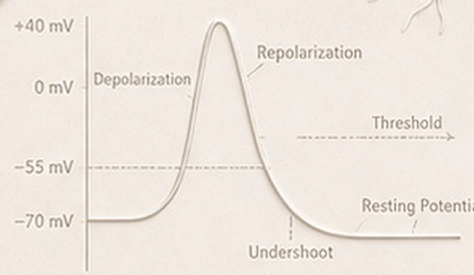

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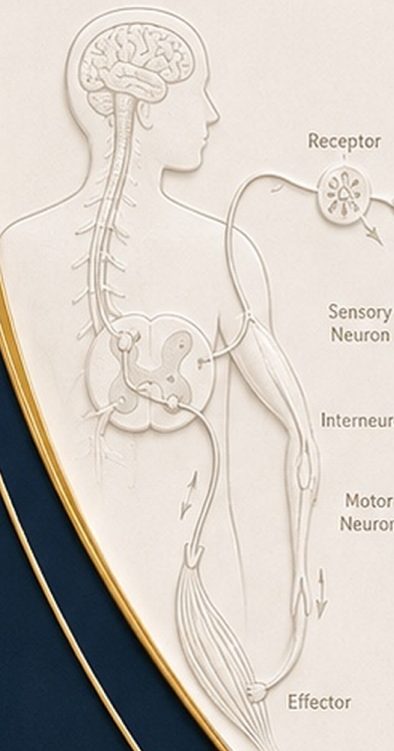
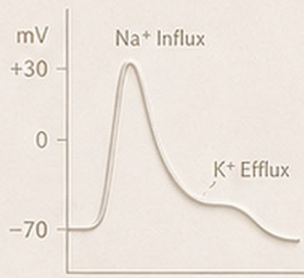
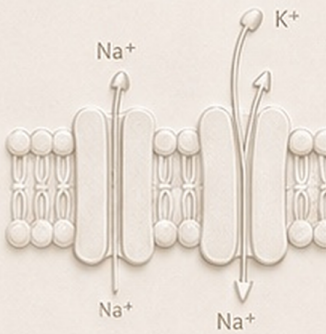
PHYSIOLOGY







Lecture 1 - Skeletal Muscle Physiology

Part 1: MCQs (Choose the correct answer):

1. Muscles are best described as machines that convert:

A. Mechanical energy into stored chemical energy
B. Stored chemical energy into mechanical energy (work) and heat
C. Heat energy into stored chemical energy
D. Electrical energy into chemical energy only
E. Chemical energy into electrical energy only

2. Muscles constitute about 50% of the body weight. The share of skeletal muscle alone is approximately:

A. 10% of the body weight
B. 20% of the body weight
C. 30% of the body weight
D. 40% of the body weight
E. 50% of the body weight

3. Which type of muscle is voluntary, striated, supplied by somatic nerves and attached to the skeleton?

A. Skeletal muscle
B. Cardiac muscle
C. Smooth muscle of the viscera
D. Both cardiac and smooth muscle
E. All three types of muscle

4. As regards the cross striations of the different types of muscle:

A. All three types of muscle are striated
B. Skeletal and cardiac muscles are striated while smooth muscle is plane
C. Only skeletal muscle is striated
D. Smooth and cardiac muscles are striated while skeletal muscle is plane
E. Only smooth muscle is striated

5. During rest, the percentage of body heat production that results from muscle activity is about:

A. 10%
B. 25%
C. 40%
D. 50%
E. 90%

6. Which of the following is a function of the skeletal muscle?

A. Movement of the blood inside the heart
B. Movement of the contents of the viscera
C. Maintenance of the body posture by tonic contraction and muscle tone
D. Reduction of heat production during exercise
E. Storage of extracellular fluid

