Human Anatomy

Muscle Tissue and
Organization

Tissue and Organization

- Over 700 skeletal muscles have been named.
- Form the muscular system.
- Muscle tissue is distributed almost everywhere in the body.
- Responsible for the movement of materials within and throughout the body.

4 Unique Characteristics of Muscle Tissue

- Excitability is equated with responsiveness.
- Contractility causes the fiber to shorten resulting in either a pull on bones or the movement of specific body parts.
- Elasticity is the muscle's ability to return to its original length when tension is released.
- Extensibility is capability of extending in length in response to the contraction of opposing muscle fibers.

Skeletal Muscle Tissue

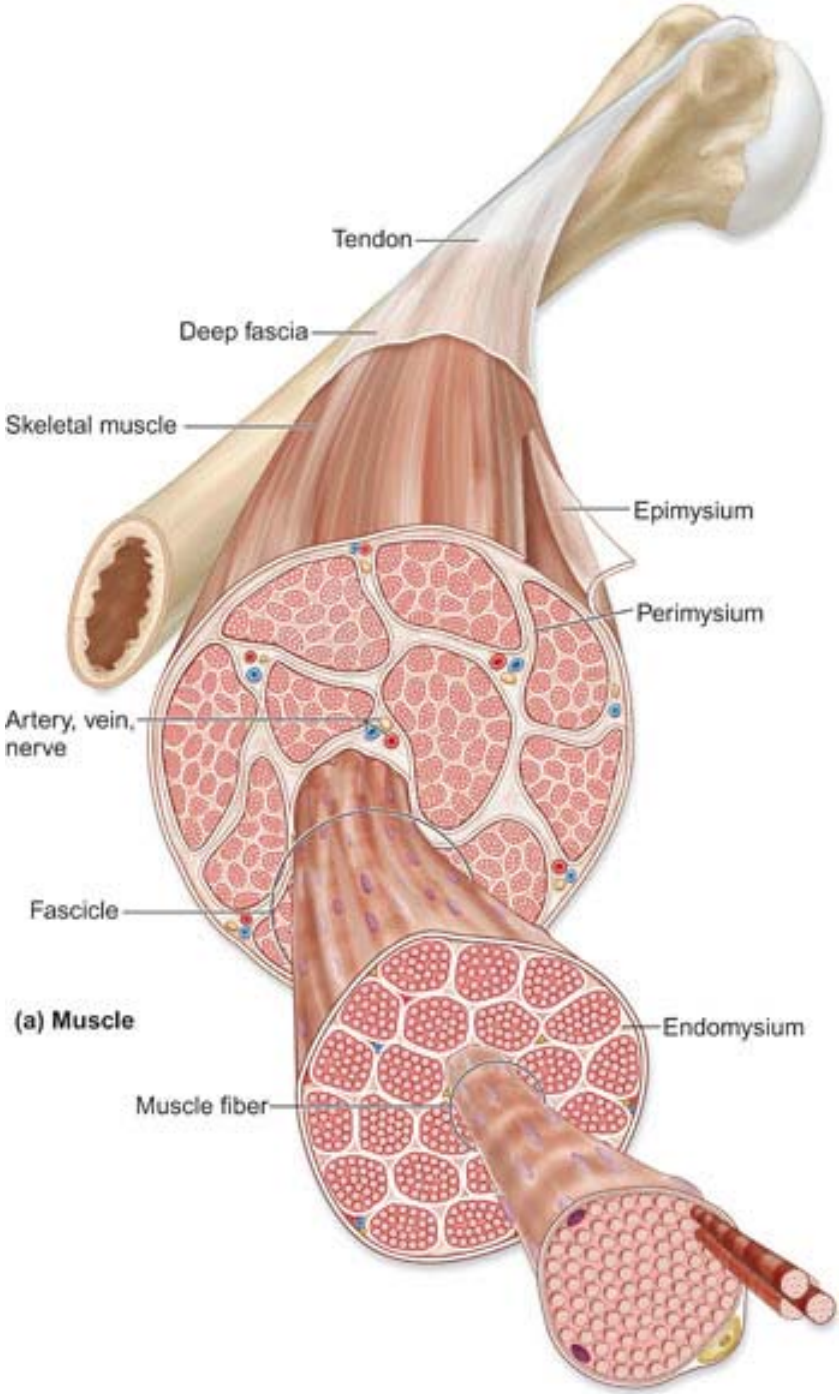
- Skeletal muscles are organs
- Vary in shape and size
- A skeletal muscle is composed of cells
  - Each cell is as long as the muscle
  - Small muscle: 100 micrometers long; 10 micrometers in diameter
  - Large muscle: 35 centimeters long; 100 micrometers in diameter
- Skeletal Muscle cells are called MUSCLE FIBERS

Functions of Skeletal Muscle

- Body Movement
- Maintenance of posture
- Temperature regulation
- Storage and movement of materials
- Support

