# Lecture Outline: Muscle Tissue and the Muscular System

I. **Functions of the Muscular System**

A. **Movement**

1. Major function
2. Muscles pull on bones, allowing them to bend at joints

B. **Protection**

1. Layers of muscles, particularly in the anterior abdomen
2. Act as a sheath protecting abdominal viscera (organs)

C. **Thermogenesis**

1. Production of heat
2. Occurs during shivering: uncoordinated muscular contraction causes friction to raise body temperature
3. Part of homeostasis

II. **Muscle Tissue Types and Characteristics**

A. **Three Muscle Tissue Types**

1. Only **skeletal muscle** is included in the muscular system
2. **Cardiac muscle**: Makes up the heart; part of the circulatory system
3. **Smooth muscle**: Found in multiple systems; forms muscular linings of hollow organs (e.g., digestive system, uterus)

B. **Muscle Cell Terminology** (Interchangeable names for a muscle cell)

1. Muscle cell
2. Muscle fiber
3. Myofiber
4. Myocyte

C. **Comparison of Muscle Tissue Types**

1. **Skeletal Muscle**
    a. Shape: Cylindrical, non-tapering, do not branch
    b. Striations: Present and lined up
    c. Nuclei: Multi-nucleate (formed by fusion of multiple cells during development)
    d. Length: Extremely long cells, can be as long as the entire muscle
    e. Contraction:
        (1) Can only actively shorten (pull, cannot push or actively lengthen)
        (2) Requires a signal from a neuron (innervated)
    h. Control: Under conscious control
    i. Contraction Speed: Fastest; has a wide range of speeds (from very fast to intentionally slow)
2. **Cardiac Muscle**
    a. Shape: Cylindrical and branched
    b. Striations: Present, but not all lined up due to branching
    c. Contraction:
        (1) Autorythmic: Contracts on its own with a certain frequency
        (2) Can beat outside the body without neural connection
        (3) Force and frequency of contraction are modulated by the nervous and endocrine systems
    g. Control: Automatic (not conscious)
    h. Contraction Speed: Slower than skeletal muscle; individual contraction speed is consistent, but frequency can be adjusted
3. **Smooth Muscle**
    a. Contraction:
        (1) Autorythmic: Automatic (e.g., moving gut contents)
        (2) Occurs in waves of much lower frequency (over minutes)
    d. Control: Automatic (not conscious)
    e. Contraction Speed: Slowest; contracts very gradually

III. **Skeletal Muscle Structure and Function at Different Levels**

A. **Hierarchical Arrangement** (like a cable)

1. **Whole Muscle**: Bundle of fascicles
    a. Covered by **epimysium** (meaning "over muscle")
    b. Same length as the fascicles and myofibers it contains
2. **Fascicle**: Bundle of myofibers (muscle cells)
    a. Covered by **perimysium** (meaning "around muscle")
3. **Myofiber** (Muscle Cell): Bundle of myofibrils
    a. Surrounded by **endomysium** (meaning "inside muscle")
4. **Myofibril**: Organelle within a muscle cell; composed of repeating subunits called sarcomeres
    a. As long as the whole muscle
    b. Made of protein structures called myofilaments

B. **Tendons**

1. Connect muscle directly to bone
2. Composed of **dense regular connective tissue**
    a. "Dense": Many fibers packed in a small area, making it strong
    b. "Regular": Fibers aligned in parallel, making it strong in one direction (the direction of pull)

C. **Sarcomere Anatomy and Contraction**

1. **Myofilaments** (proteins within myofibrils)
    a. **Thick Filaments**: Made of **myosin** protein
        (1) Centered within the sarcomere (A band, H zone, M line)
        (2) Have golf club-like **myosin heads** that can bind to thin filaments
    d. **Thin Filaments**: Made of **actin** protein
        (1) Anchored to Z disks at the ends of the sarcomere
        (2) Extend toward the middle of the sarcomere
        (3) Contain **active sites** where myosin heads can bind
    h. Overlap exists between thick and thin filaments

2. **Contraction Mechanism** (Sliding Filament Model)
    a. Sarcomere shortens when the amount of overlap between thick and thin filaments increases
    b. Myofilaments (actin and myosin) themselves do not shorten
    c. Myosin heads pull the thin (actin) filaments toward the center of the sarcomere
    d. This action drags the Z disks closer together, shortening the sarcomere
    e. Simultaneous shortening of many sarcomeres along a myofibril leads to significant muscle shortening

