Chapter 9: Muscular System: Histology and Physiology

I. Functions of the Muscular System

A. List and describe the seven major functions of muscles:

1. ________________________________________________________________
   ________________________________________________________________
   ________________________________________________________________

2. ________________________________________________________________
   ________________________________________________________________
   ________________________________________________________________

3. ________________________________________________________________
   ________________________________________________________________
   ________________________________________________________________

4. ________________________________________________________________
   ________________________________________________________________
   ________________________________________________________________

5. ________________________________________________________________
   ________________________________________________________________
   ________________________________________________________________

6. ________________________________________________________________
   ________________________________________________________________
   ________________________________________________________________

7. ________________________________________________________________
   ________________________________________________________________
   ________________________________________________________________

II. General Functional Characteristics of Muscle

A. Properties of Muscle

1. Contractility is ____________________________
   a. Muscle shortens ____________________________
   b. Muscle lengthens ____________________________

2. Excitability is ____________________________
a. Normally stimulation comes from ____________________
b. Stimulation can also come from ____________________

3. Extensibility means ____________________________________________

4. Elasticity is __________________________________________________

B. Types of Muscle Tissue (Use Table 9.1 as needed)

1. Skeletal Muscle
   a. Where do you find skeletal muscle? ______________________________
   b. What shape are skeletal muscle cells? ____________________________
   c. How much of the body is composed of skeletal muscle? ______________
   d. Functionally skeletal muscle is responsible for many actions including:
      1. ______________________________
      2. ______________________________
      3. ______________________________
      4. ______________________________

2. Smooth Muscle
   a. Where do you find smooth muscle? ________________________________
   b. What shape are smooth muscle cells? ____________________________
   c. Smooth muscle has a wide variety of functions including:
      1. ______________________________
      2. ______________________________
      3. ______________________________
      4. ______________________________

3. Cardiac Muscle
   a. Where do you find cardiac muscle? ________________________________
   b. What shape are cardiac muscle cells? ____________________________
   c. Functionally cardiac muscle is responsible for ______________________
   d. What does autorhythmic mean? _________________________________
   e. What does involuntary control mean? _____________________________
III. Skeletal Muscle Structure

A. General

1. Skeletal muscles are composed of:
   a. ______________________________
   b. Associated with:
      1. ______________________________
      2. ______________________________
      3. ______________________________

2. What is a skeletal muscle fiber? ______________________________

3. Each fiber is a single ____________________ containing _______________
   located ______________________________________

4. What is a myoblast? ______________________________________

5. What converts a myoblast to a muscle fiber? __________________________

6. How does a muscle enlarge after birth? ______________________________

7. What does the term striated refer to? ______________________________

8. How long are skeletal muscle fibers? ______________________________

9. How thick are skeletal muscle fibers? ______________________________

B. Connective Tissue

1. What is the external lamina? ______________________________________
   a. The external lamina is produced by ______________________________

2. The sarcolemma is the ______________________________________

3. Endomysium
   a. It is composed of ______________________________________
   b. Where is it located? ______________________________________

4. Perimysium
   a. It is composed of ______________________________________
   b. What does it enclose? ______________________________________
   c. What does the term fasciculus refer to? _______________________
      __________________________________________________________
   d. How many fasciculi does a muscle contain? ___________________
5. Epimysium
   a. It is composed of _____________________________________________
   b. Where is it located? ________________________________________

6. Fascia
   a. What is a fascia? ____________________________________________
   b. What is the fascia around an individual muscle called? __________

7. The connective tissue components of muscles are continuous with:
   a. ________________________________________________
   b. _____________________________________________ &
   c. ______________________________________________

8. Functionally the connective tissue of muscle:
   a. Holds _______________________________________________
   b. Attaches ___________________________________________

C. Nerve and Blood Vessels
   1. Functionally motor neurons ________________________________
   2. Extending through the muscle connective tissue with the nerve is an
      a. ____________________ & one or two __________________
   3. What is a synapse or neuromuscular junction? ________________
   4. Each motor neuron innervates _____________________________
   5. Every muscle fiber receives ______________________________

