

Muscular System

MED 164

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Objectives

- Structure and functions of muscular system
- Characteristics of muscles
- Types of muscular tissue
- Movement of muscles
- Cell components of muscle
- Sliding filament theory
- Types of contraction
- Muscle tone
- Energetics of muscle

Objectives

- Smooth muscle
- Names of common muscles

Energetics of Muscle

- Muscles convert potential energy into kinetic energy
 - Converts ATP into movement and heat!

Functions of muscle

- **Primary function is movement**
 - Move person and substances within body
- **Provides posture**
 - Allows us to remain upright
- **Stabilizes joints**
 - Tendons connects muscles to bones and often extends over joints
- **Assists in homeostatic regulation of body temperature**
 - 85% of heat produced in body comes from muscular contraction

Characteristics of Muscular Tissue

- **Excitability**
 - ability to receive and respond to a stimulus
- **Contractility**
 - ability to shorten
- **Elasticity**
 - ability to recoil
- **Extensibility**
 - ability to be stretched

Types of Muscular Tissue

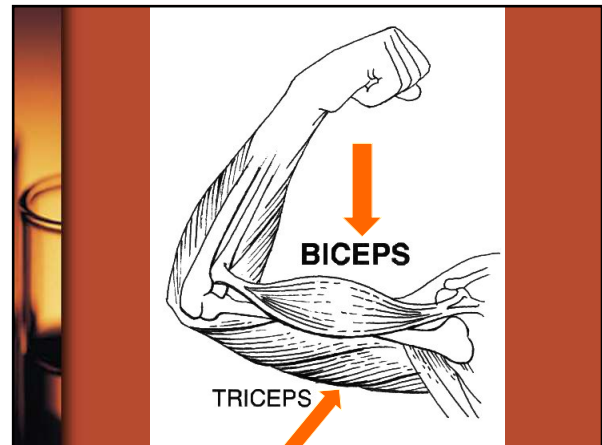
- **Skeletal**
 - Largest mass of muscles in human body
 - Voluntary
 - Controlled by peripheral nervous system
 - Tissue is striated
- **Smooth**
 - Important in physiological regulation
 - Controlled by autonomic nervous system and local mechanisms
 - Tissue is not striated

Types of Muscular Tissue

- **Cardiac**
 - Muscular tissue found in the heart
 - Doesn't require stimulation from nervous system
 - Some cardiac cells are automatic (generate their own contractile stimulus)
 - Tissue is striated
 - Cardiac muscle is hybrid of smooth and skeletal

States of a muscle

- Muscles have two states of existence
- **Contracted**
 - Muscle length is shortened
 - Cellular changes cause shortening to occur
- **Relaxed**
 - Cellular changes cause muscle relaxation
 - However, relaxation does not return the muscle back to its original length. It requires an antagonistic muscle



Force of skeletal muscle

- Force of contraction is exerted along a straight line
 - Cardiac and smooth muscle differ slightly
- Causes muscle to shorten in length

The diagram shows a red double-headed arrow pointing left and right, positioned above a solid blue horizontal rectangle. This represents the force of contraction exerted along a straight line, which causes the muscle (represented by the blue rectangle) to shorten in length.

How does the muscle create movement?

- **Origin**
 - Immoveable end of muscle
- **Insertion**
 - Moveable end of muscle
- **Agonist**
 - Prime mover
- **Synergist**
 - Helpers
- **Antagonist**
 - Oppose primer mover
 - Return muscle back to normal position

The diagram shows the biceps muscle in a human arm with the following labels: Coracoid process, Origins of biceps brachii, Tendon of long head, Tendon of short head, Biceps brachii, Radius, and Insertion of biceps brachii.

