COMS30017
Computational Neuroscience

Week 4: Synapses and Synaptic Plasticity
Video 1: WHAT IS A SYNAPSE?

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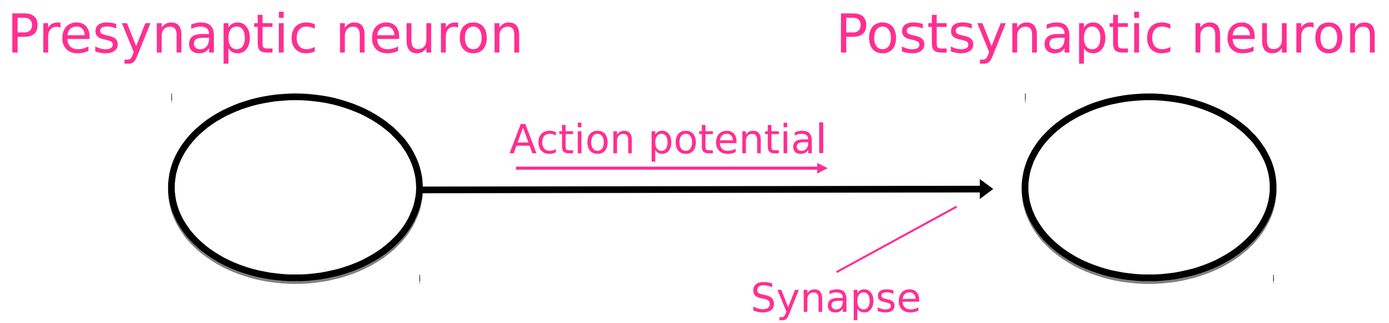
Intended learning outcomes

- What is a synapse and be able to describe how they work;
- Understand the concept of electro-chemical transmission in synapse;
- Gain some intuition over potential computational functions of a synapse;

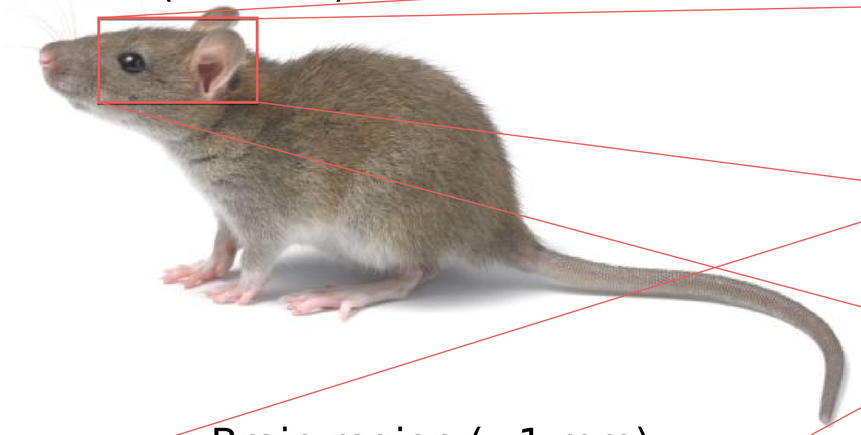
What is a synapse?

