PS4 Answer Key

Problem 1. Vision (1.5 points)

A. (0.6 point) Visual impairments

a. Match each visual impairment listed below with a single lesion or mutation in the visual system that could be responsible for it. You should not use the same lesion/mutation twice.

b. For each pair you have determined in part **a.**, explain briefly what is known about how the given lesion produces the specified visual impairment.

(i) Complete loss of vision only in the temporal halves of both visual fields.
(f) Complete saggital transection of the optic chiasm (cutting only those fibers that would normally cross there).
- fibers crossing over in the optic chiasm receive inputs from the nasal half of the retina
- nasal half of the retina receive stimuli from temporal visual field

(ii) Complete loss of vision only in the superior quadrant of the visual field on the right side. The central area is unaffected.
(c) Lesion of the lower bank of the calcarine sulcus in the left hemisphere.
- lower bank carries information from the upper visual hemifield
- left/right cross over
- overrepresentation of the fovea

(iii) Inability to perceive a pattern of bright and dark bars that have both low spatial frequency and high temporal frequency.
(i) Mutation a selective loss of function of magnocellular ganglion cells in both retinae.
- M cells are able to respond to stimuli with low spatial and high temporal resolution.
- P cells were not lesioned as color contrast and high spatial frequency vision are still intact.

(iv) Inability to see or dream in color.
(b) Bilateral and complete lesion to cortical visual area V4.
- V4 has been shown to be a very high level area involved in color perception in human lesion studies.

(v) Difficulty to adapt to different light intensities quickly.
(h) Mutation of cGMP-gated channels in the retina causing impermeability to Ca^{2+}
- Ca^{2+} inhibits guanylyl cyclase
- lowering the Ca^{2+} concentration is believed to speed up the inactivation of the visual pigments, so that the effectiveness of a given light flash in activation cGMP phosphodiesterase is reduced.

(vi) Inability to reach for visual objects normally.
(g) Bilateral lesion in the posterior parietal lobe.
- posterior parietal pathway as the ‘where’ pathway.

B. (0.9 point) Simple and Complex cells

a. A simple cell is able to recognize bars of light with a specific orientation. Draw a network of on or off center ganglion cell inputs to a simple cell that would enable it to respond to this stimulus. Draw the receptive fields of each ganglion cell needed, and the spatial relationship of these receptive fields. In a few sentences explain how your model is supposed to work.

See Fig 27-12C in Kandel book. Briefly, a simple cell receives convergent excitatory connections from 3 or more on-center cells that together represent light falling along a straight line in the retina.

b. A complex cell responds to bars of light with a specific orientation. Unlike the simple cell, the receptive field of a complex cell is generally larger and the position of light bars in receptive field is not critical in order to evoke the response in the neuron. It is believed these properties of complex cells are derived from their inputs from multiple simple cells. Draw a neuronal network of multiple simple cells (with different receptive fields) connecting to a complex cell to enable larger receptive field and orientation tuning in this complex cell. In a few sentences explain how your model is supposed to work.

See Fig 27-13B in Kandel book. Briefly, a complex cell receives convergent excitatory input from simple cells, each of which has a receptive field with same organization (orientation).

c. Furthermore, a complex cell can also respond selectively to unidirectional movement across its receptive field in a specific orientation (e.g. a horizontal light bar moving upwards). This could also be explained by the connectivity between multiple simple cells to one complex cell. In a neuronal network shown below, three simple cells (of different receptive fields) form synapses onto a complex cell at different locations on one long dendrite. This complex cell is more sensitive to a light bar moving from the receptive field of simple cell 1→2→3 but not a light bar moving in the opposite direction. Explain how this direction specificity might be achieved using what you know about electrophysiology.

Temporal summation: if a light bar is moving in the direction of 1→2→3, it evokes action potentials in 1/2/3 sequentially. As a result, EPSPs are generated in different locations along the dendrite of the complex cell. These 3 EPSPs travel along the dendrite towards the axon hillock of the complex cell, where they are summed to decide whether to fire action potentials or not.

Given the fact that 1 is farthest and 3 is closest to the axon hillock of the complex cell, a 1→2→3 stimulus may result in a near-simultaneous arrival of three EPSPs, which leads to a maximized summed EPSP. On the other hand, a 3→2→1 stimulus may produce a much lower summed EPSP.

Problem 2. The Auditory System (1.5 points)

A. Neural sensory map

The delay in time between a sound reaching one ear and the other is used to localize sound. One neuronal model for measuring this auditory delay is diagrammed below. Lines from input ear to binaural cell represent the length of neuronal axons.

a. (0.4 point) Describe the general mechanism by which the neurons shown in this model distinguish between sounds coming from sources at different locations.

The binaural neurons are connected to neurons carrying information from the right and left ears. A signal from one ear is not enough for the binaural neuron to reach threshold, but if the signals from both ears coincide, the binaural neuron reaches threshold. The coincidence of excitation is dependent on the distance the sound travels to each ear and the distance the neural signal travels within the nervous system. Different locations of sound result in the stimulation of particular neurons.

For parts **b**, **c**, & **d**, use the figure below. **(0.1 point each)**

b. Which of the neurons (**a** through **g**) would respond to a sound located immediately above the diagram (at 12 o'clock)? Hint: use a ruler.

The distance from 12 o'clock to each ear is the same. To arrive at a neuron at the same time, the signals would travel the same distance of axon. Neuron **c** is equidistant from both ears.

c. What are the possible locations of sounds that neuron **a** would respond to? Use clock coordinates with accuracy within the ½ hour (i.e. 2:00 differs from 2:30). Assume that sound travels from the source of sound to the ear at the same average speed that the information is transduced and transmitted in various steps from the ear drum to the binaural cell.

About 1:00 and 5:00. In arbitrary distance units, neuron **a** is about 8 units from the right ear and 4 units from the left ear. Consequently, the sound source must be 8 units from the left ear and 4 from the right, so the total distance from sound source to neuron **a** is equal. This puts the possible sound sources at approximately 1:00 and 5:00.

d. What are the possible locations of sounds that neuron **b** would respond to? Use clock coordinates with accuracy within the ½ hour.

About 12:30 and 5:30. In arbitrary distance units neuron **b** is about 7 units from the right ear and 5 units from the left ear. Consequently, the sound source must be 7 units from the left ear and 5 from the right, so the total distance from sound source to neuron **b** is equal. This puts the possible sound sources at approximately 12:30 and 5:30.

e. **(0.3 point)** The binaural neurons in this model represent a neural sensory map. You have read about tonotopic maps in the auditory pathway. How does this map differ from the tonotopic maps?

This map describes the sources of sound. Sounds that issue from adjacent locations will result in the firing of adjacent binaural cells. In tonotopic maps, they vary by tone or frequency of the sound, rather than source.

B. Tuning curves

f. **(0.2 point)** Draw two sets of tuning curves for neurons **a** and **b**, plotting electrical activity against clock coordinates. Draw the first set of tuning curves assuming that there is some overlap in the receptive fields of **a** & **b**. Draw the second set of tuning curves such that overlap between their receptive fields would be minimized.

g. **(0.3 point)** What is the name of the neuronal network feature could you add to the diagram to enable better two-point discrimination (i.e. the actual tuning curves will look more like the second set you have drawn than like the first set)? (Hint: it consists of two words). Explain briefly how this would achieve better two-point discrimination.

Lateral inhibition. See pages 462 – 464 in Kandel.