Muscle Tissue
- A primary tissue type, divided into:
  - skeletal muscle
  - cardiac muscle
  - smooth muscle

Functions of Skeletal Muscles
- Produce skeletal movement
- Maintain body position
- Support soft tissues
- Guard body openings
- Maintain body temperature

Organization of Connective Tissues
- Muscles have 3 layers of connective tissues:
  - epimysium
  - perimysium
  - endomysium

Epimysium
- Exterior collagen layer
- Connected to deep fascia
- Separates muscle from surrounding tissues

Perimysium
- Surrounds muscle fiber bundles (fascicles)
- Contains blood vessels and nerves

Endomysium
- Surrounds individual cells (muscle fibers)
- Contains capillaries and nerve fibers
- Contains satellite cells (stem cells) that repair damage

Muscle Attachments
- Endomysium, perimysium, and epimysium come together:
  - at ends of muscles
  - to form connective tissue attachment to bone matrix
  - i.e., tendon (bundle) or aponeurosis (sheet)
Formation of Skeletal Muscle Fibers
• Skeletal muscle cells are called fibers

Cell Structure & Organization
• Sarcolemma - cell membrane
• Sarcoplasm - cytoplasm
• T-Tubules
  - Allow entire muscle fiber to contract simultaneously
• Sarcoplasmic Reticulum
  - Contains calcium
• Myofilaments

Sarcoplasmic Reticulum
• A sac-like structure surrounding each myofibril
• Forms chambers (terminal cisternae) attached to T tubules
• Releases calcium into myofibril area
  - Calcium exits SR via terminal cisternae
• Contains pumps to bring calcium back in

Myofibrils
• Made up of bundles of protein (myofilaments)
• 2 types of myofilaments are responsible for muscle contraction
  - Thin filaments = Actin
  - Thick filaments = Myosin

Myosin
• Myosin heads are ‘spring loaded’
• During contraction, myosin heads:
  - interact with actin filaments, forming cross-bridges
  - pivot, producing motion

Actin
• Rope of 2 twisted ‘bead strands’ with active site for myosin heads to attach to
  - Has regulatory proteins wrapping around it to control when myosin can attach, or not
    • Troponin
    • Tropomyosin
Thin Filament Regulatory Proteins

- Tropomyosin:
  - wraps around actin
  - Covers active site on actin, preventing myosin crossbridges from binding
- Troponin:
  - controlled by Ca\(^{2+}\)
  - causes tropomyosin to shift (move over) and expose the active site on actin

Sarcomeres

- The contractile units of muscle
- Structural units of myofibrils
- Form visible patterns within myofibrils called striations

Lines and Zones

- Z lines:
  - the centers of the I bands
  - at 2 ends of sarcomere
- M line:
  - the center of the A band
- H zone
  - The area around the M line
  - has thick filaments but no thin filaments
Skeletal Muscle Contraction

- Sliding filament theory:
  - thin filaments of sarcomere slide toward M line
  - thin filaments move over thick filaments
  - Z lines move closer together

Initiating Contraction

- Ca^{2+} released from SR
- Ca^{2+} binds to receptor on troponin molecule
- troponin-tropomyosin complex changes
- tropomyosin moves to expose active site on actin
- myosin crossbridges attach to actin
- crossbridges pull on actin

5 Steps of the Contraction Cycle

1. Exposure of active sites (Ca^{2+}, Tn, Tm)
2. Binding of cross-bridges (myosin)
3. Pivoting of myosin heads
4. Detachment of cross-bridges (ATP)
5. Re-binding of cross-bridges

Fiber Shortening

- As sarcomeres shorten, muscle pulls together, producing tension

Relaxation

- Ca^{2+} pumps on SR membrane remove Ca^{2+} from sarcoplasm
- Sarcoplasmic Ca^{2+} concentrations fall
- Ca^{2+} detaches from troponin
- Active sites are recovered by tropomyosin
- Crossbridges detach
MUSCLE TISSUE (MUSCLE PHYSIOLOGY)
PART II: EXCITATION-CONTRACTION COUPLING
(B) NEUROMUSCULAR ACTIVATION

The Neuromuscular Junction
• Is the location of neural stimulation
• Action potential (electrical signal):
  - travels along nerve axon
  - ends at synaptic terminal