Synapses are the interactions between neurons



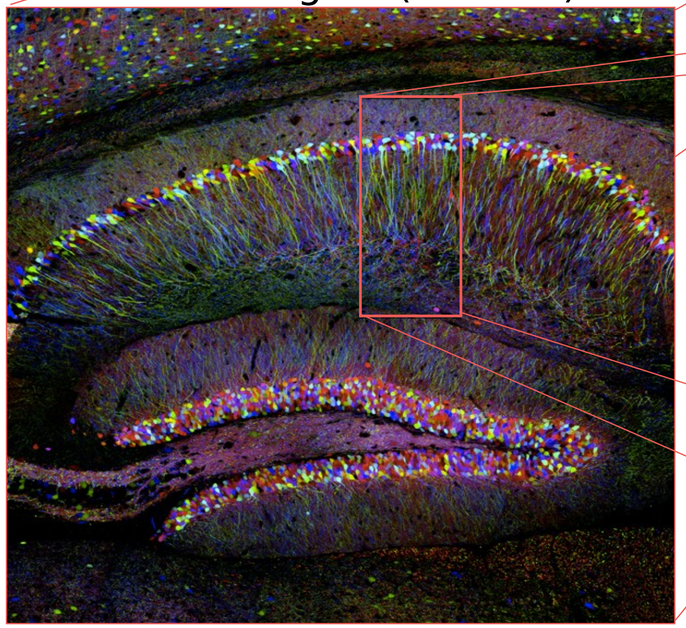
Zooming in on synapses

Animal (~10 cm)

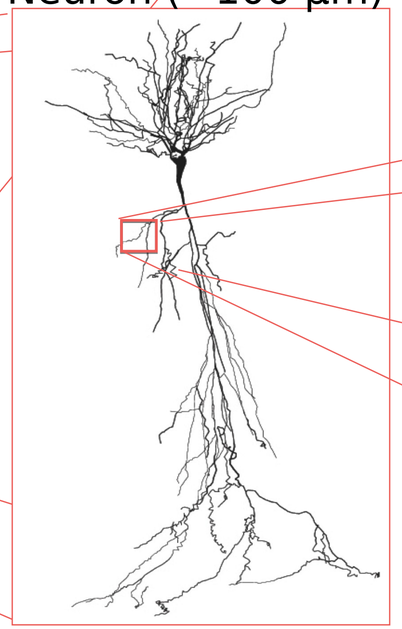


Brain (~1 cm)

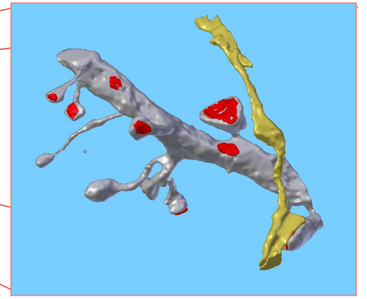
Brain region (~1 mm)



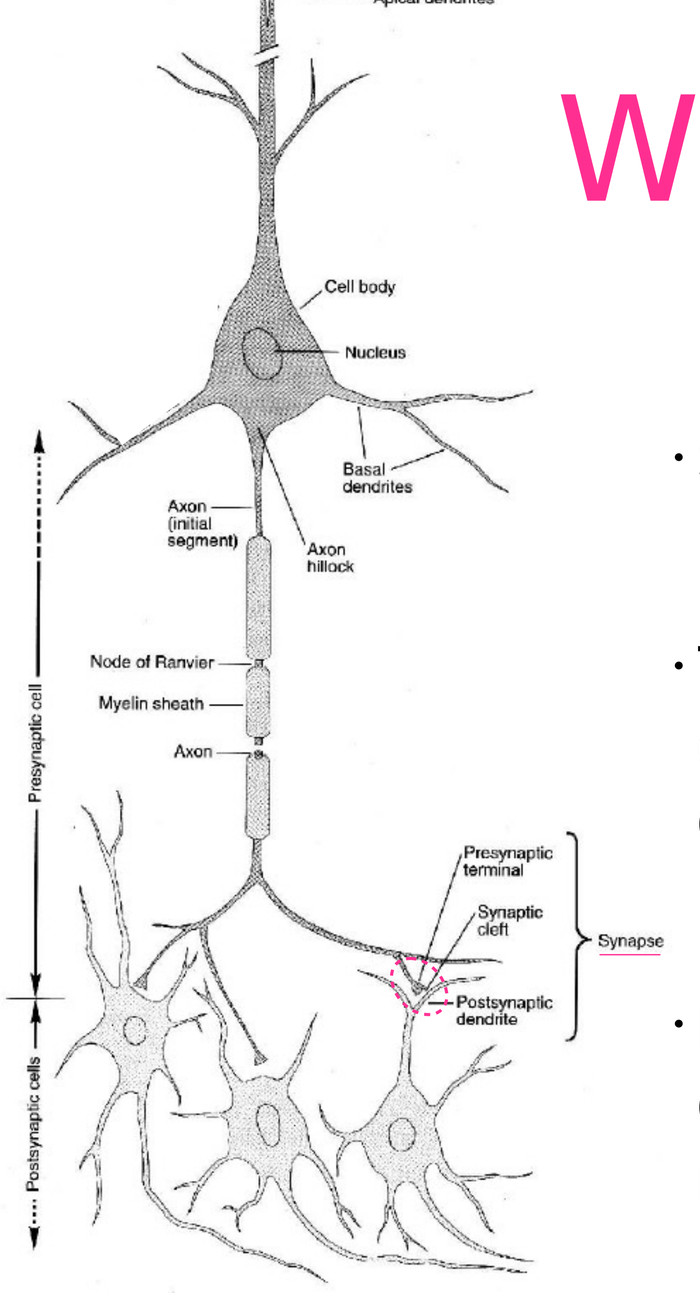
Neuron (~100 µm)



