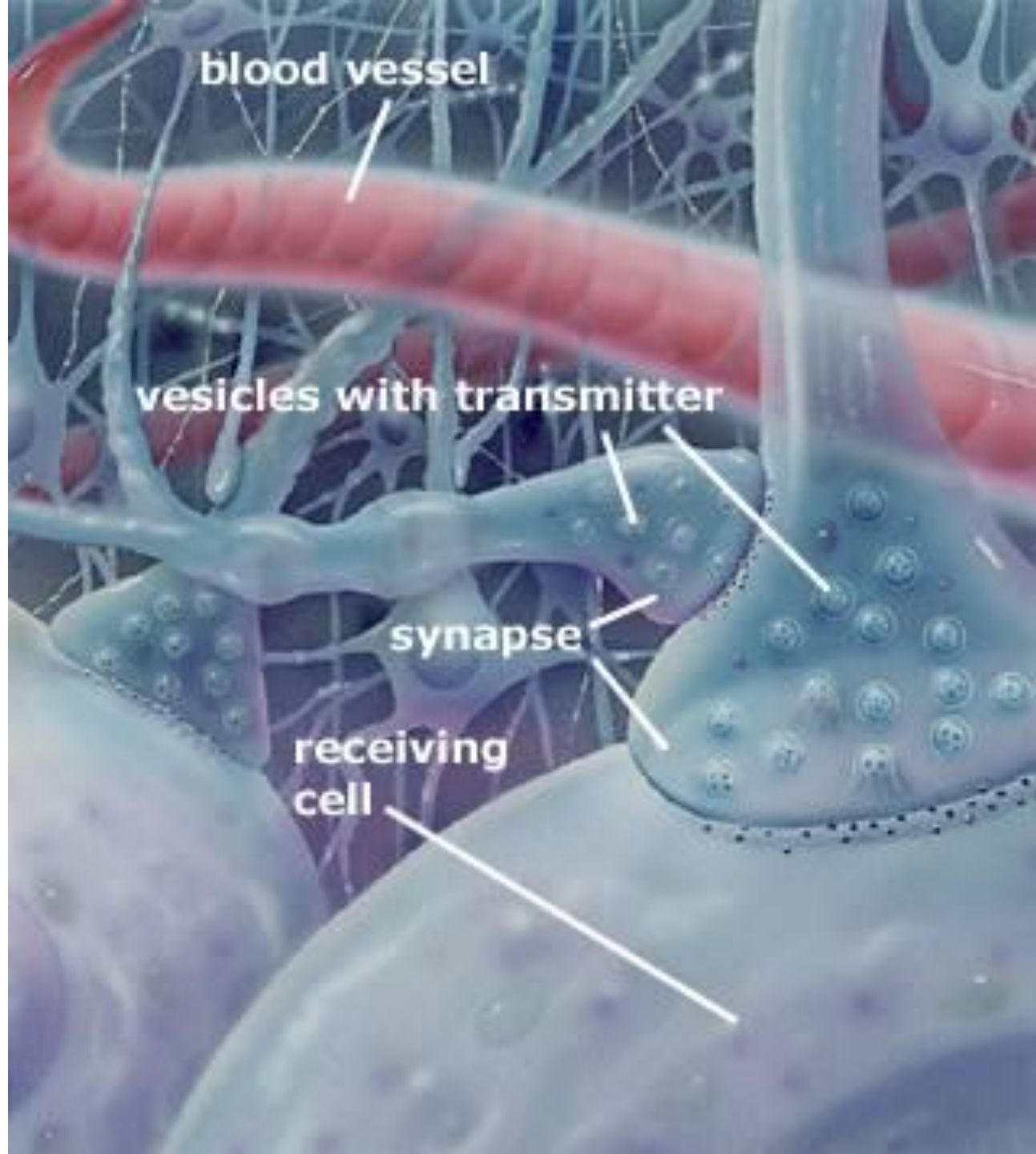


CSB 332

Neurobiology of the Synapse

Melanie A. Woodin
January 2012

Lecture 13/14
***Synaptic Plasticity &
Learning and Memory***
Chpt 16



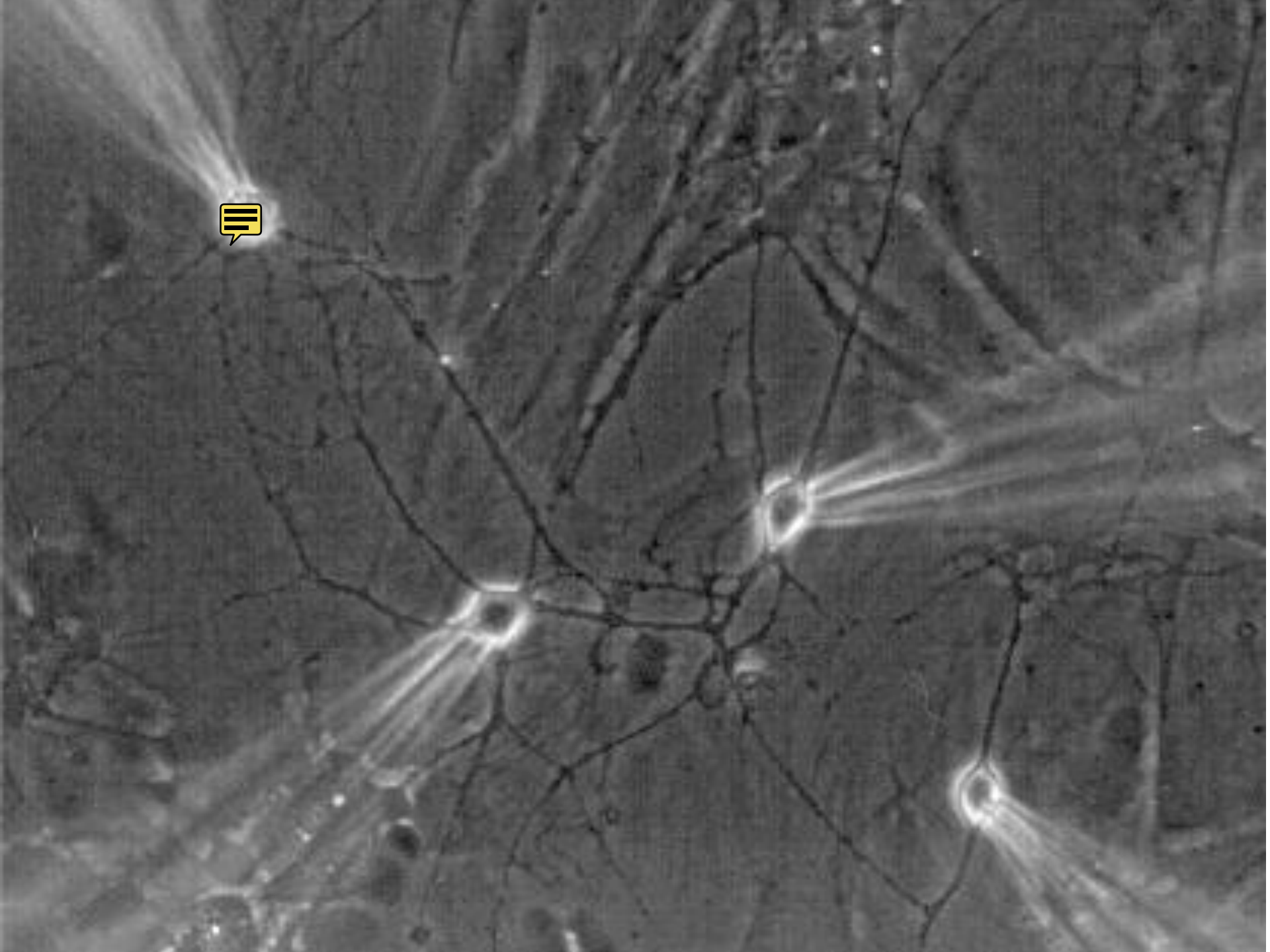


Synaptic Modifications in Cultured Hippocampal Neurons: Dependence on Spike Timing, Synaptic Strength, and Postsynaptic Cell Type

The Journal of Neuroscience,
December 15, 1998,
18(24):10464-10472

Guo-qiang Bi and Mu-ming Poo

