580.422 Physiological Foundations (Spring 2006)

Final Exam

Question 1

What is the "tuning curve (or receptive field)" of an auditory nerve neuron? Sketch it and explain the key features.

Question 2

What determines the frequency selectivity of an auditory nerve neuron? Is it determined by the biophysical property of the neuron, or the hair cell it is attached to or something else? Please explain.

Question 3

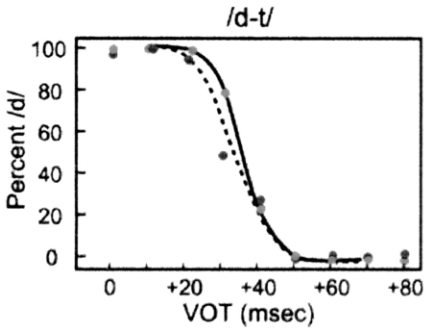
The width of the receptive field of a CNS (central nervous system) neuron can be broader or narrower than the width of the receptive field of a PNS (peripheral nervous system) neuron. What are neural mechanisms that could lead to broadening or narrowing of a neuron's receptive field from PNS to CNS?

Question 4

What are the main properties of the photoreceptors in the retina?

Question 5

The following graph shows the perceptual performance of English-speaking human listeners in recognizing whether a stimulus sounds like /da/ or /ta/ when a parameter called "voice-onset-time" (VOT) is systematically varied. Eight stimuli with different VOT (10, 20, … 80 msec) are used in this psychophysics experiment. The human listener characterize a stimulus as /da/ with a probability of nearly 100% if its VOT is between 0 and 20 msec, or 0% if its VOT is between 50 and 80 msec.



a) What principle of the perception does this experiment demonstrate?

b) Draw a curve on the graph if the task were performed by a computer that treats the stimuli as purely acoustic signals. Y-axis is the probability that the computer determines a stimulus as /da/.

Question 6

What is the “orientation selectivity” of neurons in the primary visual cortex (V1) and how is the orientation selectivity of a V1 neuron experimentally measured? Please explain with text and a sketch.

Question 7

Sketch and explain how neurons with the same or different orientation selectivity are arranged in V1.

Question 8

Is “tonotopic organization” in primary auditory cortex a topographical map or a functional map? Why? What is the equivalent map in the primary visual cortex?

Question 9

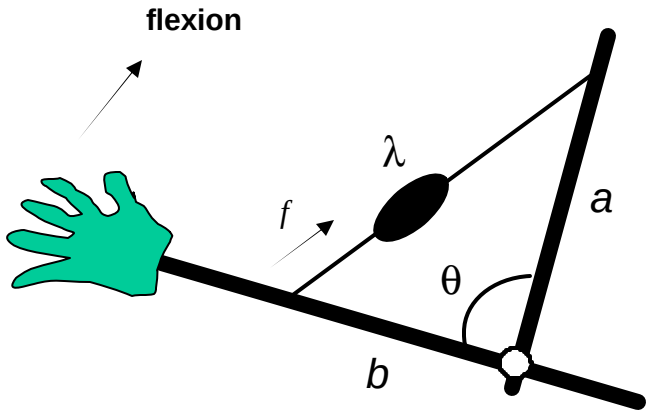
The primary somatosensory cortex (S1) has an orderly representation of hand surfaces. What would happen to this representation if, say, the second finger were amputated (because of an accident or disease)? What is this phenomena called?

Question 10

If an auditory neuron responds to a tone at 30 dB with 50 spikes/sec, sketch the inter-spike interval histogram of this neuron's discharges. On the same graph, sketch the inter-spike interval histogram of the neuron's response to a tone at 60 dB with 100 spikes/sec.

Question 11

(10 points) Below is a schematic of the elbow joint and the biceps muscle. The muscle has length λ from its origin to insertion, and produces force *f*. The length from origin to elbow joint is *a*, and the length from elbow joint to insertion is *b*. We are interested in computing the torque in the joint as a function of the force in the muscle.



a. (2 points) Write an equation for the length λ as a function of joint angle θ and lengths *a* and *b*.

b. (4 points) Suppose that we label the torque on the joint as τ. Use the expression that you wrote for muscle length to show how torque can be written as a function of muscle force and joint angle θ.

c. (2 points) What should be the value of the joint angle θ so that when the muscle produces force f, the resulting torque is maximum?

d. (2 points) Suppose we have sensors on the arm and can measure the elbow joint's velocity, $\dot{q} = \frac{dq}{dt}$. Show how you can joint velocity to compute length changes in the muscle, $\frac{dl}{dt}$.