Synapses (~1 µm)



What is a synapse?



- Synapses are the interactions between neurons.
- They convert the action potential from one neuron's axon (output signal) into a 'Post-Synaptic Potential' in the dendrite of another neuron (input signal).
- Because neurons don't quite touch, the most common type of synapse converts the signal into a chemical form as an intermediate stage.

Adapted from *Principles of Neuroscience* (E. Kandel)

How does a synapse work?

Axon
(presynaptic action potential)

Chemical signalling

Dendrite
(postsynaptic potential)

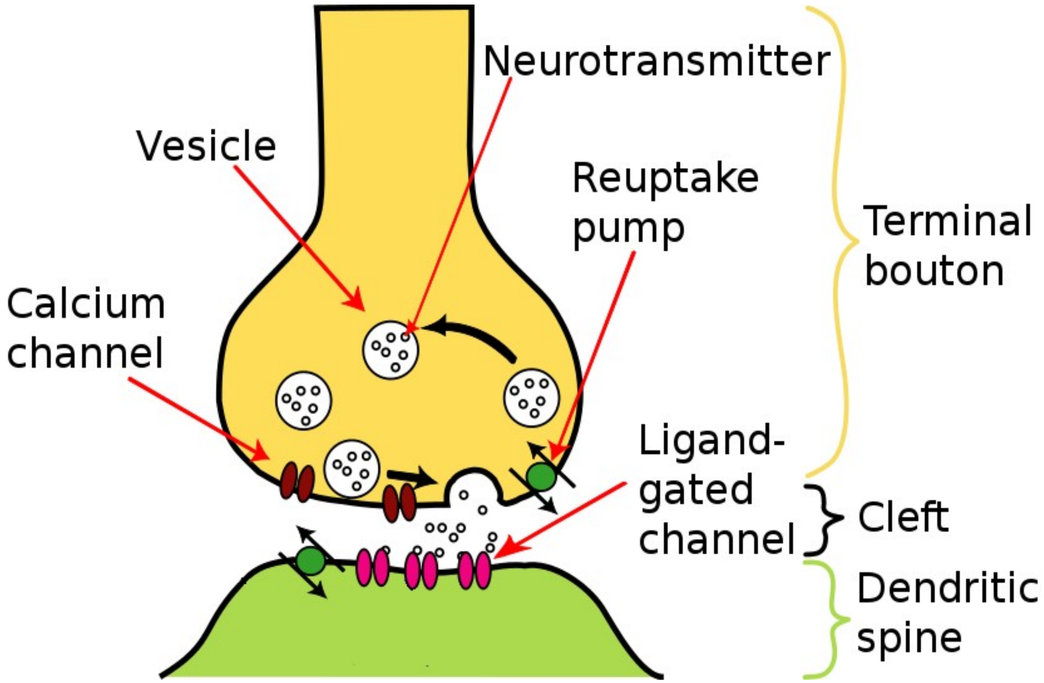
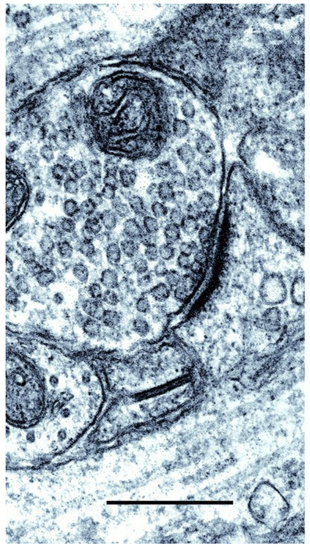
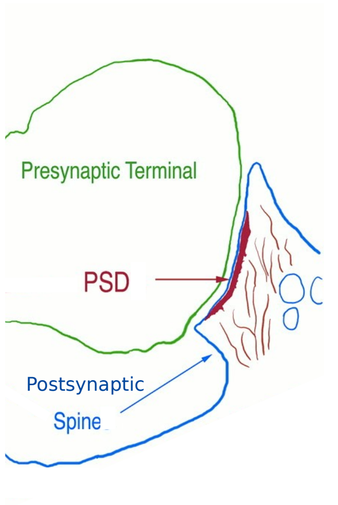


