(80/80)

Cognitive Science 107B—Winter 2007 Name (*print!*): Key

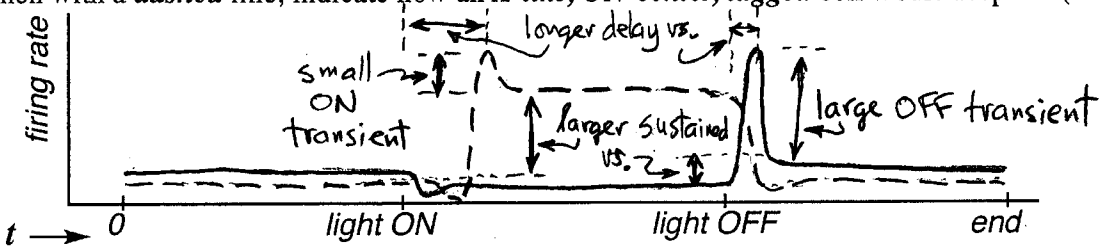
Systems Neurobiology

Second exam—8 questions, equally weighted (about 6 min/question)

1. The dLGN receives a projection from half of each retina and projects to primary visual cortex, area V1.

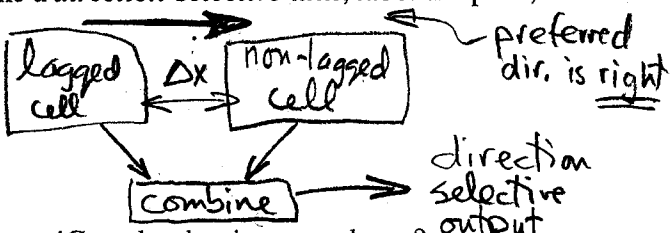
(a) Using a ***solid*** line, indicate how a ***Y-like, OFF-center, non-lagged*** cell in the ***cat dLGN*** would respond. Then with a ***dashed*** line, indicate how an ***X-like, ON-center, lagged*** cell would respond (same axes!).

3



(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.

3



– a direction-selective output is constructed by combining inputs from lagged cell and non-lagged cell displaced in space from eachother

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

2 orientation columns much smaller (~100 μm vs. ~1 mm)

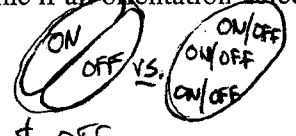
(d) Are cells in primate layer 4C-alpha monocular or binocular? What about cells in layer 4B?

2 → 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).

3



test w/ small spot ON & OFF

i) simple is separated ON & OFF subregions explain orientation select.

ii) complex if ON + OFF everywhere

test w/ bar ON & OFF

i) simple if optimal bar elicits response only in certain place

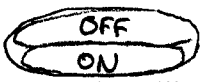
ii) complex if response all over

(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)

2

not hyper-complex!

horizontal simple cell w/ OFF over ON



or horizontal complex cell

ON and OFF responses everywhere

(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). e.g.

2

(d) The ***blobs*** contain more cytochrome oxidase than the ***interblobs***. suggesting that blob cells are more active. Describe what it is about blob and interblob cell firing patterns that might account for this difference.

