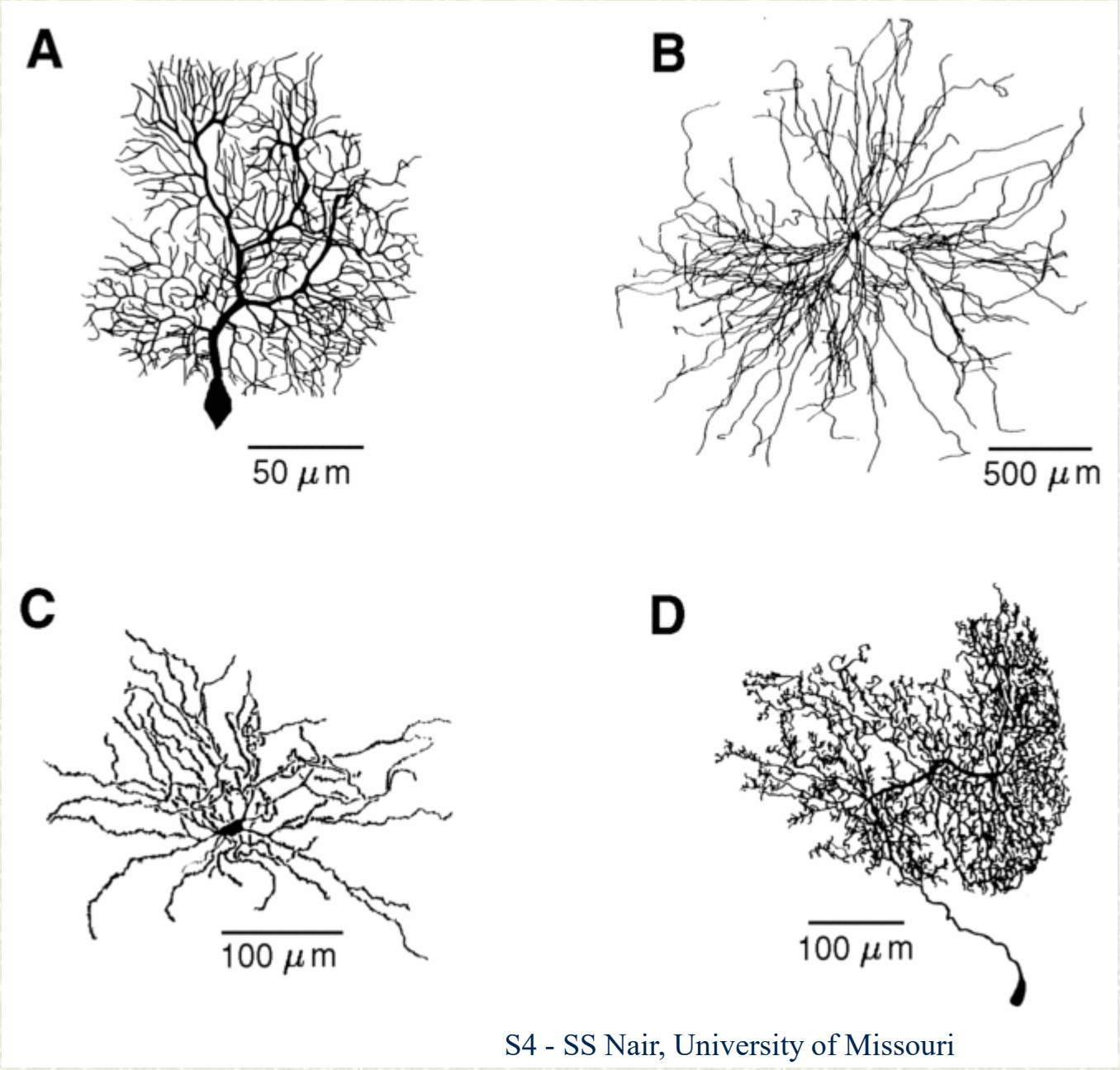
NEURON types –Why all this elaborate structure? Function?



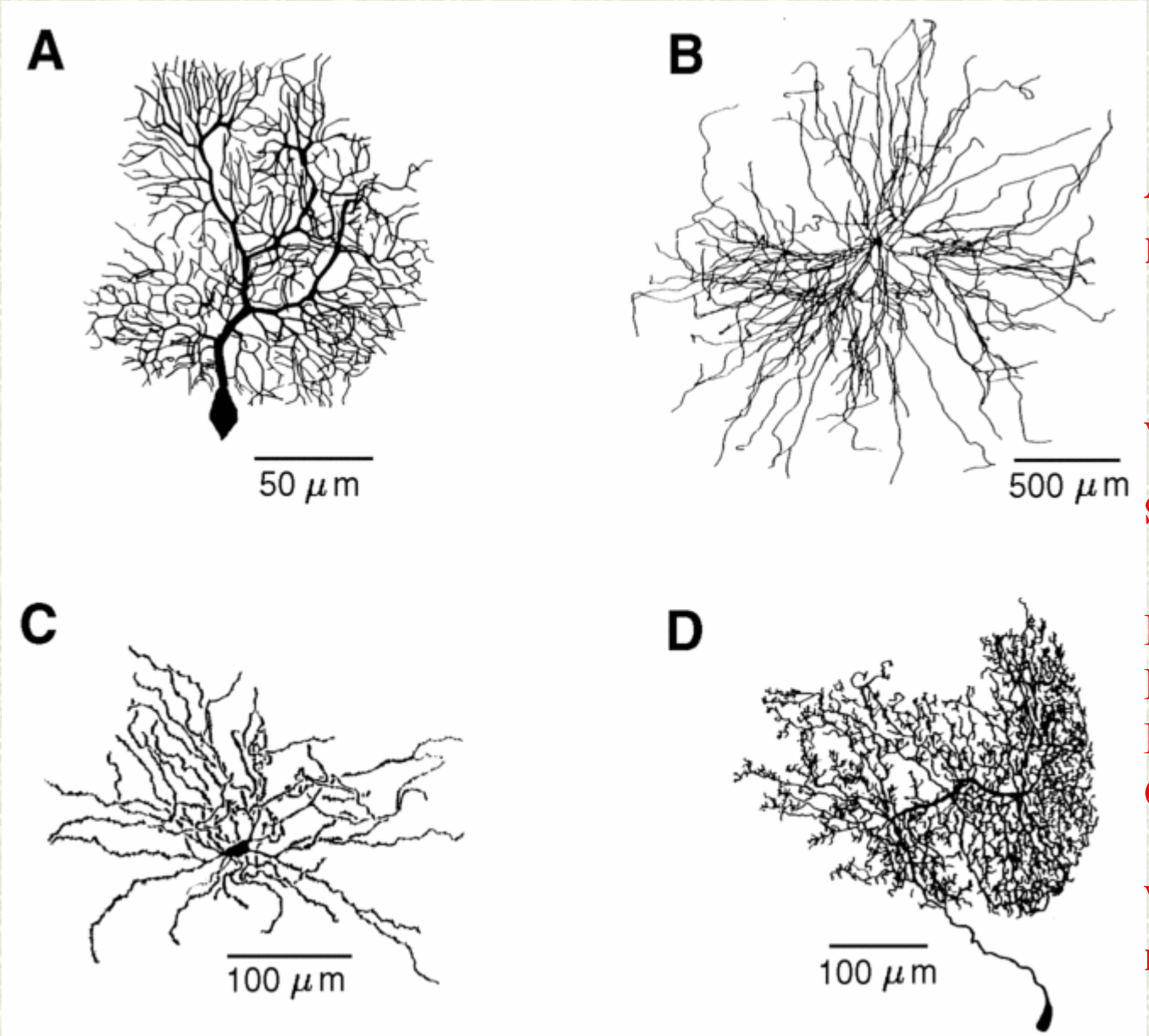
(A) Cerebellar Purkinje cell

(B) spinal cord motoneuron

(C) neostriatal spiny neuron

(D) locust interneurons

NEURON types –Why all this elaborate structure? Function?



