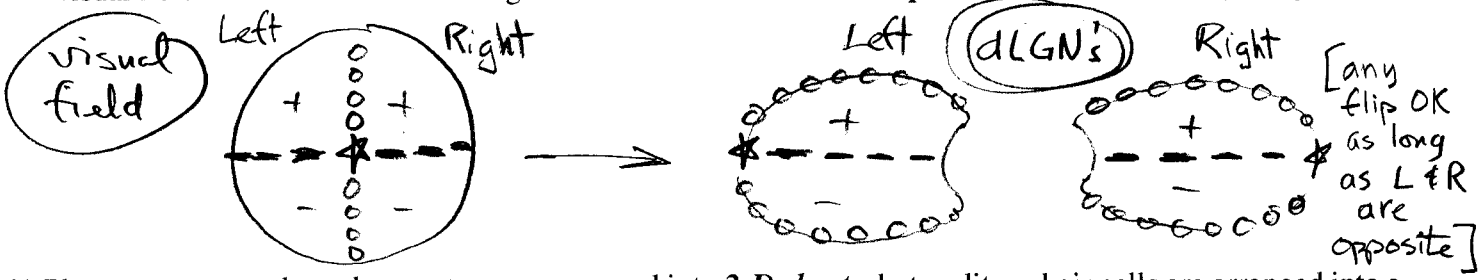
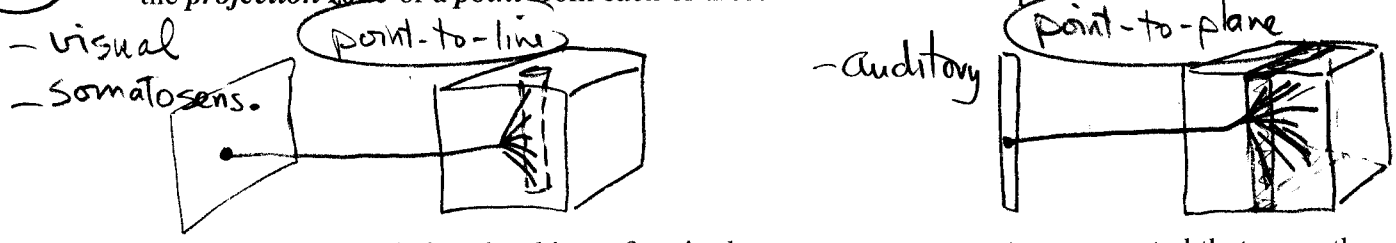
Cognitive Science 107B—Winter 2006 80/80 Name (*print!*): Key
Systems Neurobiology
Second exam—8 questions, equally weighted (about 6 min/question)

1. 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 there. This transformation strongly distorts the retinal image. Draw a ***circle*** for the visual hemifield and corresponding shape of the visual field in the ***two dLGN's*** using the ***dashes/small-circles/star/plus/minus*** convention (see Quest 3). (4)

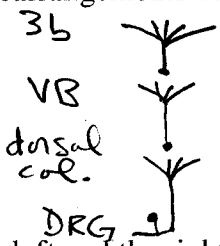


(b) Photoreceptors and touch receptors are arranged into ***2-D sheets***, but auditory hair cells are arranged into a ***1-D line***. Brain nuclei (e.g., dLGN, dorsal column nuclei, cochlear nuclei) are 3-D. Illustrate the shape of the ***projection zone of a point*** from each of these three kinds of receptor surface. (3)