IV. **Molecular Basis of Muscle Contraction (Excitation-Contraction Coupling)**

A. **Motor Unit**

1. Comprises one motor neuron and all the skeletal muscle fibers it connects to
2. The axon of a motor neuron can branch, innervating multiple muscle cells
3. If the motor neuron fires, all connected muscle fibers contract simultaneously
4. **Small motor units**: Few branches, allow for delicate movements (e.g., fingers)
5. **Large motor units**: Many branches, recruit many muscle cells at once (e.g., thigh muscles)

B. **Action Potential (AP)**

1. An electrochemical signal; a drastic change in voltage across the plasma membrane
2. **Excitable Tissues** (able to produce and send APs): Muscle tissue and nervous tissue
3. APs propagate along the neuron axon and then along the muscle cell membrane like a chain reaction

C. **Neuromuscular Junction** (Synapse)

1. The specialized site where a neuron axon terminal communicates with a muscle cell
2. Features a tiny gap called the **synaptic cleft** (extracellular fluid)
3. Steps leading to muscle cell action potential:
    a. An action potential reaches the neuron's axon terminal
    b. Voltage change causes calcium ion channels to open in the axon terminal membrane
    c. Calcium ions flow inward (influx) into the neuron
    d. Calcium influx triggers **exocytosis** of vesicles containing neurotransmitters
    e. **Acetylcholine (ACh)**, the specific neurotransmitter for skeletal muscle, is released into the synaptic cleft
    f. ACh diffuses across the cleft and binds to specific **receptors** embedded in the skeletal muscle cell membrane
    g. ACh binding causes sodium ion channels on the muscle cell membrane to open
    h. Sodium ions flow inward (influx) into the muscle cell, causing a change in voltage
    i. Sufficient sodium influx generates a new **action potential in the muscle cell**, which then propagates along its length

D. **Role of Calcium in Muscle Contraction** (within the muscle cell)

1. Before contraction, **regulatory proteins** block the active sites on actin filaments, preventing myosin binding
2. The action potential propagating along the muscle cell triggers the release of calcium ions
3. Calcium ions are released from the **sarcoplasmic reticulum** (a specialized endoplasmic reticulum within muscle cells) into the cell's interior
4. Released calcium binds to the regulatory proteins, causing them to change shape and move away from the actin active sites
5. Exposure of active sites allows myosin heads to bind to actin, forming a **crossbridge**

E. **Power Stroke and Sarcomere Shortening**

1. Once a crossbridge forms, the myosin head changes its angle/shape (the "power stroke")
2. This pulls the attached actin filament toward the center of the sarcomere
3. Since actin filaments are anchored to Z disks, the Z disks are pulled closer, shortening the entire sarcomere

V. **Muscle Abnormalities**

A. **Muscle Cramps**

1. Usually caused by an **ionic imbalance**
2. Results in abnormal action potentials being generated in muscle cells without proper neural input

B. **Muscle Spasms**

1. Occur when a neuron fires unintentionally, causing the muscle to contract
2. Muscle simply obeys the signal from the neuron

VI. **Muscle Attachment Points and Body Movements**

A. **Attachment Points**

1. Skeletal muscles typically cross a movable joint
2. Connect to bones via tendons at two points:
    a. **Origin**: The attachment point on the bone that remains relatively stationary during contraction
    b. **Insertion**: The attachment point on the bone that moves when the muscle contracts

B. **Major Kinds of Motions** (often occur in antagonistic pairs)

1. **Flexion and Extension**
    a. Occur in the **sagittal plane**
    b. **Flexion**: Decreases the angle of a joint (e.g., bending elbow, nodding "yes")
    c. **Extension**: Increases the angle of a joint, undoing flexion (e.g., straightening elbow)

    d. **Hyperextension**: Extension beyond the anatomical position (possible in some joints)

