Theory in biology: Physicists have advantages and disadvantages

Biology needs theory.

Three kinds of theory: analytic techniques, models, and physics-style theories.

Physicists have advantages: They are best theorists

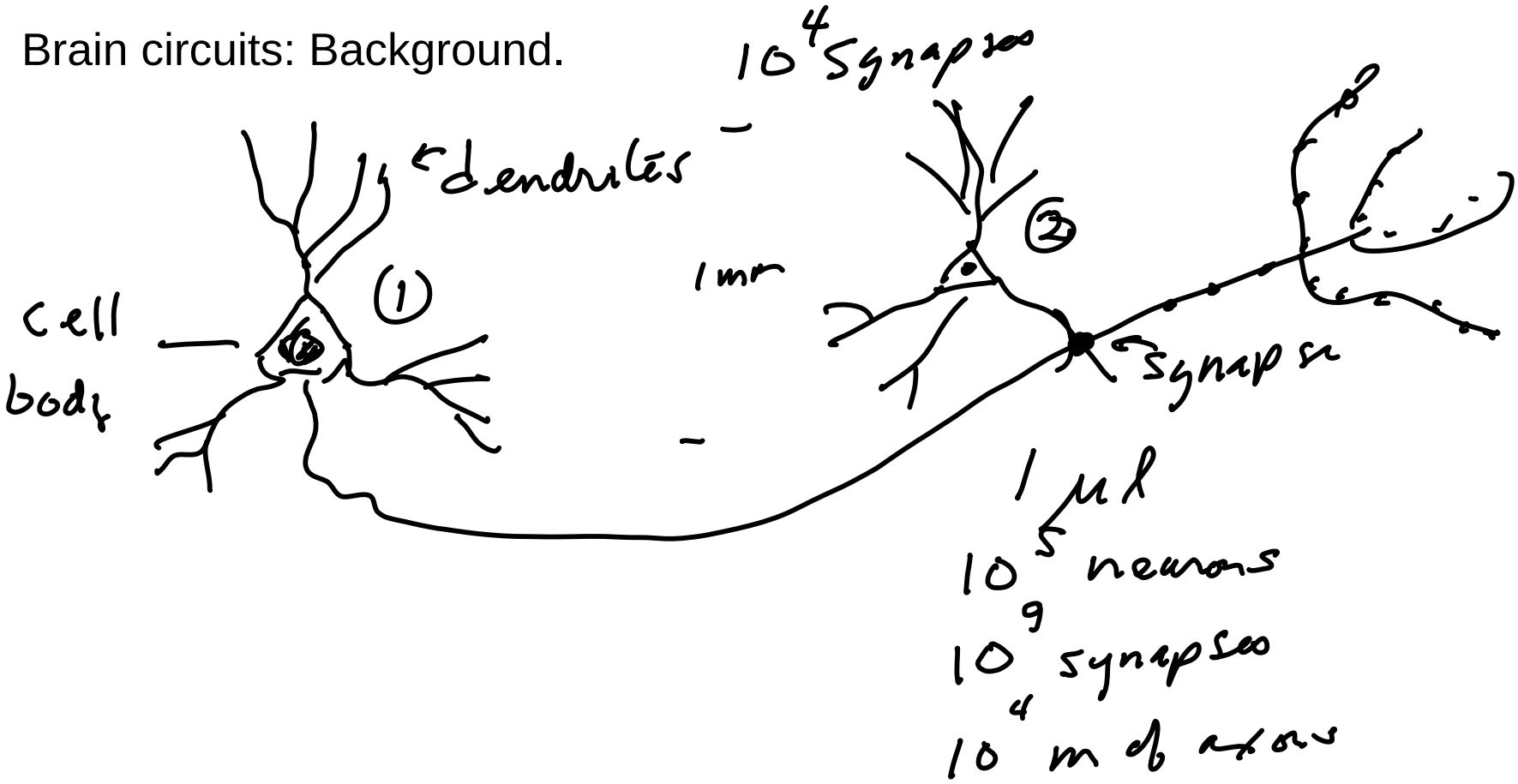
Physicists have disadvantages because of the nature of theory in biology: primacy of function for biological systems.

