MUSCLE PHYSIOLOGY

Types and Contraction Mechanism

Lecture Notes | Stage Two

Learning Objectives

- Identify the three main types of muscle tissue.
- Describe the basic structure of skeletal muscle.
- Explain the sliding filament theory and the role of calcium and ATP.
- Compare isometric, concentric, and eccentric contractions.

1. Introduction to Muscle Physiology

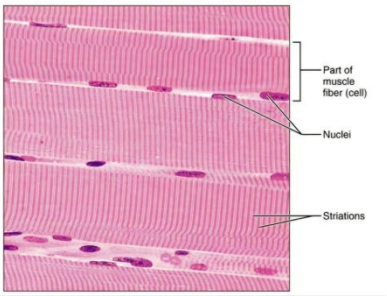
Muscle physiology is the study of how muscles function, contract, generate force, and produce movement. Muscles also help maintain posture, stabilize joints, and produce heat.

2. Types of Muscles

The human body contains three main types of muscle tissue:

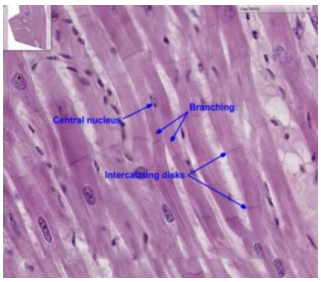
A. Skeletal Muscle

- Voluntary control: usually controlled consciously.
- Attached mainly to bones by tendons.
- Striated appearance under the microscope.
- Functions: body movement, posture, and joint stabilization.



B. Cardiac Muscle

- Involuntary control.
- Found in the wall of the heart (myocardium).
- Striated, branched cells with intercalated discs.
- Function: rhythmic contraction to pump blood.



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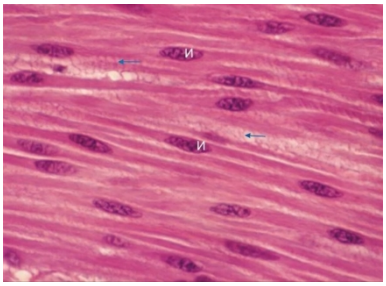
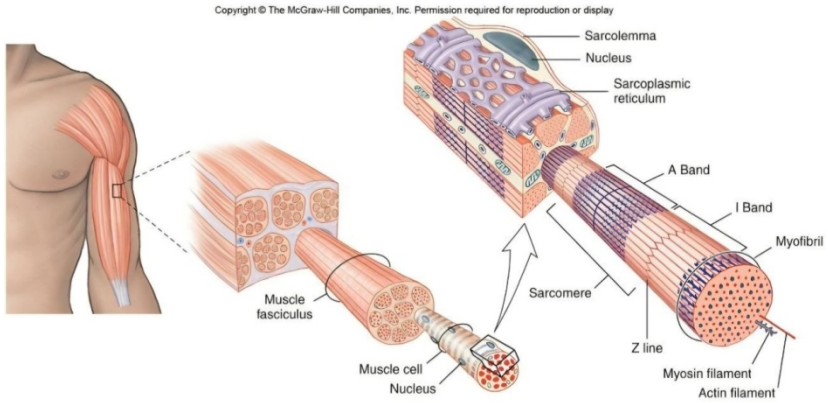
C. Smooth Muscle

- Involuntary control.
- Found in the walls of organs and blood vessels.
- Non-striated, spindle-shaped cells.
- Functions: moving substances through organs and regulating vessel diameter.



3. Structure of Skeletal Muscle

Skeletal muscle is organized from larger structures into smaller components. A muscle contains fascicles; each fascicle contains muscle fibers (cells); each fiber contains myofibrils; and myofibrils contain repeating sarcomeres.



Key Components

- **Sarcomere**: the basic contractile unit of striated muscle.
- **Actin**: the main thin filament protein.
- **Myosin:** the main thick filament protein; its heads bind to actin.
- **Sarcoplasmic reticulum**: stores and releases calcium ions (Ca^{2+}).
- **ATP**: supplies energy for the cross-bridge cycle and calcium pumping.

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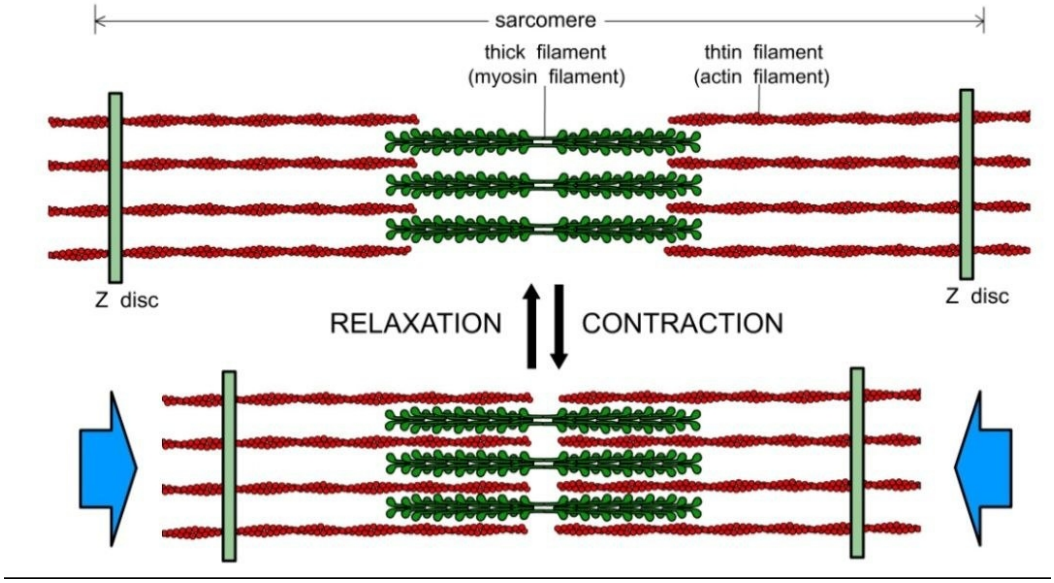
4. Mechanism of Muscle Contraction