D. Muscle Fibers
   1. The cytoplasm of a skeletal muscle fiber is called ________________
   2. What is a myofibril? ________________________________________
      a. How long is a myofibril compared to the muscle fiber? __________
   3. Myofibrils are composed of protein filaments called _______________
   4. Actin myofilaments (thin myofilaments):
      a. Are approximately _________ in diameter & __________ in length
   5. Myosin myofilaments (thick myofilaments):
      a. Are approximately _________ in diameter & __________ in length
   6. What is a sarcomere? ________________________________________
7. Actin Myofilaments
   a. What is the shape of globular actin (G actin)?
   b. Connecting approximately 200 G actin molecules together forms one polymer stand called
   c. Two strands of F actin are coiled to
   d. Each G actin monomer has
   e. Tropomyosin is an
   f. How many G actin active sites does tropomyosin cover?
   g. Troponin is composed of __________ subunits:
      1. One subunit binds to
      2. One subunit binds to
      3. One subunit binds to
   h. The complex of tropomyosin and troponin regulates 

8. Myosin Myofilaments
   a. What is the basic shape of a myosin molecule?
   b. Each myosin molecule is composed of:
      1. Two ______________ wound together to ______________
         lying parallel __________________
      2. Two __________ that extend __________________
   c. Where are the four light chain myosin molecules located?
   d. How many myosin molecules in a myosin myofilament?
   e. What are the three functions of the myosin heads?
      1. Heads can __________________
      2. Have a hinge region that __________________
      3. Heads have ________________ that __________________

9. Sarcomeres
   a. A sarcomere extends from __________ to an ______________
   b. What is a Z disk?
   c. What causes the striated appearance of a myofibril?
d. The I band consists only of ______________________________

e. The A band extends the ______________________________
   1. The _________ & _________ myofilaments ___________________
   2. Each myosin myofilament is surrounded by ___________________

f. The H zone contains only ______________________________

g. Where is the M line? ______________________________

h. What is the M line? ______________________________

i. Since the A bands and I bands of parallel myofibrils are aligned it creates
   ______________________________ a microscope

IV. Sliding Filament Model
   A. Actin and myosin myofilaments _________________ length
   B. Actin and myosin myofilaments _________________
      1. This results in the sarcomere _________________
   C. When sarcomeres shorten the _________________ shorten
   D. When myofibrils shorten the _________________ shorten
   E. Therefore sarcomeres are responsible for ______________________________

V. Physiology of Skeletal Muscle Fibers
   A. Membrane Potentials
      1. What does polarized mean? ______________________________
      2. What is the resting membrane potential? ______________________________
      3. The membrane becomes polarized when ______________________________
      4. What is the resting membrane potential of a muscle cell? _______________
      5. Why is this reported as a negative number? ______________________________
B. Ion Channels
1. The permeability of the plasma membrane changes as a result of __________________________

2. The diffusion of ions through the channels __________________________
and produces an __________________________

3. Ligand-gated ion channels
   a. What is a ligand? __________________________
   b. What is a receptor? __________________________
   c. How are ligand-gated ion channels opened? __________________________
      __________________________
   d. What is a neurotransmitter? __________________________

4. How are voltage-gated ion channels opened or closed? __________________________
   __________________________

5. Can any ion move through any ion channel? Why? __________________________
   __________________________

6. When ions move through ion channels are they moving up the concentration
   gradient, or down the concentration gradient? __________________________

C. Action Potentials
1. The two phases of an action potential are __________ & __________

2. Depolarization occurs __________________________

3. Depolarization is triggered if the membrane is changed to __________________________

4. What is repolarization? __________________________

5. Depolarization and repolarization result from __________________________

6. Before stimulation the gated ion channels are __________________________

7. When the cell is stimulated:
   a. Gated Na⁺ channels _________ & Na⁺ __________________________
   b. The positive charged Na⁺ makes the inside __________________________
   c. If threshold is reached many _________ open rapidly & _________
      into the cell until __________________________ briefly

