Name _____

Controversies in Neuroscience (03-101-A1)
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Fall 2013
FINAL EXAMINATION

The exam is closed notes, closed book. There are 10 problems. There are a total of 7 pages (**not** including this cover page). The exam is due at 4:00 pm.

Read each question carefully. Use the back if you need more space. Come ask me if you have any questions.

1) _____/4

2) _____/3

3) _____/4

4) _____/5

5) _____/4

6) _____/6

7) _____/5

8) _____/9

9) _____/10

10) _____/10

TOTAL _____/60

1) (**4 points total**)

a) Compare and contrast working memory with long-term declarative memory. (2 points)

Both conscious (1 point)
Working is what you're thinking about now, long-term is long term (1 point)

b) Phineas Gage had damage to his frontal lobes which causes difficulty with working memory. For each task below, state whether H.M. (Henry Molaison), Phineas Gage (P.G.), or both would have trouble with it. (2 points) 0.25 – 0.5 points each, depending on what error is made.

_PG_ Remembering a phone number for 2 minutes, without distractions

both Remembering a phone number for 15 minutes, after distraction

_HM_ Learning a new person's name

_HM_ Learning his way around a new neighborhood

_PG_ Sorting cards first by suit, then switching to sort by number

2) (**3 points total**)
a) Explain what is meant by procedural learning. Give an example. (1 points)

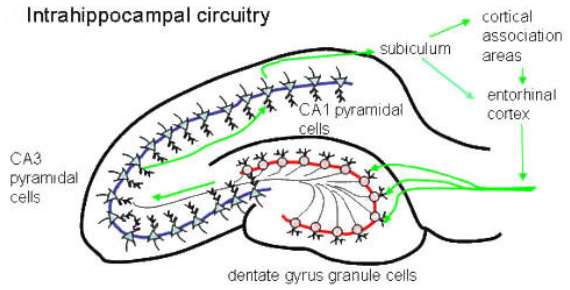
Skills/habits (0.5 points) Bike riding, mirror drawing, etc. (0.5 points)

b) Are patients like H.M. & E.P. who have damage to their hippocampi able to learn new procedures? Include in your answer a description of the brain area(s) involved. (2 points)

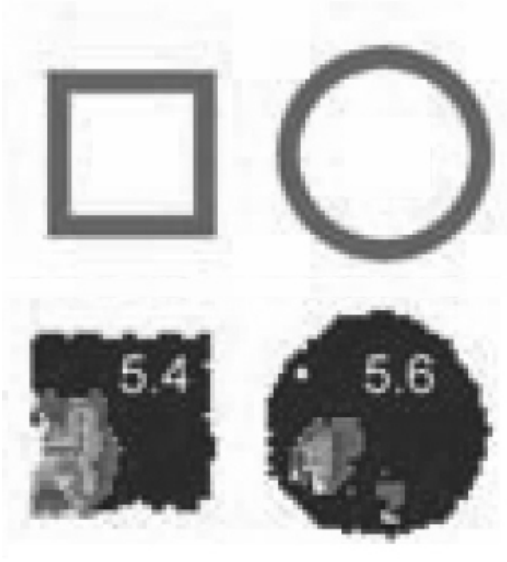
Yes (1 point). Basal ganglia or striatum (1 point)

3) Sketch the hippocampus and label the three main cell types in each area. Also, label the connections, input structure(s), and output structure(s). (You do not need to name the pathways, but it should be clear the order of information flow to and from each area.) (4 points)
(***USE THE BACK!!!***)

Entorhinal -> Dentate -> CA3 -> CA1 -> Subiculum (1 point for each structure name, 3 points for getting all the connections right: -1 per missed connection)
[1 point can be earned for "place cells" and 1 for "grid cells] sketch optional:



4) (**5 points total**) The image below shows the place field for a single cell in a rat's hippocampus when the animal is in a square box (left) or a round box (right).



a) Compare the responses in the two boxes. (1 point)

