NEUROSCIENCE I

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TODAY

* Introduction to neurons

* Simple neural circuits

GOAL

* basic understanding of how real neurons work & their complexities

* basic understanding of some neuroscience terms (action potential, synapse, myelin)

* beginning to understand neural circuits

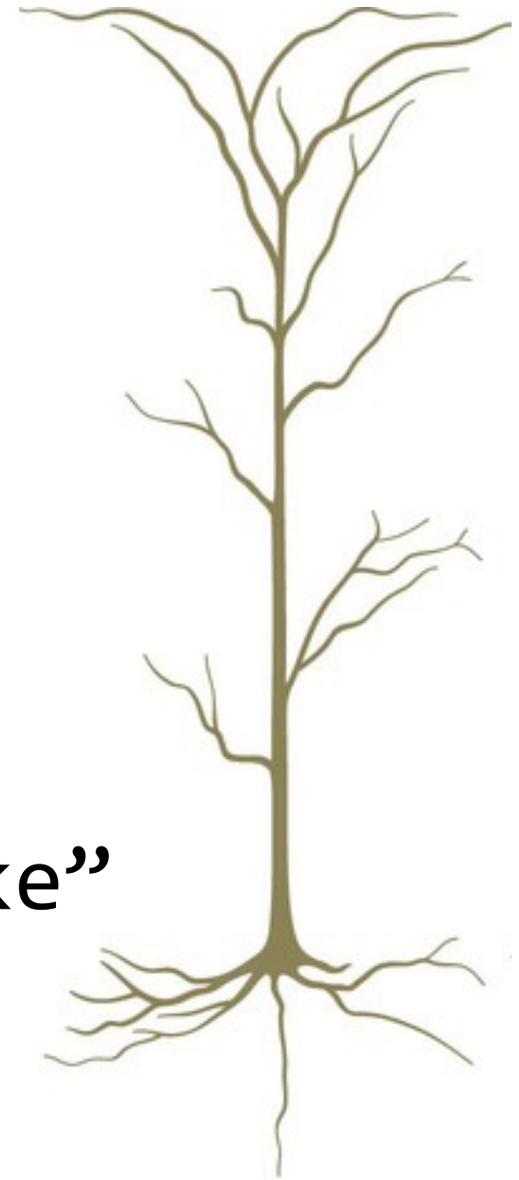
NOT GOAL

* memorize every step in action potential

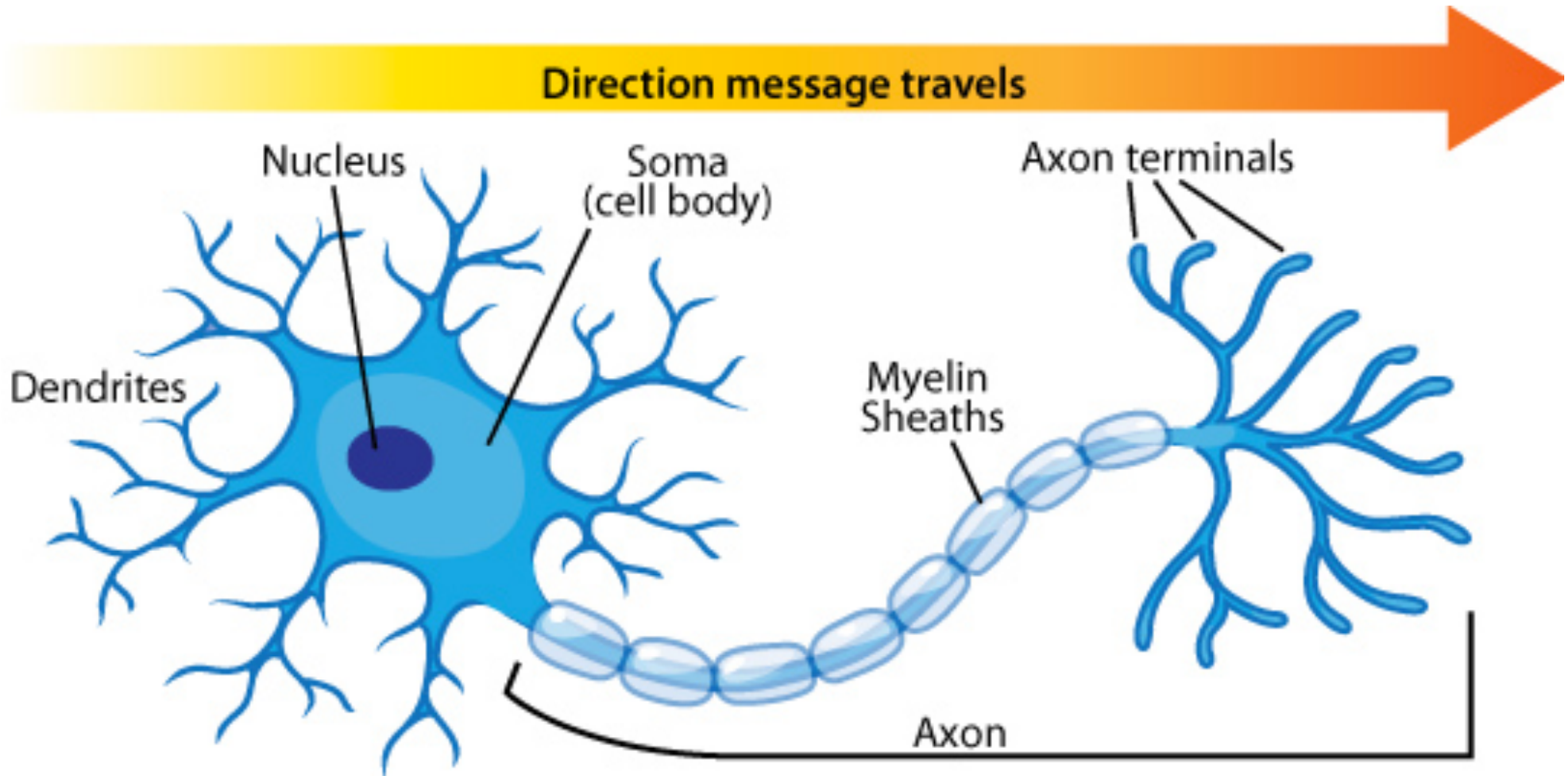
* become biologists

NEURONS

* **Neurons** are cells that are specialized for rapidly processing and communicating information
* In most neurons, activity is **binary**
  * On = action potential = “spike”
  * Off = rest



