

NEURAL COMPUTATION

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LAST TIME

- * neurons
- * action potentials (aka spikes)
- * myelin / spike propagation
- * synapses
 - * neurotransmitters
- * neural circuits (the Owl!)

TODAY

- * finish up sound localization circuit
- * synaptic plasticity
- * homeostasis
- * hebbian learning & how to fix it

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?**



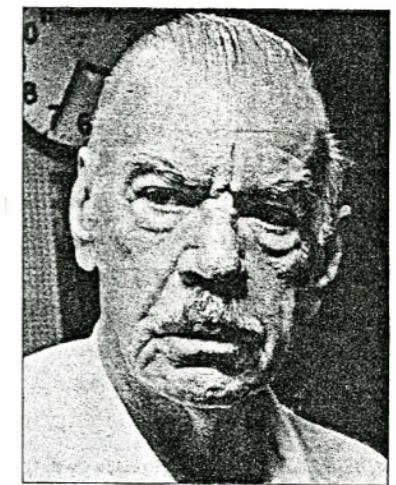
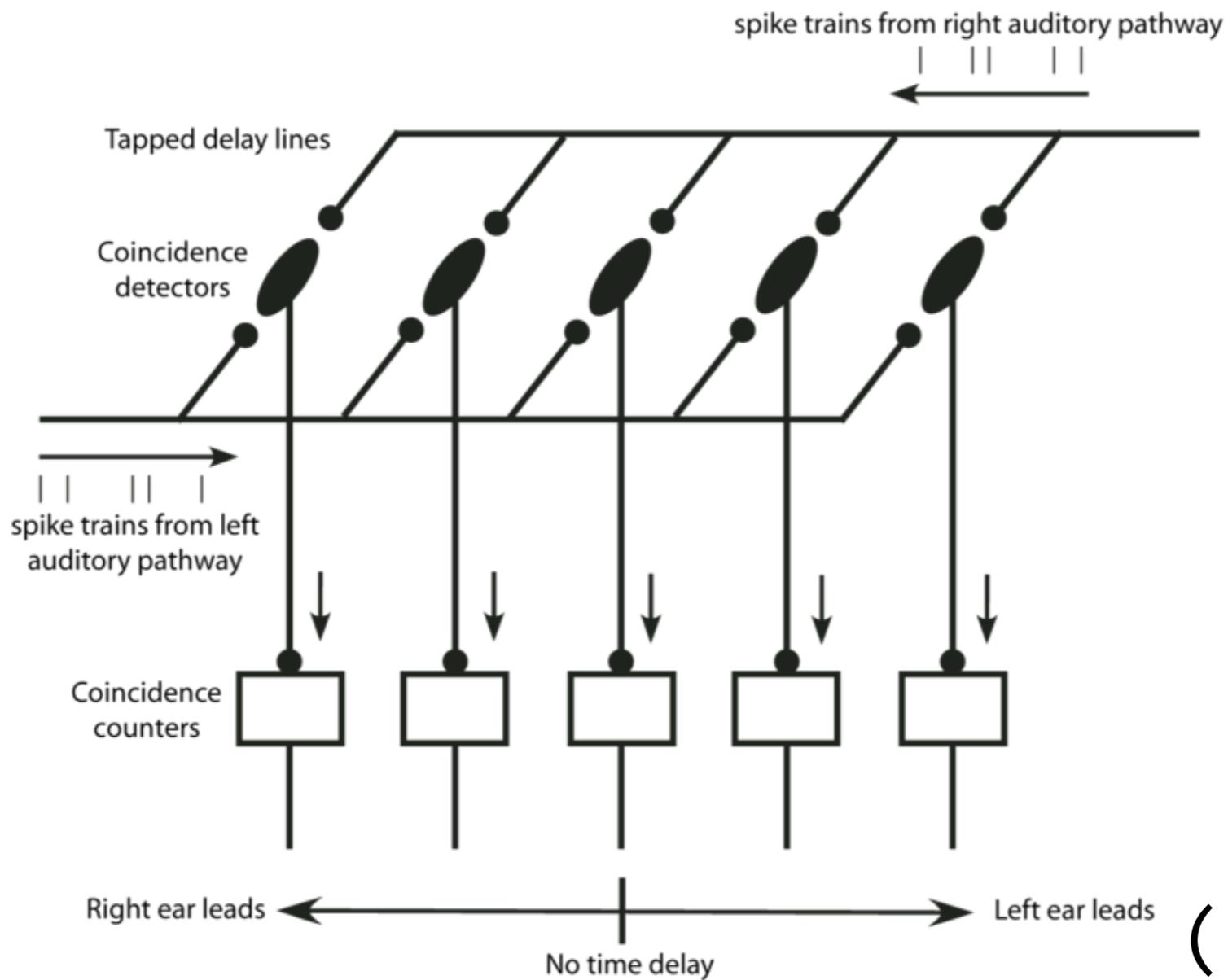
NEURAL CIRCUITS