7. The connective tissue sheath that surrounds the whole skeletal muscle is the:

A. Endomysium
B. Perimysium
C. Epimysium
D. Sarcolemma
E. Sarcoplasmic reticulum

8. A fascicle (bundle of muscle fibers) is wrapped by the:

A. Epimysium
B. Perimysium
C. Endomysium
D. Tendon
E. Sarcolemma

9. The plasma membrane of the skeletal muscle fiber is called the:

A. Sarcomere
B. Sarcoplasm
C. Sarcolemma
D. Endomysium
E. Epimysium

10. Each skeletal muscle fiber contains all of the following EXCEPT:

A. Myofibrils
B. Mitochondria
C. Many nuclei
D. Two types of tubules
E. One single centrally placed nucleus

11. The longitudinal tubules of the skeletal muscle fiber:

A. Are known as the sarcoplasmic reticulum and lie parallel to the myofibril
B. Cross the muscle fiber from one side to the opposite side
C. Contain extracellular fluid
D. Are invaginations of the sarcolemma
E. Transmit the action potential to the interior of the fiber

12. The enlarged ends of the longitudinal tubules that lie near the T-tubules are called the:

A. Motor end plates
B. Terminal cisterns
C. Z lines
D. M lines
E. H zones

13. A triad in the skeletal muscle is formed of:

A. One T-tubule and two terminal cisterns, one on either side
B. Two T-tubules and one terminal cistern
C. Three terminal cisterns of the sarcoplasmic reticulum
D. Three adjacent myofibrils
E. One myofibril and two mitochondria

14. Which of the following is a function of the sarcoplasmic reticulum of the skeletal muscle?

A. Transmission of the action potential to the interior of the fiber
B. Storage of calcium in a very high concentration in its cisternae
C. Storage of extracellular fluid rich in sodium and chloride
D. Degradation of acetylcholine
E. Formation of the motor end plate

15. As regards the transverse tubules (T-tubules) of the skeletal muscle:

A. They lie parallel to the myofibrils
B. They store calcium in a very high concentration
C. They are invaginations of the membrane containing extracellular fluid and transmit the action potential to the interior of the fiber
D. They possess a calcium pump in their wall
E. They contain the acetylcholinesterase enzyme

16. The thick filament protein of the myofibril is:

A. Actin
B. Troponin
C. Tropomyosin
D. Myosin
E. Acetylcholinesterase

17. Which of the following statements about the myosin molecule is correct?

A. It is formed of a tail plus two heads, and these heads are the cross bridges
B. It is spherical and forms two chains that coil around each other
C. It wraps around the chain of actin
D. It carries the binding site for calcium ions
E. It is one of the thin filament proteins

18. The myosin head (cross bridge) carries binding sites for:

A. ATP and actin
B. Calcium and tropomyosin
C. Acetylcholine and sodium
D. Troponin and calcium
E. Potassium and chloride

19. The thin filament protein that carries the binding site for calcium ions is:

A. Actin
B. Myosin
C. Troponin
D. Tropomyosin
E. Myoglobin

20. Tropomyosin of the thin filament:

A. Is spherical and forms two chains that coil around each other
B. Wraps around the chain of actin and is connected to troponin
C. Carries the ATPase activity of the sarcomere
D. Has binding sites for calcium ions
E. Forms the cross bridges of the thick filament

21. The functional unit of the skeletal muscle is the sarcomere, which is bounded on either side by:

A. A bands
B. I bands
C. Z lines
D. M lines
E. H zones

22. During contraction of the skeletal muscle:

A. The A band disappears while the I band remains constant
B. The I band is reduced while the A band remains constant
C. Both the A band and the I band disappear
D. The two Z lines move further apart from each other
E. The thick filaments slide along the thin filaments and the I band widens

23. Excitation–contraction coupling of the skeletal muscle starts with:

A. Binding of the myosin head to the actin filament
B. Spread of the action potential along the T-tubules causing release of calcium from the sarcoplasmic reticulum
C. Active pumping of calcium into the terminal cisterns
D. Bending of the myosin head
E. Degradation of acetylcholine by acetylcholinesterase

24. The calcium released during excitation–contraction coupling produces contraction by:

A. Binding to troponin C, so that the troponin–tropomyosin complex moves and exposes the active site on actin
B. Binding to the tail of the myosin molecule
C. Binding to the ATP binding site of the myosin head
D. Binding to the nicotinic receptor of the motor end plate
E. Blocking the active site on the actin filament