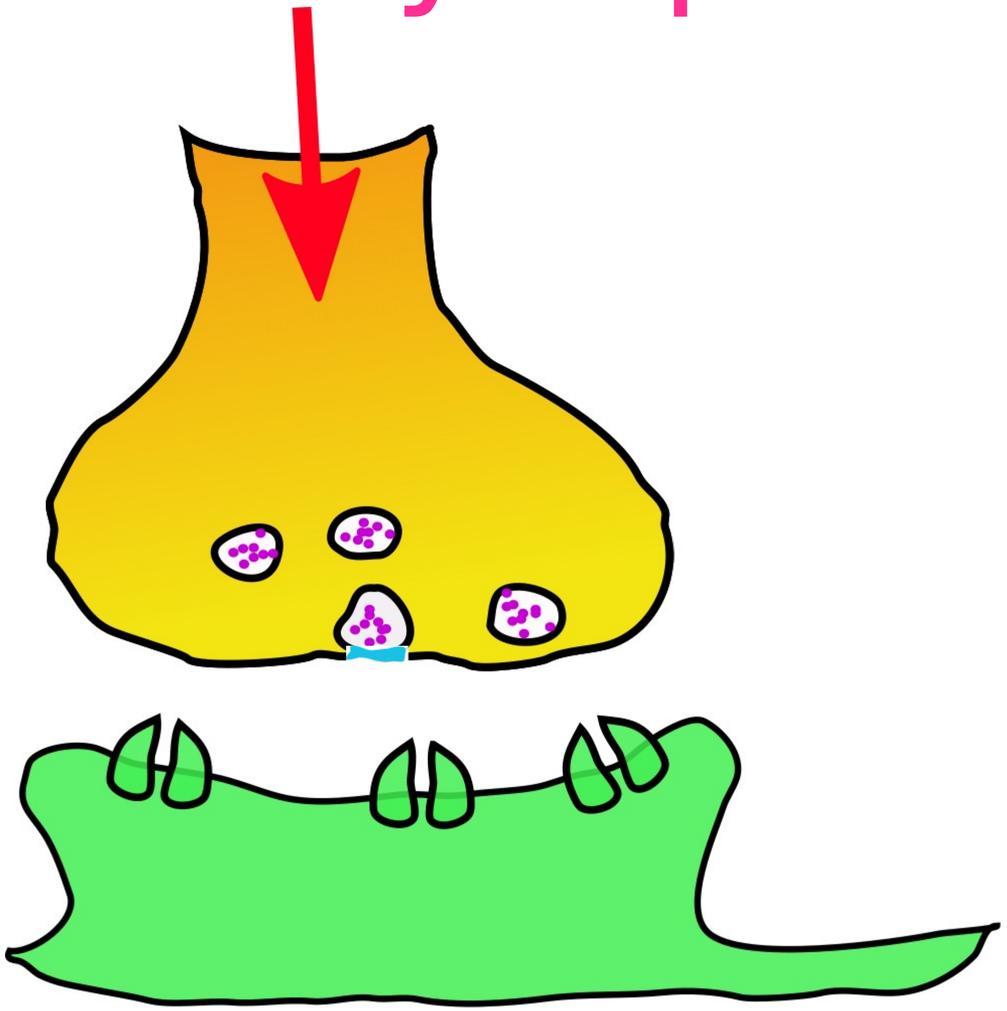
Image from Wikipedia (modified by C Houghton)





