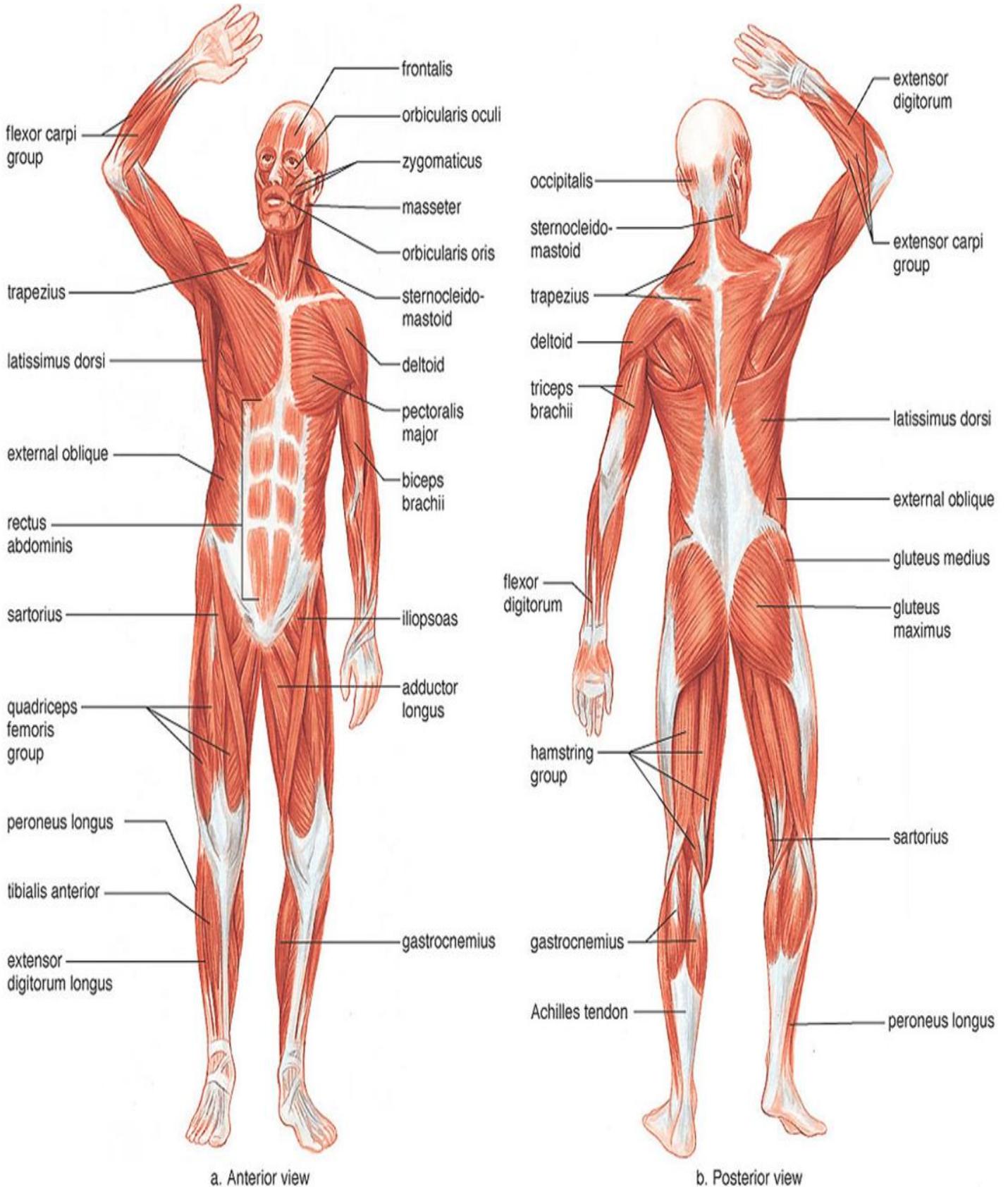




Lec.4

The Muscular System





The muscular system

The muscular system is one of the most important systems of the human body. It is responsible for **Movement**, **Posture**, **Stability**, and the **Production of heat**. Muscles work together with the skeletal and nervous systems to allow the body to move and perform vital functions.

A muscle: *Is a specialized tissue that has the ability to contract and relax. Muscle tissue converts chemical energy (ATP) into mechanical energy, producing force and movement.*

All muscle tissues are composed of specialized cells known as **Muscle Fibers**, which share common physiological characteristics.

