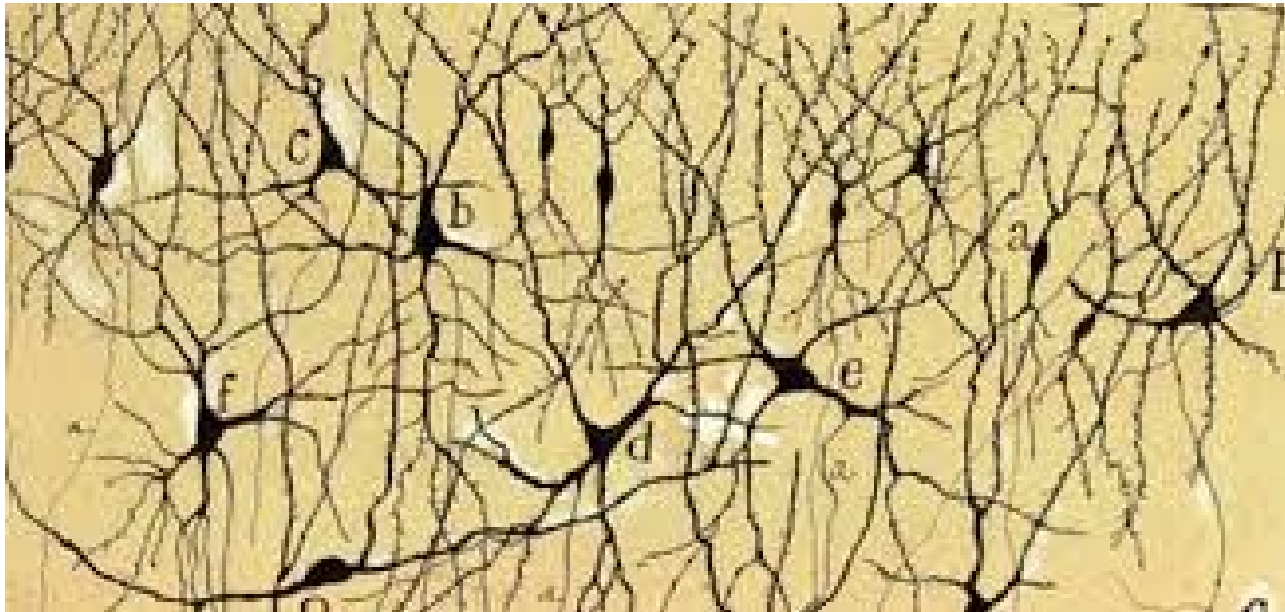
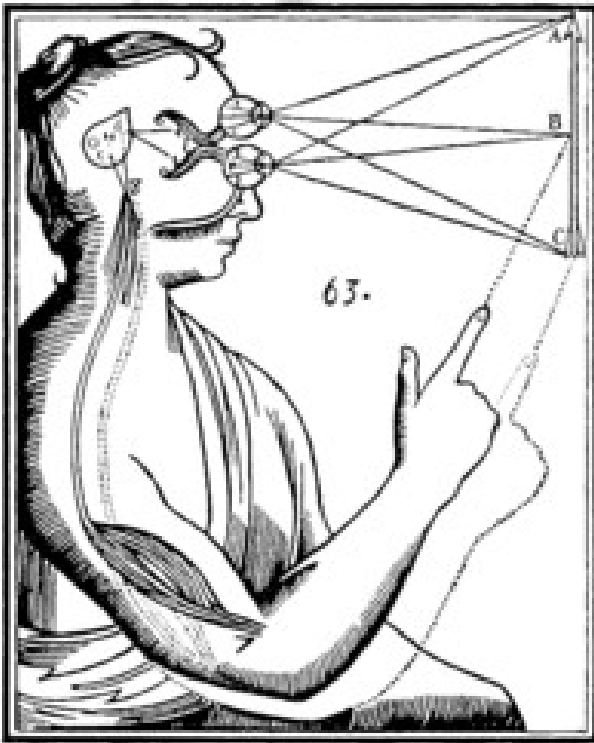


Neuroscience and the Hopfield Model



Samuel Johnson
Warwick Mathematics Institute, and
Centre for Complexity Science,
University of Warwick, UK



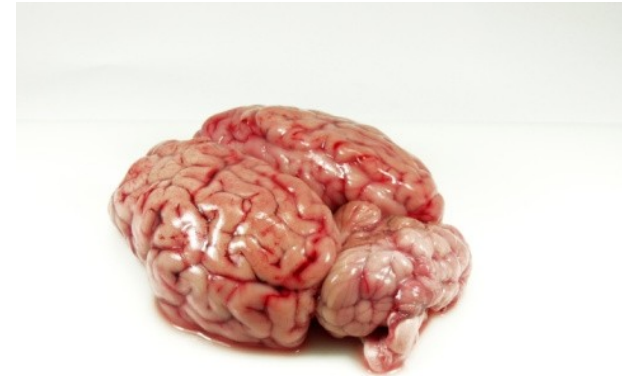
“[The] mechanism of our body is so constructed that simply by this gland's being moved in any way by the soul or by any other cause, it drives the surrounding spirits towards the pores of the brain, which direct them through the nerves to the muscles; and in this way the gland makes the spirits move the limbs.”

