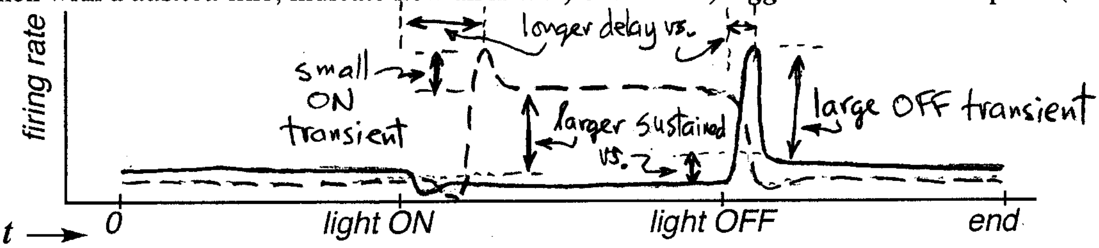
Cognitive Science 107B — Winter 2007 (80/80) Name (*print!*): Key
Systems Neurobiology
Second exam — 8 questions, equally weighted (about 6 min/question)

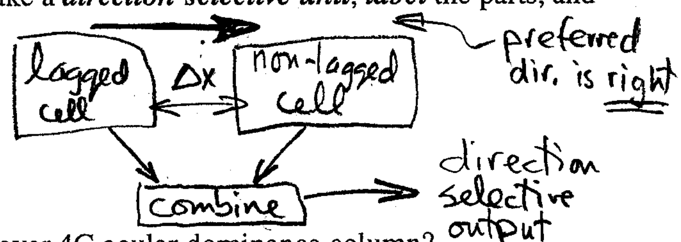
1. The dLGN receives a projection from half of each retina and projects to primary visual cortex, area V1.

(3) (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.

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



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

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

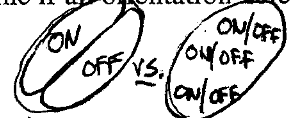
(2) (d) Are cells in primate layer 4C-alpha monocular or binocular? What about cells in layer 4B?

→ monocular   → binocular

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

(3) (a) Describe an explicit experiment to determine if an orientation-selective V1 cell is *simple* or *complex* (several answers possible).

test w/ small spot ON & OFF
i) simple is separated ON & OFF subregions explain orientation select.
ii) complex if ON + OFF everywhere

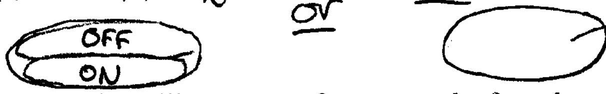


test w/ bar ON & OFF
i) simple if optimal bar elicits response only in certain place
ii) complex if response all over

(2) (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) → not hypercomplex!

[others OK if smaller RF]

horizontal simple cell w/ OFF over ON   or   horizontal complex cell

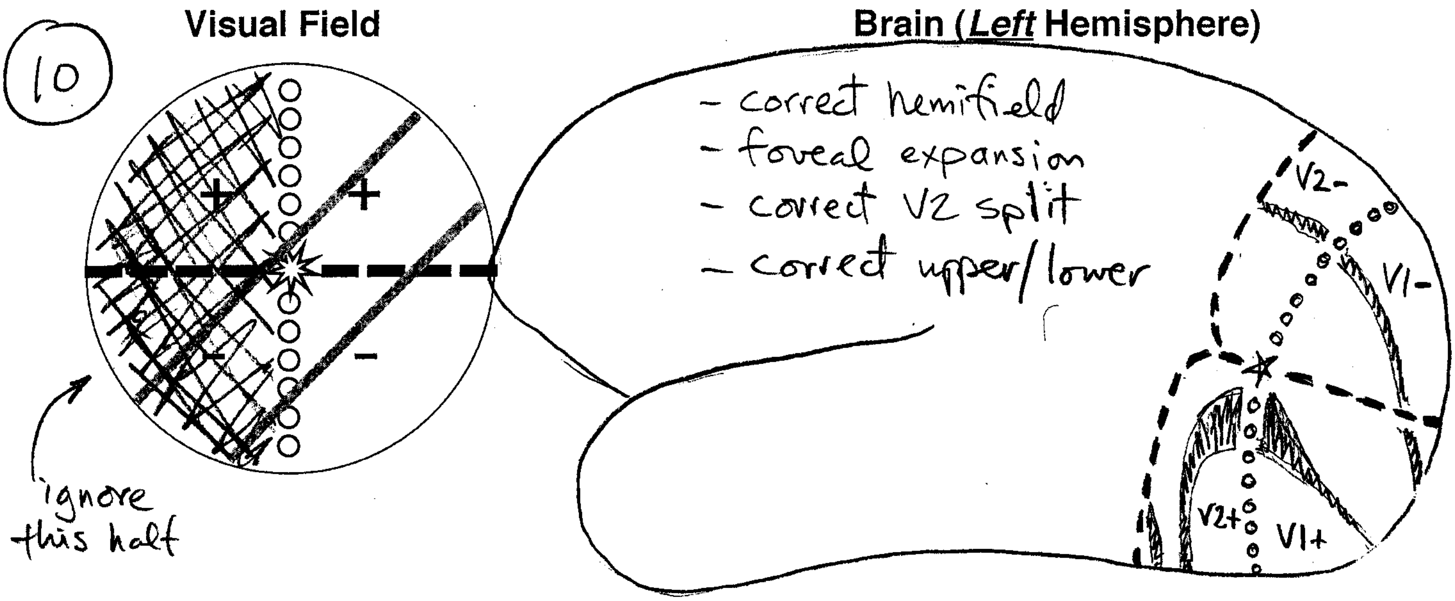


(2) (c) Draw another ellipse over a feature on the face that would give a good response from a ***hypercomplex*** cell (several answers possible -- use the long axis of the ellipse to indicate orientation selectivity). e.g.