Skeletal Muscle Structure

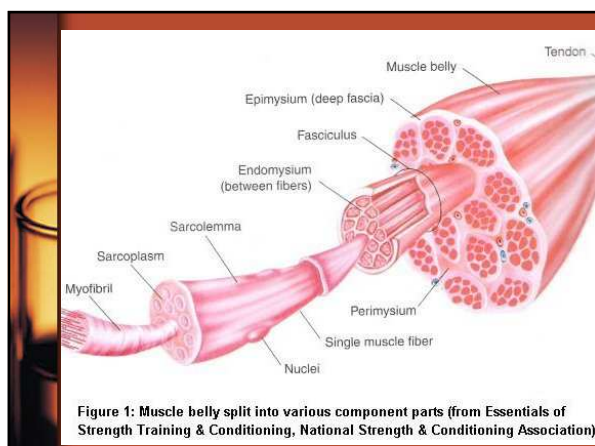
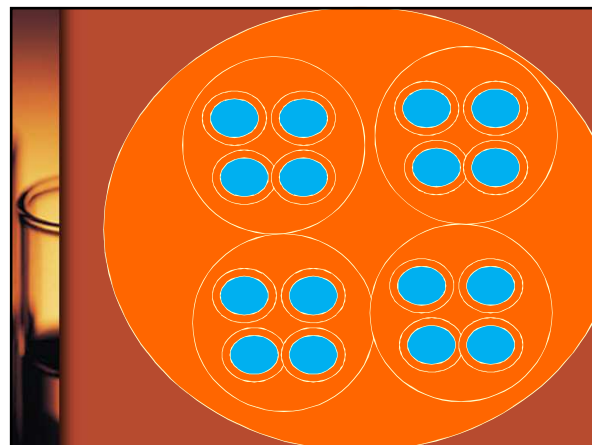
- Primarily made of two tissue types
 - Contractile cells called myocytes (muscle cells)
 - Connective tissue
 - Can connect muscles to muscles
 - Can connect muscles to bones

Connective Tissue of Skeletal Muscle

- Individual myocytes are covered by **endomysium**
- Groups of myocytes (fasiculus) are covered by **perimysium**
- Groups of fasciuli (muscle) are covered by **epimysium**
- Additional tougher layer covers the muscle called **fascia**

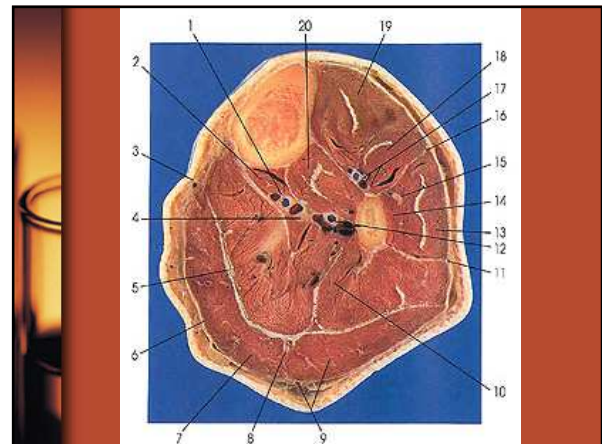
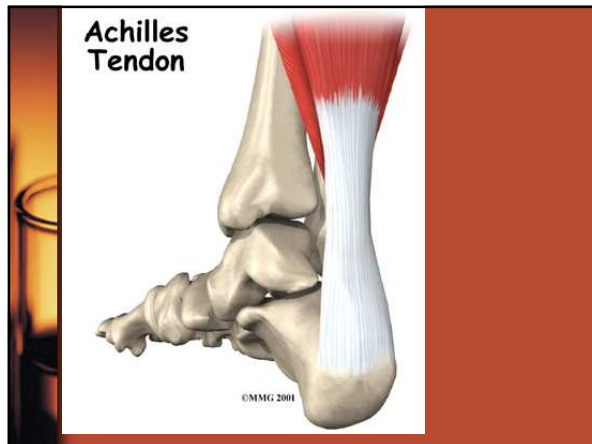
Muscle to Muscle Connection

- Endo, peri, and epimysium are all made of same type of connective tissue
- Composed of collagen and elastin
 - Gives tissue strength and elasticity
- Fascia primarily made of collagen and very little elastin
 - Strong but does not stretch
 - Cause a condition called compartment syndrome



Muscle to Bone Connection

- Tendons connect muscles to bones
- Made of collagen and elastin
 - Much more collagen than elastin
 - Tendons have some flexibility
 - Tendons are very strong



Myocytes

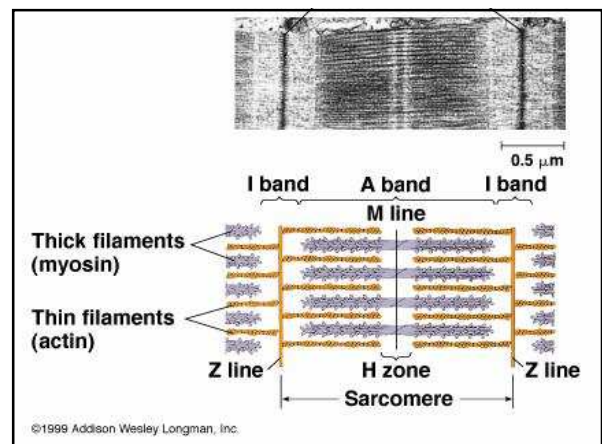
- Thickest cell in the body
- One of the longest cell types in the body
 - Some neurons are longer!
- Large multinucleated cells result from fusion of many smaller cells in uterine development
 - Begin forming during second trimester