In both the cell fires in the bottom left corner

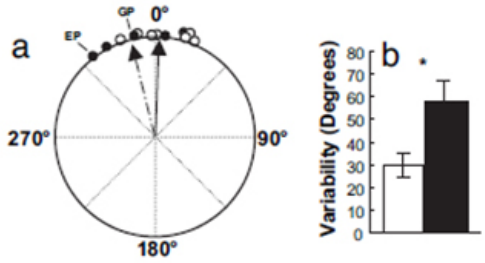
b) Discuss what this cell's response implies for the ability of the ***animal as a whole*** to distinguish between the two environments. (2 points)

It is fine to hypothesize either that the animal thinks of them as the same or that it thinks they're different. Consistent with below (1 point)
Discussion of other cells & information integration (1 point)
[If other cells are not discussed, 1 point for discussing THIS cell's ability to distinguish]

c) Describe an additional experiment that you would need to perform to confirm your answer to part (b) above, what result would you predict? (2 points)

Record from other cells and see if any distinguish between the environment. Such as one that fires in the bottom left of the square but not the circle. 0.5 point for hypothesis that is consistent with above, 1 point for experimental design, 0.5 point for discussion of recording other cells' responses.

5) (**4 points total**) Shrager & Squire found no difference between healthy controls and patients with hippocampal damage in their ability to navigate short paths. Imagine that **instead**, when they plotted the individual mean direction pointed (left) and subject-by-subject variability (right) *immediately* following walking, they had found the following:



Open (white) symbols are healthy controls, filled (black) are patients with hippocampal damage

Describe these results and interpret them in the context of the debate about the hippocampus' function as a navigation vs. declarative memory structure. (4 points)

Although patients do about as well as controls on average at pointing back to their starting location, they have much more variability from one trial to the next (2 points)
This is consistent with the hypothesis that the role of the hippocampus is in navigating space (or path integration) (2 points)
[up to 2 points partial credit for well-reasoned, but wrong conclusion that this would support the memory structure theory]

6) (**6 points total**)

a) What is meant by the equation for synaptic strength: M = n*p*q? For each term, explain what it refers to and whether this is presynaptic, postsynaptic, or both. (3 points)

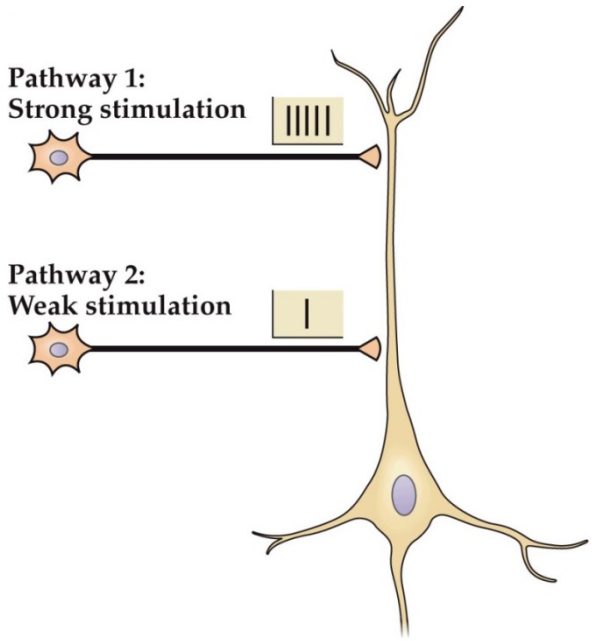
n: number of functional synapses (pre & post) (1 point)
p: probability of release of vesicle (pre) (1 point)
q: response to a single vesicle (post) (1 point)

b) Imagine that following long-term potentiation (LTP), mean synaptic strength changes, but the inverse square of the coefficient of variation: $V^{-2} = \frac{M^2}{\sigma^2} = \frac{np}{1-p}$ does not change. What would this imply about whether LTP is expressed presynaptically or postsynaptically? What would change at the synapse (be as specific as possible about what molecule or receptor changes its number or activity)? (3 points) (***USE THE BACK!!!!***)

The only way for M to change without a change in V^{-2} is for q to change (0.5 point)
This implies a postsynaptic change (1 point)
New AMPA receptors must have been added to the postsynaptic membrane (1.5 points)

