

Signal Transduction Practice Problems:

1. In a cat, the A fibres (neurons) of the saphenous nerve have a maximum conduction speed that is approximately ten times faster than the conduction speed of the B fibres of the saphenous nerve. Both the A and B fibres have myelinated axons. However, the A fibres have a maximum axon diameter of $22\mu\text{m}$, while the B fibres have a maximum axon diameter of $3\mu\text{m}$. Explain how this difference in axon diameter allows for the A fibres to have a higher conduction speed than the B fibres. Be as quantitative as possible.

2. Many different factors affect the conduction speed of action potentials in neurons.

a) Explain why increasing temperature (within the range of tolerance) increases conduction speed.

b) Explain why increasing the density of K^+ leak channels in the cell membrane of an axon decreases conduction speed.

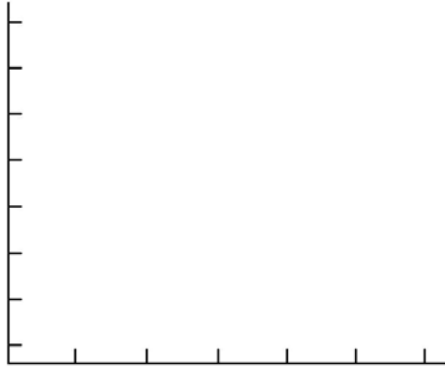
3. Consider two neurons, X and Y, which are identical except that the membrane capacitance of X is twice as large as the capacitance of Y. In both of these neurons, the resting membrane potential is -70mV and the threshold potential is -55mV .

At the axon hillock of each of these two neurons, a large inhibitory graded potential arrives, hyperpolarizing the cell membrane to -85mV . In each of these two neurons, several milliseconds later, an excitatory graded potential with a magnitude of 120mV arrives at the axon hillock.

Compare the probability of firing an action potential in neurons X and Y (i.e. which one is most likely to generate an AP at the axon hillock?).

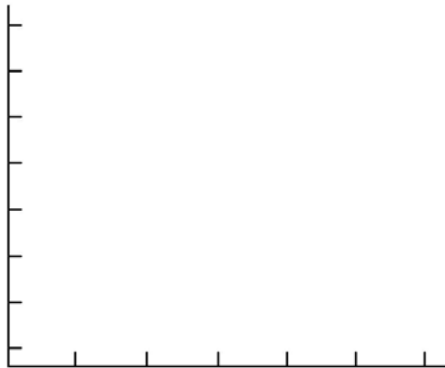
4. There are at least 11 different isoforms of voltage-gated Na^+ in mammals alone! Consider how different isoforms of voltage-gated Na^+ channels might influence the generation of action potentials in different neurons.

a) Using the axes provided below, draw a “typical” action potential for a “typical” neuron with a resting membrane potential of -70mV and a threshold potential of -55mV . Clearly label the axes. Be quantitative (use numbers).



b) Now consider a neuron that has an isoform of voltage-gated Na^+ channel in which the inactivation gate closes earlier than normal (but which has the “typical” isoform of voltage-gated K^+ channel). Using the axes provided below, draw an action potential that you would predict a neuron with this isoform of voltage-gated Na^+ channel would generate.

c) Now consider a different neuron that has an isoform of voltage-gated Na^+ channel in which the inactivation gate closes more slowly than normal (but which has the “typical” isoform of voltage-gated K^+ channel). Using the axes provided below, draw an action potential that you would predict a neuron with this isoform of voltage-gated Na^+ channel would generate.



d) Now consider a different neuron that has the “typical” isoform of voltage-gated K^+ channel but which has an isoform of voltage-gated Na^+ channel in which threshold voltage is higher than normal. How would the excitability of this neuron compare to that of a “typical” neuron? Explain your answer.

5. Imagine that you are studying two identical, “typical” neurons. You stimulate the first neuron, X, with a weak signal, which triggers a low frequency of action potentials, approximately 25 per second. You stimulate the second neuron, Y, with a relatively strong signal, which triggers a higher frequency of action potentials, approximately 250 per second. You then measure the concentration of neurotransmitter released by X and Y. Which neuron would you expect to release more neurotransmitter? Clearly explain why. (4 marks)

6. Fluoxetine (trade name Prozac) is a selective serotonin reuptake inhibitor used to treat clinical depression. Imagine that you have two identical neural synapses, F and C, each with a “typical” presynaptic neuron that produces serotonin as a neurotransmitter. Both F and C have identical synaptic clefts and identical “typical” postsynaptic neurons. The only difference is that neural synapse F has been treated with fluoxetine while synapse C has not. You stimulate both presynaptic neurons to produce a single action potential. How would the response of the postsynaptic neuron differ in F and in C? Clearly explain your answer. (4 marks)

7. Consider two neurons, A and B, which are identical except that the membrane capacitance of A is three times as large as the capacitance of B. A suprathreshold stimulus triggers an action potential at the axon hillock, at exactly the same spot and same time. Will the action potential reach the axon terminals first in X or in Y? Explain.