—René Descartes, *Passions of the soul* (1649)



"Souls are immaterial subjects of mental properties. They have sensations and thoughts, desires and beliefs, and perform intentional actions. Souls are essential parts of human beings..."

—Richard Swinburne, *The Evolution of the Soul* (1997)



"[T]he most commonsensical solution to the biocentrism problem parallels an elaboration that naturally accommodates personality survival. Neither of these elaborations appears to require any basic change in the orthodox theory. But both require a relaxing of the idea that physical and mental events occur only when paired together."

—Henry P. Stapp, *Compatibility of Contemporary Physical Theory with Personality Survival* (2015)

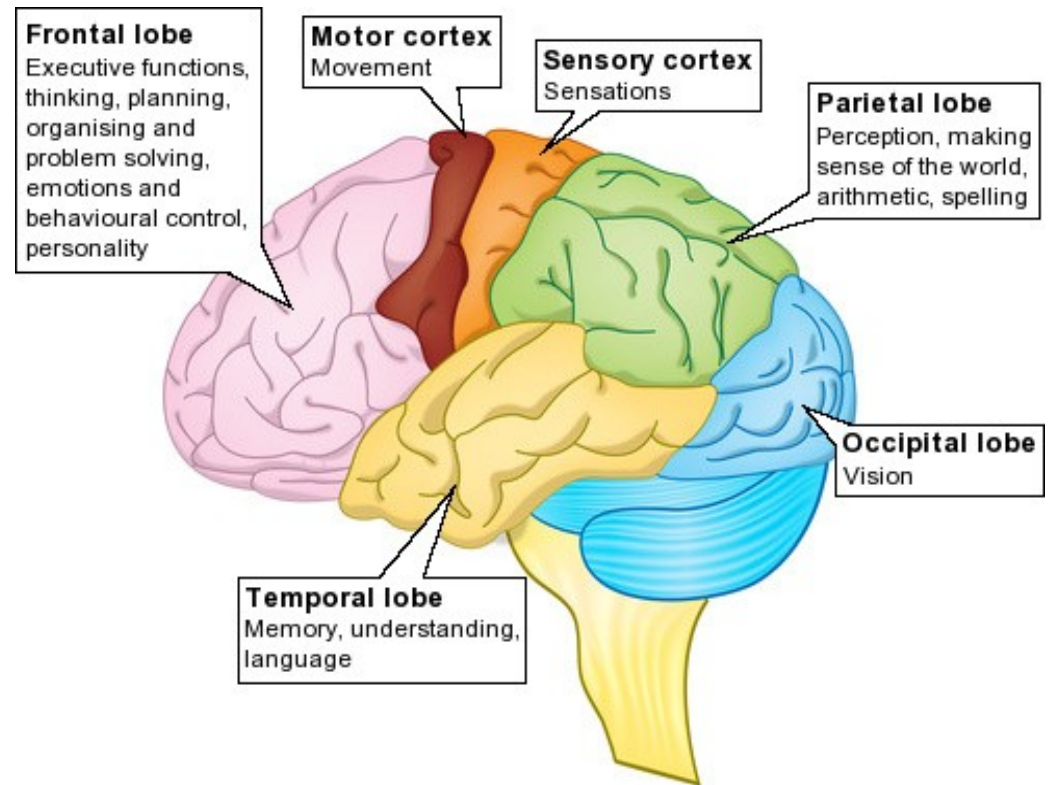


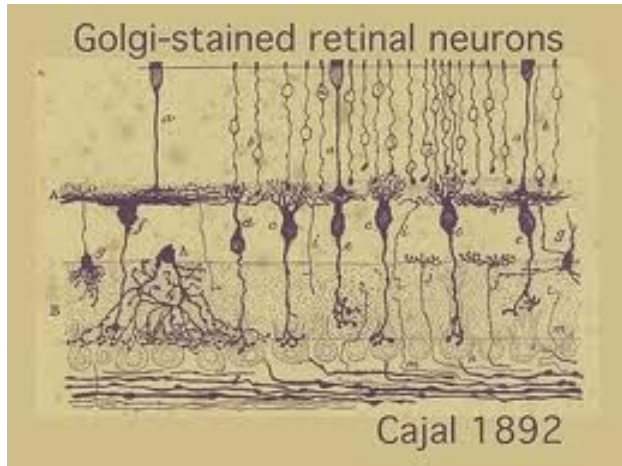
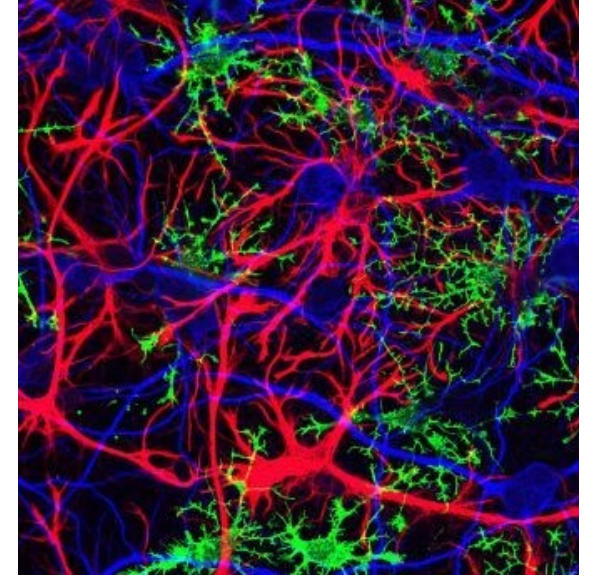
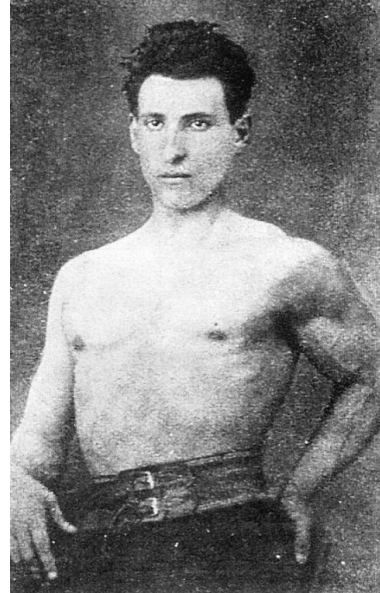
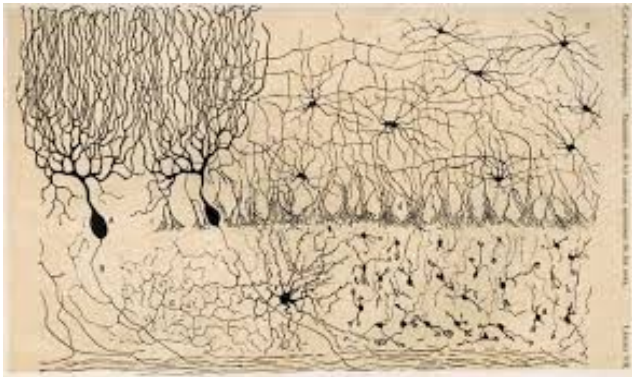


A moral man, Phineas Gage
Tamping powder down holes for his wage
Blew his special-made probe
Through his left frontal lobe
Now he drinks, swears, and flies in a rage.
— Anonymous

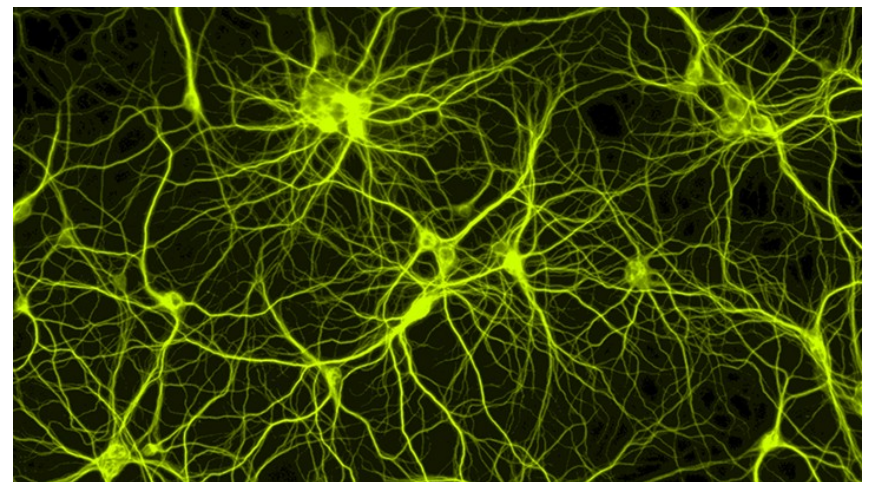
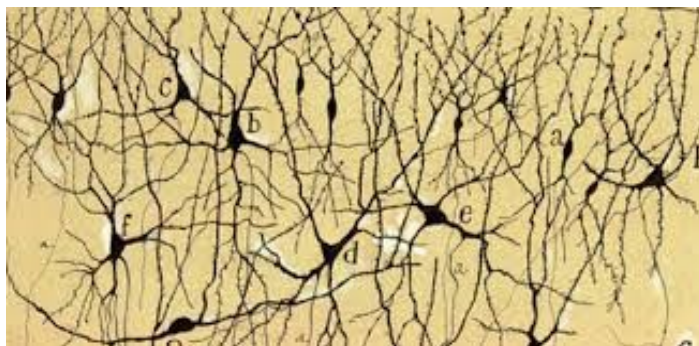