NEURONS


Direction message travels
Nucleus
Soma
(cell body)
Axon terminals
Dendrites
Myelin
Sheaths
Axon

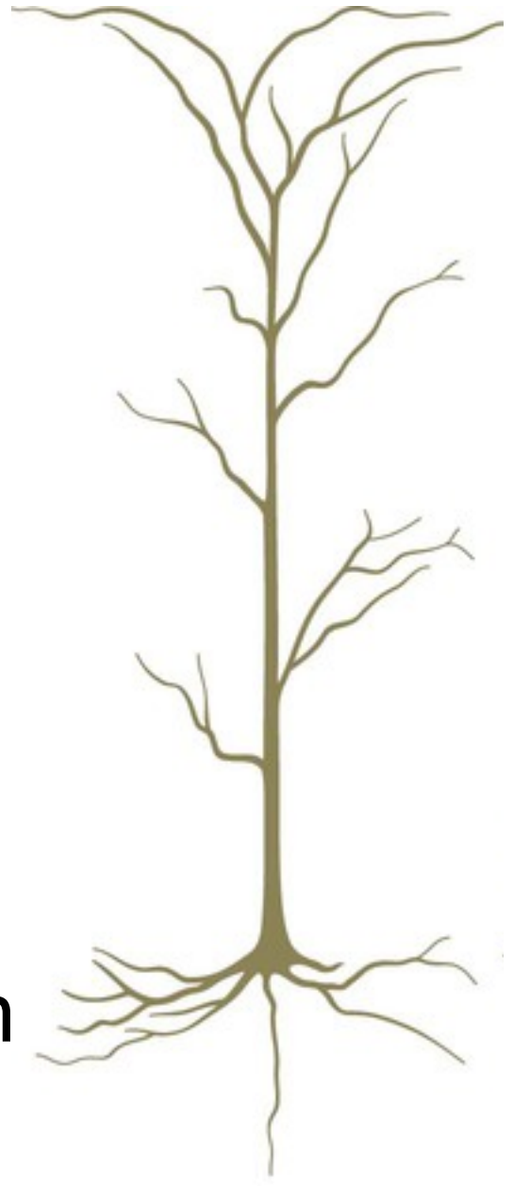
NEURONS

* Neurons work by manipulating **electro-chemical gradients**

  * Na+ is moved out of the cell

  * K+ is moved into the cell

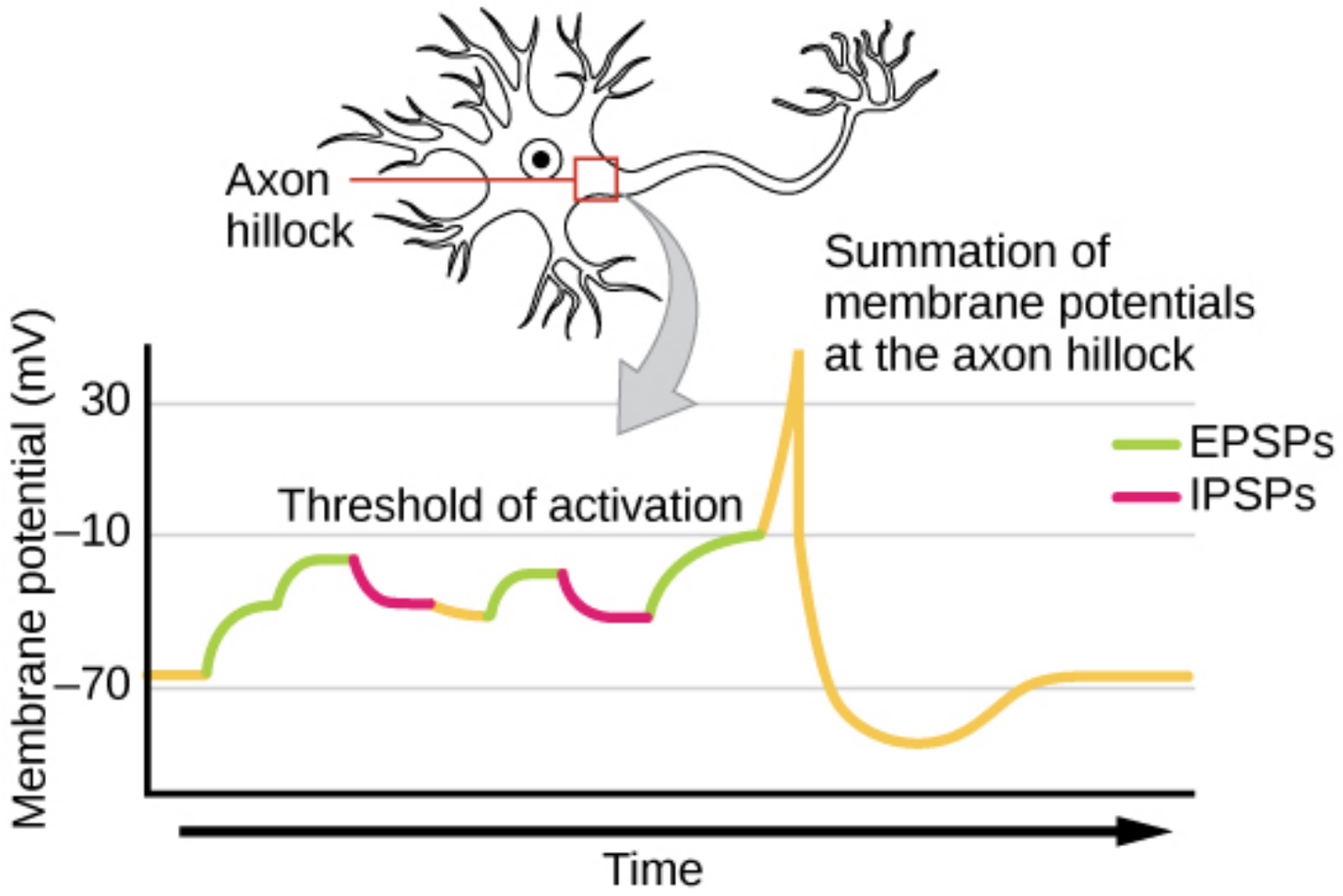
* Most of the energy used by our brains goes to maintaining a **rest potential** of -70mV in each neuron