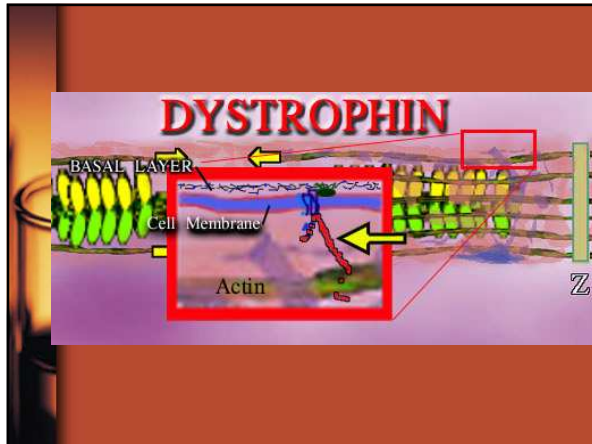
Myocytes

- Contains specialized organelles
 - **T-tubules** are invaginations of cell membrane
 - **Sarcoplasmic reticulum** specialized ER that holds large amounts of calcium ions
 - **Sarcolemma** is another name for cell membrane of a muscle cell
 - **Myofibrils** specialized proteins designed for contraction
 - Gives muscle ability to contract
 - Made of actin and myosin

Myofibrils

- Picture cables running throughout the cell
- Gives skeletal muscle striated appearance
- Organization of myosin and actin gives the cell a striated appearance





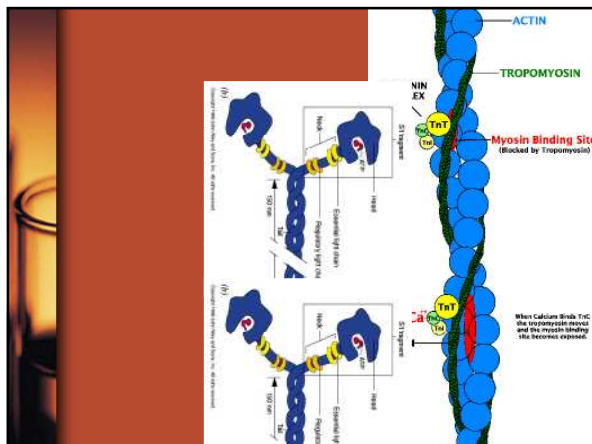
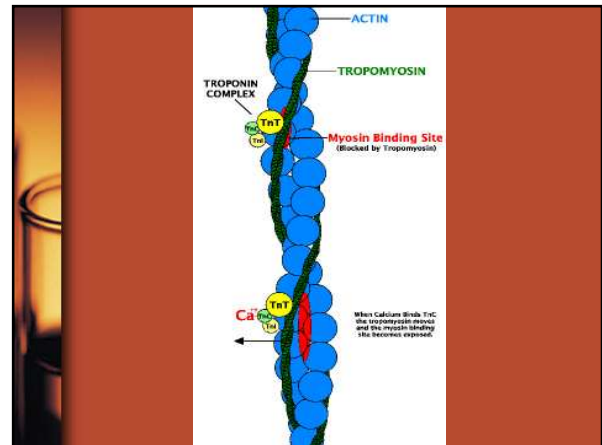
Myosin

- Also called the "thick filament"
- Contains two regions
 - Head that binds actin
 - Chain that twists together with other myosin filaments

S1 fragment
Head
ATP
Neck
Essential light chain
Regulatory light chain
Tail
150 nm
(b)
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Actin

- Also called "thin filament"
- Contains a binding site for the myosin head
- Two other proteins bound to actin
 - Tropomyosin
 - Troponin
- Covers the myosin binding site
- Binds tropomyosin to actin
- When bound to calcium it uncovers binding site