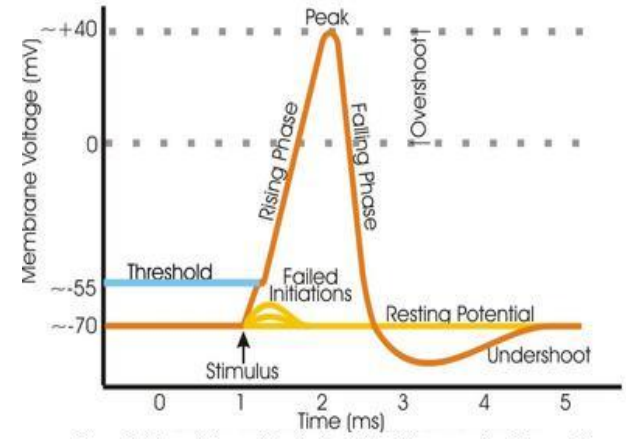
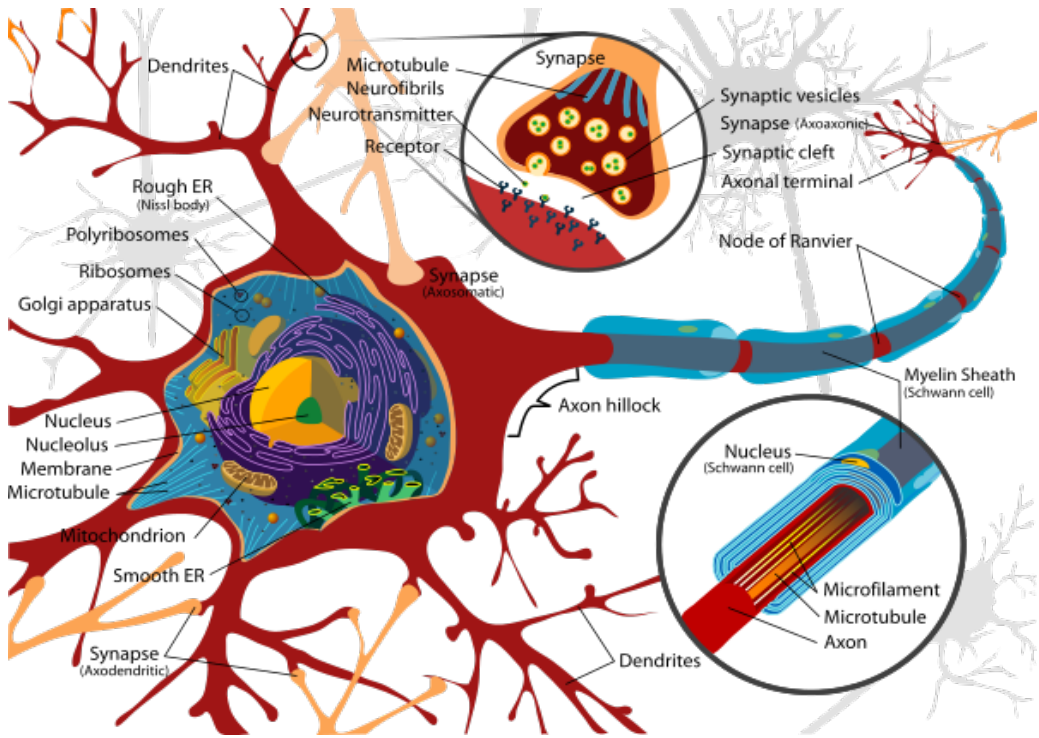
"Doctor, here is business
enough for you."