7) (**5 points total)** In the diagram below, the two pathways are *simultaneously* stimulated as illustrated.

a) For **each** pathway, *note whether it will be strengthened, weakened, or unchanged by the stimulus*. (1 point)



Both will be strengthened (0.5 point for each pathway)

b) For pathway 1, describe the events at the synapse that lead to the answer you gave above (refer to what happens to the postsynaptic NMDA receptors at this synapse). (2 points)

Strong stimulation means glutamate will be in the synapse while the postsynaptic cell is firing (0.5 point). The postsynaptic action potentials cause Mg^{2+} to come off the NMDA receptors (1 point) so Ca^{2+} can enter (0.5 point).

c) For pathway 2, describe the events at the synapse that lead to the answer you gave above (refer to what happens to the postsynaptic NMDA receptors at this synapse). (2 points)

Weak stimulation means glutamate will be in the synapse (0.5 point)
Strong stimulation simultaneously on pathway 1 means the postsynaptic cell will be firing (0.5 pt)
So Mg^{2+} will be off the NMDA receptors (0.5 point)
Combined with the glutamate released at the synapse, this will allow Ca^{2+} in (0.5 point)
(up to 1 point for incorrect answer that is consistent with the answer given in part (a))

8) (**9 total points**)
a) What is meant by a "silent" synapse? (1 point)

A synapse with no AMPA receptors

b) If we assume, for now, that there is no such thing as a silent synapse, explain how stimulating a single excitatory projection can be used to directly measure probability of release? What equation would you use to calculate release probability from failures and successes? (2 points)

If there is a single synaptic contact, then you can directly measure release probability as:

$$p = \frac{successes}{successes + failures}$$ (or successes/total)

1 point for discussion of p in terms of successes and failures without using the equation (this 1 point can be earned if this idea appears in (c) below too).

c) If, after LTP induction, the percentage of failures decreases, but the average size of successes remains unchanged, what does this mean the site of LTP expression is? Explain your answer in terms of probability of release and postsynaptic sensitivity to a single vesicle (quantum). (Continue to assume for now that there is no such thing as a silent synapse.) (3 points)

If number of failures decreases, then by definition successes increases and p increases (1 point)
If the size of successes doesn't change, then that means that postsynaptic sensitivity hasn't changed (1 point)
Therefore, LTP must be presynaptic (1 point)

d) Now, if we allow for the possibility of silent synapses, explain how the results above can be accounted for by a purely postsynaptic change. (3 points)

If there are two points (or more) of contact where transmitter is released, but one of them is silent (has no AMPA receptors), then initially, we'll only see a success when one releases, but not the other. (2 points)
After LTP, the silent synapse could become non-silent (AMPA receptors inserted), so now when presynaptic release happens there (just like it always did), we will see it and measure it as a success (1 point)

9) (**10 total points**) Read the attached paper by Bender, et al. This paper is attempting to determine the mechanism (either presynaptic decrease in release or postsynaptic decrease in sensitivity) at the connection between layer 4 and layer 2/3 cells in the somatosensory (touch) area of a rats brain following a particular experiment.

a) What did they do to the rats to cause this synapse to weaken? (2 points)

Trimmed some of the whiskers

b) Is the change presynaptic or postsynaptic? (1 point)

Presynaptic

c) Describe one experiment that was done comparing brain slices from control vs. manipulated rats that supports the conclusion from part b. (7 points)

There are several lines of evidence to discuss, the most likely one is the use-dependent block by MK-801, but a number of others can be discussed.

10) (**10 total points**) Read the attached paper by Jeneson, et al. This paper is attempting look at different subjects' ability to remember spatial relationships in the short term.

a) Why might patients with damage to their hippocampus have short-term problems with object location? (4 points)

If the hippocampus is a spatial orientation structure, a patient might have problems with spatial relationships, even in the short-term.

b) Do they find any significant impairment in patients' ability to remember object location for short periods of time? (1 point)

No

c) Describe one experiment that was done to support the conclusion in part b. (5 points)

Several are possible, but remembering object locations after very short delays is the most likely one to be discussed.