1) During an action potential, a membrane cannot depolarize above:
   a) The equilibrium potential of sodium
   b) The equilibrium potential of potassium
   c) Zero
   d) The threshold value
   e) There is no limit.

2) Put these in order:
   I – repolarization
   II- depolarization of action potential
   III- rest
   IV- depolarization to threshold
   a) II, I, IV, III
   b) I, II, III, IV
   c) III, IV, II, I
   d) IV, I, II, III

3) Acetylcholine is:
   a) A type of ligand-gated channel
   b) An excitatory neurotransmitter
   c) An inhibitory neurotransmitter
   d) None of these are correct.

4) If sodium channels are opened in the dendrite, what occurs?
   a) Hyperpolarization
   b) Depolarization
   c) Action Potential
   d) Not enough information to answer.

5) Electrical synapses are similar to chemical synapses in that:
   a) They have a synaptic cleft
   b) Ions flow directly from one cell into another
   c) A neurotransmitter transfers the signal from one cell to another
   d) Both depolarizing and hyperpolarizing stimuli can be passed to the postsynaptic cell.
   e) None of these

6) An effect of stimulating the sympathetic nervous system is:
   a) Increased rate of digestion
   b) Increased glucose uptake in the liver
   c) Pupil contraction
   d) Airway relaxation
   e) None of these

7) Which of the following is NOT a way we discussed drugs like antidepressants, heroin and opium working?
   a) Prevent the reuptake of neurotransmitter from the synaptic cleft
   b) Increase the release of neurotransmitter from the presynaptic cell
c) Directly bind to neurotransmitter receptors
d) Poison neurons, causing cell death

8) Ion X, which has a negative charge, is more concentrated inside the cell than outside the cell. A neurotransmitter binds a ligand-gated X channel, opening it. What effect would this have on the cell?
   a) An excitatory postsynaptic potential
   b) An inhibitory postsynaptic potential
   c) An action potential
   d) Decreasing the threshold voltage
   e) Increasing the threshold voltage

9) Three electrodes, A, B, and C, are inserted into the axon of a neuron. The voltmeter measures the three profiles drawn below. What is the order of the electrodes, starting from the electron closest to the axon hillock?

   A
   B
   C

   a) B,C,A
   b) C,A,B
   c) C,B,A
   d) A,B,C

10) Tetrodotoxin, the pufferfish toxin, blocks voltage-gated sodium channels. What effect would this have on a cell’s resting membrane potential and action potentials?
    a) No effect, no action potentials
    b) Resting membrane potential high, no action potentials
    c) No effect, no effect
    d) Resting membrane potential high, no effect

11) Which of the following sensory systems use mechanoreceptors?
    a) Hearing
    b) Balance
    c) Touch
    d) A and C
    e) A, B and C

12) Membrane A has a radius of 50 µm and a thickness of 2 µm. Membrane B has a radius of 25 µm and a thickness of 1 µm. On the left side of each membrane is a 5mM solution of KCl; on the right side is a 10mM solution of KCl. Which of these statements is true?
a) The rate of diffusion across both membranes is the same.
b) **The rate of diffusion is higher across Membrane A.**
c) The rate of diffusion is higher across Membrane B.
d) Not enough information.

13) If I treat a sample of skeletal muscle cells with a toxin that degrades tropomyosin, what effect would I expect to see?
   a) No difference from normal cells.
   b) Muscle cells are unable to contract.
   c) Muscle cells do not respond to acetylcholine.
   **d) Muscle cells are unable to relax.**
   e) Muscle cells grow longer and shorter randomly.

14) I surgically modify a fully functional heart. When I am done, only the atria contract rhythmically. Which of the following did I likely remove?
   a) The sinoatrial node
   **b) The atrioventricular node**
   c) The pacemaker cells
   d) The atrioventricular valve
   e) The gap junctions

15) Which of the following statements is FALSE?
   a) Sarcomeres are randomly aligned in smooth muscle
   **b) Acetylcholine causes heart rate to increase**
   c) Blood returns to the heart through muscular contractions and one-way valves
   d) Hemoglobin has a higher affinity for oxygen in a high-pH environment
   e) Cold water is capable of carrying more dissolved oxygen than warm water

16) Which of the following is true of both vertebrates and insects?
   a) Gas exchange occurs through lungs
   **b) Muscles are found in antagonistic pairs**
   c) The skeleton is dynamic and is constantly remodeled
   d) The role of the heart is to squirt bloodlike fluid onto the tissues

17) ATP hydrolysis occurs during which step of muscle movement?
   a) **Release of myosin from actin**
   b) Cocking the myosin head
   c) Binding of myosin to actin
   d) Myosin pulling on actin
   e) Removing tropomyosin from actin binding sites

18) Which of the following statements is true?
   a) White muscle has a high concentration of glycolytic enzymes and fatigues slowly.
   b) Red muscle has a high concentration of glycolytic enzymes and fatigues slowly.
   c) White muscle contains lots of myoglobin and mitochondria and fatigues slowly.
   **d) Red muscle contains lots of myoglobin and mitochondria and fatigues slowly.**

19) Which of these bohr shift effects is not correct?
   a) Low temperature: high hemoglobin-oxygen affinity
   b) Low pH: low hemoglobin-oxygen affinity
   **c) Fetal hemoglobin: higher hemoglobin-oxygen affinity**
   d) None- all are correct bohr shift effects.
20) Put these vessels in order from greatest to smallest cross-sectional area of the individual vessel, and from greatest to smallest velocity: capillaries, arteries, veins.
   a) Veins, arteries, capillaries; arteries, veins, capillaries
   b) Veins, capillaries, arteries; veins, capillaries, arteries
   c) Capillaries, veins, arteries; arteries, veins, capillaries
   d) Arteries, capillaries, veins; arteries, capillaries, veins
   e) Veins, arteries, capillaries; arteries, capillaries, veins

1) Neuron physiology- label dendrites, cell body, axon hillock, axon, synapses, synaptic vesicles, postsynaptic and presynaptic cell. Show how the signal flows through the cell.

