Exam #:________

Physiological Foundations Spring 2002: Midterm Examination

March 13, 2002

Name: ____

SSN: ____

TA (For exam pick up): ______________________________

Signature: ____

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EXTRA CREDIT ____/3

TOTAL__________/80

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1. (2 pts) In one sentence each, describe <u>two</u> important anatomical or physiological features true for all fibers in the somatosensory pathway from the periphery to the CNS.

2. There are two major motor (efferent) systems.
(2 pts) Name them and give an example of one tissue innervated by each system:

3. Consider the populations of dendrites of three kinds of neurons, 1. alpha motoneurons, 2. dorsal root ganglionic neurons, and 3. sympathetic postganglionic neurons.

(4 pts) Which population has the most complex dendritic trees?

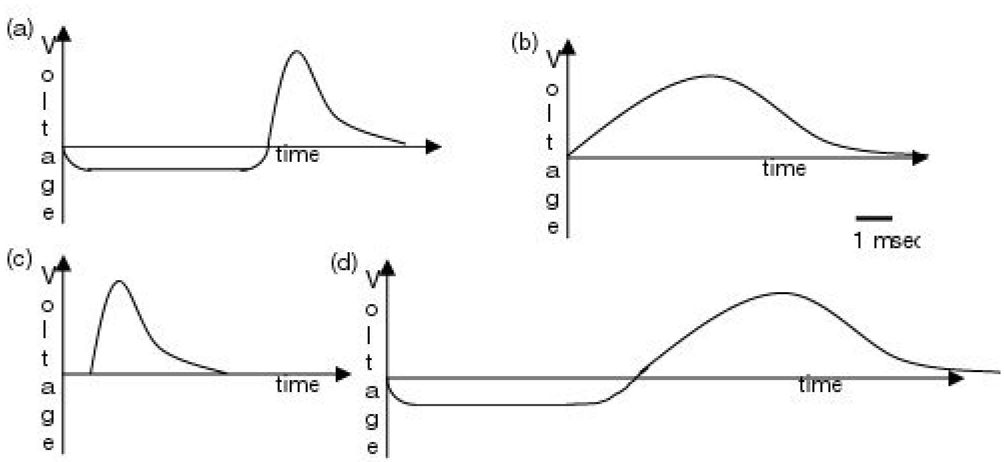
Which population has the least complex dendritic trees?

4. (3 pts) In one sentence, describe how closely (in mmHg) the baroreceptor reflex regulates mean arterial pressure on a short-term basis.

5. (4 pts) **a)** In the absence of the baroreceptor reflex, a sudden cardiovascular disturbance (such as suddenly standing up) would cause a perturbation of arterial pressure approximately how many times that which would occur if the baroreceptors were intact?

b) What is the open loop gain of the baroreceptor reflex?

6. (2 pts) Consider a Hodgkin-Huxley neuron, with the normal sodium and potassium conductances $g_{Na}=\hat{g}_{Na}m^3h$ and $g_K=\hat{g}_K n^4$. Assume they all have the same maximum, and the baseline is V_{rest}. Which of the EPSP traces shown below is most likely to cause the neuron to fire an action potential?



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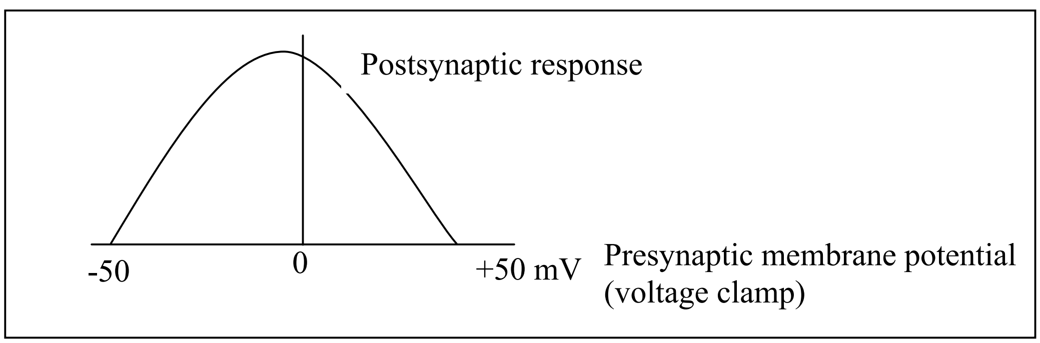
7. (5 pts) Match them up. Fill in the blanks in column A with a number from column B and a number from column C. Numbers can appear in more than one blank.