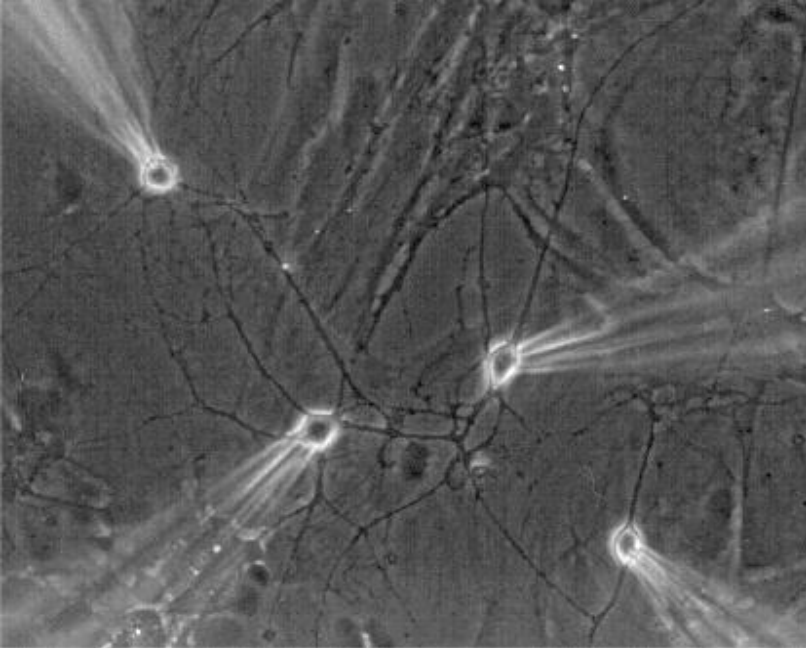




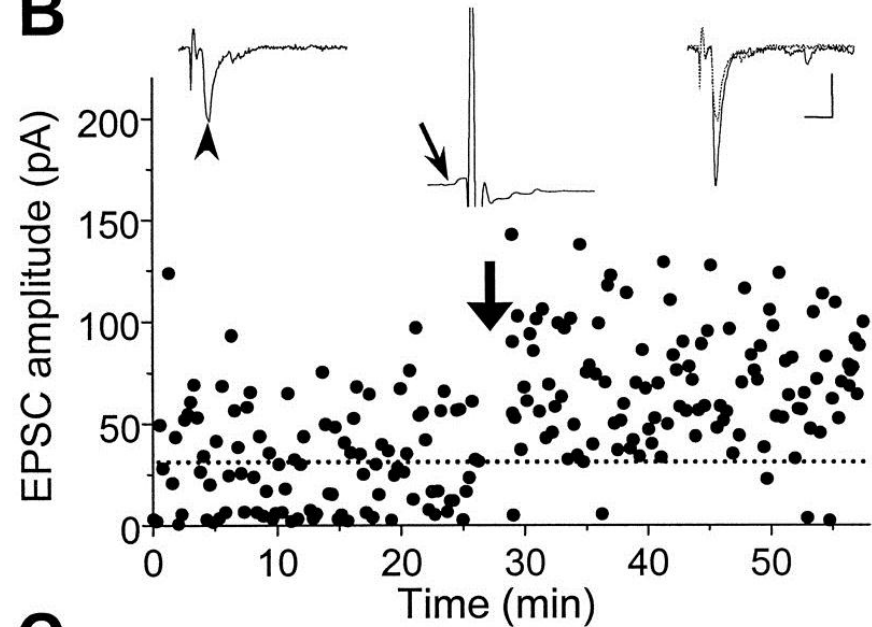


Spike-Timing Dependent Synaptic Plasticity

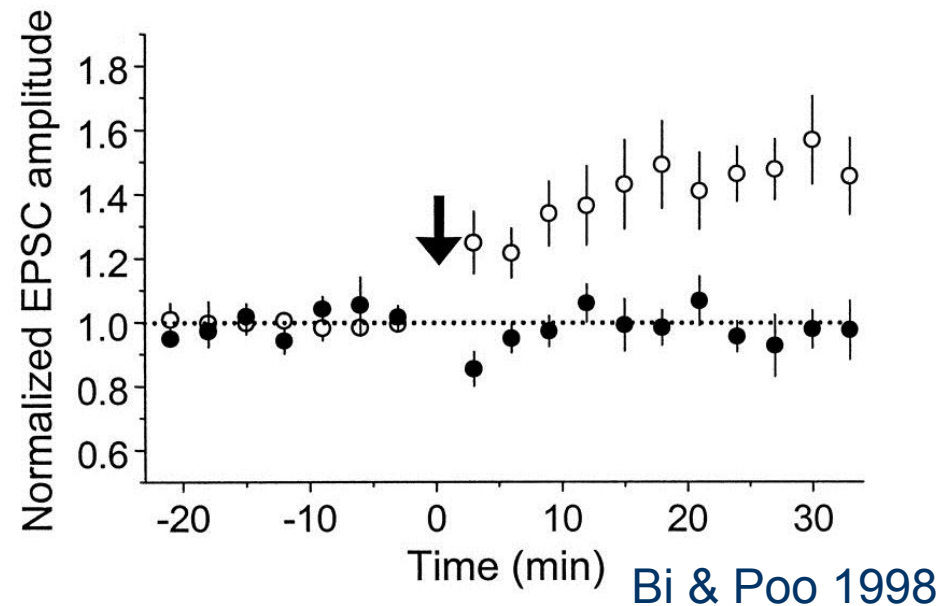
- Instead of inducing LTP with high-frequency presynaptic stimulation, spike-timing protocols use lower-frequencies with paired pre- and postsynaptic activity
- Positive spike-timing interval: EPSP arrives before the postsynaptic AP is fired
- Negative spike-timing interval: EPSP arrives after the postsynaptic AP is fired



