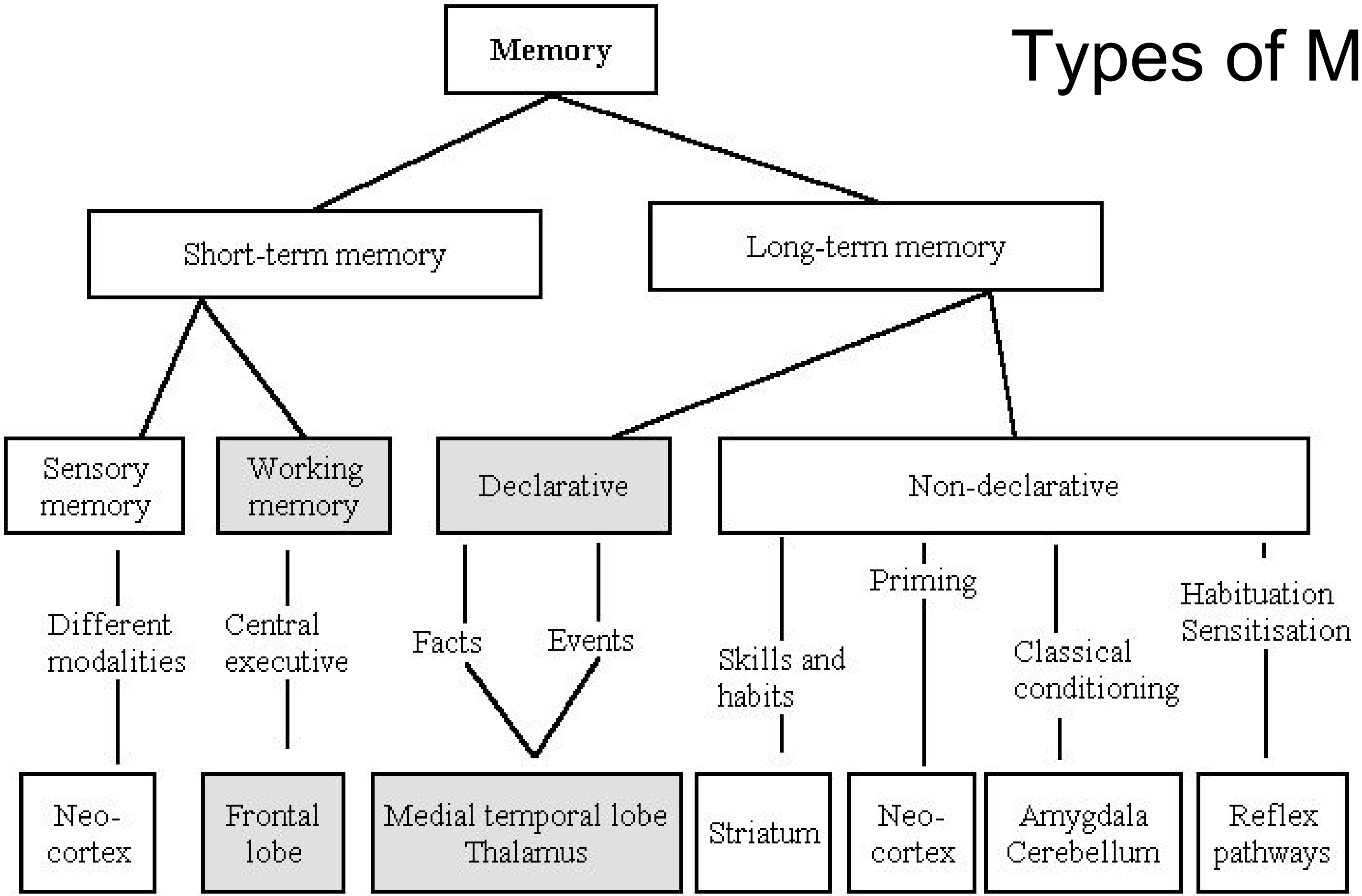
