PSY 568/768 – SDSU Systems Neuroscience ***Name*** ________________________________

Final exam – 12 equally weighted questions (8-10 min/question)

1. Axonal action potentials result from opening and closing ***voltage-gated*** sodium and potassium channels.

(a) A neuron whose resting membrane potential is -80 mV is first: ***(1) voltage-clamped to -10 mV*** and kept there for ***half a second***, and then ***(2) voltage-clamped to -80 mV*** and kept ***there***. Carefully draw a graph with ***2 traces*** showing how the ***conductance*** of voltage-sensitive ***sodium*** and ***potassium*** channels changes with time. ***Label** both axes, plot **inward** conductances as '**up**', **outward** conductances as '**down**', show **zero** on y-axis, and use **two arrows*** to mark where voltage clamp is ***first*** set to -20 mV and ***then*** set to -80 mV.

(b) At an axonal branch point, a spike may fail to go down both branches. Assuming that ***capacitance*** is the main variable responsible for conduction ***failure***, should a ***fail-safe branch*** off of a main axon begin with a ***small*** or ***large*** diameter? *Explain your answer in a few words*.

2. We compared *signal processing strategies* in the *visual*, *somatosensory*, and *auditory* systems.

(a) Give an example of a ***transient*** and a ***sustained*** cell type (say where located) in the ***somatosensory*** system.

(a) Give an example of ***transient*** cell type and a ***sustained*** cell type (say where located) in the ***visual*** system.

(b) We discussed how ***MT*** might solve the ***aperture problem for pattern translation***. Describe an example a ***different*** processing problem in the ***visual system*** that could ***also*** be described as an 'aperture problem'.

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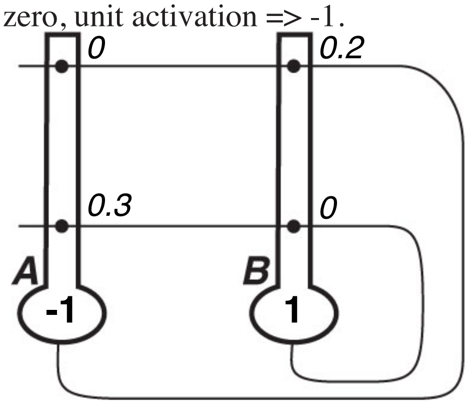
3. This recurrent network has 2 units (***initial*** activations are inside) and ***4 weights*** (italic numbers). The update rule is: if weighted sum of inputs is above/equal zero, unit activation => 1; if below zero, unit activation => -1.



(a) ***Update*** each unit ***once***, left to right (A, then B). ***Show calculations*** (don't forget to propagate any changed output!)

(b) ***Was*** network in a stable state ***before*** you updated it? -- ***why or why not****?*

(c) ***Is*** network in a stable state ***after*** you updated all the units ***once***? -- ***why* or *why not****?*

(d) ***Is*** this ***weight matrix*** symmetric? -- ***say why it is or isn't***

4. We discussed the functional organization of auditory receptors known as ***hair cells*** and their ***initial projections***.

(a) What would you have to do to an ***isolated*** hair cell to make it release a burst of neurotransmitter (*without* poking a large hole in it :-})?

(b) ***Cochlear ganglion cells*** receiving inputs from ***inner hair cells*** generate a ***single train of spikes***. Describe in a few words (or with a diagram) how that ***one*** spike train is divided into "***time***" and "***amplitude***" signals.

(c) What is the ***name of the neural structure*** where ***coincidence-detection*** first occurs the ***owl auditory system***?

(d) In the visual and somatosensory systems, receptors (photoreceptors, touch receptors) are arranged in ***2-D sheets***. How are ***auditory receptors*** arranged ***differently***?

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5. The motor system has several ***direct spinal output pathways*** and several 'loop' motor output pathways such as the one through the ***cerebellum***.

(a) What are the ***four*** *main* ***motor output pathways*** in mammals that project to the spinal cord?

(b) ***Starting*** at ***somatosensory cortex***, list a sequence of connected neural structures (*in correct order*, beginning to end!) by which activity can get to spinal motor neurons ***by way of the cerebellum***

(c) What ***difference*** between the output connectivity of ***motor cortex in cats*** and ***motor cortex in primates*** led to idea that primate motor cortex is at a ***lower*** hierarchical level than it is in cats?