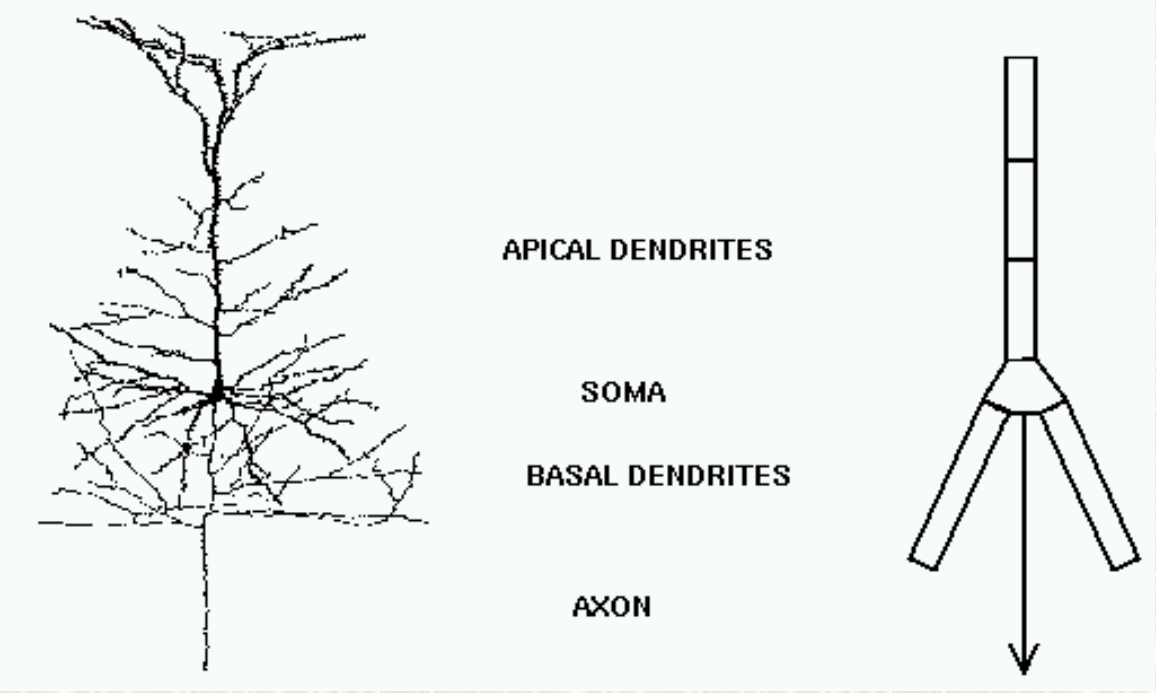
Antenna to receive inputs?

Where is the soma?

Function – RECEIVE, INTEGRATE, COMMUNICATE

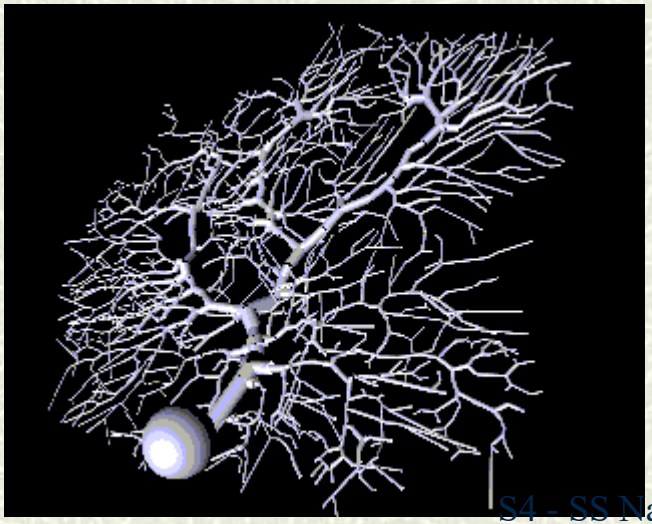
What part of the neuron does what?

Multi-compartmental models



simple model of a pyramidal cell

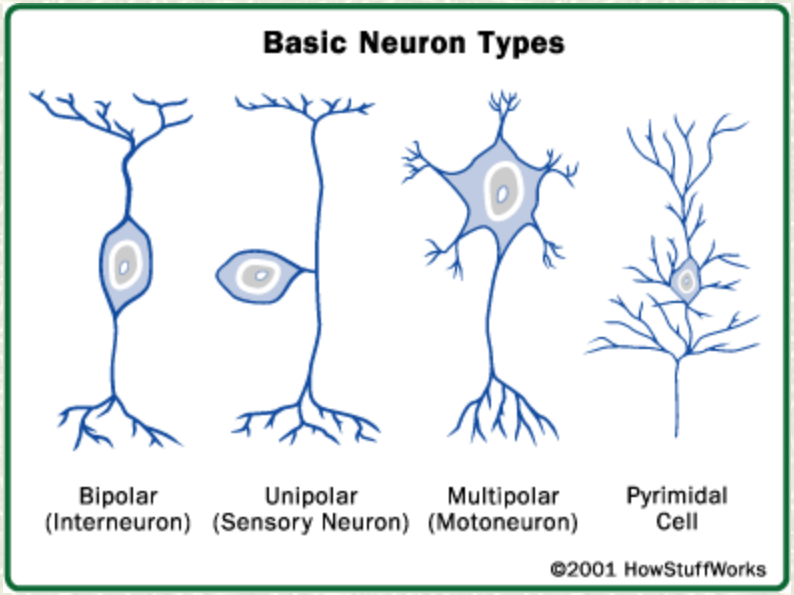
RECEIVE, INTEGRATE, COMMUNICATE



detailed model of a purkenje cell

-4550 compartments and 8021 channels (De Schutter and Bower 1994)

Computational models so far – all single compartments



Can a biological neuron be modeled as a single compartment?
– depends on the application

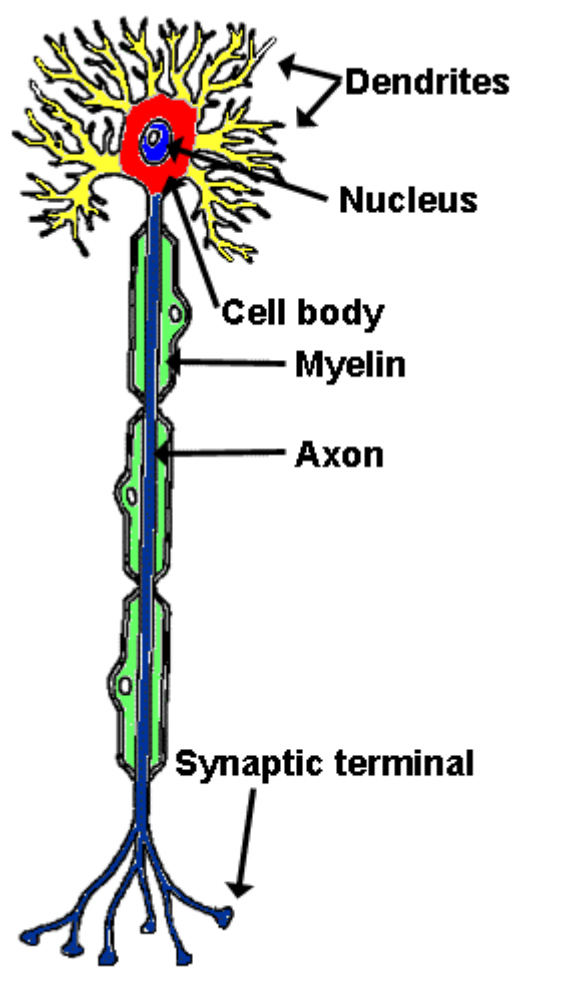
• Multi-compartment model of a single neuron - dendrite compartments, soma, axon compartments,…..

