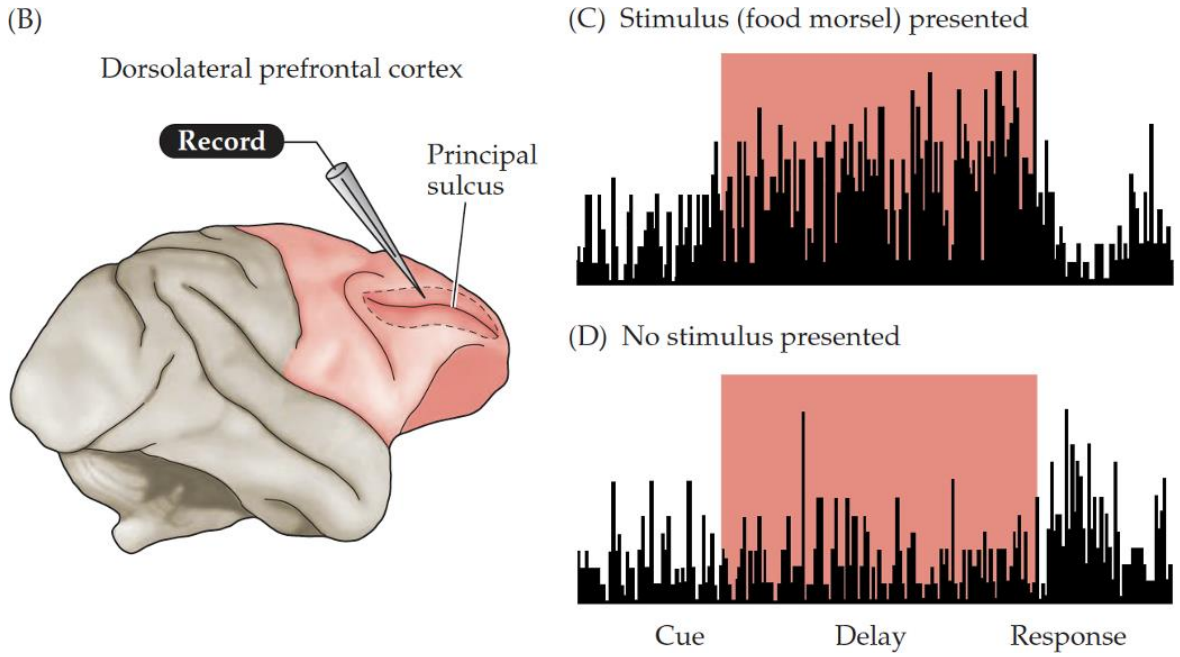
Neuroscience BIO-311

Exercise Solutions: Memory & Cognitive Maps of Space

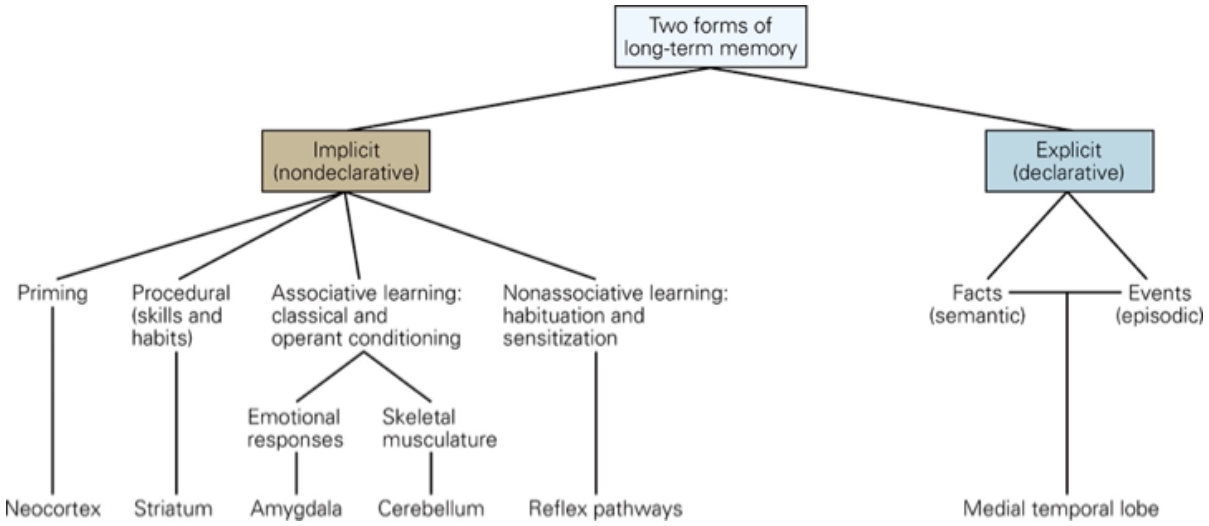
1) i) At what timescale does the "short-term" memory operate? ii) Which brain regions are involved? iii) Explain how this has been shown in monkeys using food cache experiments.