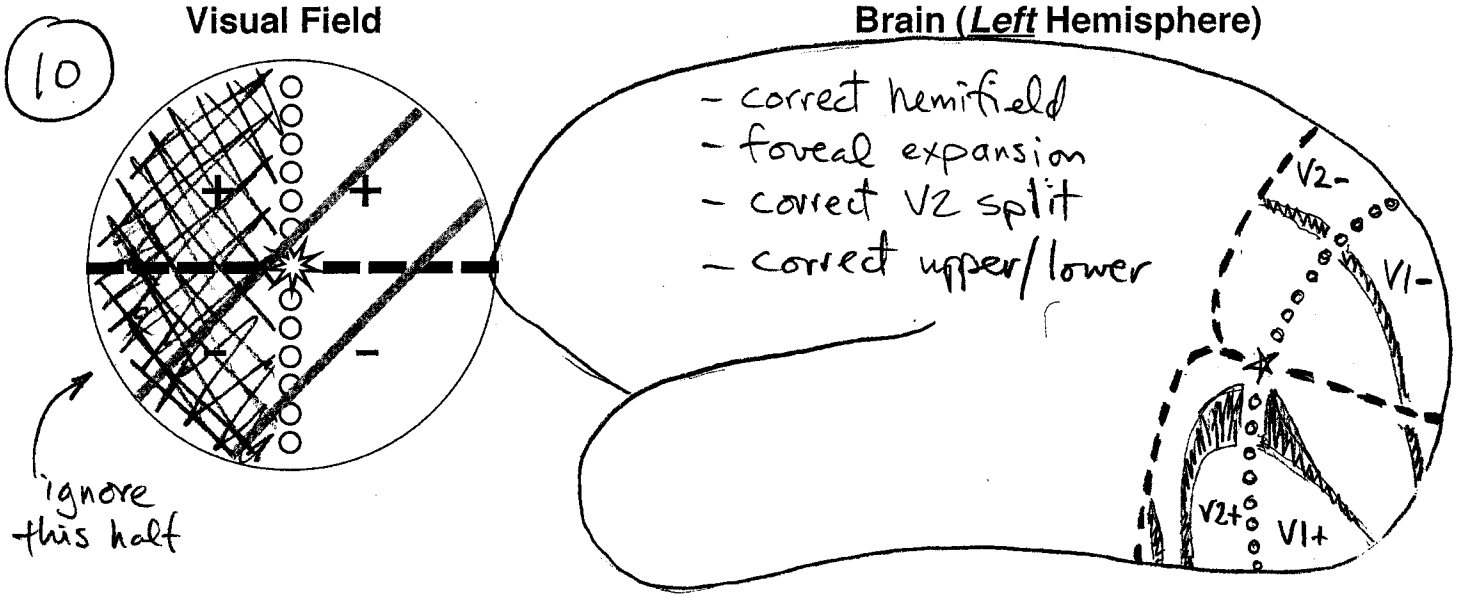
3

– 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 left hemisphere. Use the ***dashes/small-circles/star/plus/minus*** convention used below. Remember the ***fovea***!

10

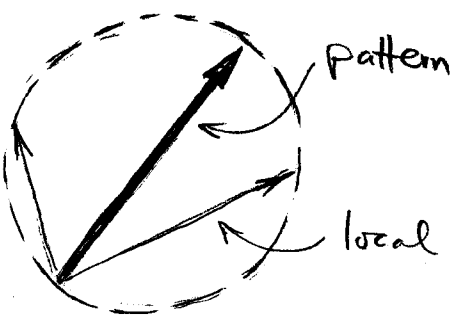


4. We discussed the aperture problem for pattern translation, but also 'aperture problems' in general.

(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!

3

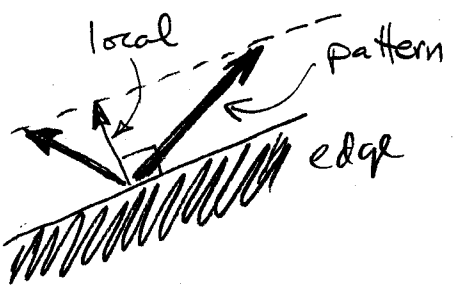
- pattern direction is diameter of circle
- local directions any chord starting at base of pattern dir.



(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!

3

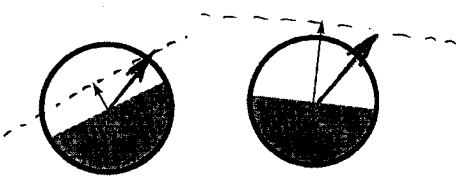
- local direction is perpendicular to contour
- pattern directions extend from base of local to edge-parallel dashed line



(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.

2

- shared pattern direction to right of 2 local dirs.



(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.

2

- walking backwards, watching an object move away, falling down a well looking up (ans. from 2001), etc., etc.

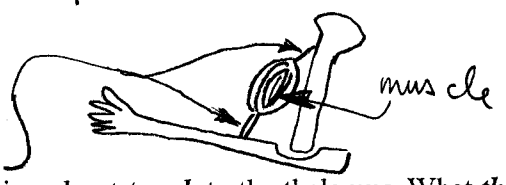
5. We described the different types of receptors and input pathways in the somatosensory system.

(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?

(3) – increase, since muscle-spindle-muscle (intrafusal) fibers will stretch the stretch receptor

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

(2) – 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?