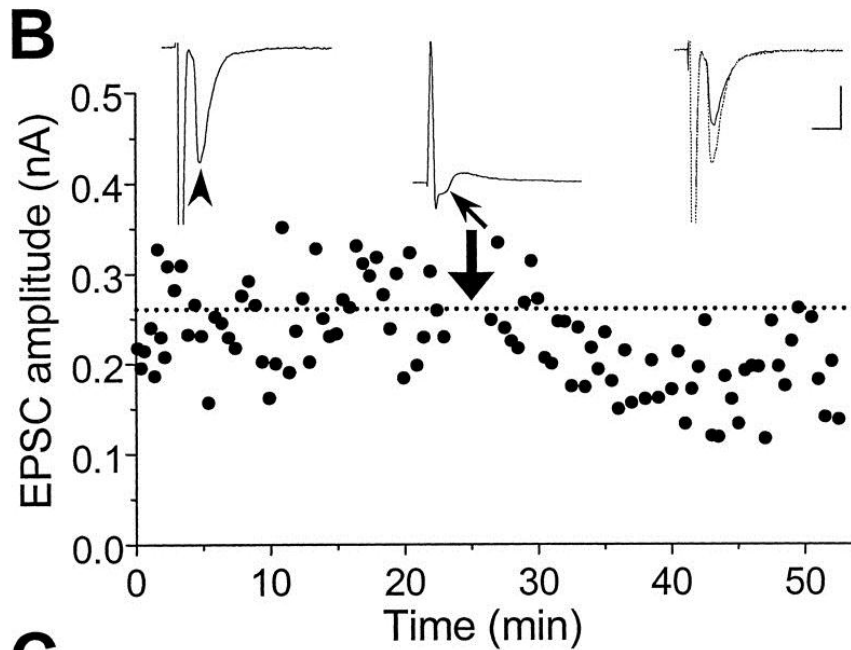
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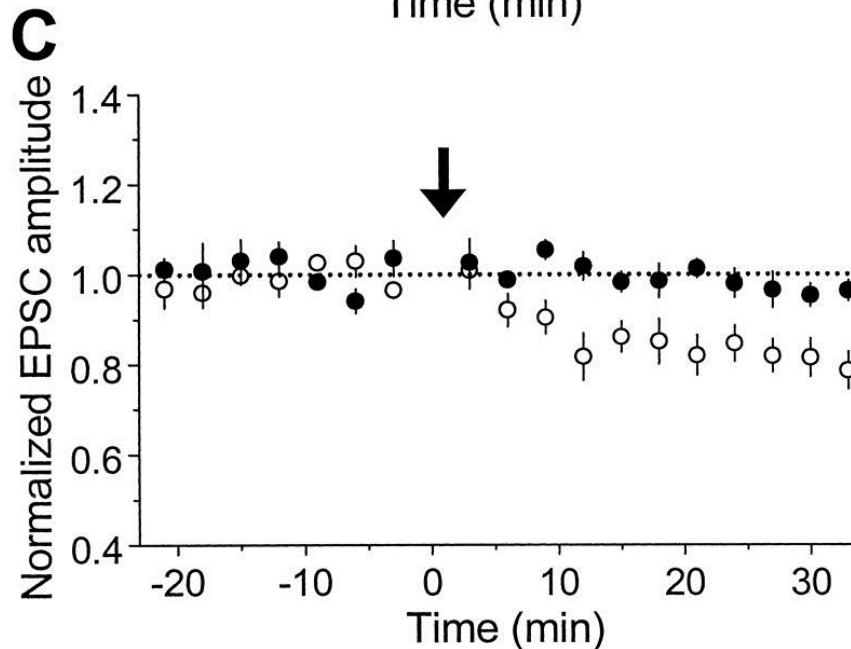
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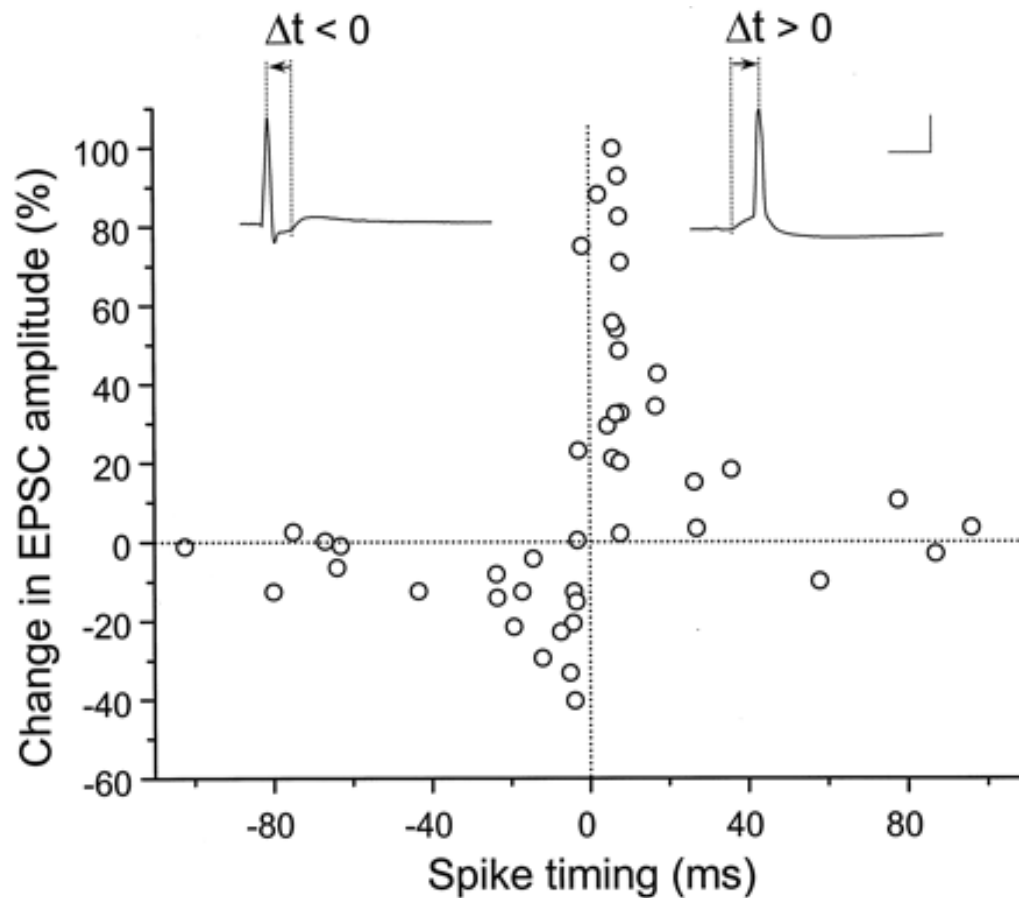