• Multi-cell models

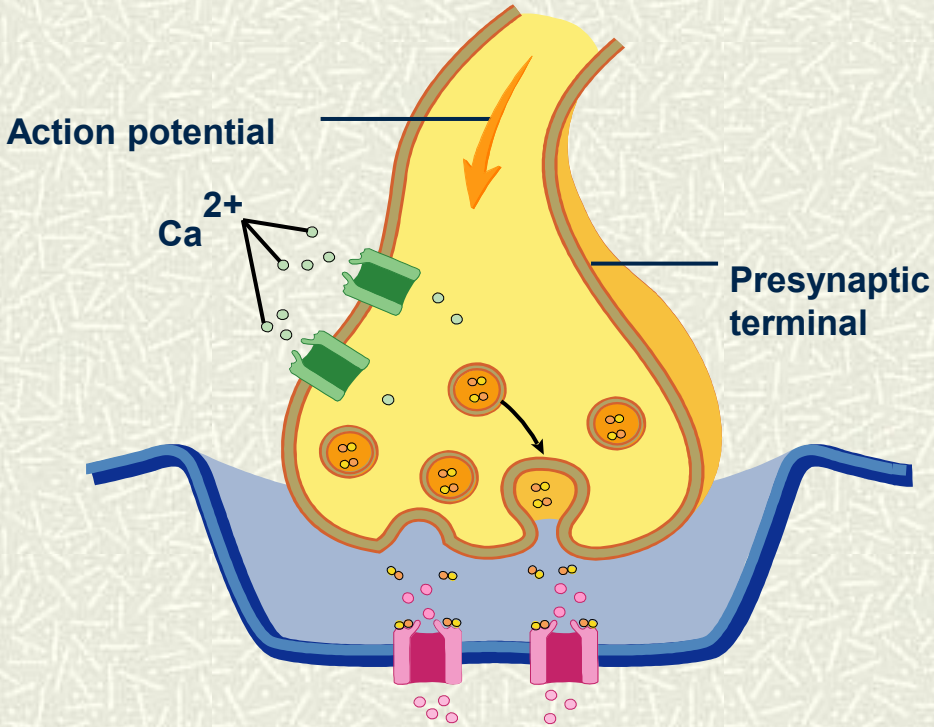
• Models for brain regions?

• Models for the brain?

RECEIVE – Dendrites; INTEGRATE – soma+initial segment of axon
COMMUNICATE?



Communication is via SYNAPSES – recall from Biology slides



RECEIVE – Dendrites; INTEGRATE – soma+initial segment of axon
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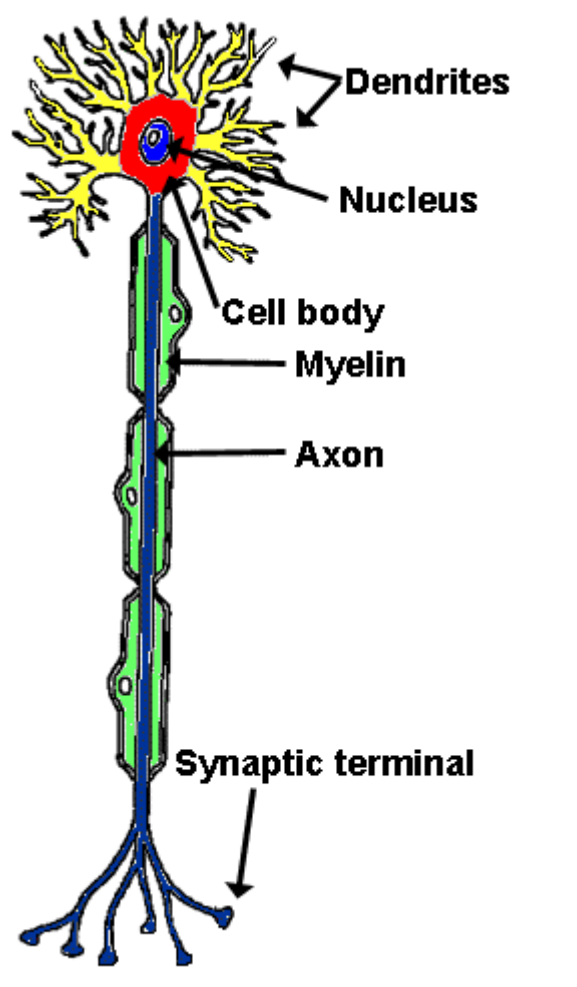