General Characteristics of Muscle Tissue: All muscle tissues exhibit the following properties:

- 1. Excitability (Responsiveness):** Ability to respond to chemical, mechanical, or electrical stimuli.
- 2. Conductivity:** Ability to transmit excitation along the muscle cell membrane, initiating contraction.
- 3. Contractility:** Ability to shorten and generate force.
- 4. Extensibility:** Ability to stretch without damage.
- 5. Elasticity:** Ability to return to original length after stretching.

Types of Muscle Tissue: *Muscle tissue is classified into three main types:*

- 1. Skeletal Muscle**
- 2. Cardiac Muscle**
- 3. Smooth Muscle**



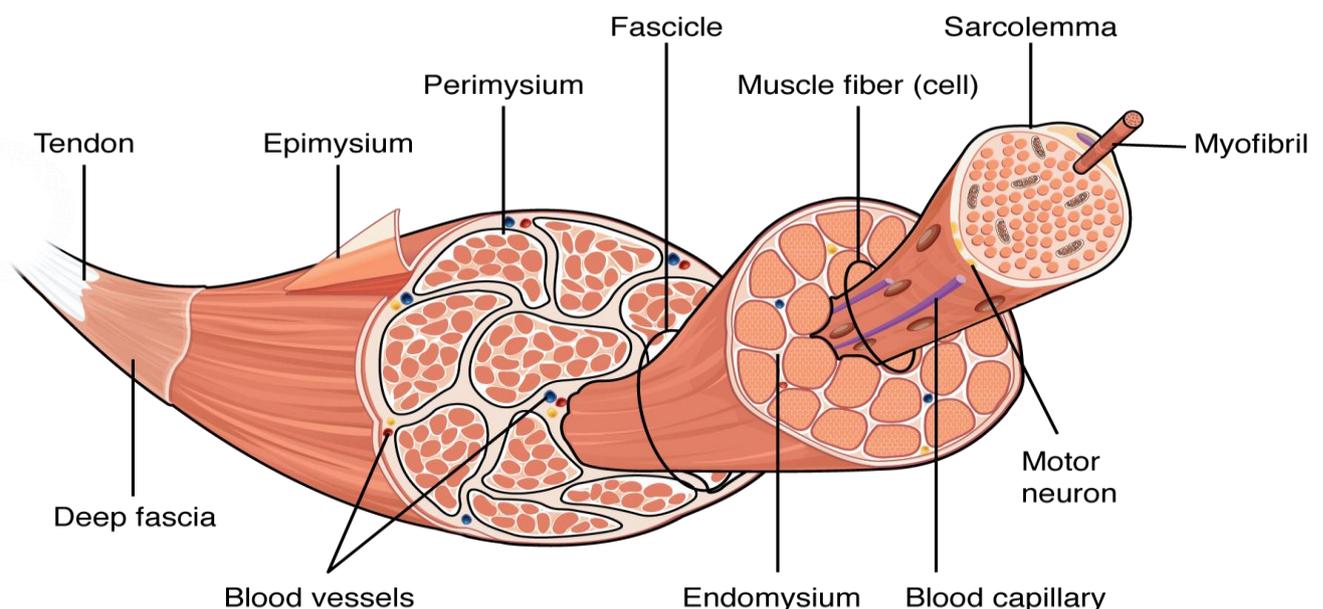
I. Skeletal Muscle

Is a type of muscle tissue composed of **long, cylindrical, multinucleated fibers** that are attached to bones by tendons. It is responsible for **Voluntary Movements** of the body and is controlled by the **Somatic Nervous System**.

A. Structural of Skeletal Muscle

1. Structures of the Whole Muscle

- ✓ **Epimysium:** Dense connective tissue surrounding the entire muscle.
- ✓ **Fascicle:** Bundle of muscle fibers.
- ✓ **Perimysium:** Connective tissue surrounding each fascicle.
- ✓ **Muscle Fiber (Muscle Cell):** Long, cylindrical, multinucleated cell.
- ✓ **Endomysium:** Thin connective tissue surrounding each muscle fiber.
- ✓ **Myofibrils:** Contractile elements within muscle fibers.
- ✓ **Deep Fascia:** Dense connective tissue surrounding muscles.
- ✓ **Tendon:** Connective tissue attaching muscle to bone.
- ✓ **Satellite Cells:** Involved in muscle growth and repair.