- LTP & LTD can also be induced by low-frequency (1-10Hz) coincident pre- and postsynaptic activity
- Positive spike-timing intervals induce LTP, negative spike timing intervals induce LTD



- STDP with negative spike-timing intervals induces LTD



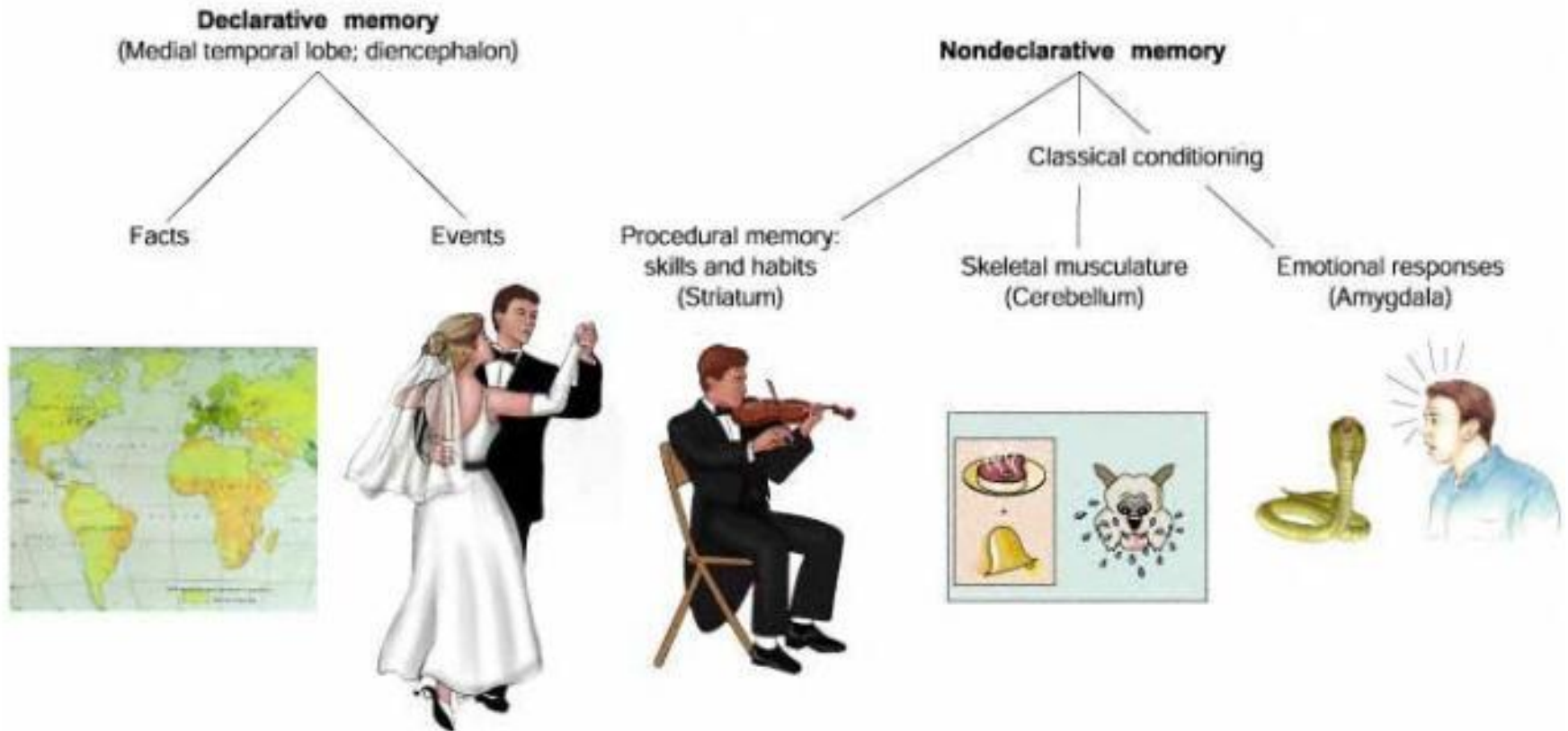


Critical window for the induction of synaptic potentiation and depression. The percentage change in the EPSC amplitude at 20-30 min after the repetitive coincident spiking (60 pulses at 1 Hz) was plotted against the spike timing. Spike timing was defined by the time interval (t) between the onset of the EPSP and the peak of the postsynaptic action potential during each cycle of repetitive stimulation, as illustrated by the traces above.

The Woman Who Could Not Forget

- <http://www.youtube.com/watch?v=SoxsMMV538U&feature=related>

Different types of learning and memory



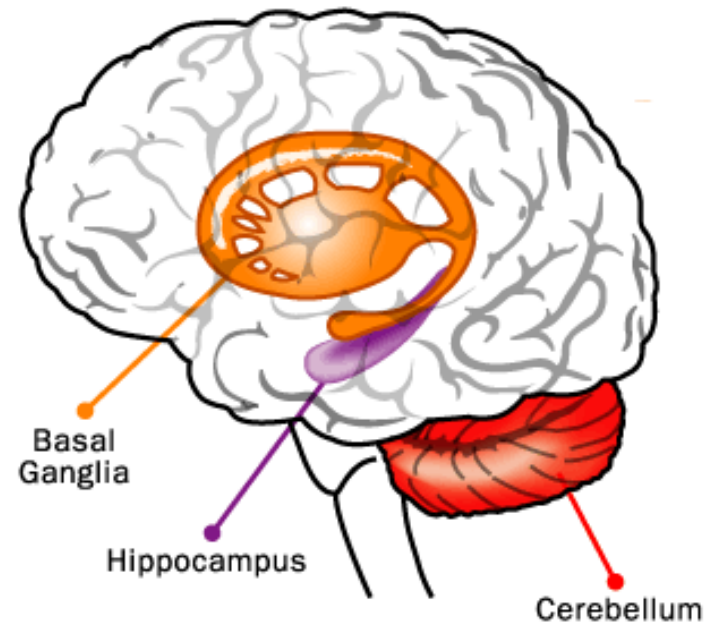
Procedural Memory

- also known as implicit memory
- the long-term memory of skills and procedures
- Often called our “how to” knowledge
- It can be used without thinking about it
- e.g. learn to ride a bike or to type