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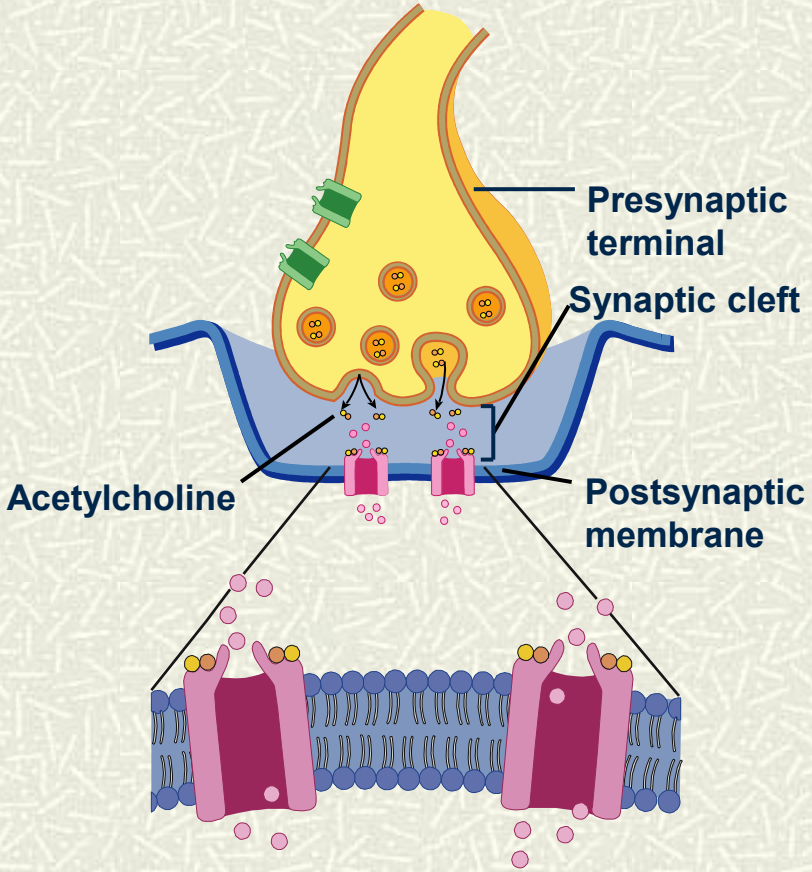
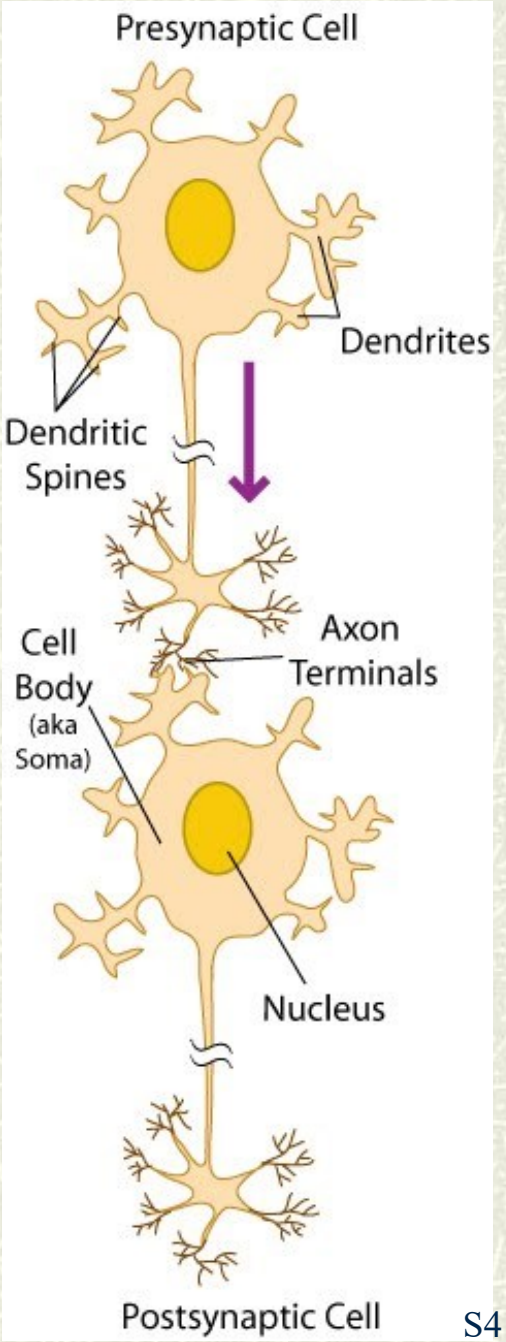
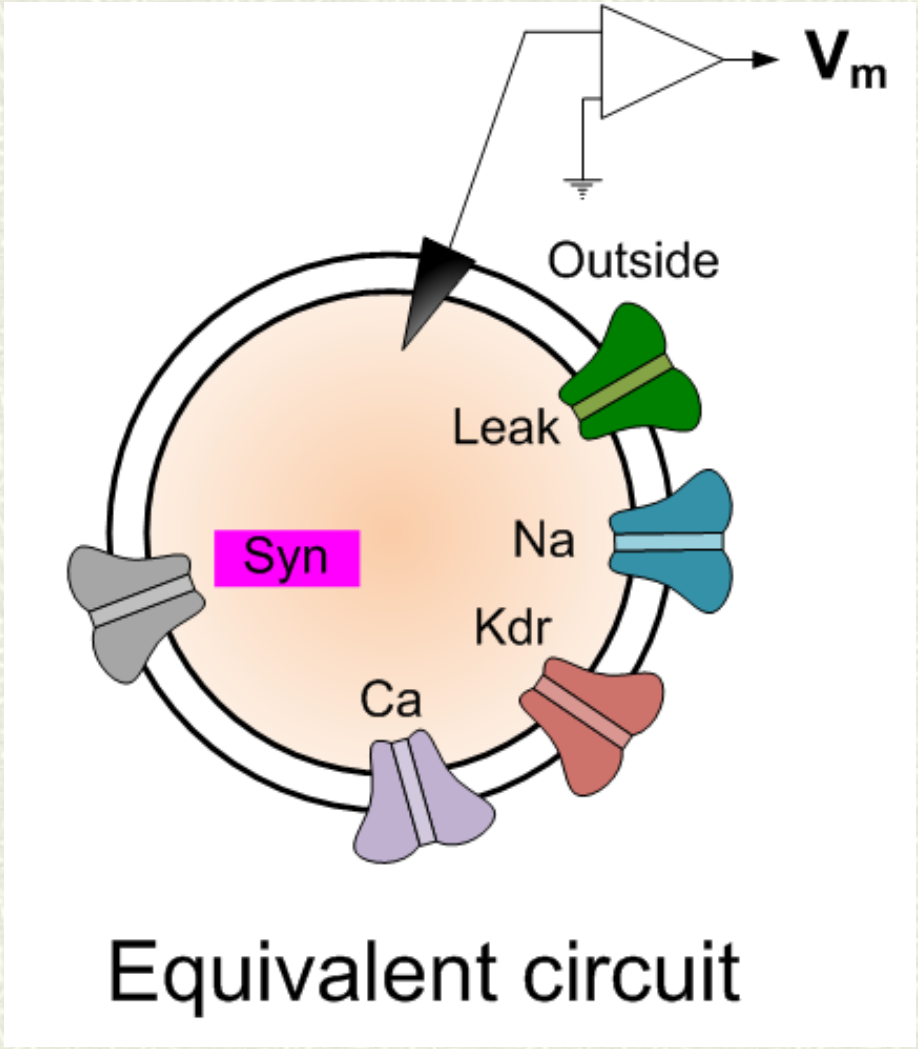


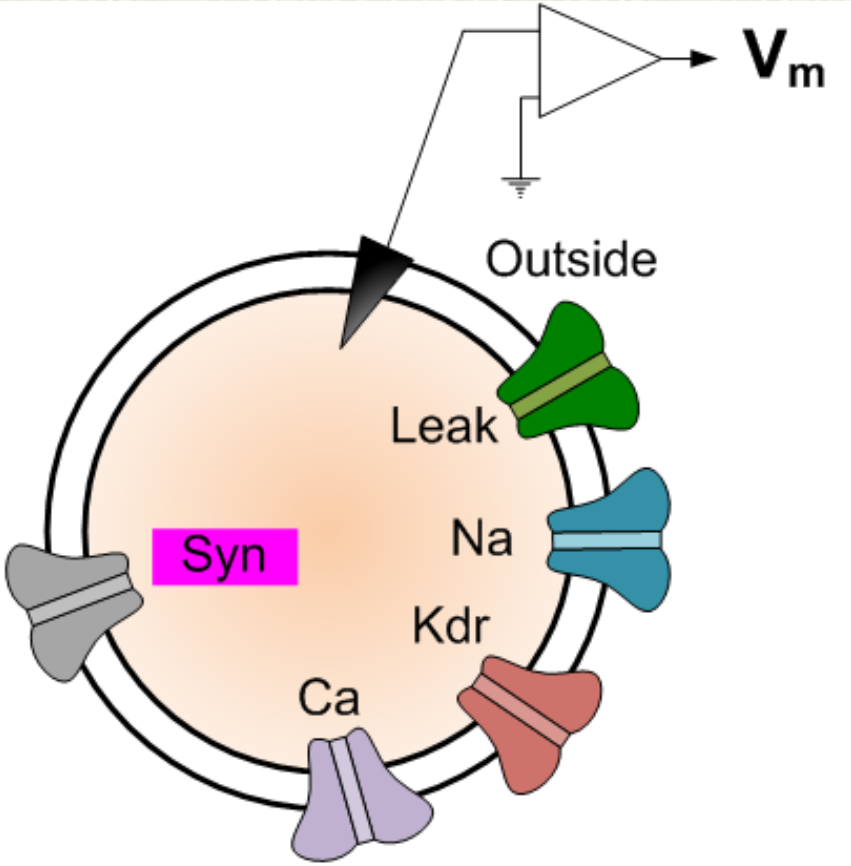
Modeling synaptic communication

Enlarged view of dendrite showing spines





Modeling synaptic communication



Equivalent circuit

What is the equation for G_{Na}?