25. Relaxation of the skeletal muscle occurs as a result of:

A. Passive diffusion of calcium out of the muscle fiber
B. Active pumping of calcium back into its intracellular stores
C. A rise in the cytosolic calcium concentration
D. Depletion of troponin from the thin filament
E. A decrease in the ATP concentration within the sarcomere

26. As regards the role of ATP in the skeletal muscle:

A. It is needed for the sliding of the contractile filaments only
B. It is needed for calcium reuptake only
C. It is needed for both the sliding of the contractile filaments and calcium reuptake
D. It is needed only for the degradation of acetylcholine
E. It is not needed at all during relaxation

27. A motor unit is defined as:

A. A motor neuron and the muscle fibres supplied by it
B. All the motor neurons that supply one muscle fibre
C. One motor neuron and one muscle fibre only
D. One T-tubule with the two terminal cisterns on either side
E. One myofibril with its surrounding sarcoplasmic reticulum

28. In muscles that perform fine and delicate movements, such as the eye muscles, each motor unit contains:

A. Less than 10 muscle fibres
B. About 100 muscle fibres
C. About 500 muscle fibres
D. 1000–2000 muscle fibres
E. More than 5000 muscle fibres

29. The synaptic cleft of the neuromuscular junction:

A. Is 30–50 nm in width and contains the acetylcholinesterase enzyme
B. Contains the acetylcholine vesicles
C. Contains intracellular fluid rich in potassium
D. Contains the voltage gated calcium channels
E. Carries the nicotinic receptors

30. As regards transmission at the neuromuscular junction:

A. Acetylcholine acts on the muscarinic receptors of the motor end plate
B. Acetylcholine increases Na+ influx producing the end plate potential, and is then degraded by acetylcholinesterase
C. The end plate potential is a hyperpolarization of the postsynaptic membrane
D. Release of acetylcholine follows the entry of potassium into the axon terminal
E. The end plate potential is long lasting because acetylcholine is not degraded

Part 2: Essay / Short-Answer Questions:

1. Skeletal muscle in general.

A. Mention the percentage of the body weight formed by the muscles and by the skeletal muscle, and name the three types of muscle.

B. Enumerate the functions of the skeletal muscle.

2. Tabulate a comparison between the three types of muscle as regards the following points.

Point of comparison	Skeletal	Cardiac	Smooth
Control			
Cross striations			
Nerve supply			
Location			
Function			

3. The tubular system of the skeletal muscle.

A. Compare the longitudinal tubules and the transverse tubules as regards their arrangement, their content and their function.