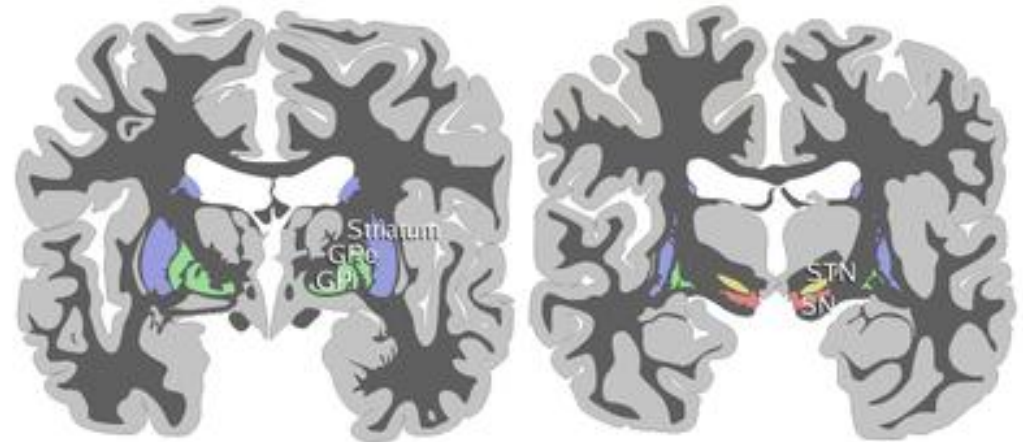
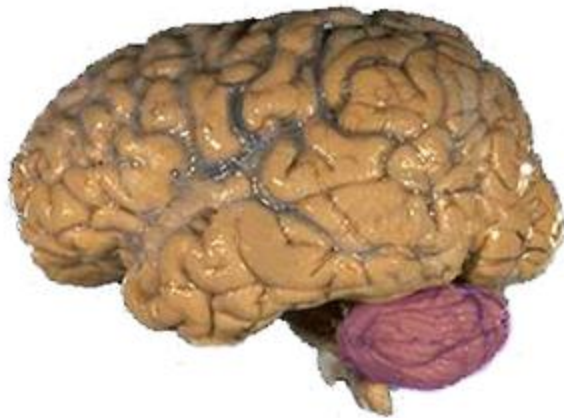


Procedural Memory

- Studies of people with certain brain injuries (such as damage to the hippocampus) suggest that procedural memory and episodic memory use different parts of the brain, and can work independently
- damage to the cerebellum and the basal ganglia seems to particularly affect procedural learning



Cerebellum & Basal Ganglia



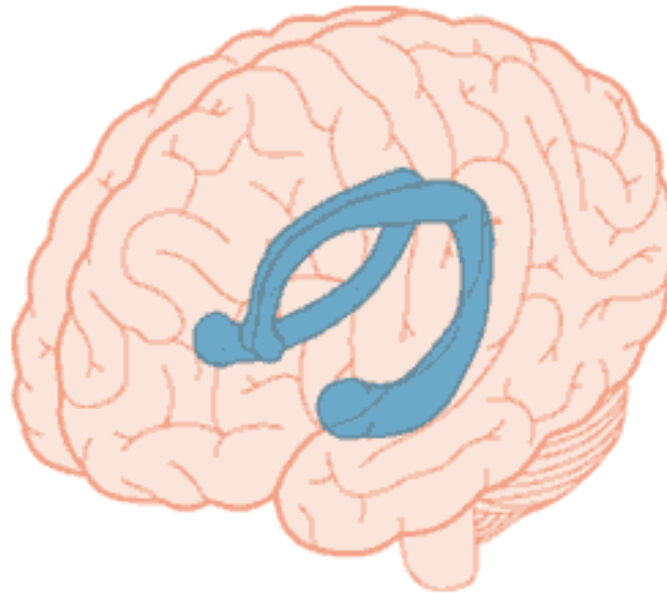
- The **basal ganglia** are a group of nuclei in the brain associated with motor and learning functions. However, no single function can be definitively assigned to the mammalian basal ganglia
- The **cerebellum** is a region of the brain that plays an important role in the integration of sensory perception and motor output. It provides constant feedback on body position to fine-tune motor movements.



Declarative Memory

- the aspect of memory that stores facts and events
- It applies to standard textbook learning and knowledge
- it is contrasted with procedural memory, which applies to skills
- It is subject to forgetting, but frequently-accessed memories can last indefinitely
- Declarative memory can be divided into episodic memory (knowledge about the event of learning something) and semantic memory (knowledge independent of context).

Declarative Memory



www.BrainConnection.com
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- Requires the hippocampus and certain regions of the cerebral cortex





Forgetting & Amnesia

Forgetting - A natural process thought to be necessary for the acquisition of new memories

Pathological memory loss is ***amnesia***:

Anterograde amnesia refers to the inability to establish new memories

Retrograde amnesia is the inability to recall past memories

Episodic Memory

- also called autobiographical memory
- a sub-category of declarative memory
- It is the recollection of events
- It includes time, place and associated emotions

Semantic Memory

- your memory for meanings and general (impersonal) facts
- e.g. your knowledge of the difference between a butterfly and a bird
- There is debate about whether semantic memory requires the same brain structures as episodic memory

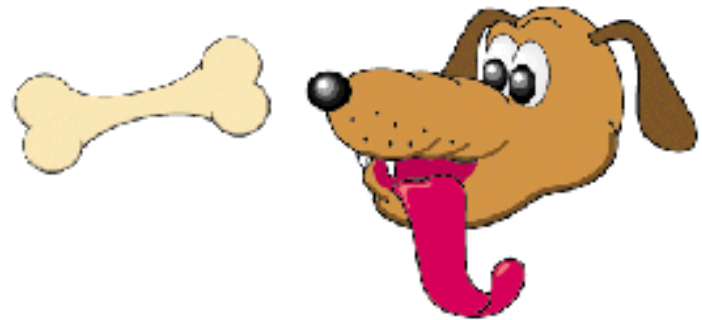
Classical Conditioning

- First demonstrated by Ivan Pavlov, the famous Russian physiologist
- Pavlov conditioned dogs to salivate when they hear a bell
- *Classical* conditioning forms an association between two stimuli.
- Pavlov began pairing a bell sound with the meat powder and found that even when the meat powder was not presented, the dog would eventually begin to salivate after hearing the bell. Since the meat powder naturally results in salivation, these two variables are called the **unconditioned stimulus** (UCS) and the **unconditioned response** (UCR), respectively. The bell and salivation are not naturally occurring; the dog was conditioned to respond to the bell. Therefore, the bell is considered the **conditioned stimulus** (CS), and the salivation to the bell, the **conditioned response** (CR).