i) seconds to minutes
ii) the prefrontal cortex
iii) Activity increases during the delay period, not during the behavioral response. Thus, 'working memory' is a short-term memory important for organizing future purposeful behavior.

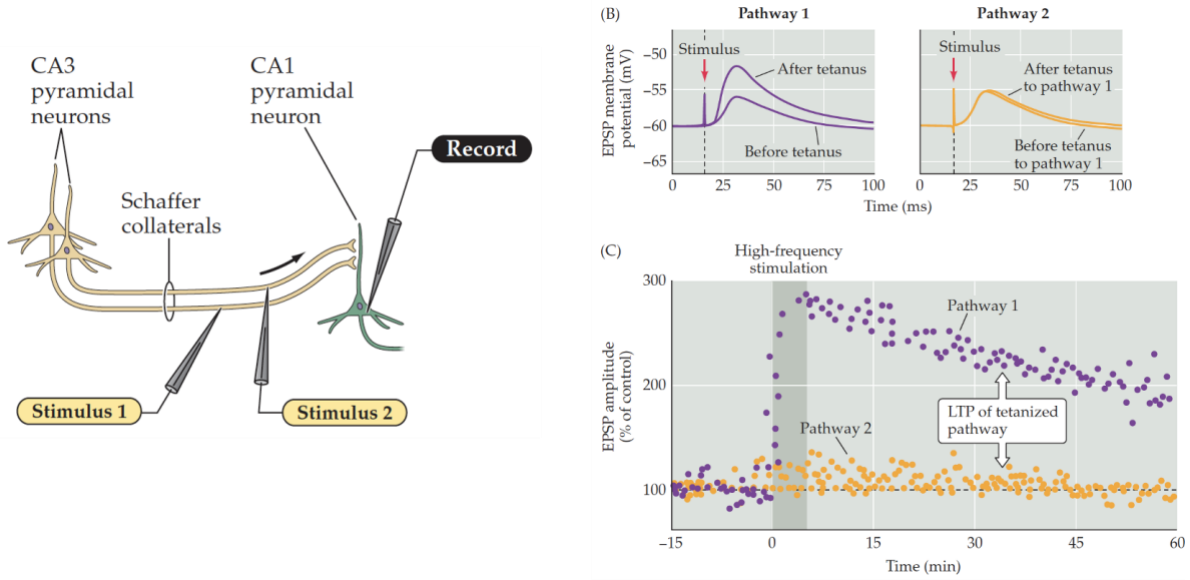


2) (i) Explain the difference between "implicit" (also called "non declarative") and explicit (or "declarative") long-term memories. (ii) Name 3 examples for non-declarative long-term memories.

implicit: usually expressed subconsciously
explicit: expressed consciously, can be expressed verbally



3) **i) Which phenomenon is illustrated in the Figure 8.7 of Purves? ii) What is meant by 'tetanus' and what does it represent in physiological conditions? iii) What is the difference between pathways 1 and 2? iv) Remember from the first modules, we described aneuron as a unit performing a weighted sum of its synaptic inputs. How does this sum change between time t=0 and time t= 15 min in this scenario?**



Answer:

i) Long-term plasticity in the hippocampus

ii) tetanic stimulation: brief, high-frequency stimulation of a given axon. This increases the likelihood of simultaneous depolarisation in the pre- and postsynaptic neurons.