NEURONS

* Spiking is governed by **voltage-gated ion channels**

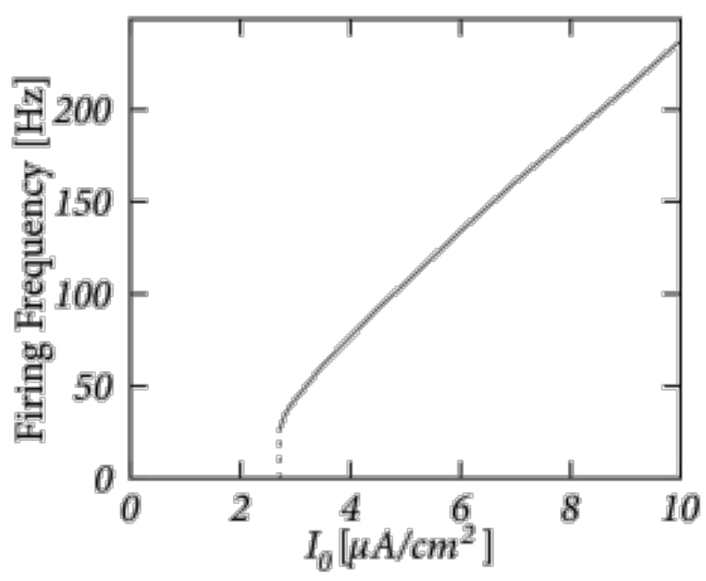
* Voltage-gated Na+ channels open when potential rises above the **threshold potential**



NEURONS

* Voltage-gated channels create a **nonlinear dependence** between neural input and output

* This is an **output nonlinearity**



NEURONS

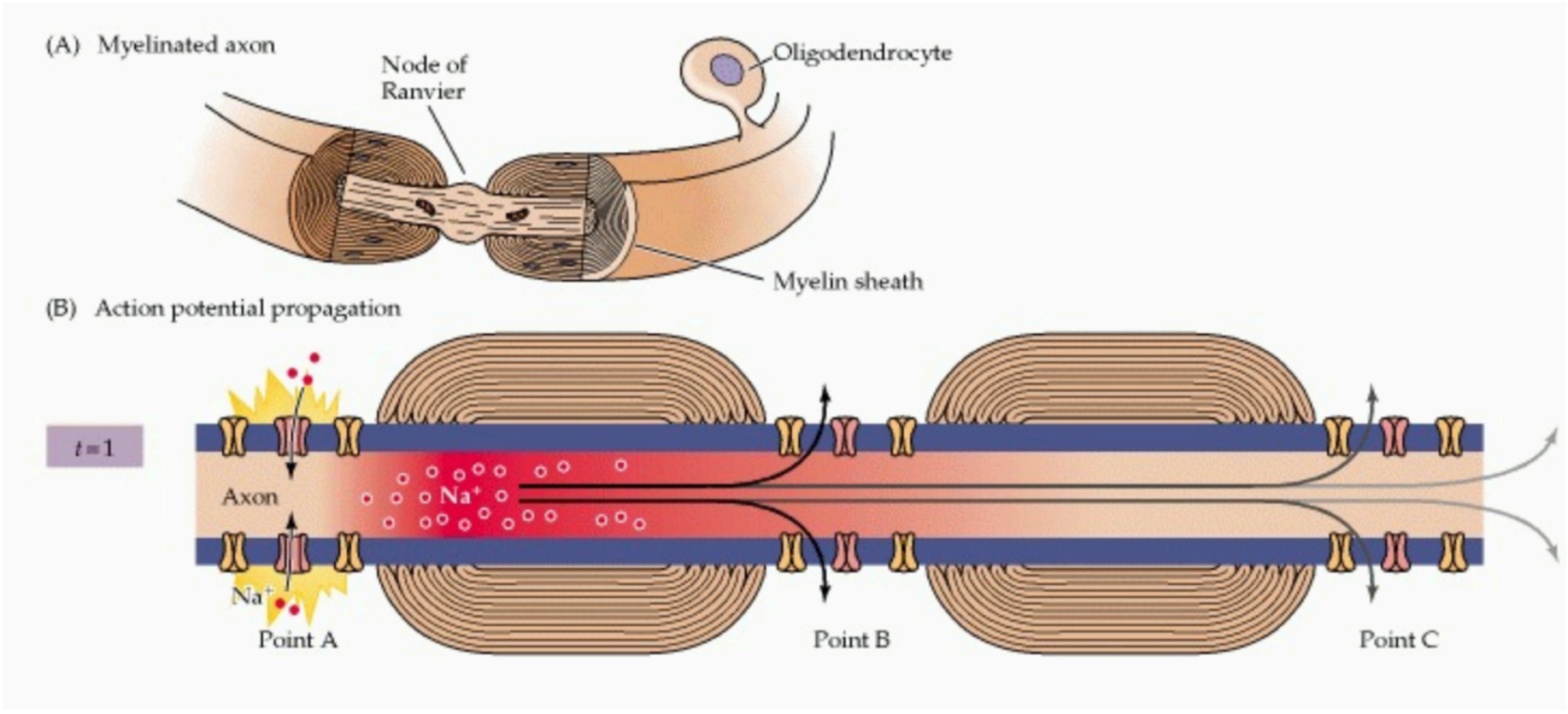
* Spike propagation along an axon is an **active process**

