Exam #:_____

Physiological Foundations Spring 2003: Final Examination

May 8, 2003

Name: _____

SSN: _____

TA: _____

Signature: _____

1. ____/4
2. ____/2
3. ____/2
4. ____/4
5. ____/4
6. ____/4
7. ____/5
8. ____/1
9. ____/3
10. ____/2
11. ____/2
12. ____/2
13. ____/4
14. ____/1
15. ____/4
16. ____/2
17. ____/5
18. ____/3
19. ____/3
20. ____/3
21. ____/1

EXTRA CREDIT ____/3

TOTAL_____/61

Name _____

1. (4pts) Draw the pain and discriminative touch pathways from the periphery to the cortex for both right and left sides at **one** level (such as cervical, lumbar, etc.). Show the sites of all synapses and the sites of all crossings of the pathways. **82%**

Name _____

2. (2pts) A patient gave the following answers in response to a neurologist's questions about sensory deficits. Can she feel: **64%**

Painful stimulation of the left leg	yes
Painful stimulation of the right leg	yes
Light touch of the left leg	yes
Light touch of the right leg	yes
Painful stimulation of the left hand	no
Painful stimulation of the right hand	no
Light touch of the left hand	yes
Light touch of the right hand	yes

Show on the figure above with a black line a **single** spinal lesion that could cause these observations. Remember that the lesion has to be at the correct medial/lateral location and at the right level (sacral, lumbar, thoracic or cervical) of the spinal cord.

3. (2pts) Explain what is meant by the frequency selectivity of an auditory neuron? How is the frequency selectivity created in the auditory system? **65%**

Name _____

4. A series of equally spaced sensory stimuli: **83%**

(X_0, X_2, …, X_5, where $X_{i+1} = X_i + \Delta X$, i = 0, 2, … , 4)

are randomly presented to a subject, one at a time. The subject is asked to press a red button if he/she thinks that stimulus X_0 is presented or press a green button if he/she thinks stimulus X_5 is presented. This process is repeated 100 times (i.e., each X_i is presented 100 times).

4a. (2pts) Calculate and plot the probability that the subject perceives stimulus X_0 when X_i is presented for each X_i (i = 0, 2, … , 5) (i.e. how many times the red button is pressed out of 100 X_i stimuli). Assume that the subject's perception of X_i as X_0 or X_5 is proportional to the distance between X_i and X_0 or between X_i and X_5.

4b. (2pts) Sketch a plot if $\{X_i\}$ (i = 0, 2, … , 5) stimuli are perceived "categorically" by the subject, with X_0 and X_5 being two categories.

5a. (1pt) When you see an object on the far right side of your visual field (e.g., 80 degree off the midline), which type of visual receptor is responsible for processing the visual image of this object? **94%**

5b. (3pts) What is the other main visual receptor? Describe the main properties of these two visual receptors in terms of 1) distribution on the retina; 2) functions for day/night; 3) color vision.

6. (4pts) Neurons in MSO (a central auditory nucleus) receive inputs from both ears via auditory nerves from both sides. These neurons process inter-aural time differences (ITD) using a mechanism called "coincidence detection" meaning that an MSO neuron only fires when spikes coming from the two auditory nerves arrive nearly simultaneously. **63%**

Name _____

(1) In order for MSO neurons to reliably detect ITD created by a tone from a sound source located off the midline, what is the required property of spike trains (i.e. their temporal discharge patterns) received by MSO neurons and why?

(2) Can spikes trains produced by MSO neurons be described as an ideal Poisson process? Explain your answers.

Name _____

7. A somatosensory neuron has a receptive field on the tip of a finger. This neuron discharges when a mechanical probe touches the fingertip and vibrates for 200 msec (0.2 second). The touch and vibration begin at time 0 and end at time 200 msec. The followings are observed spike times (occurrences of action potentials) in msec during this period for 5 such trials. **71%**

Stimulus duration: 0-200 msec
Trial #1: [23, 24, 28, 72, 76, 122, 129, 178];
Trial #2: [25, 75, 77, 124, 127, 172];
Trial #3: [26, 79, 125, 174, 176];
Trial #4: [21, 23, 74, 123, 126, 171, 179];
Trial #5: [22, 27, 28, 75, 78, 128, 173, 175, 178];

7a. (2pts) What is the overall mean firing rate (or average discharge rate) of this neuron in response to the stimulation on its receptive field (all trials, time period [0, 200] msec)? Based on firing rate of each trial, can you tell in which trial the strength of the stimulus on the fingertip is the strongest and in which trial the strength is the weakest? Show your step-by-step calculations.

Name _____

7b. (3pts) Compute and plot the PSTH (post-stimulus histogram) for these data using a binwidth of 10 msec. Label all the axes. Can you estimate the frequency (Hz) of the vibration applied to the fingertip?

