1. The dLGN receives a projection from half of each retina and projects to primary visual cortex, area V1.
   (a) Using a solid line, indicate how a Y-like, OFF-center, non-lagged cell in the cat dLGN would respond. Then with a dashed line, indicate how an X-like, ON-center, lagged cell would respond (same axes!).

   ![Diagram showing neuronal responses]

   (b) Lagged and non-lagged cells may help generate direction selectivity. Draw a simple block diagram of how a lagged and a non-lagged cell could be used to make a direction-selective unit, label the parts, and indicate which direction is preferred.

   - A direction-selective output is constructed by combining inputs from lagged cell and non-lagged cell displaced in space from each other

   (c) Which is larger -- a layer 3 orientation column or a layer 4C ocular dominance column?

   - Orientation columns much smaller (~150 μm vs. ~1 mm)

   (d) Are cells in primate layer 4C-alpha monocular or binocular? What about cells in layer 4B?

   - Monocular
   - Binocular

2. This question applies to neurons in primary visual cortex, area V1.
   (a) Describe an explicit experiment to determine if an orientation-selective V1 cell is simple or complex (several answers possible).

   ![Test with small spot ON & OFF]

   - Simple if optimal bar elicits response only in certain place
   - Complex if response all over

   (b) The horizontal ellipses show the receptive field of a neuron tuned to horizontal orientations before and after an eye movement. Describe the precise features of an orientation-selective neuron that would increase its firing after the eye movement (several answers possible).

   ![Horizontal simple cell vs. complex cell]

   (c) Draw another ellipse over a feature on the face that would give a good response from a hypercomplex cell (several answers possible -- use the long axis of the ellipse to indicate orientation selectivity).

   (d) The blobs contain more cytochrome oxidase than the interblobs, suggesting that blob cells are more active.

   - Interblobs have a smaller range of firing rates (and lower max)
   - Blobs have a wider range of firing rates (and higher max)
3. Area V1 and area V2 in primates each have a map of a portion of the visual field. The entire visual field is drawn at the left with two gray lines superimposed on it. In the space below, make a careful diagram of what activity the gray lines would generate in V1 and V2 in the right hemisphere. Use the dashes/small-circles/star/plus/minus convention used below. Remember the fovea!

4. We discussed the aperture problem for pattern translation, but also 'aperture problems' in general.

(a) Illustrate (in space to right) one pattern direction with a thick arrow, and then two different local directions with thin arrows that are consistent with that one pattern direction. Draw angles and lengths accurately!

(b) Illustrate (in space to right) one local direction with a thin arrow, and then two different pattern directions with thick arrows that could possibly have generated that one local direction. Draw angles and lengths accurately!

(c) Here are two apertures viewing different parts of a scene containing one moving object. The local direction detected inside each one is shown with thin arrows. Illustrate the direction the object is moving.

(d) MSTd neurons response to rotations, spiraling movement, expansions, and contractions. Give an example of a visual stimulus situation that would result in a contracting pattern of movement in the visual field.

- walking backwards, watching an object move away, falling down a well looking up (ans. from 2001), etc., etc.
5. We described the different types of receptors and input pathways in the somatosensory system.

(a) Normally, alpha motoneurons (synapsing on main muscle) and gamma motoneurons (synapsing on muscle-spindle muscle) are co-activated. If the gamma motoneurons were accidentally over-activated, would this increase or decrease the firing of a muscle spindle? Very briefly, why?

\[ \text{increase, since muscle-spindle-muscle (intratufusal) fibers will stretch the stretch receptor} \]

(b) Where are the somatosensory receptors that detect force?

\[ \text{Golgi tendon organs (Ib), which detect force, are in tendons} \]

(c) One somatosensory pathway predominantly carries information about touch to the thalamus. What three nuclei in this pathway make synapses on thalamic neurons?

\[ \text{gracile nucleus, cuneate nucleus, principal sensory nucleus of the trigeminal (N. IV)} \]

(d) What is the distinction between rapidly-adapting and slowly-adapting receptors (touch, stretch, pain) analogous to in the visual system?

\[ \begin{align*}
\text{rapidly-adapting} & \Rightarrow Y-like, \text{ magnoc, transient} \\
\text{slowly-adapting} & \Rightarrow X-like, \text{ parvo, sustained} \\
\text{any OK} & 
\end{align*} \]

6. We discussed 'recepto-topic' maps in the visual, somatosensory, and auditory systems.

(a) The sharply-peaked distribution of photoreceptor density in one retina is mapped onto two dLGN's by spreading out the retinal ganglion cell axons to achieve a uniform density in the dLGN, which strongly distorts the retinal image. What aspect of the input image is preserved by this transformation?

\[ \text{local shape (local angles and local dimensions), the overall size can vary} \]

(b) Cortical somatosensory maps contain many "discontinuities". Give an example of what is meant by this.

\[ \text{a small movement along a cortical representation results in a large movement to a non-overlapping receptive field on the skin surface} \]

(c) Why were the somatosensory cortex rearrangements observed in the Silver Spring monkeys (long-term sensory denervation of an arm) thought to involve sprouting of new axons?

\[ \text{the complete invasion of the former arm and hand representation by the face required sprouting because the successive divergence of axons terminals is not large enough to explain 1-2 cm remap} \]
7. Cochlear ganglion cells project to both *nucleus angularis* (NA) and *nucleus magnocellularis* (NM) in the barn owl. Each *nucleus laminaris* (NL) then receives input from both the left and right nucleus magnocellularis.

(a) Draw two different pure-tone auditory stimuli of different amplitudes and the corresponding spike trains that you might expect from a cell in NA.

(b) Assume that a left NM cell generates 2 spikes and a right NM cell generates 2 spikes, all in response to the same sound stimulus. Given that there is no certainty that a given sound wavefront will generate a spike in both left and right NM cells, what is the maximum number of different interaural time delays (ITD’s) this data consistent with? Very briefly explain your answer.

(c) If a source emits a noise containing many frequencies, it will activate neuron at many different locations within the lateral part of the central nucleus of the inferior colliculus (ICc-lateral). How then can the true interaural delay be determined?

- By summing across frequencies in ICc-liat $\rightarrow$ ICx, finding the maximum response will identify the true ITD.

(d) Why is it difficult to detect the location (azimuth) of a pure tone source?

- A pure tone results in multiple columns with same sum.

8. An echolocating bat emits high frequency calls that are reflected off of objects in the environment and analyzed by its auditory system.

(a) Primates use *eye movements* to place the fovea, which has a greater concentration of receptors than the retinal periphery, over interesting targets. Bats, by analogy, are said to have an 'acoustic fovea'. What *bat behavior* inspired this analogy?

(b) A vowel spoken by *one speaker* sounds the same, regardless of the *pitch* (fundamental frequency) of their voice. Why?

(c) We drew a specific analogy between the *processing* of the constant frequency parts of bat echolocating calls and human vowels, despite their very different *functions* (detecting Doppler shift vs. identifying vowels across speakers). Explain why the *signal processing problems* solved are nevertheless similar.

- In both cases, the freq difference between two bands of frequencies must be detected independent of the absolute frequencies involved.