- * Marr's levels
- * Comp. goal: find 
- * Algorithm: ??
- * Implementation: ??



JEFFRESS MODEL

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

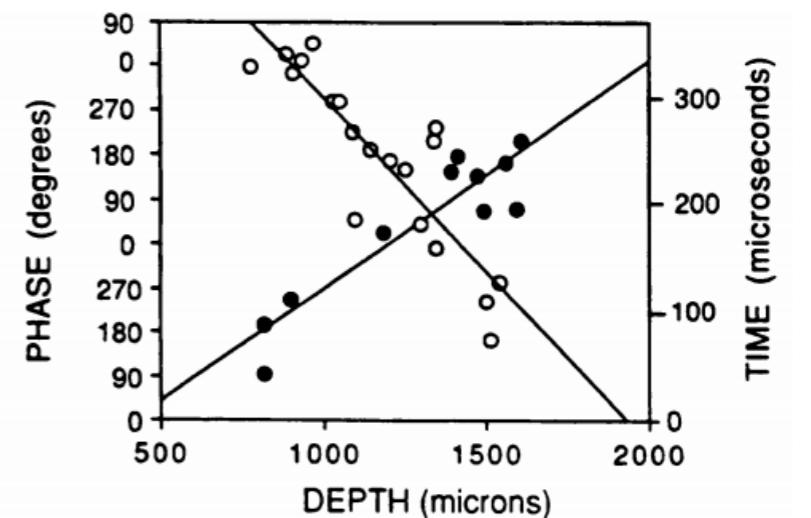
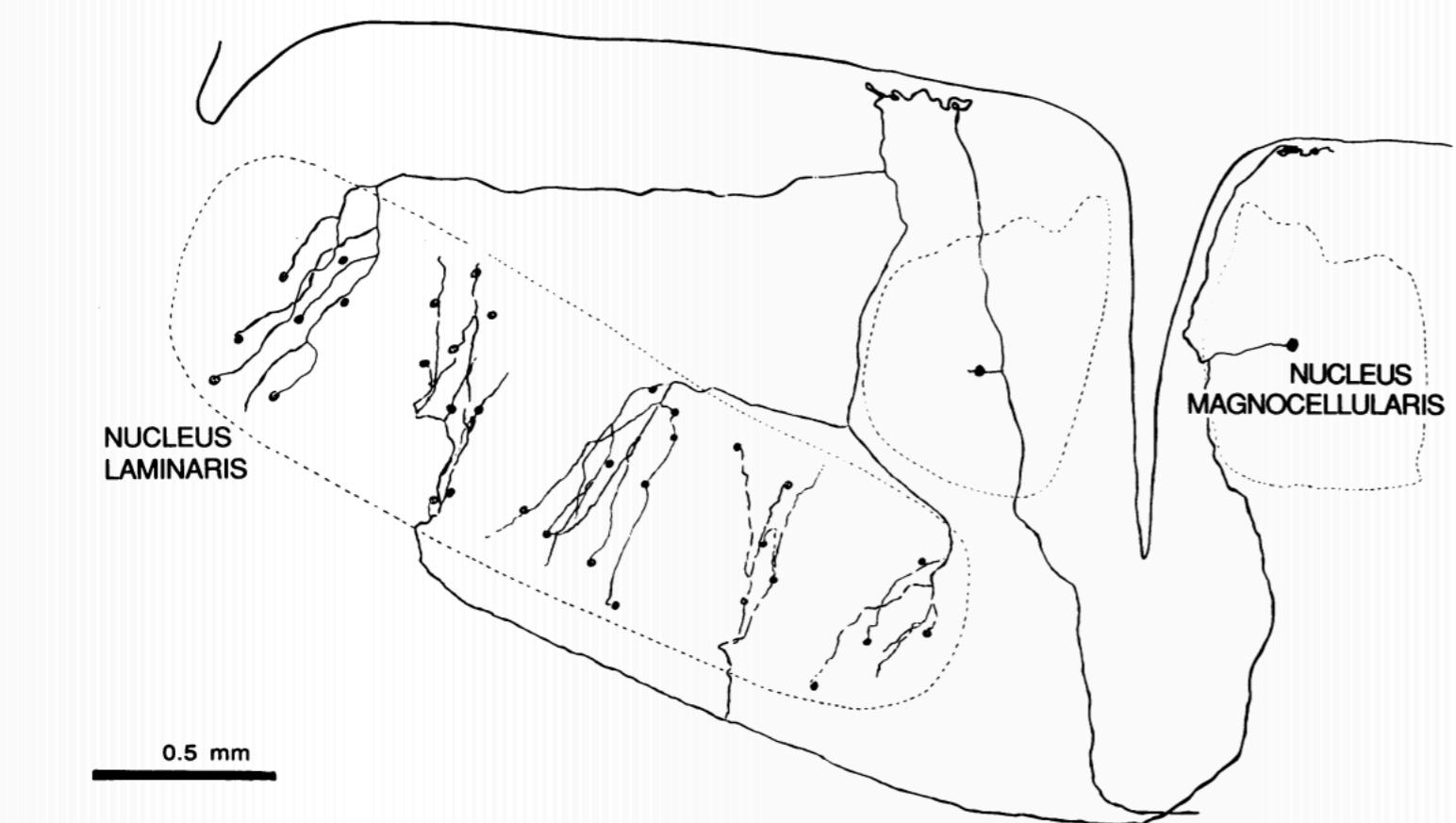