How is G_{syn} different?

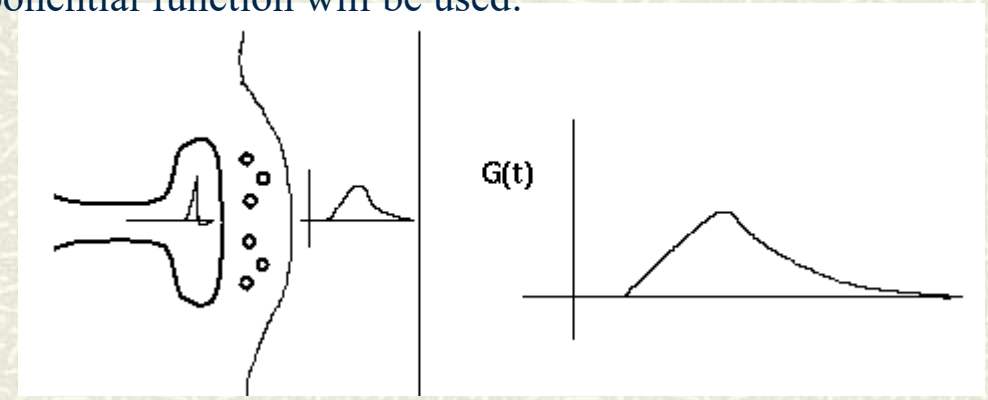
What is an equation for G_{Syn}?

MODELING SYNAPSES

"This diagram shows a synapse with an action potential propagating to the pre-synaptic terminal, causing neurotransmitter release, and the resulting post-synaptic conductance change, G(t). Current flow through this conductance can lead to a post-synaptic potential (PSP).
There is a lot of biochemistry and molecular biology involved in this behavior, often involving complicated chains of reactions and 'second messengers'. Fortunately, we can often use an empirical fit to the observed behavior, rather than modeling it in detail.
Typically, the conductance change from a quantum of neurotransmitter follows a linear rise and exponential decay, so it is often modeled with a so-called "alpha" function with a single time constant, tau. Sometimes, a dual exponential function will be used:

$$G_k(t) = g_{max} \frac{t}{\tau} e^{(1-t/\tau)}$$

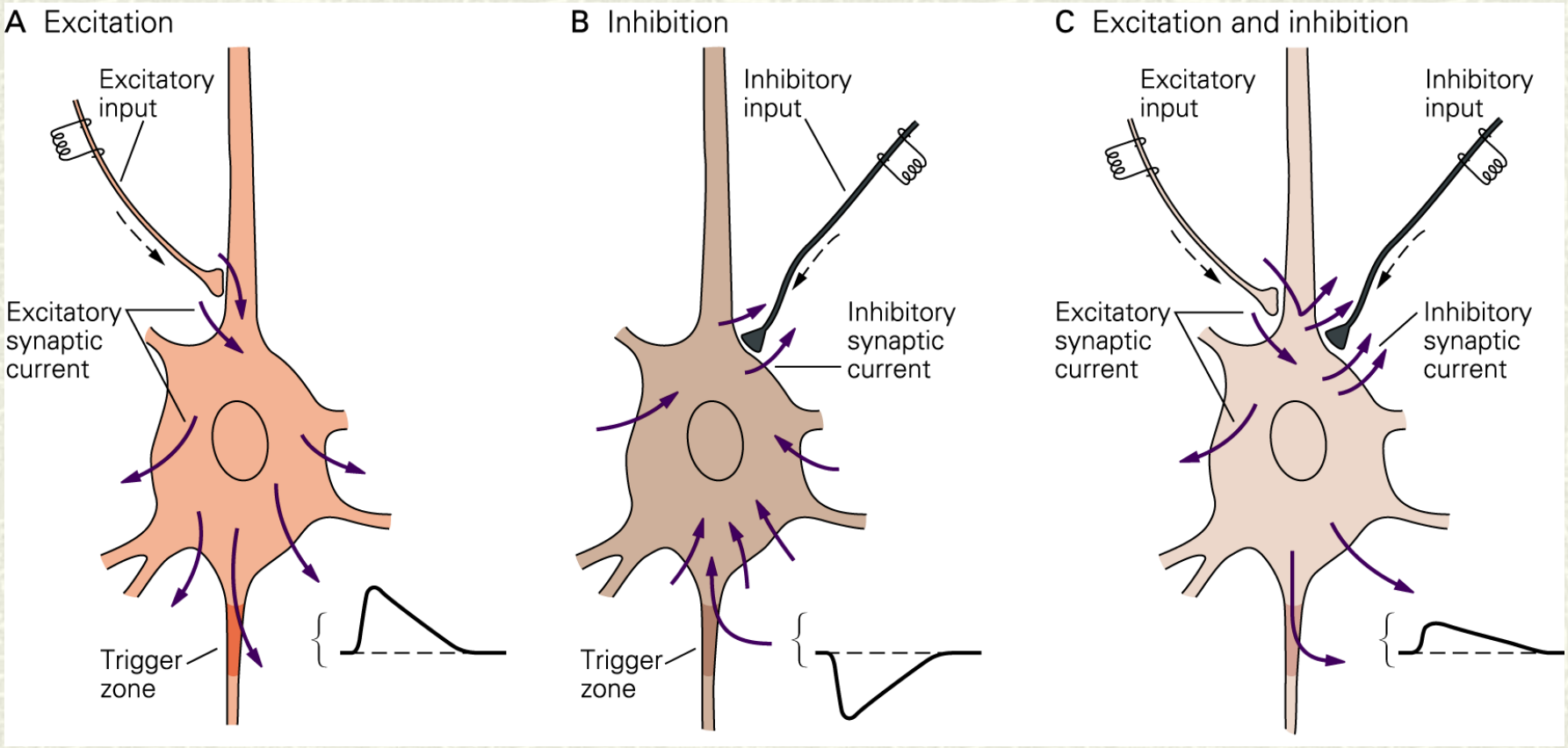
$$G_k(t) = \frac{A g_{max}}{\tau_1 - \tau_2} (e^{-t/\tau_1} - e^{-t/\tau_2})$$



Typically, the conductance change from a quantum of neurotransmitter follows a linear rise and exponential decay, so it is often modeled with a so-called "alpha" function with a single time constant, tau. Sometimes, a dual exponential function will be used.