A. Function			B. Dominant ion	C. Typical equilibrium potential or reversal potential
EPSP	____	____	1. Na^{-+}	11. –70 to –90 mV
peak of the AP	____	____	2. K^+	12. 0 mV
IPSP	____	____	3. Na^+ and K^+	13. -20 mV
afterhyperpolarization	____	____	4. Ca^{++}	14. +50 mV
release of neurotransmitter	____	____	5. Cl^-	15. +100 mV
			6. HCO_3^-	16. –120 mV

8. (4 pts) At the squid giant synapse it is possible to voltage-clamp the presynaptic terminal, while simultaneously recording the postsynaptic response with another electrode. Tetrodotoxin and TEA are used to block voltage-gated sodium and potassium channels. This experiment reveals the relationship between <u>presynaptic</u> membrane potential (obtained in voltage clamp) and <u>postsynaptic</u> response (presented as the change in membrane potential) shown below. Explain the shape of this relationship. What factors cause the postsynaptic response to rise and then fall when the presynaptic membrane is voltage-clamped between –50 and +50 mV?



9. (5 pts) During an extended series of recordings from the neuromuscular junction of a cockroach, spontaneous end-plate potentials that averaged 1.5 mV in amplitude were observed. The average response to a series of 200 presynaptic action potentials was 6.0 mV. During that series of presynaptic action potentials (elicited by electrical shock to the motorneuron axon), a postsynaptic response was observed during 196 of those trials. Compute the quantum content of this synapse.

10. (4 pts) Stimulation of pain fibers in the left leg produces inhibition (reduced frequency of action potentials) of flexor motorneurons to the right leg. This inhibition is blocked by strychnine, an antagonist of glycine receptors. Intracellular recording showed that this synaptic input resulted in a 3 mV depolarization from the resting potential of –75 mV. This synaptic depolarization reversed in sign at –70 mV. What ion is most likely to carry the synaptic current (assume only a single specie of ion is involved)? What makes this synaptic input inhibitory?

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11. (3 pts) Intracellular recording from cells in the cortex showed that repeated stimulation of thalamic inputs caused long-lasting increases in the amplitude of excitatory postsynaptic potentials. The average response amplitude increased 2.5-fold and that increase lasted for several hours. Over the same time course, miniature (spontaneous) excitatory synaptic potentials in these cells also increased 2.5 fold in amplitude. Does this long-lasting increase in thalamic input strength result from a change in postsynaptic sensitivity, or from a change in quantal content of the presynaptic inputs? Explain your reasoning.

12. (7 pts) **a)** Draw the electrical circuit for a membrane compartment containing calcium channels, potassium channels, and synaptic channels. Identify all circuit elements with labels (like "E_K" or "G_{Cl}"). **b)** If the calcium conductance is zero at the resting potential, what is the resting potential (in terms of the components of the circuit)? **c)** If the synaptic conductance is increased, the membrane potential will change. Tell how you decide whether it is a depolarization or a hyperpolarization?

a) The circuit (4 pts)

b) Resting potential: (2 pts) ______________________

c) Depolarization or hyperpolarization? (1 pt)

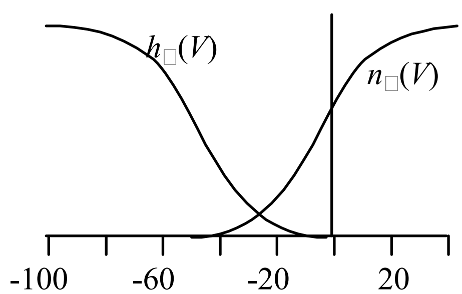
13. (6 pts) List 3 mechanisms, direct and indirect, by which calcium currents can affect the membrane potential of a cell. In each case, tell whether the effect is hyperpolarizing or depolarizing (or either).

