Bi 360: Midterm Review

Basic Neurobiology

1) Many axons are surrounded by a fatty insulating sheath called __myelin________, which is interrupted at regular intervals at the _______Nodes of Ranvier________________, where the action potential is ___regenerated______________.

2) Transduction with respect to neuronal signaling refers to what?

Information travels down an axon as an electrical signal. When it reaches the terminal, the signal is converted into a chemical signal which gets released across the synaptic cleft. Once this chemical signal reaches the post-synaptic cell, the signal is once again converted back into an electrical signal.

3) What is the difference between concepts of permeability and conductance?

Permeability is a measure of the number of open channels independent of whether ions flow through those channels

Conductance is a measure of the number of open channels when ions are flowing through those channels.

4) Below is a diagram of the knee jerk reflex. The reflex consists of a sensory neuron, motoneuron, and muscle. Locate and identify on the diagram all passive and active potentials in the neurons and muscle as well as chemical synapses.

The reflex begins with a passive electrical signal in the sensory neuron dendrites which becomes an action potential that invades the synaptic terminal. Transmitter release at the sensory neuron – motor neuron chemical synapse triggers an EPSP in the motor neuron which in turn produces an action potential that reaches the motor terminal and activates voltage dependent calcium

[Diagram of the knee jerk reflex with labeled potentials and synapses]
channels and transmitter release. The transmitter crosses the neuromuscular junction and activates an EPP which causes an action potential in the muscle.

**Drugs**

1) Tetrodotoxin blocks voltage dependent $K^+$ channels. (T/F)

2) Tetraethylammonium (TEA) prevents the action potential from being produced. (T/F)

3) Radioactive TTX is commonly used to determine the density and distribution of voltage dependent $Na^+$ channels. What would you expect the pattern of TTX labeling to be in a …

   a) myelinated axon

   TTX labeling would be localized only at the Nodes of Ranvier as these areas have a high concentration of voltage gated $Na^+$ channels.

   b) non-myelinated axon

   TTX labeling would be distributed evenly along the entire length of a non-myelinated axon.

   c) dendrite

   TTX labeling would not be present because dendrites are passive membranes and thus do not have any voltage dependent channels.

**The Action Potential**

1) A neuron receives a stimulus that, by itself, can bring the neuron to threshold, but no action potential is produced. Explain what could cause this.

   Neurons receive input from many neurons at the same time. If the neuron is receiving many inhibitory signals from other neurons, a single excitatory input may not be enough to reach threshold and no action potential will be produced.

2) What ion is responsible for the undershoot in the action potential and why?

   $K^+$ ions. When voltage-gated $K^+$ channels are open in response to a change in voltage, $K^+$ ions are released out of the cell. An overwhelming amount of $K^+$ ions are released out of the cell that it the membrane potential gets near the equilibrium potential of $K^+$. It returns back to normal after voltage-gated $K^+$ channels are closed.

3) Why doesn’t the action potential peak at the equilibrium potential of $Na^+$?

   It doesn’t peak at the $Na^+$ equilibrium potential because voltage gated $K^+$ channels open before the voltage dependent $Na^+$ channels close.
4) Plot the magnitude and time course of an action potential and the $G_{Na}$ and $G_K$ that underlies an action potential on the following graph. Be as accurate as possible and label each plot.

5) You are the chief scientific officer on the Starship Enterprise, travelling around the galaxy and going where no person has gone before. You encounter a new human-like species with 2 hearts, green blood and an unusual nervous system. Using standard intracellular recording techniques, you record the action potential from one of the alien’s motoneurons as shown below. The alien’s green blood has the same ions as humans ($K^+$, $Na^+$, $Cl^-$, $Ca^{2+}$) except that their concentrations are reversed, i.e., the extracellular fluid has high $[K^+]$, high $[Ca^{2+}]$, low $[Na^+]$ and low $[Cl^-]$ while the cytoplasm has low $[K^+]$, low $[Ca^{2+}]$, high $[Na^+]$ and high $[Cl^-]$.