Before conditioning

**FOOD
(UCS)**

**SALIVATION
(UCR)**



BELL

NO RESPONSE



During conditioning

**BELL +
FOOD
(UCS)**

**SALIVATION
(UCR)**

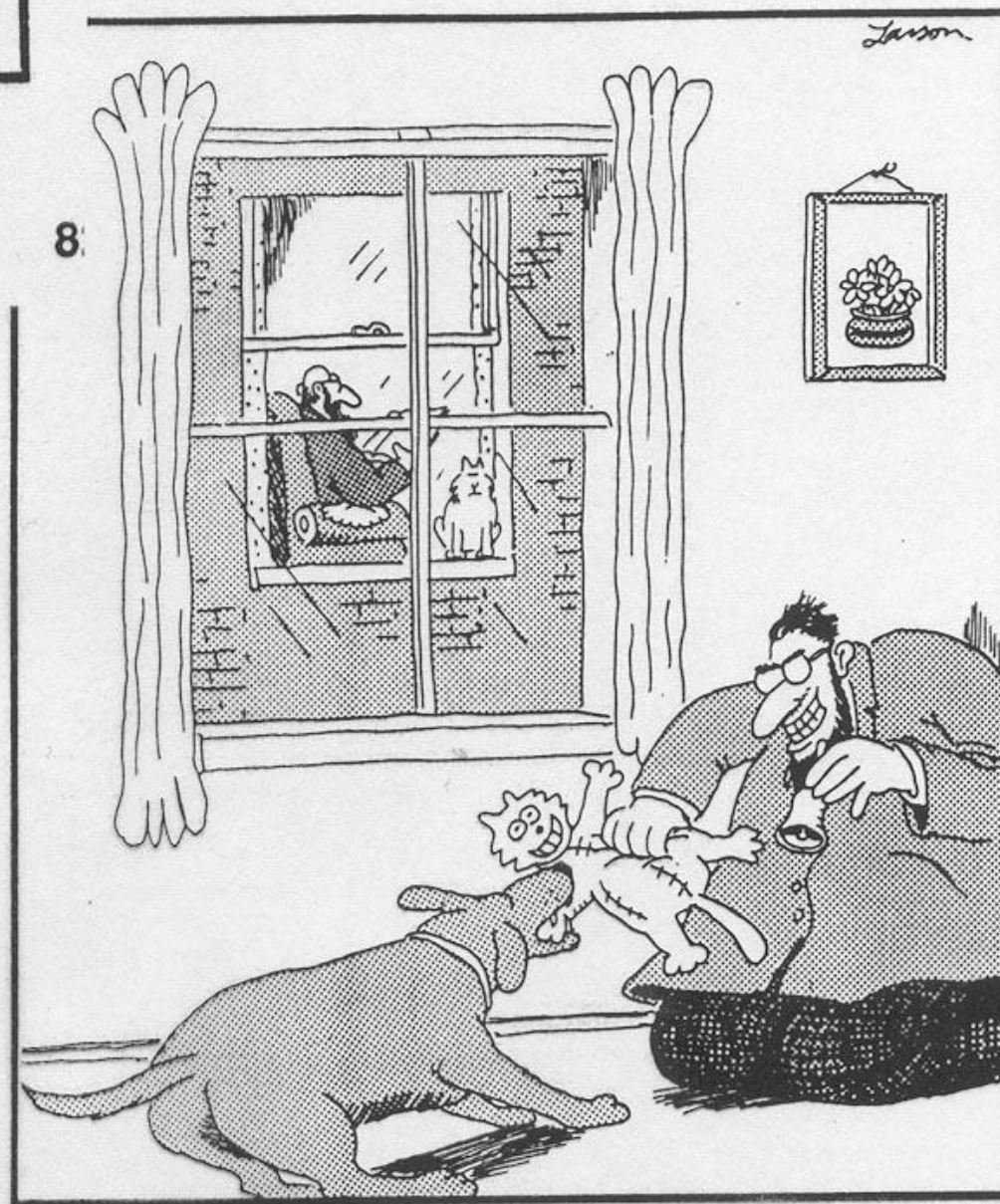


After conditioning

**BELL
(CS)**

**SALIVATION
(CR)**





Unbeknownst to most students of psychology, Pavlov's first experiment was to ring a bell and cause his dog to attack Freud's cat.

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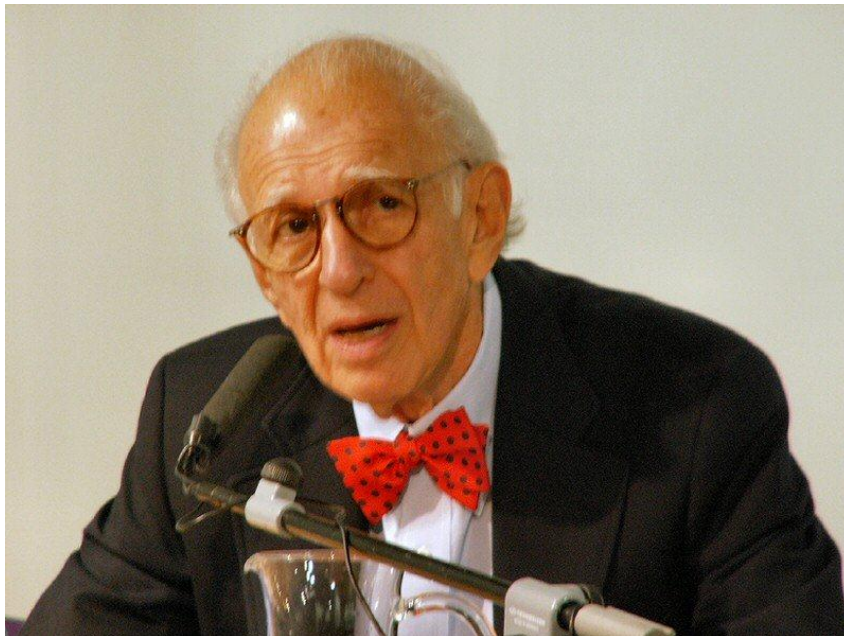
- *Operant* conditioning forms an association between a behavior and a consequence.
- It is based on + and – reinforcement of the behaviour (e.g. rewards and punishments)
- Consequences have to be immediate, or clearly linked to the behavior





Eric Kandel on Memory

- <http://www.hhmi.org/biointeractive/neuroscience/lectures.html> from 35-52 min



- **Born:** 1929 Vienna, Austria
- **Fields:** psychiatrist and neuroscience
- **Known for:** physiology of memory
- **Notable awards:** Nobel Prize in Physiology or Medicine 2000