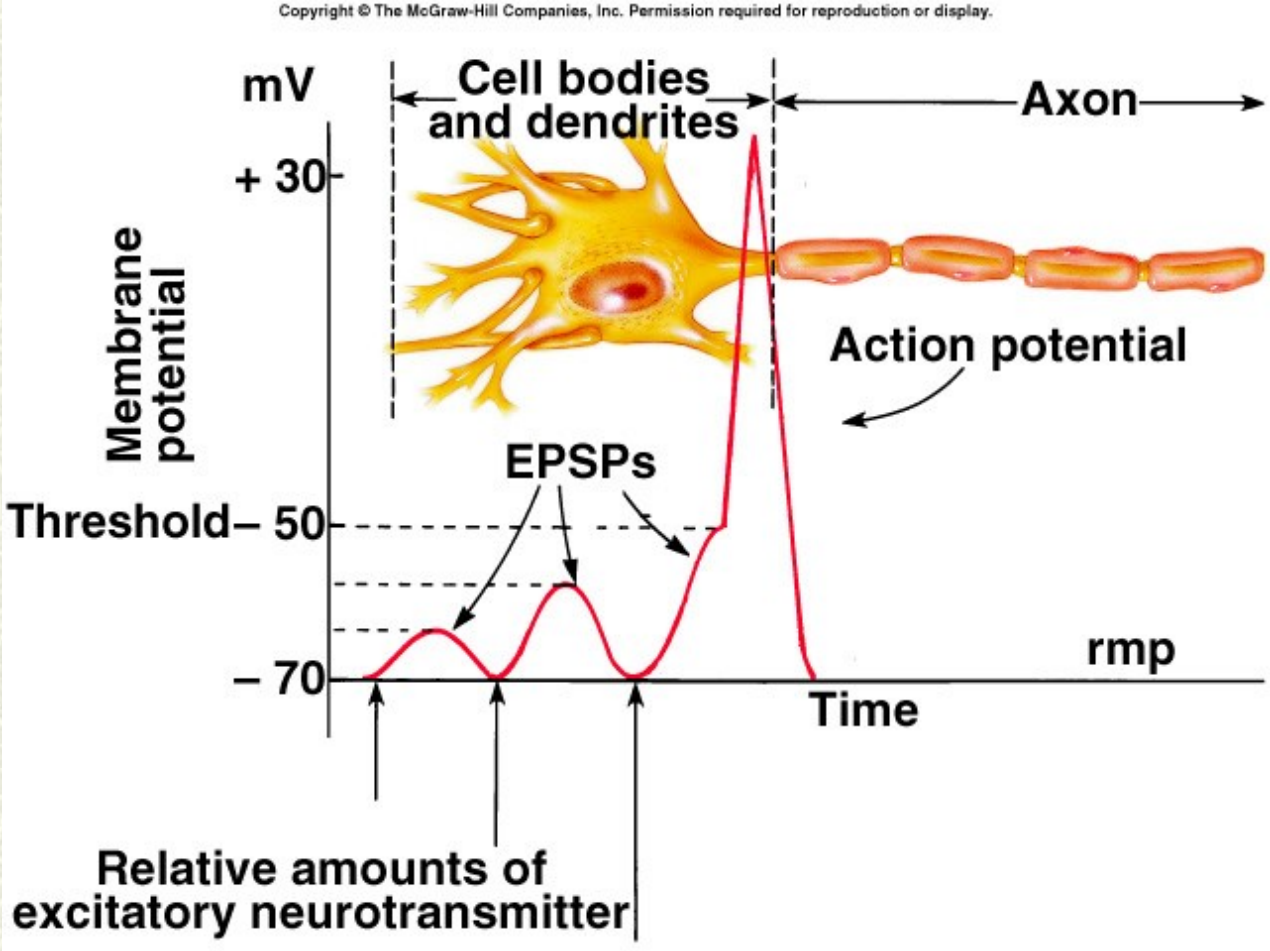
Same model for both types of synapses – note that the reversal potential for the ions that the synapse passes determines whether the synapse is excitatory or inhibitory. "

Individual synapses can be excitatory or inhibitory



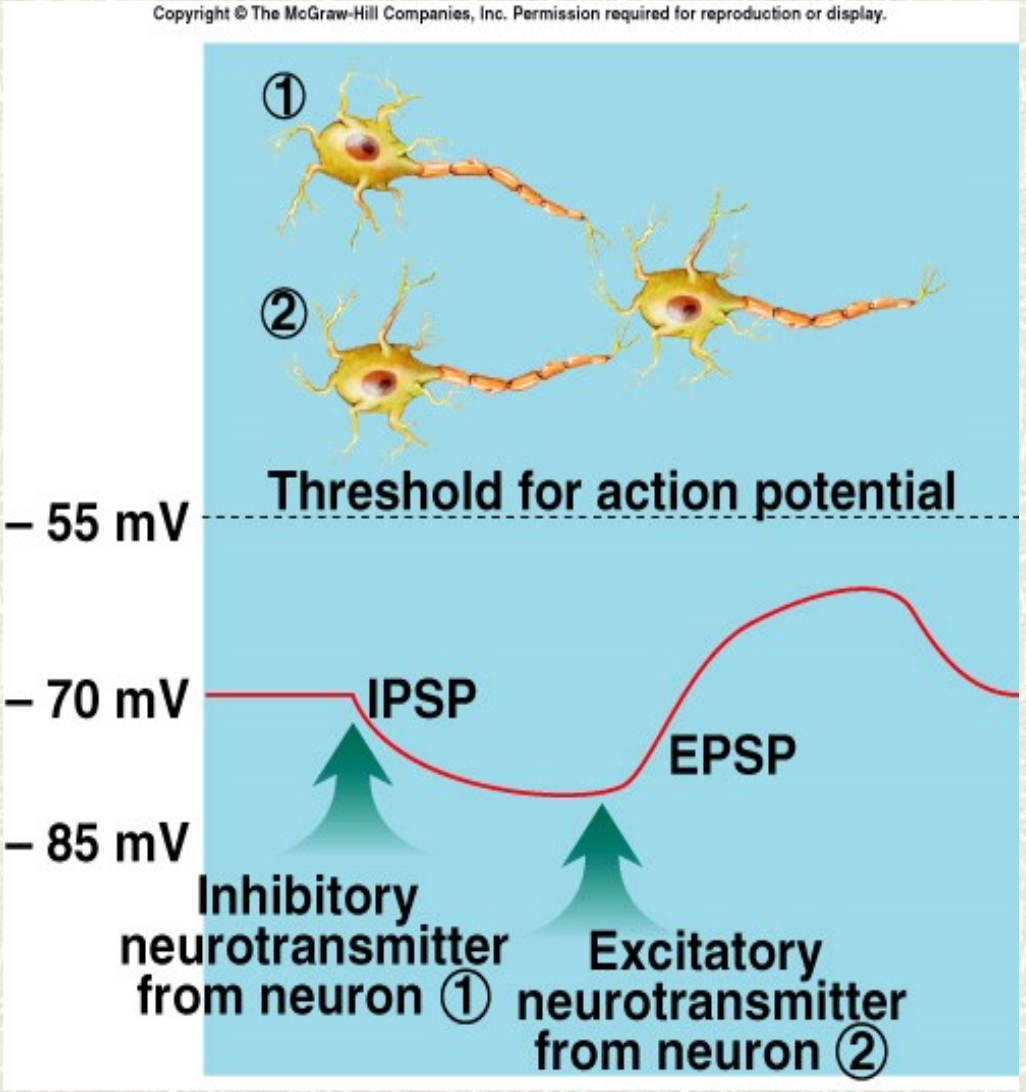
Excitatory Post-Synaptic Potentials (EPSPs)

- Graded in magnitude
- Have no threshold
- Cause depolarization
- Summate
- Have no refractory period