2. **Rotation**
    a. Pivoting motion (e.g., shaking head "no" between atlas and axis vertebrae, rotating femur)
3. **Abduction and Adduction**
    a. Occur in the **frontal (coronal) plane**
    b. **Abduction**: Movement of a body part farther from the midline (e.g., lifting arm out to the side, spreading fingers)
    c. **Adduction**: Movement of a body part toward the midline, undoing abduction (e.g., bringing arm back to side, bringing fingers together)
4. **Circumduction**
    a. Movement of a limb in a cone shape
    b. Combination of flexion, abduction, extension, and adduction
5. **Dorsiflexion and Plantar Flexion** (specific to the foot/ankle)
    a. Occur in the **sagittal plane**
    b. **Dorsiflexion**: Moving the ankle so toes are closer to the front of the body (pulling foot up)
    c. **Plantar Flexion**: Moving the ankle so toes are farther from the front of the body (pointing toes, standing on balls of feet)
6. **Eversion and Inversion** (specific to the foot)
    a. Occur in the **frontal (coronal) plane**
    b. **Eversion**: Pointing the sole of the foot laterally (outward)
    c. **Inversion**: Pointing the sole of the foot medially (inward); excessive inversion can cause a "rolled ankle"
7. **Pronation and Supination** (specific to the forearm)
    a. **Supination**: Palms facing anteriorly (anatomical position); radius and ulna are parallel
    b. **Pronation**: Palms facing posteriorly/downward; the radius twists over the ulna, crossing the bones

8. **Opposition and Reposition** (specific to the thumb)
    a. **Opposition**: Bringing the thumb together with the tip of any other finger
    b. **Reposition**: The opposite action, moving the thumb away from the fingers

VII. **Specific Muscles of the Body (Lab Material)**

A. **Muscles of the Head and Neck**

1. **Orbicularis Oculi**: Muscle around the eye (oculi refers to eye, orbicularis refers to spherical shape)
2. **Masseter**:
    a. Muscle of mastication (chewing)
    b. Extremely strong for its size
    c. Originates on the zygomatic arch (part of the temporal bone)
    d. Inserts on the mandible
    e. Action: Pulls the mandible superiorly (upward)
3. **Sternocleidomastoid**:
    a. Long name reflecting attachment points:
        (1) "Sterno": Sternum
        (2) "Clydo": Clavicle
        (3) "Mastoid": Mastoid process (a breast-like projection of the temporal bone)

B. **Muscles of the Torso and Upper Limb**

1. **Deltoid**:
    a. "Deltoid": Means triangular shape (like the Greek letter Delta)
    b. Covers the shoulder region
2. **Pectoralis Major**:
    a. "Pectoralis": Refers to the chest or breastplate region
    b. "Major": The larger and more superficial of the pectoralis muscles
3. **Biceps Brachii**:
    a. "Brachii": Refers to the arm (brachium)

b. "Biceps": A singular term meaning "two heads," referring to its two heads of origin (attachment points) superiorly

4. **Rectus Abdominis**:
    a. "Abdominis": An abdominal muscle
    b. "Rectus": Means straight; its fibers are arranged straight along the long axis
    c. Contributes to protection of abdominal organs
5. **External Oblique**:
    a. Superficial abdominal muscle, located on either side of the rectus abdominis
    b. "Oblique": Refers to its diagonal fiber arrangement (forms a V-shape)
    c. Part of a three-layered abdominal wall (internal oblique and transversus abdominis are deeper but not required)

C. **Muscles of the Lower Limb**

1. **Sartorius**:
    a. Longest muscle in the body
    b. Originates on the coxal bone (ischium) and extends diagonally across the thigh to the medial part of the knee
    c. "Sartorius" (tailor's muscle): Named because its action allows crossing the legs, similar to a tailor's sitting posture
2. **Quadriceps Femoris Group**:
    a. "Quadriceps": Refers to the four muscles in this group
    b. "Femoris": Refers to its location in the thigh (femur region)
    c. Primary action: Straightens the knee
    d. Three individual muscles to know within this group:
        (1) **Rectus Femoris**: Straight down the front of the thigh
        (2) **Vastus Lateralis**: Large muscle positioned laterally on the thigh
        (3) **Vastus Medialis**: Large muscle positioned medially on the thigh

3. **Gastrocnemius**:
    a. Posterior leg muscle (calf muscle)
    b. "Gastro": Means belly, referring to its prominent "bellies" or fatty parts
    c. Connected to the **calcaneal tendon** (Achilles tendon)
    d. The calcaneal tendon attaches to the calcaneus (heel bone)
    e. Action: Causes **plantar flexion** (e.g., standing on the balls of the feet)