1. (6 pts) a) Memory can be divided into two basic types, Declarative and Procedural. Describe these two types of memory and give an example of each to illustrate how they differ.

Declarative: Recalling an event, place, name, e.g., name of a person
Procedural: Motor memory, e.g., riding a bike

b) What do Lashley’s experiments indicate with regard to where memories (for navigating a maze) are localized?

Such memories are represented in a distributed fashion — not in a single region of the brain.

2. (10 pts). In many behaviors, sensory input is followed by motor output. Control of such behaviors varies from ‘Open-loop’ or ‘Closed-loop’ control of the motor output, depending on the type of behavior.

a) Label the following behaviors with regard to whether they are predominantly Open or Closed loop.

Closed: Slow, tracking-type eye movements.
Open: Saccadic eye movements
Open: Swinging a bat to hit a baseball
Open: Signing your name
Closed: Tracing a picture
Open: Vestibular-ocular reflex

b) Explain the difference between open vs. closed-loop behaviors (what factor usually makes open-loop control necessary).

Closed loop: Sensory feedback is used in executing the behavior.
Open loop: Fast — Feedback can’t be used because there is insufficient time.

c) The neural circuits that govern many open-loop behaviors often include feedforward projections to the cerebellum. What important role does the cerebellum play in the control of ‘open-loop’ behaviors? In your answer, describe the special role of feedback in open-loop behavior.

Calibration, based on ‘error’ info that is evaluated after behavior is finished.
3. (11 pts) a) Developmental plasticity in the neural circuit governing sound localization in barn owls represents a case of ‘supervised’ learning. An experiment is performed where prismatic goggles are placed on an owl that is 2 weeks old. This treatment shifts the visual field 15 degrees to the left (perceived location of visual targets are 15 degrees left of where they actually are located). Immediately after the goggles are placed on the owl, recordings are made from neurons located at site X on the optic tectum space map. On the plot below, indicate the expected positions of the visual receptive field centers and auditory receptive field centers of the recorded neurons.

![Diagram of Right optic tectum with expected positions marked]

b) At 10 weeks, recordings are again made from neurons located at site X on the optic tectum space map; the goggles are still in place. On the plot below, indicate the expected positions of the visual receptive field centers and auditory receptive field centers of the recorded neuron.

![Diagram with expectation points marked]

(c) What changes occurred in the MLD that gave rise to these changes (describe 3 changes in connectivity and cellular/molecular properties that occurred?)

- The connectivity between Lm and Lcx changed to match the visual system – new connections were made.
- New synapses utilize NMDA-type glutamate receptors.
- Inhibitory suppression of “old” connections (GABA)
4. (7pts) a) The cortical areas labeled above are most active, as measured by fMRI, during which of the following behaviors? (Place the appropriate letter in each blank below).

F  When reading (seeing) words.
G  When seeing complex images, such as faces.
E  When performing simple motor acts.
D  When thinking of a verb that is appropriate for a particular noun.
B  When planning a baseball swing

b) Which regions correspond to Broca’s area and Wernicke’s area? What functions are associated with each of these regions?

Broca’s  A  producing syntactically correct speech, e.g., sentences.
Wernicke’s  C  understanding speech.
5. (11 pts.) The mammalian superior colliculus is mapped in ‘motor coordinates’. It, therefore, represents a computational map for motor control (control of saccadic eye movements).

a) What computation is performed in the superior colliculus? As a result, the magnitude and direction of any particular saccade is determined by what factor?

\[ \text{motor error} = \text{desired eye position} - \text{current eye position} \]

site of max. activity in Superior Colliculus (motor error is mapped)

b) A monkey is trained to make the 3 saccades shown below. The animal, therefore shifts its gaze from point X→A, then from A→B, and finally from B→C. Thus the final position of the eyes is 10 degrees up & 35 degrees right.

On the map below, indicate the sites of maximal activity prior to each of these 3 saccades; label each site (eg X→A, A→B ....).

c) Each neuron in the S.C. has what is called a ‘movement field’. What does this term refer to?

\[ \text{The range of movements (saccades) prior to which the neuron produces a burst of spikes} \]
6. (8 pts). From your knowledge of developmental plasticity in the visual system, explain what experimental conditions (manipulations of visual experience) during the sensitive period (first 2 months after birth) result in the ocular dominance characteristics of visual cortical neurons that is shown below:

![Graph showing ocular dominance](image)

**Exp 1**: Left eye was closed during the sensitive period.

**Exp 2**: Both eyes were closed.

b) Explain what these results suggest with regard to the factors that are important in producing binocular cells in the visual cortex.

- Inputs (synapses) that are active synchronously are strengthened and maintained; degree of strengthening is proportional to the number of other synapses that are also active at the same time.

c) Would you expect ocular dominance bands in the Lateral Geniculate N. to be normal in these experimental conditions? Explain your answer.