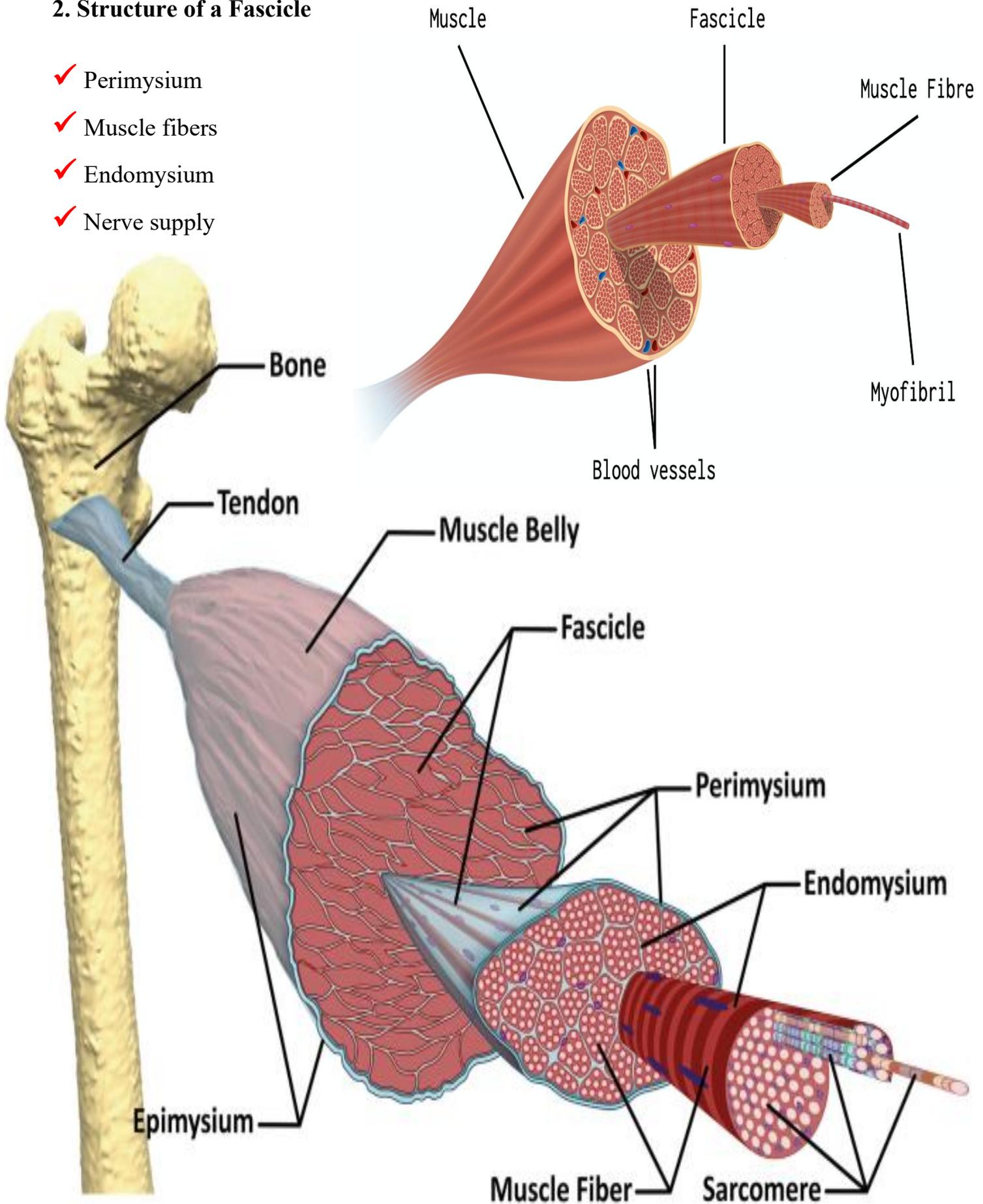


Anatomy and Physiology



2. Structure of a Fascicle

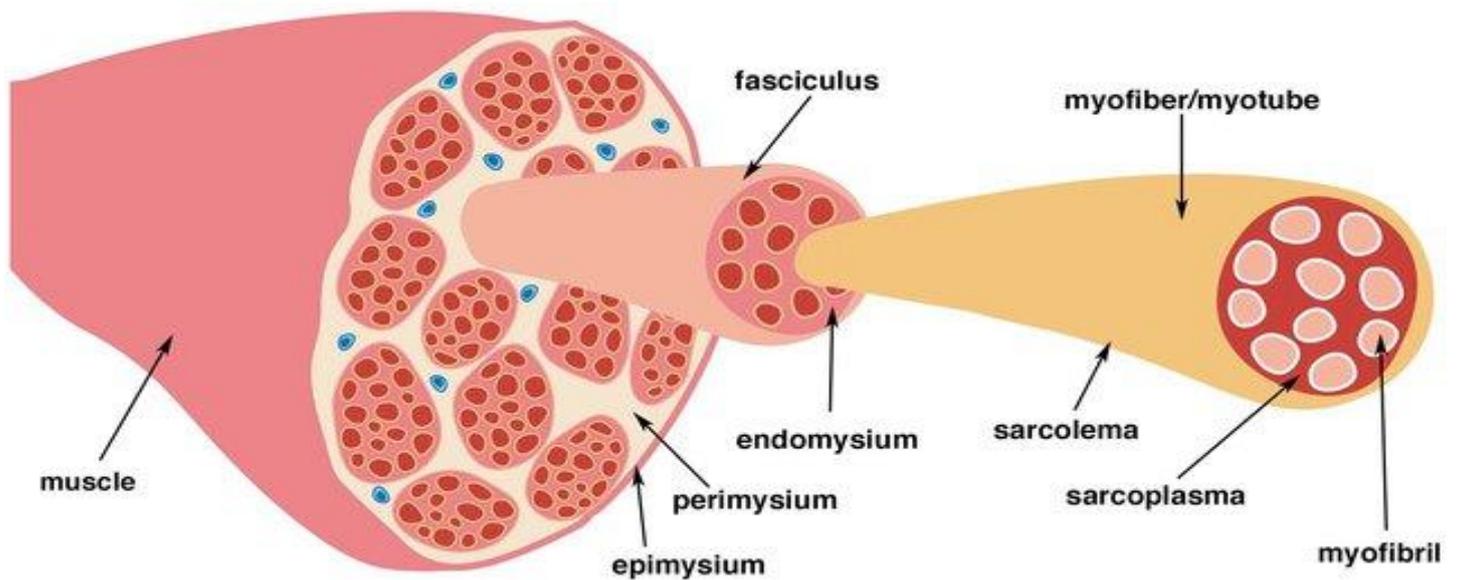
- ✓ Perimysium
- ✓ Muscle fibers
- ✓ Endomysium
- ✓ Nerve supply





3. Structure of a Muscle Fiber (Muscle Cell)

- ✓ Endomysium
- ✓ Myofibrils
- ✓ Neuromuscular junction
- ✓ Multiple peripheral nuclei



B. Myofibrils and Myofilaments

Structural Organization of Myofibrils : Myofibrils are composed of repeating functional units called **sarcomeres**.

Sarcomere: The smallest contractile unit of striated muscle.

Each sarcomere consists of:

- ✓ **Thin filament**: Actin
- ✓ **Thick filament**: Myosin

The precise arrangement of these filaments is responsible for muscle contraction.



C. Neuromuscular Junction (NMJ)

The **neuromuscular junction** is a specialized chemical synapse between a motor neuron and a skeletal muscle fiber, allowing neural control of muscle contraction.

- ✓ Site where a motor neuron communicates with a muscle fiber
- ✓ Neurotransmitter: **Acetylcholine**
- ✓ Initiates muscle contraction

Mechanism of Contraction (Sliding Filament Theory)

1. Nerve impulse reaches muscle fiber
2. Calcium ions released from sarcoplasmic reticulum
3. Myosin heads bind to actin (cross-bridge formation)
4. ATP causes power stroke
5. Sarcomere shortens
6. Muscle contracts

Development of Skeletal Muscle (Myogenesis)

The development of skeletal muscle is known as **myogenesis**. It is a complex, well-organized process that begins during **embryonic development** and continues after birth through growth, adaptation, and repair.