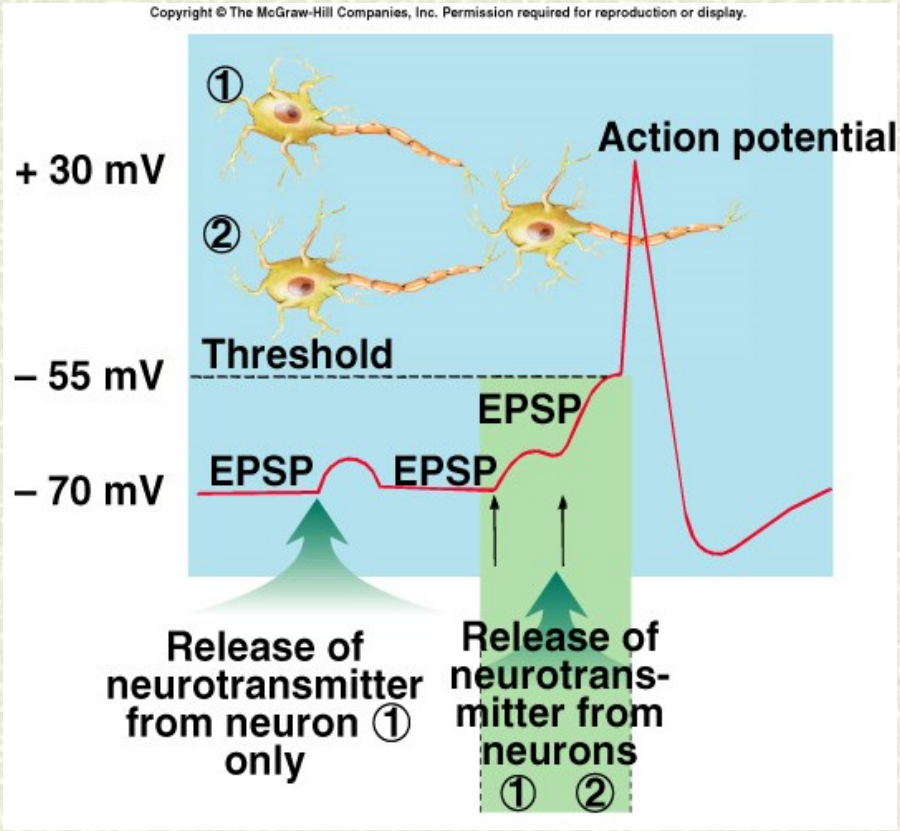
Synaptic Inhibition

- Postsynaptic inhibition
  - GABA & glycine (among others) produce IPSPs
  - IPSPs dampen EPSPs
  - Making it harder to reach threshold
- Presynaptic inhibition:
  - Occurs when 1 neuron synapses onto axon or bouton of another neuron, inhibiting release of its NT



Spatial Summation

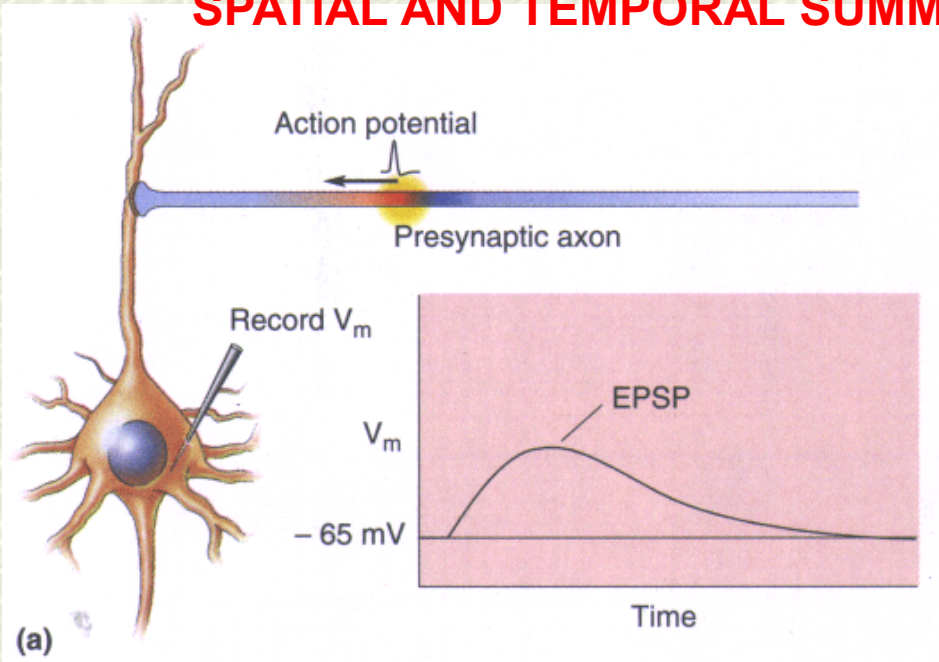
- Cable properties cause EPSPs to fade quickly over time & distance
- Spatial summation takes place when EPSPs from different synapses occur in postsynaptic cell at same time