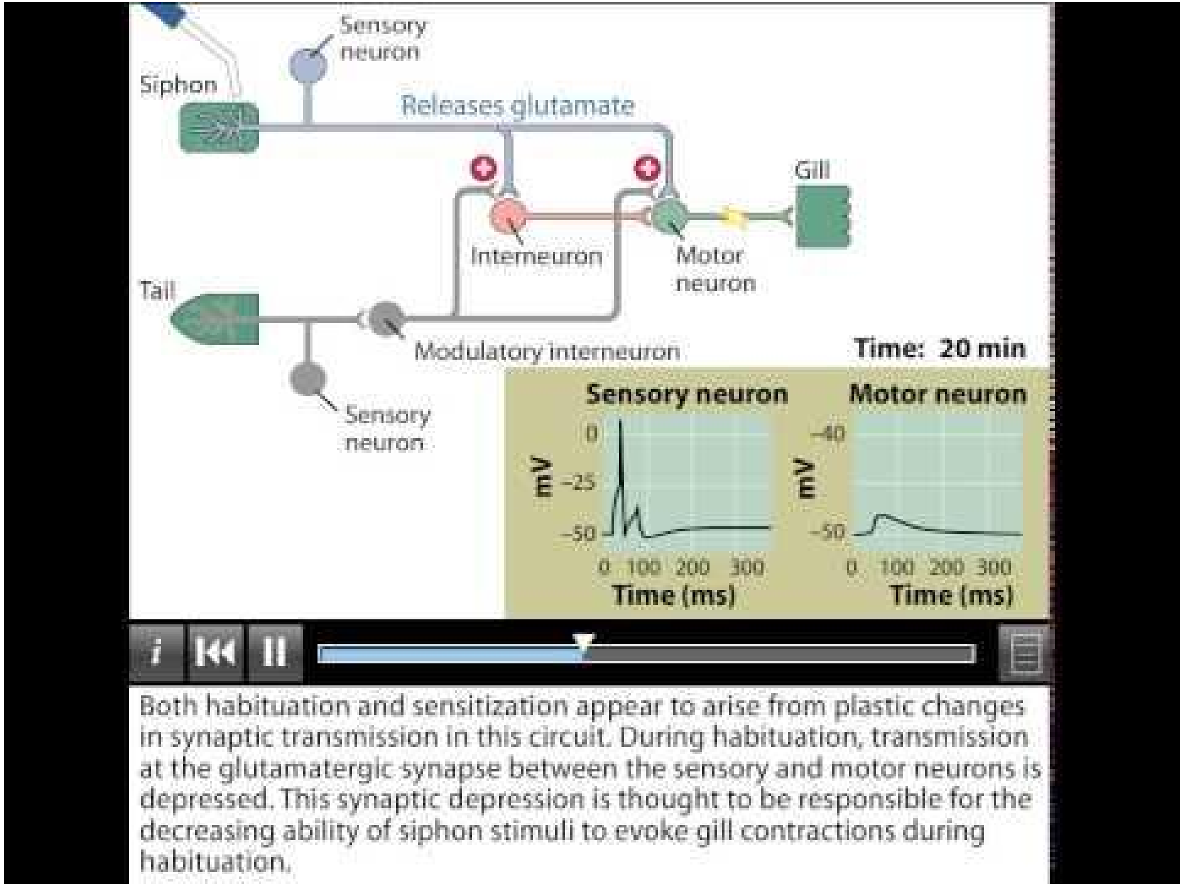
Memory