* In naive implementations (invertebrates) spike propagation is **slow** (0.5-10 m/s)

  * (And proportional to axon diameter, hence the squid giant axon)

NEURONS

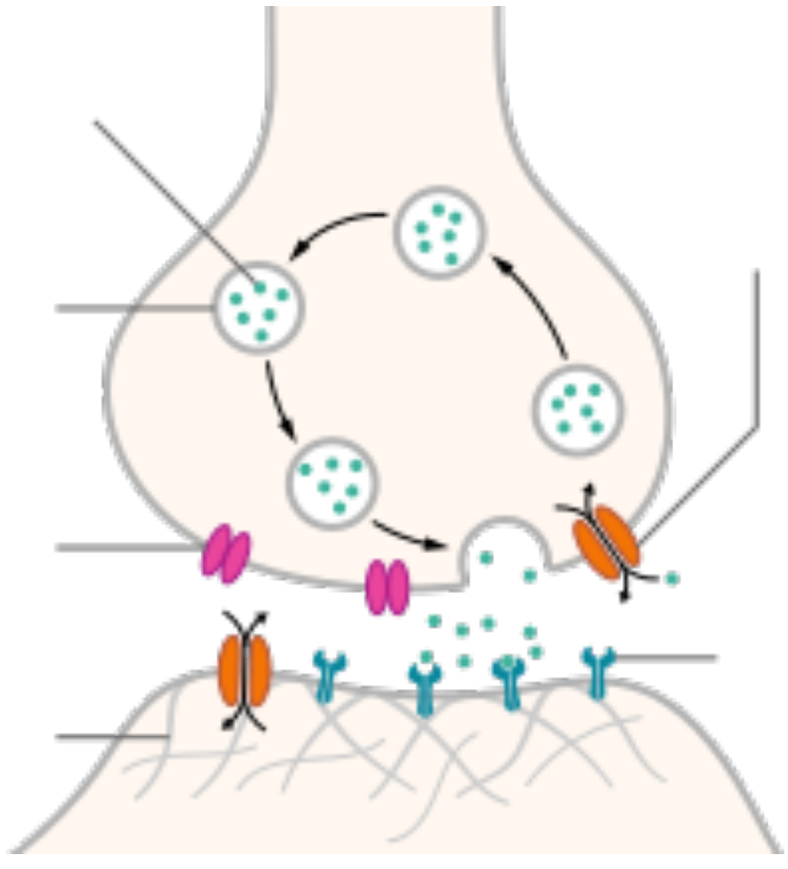
* In advanced implementations (vertebrates), insulating **myelin** surrounds axons, yielding faster propagation (~150 m/s)



SYNAPSES

* Neurons form **synapses**: connections that carry information from one neuron to another

* Synapses convert spikes into chemical signals (**neurotransmitters**) that are re-converted into electrical signals



SYNAPSES

* Synapses can be **excitatory, inhibitory,** or more complicated

* Their effect is determined by the type of neurotransmitter released

  * **Glutamate** = excitatory

  * **GABA** = inhibitory

SYNAPSES

* Each neuron only releases one type of neurotransmitter

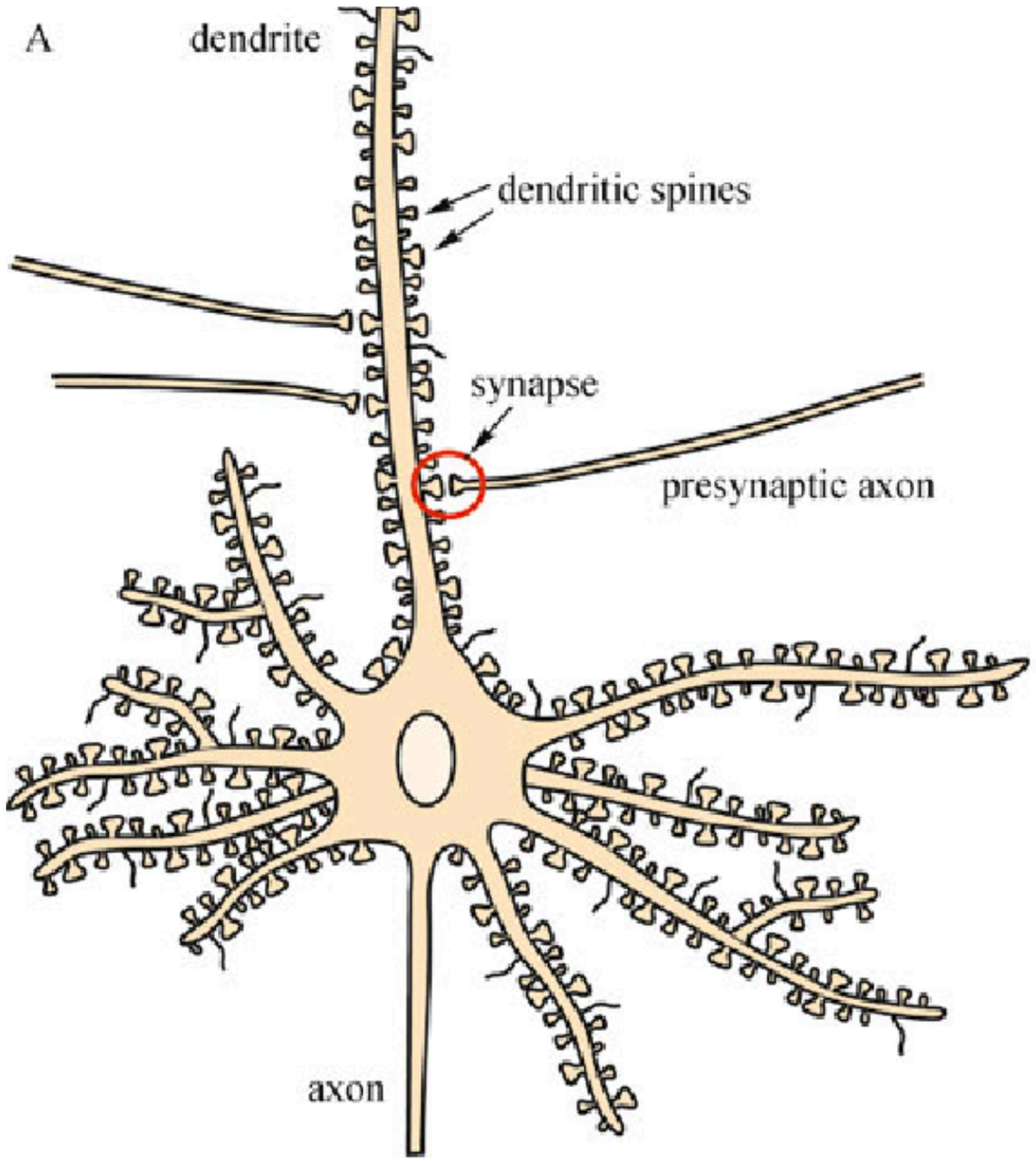
* Neurons are often described by the their neurotransmitter + “-ergic”

