COMS30017
Computational Neuroscience

Week 4: Synapses and Synaptic Plasticity
Video 4: SHORT-TERM SYNAPTIC PLASTICITY

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Intended learning outcomes

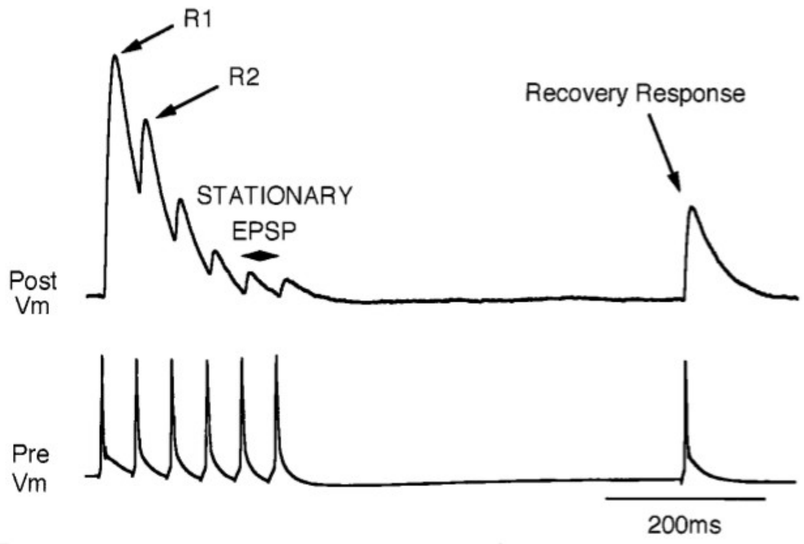
- Understand the concept of Short-Term Plasticity (STP)
- Be able to understand the equations for a simple model of STP
- Be able to describe STP as an information filter.

Short-term plasticity

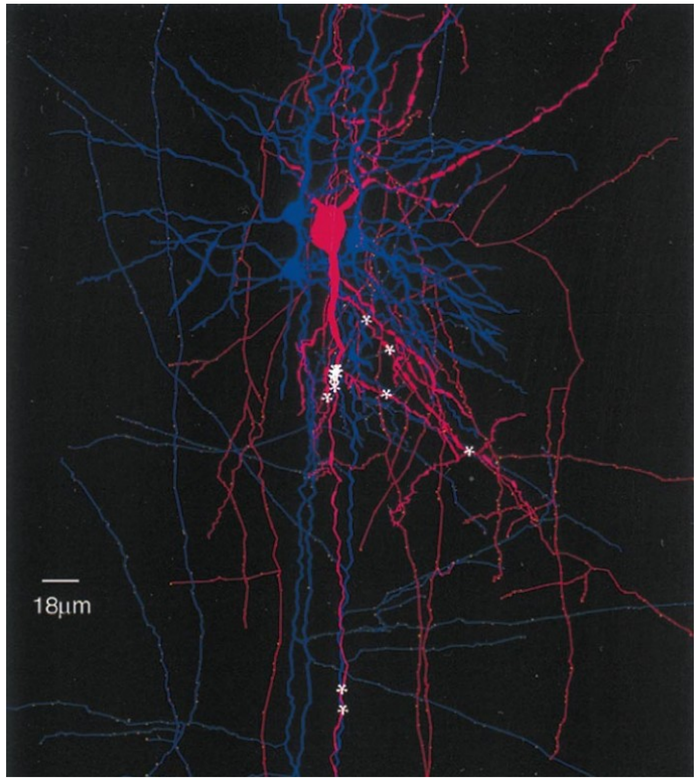
- Short-term synaptic plasticity is thought to be involved in fast cognitive processing.
- Similar timescale to electrical dynamics.
- Some synapses facilitate (increase their strength with use) while others depress (decrease their strength with use).
- Most synapses fall into one category or the other.

STP in an experiment

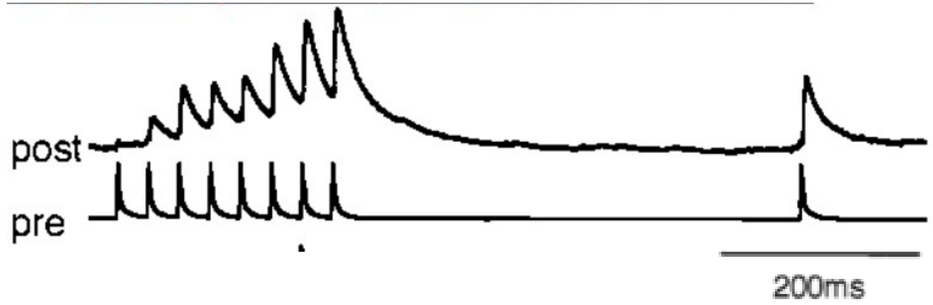
Depression



Tsodyks & Markram, PNAS (1997)