*Lloyd Jeffress
(1900-1986)
UT prof!*

(Jeffress, 1948)

JEFFRESS MODEL

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

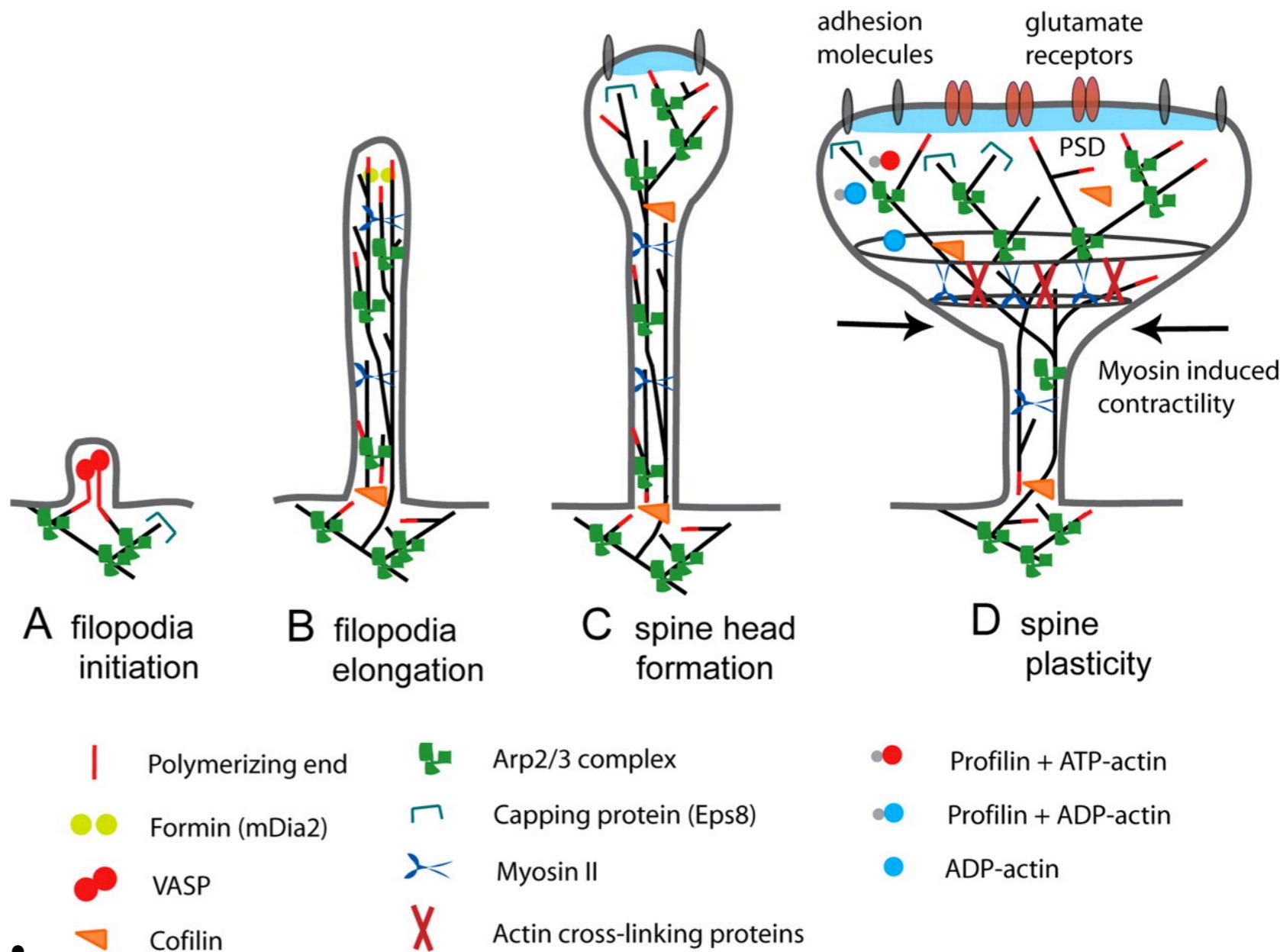


- ipsilateral ear
- contralateral ear

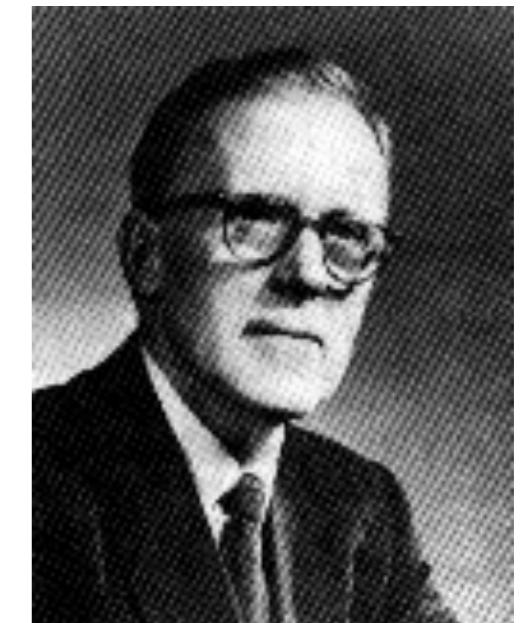
Recall: SYNAPSES

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

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



HEBBIAN LEARNING



- * Synaptic weights are **plastic**
- * **Hebb's rule:**
 - * *Neurons that fire together, wire together*

Donald Hebb
(1904-1985)

HEBBIAN LEARNING

- * Suppose we have a linear neuron with inputs x , weights w , and output y :

$$y = \sum_j w_j x_j$$

- * Hebb's insight implies a learning rule:

$$\Delta w_j = \eta x_j y$$

HEBBIAN LEARNING

- * BUT Hebb's rule is **unstable** (*notebook example*)
 - * Synaptic weights always diverge to infinity!
 - * This would be bad if it happened in the brain!!

INSTABILITY

- * Unless carefully tuned, activity in recurrent neural networks (e.g. brains) can also be **unstable**
 - * Unstable networks tend to either become **quiescent** (converge to zero activity),
 - * or **diverge**

INSTABILITY

- * Example: seizure / epilepsy



HOMEOSTASIS

- * Thankfully, many mechanisms in biological neural networks maintain **homeostasis**
- * Neurons seem to have a **target level** of activity
 - * If activity is too low, it is raised
 - * If activity is too high, it is lowered

HOMEOSTASIS

- * Homeostatic plasticity seems to come in two flavors:
 - * Intrinsic homeostasis
 - * Synaptic homeostasis

