Lecture4: Muscle Physiology

Learning Objectives

By the end of this lecture, students should be able to:

1. Describe the three main types of muscles.
2. Understand the structure of skeletal muscle fibers.
3. Explain the mechanism of muscle contraction (Sliding Filament Theory).
4. Understand the role of calcium and ATP in muscle contraction.
5. Differentiate between isotonic and isometric contractions.

The muscular system is an organ system composed of the muscle tissue. There are three types of muscle tissue:

- **Cardiac muscle**, which comprises the myocardium of the heart
- **Smooth muscle**, which is found in the walls of the hollow organs and blood vessels
- **Skeletal muscle**, which composes the skeletal muscles

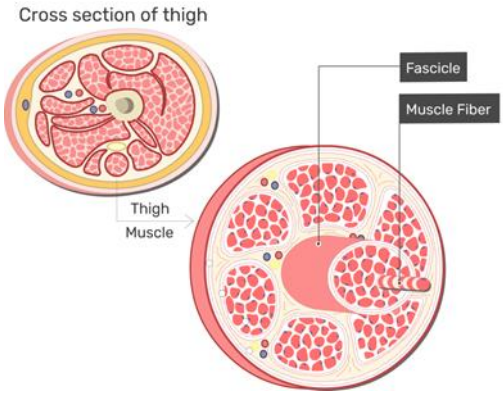
All three types share a characteristic in common - the ability to **contract**. Only skeletal muscles contract voluntarily, enabling us to move the parts of our body. Cardiac and smooth muscles contract involuntarily, as they are under control of the autonomic nervous system.

Types of muscles

Type	Location	Control	Features
Skeletal muscle	Attached to bones	Voluntary	Striated, multinucleated
Cardiac muscle	Heart	Involuntary	Striated, branched
Smooth muscle	Walls of organs (stomach, blood v	Involuntary	Non-striated, single nucleus

Muscle physiology is a branch of physiology that studies the mechanism behind muscle contraction.

🔬 2. Structure of Skeletal Muscle



Skeletal muscles are the type of muscle tissue that enable us with voluntary movements. They are attached to the bones of the skeleton by tendons.

Skeletal muscle fibers have a striated (striped) appearance on histological sections because they are made up of smaller units called **sarcomeres** that run parallel to each other, giving the muscle the striated appearance.

A sarcomere is the smallest functional unit of skeletal muscle tissue, and each sarcomere has thick and thin filaments primarily composed of the proteins thick **myosin** and thin **actin**.

The interaction of actin and myosin causes **muscle contraction** and therefore movement.

A skeletal muscle is made up of bundles:

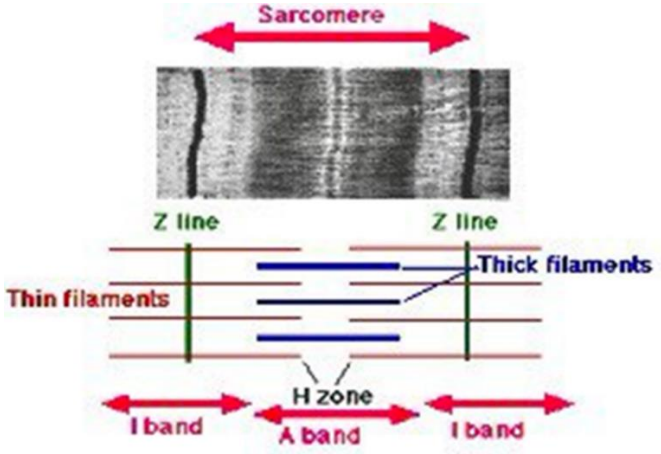
• Muscle → Fascicles → Muscle fibers (cells) → Myofibrils → Myofilaments