Steps in biological theory construction: (1) Select a system, (2) understand its function, (3) identify properties required for the function, and (4) use the properties to make quantitative predictions about the system.

Central role of the evolutionary perspective.

Two examples: (1) brain circuits and (2) the visual system.

Brain circuits: Background.



Brain circuits: function

Compute efficiently: mimimize conduction delays, minimize signal attenuation, maximize component density and connectivity.

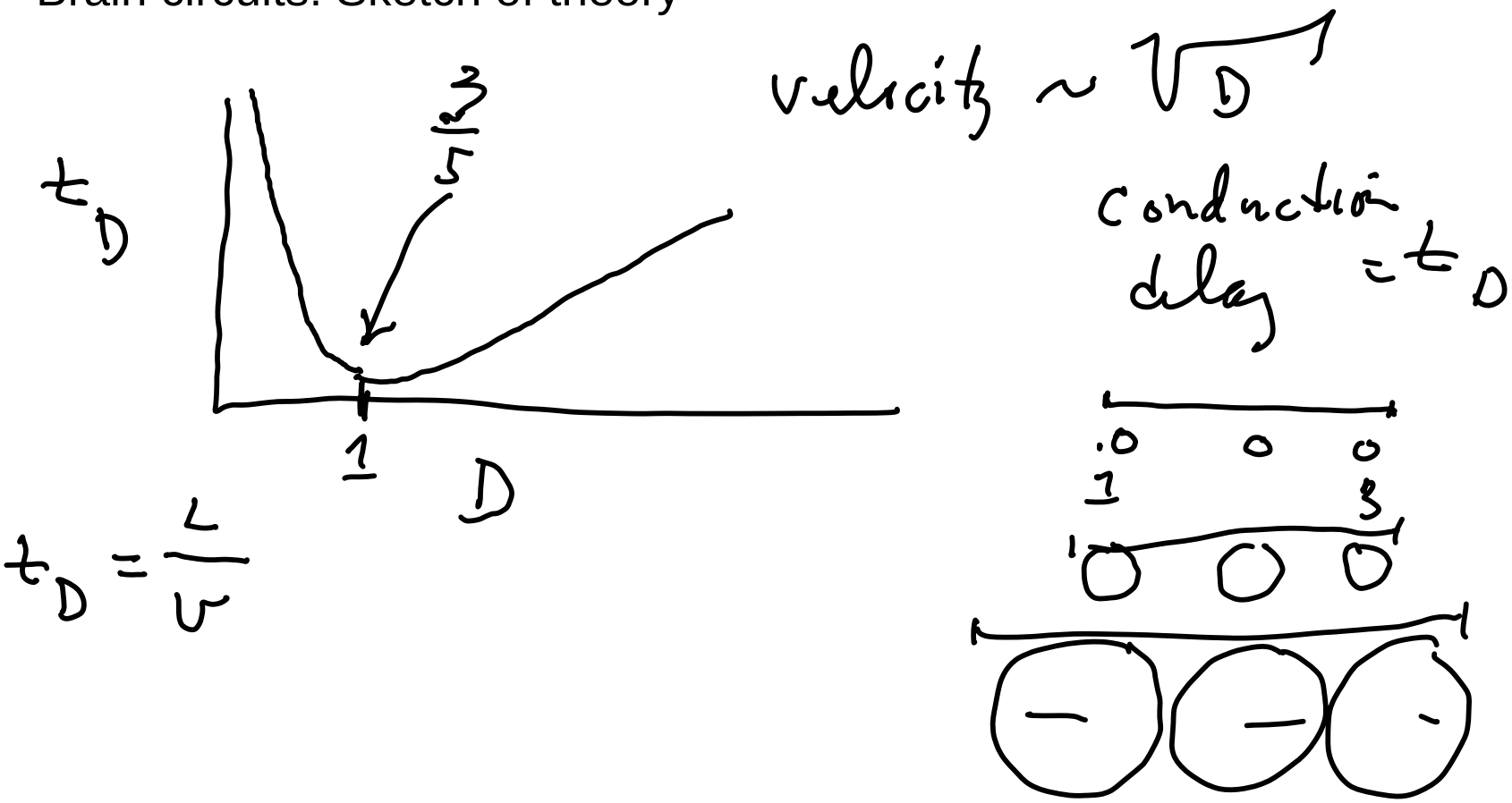
Brain function: Result

3/5 of the neuropil volume should be wire to maximaze efficiency

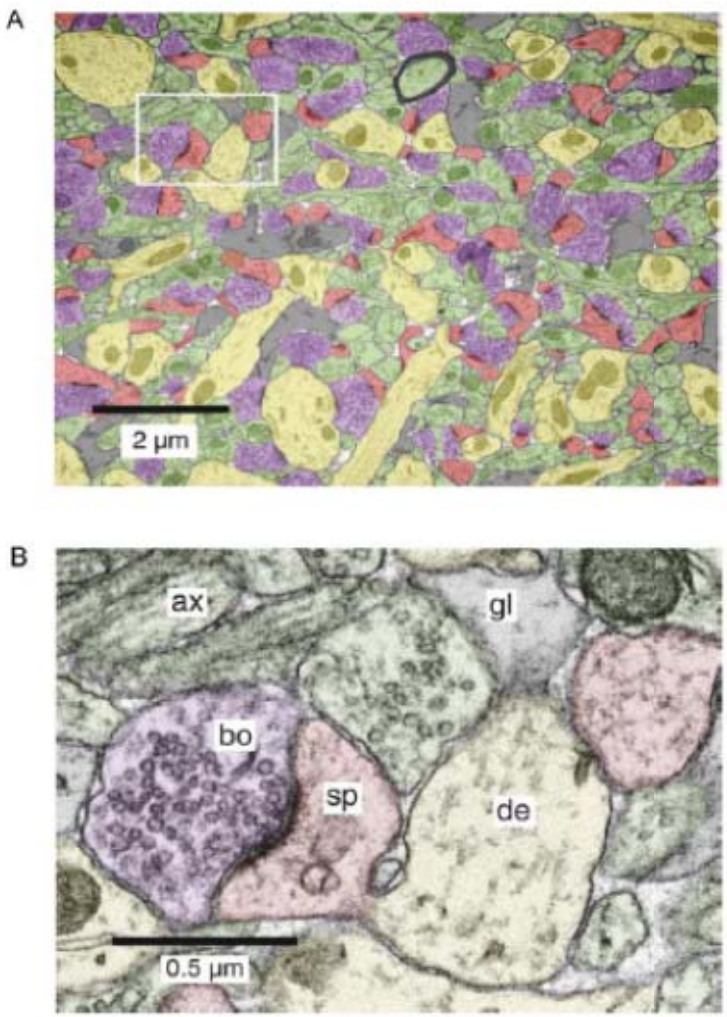
wire = axons & dendrites

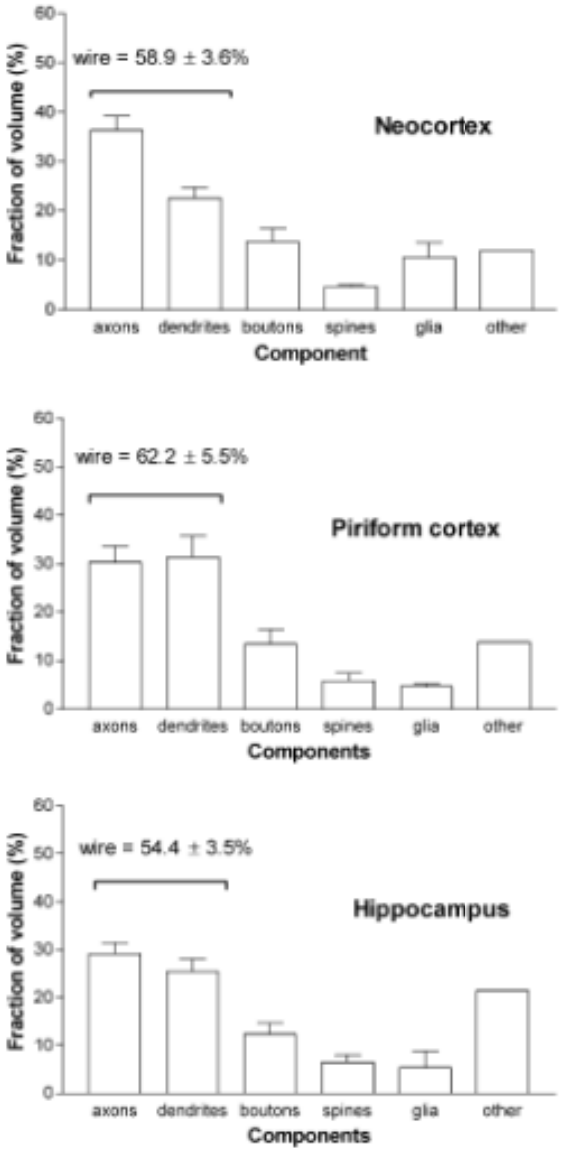
non-wire = synapses, extracellular space, glia cells