Question 12

(5 points) You are working on a project to help restore some function to the hand of patients who have suffered spinal cord injury in the cervical regions, as is typical in automobile accidents where whiplash takes place. You will try to electrically stimulate the hand muscles so that they can form a grip. However, you need to give the patient a way to turn the stimulation on and off. You are considering two candidate approaches: in the first approach, you will implant a sensor in the shoulder so that raising it will turn the sensor on or off. In the second approach, you will implant a sensor on the bottom of the foot, so that tapping the foot will turn the stimulation on or off. Which is a better idea? Explain.

Question 13

Suppose you are examining the composition of hand muscles and leg muscles of a patient who had a stroke that made them unable to walk or use their legs but left control of their upper limbs intact. You take a small biopsy sample from a hand muscle and another one from a leg muscle and examine each under a microscope. When you view one sample, you see a large number of small muscle fibers with a rich supply of blood vessels and high density of mitochondria. In the second sample, you see a large number of large, pale muscle fibers with few blood vessels and low density of mitochondria.

a. (2 points) What type of muscle fibers are you seeing in the second sample?

b. (2 points) Is the second sample from the leg or hand muscles? Explain.

Question 14

(2 points) Suppose you ask a volunteer to sit at a table and rest both their elbow on the table, with the palm of their hand facing up toward the ceiling. You ask them to close their eyes. You ask the person to keep their eyes closed and simply try to match the angle of their right elbow with their left elbow. You take out your cell phone and put it in vibrator mode and place on their right biceps and get it to start vibrating. What will the subject do with their left arm? Explain.

Question 15

You are recording from the motor neurons of a cat leg muscle. At the same time, you are recording from an interneuron that projects to the motorneurons that you are recording from. You note that the motor neuron is firing at some frequency. While keeping the muscle at an isometric condition, you activate the Golgi-tendon organ afferents in that muscle. You notice that the firing rates of the interneuron and the motor neuron changes.

a. (2 points) Do you think that the firing rate of the interneuron should increase or decrease? Explain.

b. (2 points) Do you think that the firing rate of the motor neuron should increase or decrease? Explain.

Question 16

(2 points) Name the major descending tract that originates from the motor cortex and sends axons to the spinal cord.

Question 17

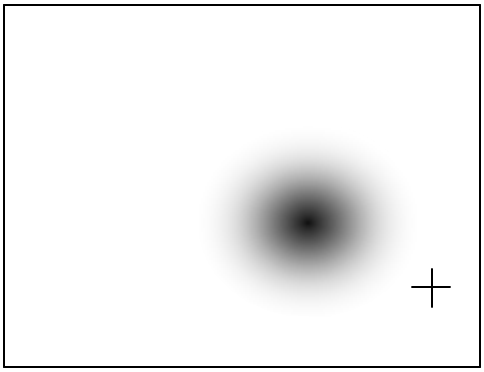
Suppose a split brain patient has agreed to volunteer for your experiment. The volunteer fixates a dot on the computer screen while you flash two images, one to the right and the other to the left of the fixation spot. The image on the right is a cup and the image on the left is a pencil.

a. (3 points) You ask the volunteer to tell you what they see. What do you expect them to say? Explain.

b. (4 points) You have arranged it so that under a small table there are some objects, including a cup and a pencil. The volunteer cannot see the objects, as they are hidden behind a curtain. Now you ask the volunteer to use their right arm and search under a table and pick what they saw. What do you expect them to pick out? You place the object back under the table. Now you ask them to use their left arm to pick out the object that they saw. What do you expect them to pick out?

Question 18

(2 points) A monkey is fixating a cross on the screen. A cell in the posterior parietal cortex that has a retinocentric receptive field discharges when a spot of light appears in the area shown below in **A**. The discharge is strongest in the area that is darkest in color. Now the monkey shifts his eyes to the new fixation point in **B**. Draw the region where the cell will have its receptive field.



A)

B)

Question 19

(4 points) Now suppose that we keep the monkey fixating the center point in B. While he is fixating, a light is flashed in the left edge of the cell's receptive field. Now slowly we move the light along the x-axis (horizontal line) so that it crosses the center of the receptive field and then moves to the right of it. Plot the cell's firing frequency as a function of stimulus position with respect to center of receptive field. If this cell has gain-field properties, what would its response look like if you did the same experiment in part A (assume that the gain field has a slope that is decreasing as the eyes move to the right).

Question 20

(6 points) Design an experiment to test the difference between how neurons in premotor and primary motor cortex (M1) encode movements. You can use the example given in lecture, or design your own experiment. Describe:

1) the task that is being performed (2 points)

2) the expected result (2 points)

3) how does this demonstrates the difference between what neurons encode in these two areas.(2 points)