14. (3 pts) The figures below show the HH parameters $n_\infty(V)$ and $h_\infty(V)$ for an X channel whose conductance is given by $\hat{G}nh$. Tell whether the conductance of the channel will be increased or decreased (or you can't tell) by an EPSP that carries the membrane potential from its resting value of –60 mV to a peak value of –50 mV. Assume that the time constants of the channel are fast enough to produce a change in each case.

a) Increase _______

Decrease _______

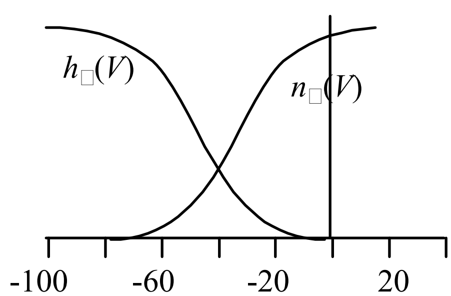
Can't tell _______



b) Increase _______

Decrease _______

Can't tell _______



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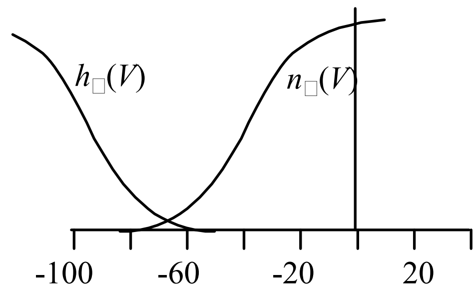
c) Increase _______
Decrease _______
Can't tell _______



15. (6 pts) **a)** A synapse on a cell is activated, causing an action potential; soon after the action potential, the synapse is activated again (i.e. the presynaptic terminal is invaded by an action potential). This time, the postsynaptic cell does not fire an action potential. Give two hypotheses to explain the spike failure on the second (apparently identical) input and briefly explain the mechanism for each hypothesis.

b) Suppose that you are recording intracellularly in the postsynaptic cell. You notice that the second EPSP is <u>larger</u> than the first. Does that narrow down your choice between the two hypotheses?

16. (2 pts) Which of the following will case the EPSP produced by a synapse in the soma to be larger?

____ Moving the synapse farther away along the dendritic tree from the soma.

____ Making the dendritic tree longer, but leaving the synapse the same distance from the soma.

____ Decreasing the synaptic conductance.

____ Adding a simultaneously activated inhibitory conductance between the synapse and soma.

____ Adding another, simultaneously activated, excitatory synapse at the same point in the dendritic tree.

17. (4 pts) Draw a picture of a dendritic branch, showing the commonly-observed specializations of the locations of excitatory versus inhibitory synapses. Explain why each synaptic type is located in this way.