(d) We discussed the ***neural basis of classical conditioning*** induced by pairing a tone with an air puff. Define the ***conditioned response*** in this case. One lesion locus ***immediately*** abolished the learned ***conditioned*** response without affecting the ***unconditioned*** response. ***Where*** was that lesion located?

6. We also discussed a motor system 'loop' involving the **striatum**.

(a) Starting at ***visual area LIP***, list a sequence of connected neural structures (in correct order, beginning to end!) by which activity can get to ***motor neurons*** by way of the ***striatum***

(b) One treatment for Parkinson's disease is to lesion the ***globus pallidus***. Explain in a few words why ***damage*** to this motor structure could possibly lead to ***improved*** capability for movement.

(c) An unusual so-called '***anomalous***' ***rectifier potassium current/channel*** was discovered in striatal neurons (medium spiny cells in the caudate/putamen). What primary feature of the ***activation*** of this current/channel is '***anomalous***' compared to the *standard rectifier current* activated during a spike?

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7. Primates make four main classes of eye movements (***not including*** *vergence* [=non-conjugate movements] and *accommodation* [=focus]).

Name the four main types and ***describe*** the main goal of each type in ***a few words***

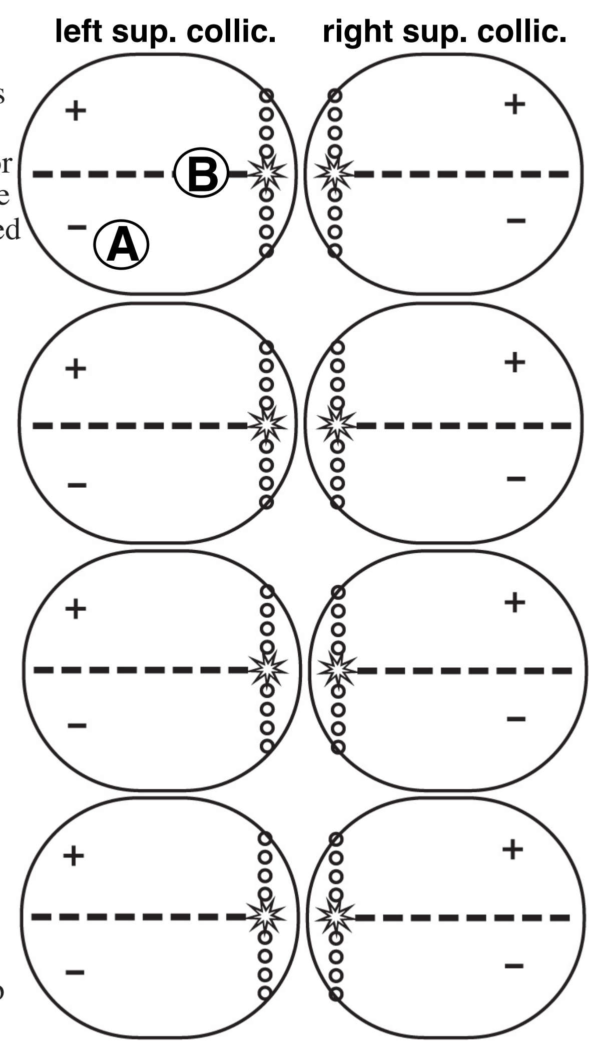
(a) Type: Goal:

(b) Type: Goal:

(c) Type: Goal:

(d) Type: Goal:

(e) Though it involves neck muscles instead of eye muscles, the head-bobbing movement of pigeons is functionally most similar to ***one*** type of eye movement above. Which one?



8. The primate superior colliculus contains a retinal hemifield map in its superficial and intermediate layers and a motor map in its deeper layers (colliculus shown in ***surface view*** in Figures at right). The ***right*** superior colliculus ovals represent the ***left*** visual hemifield, and the ***left*** ovals, the ***right*** visual hemifield. The location of superficial layer activity generated by ***two peripheral targets***, **A** and **B** is shown in the top panel.

(a) Assume both targets *disappear* while animal is still looking at the *central fixation*. Having been trained on the double-step saccade task, the animal gets ready to make a saccade to ***<u>where A was</u>***. ***Shade in*** location of ***deep layer activity*** just ***before*** that saccade.

(b) Now assume the animal has just made a saccade to ***<u>where A was</u>*** and is getting ready to make a second saccade to ***<u>where B was</u>***. ***Shade in deep layer activity*** just ***before*** the second saccade.

(c) Finally, assume that both targets now come back ***ON*** (same locations as before), ***after*** the animal has made the saccade to where ***B*** was. Draw the ***superficial layer*** activity (label it "A" and "B") that would result.