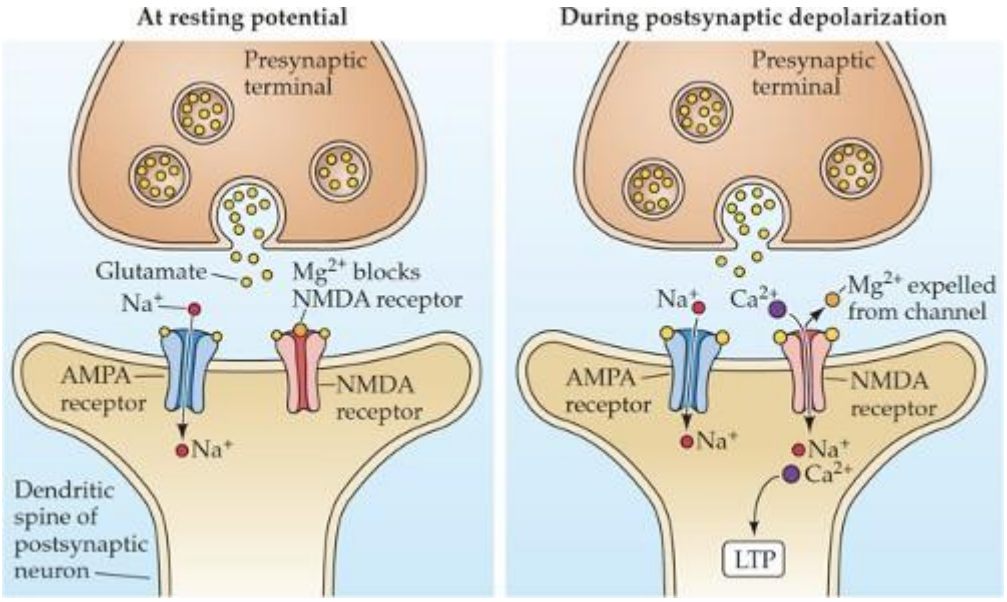
iii) pathway 1 and 2 are identical in terms of wiring. Only the presynaptic neuron of pathway 1 has undergone tetanic stimulation.

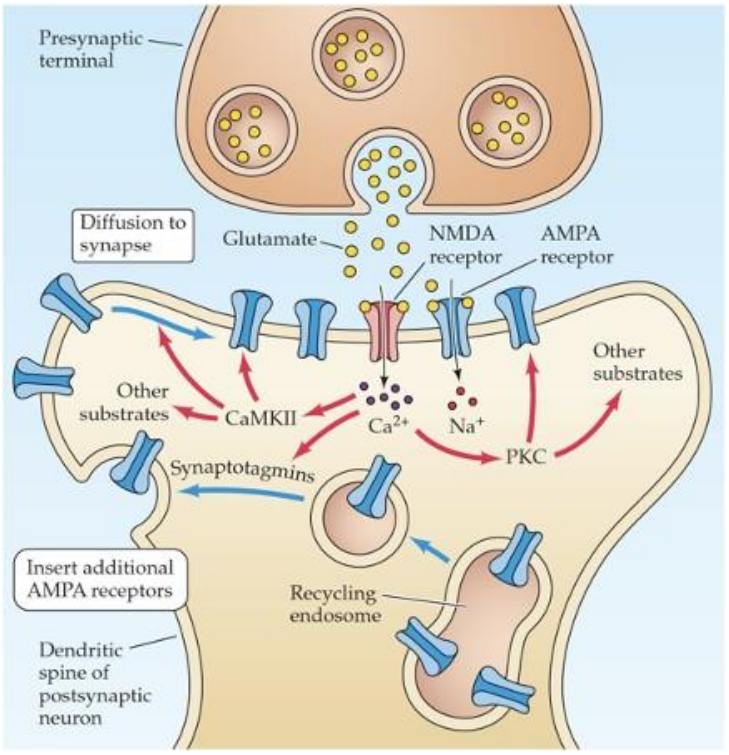
iv) the weight assigned to the pathway 1 increases after long term potentiation, therefore the postsynaptic neuron responds more strongly to activity of presynaptic neuron 1.