Adapted from Mary Kennedy (Science, 2000)

How does a synapse work?



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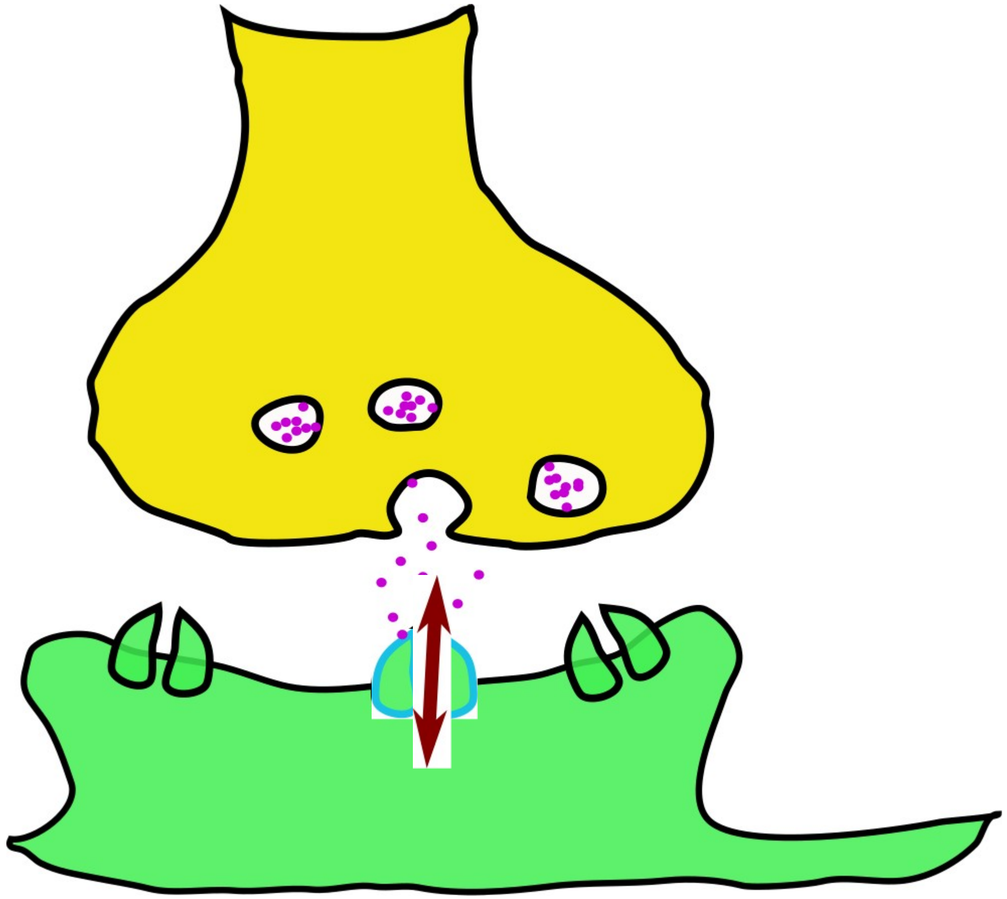