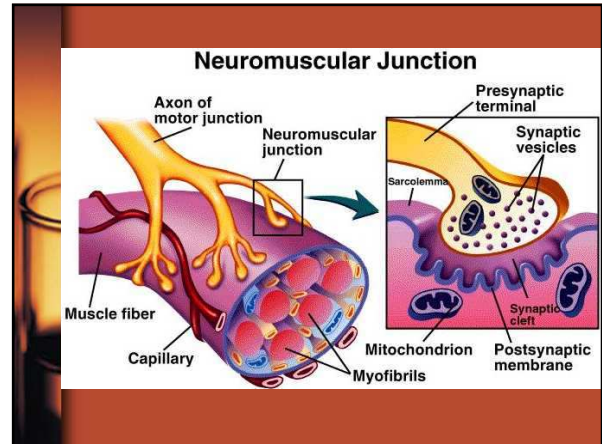


Sliding Filament Theory

- Calcium releases from SR and binds to troponin
- Myosin binds actin
- "Power stroke" myosin head contracts and pulls actin toward M line
- ATP binds myosin head and myosin and actin release from each other
- ATP is catabolized and myosin head restores its "cocked" shape
- Calcium goes back to SR

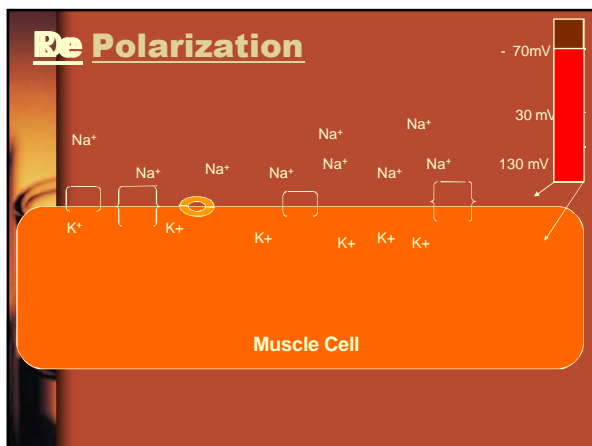
Neuromuscular Junction

- Every muscle is controlled by a nerve
- Nerve does not directly touch the muscle
- It communicates through a space called the synapse
- Nerve releases chemicals called neurotransmitters that open channels in the muscle cell



Action Potential

- Membrane of muscle cell is specialized to carry transmit electrical signals over its surface
- Signal is called an action potential
- Results from the temporary movement of ions across the membrane



Types of contraction

- Isometric
 - Muscles contract but no physical movement is seen
 - Involved in “muscle tone”
 - All muscles have some degree of tone
 - Posture results from tone
- Isometric exercise increases muscle tone and strength but not size
 - Hanging from a bar

Types of contraction

- Isotonic
 - Muscles contract and move
- Isotonic exercise improves muscle tone, strength, and size
 - Pull ups on a bar

Muscle Tone

- State of continuous, passive partial contraction of a muscle
- Occurs without thought or conscious decision
- Helps guard against danger and assists with maintaining balance

Energetics of Muscle

- Muscle requires a lot of energy (ATP)
- Even in well trained athletes, there is only 5-6 seconds of energy available as ATP
- Muscle cells must be able to create ATP quickly
- The hydrolysis of ATP results in ADP and an inorganic phosphate molecule
- Muscle cells can regenerate ATP in three different mechanisms

ATP anabolism

- Phosphagen System
 - Creatine Phosphate
 - Gives 10 – 15 seconds of energy
- Glycogen - Lactic Acid System
 - Breaks glycogen into glucose and rapidly breaks down through glycolysis
 - Gives 30 – 40 seconds of energy
- Aerobic Respiration
 - Sends pyruvate to mitochondria
 - Lasts as long as there are resources
 - Limited by oxygen

Oxygen in muscle

- Muscle cells get oxygen through two mechanisms
 - Hemoglobin from red blood cells
 - Myoglobin in muscle cells
- After periods of intense exercise, you will deplete the oxygen stored in the body
 - Oxygen debt
- Stores need to be replenished immediately after exercising
 - Breathe hard and fast

Heat Production

- Hydrolysis of ATP produces 30.5 kJ of heat
- Body temperature is increased when muscles are active
- Used when body is hypothermic -> shivering

Smooth Muscle

- Contains actin and myosin but not arranged in sarcomeres
 - Not striated
 - Filaments are connected to dense bodies
- Cells are branched and connect to more than one cell
- Contraction results from same interactions of myosin and actin but it is stimulated in a different manner
- Doesn't contain troponin it utilizes a protein called calmodulin

Smooth Muscle

- Each muscle does not require its own nerve supply
- Cells are connected by gap junctions and are able to communicate with each other
- Responds slower than skeletal muscle
- More resistant to fatigue
- Doesn't use the same amount of energy