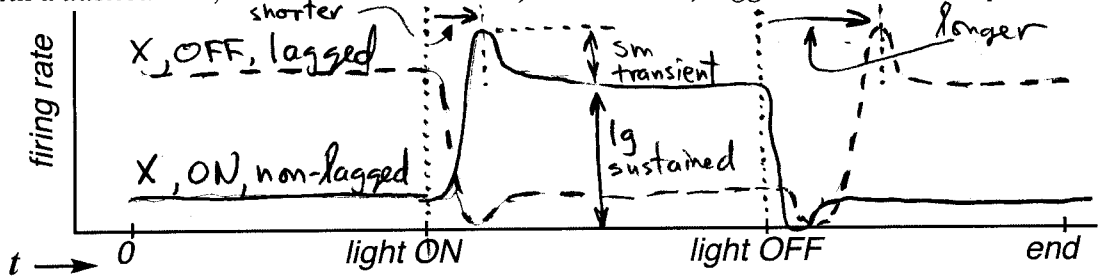
(c) Experiments manipulating the skin surface in the somatosensory system suggested that maps there are ***dynamically maintained*** by patterns of stimulation. Why are most of these rearrangements ***not*** thought to involve sprouting of new axons? (3)

- there are 3 stages of divergence (dorsal root ganglion → dorsal col. → VB → 3b) which makes it possible to move R.F.'s by strengthening/weakening existing synapses



2. The dorsal lateral geniculate nucleus (dLGN) receives a projection from both the left and the right retina and projects to primary visual cortex, area V1.

(a) Using ***solid*** line, indicate how a ***X-like, ON-center, non-lagged*** cell in the ***cat dLGN*** would respond. Then with a ***dashed*** line, indicate how an ***X-like, OFF-center, lagged*** cell would respond (same axes!). (4)



- lagged more delay
- ON vs OFF
- small transient w/ large sustained

(b) What are the names of the ***three*** different kinds of ***layers/streams*** in the ***primate dLGN***? (3)

magnocellular
parvocellular
intralaminar

(c) Which layer(s) of area V1 are ***not*** orientation selective? (1)

4C [or] 4Cα 4Cβ

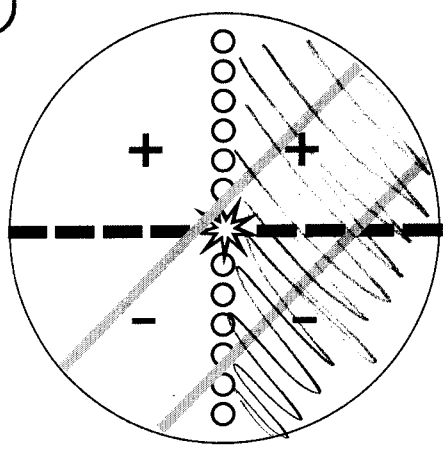
(d) Which layer(s) of area V1 contains the most prominent ***cytochrome oxidase 'blobs'***? (2)

2/3 and 5, 6

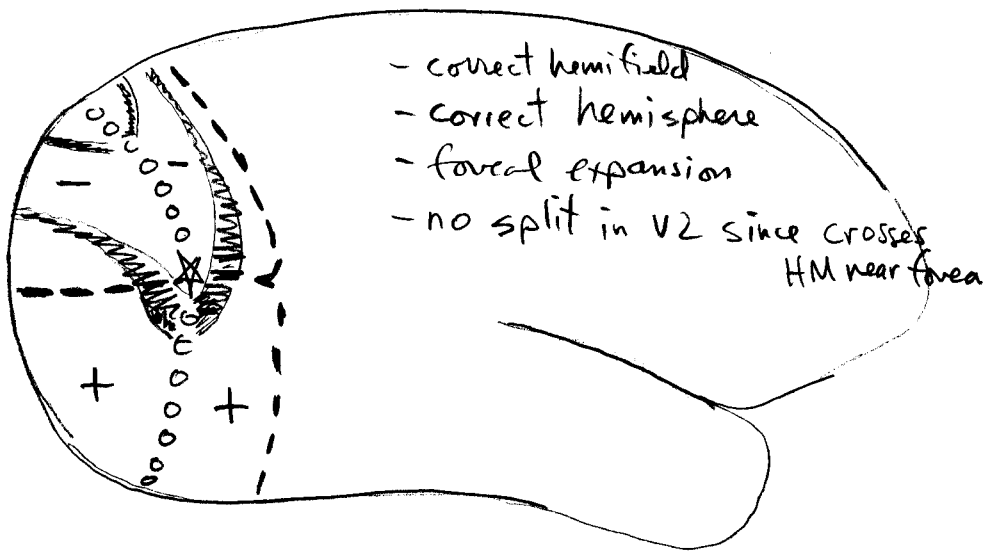
3. Area V1 and area V2 in primates each have a map of a portion of the visual field. The ***entire*** visual field is drawn at the left with ***two gray lines*** superimposed on it. In the space below, make a ***careful*** diagram of what activity the gray lines would generate in V1 and V2 in the ***right***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