The sliding filament theory explains how actin and myosin filaments slide past one another. The filaments themselves do not significantly shorten; instead, the sarcomere shortens and tension is produced.



Steps of Skeletal Muscle Contraction

1. Nerve stimulation: A motor neuron impulse reaches the neuromuscular junction.

2. Acetylcholine release: The nerve terminal releases acetylcholine (ACh), which binds to receptors on the muscle membrane.

3. Muscle action potential: The muscle membrane depolarizes, and the signal travels along the sarcolemma and into T-tubules.

4. Calcium release: The sarcoplasmic reticulum releases Ca^{2+} into the cytoplasm.

5. Cross-bridge formation: Calcium binds to troponin, moving tropomyosin and exposing binding sites on actin. Myosin binds to actin.

6. Power stroke: Myosin heads pull actin filaments inward, generating force and shortening the sarcomere.

7. Detachment and reset: ATP binds to myosin, allowing it to detach from actin; ATP hydrolysis re-cocks the myosin head.

8. Relaxation: When stimulation stops, Ca^{2+} is pumped back into the sarcoplasmic reticulum. Tropomyosin covers the binding sites and tension falls.

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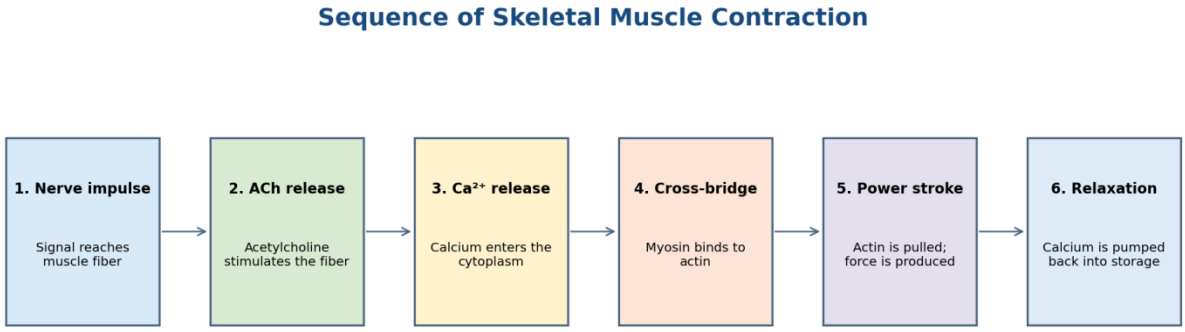
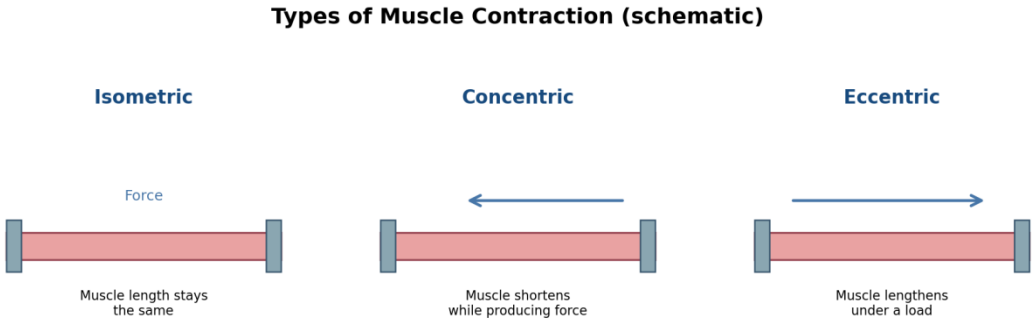


Important note: ATP is required for myosin detachment from actin and for pumping calcium back into storage. Without ATP, normal relaxation cannot occur.

5. Types of Muscle Contraction



Type	Description	Example
Isometric	Muscle produces tension without a major change in length.	Holding a heavy object still.
Concentric	Muscle shortens while producing force.	Lifting a dumbbell.
Eccentric	Muscle lengthens while producing force under a load.	Slowly lowering a dumbbell.

6. Factors Affecting Muscle Contraction

- Availability of calcium ions.
- Availability of ATP.
- Strength and frequency of nerve stimulation.
- Muscle fatigue and metabolic conditions.
- Temperature and the condition of the muscle.

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7. Summary

- The three muscle types are skeletal, cardiac, and smooth.
- The sarcomere is the basic contractile unit of striated muscle.
- Actin and myosin are the main contractile proteins.
- Calcium enables actin–myosin interaction.
- ATP is essential for cross-bridge cycling and muscle relaxation.

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