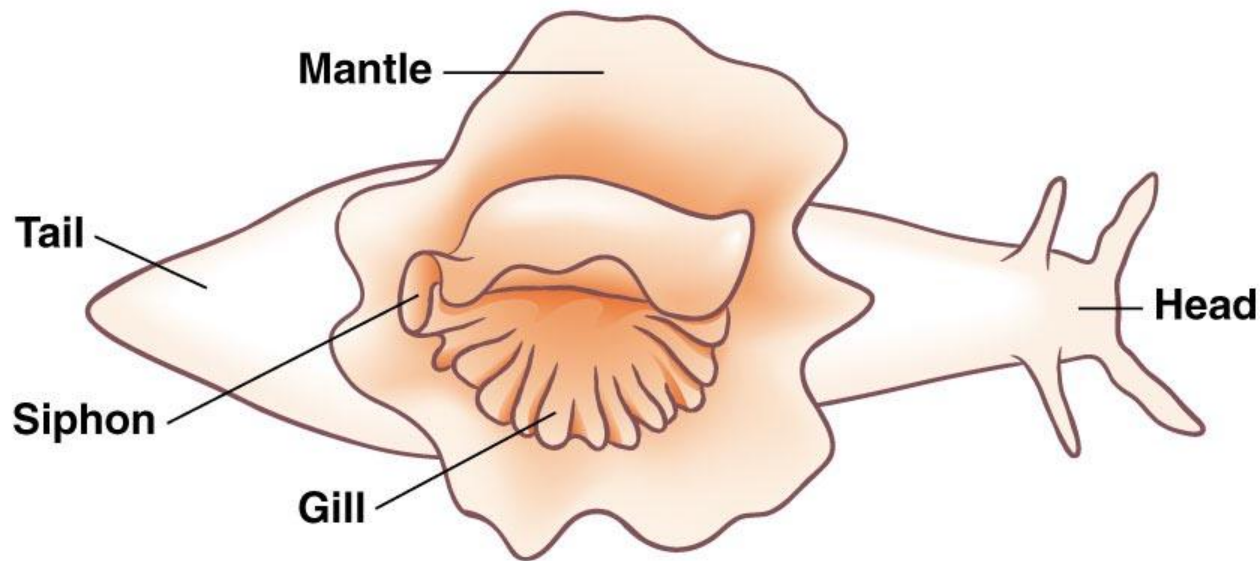


Invertebrate Learning & Memory

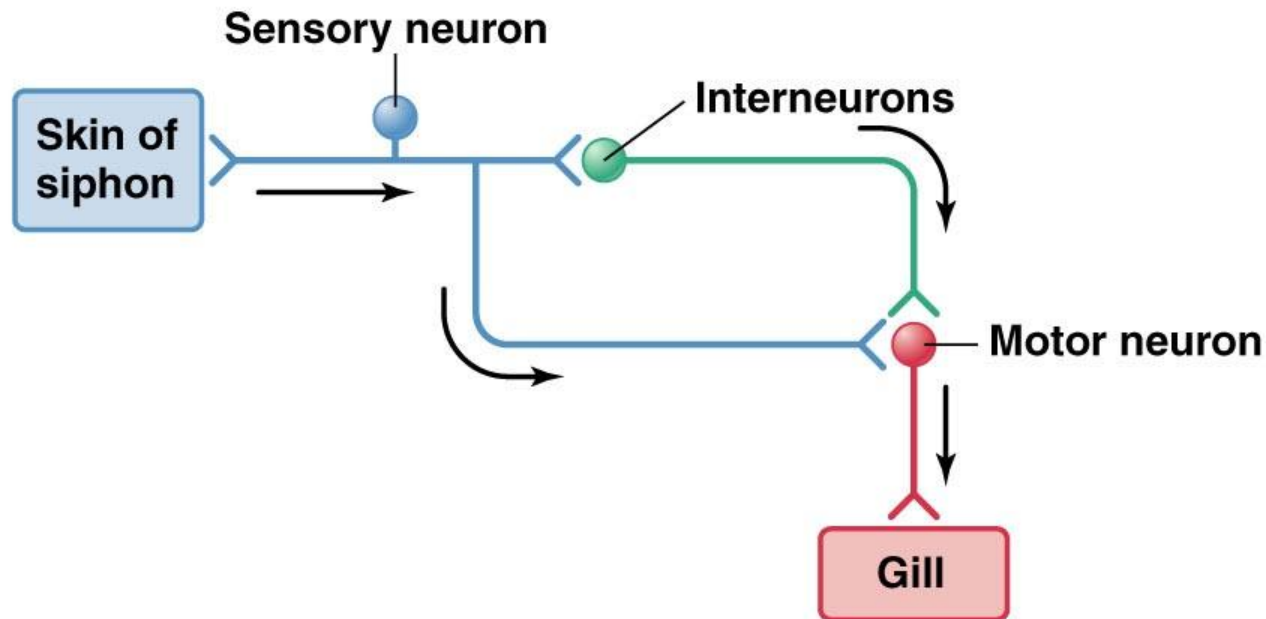
- Well studied in the sea slug, *Aplysia* (~20,000 neurons)
- *Habituation*
 - Decline in response to a stimulus after repeated exposure
 - Allows animal to ignore unimportant stimuli and focus on novel stimuli
 - Caused by changes in the presynaptic axon terminal
 - Inactivation of Ca^{2+} channels \rightarrow \downarrow neurotransmitter release