8. Shortly after the inside of the plasma membrane becomes positive:
   a. Closing of _________ & opening of __________________________
1. The movement of __________ into the cell stops
2. The movement of __________ out of the cell increases
   b. Therefore, the inside of the plasma membrane becomes __________ and the outside of the plasma membrane becomes _____________
9. The resting membrane potential is reestablished when _________________
10. The all-or-none principle
   a. What does the “all” refer to? ___________________________________________________________________
   b. What does the “none” refer to? ___________________________________________________________________
11. What does propagate mean in terms of an action potential? ________________
       ____________________________________________________________________________________________
12. What is action potential frequency? _____________________________
D. Neuromuscular Junction
1. Neuromuscular junction (synapse) consists of ____________ & _________________
2. What is a presynaptic terminal? _________________________________
3. What is a synaptic cleft? ______________________________________
4. What is the postsynaptic membrane (motor end-plate)? _______________
       ____________________________________________________________________________________________
5. Where are the synaptic vesicles located? __________________________
6. Acetylcholine functions as a ______________________
7. What does a neurotransmitter do? ___________________________________________________________________
   ____________________________________________________________________________________________
8. When an action potential reaches the presynaptic terminal it:
   a. Causes ____________________ to open
   b. As a result ____________________ into the cell
   c. Inside the cell the Ca²⁺ cause ____________________ by _________________
   d. The acetylcholine diffuses across __________ & bind to _____________
   e. This causes ____________________ to open & ____________________
9. What is acetylcholinesterase and what does it do? _________________
   ____________________________________________________________________________________________
10. Acetylcholine is broken down into ______________ & _______________
a. What happens to the choline molecules? __________________________
b. What happens to the acetic acid molecules? _______________________

E. Excitation-Contraction Coupling
1. What is a transverse tubule (T tubule)? ______________________________
   ______________________________________________________________
2. What is the sarcoplasmic reticulum? ________________________________
   a. The enlarged portion of the sarcoplasmic reticulum is called ___________
3. What are the 3 components of a triad? ______________________________
4. What is stored inside the sarcoplasmic reticulum? ________________
5. Excitation-contraction coupling begins at __________________________
   with the production of ____________________________ in the sarcolemma
   a. The action potential is propagated ______________________________
   b. The T tubules undergo ____________________________
   c. Depolarization at the triads causes ______________________________
   d. This allows ___________ to rapidly ______________________________
   e. ___________ bind to ____________________ of the actin myofilaments
   f. This combination causes the ______________________________
   g. That exposes ___________ on the G actin which then bind to __________
      of ____________________ to form ____________________

F. Cross-Bridge Movement
1. After the myosin heads bind to the actin active site:
   a. Myosin molecules move ______________________________
   b. Forcing ____________________ to slide ____________________
2. After movement the myosin head releases and _______________________
3. The myosin head can then ______________________________
   followed by ___________, release of ____________, and ______________
4. The cycle is: cross-bridge ___________, ___________, ___________, & ___________
5. Each cycle of cross-bridge formation requires energy from ______________
   a. Release of the myosin head requires ___________ to bind ____________
   b. ATPase in the myosin head ______________________________
      1. Energy is stored in ______________________________
2. Both __________ & __________ remain ____________________
   c. The cross-bridge is released as a result of ______________________ and the myosin head returns ______________________________
   d. Then the myosin molecule binds _________________________________
      1. As a result of this binding __________________ from the myosin head
   e. Much of the stored energy is used for _____________ & _____________
      1. And the ____________________ is released from the myosin head
   f. Before the cross-bridge can be released __________________________

6. What is a power stroke? ______________________________________
7. What is a recovery stroke? ______________________________________

G. Muscle Relaxation
1. Occurs as a result of the __________________ back into _____________
2. This results in the troponin-tropomyosin complex __________________
   which __________________________________________________
3. Therefore ____________________ reform and ____________________
4. During relaxation of muscle ATP is needed for the active transport of:
   a. ______________________________
   b. ______________________________
   c. ______________________________