Putting memory into our memories

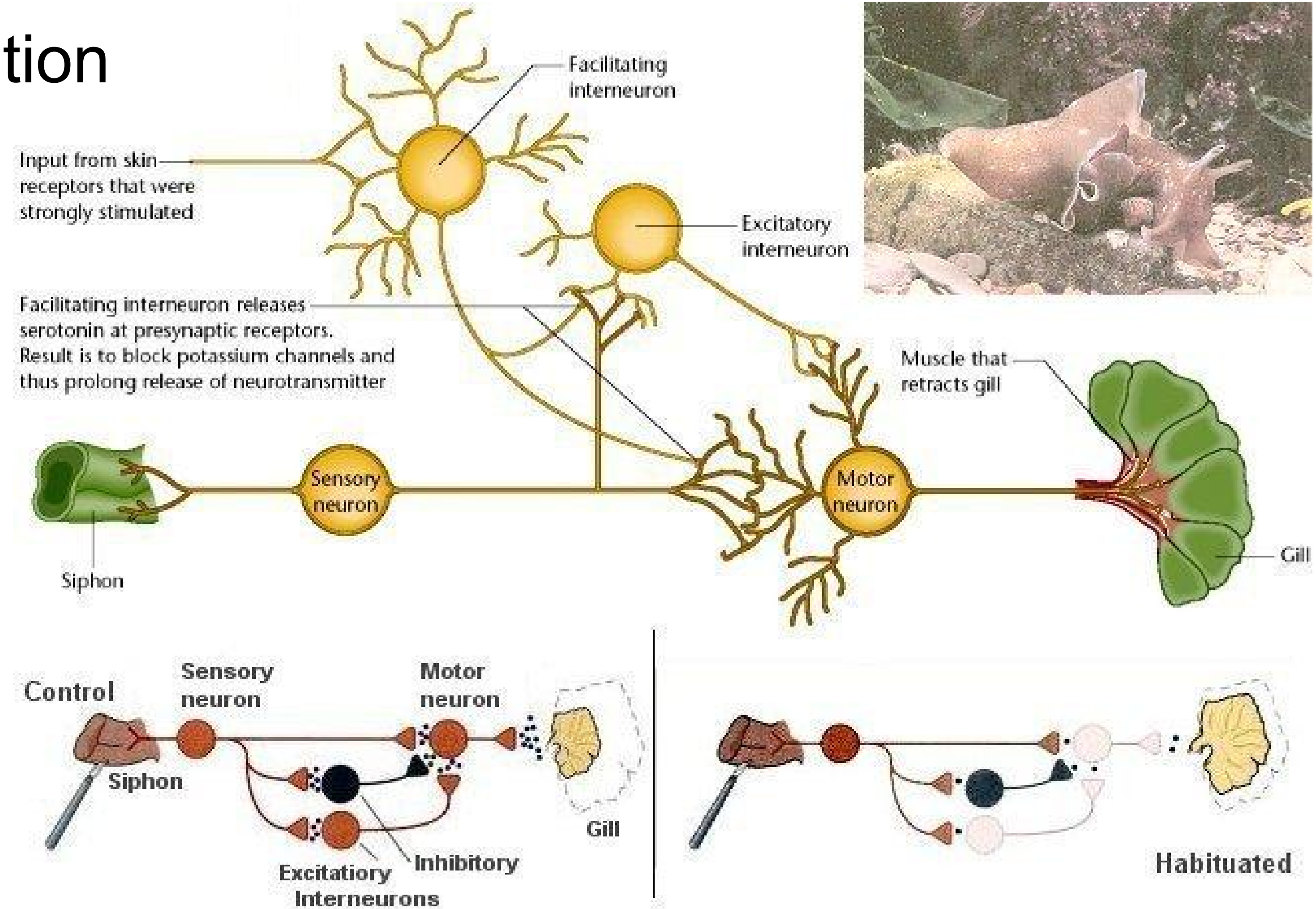
Types of Memory



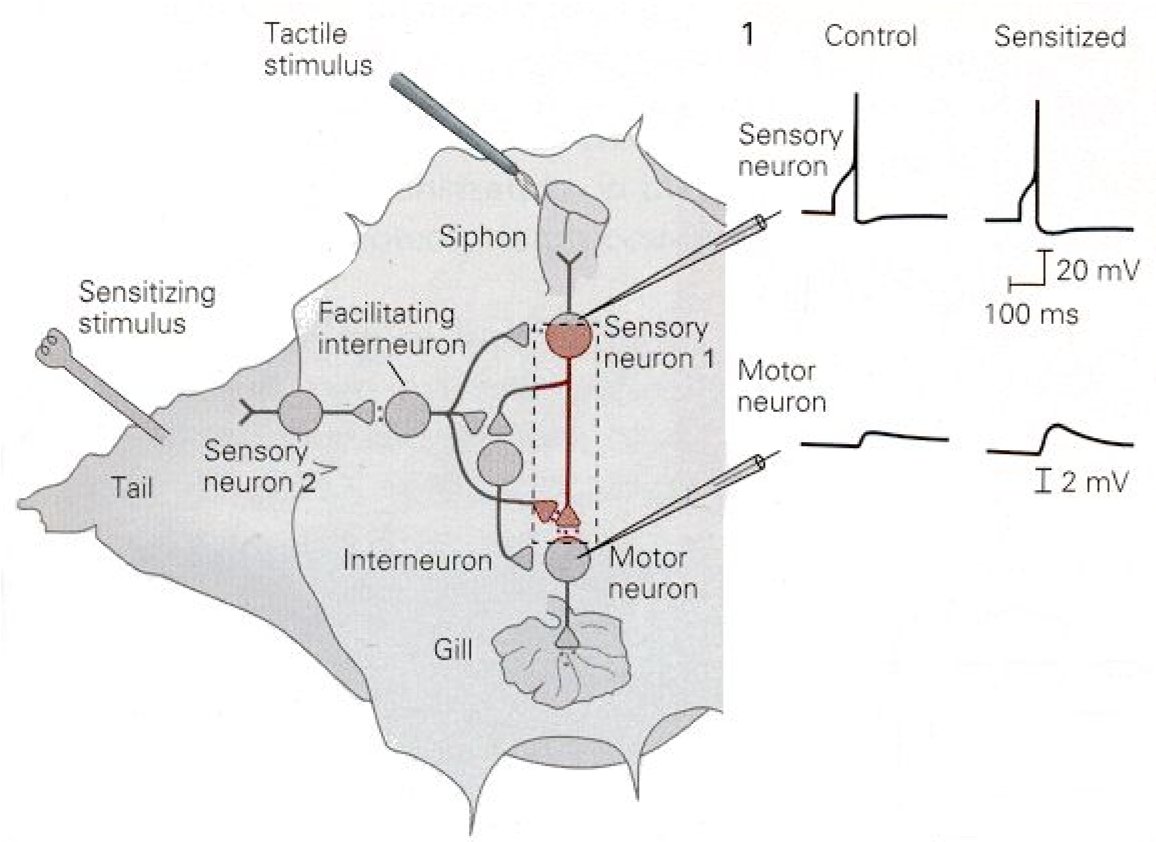
First 7 Chapters of Kandel's Book in 9 Minutes