Synaptic Terminal
• Releases neurotransmitter (acetylcholine)
• Into the synaptic cleft (gap between synaptic terminal and motor end plate)

The Neurotransmitter
• Acetylcholine:
  - travels across the synaptic cleft
  - binds to membrane receptors on sarcolemma (motor end plate)
  - causes sodium-ion rush into sarcoplasm
  - is quickly broken down and inactivated by enzyme (acetylcholinesterase)

Motor Units in a Skeletal Muscle
• Contain hundreds of muscle fibers
• That contract at the same time Controlled by a single motor neuron

Recruitment (Multiple Motor Units)
• In a whole muscle or group of muscles, smooth motion and increasing tension is produced by slowly increasing size or number of motor units stimulated
Tension Production

• The all-or-none principal:
  - as a whole, a muscle fiber is either contracted or relaxed

Tension of a Single Muscle Fiber

• Depends on the number of crossbridges attached:
  - fiber’s resting length at the time of stimulation
  - frequency of stimulation

3 Phases of a Twitch

• Latent period
  • Ca\(^{2+}\) release
  • Troponin- Ca\(^{2+}\) binding
  • Tropomyosin move over
• Contraction phase
  • Crossbridge binding
• Relaxation phase
  • Crossbridge unbinding

Frequency of Stimulation

• A single neural stimulation produces:
  - a single contraction or twitch
• Sustained muscular contractions:
  - require many repeated stimuli

Treppe

• A stair-step increase in twitch tension
• Repeated stimulations immediately after relaxation phase

Wave Summation

• Increasing tension or summation of twitches
• Repeated stimulations before the end of relaxation phase

Incomplete Tetanus

• Twitches reach maximum tension if rapid stimulation continues and muscle is not allowed to relax entirely
Complete Tetanus

- If stimulation frequency is high enough, muscle never begins to relax, and is in continuous contraction

*What are the types of muscle contractions, and how do they differ?*

2 Types of Skeletal Muscle Tension

- **Isotonic contraction**
  - Muscle changes length
  - **Concentric contraction**
    - Shortens with tension
  - **Eccentric contraction**
    - Lengthens with tension

- **Isometric contraction**
  - Muscle stays same length
  - Develops tension without shortening
ATP and Muscle Contraction
- Muscles (and all cells) need ATP
- Two methods to produce ATP
  - Glycolysis in cytosol
    - Does not need oxygen
  - Krebs cycle and electron transport chain
    - In mitochondria
    - Needs oxygen to sustain production

ATP and CP Reserves
- Adenosine triphosphate (ATP):
  - the active energy molecule
- Creatine phosphate (CP):
  - the storage molecule for excess ATP energy in resting muscle

Low - High Exertion
Low exertion
- Little ATP needed
- Plenty of oxygen available
- Energy:
  - Glycolysis
  - Krebs/electron transport chain

High exertion
- Lots of ATP needed
- Limited oxygen due to increased demand
- Energy:
  - Glycolysis byproduct produced = lactic acid
  - Krebs/electron transport limited due to lack of oxygen

3 Types of Skeletal Muscle Fibers
- Fast (twitch) fibers
  - Large size, few mitochondria
  - Increases size with strength (hypertrophy)
  - Strong, fast, fatigue quickly
- Slow (twitch) fibers
  - Lots of mitochondria and myoglobin
  - Slow, long-lasting contractions
- Intermediate fibers
Cardiac Tissue
Cardiocytes:
- striated
- involuntary
- small and branched
- single nucleus
- self-activated
- all cardiocytes contract with each beat
- have intercalated discs
  - are specialized contact points between cardiocytes

Cardiac Force Development
- One stimulation at a time
  - No wave summation, tetanus, etc.
- Muscle fiber stretch
- Neurologic or Adrenergic activation
- ...troponin activation increases crossbridge formation

Smooth Muscle in Body Systems
- Blood vessels:
  - regulates blood pressure and flow
- Reproductive and glandular systems:
  - produces movements
- Digestive and urinary systems:
  - forms sphincters
  - produces contractions
- Integumentary system:
  - arrector pili muscles cause goose bumps

Smooth Muscle Tissue
- no striations, involuntary
- Slender fibers
- single nucleus
- no T tubules, myofibrils, or sarcomeres
- no tendons or aponeuroses
- sustains contractions for extended periods of time