B. Define the triad, and mention the two functions of the sarcoplasmic reticulum.

4. The myofibril.

A. Enumerate the muscle proteins that form the thick and the thin filaments.

B. Describe the structure of the myosin molecule, and mention the binding sites present on the myosin head.

C. Mention the role of troponin and of tropomyosin of the thin filament.

5. The sarcomere.

A. Define the sarcomere, and mention its boundaries and the bands present in it.

B. Mention the changes that occur in the bands and in the Z lines during muscle contraction.

6. Excitation–contraction coupling.

A. Enumerate, in order, the steps of excitation–contraction coupling in the skeletal muscle.

B. Mention the two steps at which ATP is needed during contraction and relaxation.

7. The neuromuscular junction.

A. Define the neuromuscular junction and the motor unit, giving an example of a small and of a large motor unit.

B. Enumerate the three structures that form the neuromuscular junction, and mention the contents of each one.

C. Describe the mechanism of neuromuscular transmission, and mention the fate of acetylcholine.

Part 1: MCQ Answer Key

1 **B** – Stored chemical energy into mechanical energy (work) and heat Slide 3 (muscles are machines converting stored chemical energy into work and heat)
2 **D** – 40% of the body weight Slide 3 (all muscles = 50% of body weight; smooth + cardiac muscle together = 10%)
3 **A** – Skeletal muscle Slide 5 (voluntary, striated, somatic nerve supply, attached to the skeleton)
4 **B** – Skeletal and cardiac muscles are striated while smooth muscle is plane Slide 5
5 **D** – 50% Slide 6 (50% of resting heat production is due to muscle activity; heat production is much increased during exercise)
6 **C** – Maintenance of the body posture by tonic contraction and muscle tone Slides 5 & 6 (movement of joints, posture and stability)
7 **C** – Epimysium Slide 7 (epimysium surrounds the whole muscle)
8 **B** – Perimysium Slide 7 (perimysium wraps a fascicle; endomysium lies between individual muscle fibers)
9 **C** – Sarcolemma Slide 9 (the plasma membrane of the muscle cell)
10 **E** – One single centrally placed nucleus Slide 10 (each fiber contains myofibrils, mitochondria, many nuclei and two types of tubules)
11 **A** – The sarcoplasmic reticulum, lying parallel to the myofibril Slide 12
12 **B** – Terminal cisterns Slide 12 (the longitudinal tubules enlarge near the T-tubules to form the terminal cistern)
13 **A** – One T-tubule and two terminal cisterns, one on either side Slide 12
14 **B** – Storage of calcium in a very high concentration in its cisternae Slide 12 (it also has a Ca++ pump in its wall)
15 **C** – Invaginations of the membrane containing extracellular fluid that transmit the action potential to the interior Slide 13
16 **D** – Myosin Slide 14 (thick protein = myosin; thin proteins = actin, troponin and tropomyosin)
17 **A** – A tail plus two heads, and these heads are the cross bridges Slide 15
18 **A** – ATP and actin Slide 15 (the myosin head has ATP binding sites and actin-binding sites)
19 **C** – Troponin Slide 16 (calcium filling this site changes the shape and position of troponin)
20 **B** – Wraps around the chain of actin and is connected to troponin Slide 16
21 **C** – Z lines Slide 18 (the sarcomere has a central dark A band and two peripheral light I bands)
22 **B** – The I band is reduced while the A band remains constant Slides 18 & 20 (H zone reduced and the two Z lines get close)
23 **B** – Spread of the action potential along the T-tubules releasing Ca++ from the sarcoplasmic reticulum Slide 26 (step 1)
24 **A** – Binding to troponin C so the troponin–tropomyosin complex moves and exposes the active site on actin Slide 26 (steps 2 & 3)
25 **B** – Active pumping of calcium back into its intracellular stores Slide 26 (step 8)
26 **C** – For both the sliding of the contractile filaments and calcium reuptake Slide 26 (ATP for contraction and for relaxation)
27 **A** – A motor neuron and the muscle fibres supplied by it Slide 28
28 **A** – Less than 10 muscle fibres Slide 28 (coarse movements, e.g. gastrocnemius, 1000–2000 fibres)
29 **A** – 30–50 nm in width and contains acetylcholinesterase Slide 30 (it also contains extracellular fluid: Na and Cl)
30 **B** – Increases Na+ influx producing the end plate potential, then degraded by acetylcholinesterase Slide 31 (nicotinic receptor; ACh → CoA + choline)

Part 2: Essay Answer Key

1. Skeletal muscle in general — Slides 3 & 6

- A. Muscles constitute 50% of the body weight: skeletal muscle 40%, and smooth + cardiac muscle together 10%. The three types are skeletal, smooth and cardiac muscle.
- B. Functions: (1) Movements of the body as a whole or of a part of it (e.g. one limb). (2) Maintenance of the body posture by their tonic contraction and muscle tone. (3) Control of body temperature — 50% of heat production during rest is due to muscle activity, and during exercise heat production is much increased.

2. Comparison between the three types of muscle — Slide 5

- Control: skeletal = voluntary; cardiac = involuntary; smooth = involuntary.
- Cross striations: skeletal = striated; cardiac = striated; smooth = plane.
- Nerve supply: skeletal = somatic; cardiac = autonomic; smooth = autonomic.
- Location: skeletal = attached to the skeleton; cardiac = in the wall of the heart; smooth = in the wall of the viscera.
- Function: skeletal = movement of joints, maintenance of posture and stability; cardiac = movement of blood; smooth = movement of the contents.