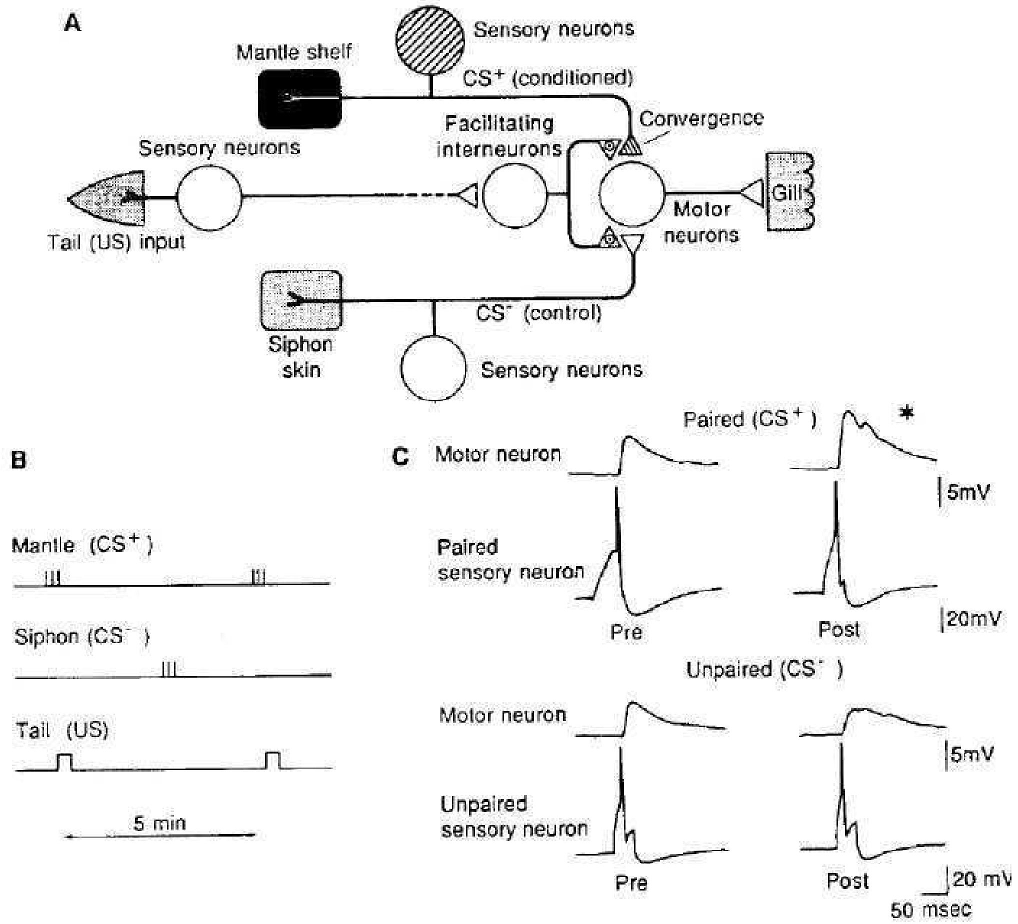
Habituation



Sensitization

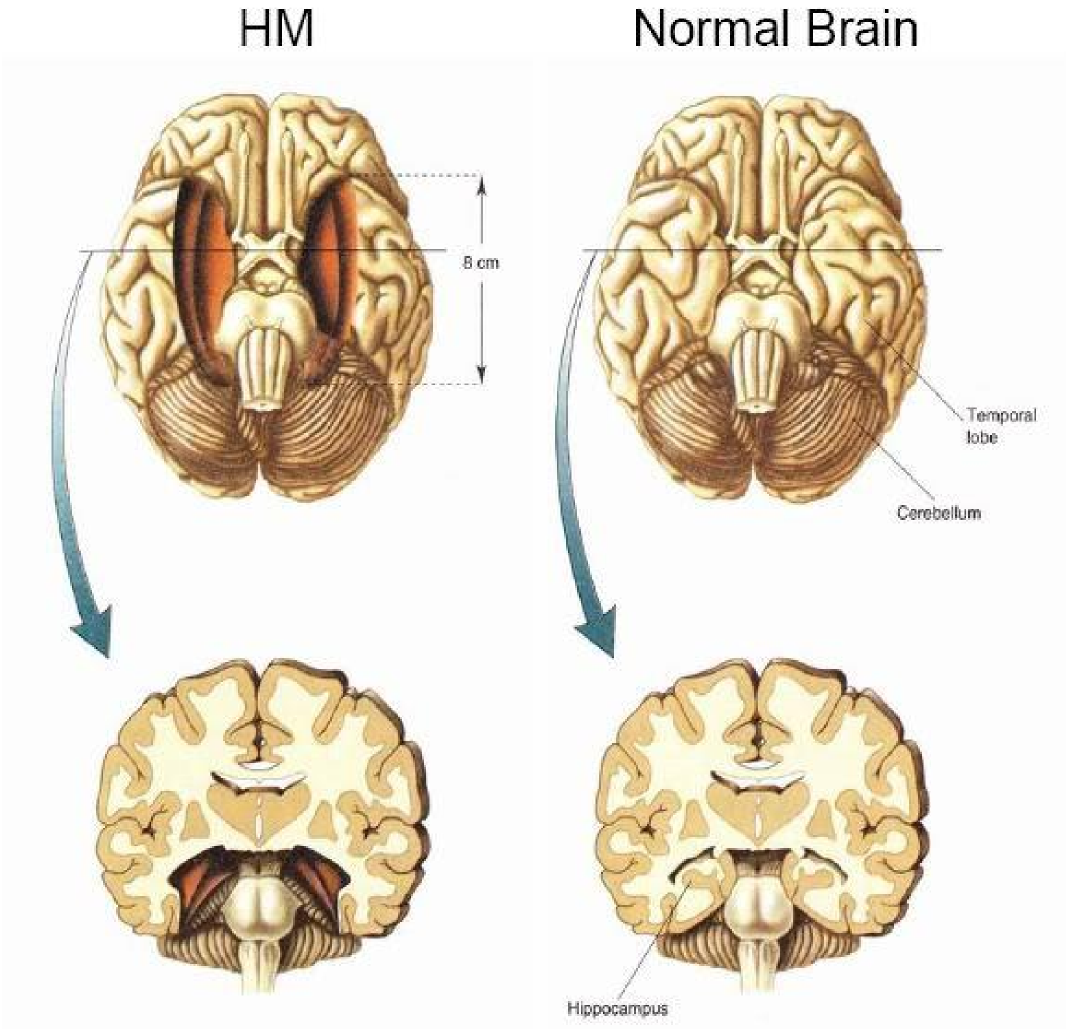


Classical Conditioning



Declarative Memory

- Normal recall of life preceding surgery
- Could still learn new physical skills
- Had complete faculty over working memory
- Complete inability to form new memories post surgery