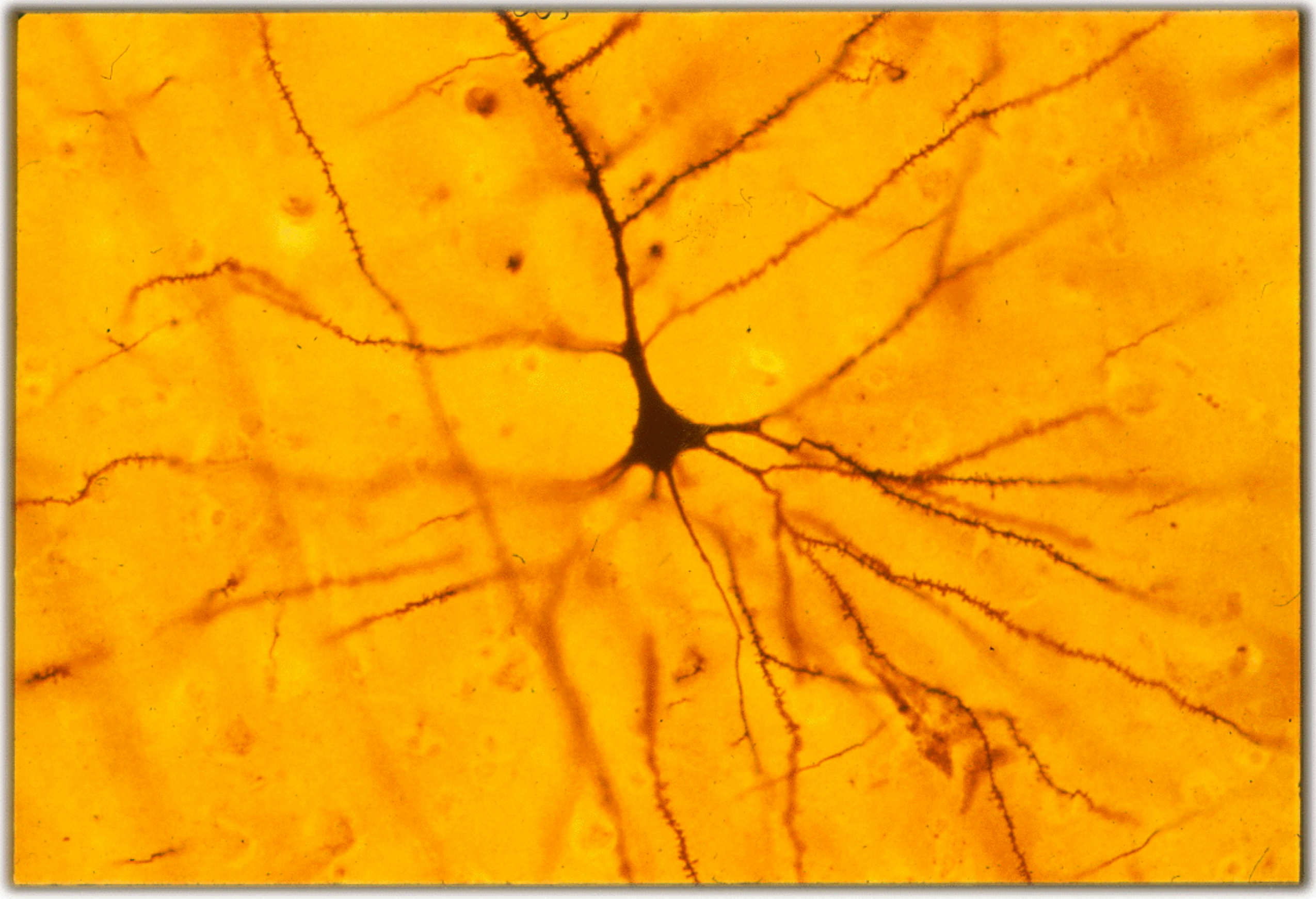
  * E.g. “**glutamatergic**” neurons release glutamate, “GABAergic”, “dopaminergic”, “serotonergic”, etc.