(3) (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.

– 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***!

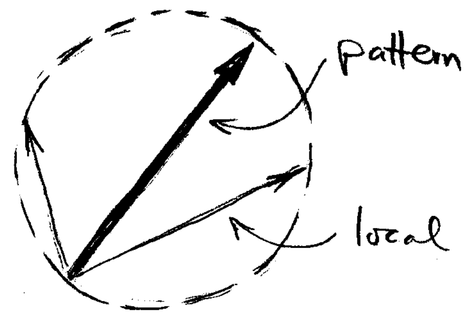


4. We discussed the aperture problem for pattern translation, but also 'aperture problems' in general.

(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!

(3)

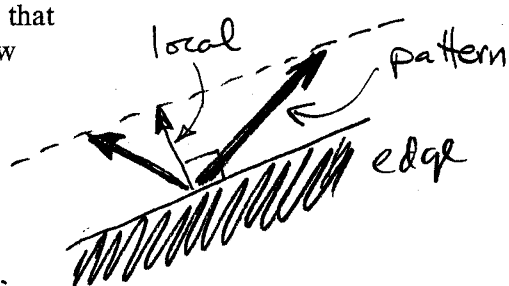
- pattern direction is diameter of circle
- local directions any chord starting at base of pattern dir.



(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)

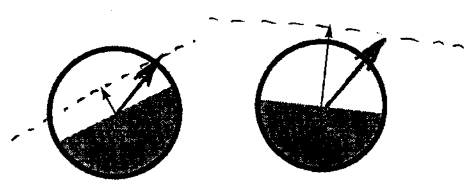
- local direction is perpendicular to contour
- pattern directions extend from base of local to edge-parallel dashed line



(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.

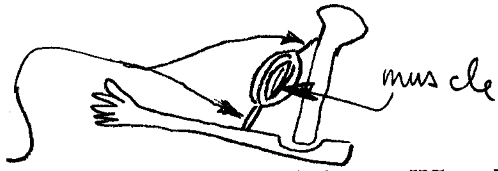
5. We described the different types of receptors and input pathways in the somatosensory system.

(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
slowly-adapting → X-like, parvo, sustained] [any OK]

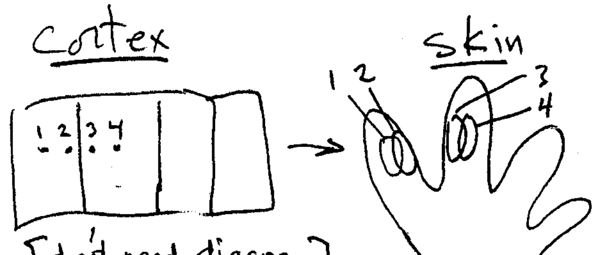
6. We discussed '***recepto-topic***' maps in the visual, somatosensory, and auditory systems.

(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

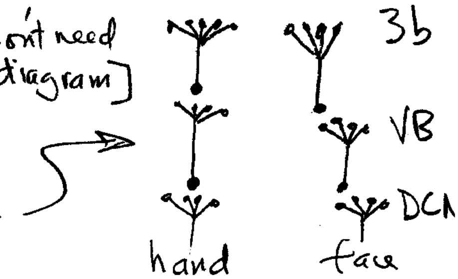


[don't need diagram]

(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

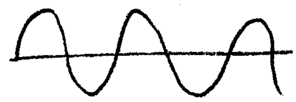
[don't need diagram]



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)

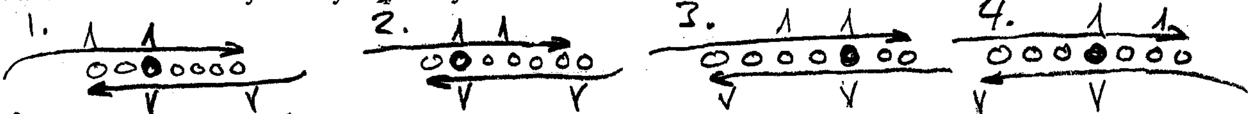
soft stim  loud stim  [same freq!]

response  response  [more, not phase-locked]

(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)

four possible

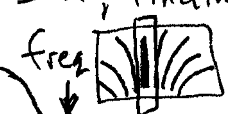


coincidences in most general case where diff. wavefronts responded to

(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)

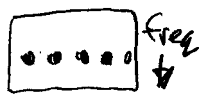
– by summing across frequencies in ICc lat → ICx, finding the maximum response will identify the true ITd



(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?

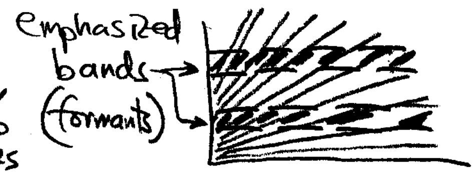
(3)

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