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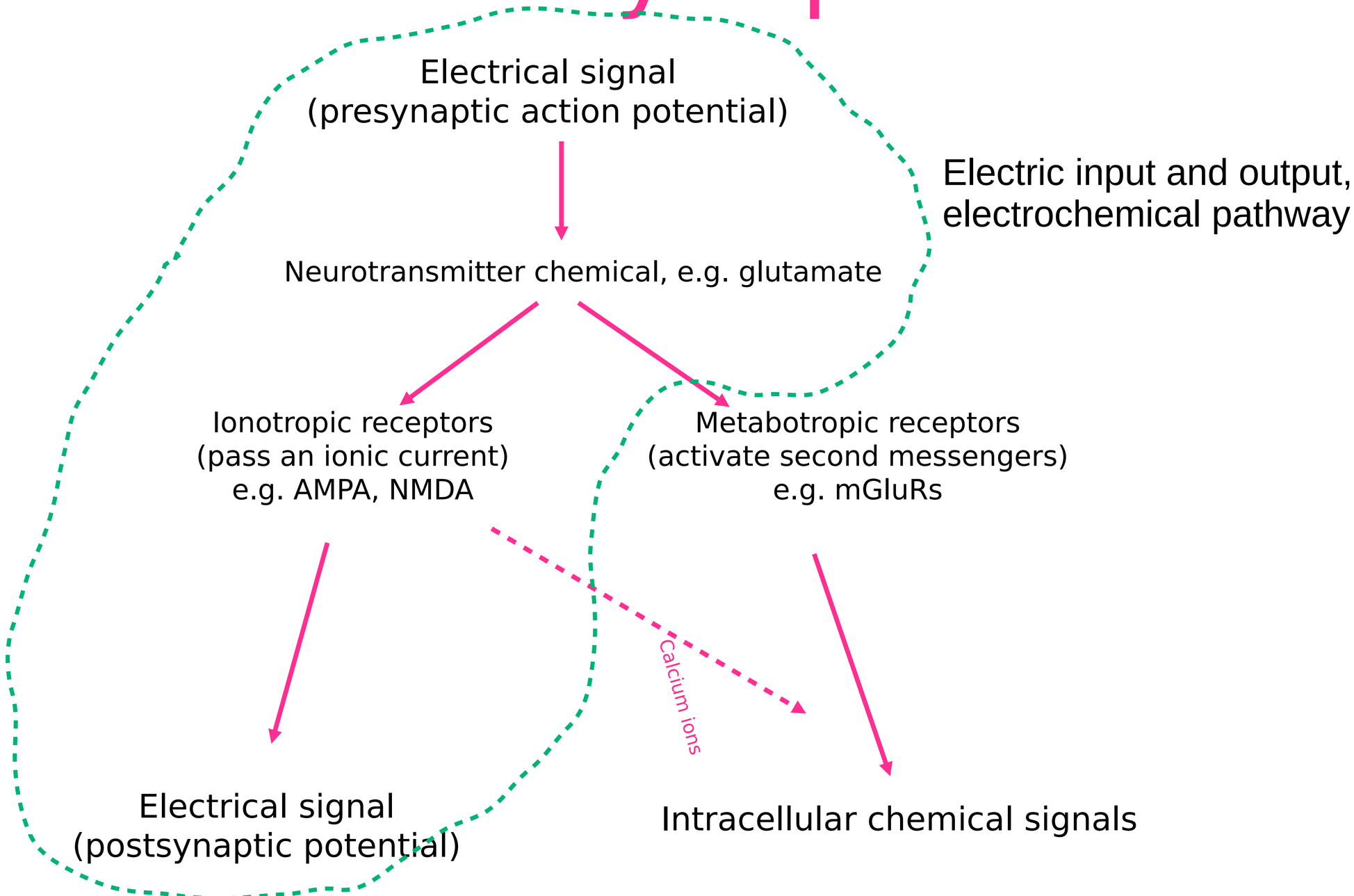