4) **i) Under which conditions do we observe long-term potentiation (plasticity that reinforces a synapse)? ii) What is the underlying molecular mechanism (channels and signaling pathway)?**

i) Simultaneous vesicle release from the presynaptic neuron and depolarisation of the postsynaptic neuron. This corresponds to the successful activity of a synapse, that is therefore reinforced as being meaningful.

ii) NMDA-receptor opens only when two conditions are met: i) glutamate is bound to the receptor (released from the presynaptic neuron) and ii) the postsynaptic cell is depolarized or fires an AP (to relieve the voltage-dependent Mg2+ block of NMDA-receptors). Thus, NMDA-receptors are "coincidence detectors" of pre- and postsynaptic activity. The Ca2+ ions that enter the cell through the channel activate postsynaptic protein kinases, such as CaMKII and PKC, that trigger a series of phosphorylation reactions. The phosphorylation reactions facilitate the diffusion and binding of AMPA receptors into the postsynaptic density, which increases the sensitivity of the spine to glutamate, and trigger other events, eg at the transcriptional and post-translational protein modification level.

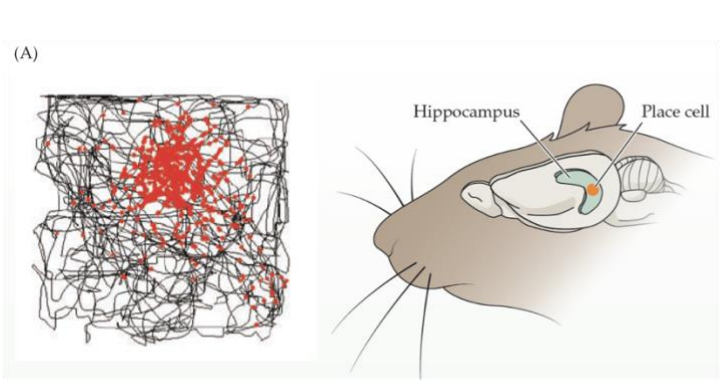


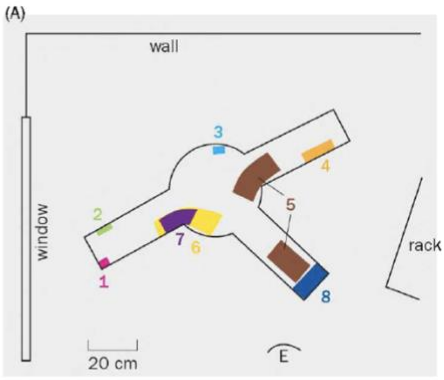


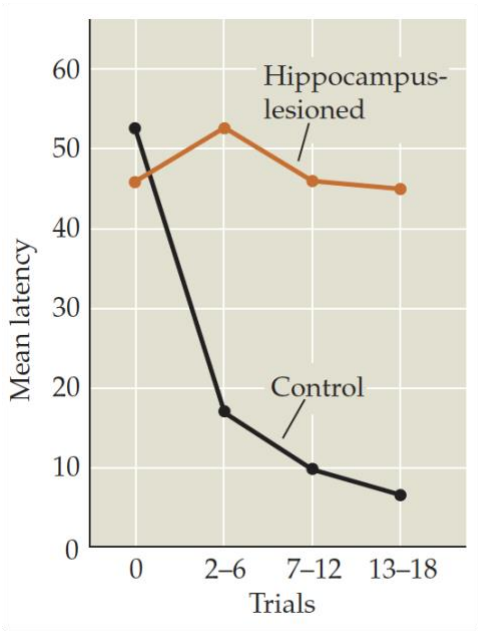
5) (i) Describe the concept of a "place cell" in the hippocampus of a freely moving rat/mouse. (ii) In consequence, explain why the performance of rats/mice with a lesion in the hippocampus drops in the "Morris water maze" test.

