical framework: music. We can store musical ideas in a score, on sheet music (spatial-only representation), which we activate in performance (spatiotemporal execution).

(2) Next we'll need to consider the "representation problem": Which spatiotemporal pattern represents which mental object? What are mental objects? Calvin adapts Richard Dawkins' notion of the *meme* for this purpose (note that we're using this term to reference anything copied from one mind to another by imitation). Calvin's hypothesis is that just as memes pass *between* or *among* minds, patterns of neural activity may be multiply copied *within* brains. If so, population thinking is essential to our model: it's the shaping up process over successive generations that matters, not trimming individuals (*not*, that is, in the way you might even now be pruning a philosophy paper, or I find myself editing these lecture notes).

(3) *Natural Selection is not enough.* In fact, there are six essential factors required for evolution.

(i) A Code or Pattern.
(ii) A Copying Mechanism.
(iii) Variation from Chance.
(iv) Competition for limited space.
(v) Natural Selection (i.e., a biased environment).
(vi) Survival (skewed until reproductive maturity).

Calvin's project is, in short: finding neural equivalents to these six elements. Looking to memory, we will need to identify the neural analogy to the gene—that is, the "unit of inheritance."

(4) *Five Catalysts*. In addition to the six Darwinian Essentials we find in the evolutionary history of life on Planet Earth, there are five phenomena that enhance and/or accelerate evolutionary change.

(i) Stability (like "getting into a rut).
(ii) Systematic Recombination (which generates more variants than mutations).
(iii) Fluctuating Environments (which shape up multi-environmental adaptations).
(iv) Parcellation (that is, isolating reproductive communities).
(v) Local Extinctions (which create empty niches).

* * *

— Chapter 2 —

Cloning in Cerebral Cortex

(1) This chapter deals with the first Darwinian essential: Copying. The unit of empirical significance is a circuit among pyramidal neurons in the second and third superficial layers of the cerebral cortex. Moreover, when activated, these units appear as clusters, 0.5 mm apart from one another, thereby effecting *recurrent excitation* plus *lateral inhibition*.

(2) The six layers of the cerebral cortex can be likened to a mail room (an analogy earlier advanced by Richard Dawkins, by the way).

Layer 4 = The IN-BOX (inputs from the thalamus terminate here)

Layers 5 & 6 = The OUT-BOX (axons go from cortex back to thalamus & to the spinal column)

Layers 1, 2, & 3 = The INTER-OFFICE MEMOS.

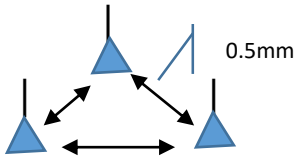
(3) *Pyramidal Neurons*. Taking a cue from Conan Doyle's story, "Silver Blaze," Calvin's empirical research revealed that *silent neighbors* are critical to the neurophysiology of memory. In the Sherlock Holmes story, the clue that revealed the identity of the perpetrator (who stole a prize horse, Silver Blaze, from the owner's stable) was the "singular fact that the dog *didn't* bark in the night." Just as Holmes realized that this fact implied that the dog knew the perpetrator well, Calvin came to realize that silent neighbors (excited axons extend past *inhibited* neurons to communicate with other excited neurons just 0.5 mm distant) provide the key to *recurrent excitation*. Here, he offers another analogy: the entrainment of firefly flashes. Fireflies will soon appear on our lawns and streets, and as the night progresses, you'll see them lighting up in a simple sequence driven by an elementary algorithm: advance to the next flash when stimulated by light. This sort of entrainment can also be seen (although not for a while during the current pandemic, unfortunately) on playgrounds, as children take to swing sets having several seats on one horizontal bar: initially each child may swing at a different tempo and frequency, but after a

while, they'll all swing in a single rhythm, thanks to harmonic resonance. In cerebral cortex, the *Elements of Entrainment* comprise:

(a) Mutual re-excitation;
(b) Silent gaps (to focus re-excitation); and
(c) Entrainment tendencies via harmonic resonance.

These elements display the potential for neuronal activity to acquire the character of a Darwin Machine.

(4) The fundamental unit, according to Calvin, is a hot-spot among equilateral triangular arrays of entrained pyramidal neurons. This basis, he claims, can then add neurons at 0.5 mm distances. On the musical analogy, we then have a three-voice chorus; this is sufficient for *synchrony* (singing in unison), but for explanations of more complex activity, we'll need to understand how the brain manages *polyphony*.



* * *

Next time, we'll look to Chapters 3 and 4 of *The Cerebral Code*, where Calvin presents a model for explaining how a compressed code can emerge from the hexagon theory, and how the Darwinian schema can explain the partitioning of cloning competitions in cerebral cortex. Be well everyone, and, although I imagine you are probably quite tired by now of my continuing to say so, do remember: social distancing continues to save lives, which is presumably why we are still not in JUB 202 presently.