10

Visual Field



Brain (Right Hemisphere)



4. This question applies to neurons in primary visual cortex, area V1.

(a) Outline *2* different places on the image (use ellipse size shown!) that would strongly activate a ***horizontal-orientation-tuned, end-stopped*** cell (more than 2 answers possible).

2

use this size for excitatory receptive field

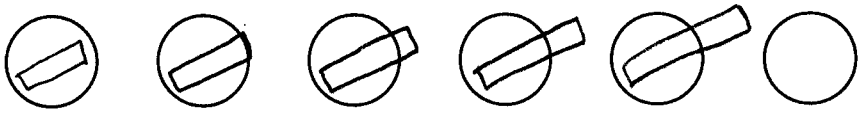
(b) Assume a V1 cell is orientation-selective. Draw *two series* of stimuli in the circles (each representing the receptive field of the ***same*** neuron) that could be used to ***determine*** the cell's ***orientation selectivity*** and then whether or not the cell was ***end-stopped***

2

orientation test

0 - 180°

end-stopping test



[one or both ends OK]

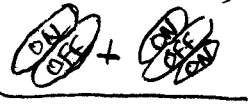
(c) Simple cells have separated ON and OFF response subregions within their receptive fields, while complex cells respond to ON and OFF at each point in the receptive field. Simple cells can be constructed by having a cell receive input from parallel rows of ON and OFF cells. Describe one method of ***constructing a complex cell*** (several answers possible).

3

1. complex cell gets input from simple cells with offset ON & OFF subfields

[or]

2. input from rows of ON & OFF dLGN cells with many different offsets



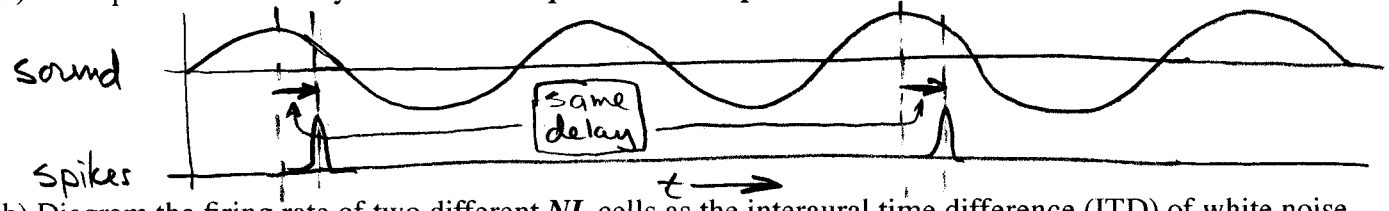
(d) Blob cells are sensitive to brightness, but ***not*** orientation. What ***function*** did we suggest this might this be useful for in class (several answers possible)?