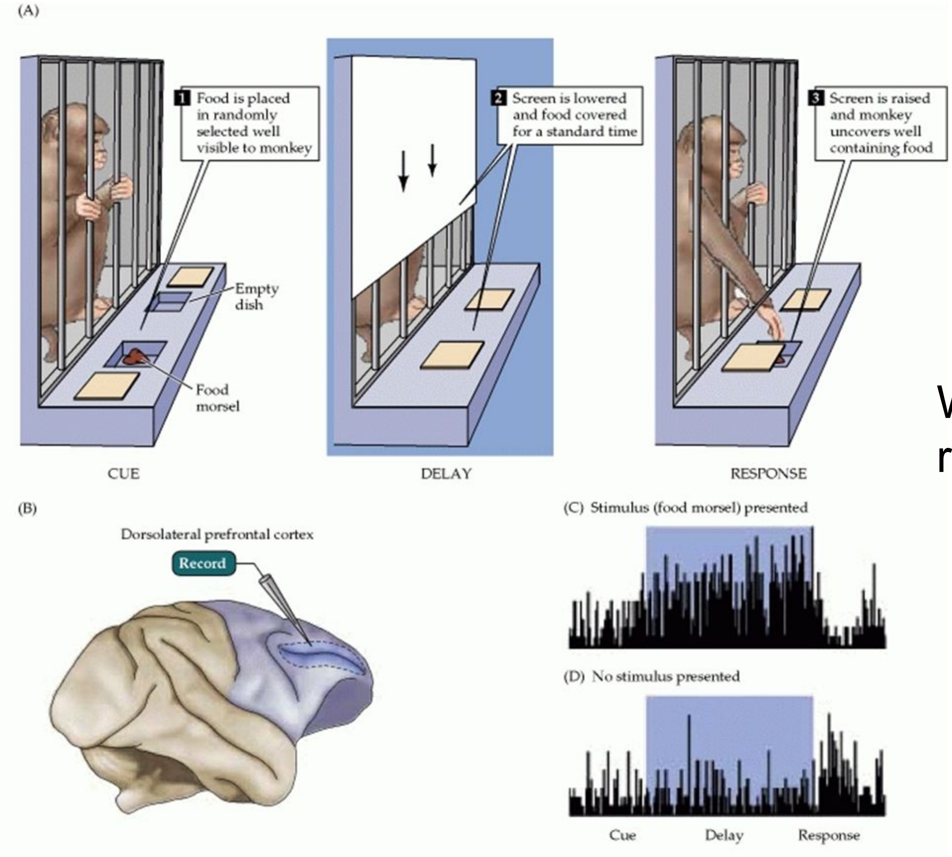


Working Memory

Working Memory (WM)

- Less biologically understood than nondeclarative memories
- More biologically understood than declarative memories
- Potential to enhance ANNs with artificial “working memory”
- New working memory faculty coming to FSU, Dr. Derek Nee
- Involves
  - Dynamical systems
  - Recurrent Neural Networks
  - Oscillations and Population Spikes
  - Calcium
  - Engrams (Polychrony!)

Working Memory (WM) - Synaptic Reverberation



WM theorized to be sustained by synaptic reverberation in a recurrent circuit

Working Memory (WM) - Localization

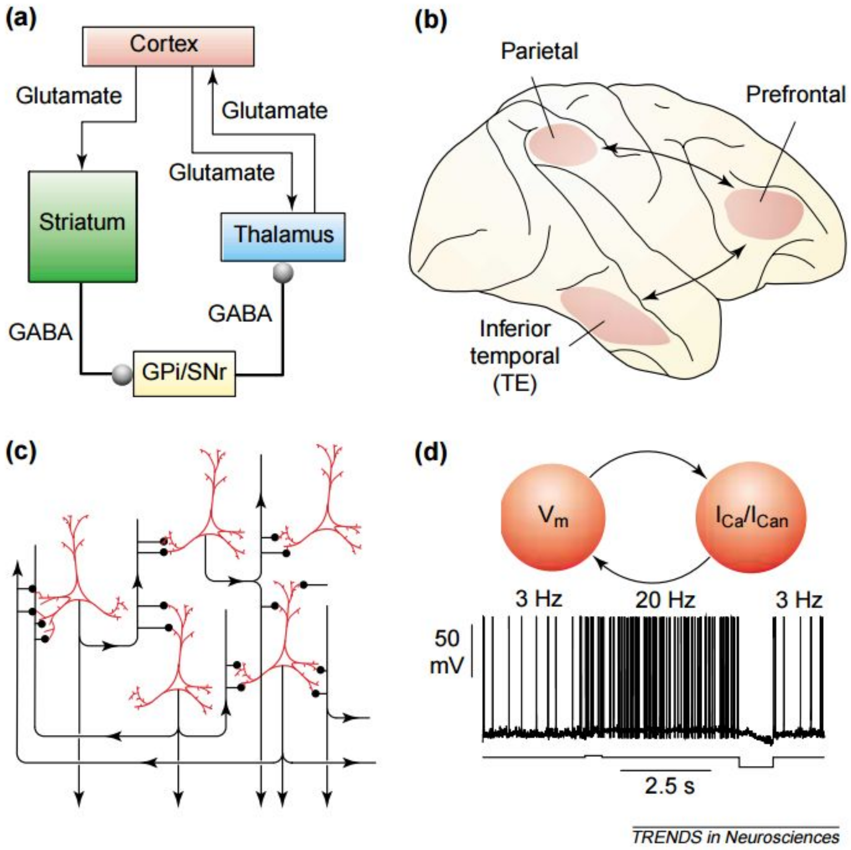
What is the scale of neural activity involved?