VI. Physiology of Skeletal Muscle
A. Muscle Twitch
1. What is the lag phase (latent phase)? ____________________________
2. What is the contraction phase? _________________________________
3. What is the relaxation phase? _________________________________
4. Muscle contraction is measured as a force called __________________

B. Stimulus Strength and Muscle Contraction
1. What is the all-or-none law of skeletal muscle contraction? ____________
2. What is a subthreshold stimulus? _________________________________
3. What is a threshold stimulus? _________________________________
4. Define the term “motor unit” _______________________________________
5. How do motor units respond? ______________________________________
6. Whole muscles respond to stimuli in ______________________________
   a. This means _________________________________________________
7. What does multiple motor unit summation refer to? ____________________
   ______________________________________________________________
8. What is a submaximal stimulus? _________________________________
9. A maximal stimulus _____________________________________________
10. What effect does a supramaximal stimulus have on the strength of muscle
    contraction? __________________________________________________
11. What does the phrase “motor units recruited” mean? __________________
    ______________________________________________________________
12. How many motor fibers in a motor unit involved in precise movements? _____
13. How many motor fibers in a motor unit involved in powerful movements? ____

C. Stimulus Frequency and Muscle Contraction
   1. As the frequency of action potentials increases _______________________
   2. What happens during incomplete tetanus? ___________________________
   3. What happens during complete tetanus? _____________________________
   4. How would a muscle be stimulated to produce treppe? __________________
      ______________________________________________________________
   5. Treppe is probably the result of __________________________________

VII. Types of Muscle Contractions
A. In isometric contractions the ____________________ doesn’t change, but the
   ________________________________ during the contraction process
B. In isotonic contractions the ______________________________ is constant,
   but the ______________________________ changes
   1. What type of isotonic contractions are concentric contractions? _________
   2. What type of isotonic contractions are eccentric contractions? __________
C. Muscle tone refers to ________________________________________________________________________
   1. These contractions are responsible for:
      a. ________________________________________________________________________
      b. ________________________________________________________________________
      c. ________________________________________________________________________
   2. Muscles are able to produce smooth movements since motor units are contracting and relaxing ______________________________

D. Length Versus Tension
   1. What is active tension? ________________________________________
   2. What is passive tension? ________________________________________
   3. What is total tension? ________________________________________

VIII. Fatigue
   A. What is fatigue? __________________________________________________
      1. Psychologic fatigue occurs when the individual ________________________
      2. Muscular fatigue results from ______________________________________
      3. Synaptic fatigue occurs in the ________________ due to lack of __________
   B. Physiologic Contracture and Rigor Mortis
      1. What is physiological contracture? __________________________________
         a. Caused by a lack of ________________________________________
         b. As a result __________ accumulates in sarcoplasm
         c. Previously formed cross-bridges ______________________________
   C. Rigor Mortis
      1. This is the development of _________________________________________
      2. Low levels of ATP prevent __________________________________________
      3. Over time _________ leaks out of the ______________________________
      4. As _________ increase in the sarcoplasm ___________________________
      5. Cross-bridges are unable to _________ & _________ to cause contraction
      6. Therefore the muscles remain _____________________________________
IX. Energy Sources

A. Creatine Phosphate
1. When is creatine phosphate synthesized? ____________________________
2. Functionally creatine phosphate _________________________________
3. The chemical formula for the conversion of creatine phosphate to ATP is: __________________________________________________________

B. Anaerobic Respiration
1. When does anaerobic respiration occur? ___________________________
2. It involves the breakdown of glucose to __________ & __________
3. For each molecule of glucose there is a net production of __________
   and __________
4. What happens to most of the lactic acid? _________________________
5. What is the advantage of anaerobic respiration? __________________
   ______________________________________________________________
6. ATP formation from creatine phosphate & anaerobic respiration is limited by:
   a. Depletion of ____________________
   b. Depletion of ____________________
   c. Buildup of _______________________