3

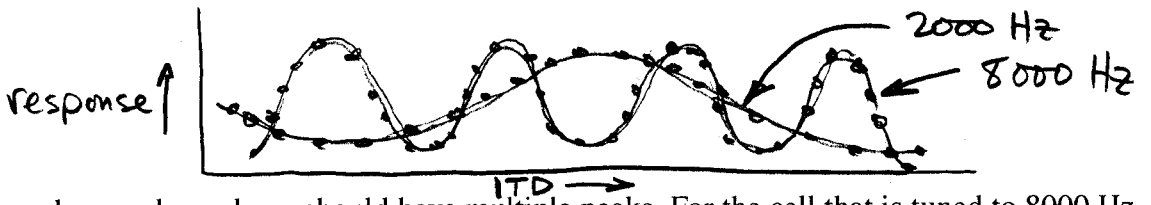
- detecting brightness for the purpose of determining shape from shading without getting shading confused with orientation

5. 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 pure-tone auditory stimulus and ***2 phase-locked spikes*** from ***NM*** to this stimulus on same time scale. (3)



(b) Diagram the firing rate of two different ***NL*** cells as the interaural time difference (ITD) of white noise sound is varied. Assume one cell is tuned to 2000 Hz and the other is tuned to 8000 Hz. (2)



[peak spacing 4X as wide for 8000 Hz]

(c) The graphs you drew above should have multiple peaks. For the cell that is tuned to 8000 Hz, what is the time between two adjacent peaks (the difference in ITD) in microseconds? (show calculation) (2)

Hz is cyc/sec

– spacing between peaks is time between successive wavefronts of sound wave

$\frac{1}{8000 \text{ cyc/sec}} = \frac{1}{8000} \text{ sec/cyc} =$ **125 μ sec**

(d) How does a barn owl detect the ***elevation*** of a sound? (one-word answer not enough) (3)

– one ear points down and the other points up

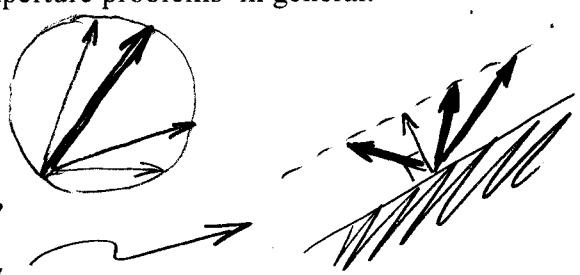
– by comparing the loudness between ears, elevation can be measured

6. 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 ***three*** different ***local directions*** with ***thin arrows*** that are ***consistent*** with that one pattern direction. Draw angles and lengths accurately! (can be from any object) (2)

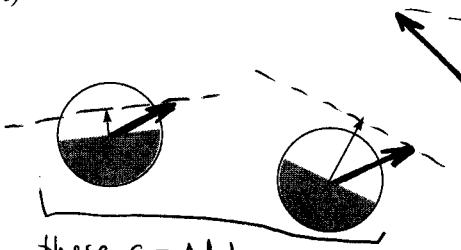
(b) Illustrate (in space to right) ***one local direction*** with a ***thin arrow,*** and then ***three*** different ***pattern directions*** with ***thick arrows*** that could possibly have generated that one local direction. Draw angles and lengths accurately! (can be from any object) (2)

[reuse from last test]

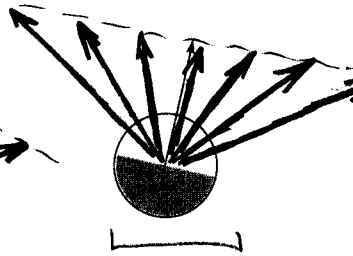


(c) Here are three apertures viewing different parts of a scene. The ***local direction*** detected inside each one is shown with thin arrows. Assuming objects in this scene only move along straight lines, what is the ***minimum*** number of moving objects in this scene? Describe briefly how you reached your conclusion. (3)