A. Closed thalamo–cortical loop and/or cortico–striato–thalamic–cortical circuit

B. Reciprocal interactions between two cortical areas

C. Excitatory recurrent collaterals within a local circuit

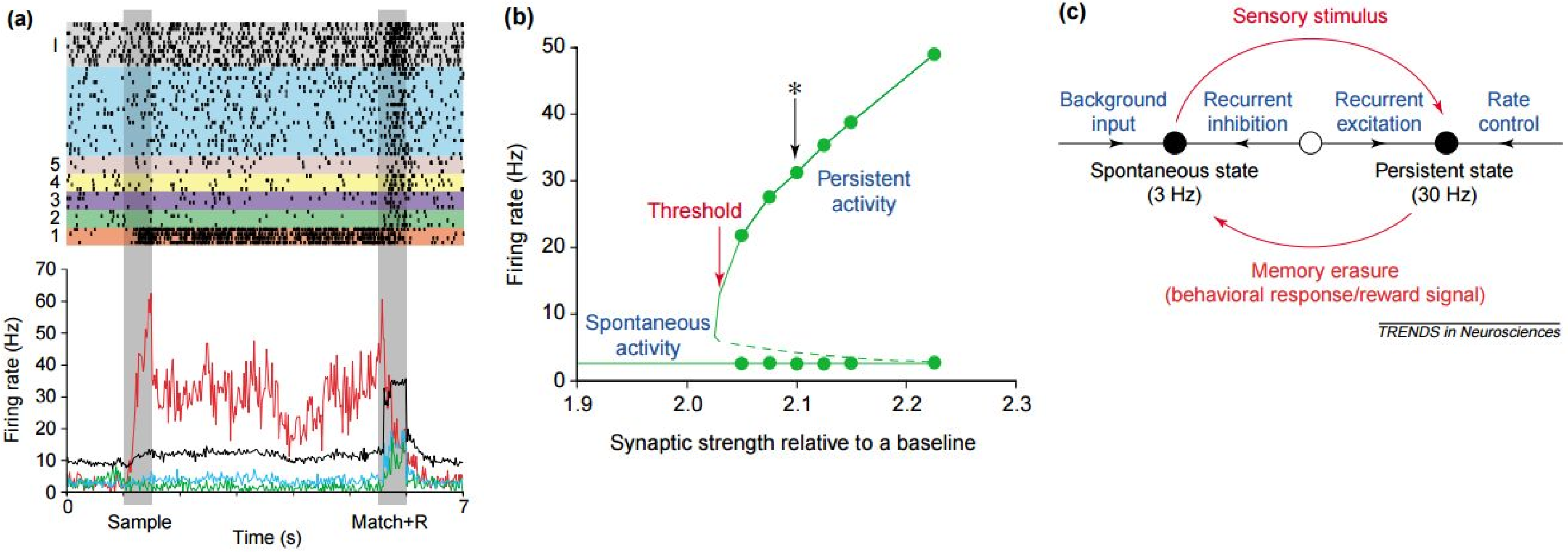
D. Intrinsic regenerative dynamics of single neurons



Working Memory (WM) - Attractor Paradigm

Since the 1970s, it has been proposed that delay activity patterns can be theoretically described by ‘dynamical attractors’

Neural networks display many attractor states each representing particular memories