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Anatomy and Physiology



Major Skeletal Muscles: Location and Function

Name of Skeletal Muscle	Location in the Body	Main Function
Frontalis	Forehead	Raises eyebrows, wrinkles forehead
Orbicularis oculi	Around the eye	Closes the eyelids
Orbicularis oris	Around the mouth	Closes and protrudes lips
Masseter	Side of the jaw	Elevates mandible (chewing)
Sternocleidomastoid	Neck	Rotates and flexes the head
Trapezius	Upper back and neck	Moves, elevates, and stabilizes scapula
Deltoid	Shoulder	Abducts the arm
Pectoralis major	Chest	Adducts and flexes the arm
Latissimus dorsi	Mid to lower back	Extends and adducts the arm
Biceps brachii	Front of upper arm	Flexes elbow, supinates forearm
Triceps brachii	Back of upper arm	Extends elbow
Brachialis	Upper arm	Primary elbow flexor
Rectus abdominis	Anterior abdominal wall	Flexes trunk, compresses abdomen
External oblique	Side of abdomen	Rotates and flexes trunk
Erector spinae	Along vertebral column	Extends and supports spine
Gluteus maximus	Buttocks	Extends hip, maintains posture
Iliopsoas	Pelvis to femur	Flexes hip
Adductor longus	Medial thigh	Adducts thigh
Sartorius	Anterior thigh	Flexes hip and knee
Quadriceps femoris	Front of thigh	Extends knee
Hamstrings	Back of thigh	Flexes knee, extends hip
Tibialis anterior	Front of leg	Dorsiflexes foot
Gastrocnemius	Back of lower leg (calf)	Plantar flexes foot
Soleus	Deep calf	Maintains posture, plantar flexion

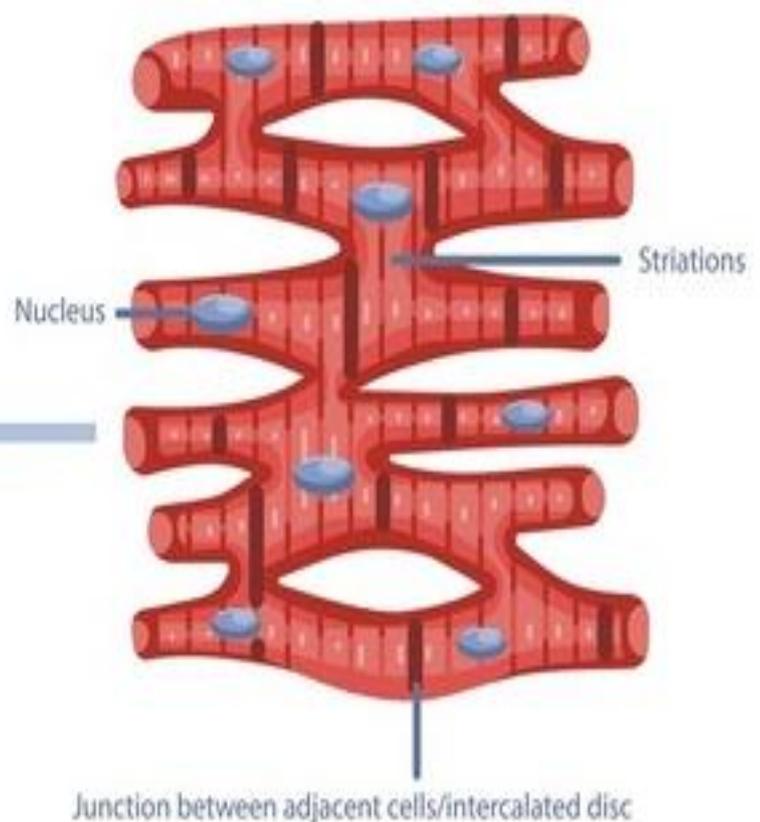
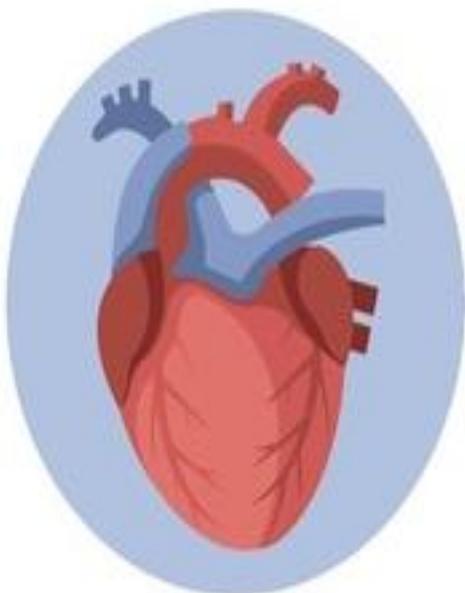


2. Cardiac Muscle

Cardiac muscle fibers are individual muscle cells arranged in interconnected bundles. Unlike skeletal muscle fibers, they are **shorter and thicker** and usually contain **one centrally located nucleus**, although occasionally two nuclei may be present. Cardiac muscle fibers exhibit **Y-shaped branching**, allowing them to join with adjacent fibers. These fibers are connected end-to-end by specialized junctions known as **intercalated discs**, which provide strong mechanical attachment and facilitate rapid electrical communication between cells, ensuring coordinated contraction of the heart.