SYNAPSES

* Synapses form between axons (of the **presynaptic neuron**) and dendrites (of the **postsynaptic neuron**)

* Most synapses form on **dendritic spines**

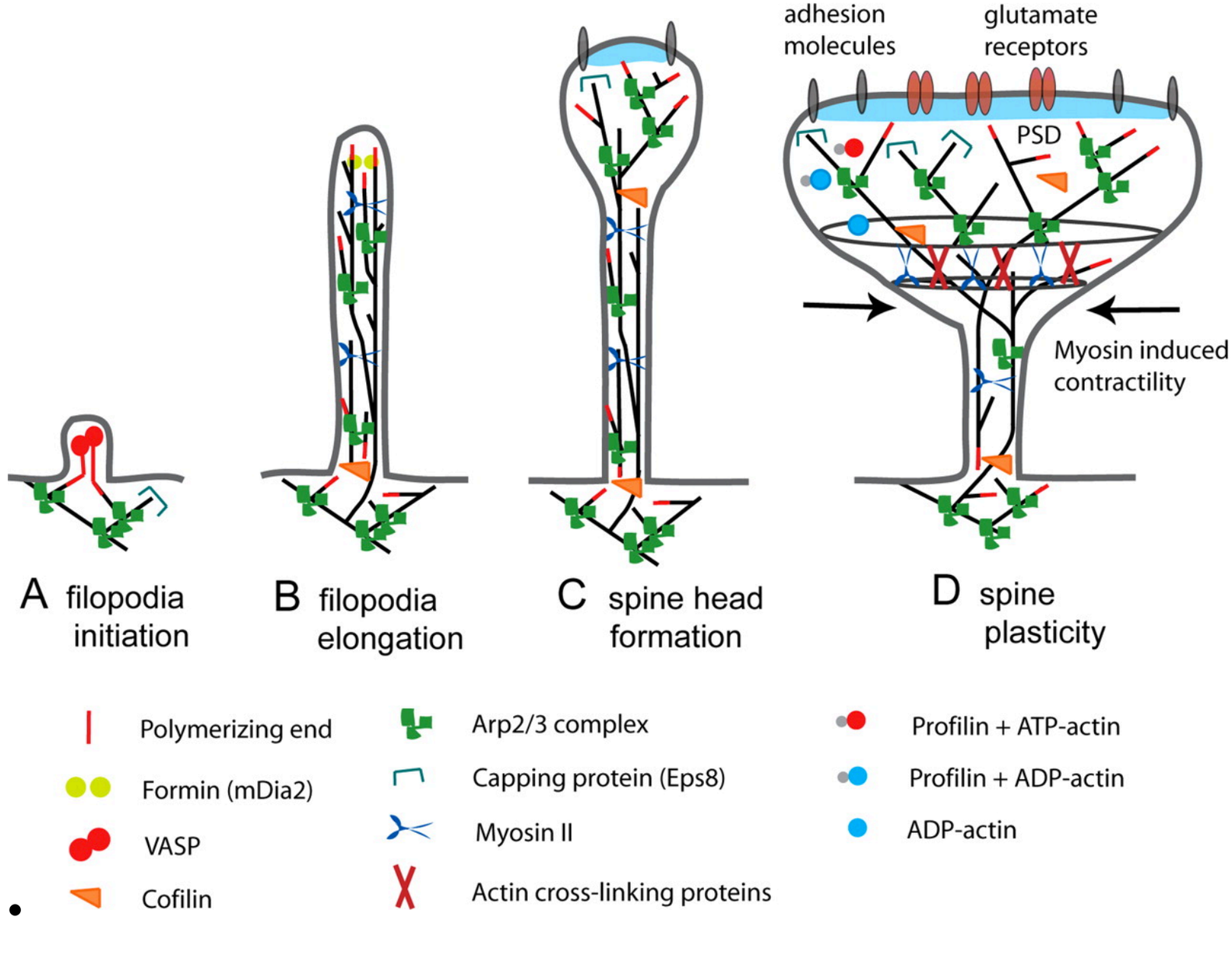




SYNAPSES

* Synapses vary in **strength** (the effect of an incoming spike)

* *MANY* factors influence synaptic strength, stability, etc.



SYNAPSES

Donald Hebb
(1904-1985)

* Synaptic weights are **plastic**

* **Hebbian Learning:**

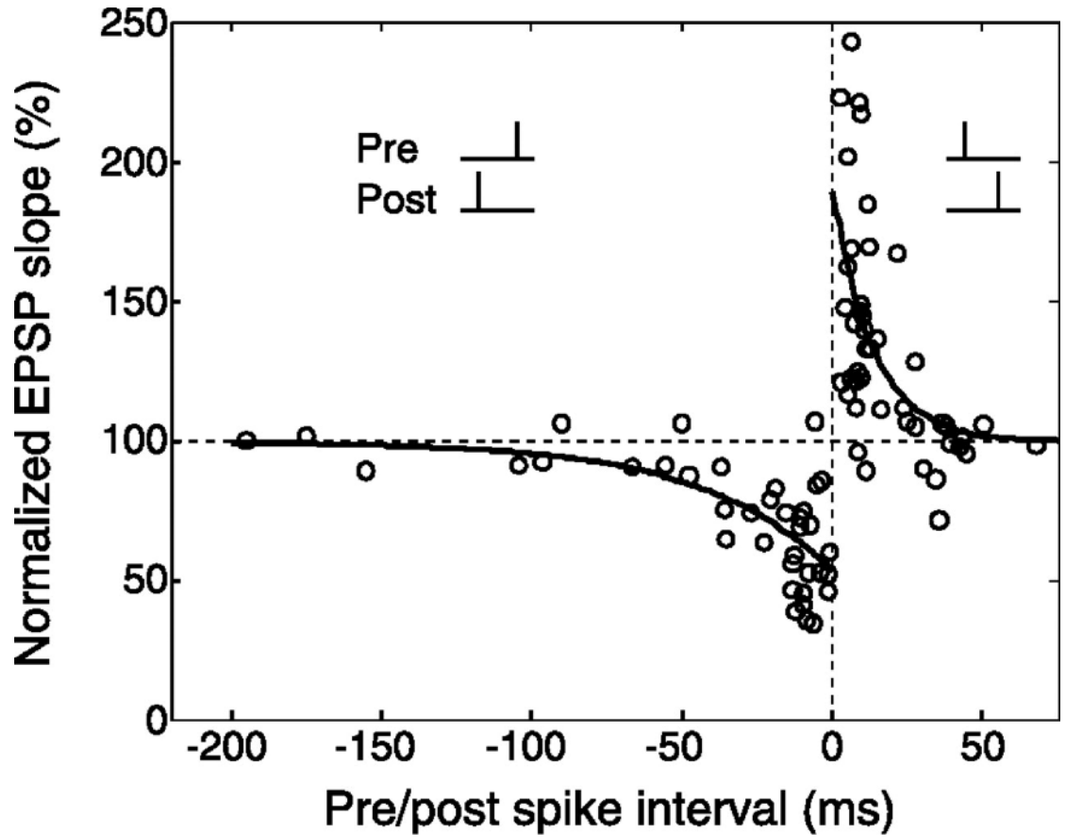
  * *Neurons that fire together, wire together*