S. Ramón y Cajal



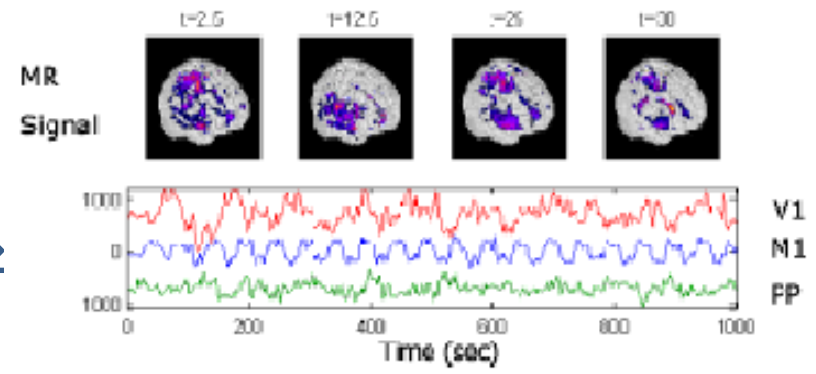


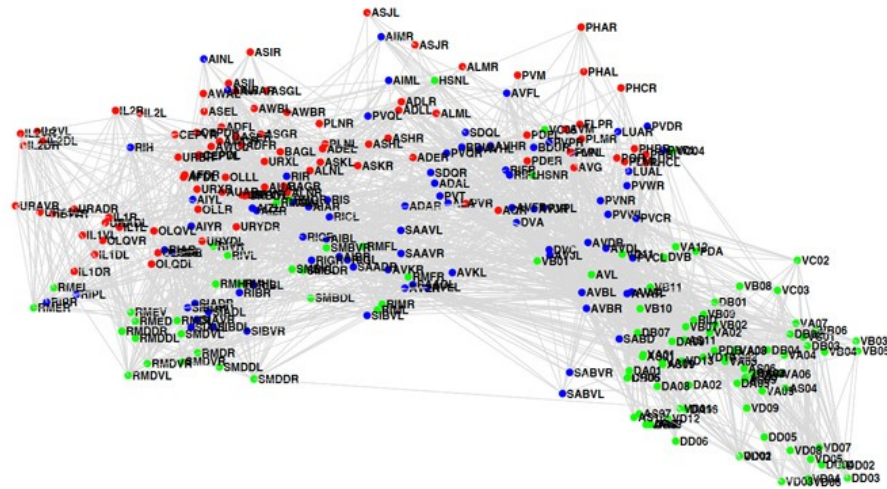
Action Potential



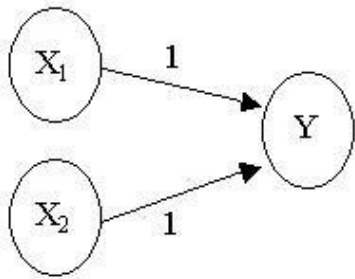
← Structural

Functional →

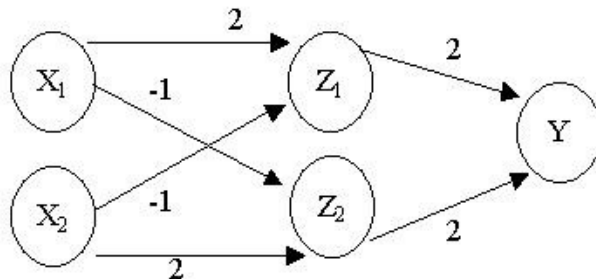




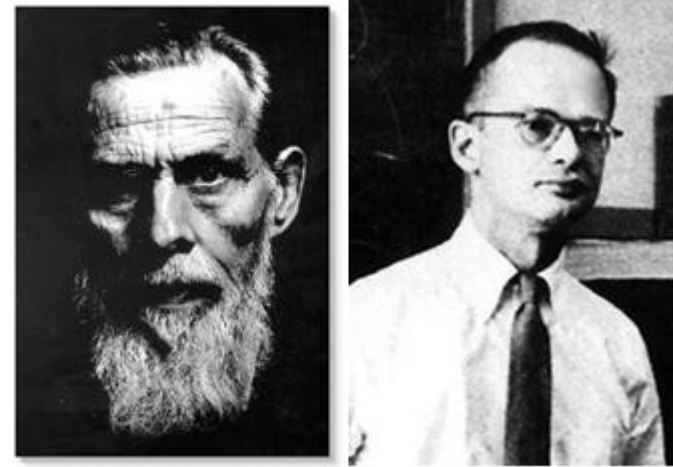
	# neurons	# synapses
C. elegans	302	~ 7,500
Fruit fly	10^5	10^7
Mouse	$7.1 \cdot 10^7$	10^{11}
Human	$8.6 \cdot 10^{10}$	$10^{14}-10^{15}$
Elephant	$2.57 \cdot 10^{11}$?



AND Function



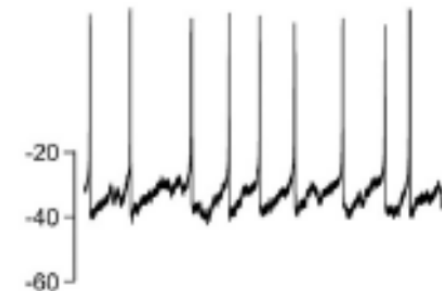
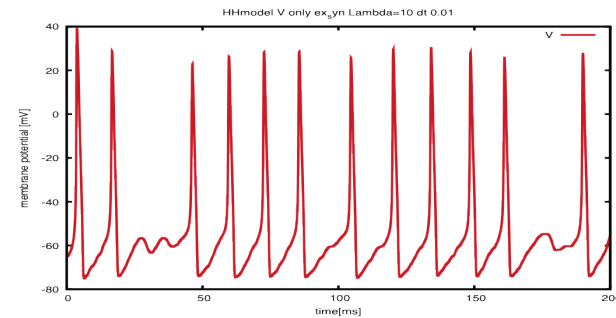
XOR Function