Working Memory (WM) - Questions

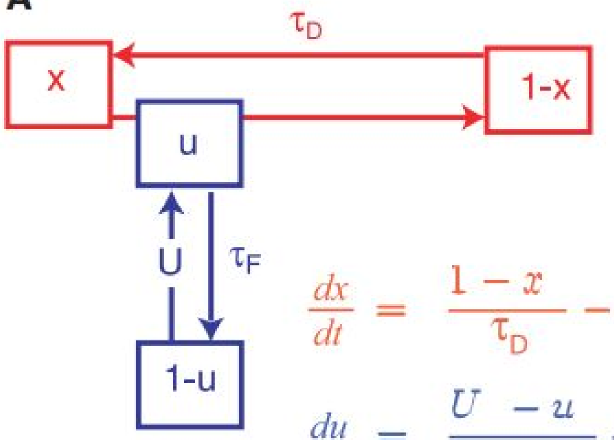
- If polychronous groups are realistic, how can they be reconciled with WM?
- What type of stimulus patterns are required to give rise to these ‘attractors’?
- What is the minimum anatomical substrate of a reverberatory circuit capable of persistent neural activity?
- Is persistent activity primarily sustained by synaptic reverberation, or by bistable dynamics of single neurons?
- What is the NMDA:AMPA ratio at recurrent synapses of association cortices, especially in the prefrontal cortex?
- How does this ratio depend on the frequency of repetitive stimulation and on neuromodulation?
- What are the negative feedback mechanisms responsible for the rate control in a working memory network?
- Is delay period activity asynchronous between neurons, or does it display partial network synchrony and coherent oscillations?
- Is delay period activity more sensitive to NMDAR antagonists compared with AMPAR antagonists?
- Does persistent activity disappear in an abrupt fashion, with a graded block of NMDAR and AMPAR channels, as predicted by the attractor model?
- How significant are drifts of persistent activity during working memory? Are drifts random or systematic over trials?
- What are the biological mechanisms underlying the robustness of a memory network with a continuum of persistent activity patterns? (evolutionary techniques)

Synaptic Theory of Working Memory

This is an addition to the reverberation theory about working memory. It adds that working memory is sustained by calcium-mediated synaptic facilitation in the recurrent connections of the neocortical networks.

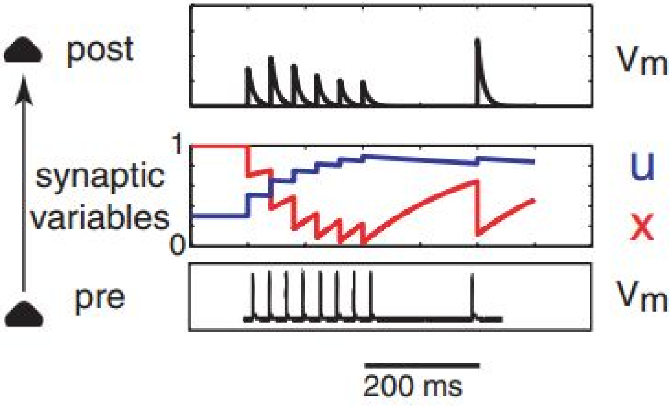
Simple integrate-and-fire neurons with a resources model approach to plasticity

A



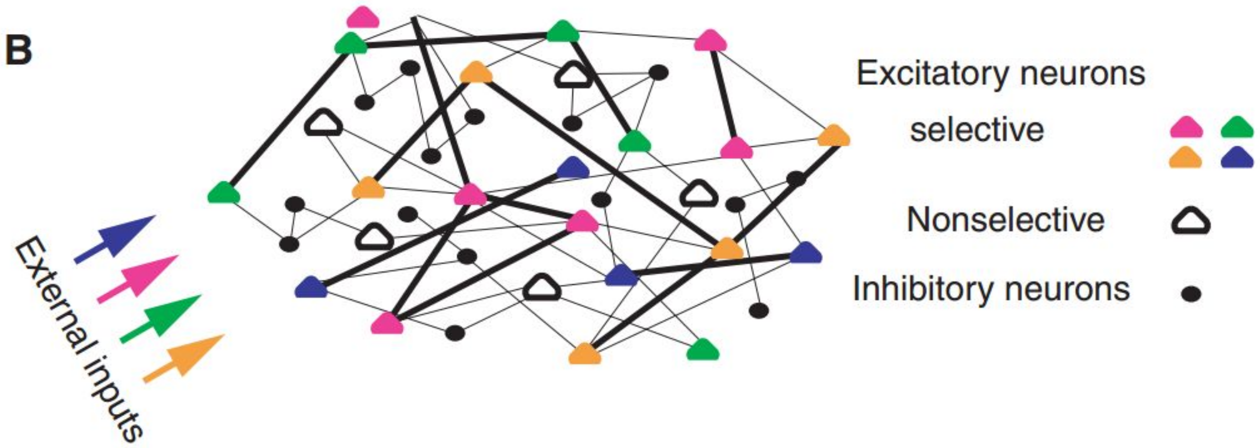
$$\frac{dx}{dt} = \frac{1-x}{\tau_D} - u\, x\, \delta(t-t_{sp})$$