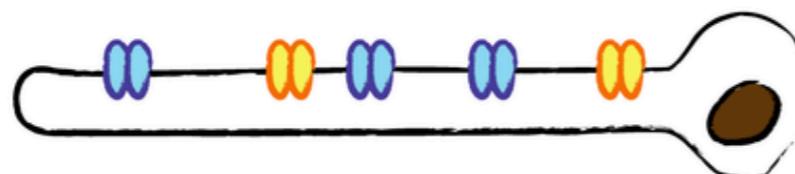
HOMEOSTASIS

- * In **intrinsic homeostasis**, electrical properties of neurons are changed

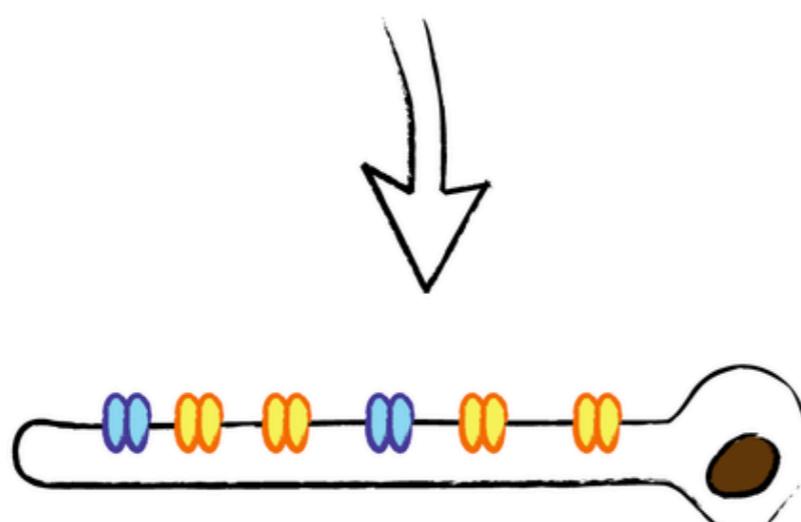
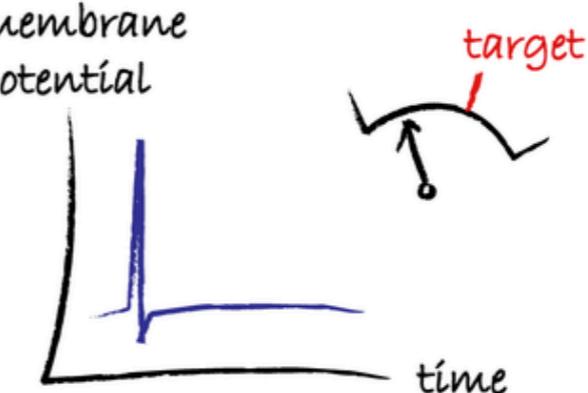
Intrinsic homeostasis