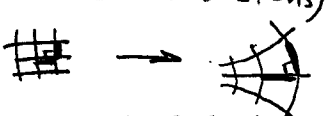
(3)
- gracile nucleus
- cuneate nucleus
- principal sensory nucleus of the trigeminal (N. V)

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

(2)
- rapidly-adapting → Y-like, magno, transient [any OK]
- slowly-adapting → X-like, parvo, sustained

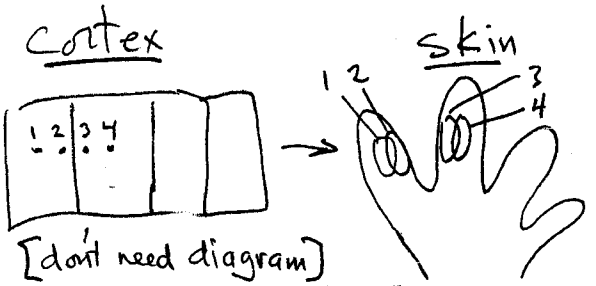
6. We discussed '***recepto-topic***' maps in the visual, somatosensory, and auditory systems.

(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?

(2)
- local shape (local angles and local dimensions)
- the overall size can vary e.g. 

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

(4) – a small movement along a cortical representation results in a large movement to a non-overlapping receptive field on the skin surface

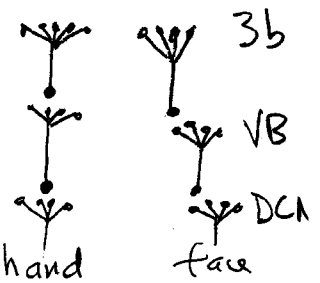


[don't need diagram]

(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?

(4) – the complete invasion of the former arm and hand representation by the face required sprouting because the successive divergence of axons terminals is <u>not</u> large enough to explain 1-2 cm remap

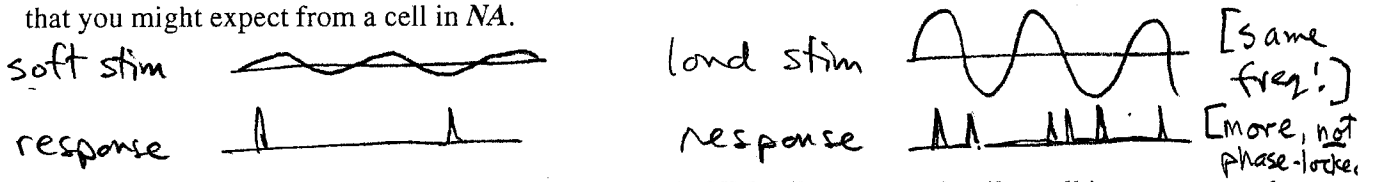
[don't need diagram]



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*.

(3)



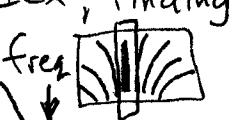
(b) Assume that a left *NM* cell generates 2 spikes and a right *NM* cell generates 2 spikes, all in response to the same sound stimulus. Given that there is no certainty that a given sound wavefront will generate a spike in both left and right *NM* cells, what is the ***maximum*** number of different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

(2)

(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?

(3)

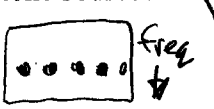
– by summing across frequencies in ICc lat → ICx, finding the maximum response will identify the true ITd



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

(2)

– a pure tone results in multiple columns w/ 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?

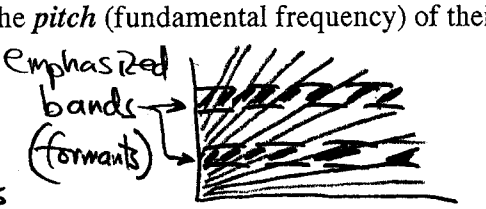
(3)

bats vary the frequency of the outgoing call so that (the 2nd harmonic of) the echo always comes back around 60-62 kHz, where A-I has an expanded representation

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

(3)

– the resonant frequencies of the vocal tract (set by tongue) pass same bands of frequencies as fundamental freq. of voice changes



(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.

(4)

– in both cases, the freq difference between two bands of frequencies must be detected independant of the absolute frequencies involved