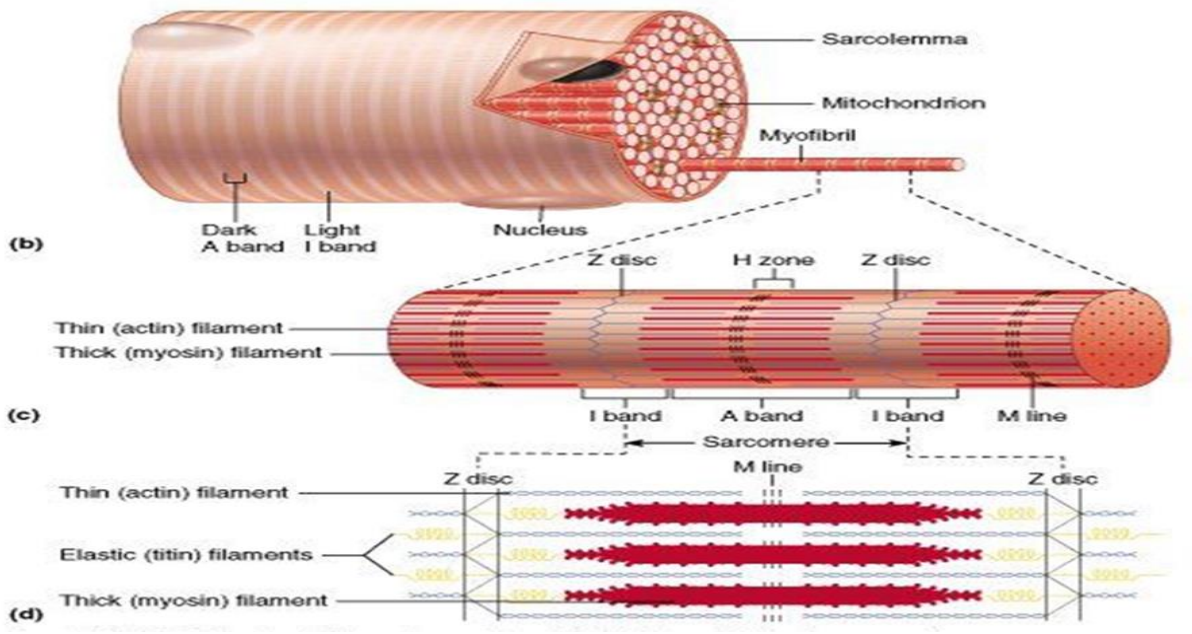
• Myofilaments are the proteins:

• Actin (thin filament)

• Myosin (thick filament)

 The sarcomere is the basic contractile unit of muscle — from Z line to Z line.





⚙ **3. Muscle contraction** is shortening of the muscle fibers initiated by action potentials in motor neurons which cause the release of neurotransmitters from synaptic vesicles.

☞ simply, the neuronal stimulus (action potential) causes the neuron to release a chemical messenger (neurotransmitter) which excites the membrane of the muscle cell and causes it to contract.

On the molecular level, the contraction is a result of an interaction cascade between **myosin** and **actin filaments** inside a muscle fiber (muscle cell).

When enough skeletal muscle cells are excited and contract, that translates into a movement.

Mechanism of Muscle Contraction: Sliding Filament Theory

Step-by-step process:

1. Nerve impulse reaches the muscle fiber → releases acetylcholine (ACh) at the neuromuscular junction.

2. This triggers depolarization of the muscle membrane → Calcium ions (Ca^{2+}) are released from the sarcoplasmic reticulum (SR).

3. Calcium binds to troponin, moving tropomyosin away from binding sites on actin.

4. Myosin heads attach to actin → forming cross-bridges.

5. Using ATP, myosin heads pull actin filaments toward the center of the sarcomere → contraction.

6. When stimulation stops, Ca^{2+} returns to SR, cross-bridges detach, and the muscle relaxes.

💡 Summary Formula:

Excitation → Calcium release → Cross-bridge cycling → Contraction → Relaxation

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🔋 4. Role of ATP and Calcium

- **Calcium (Ca^{2+}):** Starts contraction by binding to troponin.
- **ATP:**
- Detaches myosin from actin.
- Provides energy for myosin head movement.
- Powers calcium reuptake into SR.

Without ATP → muscles stay stiff (as in rigor mortis).
