Remote Learning Module for 24 April 2020

Lecture Notes on *The Cerebral Code* – Chapters 5 & 6

Last class we delved into Chapters 3 and 4 of William Calvin's *Cerebral Code*, wherein he develops his model for understanding how brains shape up thoughts in milliseconds to minutes of evolutionary change. We closed with five of the six Darwinian essentials in place: Patterns, Copy Mechanisms, Variations, Workspaces, and Environmental Constraints. Today, as we look to Chapters 5 & 6, we'll further explore the cortical equivalent of a biased environment, and the analog we'll need for generating selection effects comparable to biological Natural Selection.

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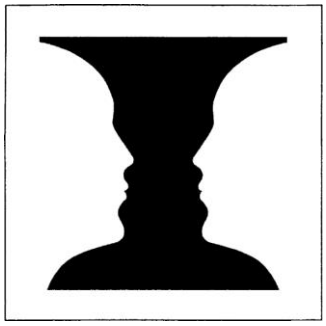
— Chapter 5 —

Resonating with Your Chaotic Memories

(1) Still exploring the fifth Darwinian Essential, the Environment, Calvin notes how mental environments, if they are to serve as contexts in which evolutionary development can take place, should turn out to be highly *variegated*, with variations displayed among physiological states, sensory inputs, neuromodulators, thalamus, and, for our consideration today, the memorized environment. Memory is a hard problem for the hexagon theory because we need a new level of organization in order to explain the shift from active patterns of neural activity (subject to spatiotemporal constraints) to passive patterns, that is, *spatial only* long-term storage.

(2) The key hypothesis here is *Resonance*. To give us an introduction to this hypothesis, Calvin provides examples of how two waves, squeezed into a shorter wavelength, but keeping *frequency* constant, will increase in *amplitude*—just as a bay resonates to tidal frequencies. He notes (with a delightful cartoon) how a car will resonate to a bumpy road at only one speed—the resonant frequency, and this example provides him with a model for spatial-only connectivity in cerebral cortex: on analogy, we should look for bumps and ruts in the brain.

(3) The general model for the right resonant frequency is that of a *Chaotic Attractor* (like the flutter of a butterfly's wings). We can see such attractors in the figure/ground gestalt shifts we experience when looking at things like the "love cup":



The primary payoff of this analogy is to show that intelligent states flit on the edges of chaos; they are a sort of controlled disorder. Once a momentary spatiotemporal pattern of brain activity comes close to attractor pattern (say, the cup above), it will conform to the attractor. Notice that what's happening in these visual cases is that from a wide set of starting points, you eventually come to see either the two faces or the cup. So, Calvin surmises, we should expect to find something similar going on in cell assemblies: a basin of attraction which, from a variety of starting points, will call up a given memory.

(4) Thinking about memory from this neurological standpoint, we may want to remember (yes, the iteration is intended) Ian Hacking's reflections on how we go about the business of remembering our past experiences—calling up scenes). So, let's consider Calvin's citation from Walter Freeman: when remembering, "the perceptual message sent to the forebrain is a *construction*, not the residue of a filter or algorithm"; the construction replaces sensory inputs with endogenous constructions. We are left with an epistemological solipsism in brains. We also have a nice analogy to square dancing: novices will start out copying exactly what the caller specifies, but after the caller stops, having gotten the gist, the dancers continue on, bopping 'til they drop. There is an important constraint on all this though: copying copies of copies, etc., requires a digital code.

(5) With attractor patterns, it's much easier to explain recall: the pattern can be reignited from all over the territory, just as a blackboard or whiteboard ghost (oh, how I miss them) can be revived from anywhere. We can also explain lost recall: when new attractors come to dominate the territory.

(6) Let's ask now: How exactly is this sort of sculpting of patterns accomplished neurophysiologically? Here, Calvin relies on a well-established understanding of how NMDA postsynaptic receptors for excitatory glutamate operate (we saw this process in Churchland; if you remember her account, then there are ion channels in your brain right now inducing voltage depolarization for a specific aggregate of synapses in your frontal cortex).

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— Chapter 6 —

Partitioning the Playfield

(1) We shift now from the environment *per se* to selection effects, noting Calvin's guiding inspiration: the genotype/phenotype duality. The lineage of investigations leading up to Calvin's original account traces models for selection effects from John Young's discoveries in the early 1960s, through Richard Dawkins' developmental account (selective juvenile mortality of unused connections) to Jean-Pierre Changeux's "Levels of Organization" account (you'll recall this from our recent tour of *Mind, Matter, and Mathematics*), to Gerald Edelman's *Neural Darwinism*.

(2) While Calvin is in substantial agreement with Edelman, he (Calvin) figures that Edelman wound up confusing selectionist carving of an already variegated terrain, with genuine evolution.

What was missing from Edelman's models (both early, 1977, and late, 1988) was the Darwinian Algorithm of deriving high quality from crude beginnings, that is, from making lots of cheap copies. Edelman's *reentry* story, Calvin argues, is like editing a manuscript (something I'll doubtless do before committing these note to the Internet for your reading pleasure). But for understanding how we're able to generate new prose, new ideas, we'll need *Population Thinking*.

(3) Our first candidate is *episodic memory*, which is accomplished by activations in the entorhinal cortex being copied to the adjacent hippocampus. These structures are found in the brains of rats, monkeys and chimps as well as human brains, by the way. The importance of population based models is that they provide the key to transforming Edelman's residual teleological processes into a purely mechanical account.

(4) We now find a nice range of concepts from population-based evolutionary biology will help make sense of this mechanical account. These are the five additional catalysts we saw in the Prologue. Barriers (parcellated geography of the sort Darwin found on the Galapagos Islands) create demes; pathways through barriers create gateways; these two phenomena provide a mechanical description of emergent patterns via escaping error correction. And this mechanism is exactly what we need for the emergence of novelty, and for explaining how ambiguous perception (is it an apple, a lemon, or a baseball?) settles into recognition: decision occurs when there is enough of one pattern-type singing in a chorus.

(5) Climate fluctuations speed up biological evolution; so too, cortical excitability fluctuations might speed up hexagonal competitions: some areas will be converted into barriers, thus partitioning the playing-field. Empty niches also speed up evolution in the natural environment. A niche is the outward projection of an organism's needs; when they empty out, new organisms can take up the resources that remain behind. Think here of the blackboard ghosts we pined for moments ago.

(6) So now we have our essentials and our catalysts. After the Intermission, we'll be able to take up the theory of consciousness.

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Next time, we'll look to Chapters 7 through 9 of *The Cerebral Code*, where we'll encounter Brownian Motion in brains, Convergent Zones (you'll recall these from Damasio), and Chimes on the Quarter Hour, as Calvin brings his musical analogy to a thrilling crescendo. Be well everyone, and, as we continue our undoubtedly strenuous efforts in the exercise of social distancing, perhaps this would be an excellent time to listen to some of your favorite music!