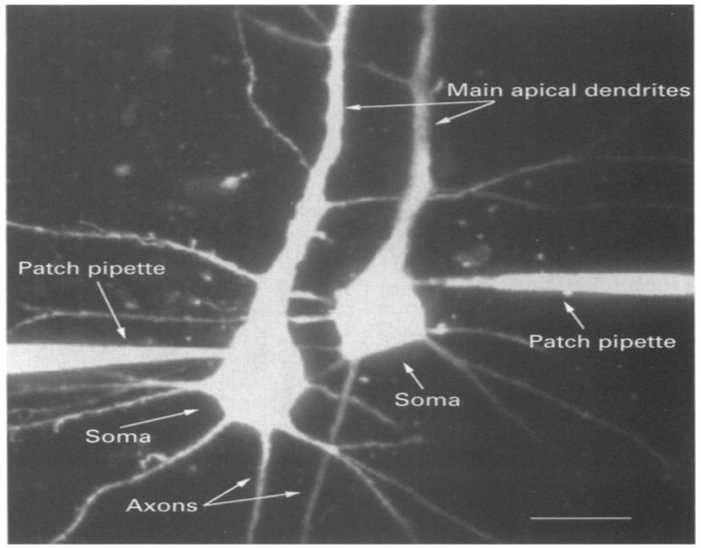
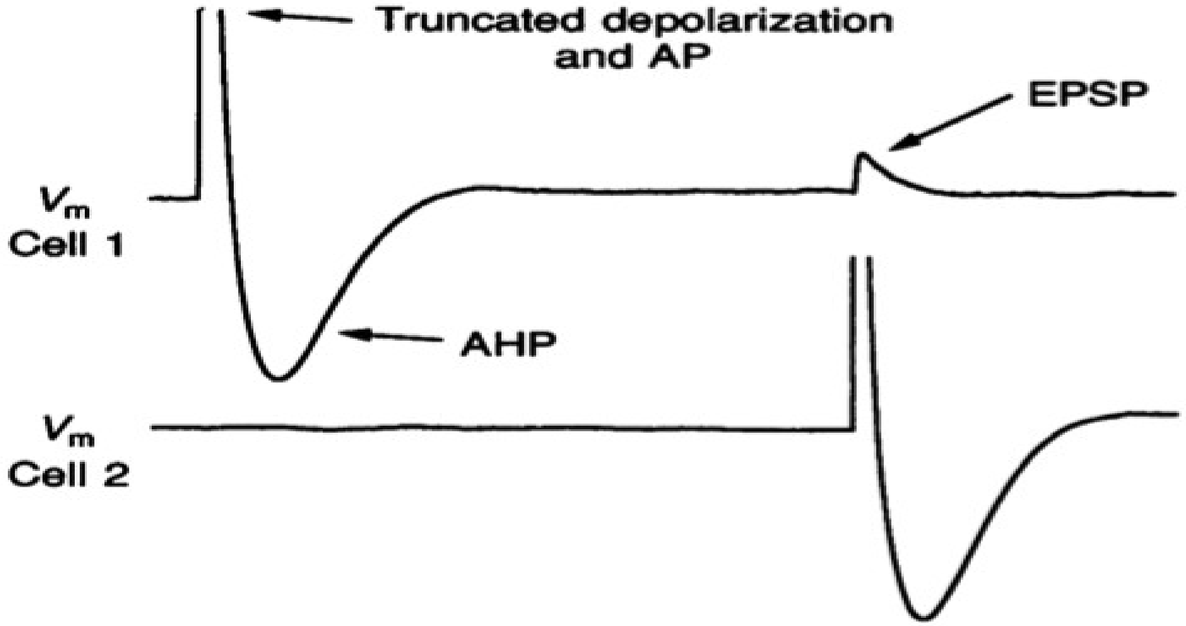