Cardiac muscle fibers:

- ✓ Are **shorter and thicker** than skeletal muscle fibers.
- ✓ Have **one or two centrally located nuclei**.
- ✓ Form **Y-shaped branching fibers**.
- ✓ Are connected by **intercalated discs**.





Specific Structural Features

1. Intercalated discs
2. Central nucleus
3. Dependence on extracellular Ca^{2+} and sarcoplasmic reticulum
4. Slow onset of contraction
5. Highly resistant to fatigue

Control of Cardiac Muscle Contraction

1. Automaticity (Pacemaker cells)
2. Autonomic nervous system
3. Blood-borne chemicals (hormones, ions)

Metabolism

Cardiac muscle depends mainly on **aerobic metabolism** using fats and carbohydrates.

3. Smooth Muscle

Smooth muscle is a type of **involuntary, non-striated muscle** found in the walls of **hollow organs and tubes**. Its main function is to **move substances through the body** and control internal organ functions.

Structure of Smooth Muscle

- ✓ Cells are spindle-shaped (fusiform) and tapered at both ends.
- ✓ Each cell contains a single, centrally located nucleus.
- ✓ Smooth muscle fibers do not have striations because actin and myosin filaments are arranged irregularly.



- ✓ Fibers are connected to each other by gap junctions in certain types, allowing coordinated contraction.

Characteristics of Smooth Muscle Fibers

1. Small spindle-shaped cells
2. Single central nucleus
3. Capacity for cell division
4. Presence of thick and thin filaments with **dense bodies**
5. No organized myofibrils
6. Slow, sustained contraction
7. Resistant to fatigue
8. Primarily aerobic metabolism
9. Dependence on extracellular Ca^{2+}
10. Absence of T-tubules; dispersed sarcoplasmic

Types of Smooth Muscle

1. Single-unit (visceral) smooth muscle:

- ☞ Found in the **walls of most hollow organs** (e.g., intestines, stomach, uterus).
- ☞ Cells are connected by gap junctions, so the fibers **contract as a single unit**.