W McCulloch and W Pitts in 1943



AL Hodgkin & A Huxley (1952)



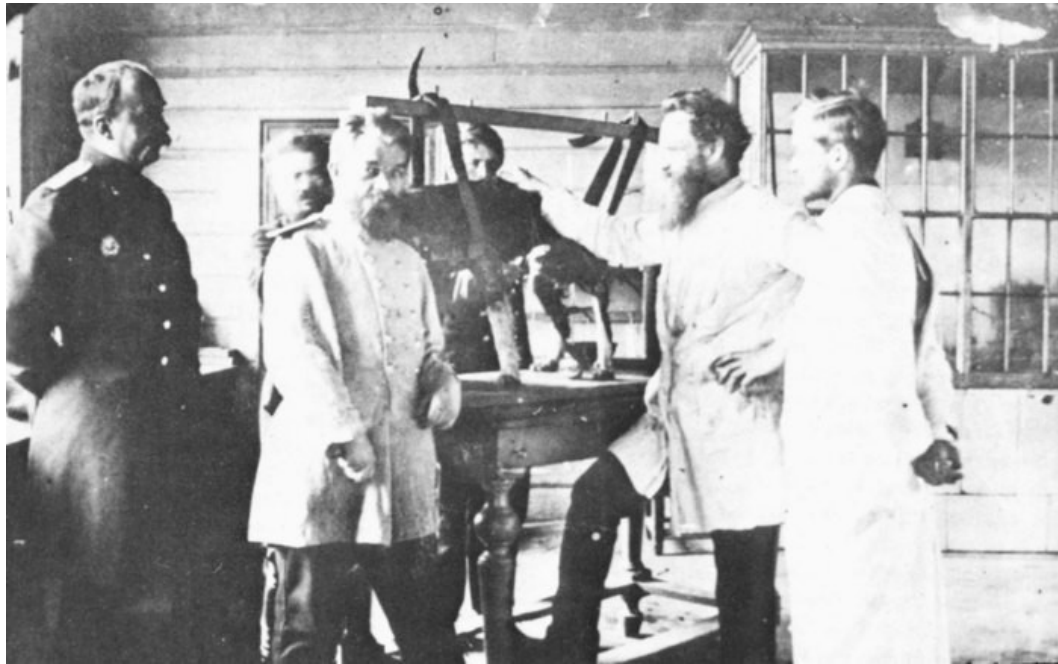
Hodgkin-Huxley model of electrical activity in the squid giant axon

$$C_m \frac{dV}{dt} = -g_{Na} m^3 h (V - V_{Na}) - g_K n^4 (V - V_K) - g_L (V - V_L) + I_a(t)$$

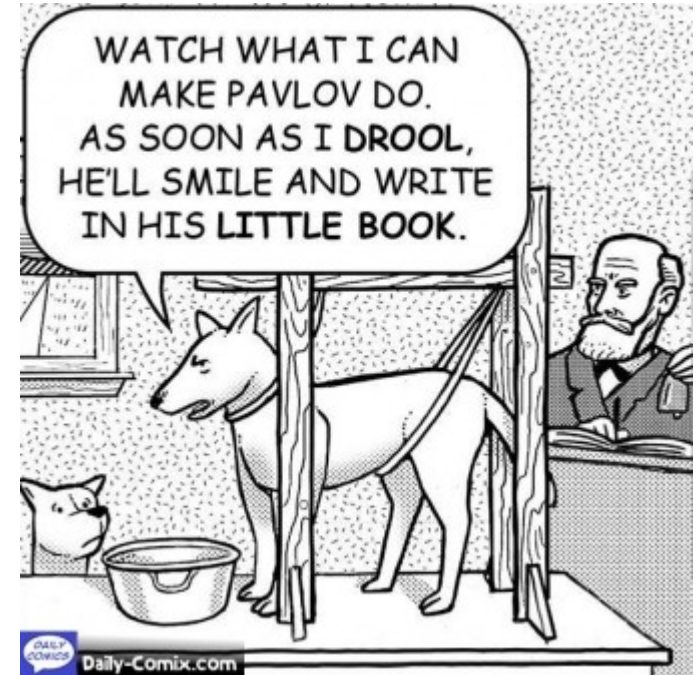
$$\frac{dm}{dt} = \frac{m_{\infty}(V) - m}{\tau_m(V)}$$

