

Exam #: \_\_\_\_\_

Physiological Foundations Spring 2003: Midterm Examination

March 17, 2003

Name: \_\_\_\_\_

SSN: \_\_\_\_\_

TA (For exam pick up): \_\_\_\_\_

Signature: \_\_\_\_\_

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**EXTRA CREDIT** \_\_\_/3

TOTAL \_\_\_\_\_/53

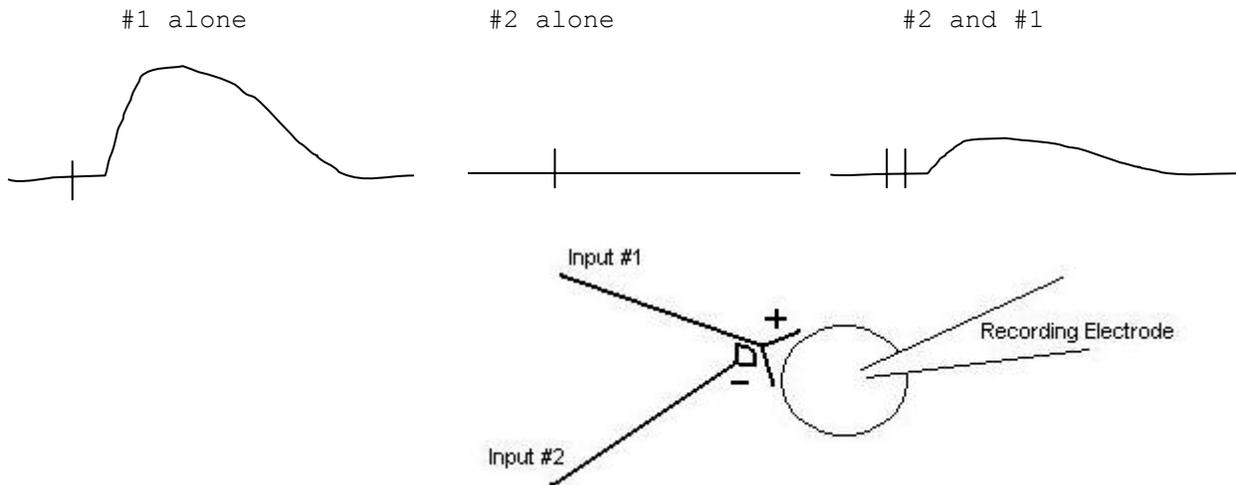


5. (3 pts) Some potassium channels are blocked when magnesium ( $Mg^{++}$ ) ions flow through the channels in an inward direction (i.e. from the extracellular space toward the intracellular space). Suppose the  $Mg^{++}$  concentration is 1 mM outside the cell and 3 mM inside the cell and the resting potential is -60 mV. Will those potassium channels be blocked in this situation?
6. (6 pts) Suppose that a cell membrane contains the following channels:
- a.  $Ca^{++}$  channel that is voltage-activated and inactivated by  $Ca^{++}$  concentration.
  - b.  $Ca^{++}$  and voltage activated potassium channel, no inactivation
  - c.  $Cl^-$  channel that is activated only by  $Ca^{++}$ , no inactivation

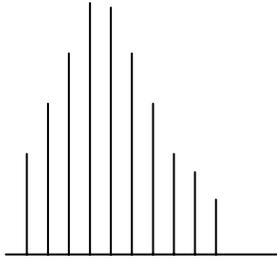
Write a set of differential equations for this membrane. Make sure you indicate what variables the functions in the Hodgkin-Huxley equations depend on. Obviously you will not be able to write out explicit functions for things like  $m^\infty(V, Ca)$ , but you should indicate that they are functions of  $V$  or  $Ca$  or whatever (Hint: you should end up with 6 differential equations).



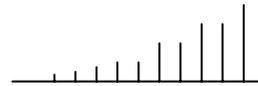
10. (2 pts) You've begun a project to study synaptic integration in the central nervous system of the medicinal leech with Professor X, the increasingly vague emeritus professor of biology. You will study the effects of stimulating two separate peripheral nerves on the activity of an interneuron. While making intracellular recordings from the interneuron you find that stimulating input #1 alone produces an average excitatory postsynaptic potential of a few millivolts, while stimulating input #2 alone doesn't seem to do much of anything. However, stimulating #1 and #2 together causes less excitation than #1 alone. You see EPSPs (excitatory postsynaptic potentials), but they are smaller on average. Below is shown the average EPSP recorded in each of these situations. You take your results to Professor X who exclaims, "Ahah, presynaptic inhibition!" but then wanders off for a cup of tea before explaining to you how to prove it. You reason that he means input #2 makes inhibitory synapses on the presynaptic terminals of input #1 as in the diagram to the right, thereby reducing transmitter release through presynaptic inhibition. How would you test this hypothesis using quantal analysis?