C. Aerobic Respiration
1. What is required by aerobic respiration? __________________________
2. It breaks down glucose to produce __________, __________, & __________
3. Is anaerobic or aerobic respiration more efficient? __________________
4. How many ATP's can aerobic respiration produce per glucose? _________
5. What organic molecule provides the more important energy source for 
   muscles during sustained exercise? _____________________________
6. What are the two sets of reactions that occur in the mitochondria called?
   a. ______________________________
   b. ______________________________
7. The major end products of aerobic respiration are:
   a. ______________________________
   b. ______________________________
8. What is the chemical equation for aerobic respiration of one glucose?

______________________________________________________________

9. What type of activities depend on aerobic respiration? __________________

D. Oxygen Debt

1. Define oxygen debt: ____________________________________________

______________________________________________________________

2. It represents the difference between _________ needed & __________ used

3. The increased aerobic metabolism after exercise:
   a. Reestablishes __________ & ____________________ in muscle cells
   b. Converts excess __________ to __________ and then to __________

X. Slow and Fast Fibers

A. Slow-Twitch, or High-Oxidative, Muscle Fibers

1. Slow-twitch muscle fibers:
   a. Contract ____________________
   b. Are smaller ____________________
   c. Have a ______________________________
   d. Have more ______________________________ &
   e. Are more ______________________________

2. They respond relatively slowly to ______________________________

3. Break down ATP at ____________________________________________

4. What is myoglobin? _____________________________________________

5. What ability does myoglobin enhance? ______________________________

B. Fast-Twitch, or Low-Oxidative, Muscle Fibers

1. Fast-twitch muscle fibers respond _________ to nervous stimulation.

2. Fast-twitch muscle fibers contain myosin that _________________________

3. This allows cross-bridge cycling to occur _____________________________

4. Fast-twitch muscle fibers have:
   a. Less well-developed ______________________________
   b. Have very little ______________________________
c. Fewer and smaller ______________________________

d. Have large deposits ______________________________

e. Well adapted to perform ______________________________

5. The fast-twitch muscle fibers tend to:
   a. Contract ___________________
   b. And fatigue ____________________

C. Distribution of Fast-Twitch and Slow-Twitch Muscle Fibers
   1. Most human muscle have ______________________________
   2. Large postural fibers contain ______________________________
   3. Muscles of the upper limbs contain ______________________________
   4. A good sprinter would have ______________________________
   5. A marathon runner would have ______________________________
   6. A person with a balanced mixture of slow-twitch and fast-twitch muscle fibers would be able to ______________________________

D. Effects of Exercise
   1. In response to exercise a muscle ______________________________
   2. A muscle that is not used ____________________ or __________________
   3. These changes result from ______________________________
   4. What increases in a muscle cell when it enlarges? ____________________
      ____________________
   5. What other elements of a muscle increase? ____________________
      ____________________
   6. When is a decrease in the number of muscle cells possible? ____________________
      ____________________

XI. Heat Production
   A. Energy from skeletal muscle metabolism in the form of heat is responsible for normal ______________________________
   B. The body responds to higher than normal body temperature by:
      1. ____________________ of blood vessels in the ____________________ &
      2. ____________________
C. The body responds to lower than normal body temperature by _______________

XII. Smooth Muscle

A. General Characteristics of Smooth Muscle
   1. Smooth muscle cells are ________ than skeletal muscle cells.
   2. Smooth muscle cells contain ________ actin and myosin myofilaments.
   3. There are more ________ than ________ myofilaments.
   4. Instead of sarcomeres, the myofilaments are __________________________
      a. This is the reason that smooth muscle cells are not ________________
   5. What are dense bodies? __________________________________________
      a. What are they equivalent to? ________________________________
   6. What forms an intracellular cytoskeleton? __________________________
   7. How do smooth muscle cells shorten? _____________________________
   8. Sarcoplasmic reticulum is _________________________________
   9. What are caveolae? _____________________________________________
      a. What is their possible function? ______________________________