$$\frac{dh}{dt} = \frac{h_{\infty}(V) - h}{\tau_h(V)}$$

$$\frac{dn}{dt} = \frac{n_{\infty}(V) - n}{\tau_n(V)}$$



IP Pavlov



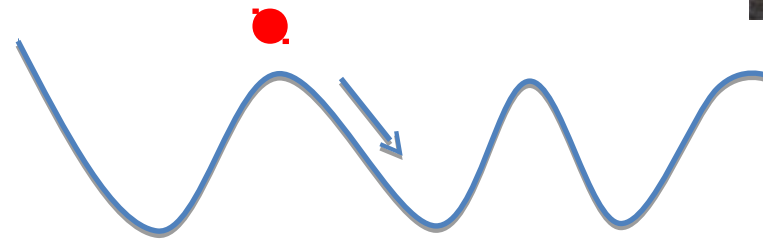
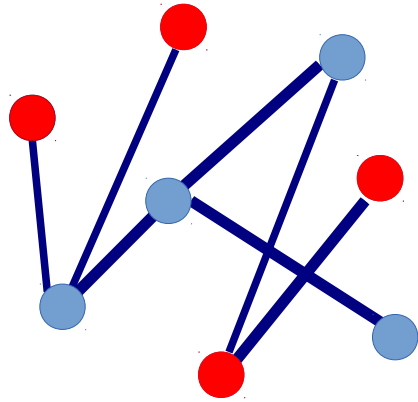
"Cells that fire together, wire together"



DO Hebb



Amari-Hopfield Model

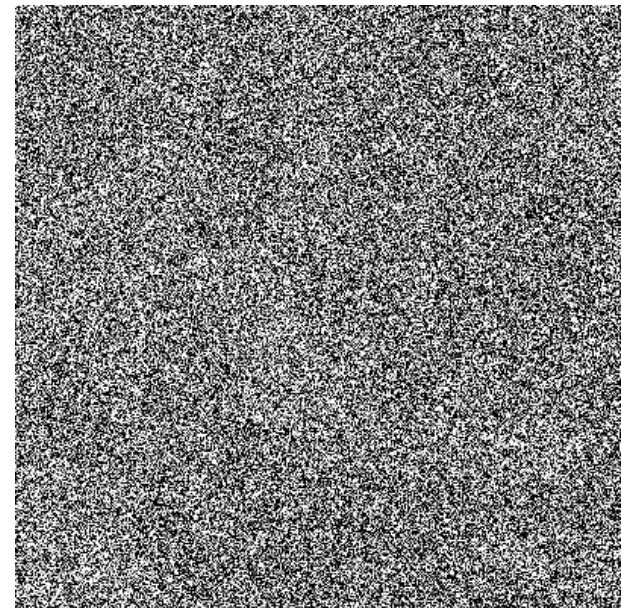


$$\xi_i^v = \pm 1$$

$$\omega_{ij} = \frac{1}{N} \sum_{v=1}^P \xi_i^v \xi_j^v$$

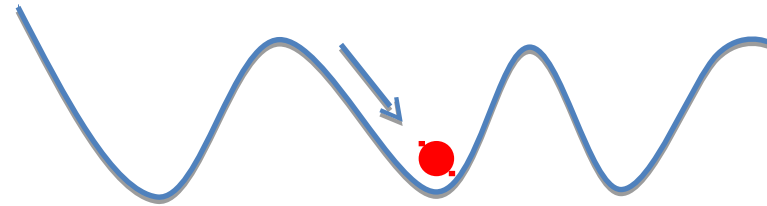
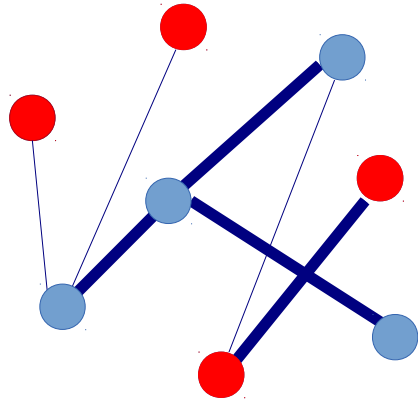
$$P(s_i = +1) = \frac{1}{2} \tanh \left[\frac{h_i - \theta_i}{T} \right] + \frac{1}{2}$$