minimum of 2 objects



these could be same object since a pattern direction (thick arrow) is shared



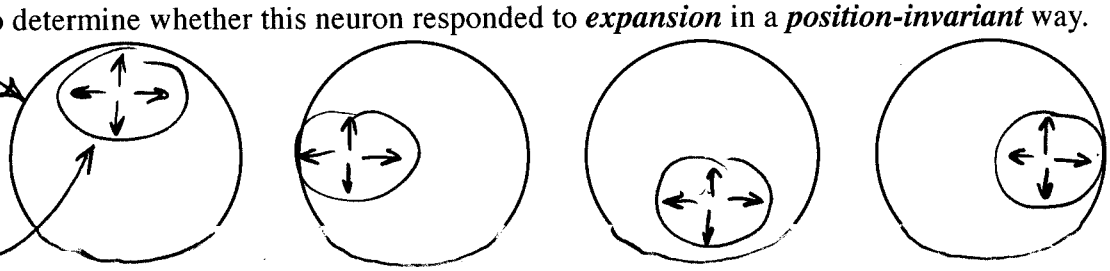
this one cannot be same pattern direction as either of other two (no shared)

(d) Draw 4 different stimuli within the circles below (representing the receptive field of an ***MSTd*** neuron), that could be used to determine whether this neuron responded to ***expansion*** in a ***position-invariant*** way. (3)

MSTd R.F.

test for position-invariance in MSTd

expanding stim pattern



7. We described the different types of receptors and input pathways in the somatosensory system.

(a) Describe the rationale given in class for why ***type Ia muscle spindles*** have their own tiny muscles.

(3)

- muscle spindle muscles co-contract w/ main muscle so muscle spindle receptor remains same length during contraction
- then, receptor generates signal only on deviation from expected contraction

(b) If while lifting an object, somebody helped you lift it without you seeing, would you expect dorsal root ganglion cells connected to Ia muscle spindles to fire ***more*** or ***less***? Why?

(2)

less, the muscle would contract faster than expected by muscle spindle spindle muscles causing muscle-spindle stretch receptor to go slack

(c) Which type of somatosensory receptors detect ***force***?

(1)

Golgi tendon organs (type Ib)

(d) Name one ***rapidly-adapting touch receptor*** and one ***slowly-adapting touch receptor.***

(2)

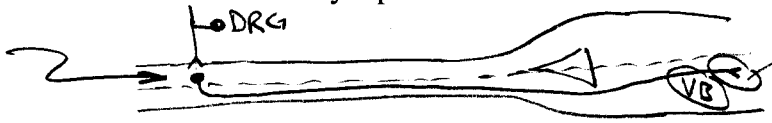
(transient) rapidly-adapting ← Meissner's corpuscles, Pacinian corpuscles, hair follicle

(sustained) slowly-adapting ← Merkel disks, Ruffini endings

(e) One somatosensory pathway predominantly carries information about ***pain and temperature*** to the thalamus. Where are the neurons located that make synapses on thalamic neurons in this pathway?

(2)

spinal cord [not DRG!]



intralaminar nuclei of thalamus

8. An experiment on the effects of ***visual attention*** on ***neurons*** in primate area ***V4d*** was described in class.

(a) What was the monkey's ***task*** in this experiment?

(3)

- maintain fixation and monitor for a small change only in the "attended" object, responding by a lever press

(b) What was the evidence that attention modulated the response?

(3)

- when "good" object was in receptive field but animal was attending "bad" object, neuron response was reduced compared to attend "good"

[can also say response to "bad" object increased by attention]

(c) This experiment envisioned a spatial 'spotlight' of attention, but did not explicitly test whether the spotlight was in fact ***spatial*** -- for example, the animal might have been attending to ***color***. By presenting stimuli that are interleaved with other, spatial attention can be minimized. ***Propose*** a simple experiment to determine if monkey V4 cells show ***attention to color*** effects. Say what the ***stimuli*** are, what the ***animal's task*** is, and what ***neuron response pattern*** would provide evidence for attention to color.

(4)

- stimuli:  checkerboard of 2 colors [or]  two overlapping lines of different colors [or]...
- task: respond to small change in one color only => "attention"
- resp. pattern: suppression of response to "good" color when attending to "bad" color