/blue/ hyperpolarizing channel

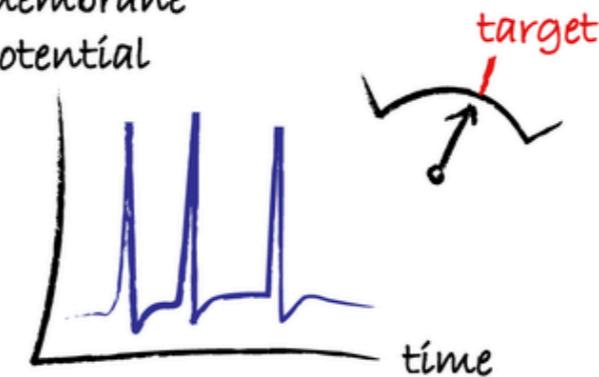
/orange/ depolarizing channel



membrane potential



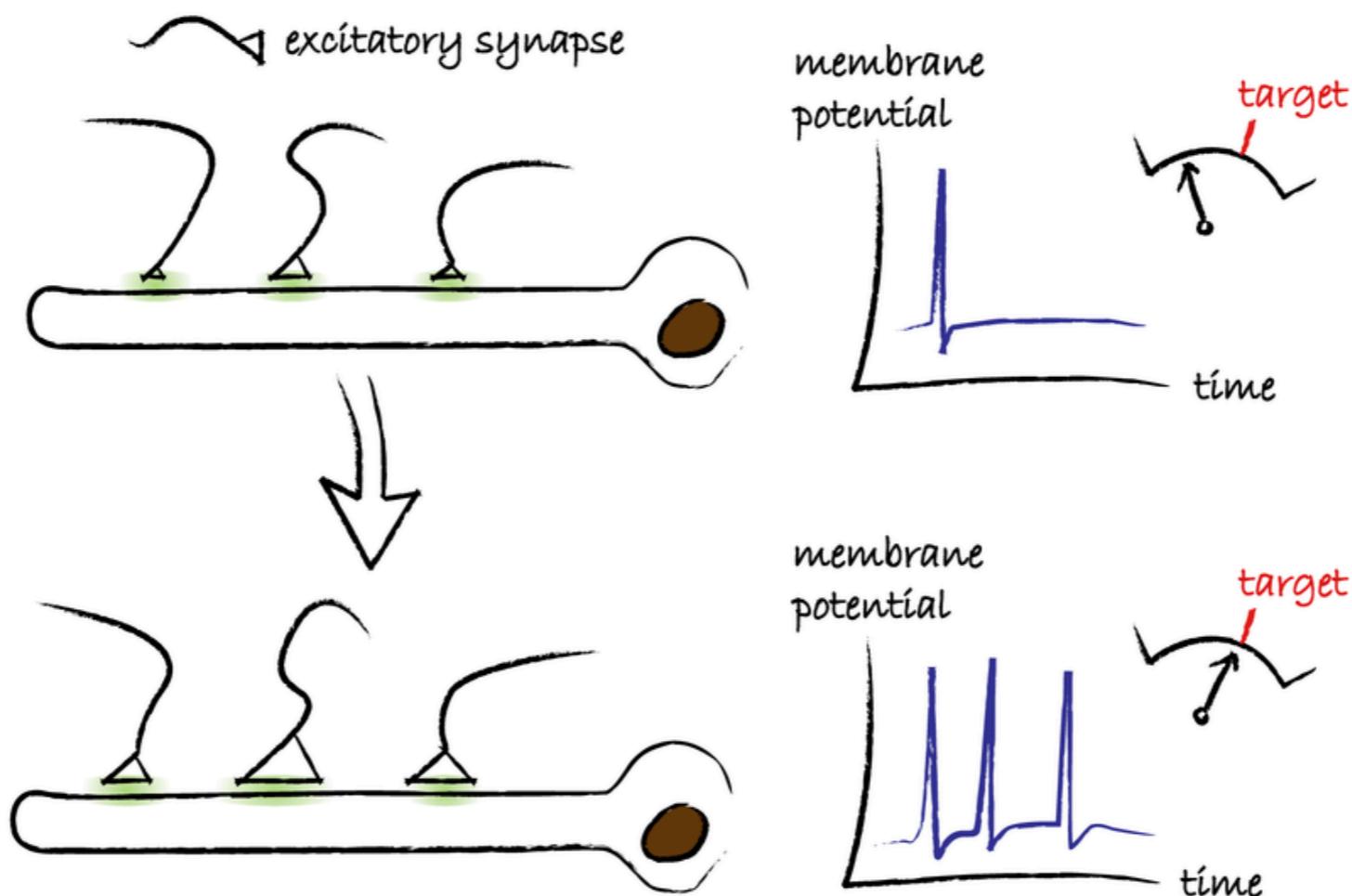
membrane potential



HOMEOSTASIS

- * In **synaptic homeostasis**, synapses are modified

Synaptic homeostasis



HOMEOSTASIS

- * Homeostasis can also be **harmful**:
 - * Tinnitus
 - * Phantom limb
 - * *Delirium tremens*

FIXING HEBB

- * How do we fix Hebb's learning rule so that it doesn't explode?

OJA'S RULE



*Erkki Oja
(1948-)*

- * Scale weight changes by output & current weights (Oja's rule):

$$\Delta w_j = \eta(x_j y - y^2 w)$$

output (y) feeds back to weight update,
preventing positive feedback loop

RECAP

- * neural circuits: Jeffress model
- * hebbian learning
- * homeostasis
- * oja's rule

NEXT TIME

- * neuroscience methods