3. The tubular system — Slides 11–13

- A. Longitudinal tubules (sarcoplasmic reticulum): lie parallel to the myofibril; contain Ca++ in a very high concentration in their cisternae; store calcium and carry a Ca++ pump in their wall. Transverse tubules (T-tubules): invaginations of the membrane into the interior of the fiber, crossing from one side to the opposite side; contain extracellular fluid; transmit the action potential to the interior of the muscle fibers.
- B. Triad = a group of one T-tubule with two terminal cisterns, one on either side. Functions of the sarcoplasmic reticulum: it stores Ca++ in a very high concentration in its cisternae, and it has a Ca++ pump in its wall.

4. The myofibril — Slides 14–16

- A. Each myofibril is formed of two types of filaments (muscle proteins): a thick protein (myosin) and thin proteins (actin, troponin and tropomyosin).
- B. Each myosin molecule has a tail plus two heads; these heads are also referred to as the cross bridges. The myosin head has ATP binding sites and actin-binding sites.
- C. Actin is spherical and forms two long chains that coil around each other. Tropomyosin wraps around the chain of actin and is connected to troponin. Troponin molecules have binding sites for calcium ions; when a calcium ion fills this site it causes a change in the shape and the position of troponin, so the troponin–tropomyosin complex moves and the active site on actin is exposed.

5. The sarcomere — Slides 18–20

- A. The sarcomere is the functional unit of the skeletal muscle — the repeated pattern of thick and thin filaments in each myofibril (the skeletal muscle therefore appears striated under the microscope). It is bounded by two Z lines, and has a central dark band (the A band) with two peripheral light bands (the I bands).
- B. During contraction the thin filaments slide along the thick filaments, leading to disappearance of the I bands while the A bands remain constant; the H zone is reduced and the two Z lines get close to each other.

6. Excitation–contraction coupling — Slide 26

- A. (1) Spread of the action potential along the transverse (T) tubules causes release of Ca++ from the sarcoplasmic reticulum. (2) Ca++ binds to troponin C. (3) The troponin–tropomyosin complex moves, exposing the active site on actin. (4) The myosin heads (cross bridges) bind to the actin filaments. (5) Bending of the myosin head occurs. (6) Sliding of the thin filaments on the thick filaments with breakdown of an ATP molecule. (7) A new cycle is repeated with a new ATP molecule. (8) On completing contraction, calcium is actively pumped back into its intracellular stores, leading to muscle relaxation.
- B. ATP is the source of energy needed for the sliding of the contractile filaments (muscle contraction) and for calcium reuptake (muscle relaxation).

7. The neuromuscular junction — Slides 28–31

- A. The neuromuscular junction is the junction between a motor neuron and the skeletal muscle fibres. A motor unit consists of a motor neuron and the muscle fibres supplied by it; muscles performing fine and delicate movements (e.g. the eye muscles) have less than 10 muscle fibres per unit, while muscles performing coarse movements (e.g. the gastrocnemius) have many fibres, 1000–2000 per unit.
- B. (1) The motor neuron (presynaptic axon): acetylcholine vesicles, mitochondria and voltage gated Ca++ channels. (2) The synaptic cleft: 30–50 nm in width, containing extracellular fluid (Na, Cl) and the acetyl cholinesterase enzyme. (3) The motor end plate (postsynaptic membrane): receptors formed of a binding protein that unites with the transmitter, and ligand channels (Na+ channels allowing Na+ entry and K+ channels allowing K+ exit).
- C. On arrival of an impulse at the motor neuron the permeability to Ca++ increases; Ca++ diffuses to the interior of the axon, leading to rupture of the vesicles and release of acetylcholine into the synaptic cleft. The released ACh attaches to the ACh receptor of the postsynaptic membrane (nicotinic receptor), which increases Na+ influx and depolarizes the postsynaptic membrane (END PLATE POTENTIAL). The action potential produced is conducted along the muscle fibers and initiates muscle contraction. The EPP is transient because ACh is degraded to CoA and choline by the acetylcholinesterase enzyme.