B. Physiology of Smooth Muscle
   1. The Ca$^{2+}$ needed for smooth muscle contraction ____________________
      ____________________ and from ________________________
   2. Smooth muscle cells contract more slowly than skeletal muscle because:
      a. Greater distance ______________________________
      b. Rate at which _________________________________
      c. Slower rate of _________________________________
   3. What regulates contraction in smooth muscle cells? ____________________
   4. The sequence of events in smooth muscle contraction is:
      a. __________ enters the sarcoplasm and binds to __________________
      b. These 2 molecules bound together activate _________________
      c. _________________ transfers a phosphate group from __________
         to __________________________________________________
      d. When phosphate groups are bound to _________________ then
         _________________ formation occurs
5. Relaxation of smooth muscle depends on the enzyme __________________
a. Functionally this enzyme removes ______________________________

6. What is the "latch state"? _________________________________________

7. As long as \( \text{Ca}^{2+} \) is present ________________________________

8. \( \text{Ca}^{2+} \) levels in the sarcoplasm are lowered as ___________________

9. Relaxation occurs in response to ________________________________

C. Types of Smooth Muscle
1. Visceral smooth muscle occurs in _________ & is found in _____________,
   _____________, & _____________ tracts
2. Visceral smooth muscle has numerous ____________________________ which allow
   _____________________________________________________________
3. As a result sheets of smooth muscle function ______________________
   a. The wave of contraction ________________________________
4. Multiunit smooth muscle occurs as:
   a. Sheets like in ________________________________
   b. Small bundles like in ________________________________ & ________________________________
   c. Single cells like in ________________________________
5. Multiunit smooth muscle has fewer ________________________________
6. Which type of smooth muscle can be autorhythmic? ________________
7. What type of smooth muscle operates as independent units? ___________

D. Electrical Properties of Smooth Muscle
1. What are pacemaker cells? ________________________________
2. How does the nervous system regulate smooth muscle contractions? ______
   _____________________________________________________________
3. How do hormones cause smooth muscle to contract? ________________
   _____________________________________________________________

E. Functional Properties of Smooth Muscle
1. List and describe four functional properties of smooth muscle:
   a. ________________________________
   b. ________________________________
   c. ________________________________
F. Regulation of Smooth Muscle
   1. Smooth muscle is innervated by the __________________ nervous system
   2. What are the two most important neurotransmitters for smooth muscle?
      a. ______________________________
      b. ______________________________
   3. What hormones regulate smooth muscle contraction?
      a. ______________________________
      b. ______________________________
   4. Smooth muscle function is also influenced by:
      a. ______________________________
      b. ______________________________
   5. The response of smooth muscle to a chemical depends on the type of
      __________________ the chemical is binding to
   6. Receptors that stimulate smooth muscle contraction open ________ or
      ________ channels
   7. Receptors that inhibit contraction __________ these channels or ________

XIII. Cardiac Muscle
   A. Where is cardiac muscle found? ______________________________
   B. What are intercalated disks? ______________________________
   C. Cardiac muscle is depolarized due to influx of __________ & __________

XIV. Effects of Aging on Skeletal Muscle
   A. Aging of skeletal muscle results in:
      1. Reduced ______________________________
      2. Increased time ______________________________
      3. Reduced ______________________________
      4. Increased ______________________________
   B. What happens to the number of muscle fibers? ____________________
      1. This begins as early as __________________________
2. By age 80 ____________________ mainly due to ____________________

C. What can slow the loss of muscle mass? ______________________________

D. Does a person lose more slow-twitch or fast-twitch muscle fibers? ____________

E. At a synapse, the surface area _______________________________
   1. Action potentials in neurons stimulate _______________________________
   2. Action potentials may not _______________________________

F. What happens to the number of motor neurons? _________________________
   1. What effect will this have on muscle control? _________________________

G. What happens to the number of capillaries? ____________________________
   1. What effect will this have on exercise? ______________________________