SYNAPSES

* Spike-timing dependent plasticity (STDP)

* Long-term potentiation (LTP)

* Long-term depression (LTD)



NEURAL CIRCUITS

* **Problem:**
  * you are an **owl**
  * you hear scratching sounds from a **delicious mouse**
  * how do you **spatially localize** the mouse using signals from your 2 ears?

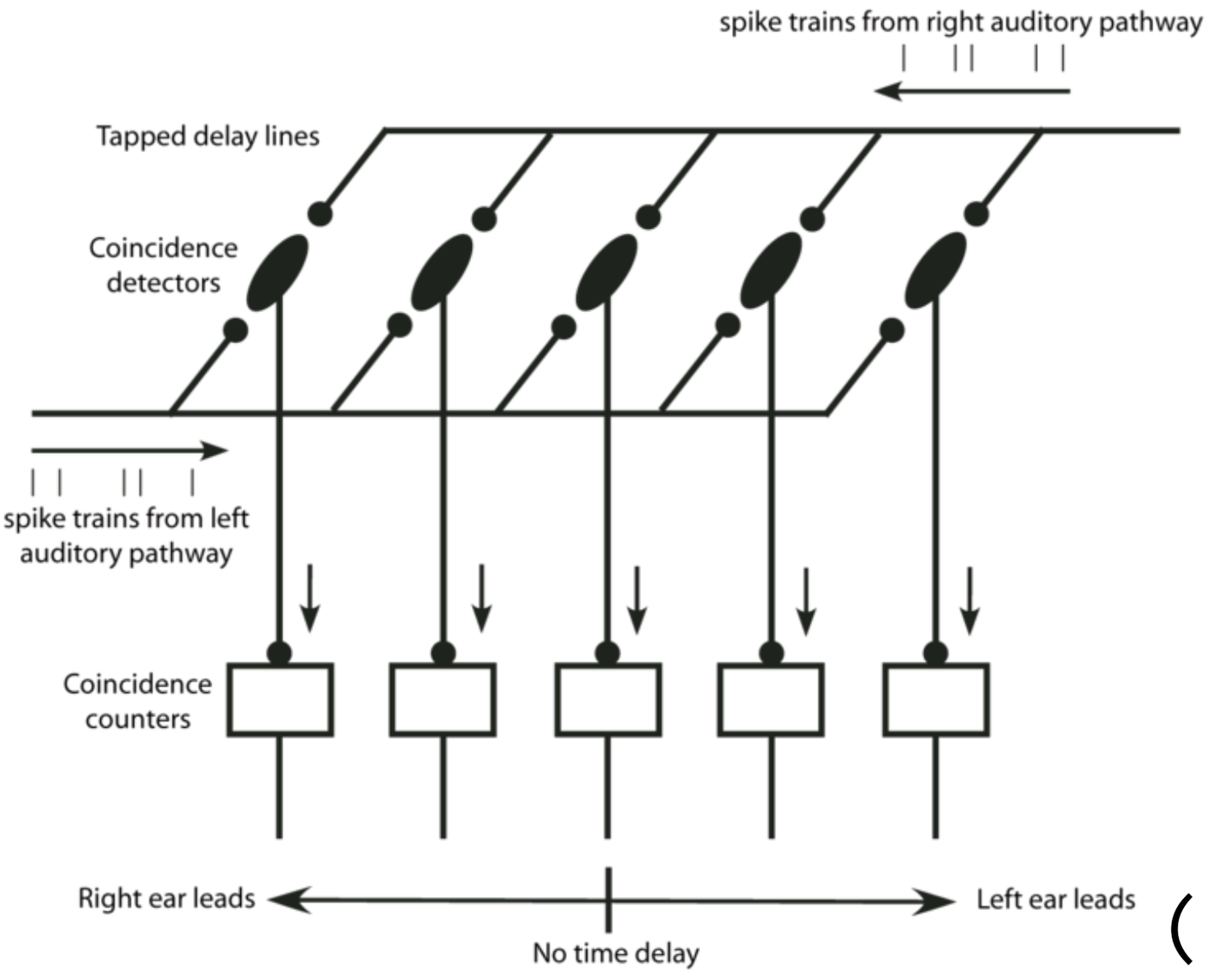
THINK

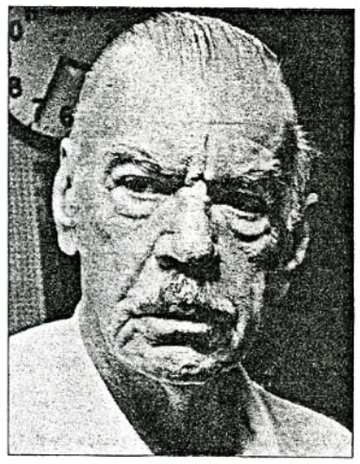
PAIR

SHARE

JEFFRESS MODEL

* Interaural time difference (ITD) can be computed by a set of **coincidence detectors**