Facilitation

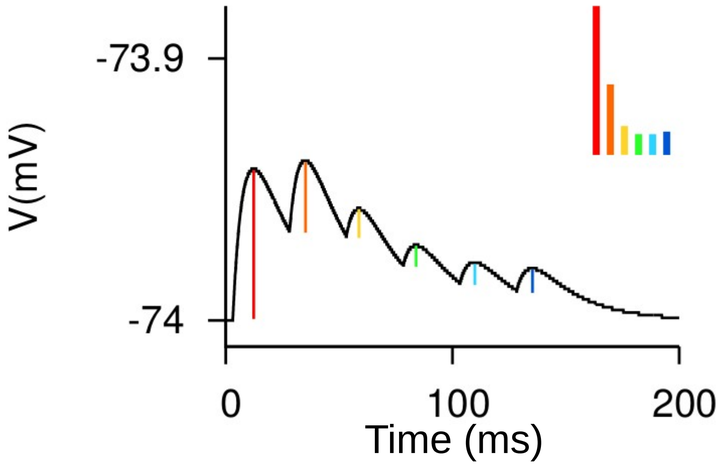


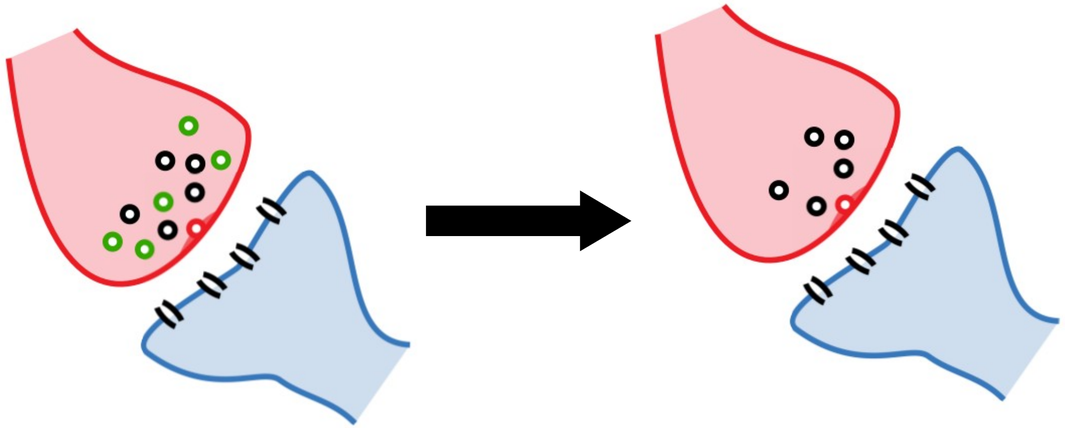
Markram, Wang, & Tsodyks, PNAS (1998)

Short-term depression

- Too many vesicles are used before more of them are prepare to be released

- Rate of vesicle replenishment limits rate of transmission:
  ➔Low-pass filter

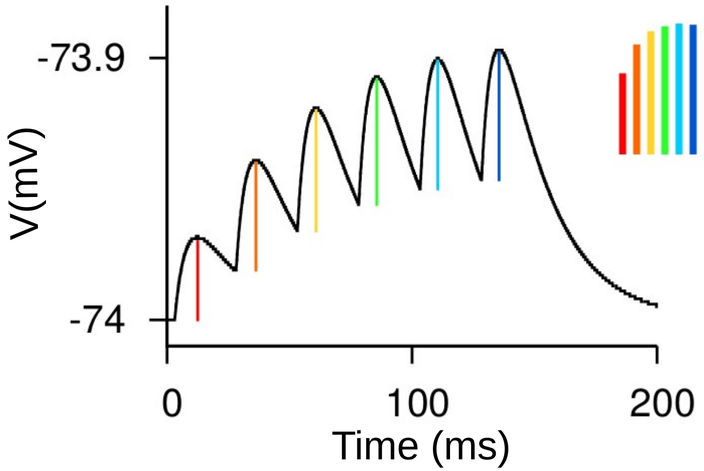


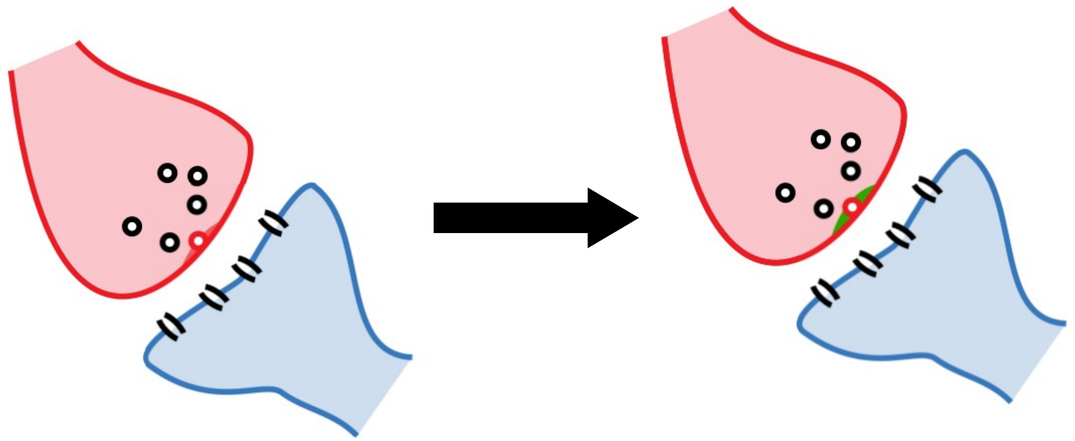


Short-term facilitation

- AP induces local Ca^{2+} influx in the presynaptic terminal
  - ➔Ca^{2+} leads to increased release probability

- Time of Ca2+ availability in the terminal limits period of available facilitation:
  - ➔High-pass filter





Short-term plasticity model

- Think of the synaptic efficacy as being determined by the available amount of some resource.

- U_{SE} is a parameter that determines how much resources get depleted with each spike.

$$\frac{dR}{dt} = \frac{I}{\tau_{rec}} - U_{SE} \cdot R \cdot \delta(t - t_{AP})$$

$$\frac{dE}{dt} = -\frac{E}{\tau_{inact}} + U_{SE} \cdot R \cdot \delta(t - t_{AP})$$

$$I = 1 - R - E,$$

Tsodyks & Markram, PNAS (1997)

Summary

- STP can be modelled as a competition for resources
- STP works as a frequency filter
- Most neurons have synapses that are either mostly facilitating or depressing