11. (2 pts) A single shock to the motor nerve innervating the levator femoralis muscle of the cockroach causes a depolarizing synaptic potential of only 10 mV in a single muscle fiber.
- A.) Repetitive stimulation at 50 Hz causes synaptic potentials that increase in size for the first five shocks, then progressively decrease for the next 5 shocks. You try to explore the underlying mechanism by replacing the external saline with one containing only 10% as much calcium.



A. normal calcium



B. 10% calcium

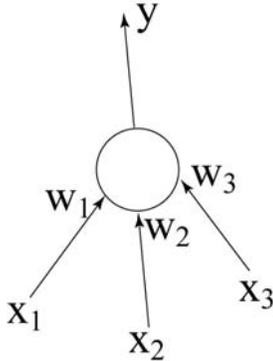
- B.) Now the first synaptic potential in the sequence of 50 Hz shocks is only ~2 mV in amplitude, but successive responses get larger to the end of the stimulation. Examples on a compressed time scale are shown. Explain these observations in terms of the presynaptic release mechanism.

12. (3 pts) Insect muscles are excited by the release of glutamate from innervating motor neurons. You changed membrane potential and showed that the glutamate-evoked depolarization had its reversal potential at -20 mV (no net ionic flux). The potassium equilibrium potential is -80 mV and that for sodium is +60 mV. What is the relative permeability of the glutamate-activated channel to sodium and potassium? (These are the only permeable ions.)

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- 13.** (5 pts) In aplysia, when the tail of the animal is shocked, the animal becomes sensitized so that touching the siphon results in a very strong retraction of the gill.
- A. Draw a diagram that includes a siphon sensory neuron, a tail sensory neuron, a gill motor neuron, and an interneuron.
  - B. Describe how this sensitization takes place.

14. (6 pts) The perceptron is an example of a feed forward network. In the figure below, we have a neuron in a perceptron network.
- Write an equation that describes output  $y$  as a function of inputs  $x_i$ , weights  $w_i$ , and threshold  $\theta$ .
  - The output of this neuron is currently  $y$ . We wish the actual output of this neuron to be  $z$ . Write the error function that we will need to minimize.
  - Derive the equation that describes how the weights  $w_i$  of this network should change in order to minimize the error function.



15. (2 pts) In a Hopfield network, imagine that we want neuron  $i$  to have an output  $S_i$ , and neuron  $j$  to have an output  $S_j$ . How should we set  $w_{ij}$ , i.e., the weight of the connection between neuron  $i$  and  $j$ ?

16. (2 pt) Hopfield network is an example of recurrent networks that have interesting collective dynamic properties. The following statements about a standard Hopfield network are all true except for one. Circle the one that is false. Pick only one answer.
- A. Each pair of neurons is always reciprocally connected with equal synaptic weights regardless of how many memory patterns are stored in the network
  - B. Multiple memory patterns can be stored in a network without interference if these patterns are statistically independent of one another
  - C. Starting from any initial state, a Hopfield network always settles into a stationary state because of the existence of a Liapunov function
  - D. After a random subset of the synaptic connections are cut off, the network can never retrieve a stored memory pattern perfectly because reciprocal connections are no longer symmetric
17. (2 pts) Population vector is a widely used algorithm for extracting information from a population of neurons with cosine tuning functions. A population vector can be constructed from the instantaneous firing rates and the preferred directions that have been measured in test trials. Suppose a new hypothetical drug can momentarily double the firing rates of all the neurons in the population. How would this drug affect the direction of the population vector?
18. (2 pts) The following statements about the hippocampus are true except one. Circle the false statement. Pick only one answer
- A. When people with severe hippocampal damage write a note to themselves, they cannot not remember the fact that they had written the note but they can still recognize their own handwriting
  - B. Hippocampus contains a high concentration of NMDA receptors that are important for synaptic plasticity
  - C. Hippocampal place cells use visual landmarks to compute where they should fire but in total darkness they still work as if the animal could still see
  - D. Hippocampus helps an animal to remember an important location for later visit
  - E. To facilitate memory consolidation, the hippocampus is inactive during sleep

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- 19.** (3 pts) EXTRA CREDIT In a stretch reflex, a sharp tap to the patellar tendon causes the quadriceps muscle to contract. Sketch the pathway through which the excitatory information at tendon and muscle spindle is sent to CNS and how it is converted into muscle contraction, also include the major structures and the direction of the pathway.