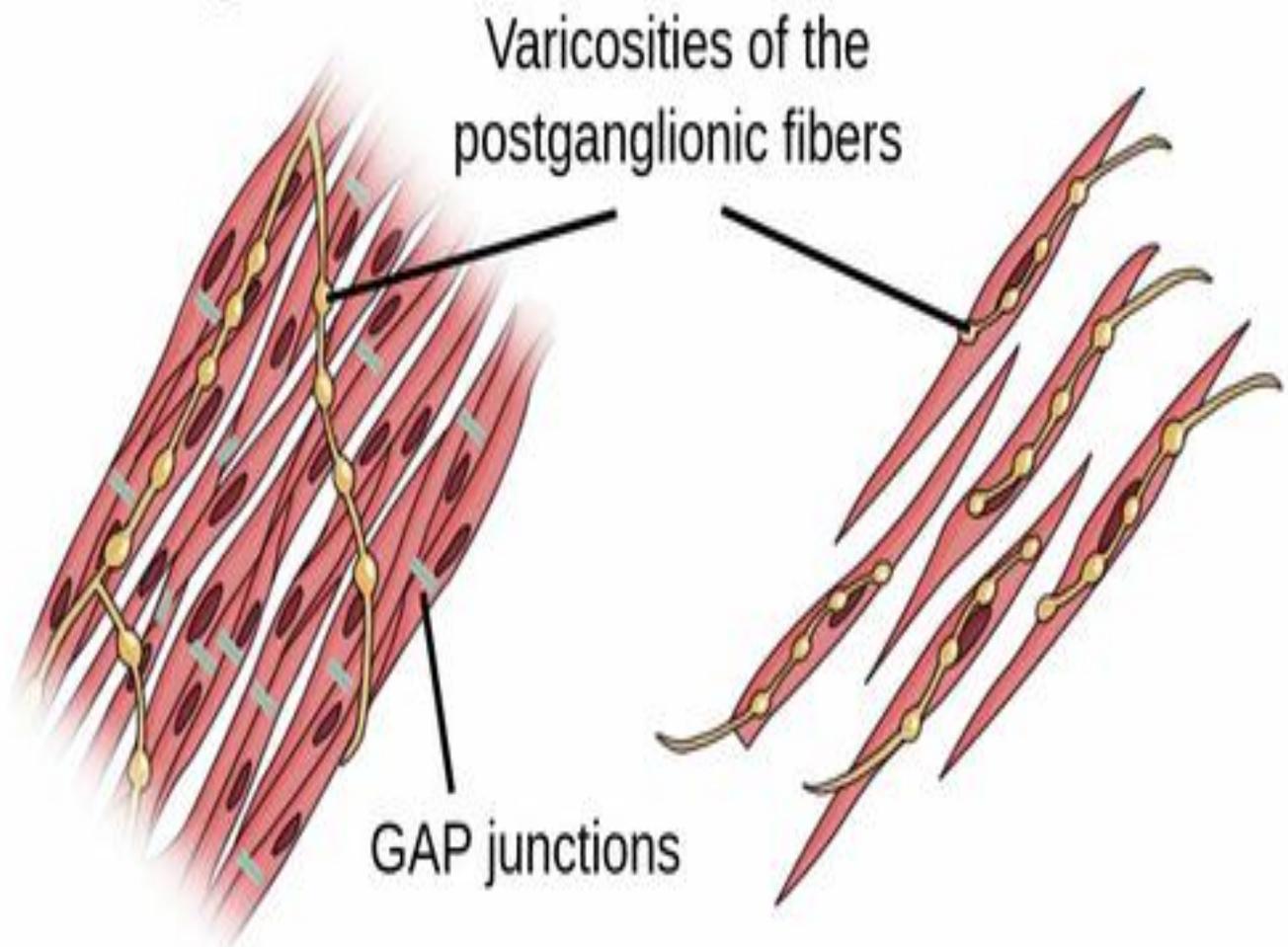
2. Multi-unit smooth muscle:

- ☞ Found in **large airways, large arteries, and iris of the eye**.
- ☞ Cells contract **independently**, allowing fine and precise movements.



Single unit

Multi unit



Functional Characteristics

- ✓ **Involuntary control** by the autonomic nervous system, hormones, and local chemical signals.
- ✓ **Slow and sustained contractions**, highly resistant to fatigue.
- ✓ **Contraction mechanism:**
 - ☞ Calcium binds to **calmodulin** instead of troponin (as in skeletal muscle).
 - ☞ Activates **myosin light-chain kinase**, allowing myosin to interact with actin.



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Functions of Smooth Muscle

- ✓ Moves food along the digestive tract (peristalsis).
- ✓ Regulates blood vessel diameter (controls blood pressure).
- ✓ Controls airways and bronchi in the respiratory system.
- ✓ Assists in urinary bladder and uterus contraction.

Comparison of Skeletal, Cardiac, and Smooth Muscle

Feature	Skeletal Muscle	Cardiac Muscle	Smooth Muscle
Location	Attached to bones	Heart wall (myocardium)	Walls of hollow organs (stomach, intestines, blood vessels, bladder, uterus, iris)
Control	Voluntary (somatic nervous system)	Involuntary (autonomic nervous system)	Involuntary (autonomic nervous system, hormones, local factors)
Fiber Shape	Long, cylindrical	Short, branched (Y-shaped)	Spindle-shaped (fusiform), tapered at ends
Nuclei	Multinucleated, peripherally located	Usually 1 centrally located (sometimes 2)	Single, centrally located
Striations	Present (visible under microscope)	Present	Absent (non-striated)
Cell Junctions	None (fibers act independently)	Intercalated discs (mechanical and electrical connections)	Gap junctions in single-unit type; none in multi-unit
Contraction Speed	Fast	Moderate	Slow
Contraction Type	Voluntary, rapid, and forceful	Involuntary, rhythmic, coordinated	Involuntary, slow, sustained
Fatigue Resistance	Low (fatigues easily)	High (resistant to fatigue)	Very high (can sustain contraction for long periods)
Regeneration/Repair	Limited; satellite cells aid growth and repair	Very limited; some regeneration possible	Moderate; can regenerate via cell division
Function	Body movement, posture, heat production, joint stabilization	Pumps blood, maintains heartbeat, circulates blood	Moves substances through organs, regulates organ diameter, controls internal flow