Name _____

8. (1pt) Neurons in the central auditory system may have a frequency receptive field (RF) and spatial RF. What is the fundamental difference between these two types of RFs other than the fact that one is defined along a frequency axis and the other along spatial axes? **48%**

9. (3pts) What are "topographic maps" and "functional maps" in the cortex? Explain the difference and give one example of each type of map. **72%**

10. (2pts) When someone loses the third finger of their left hand due to an accident, what changes would occur (if any) in the part of the primary somatosensory cortex representing hand surfaces? Why? **86%**

11. (2pts) Neurons in the peripheral visual system (retina ganglion cells) have "on-center" RFs whereas neurons in primary visual cortex (V1) have "orientation-selective" RFs. Explain how the RFs of V1 neurons are formed by convergence of inputs from peripheral neurons with "on-center" RFs. You may use graphs and text. **95%**

12. (2pts) Sketch the locations of three primary sensory cortices on a human brain: primary auditory cortex (A1), primary visual cortex (V1), and primary somatosensory cortex (S1). Indicate major landmarks on the cortical surface that are used as references. **67%**

Name _____

13. (4pts) For each component of the motor system listed, find the matching function or functions. In some cases, there may be more than one function that matches that area. **84%**

Posterior parietal cortex __B & H_____

Premotor cortex __A & E_____

Primary motor cortex ___F_____

Supplementary motor area ____D_____

Pontine reticulospinal tract ____G_____

Medullary reticulospinal tract ___C_____

Golgi tendon organ afferents ___J_____

Spindle afferents ____I____

A. Codes the vector representing the intended displacement of the hand
B. Codes the position of the target with respect to fixation point.
C. Important for inhibition of the muscles.
D. More active in memory guided sequence than in visually guided sequence.
E. More active in visually guided sequence than in memory guided sequence.
F. Transforms desired joint displacements into forces necessary to perform a movement.
G. Important for maintenance of posture through excitatory mechanisms.
H. Codes the position of the hand with respect to fixation point.
I. Codes for length of a muscle.
J. Codes for force in a muscle.

14. (1pt) In a spinal cord injury case, the patient is unable to control her fingers to grasp objects. She is also unable to control her leg muscles, but has good control of her shoulders and head. She is a candidate for a neural prosthesis to help improve grasping function of her hand. The prosthetic has two components: a sensor and a stimulator. The sensor allows the patient to control when the stimulator will be activated. Where do you think is a good location to put the sensor? Where would you put the stimulator? **81%**

Name _____

15. (4pts) Draw a graph showing wrist position (joint angle) as a function of time to illustrate a rapid flexion. Assume that increased joint angle means extension. Below this graph, draw another graph that shows wrist velocity as a function of time. Draw beneath the wrist velocity graph two new graphs showing the time course of activity in the wrist flexor and extensor muscles. Make sure that the time axis is the same in all these graphs. Label all your axes. **80%**

Name _____

16. Motor units are classified into 3 main types based on their fatigue properties and speed of contraction.
16a. (1.5pts) Name these three types. **95%**

16b. (1/2 pt) In a world class marathon runner, the thigh muscle contains mostly which two types?

17. (5pts) In a block diagram, draw the feedback system that allows for control of a muscle. In your diagram, include the following elements: alpha motor neuron, gamma motor neuron, spindle afferent, Golgi tendon organ afferent, extrafusal muscle, intrafusal muscle, spinal interneuron, and a load. Label the pathways that provide force feedback and length feedback. In the pathways that connect to the alpha motor neuron, indicate whether the signal is excitatory or inhibitory. **68%**

18a. (2pts) In order to measure short and long-latency responses to perturbation, you record EMG from the biceps muscle as the elbow is suddenly and unexpectedly extended. Draw a graph showing time on the x-axis and expected EMG on the y-axis. Label the time axis. Label the short-latency and long-latency component of the EMG response. **92%**

18b. (1pt) Which part of the CNS mediates the short-latency component of the response?

19a. (1pt) A split-brain patient is fixating a dot on a screen. An image of a cup is flashed to the right of the dot. Which hemisphere of the brain does the neural information regarding the cup appear? **88%**

19b. (1pt) The patient is instructed to reach with his left arm and try to identify from among a group of objects hidden below a table the object that was flashed. Which hemisphere of the brain will dominate control of the left arm?

19c. (1pt) Is the patient likely to be able to identify the object that was flashed?

Name _____

20. (3 pts) In order to make a reaching movement, the brain computes where the hand and target are located, and estimates the forces that are necessary to move the hand to the target. Label the missing items in the figure below, and then use your labels in the flow chart to show how force is computed. **83%**

21a. (1/2 pt) How would you go about acquiring a "motor map" from the cortex of an animal? **95%**

21b. (1/2 pt) After acquiring a motor map, we return and acquire another map from the same region a month later. During this period, the animal was trained to use his fingers to pick up small pieces of food. What should we see regarding his motor map for the fingers?

Extra Credit: 44%

Both parallel and hierarchical processing pathways exist in all sensory systems.

a. (1 pt) Explain the difference between these two types of processing and give an example of each from the auditory or visual system.

b. (1 pt) In the somatosensory system some relay neurons respond vigorously to a touch on one area of the skin but dramatically reduce their firing when an area immediately to one side of this excitatory region is touched. Explain how such a receptive field could be generated in a single hierarchical processing step. (Use a diagram and text.)

c. (1 pt) Some higher order neurons in the somatosensory system are specifically responsive to bars moving in a single direction across the skin. Considering that inhibitory responses are longer in duration than excitatory responses how might the responses of the relay neurons in part b be combined in a second processing step to produce these motion-sensitive neurons? (Use a diagram and text to explain your answer.)