$$\frac{du}{dt} = \frac{U - u}{\tau_F} + U\,(1-u)\,\delta(t-t_{sp})$$



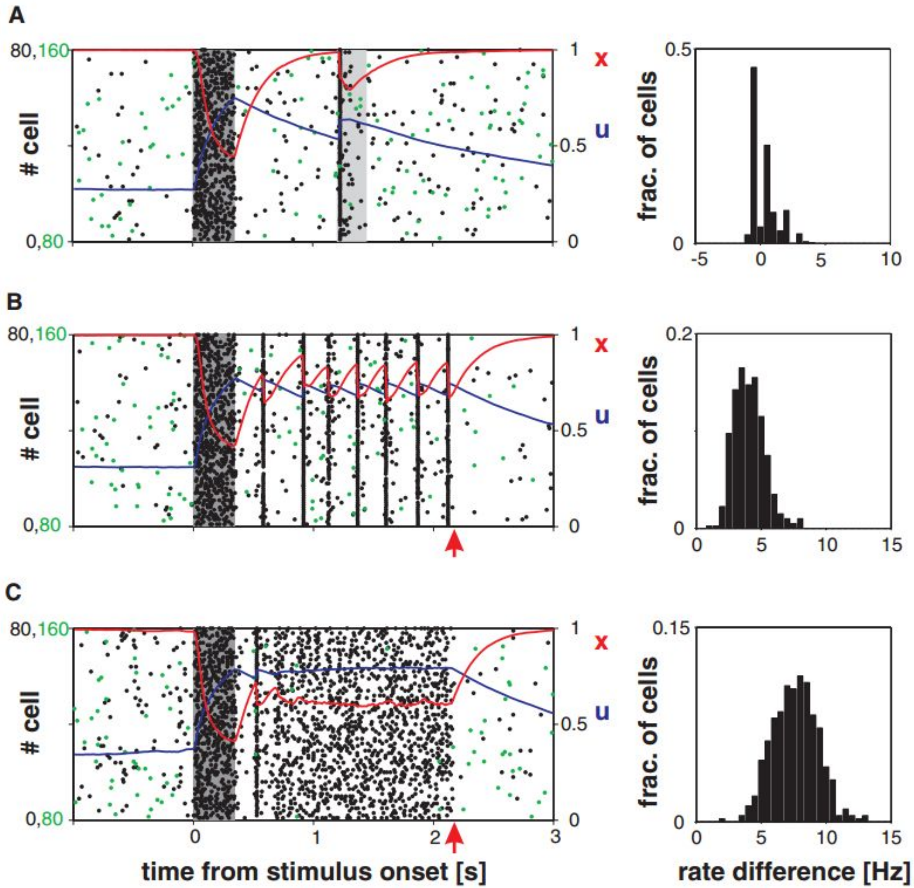
Synaptic Theory of Working Memory

Memories are “loaded” into subpopulations of the network



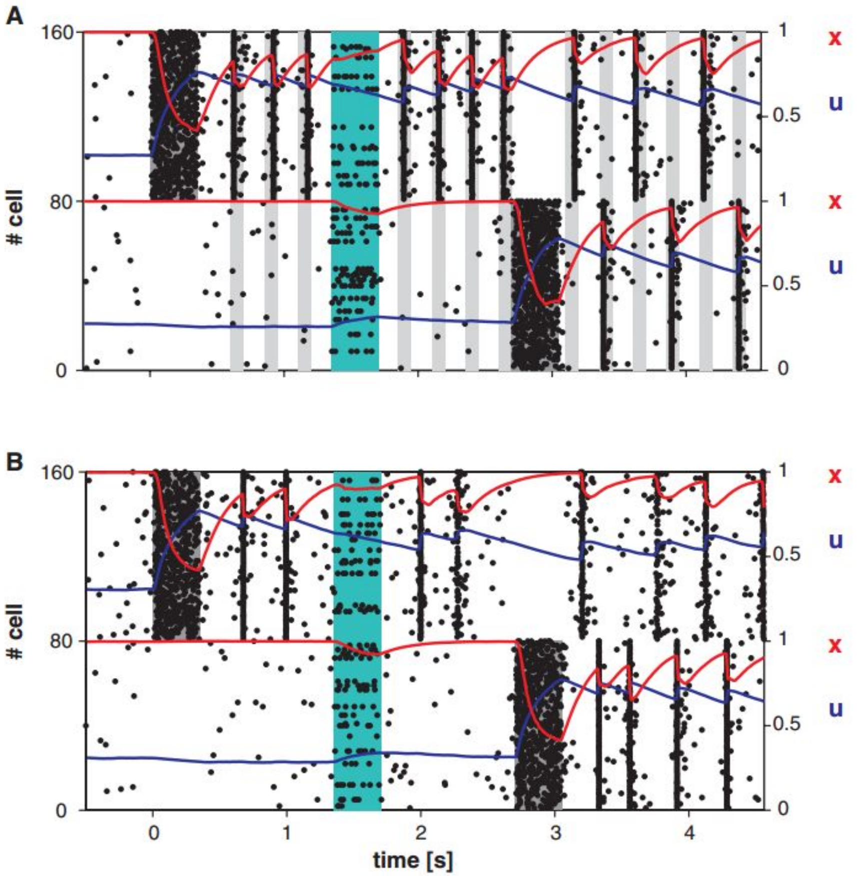
Synaptic Theory of Working Memory

Reactivation is expressed as a short epoch of synchronized activity ["population spike" (PS)], where almost every neuron in the population fires a spike within an interval of about 20 ms.



Synaptic Theory of Working Memory

Can load two memories in. Each can be represented by different population spikes. It is also robust to noise (teal)



Synaptic Theory of Working Memory - Thoughts

- This is a very simple model
- Calcium isn't explicitly modelled in their formulation
- What about a more detailed model considering the principles involved in sensitization?
- Obviously, how does astrocytic involvement in the synaptic activity affect the memories?
- This is essentially a simpler version of Izhikevich's work, just asking different questions