What kind of connection is a synapse?

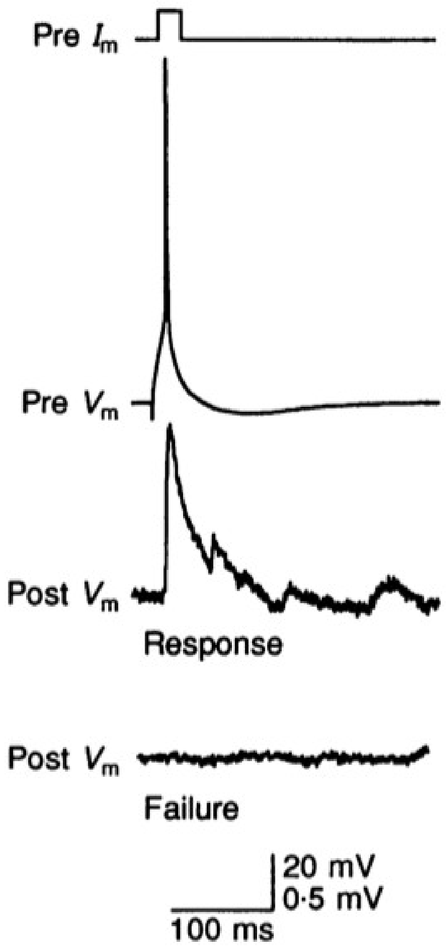
- Synapses have a defined direction
- Synapses are unreliable

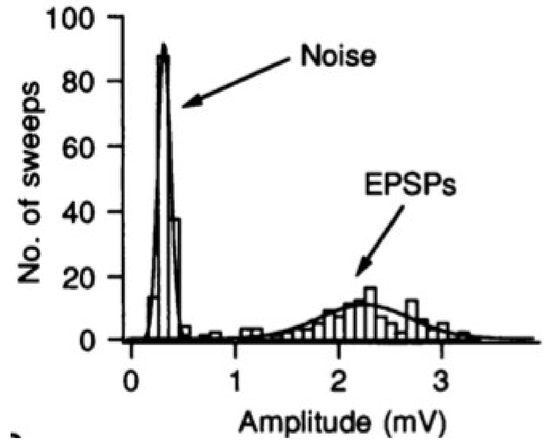


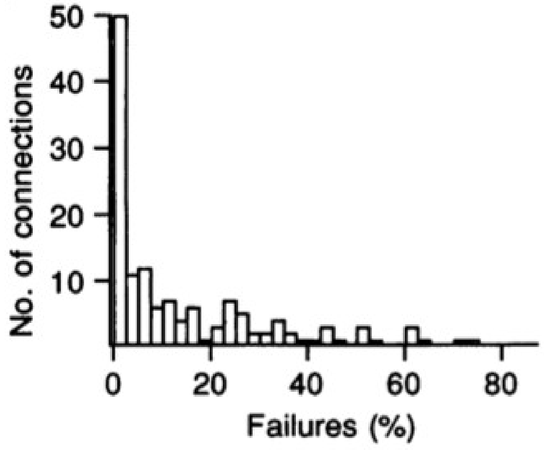


Markram et al, J Physiol (1997)

Synapses are unreliable







- Noisy channel?

Markram et al, J Physiol (1997)

What more about a synapse?

- There also exist purely electrical synapses (called ‘gap junctions’), that provide a very fast, bidirectional interaction. However, in the rest of this course we will focus on chemical synapses only.

- From a functional point of view, synapses are interesting for two reasons:
  - ➔ They are nonlinear, so can perform computations.
  - ➔ They are plastic, so can store information (memories).

Summary

- Synapses are electrochemical connections between neuronal cells. They can be excitatory or inhibitory.

- An AP triggers the release of neurotransmitters from the presynaptic neuron.

  - ➔The neurotransmitters interact with membrane channels of the postsynaptic neuron, which open to allow a small current that forms a PSP (either excitatory, EPSP, or inhibitory, IPSP).

- Neurotransmitter release is unreliable, so a synapse can be considered a probabilistic form of communication.