Brain circuits: Sketch of theory

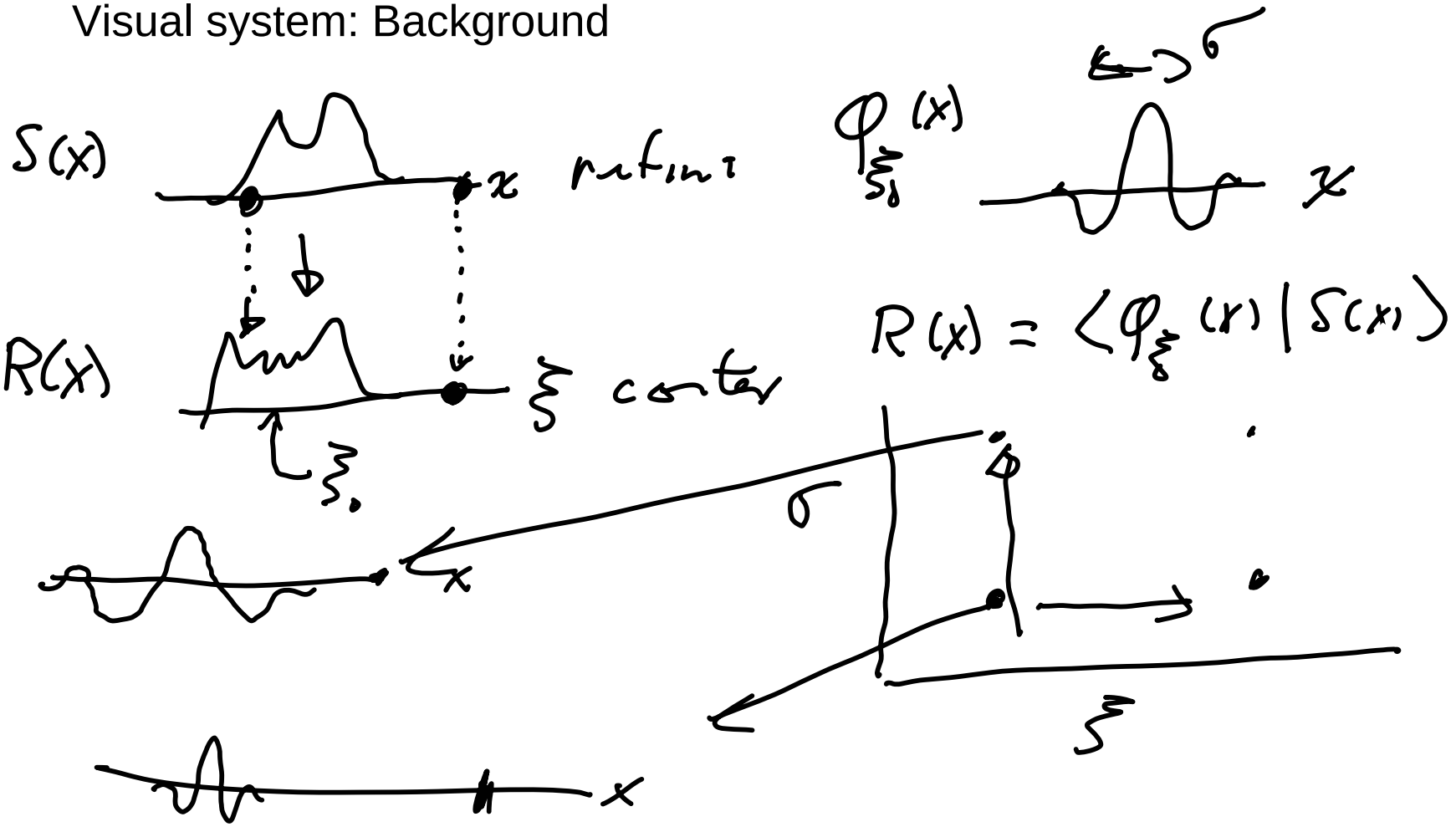


Brain circuits: Is the theory right?





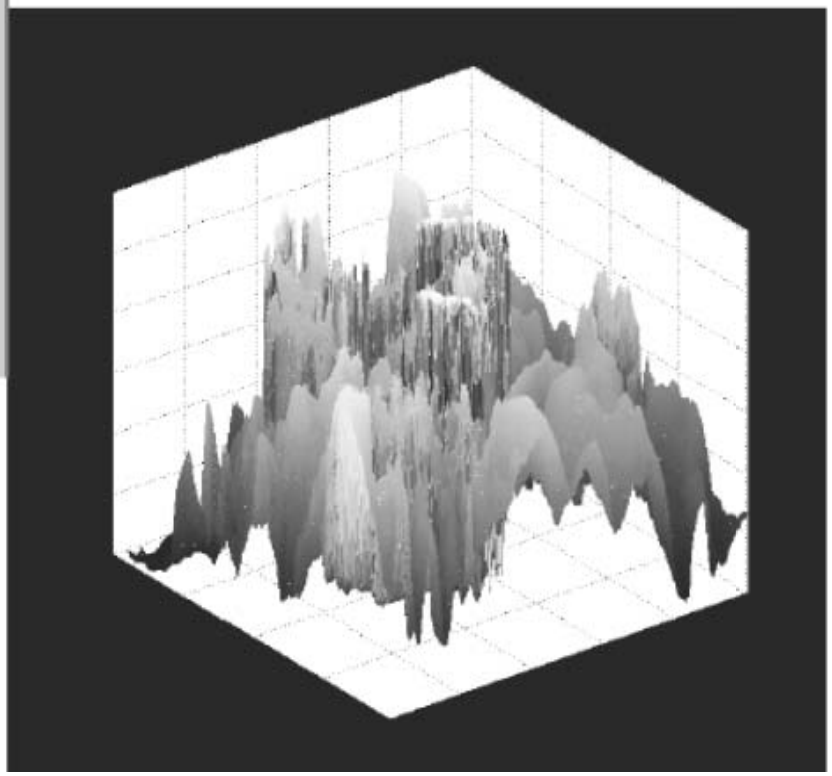
Visual system: Background



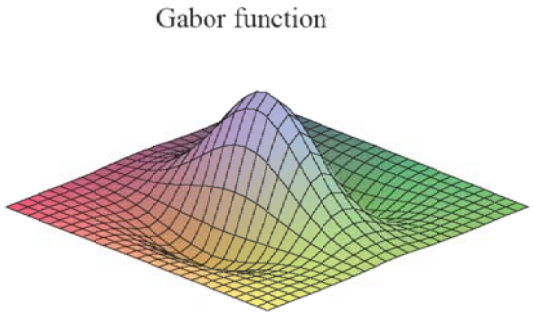
$$R(x) = \langle \varphi_{\xi_0}(x) \mid S(x) \rangle$$

Visual system: Function

Extract objects; properties of objects must be preserved until the objects have been extracted.



Visual system: Result



Visual system: Sketch of theory

Visual system: Is the theory right?