   Please see the figure in your text.

2) Action potential- draw a plot of membrane potential over time. Label the five phases (Rest, depolarization, action potential, repolarization/hyperpolarization and rest). Also label your axes, resting membrane potential, zero, sodium rest potential, potassium rest potential, and threshold.

   Please see the figure in your text.

3) Complete the following table with the words “operating, open, closed, not operating, inactive”. Explain your choices.

<table>
<thead>
<tr>
<th></th>
<th>Pump</th>
<th>K leak</th>
<th>V-gated Na</th>
<th>V-gated K</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rest</td>
<td>Open</td>
<td>Open</td>
<td>Closed</td>
<td>Closed</td>
</tr>
<tr>
<td>Depolarization</td>
<td>Open</td>
<td>Open</td>
<td>Some open, some closed</td>
<td>Closed</td>
</tr>
<tr>
<td>Action potential</td>
<td>Open</td>
<td>Open</td>
<td>All Open</td>
<td>Closed</td>
</tr>
<tr>
<td>Repolarization</td>
<td>Open</td>
<td>Open</td>
<td>Closed, inactive</td>
<td>Open</td>
</tr>
<tr>
<td>Rest</td>
<td>Open</td>
<td>Open</td>
<td>Closed</td>
<td>Closed</td>
</tr>
</tbody>
</table>

4) Synapses- label ion concentrations of Ca^{2+}, Na^+, K^+. Label synaptic vesicles, neurotransmitter, ligand-gated ion channels, voltage gated channels and the synaptic cleft. Explain how the signal crosses the synapse.

   Please see the figure in your text.

5) Draw a hair cell. Label the stereocilia, voltage-gated calcium channels, voltage-gated potassium channels, postsynaptic cell and neurotransmitter. Describe how a stimulus is translated to electrical output in the context of balance. How do hair cells detect the direction of the pressure (left vs. right)?

   Please see the figure in your text.
6) Draw a skeletal muscle cell. Label the presynaptic neuron, the t-tubules, myofibrils, myofilaments, sarcomeres, actin, myosin, sarcoplasmic reticulum, troponin and tropomyosin. Describe how an action potential is converted to movement.

*Please see the figure in your text.*

7) Countercurrent exchange- Draw a diagram. Label "to" and "from", fill in appropriate temperatures at the blanks. Be prepared to explain how countercurrent exchange works, and why it works better than concurrent exchange.

![Countercurrent Exchange Diagram](image)

8) Draw a saturation curve. List some factors that affect the hemoglobin-oxygen affinity and their effects. Describe how the carbonic anhydrase system modulates breathing rate.

*Please see the figure in your text.*

9) Draw a map of the heart and the circulatory system. Describe how blood and electrical impulses flow through the heart.

*Please see the figure in your text.*

10) Draw a picture of a capillary going through tissue. Include the lymphatic system. Describe where and how glucose, oxygen and fluid leave the blood and how oxygen and carbon dioxide are transported through the bloodstream.

*Please see the figure in your text.*

11) Compare and contrast the energy sources of red and white muscle. Be sure to discuss which substrates they use, the enzymes and other molecules involved, the products produced and the endurance of each type of cell. Give some examples of where each type of cell is located.

*Please see the figure in your text.*
12) Compare and contrast an action potential and an EPSP. They both depolarize the cell by opening sodium channels. However, EPSPs occur in the dendrites and cell body, use ligand-gated channels, and their electrical profiles may vary. In contrast, action potentials occur only on the axon. They are self-perpetuating, highly stereotyped electrical events and they use voltage-gated channels.

13) Discuss the differences between chemical and electrical synapses with special attention to synaptic plasticity.

a) Chemical synapses have receptors whose responses can be regulated and modified. Therefore, when a synapse is stimulated repeatedly, it can develop or activate different types of channels, changing its response to that stimulus. This allows learning. Electrical synapses have no way to modify their responses.

14) Discuss the differences between positive and negative feedback systems. Be sure to provide examples.

a) The difference is that in negative feedback systems, the integrator turns on an effect to counteract the observed action, while the positive feedback system magnifies that. For example, with thermoregulation, if the animal is too cold, it shivers to warm up. With positive feedback, a depolarization to threshold leads to even higher depolarization.

15) Briefly explain why the saturation curve is sigmodal shaped, and why this shape is important.

The curve is sigmoidal because hemoglobin exhibits cooperative binding— that is, the binding of one oxygen molecule makes the binding of subsequent oxygen molecules more likely. This is important because it allows the hemoglobin to rapidly unload oxygen due to a small change in oxygen saturation of the environment— it makes it much more sensitive and responsive than a linear curve.

16) Explain what controls the opening and closing of valves in the heart.

The valves are one-way valves. As the pressure in the upstream chamber (such as the atrium) rises higher than that in the downstream chamber (ventricle), the fluid pressure pushes the valve open. When pressure in the downstream chamber is higher, the fluid pressure pushes these valves shut. Note that this is purely mechanical and passive, requiring no energy.

17) List some major differences in body systems between planaria/hydra and mammals. What allows these creatures to function without many of the body systems mammals possess?

Planaria and hydra do not have respiratory or circulatory systems. These creatures are small in size, and very thin, allowing each cell to be in contact with the water. Gasses and wastes can therefore diffuse freely in and out of the organism without need of these systems.