Aplysia californica





(a) *Aplysia californica*, dorsal view



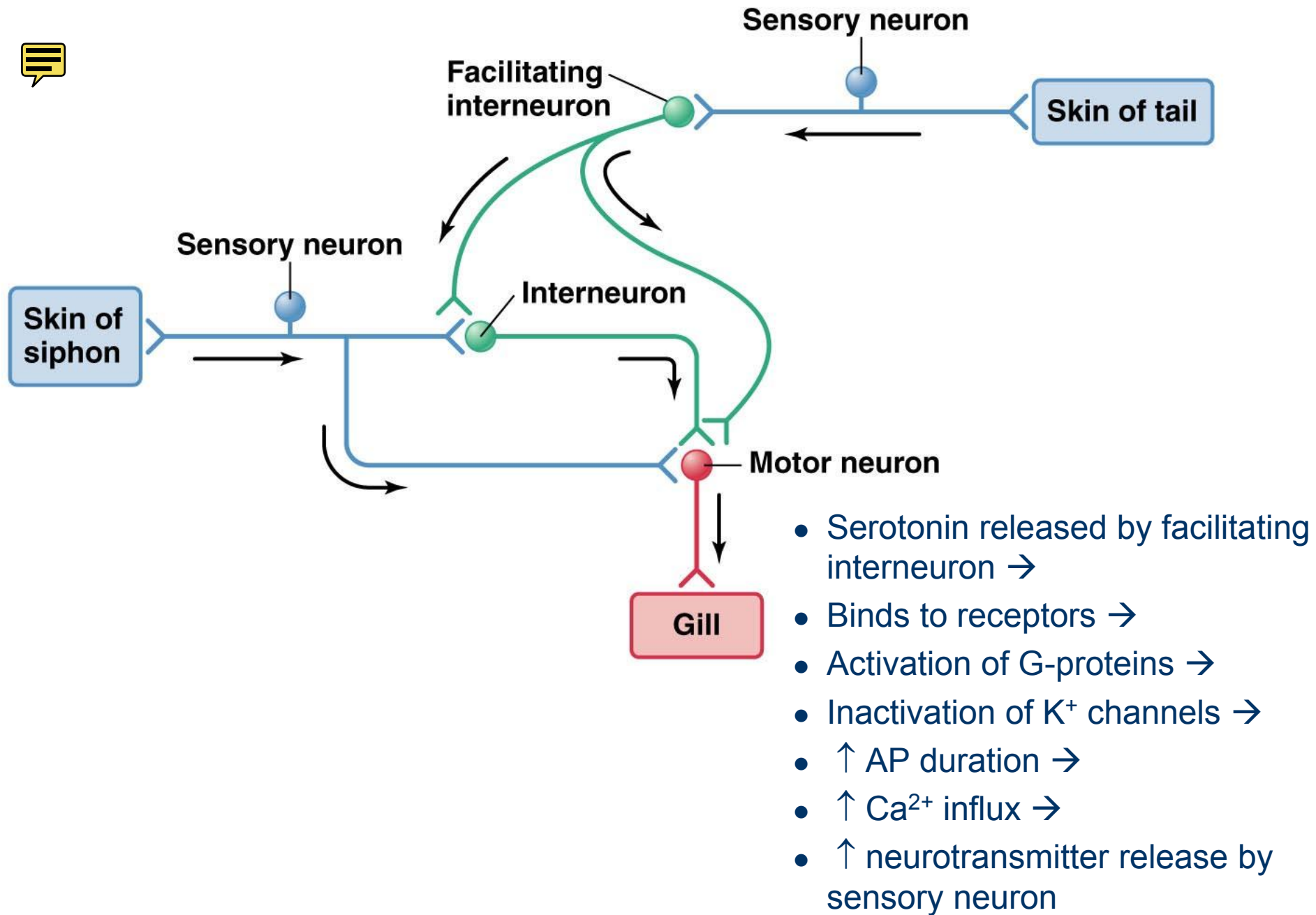
(b) The neural circuit governing the gill-withdrawal reflex

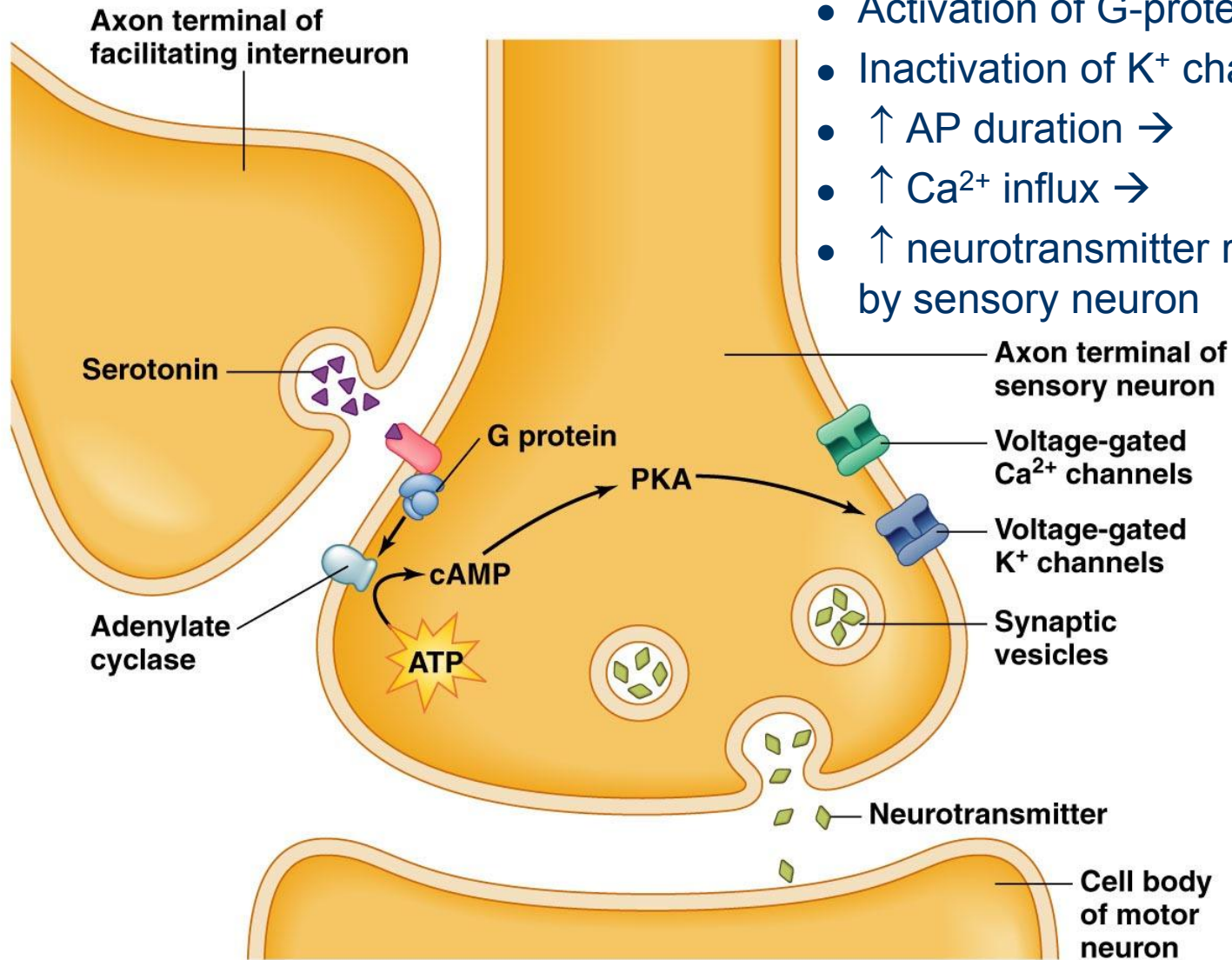


Invertebrate Learning & Memory

– *Sensitization*

- Increase in the response to a gentle stimulus after exposure to a strong stimulus
- Caused by changes in the presynaptic axon terminal
 - Involves a secondary circuit
 - Serotonin released by facilitating interneuron →
 - Binds to receptors →
 - Activation of G-proteins →
 - Inactivation of K^+ channels →
 - ↑ AP duration →
 - ↑ Ca^{2+} influx →
 - ↑ neurotransmitter release by sensory neuron





- Serotonin binds to receptors
- Activation of G-proteins
- Inactivation of K⁺ channels
- ↑ AP duration →
- ↑ Ca²⁺ influx →
- ↑ neurotransmitter release by sensory neuron