(d) Give a reason why an animal might make a double-step saccade to two vanished targets in the wild.

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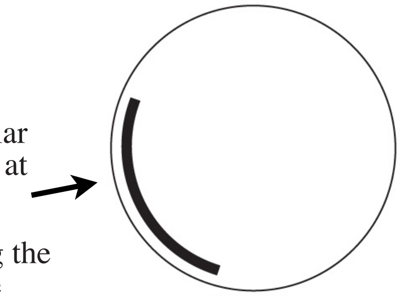
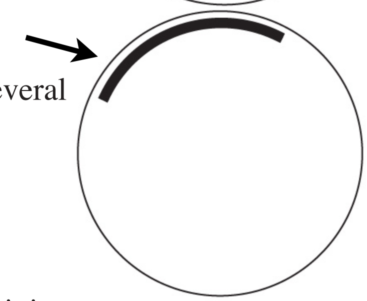
9. Limbic system neurons represent several different aspects of *where an animal thinks it is positioned in space*.

(a) ***Place/grid/head-direction*** cell firing is controlled primarily by "***distal***", not "***proximal***" cues. Give one example of each kind of cue.



(b) Indicate a typical pattern firing of ***one*** rat ***head direction cell*** in the simple circular environment at right (single cue card indicated by thick line) by drawing arrows at several location to indicate its preferred head direction at each location.



(c) The rat is removed, the cue card is changed as shown at the right (***without*** letting the rat see the change!), and the rat is put back in. Again draw arrows to indicate the preferred head direction of ***the same head direction cell*** at several locations ***now***.

(d) Name one structure where many ***place cells*** (not head direction cells) are found (several answers possible); then name a structure that contains many ***grid cells***.

10. MRI and EEG/MEG are two different methods of non-invasively recording brain activity.

(a) The RF receive coil picks up a oscillating signal from precessing protons ***all across*** the head. What ***physical part*** of an MRI machine is used to ***spatially encode*** encode the data so that a brain ***image*** can be made?

(b) Circle the part(s) of the Bloch equation below that are ***constants*** (versus variables):

$$\frac{d\vec{M}}{dt} = \vec{M} \times \gamma \vec{B} - \frac{M_x \vec{i} + M_y \vec{j}}{T_2} - \frac{(M_z - M_z^0)\vec{k}}{T_1}$$

(c) Circle the part(s) of the Bloch equation below that explains ***top-like precession of the local magnetic field***:

$$\frac{d\vec{M}}{dt} = \vec{M} \times \gamma \vec{B} - \frac{M_x \vec{i} + M_y \vec{j}}{T_2} - \frac{(M_z - M_z^0)\vec{k}}{T_1}$$

(d) EEG (and MEG) measure signals that are more directly linked to neuronal activity than the blood-oxygen signals measured by functional MRI. Give a brief explanation of ***what conditions*** are required in order for ***transmembrane currents in neurons*** to generate measurable electrical signals at scalp electrodes (or signals.

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11. The brain maintains a number of different kinds of spatial representations.

(a) Area ***VIP*** (ventral intraparietal area) contains single neurons with *somatosensory* ***and*** *visual* receptive fields. Describe (or draw a diagram explaining) the experimental evidence that many of these neurons code ***visual*** stimuli in a ***head-centered*** coordinate system (as opposed to a ***retina***-centered coordinate system)?

(b) Neurons in the deeper layers of the superior colliculus have ***auditory*** and ***visual*** receptive fields that are dynamically kept in register. For example, if the animal ***looks*** off to the ***right***, the spatial ***auditory*** receptive field of such a neuron (location where sound drives neuron) shifts to the ***left***, even when the head (and ears!) are fixed. ***Give a one-sentence rationale for why <u>in the superior colliculus</u>*** the ***<u>auditory</u>*** receptive fields shift with eye movements (as opposed to the ***<u>visual</u>*** receptive fields shifting).

12. Primate area V1 and V2 each have a visual hemifield map. At the lower right, the pattern of activity ***<u>in V2!</u>*** of the ***left and right*** hemisphere is drawn with textured shading and ***dashes/small-circles/star*** to indicate ***horizontal/ vertical/center-of-gaze***. At the left, draw what the ***<u>visual field stimulus</u>*** that caused this activity looks like using same ***dashes/small-circles/star*** convention. Remember the ***<u>fovea</u>***!

Visual Field

Brain (V2, both hemispheres)