

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 strand 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 Ca^{2+} 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. _____

- c. _____
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:
- Reestablishes _____ & _____ in muscle cells
 - Converts excess _____ to _____ and then to _____

X. Slow and Fast Fibers

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

- Slow-twitch muscle fibers:
 - Contract _____
 - Are smaller _____
 - Have a _____
 - Have more _____ &
 - Are more _____
- They respond relatively slowly to _____
- Break down ATP at _____
- What is myoglobin? _____
- What ability does myoglobin enhance? _____

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

- Fast-twitch muscle fibers respond _____ to nervous stimulation.
- Fast-twitch muscle fibers contain myosin that _____
- This allows cross-bridge cycling to occur _____
- Fast-twitch muscle fibers have:
 - Less well-developed _____
 - 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 Ca^{2+} is present _-_____
8. 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. _____

d. _____

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? _____