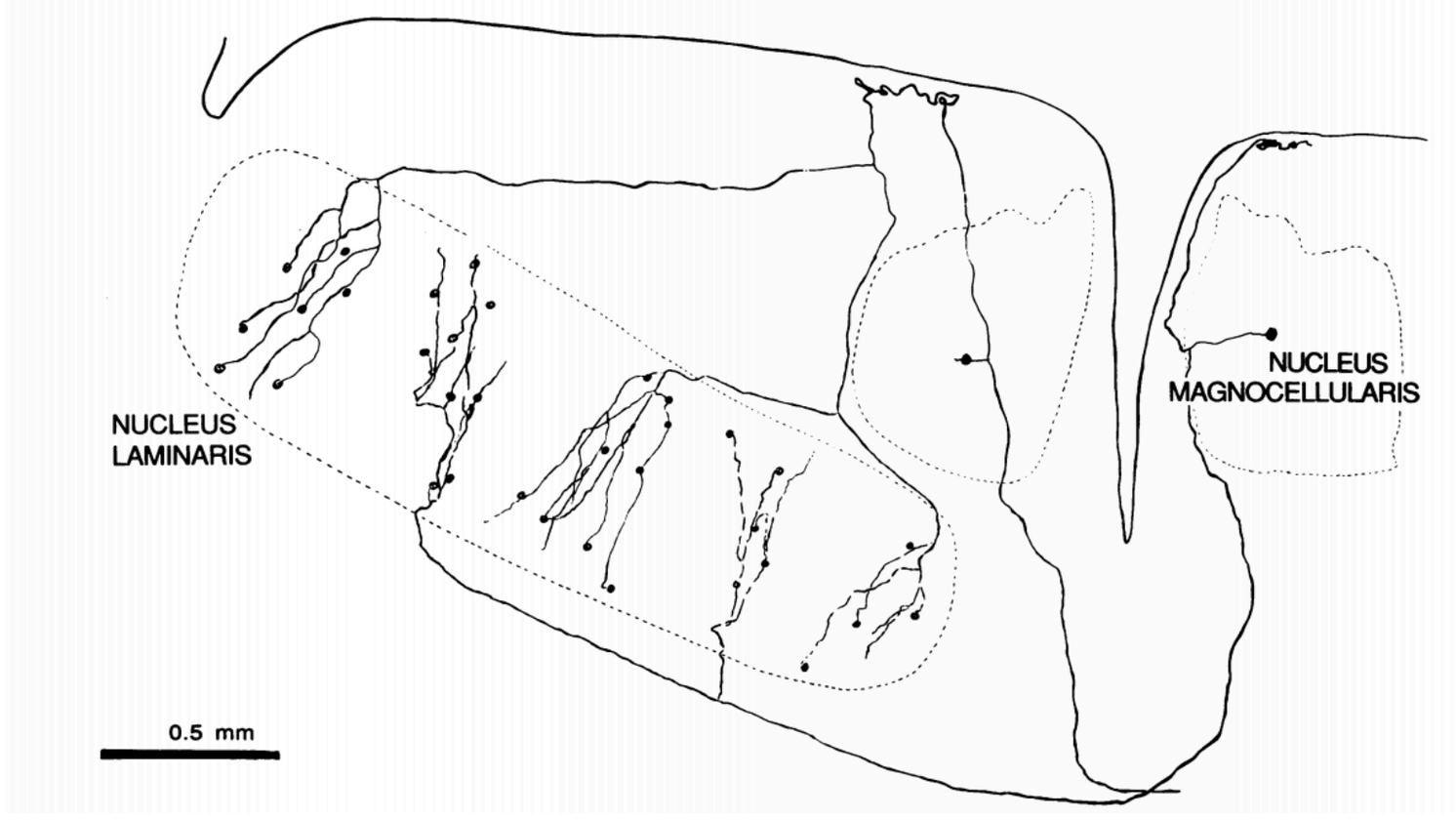


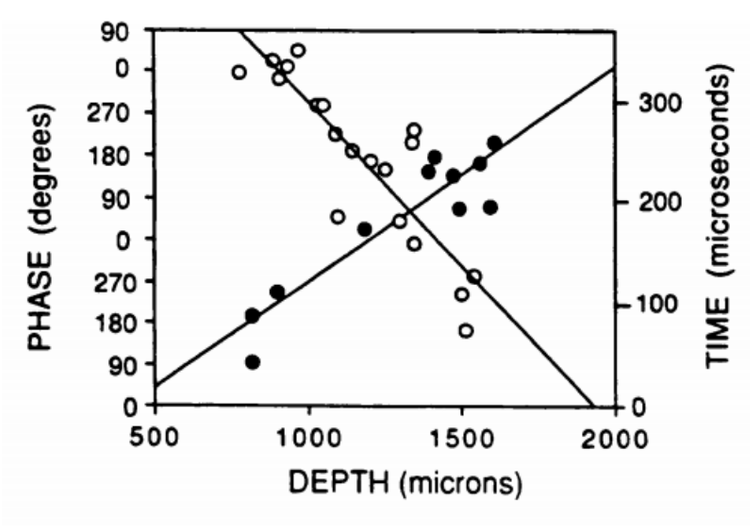
Lloyd Jeffress (1900-1986)
UT prof!

(Jeffress, 1948)

JEFFRESS MODEL

* 40 years later Carr & Konishi (PNAS 1988) confirmed that this is how barn owl hearing works





● ipsilateral ear

○ contralateral ear

RECAP

* neuron
  * action potential, nonlinearity
* synapse
  * plasticity, metaplasticity, LTP, LTD
* jeffress model

NEXT TIME

* “principles” that govern neural systems:
  * homeostasis, E/I balance, criticality