Computational Neuroscience: Collection of Annotated Bibliographies

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References

[1] A. L. Hodgkin and A. F. Huxley, "A quantitative description of membrane current and its application to conduction and excitation in nerve," in *Journal of Physiology, Volume 117*, March 1952.

Possibly one of the most important papers in modern neuroscience (as seen by almost 30,000 citations on Google Scholar), Hodgkin and Huxley use the experimental data they collected from voltage clamp techniques on giant squid axons to attempt to build a quantitative framework for neuronal communication and action potentials. Because theoretical neuroscience was such an infant field in 1952, the beginning of this article postulated ideas for the biological mechanisms of what we now know as an electrochemical process in which a resting membrane potential is built up by transmembrane protein transporters who, with the help of ATP and ionic concentration gradients, actively build a potential of around -75 mV between the inside and outside of a membrane. Some of their ideas included ionic coupling of sodium with some negative sister molecule which served to alter the membrane potential when the time arose for signal propagation. After this, they dove into mathmatical models, seeking to represent data collected quantitatively with systems of equations that best governed communicative processes between neurons. First, they build up rate constants whose form follows that of a Boltzmann distribution function, or C*exp(-E/kT). In place of "E", or

energy, they input voltage. One of the conclusions of the models they build up for conductance and rate equations is that the rate that the membrane potential reaction progresses is dependent of the concentration and current variables of ions involved in reactions (primarily sodium and potassium ions) as well as the time variable T. They test this out experimentally, and find out that sure enough, temperature differences induce phase changes of potential curves. Overall, this paper is of paramount importance in theoretical neuroscience. Hodgkin and Huxley used systems of equations to build up models of action potentials and (mostly) sucessfully stacking these models up to experimental findings, where they held firm. In doing so, these neuroscientists paved the way for exploration of both microbiological theory of action potentials and a fundamental understanding of how nerve cells communicate.

[2] W. McCulloch and W. Pitts, “A logical calculus of the ideas immanent in nervous activity.” in *The bulletin of mathematical biophysics 5.4*, 1943.

Regarded as a seminal paper in computational neuroscience as well as the basis of modern machine learning, the importance of the early formulations of McCulloch and Pitts are hard to overstate. By treating the biological existence of neurons as computational devices, these scientists applied logical theory to biological systems, most notably coming up with the idea that the communicative signaling of neurons was "all-or-nothing" and could, in theory, be quantified by algorithms that utilized AND, OR, and NOT gates. Excluding the mathematical portion of the model, the dendritic equivalent of this modeled neuron receives one or more input signals. Next, the collection of signals are processed according to weight (excitatory weight and/or inhibitory weight). After this, a binary output is determined, either 0 or 1 with zero representing no firing of the "action potential" and 1 representing firing of the "action potential". Though simplicstic in design, this model of a single neuron was profound in that it allowed for a quantitative basis of the neuron, demystifying the most integral component of the nervous system.