$$m^v = N^{-1} \sum_i s_i \xi_i^v$$





Amari-Hopfield Model

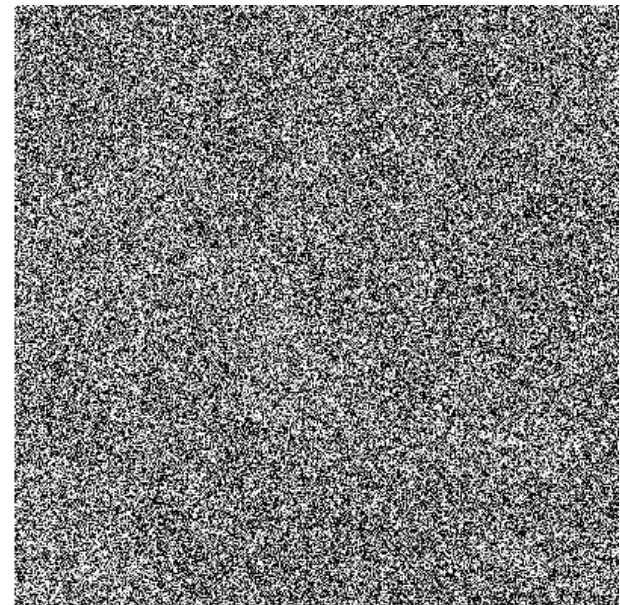


$$\xi_i^v = \pm 1$$

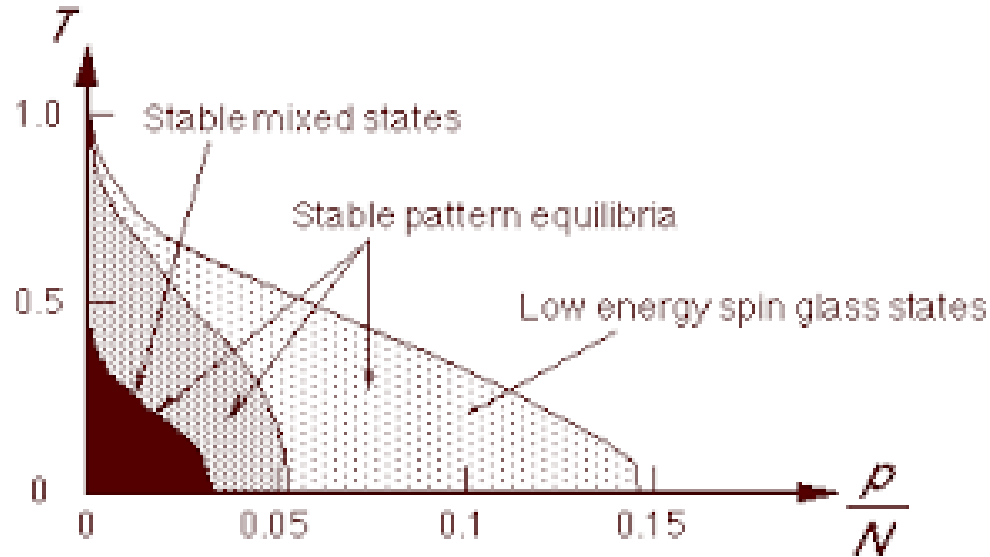
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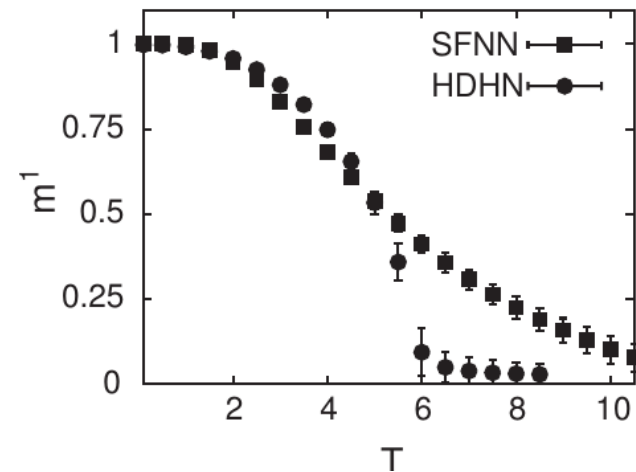
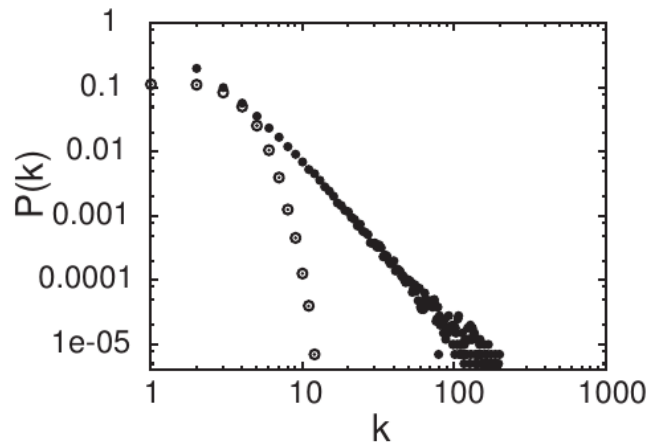
$$m^v = N^{-1} \sum_i s_i \xi_i^v$$



Amari-Hopfield Model



$$T_c = \frac{\langle k^2 \rangle}{\langle k \rangle}$$



J.J. Torres et al. / Neurocomputing 58–60 (2004)