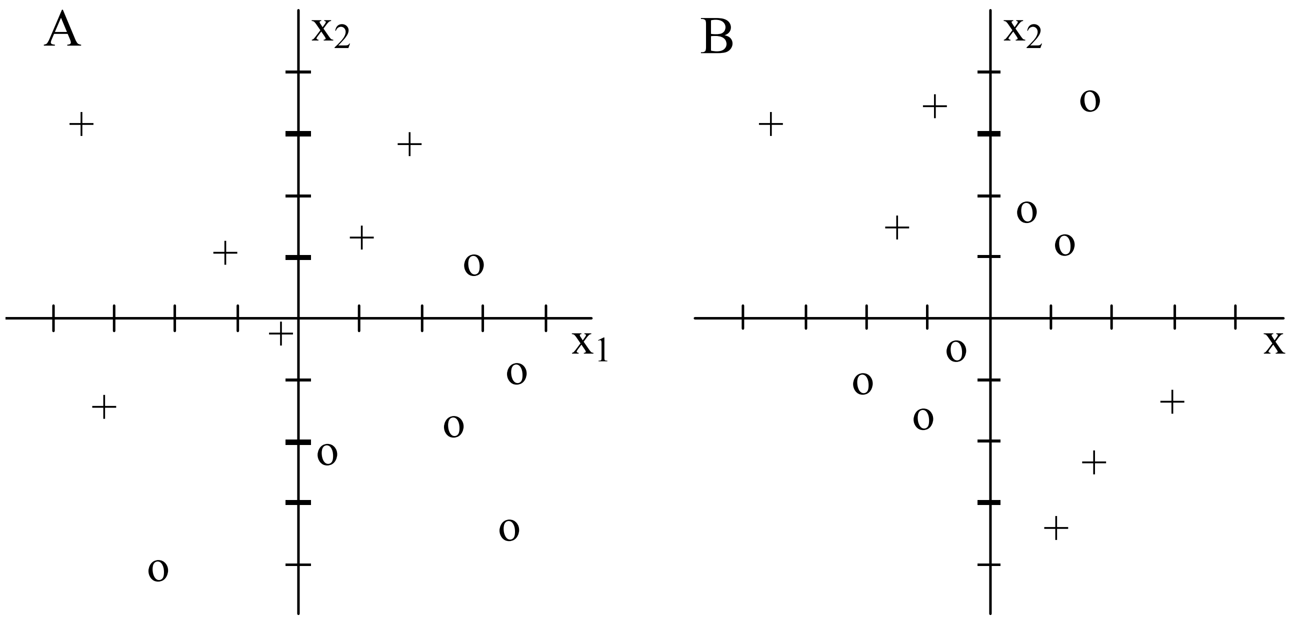
18. (2 pts) **a)** Which hemisphere of the human brain is crucial for understanding language?

b) Which hemisphere of the human brain is crucial for producing language?

19. (6 pts) Consider a perceptron with two inputs $\{x_1, x_2\}$ for which the input/output relationship is given by the following:

$$y = w_1 x_1 + w_2 x_2 \quad \text{and} \quad z = \begin{cases} -1 & \text{for } y < \gamma \\ 1 & \text{for } y \geq \gamma \end{cases}$$

For which of the following two sets of input vectors can a perceptron of this type be designed to separate the +'s from the o's? Answer yes or no next to the graph and, if the answer is yes, draw on the graph a weight vector $\{w_1, w_2\}$ that would do the trick and the line separating the two populations for that weight vector. Also give the values for w_1 and w_2 and a suitable value of γ.



20. (2 pts) What is the approximate speed of conduction of an action potential along a myelinated axon?

_____ 1 m/s
_____ 100 m/s
_____ 10 Km/s
_____ 300,000 Km/s

21. (6 pts) We have an experiment where occasionally, an air puff is given to the eye of a rabbit. In response to the air puff, the rabbit blinks his eyes. Now we play a brief tone immediately before we give the air puff. Every time we play the tone, we give the air puff. After pairing the tone with the air puff for 30 trials, we now give only the tone and omit the air puff.

a) What do we observe when we give the tone? (2 pts)

b) This experiment is an example of classical conditioning. What is the conditioned stimulus in this experiment? (2 pts)

c) Draw a circuit that includes a neuron that senses the air puff on the eyes, a motor neuron that produces the eye blink, a neuron that senses the tone, and an interneuron. Label each neuron, and draw the synapses on all neurons. (2 pts)

EXTRA CREDIT (3 pts): For the circuit above, explain how the activity in the US pathway affected the CS pathway.