A. Propose a hypothesis for the ionic basis for the falling (hyperpolarization) and rising (depolarization) phases of the alien’s motoneuron action potential, i.e., state the ion(s) involved and which way they are flowing.

There are several possible correct answers. The initial hyperpolarization (falling phase) of the action potential is likely due to an outward $Na^+$ current as there is no other ion that will hyperpolarize membrane potential. The repolarization of the action potential could be due to a $K^+$ or $Ca^{2+}$ influx, a $Cl^-$ efflux, or an inactivation of the outward $Na^+$ current.

B. Propose an experiment to test your hypothesis regarding the falling phase of the action potential.

There are many different correct answers to this question, including changing internal or external concentrations of $Na^+$, blocking the inward or outward currents with specific antagonists, or voltage clamping the membrane at the Nernst potential for $Na^+$ to abolish the inward $Na^+$ current.
Cable Theory and Experiments

1) The length constant is defined as the time it takes for an electrical signal to decrease to 63% of its original value. (T/F)

2) The presence of myelin wrapping around an axon increases conduction velocity, decreases membrane resistance and increases membrane capacitance. (T/F)

3) What is the effect of doubling axon diameter on the conduction velocity of the action potential?

Conduction velocity will increase.

The conduction velocity of the action potential is affected by the length constant which is defined as $\lambda = \sqrt{R_m/R_i}$ where $R_m =$ membrane resistance per unit area and $R_i =$ internal or axoplasmic resistance per unit area.

Increasing axon diameter decreases internal resistance which means $\lambda$ is increased. This causes current to spread further down the axon leading to a faster action potential.

4) You make the following voltage clamp recording from a squid giant axon. You hold the cell at -60mV and make a series of depolarizing steps, in increments of 30mV each, between -30 and +90mV. Explain why the magnitude of the inward early current first increases then decreases and finally reverses with increasing depolarization, while the late current continuously increases. Explain why the early current becomes outward in traces 4 and 5.

The early, or Na$^+$ inward current, increases from 1-2 because more Na$^+$ channels are open at 2 than at 1. It decreases from 2 to 3 because the driving force (Vm-E$_{Na}$) is smaller in 3 than in 2. The late outward K$^+$ current continuously increases because each voltage step clamps the membrane potential further away from E$_K$. The holding potentials in 4 and 5 are each more positive than E$_{Na}$. Hence Na$^+$ flows out of the cell against its concentration gradient because the electrical force is greater than the chemical gradient.
Synapses

1) What are the incoming signals into a neuron called?

Synaptic Potentials

2) Electrical synapses require Ca\(^{2+}\) entry into the pre-synaptic terminal for synaptic transmission. (T/F)

3) At electrical synapses, specific gap junction proteins provide direct bridges between the cytoplasm of pre- and post-synaptic cells. (T/F)

4) Neuron A makes a chemical inhibitory synapse on Neuron B. The IPSP produced in Neuron B is mediated by a rise in a K\(^{+}\) conductance. At the normal resting potential of -70 mV, the amplitude of the IPSP is -10 mV. If Neuron B is hyperpolarized to -80 mV and then Neuron A is stimulated, what will the IPSP look like (draw it)? Explain your answer briefly.

There will be no observable IPSP at -80 mV because -80 mV is the potassium equilibrium potential (EK\(^{+}\)) and thus there will be no net flow of K\(^{+}\) ions.

5) What does the existence of miniature end plate potentials tell us about the probability of vesicle release and what does this say about the process of chemical synaptic transmission?

The existence of spontaneous vesicle fusion events (miniature EPPs in the absence of a stimulus) indicates that the cell’s usual mechanisms for vesicle release are highly primed and ready to be activated quickly when an action potential reaches the pre-synaptic terminal. This priming dramatically increases the probability of vesicle fusion during depolarization of the pre-synaptic terminal and enhances the efficacy of chemical synaptic transmission.