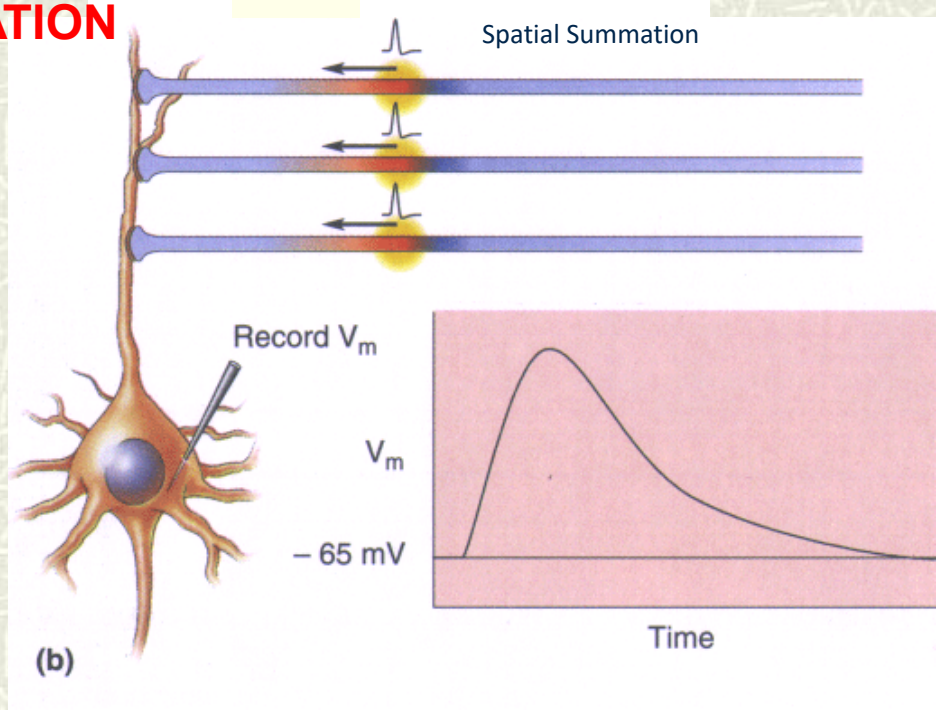


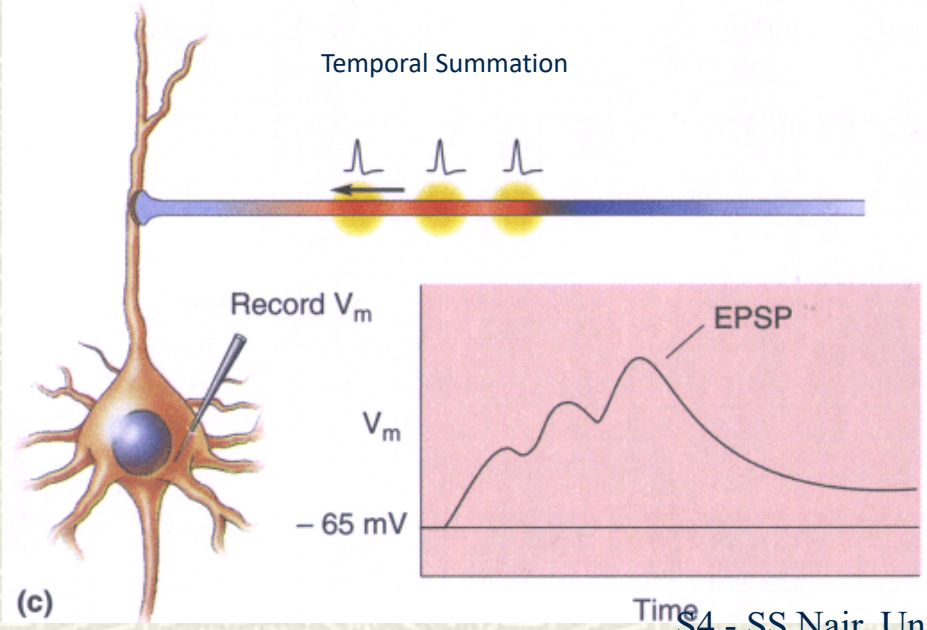
Temporal Summation

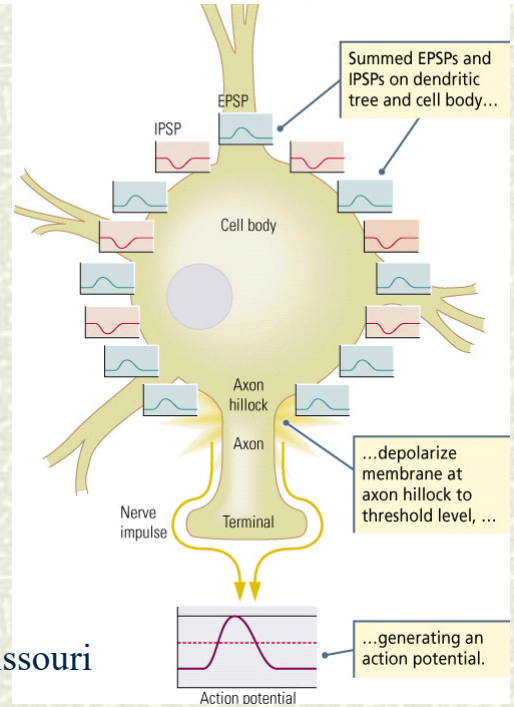
- Temporal summation occurs because EPSPs occurring closely in time sum before they fade

SPATIAL AND TEMPORAL SUMMATION

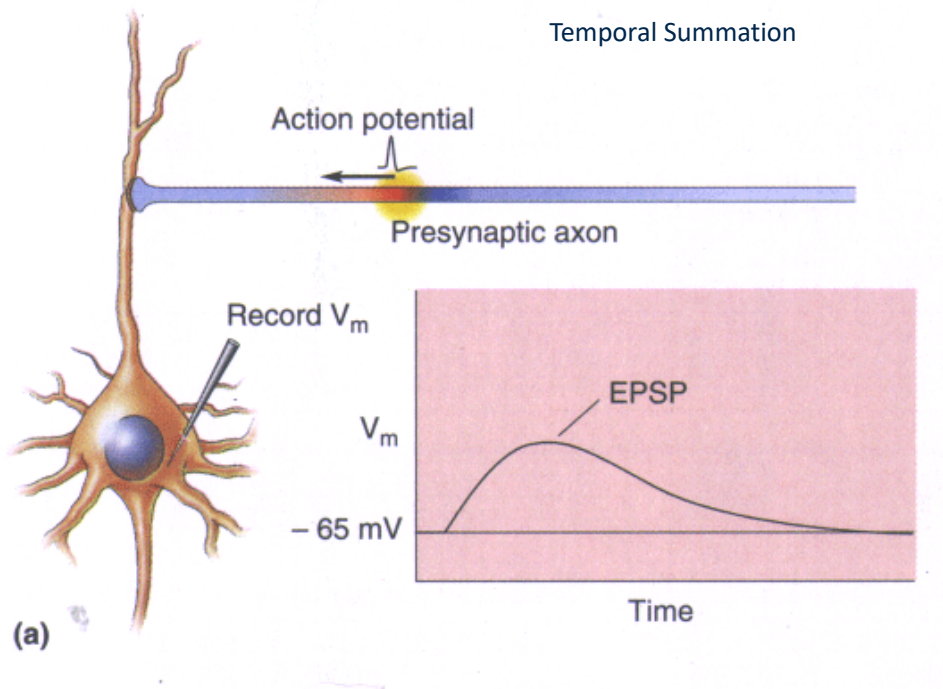








How does temporal and spatial summation work at the ionic level?



Provide a step-by-step description of activity at the ionic level to explain the EPSP seen in the soma. All key laws involved in the process should be explained and linked to the description.

Three-compartment model
to illustrate effect of excitatory and inhibitory synapses

Note: We have been focusing on single compartment cells so far but now move on to a 3-compartmental model

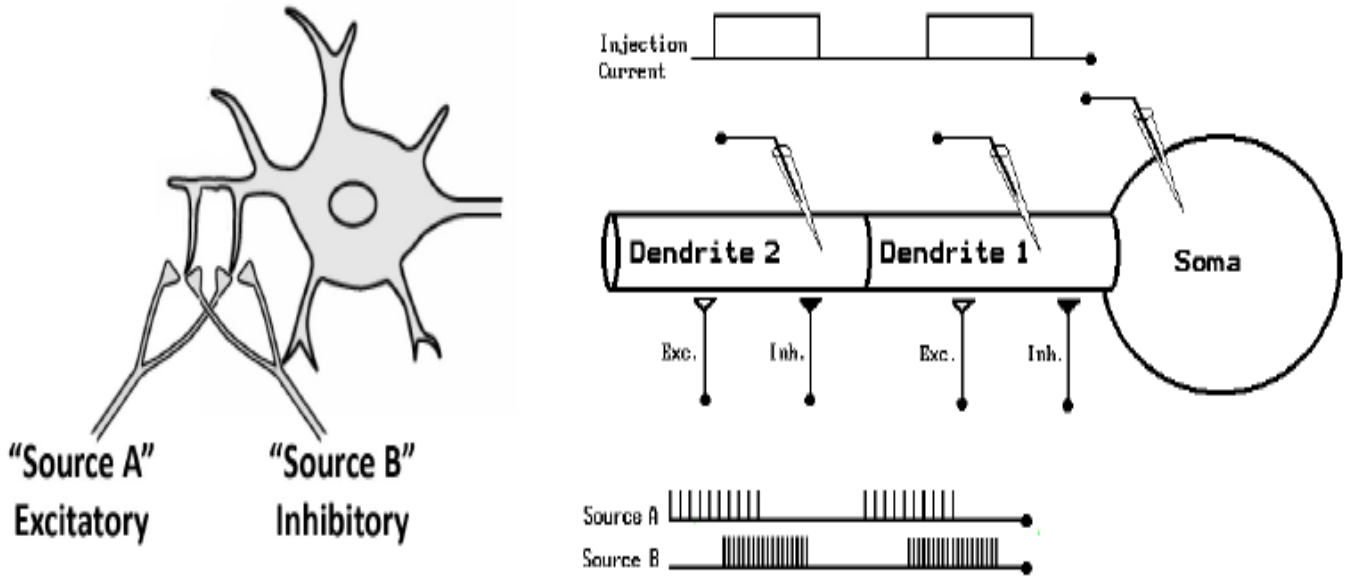


Figure 1 - Neuron Inputs (The figure on the right has been taken from a tutorial in GENESIS by Bower and Beeman, 2000).

Dendrites – passive + synaptic channels

Soma+axon – has all the active channels

Input – two types

Details included in the writeup for Software Experiment #4