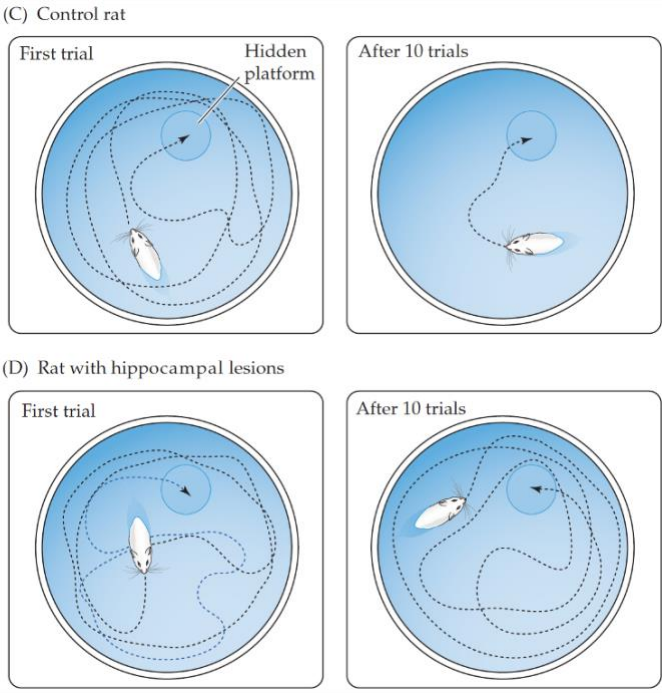
i) “place cells” in the hippocampus (different from “grid cells”!) encode location. They form when the animal is placed in a new environment and remain stable thereafter. Place cells are influenced by landmarks, but are also stably active in the dark.

ii) “place cells” are situated in the hippocampus. If that region is lesioned, no new location encoding can be made and the mice learning capacity decreases significantly.



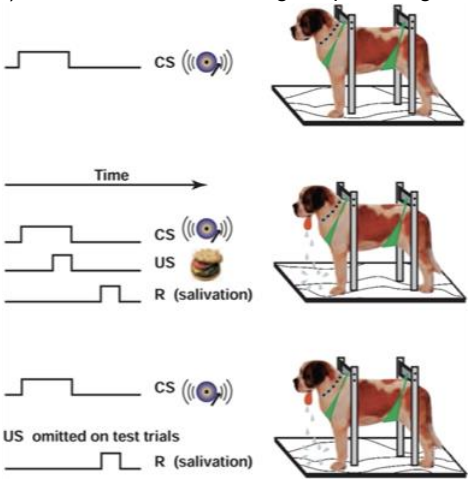


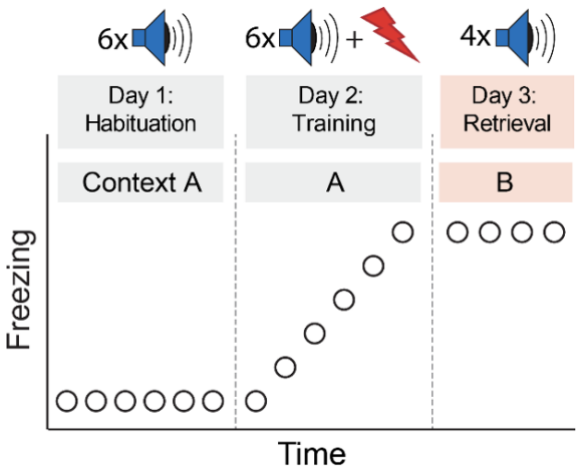




6) Explain the basic concept of classical conditioning, giving one example for an "appetitive" and another example for an "aversive" conditioning experiment. Which are the unconditioned and conditioned stimuli, and what is the conditioned response? (ii) Do you think this is a long-term memory, and if yes, to what category of long-term memory does it belong to? iii) In the example of fear conditioning, which brain region is involved?

ii) Yes. Associative learning / implicit long-term memory. iii) the amygdala





7) What is a “concept cell”?