Yes. The ocular dominance bands in LGN are established as a result of waves of activity in retina prior to birth.
7. (6 pts) The metrics of saccadic eye movements are coded in the superior colliculus. The sign of frequency differences is computed in the torus semicircularis of electric fish. A rat's position in a maze is linked to the activity of place cells in the hippocampus.

a) What do these 3 regions share in terms of how reliably the activity of individual neurons reflects the actual motor responses (or position) of the animal? (Discuss this question with regard to the issue of ambiguity of coding).

Individual Neurons are "unreliable" i.e. the motor response or position cannot be inferred from the activity of individual neurons.

b) What recent evidence suggests that the activity of 'place cells' in the hippocampus may be related to more than just 'place'?

- Linear maze: "place cells" fire when rat is moving through location & traveling in particular direction.
- "Place cells" don't fire when rat is restrained - must be actively exploring arena.

8. (12 pts) a) Using diagrams, provide an account of the processes that underlie associative conditioning (learning) of the gill-withdrawal reflex in Aplysia.

b) What additional processes must occur for the long-term storage of this memory?

pKA phosphorylates CREB

CREB

CREB·p

Binds to CRE

Activates transcription of genes,

Followed by new protein synthesis

spikes are broader, more transmitter is released.
9 (4 pts) Match the region of the electrosensory system with the computation(s) that is/are performed there.

D. Prepacemaker N.                        
C. Electrosensory lateral line lobe
A. Nucleus electrosensorius
B. Torus semicircularis

A. Strongly ‘sign-selective’ neurons of both types, and simple motor map are found here.
B. Convergence of differential phase and amplitude information- Site of a ‘neuronal democracy’
C. Selectivity for decreases of signal amplitude (I-type neurons) is generated here
D. The ‘decision’ concerning the direction to change the pacemaker frequency is evident in the firing rate of cells here.

10. Matching (6 pts)
C. Robust N. of archistriatum (RA)            
E. Vestibulocerebellum
D. Preoptic area
F. Cerebrocerebellum
B. Ventromedial hypothalamus
A. Midbrain and medullary reticular formation.

A. Triggers lordosis behavior
B. Estrogen dependent activity- important for lordosis behavior.
C. Undergoes seasonal fluctuations in size, due to testosterone. Vocal motor region.
D. Sexually dimorphic region
E. Important for maintaining balance and adjusting gain of VOR.
F. Important for orchestrating movements involving multiple joints.
11. 11 pts Associative conditioning of the eye-blink reflex of rabbits is an example of 'procedural' learning. The rabbit is trained to associate the auditory stimulus with the air puff to the eye.

a) Below, indicate whether you think an eye blink will occur in the following conditions:

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Blink to Puff?</th>
<th>Blink to Tone?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red N. inactivated during training</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Red N. inactivated only during testing (after training is complete)</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Interpositus N. inactivated during training</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Interpositus N. inactivated during testing</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>

b) From your knowledge of the 'modifiable efference copy' in electric fish, draw (complete) the traces below to reflect what you would expect to see in recordings from purkinje cells in the rabbit cerebellum, during and after pairing of mossy fiber and climbing fiber stimulation.
c) How should this pairing of mossy fiber and climbing fiber stimulation influence the strength of inhibition that the purkinje neurons have on the interpositus (output) cells?

*should decrease the inhibition*

d) If the CS during paired stimulation was a tone of 1 kHz, would you expect a tone of 4 kHz to cause an eyeblink? In explaining your answer, consider the properties of the granule cell/parallel fiber system.

*No. The conditioning will selectively influence the 1 kHz pathway (inputs); only the synapses of the granule cells activated by the 1 kHz tone will be changed—plastic synapses are those from parallel fibers to P-cell dendrites.*

12. (8 pts) Neuroendocrine system:

a) Over the course of development, hormones can affect the structure of the nervous system in important ways. Describe two effects that Ecdysone can have on the structure of the nervous system.

- promote changes in dendritic structure
- birth or death of particular neurons
b) We discussed in class the characteristics of individuals that are genetically female (XX), but have Adrenogenital Syndrome. Its counterpart, Androgen Insensitivity Syndrome, is a genetic condition in which a fetus that is genetically male (XY) lacks the ability to respond to the male hormones (i.e. testosterone) its embryonic testes produce. Would you expect these individuals to be more male-like or female-like in their appearance and behavior? In your answer, explain the role of hormones in the sexual differentiation of the brain in the developing fetus. (Hint: what is the default sexual condition of the brain?)

more female-like. The brain starts out “female” and must be “masculinized” by the action of male hormones early in development.

13. (4 pts) Split Brain question: A patient has had a section of the corpus callosum. Subsequently the patient is tested on the following tasks:

a) The subject is shown a banana in the left visual field. Will he/she be able to verbally describe this object? Explain your answer (1 sentence).

No, Language is controlled by left hemisphere
Left Vis Field into → Right Vis Cx

b) Will this subject be able to select a banana (without seeing it) from a group of other objects? Which hand must he/she use?

Yes, but only wi the left hand.