Composition of Skeletal Muscle

- Each skeletal muscle is composed of fascicles.
  - bundles of muscle fibers
- Muscle fibers contain myofibrils.
  - composed of myofilaments

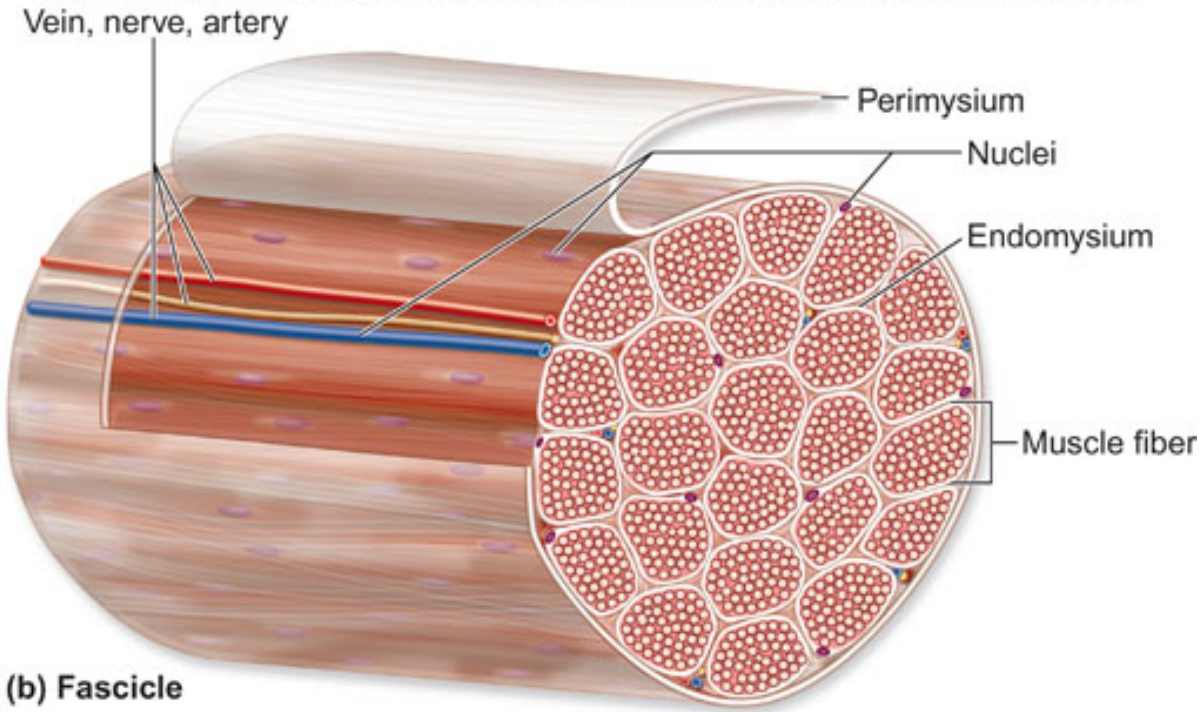


Connective Tissue Components

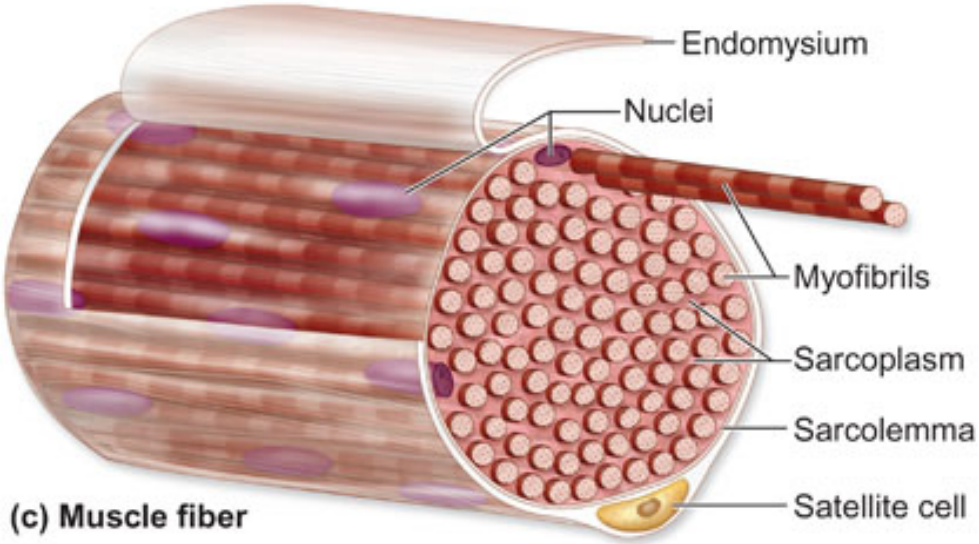
- Three layers of CT
  - Collagen fibers
  - Elastic fibers
- Endomyseium: surrounds each muscle fiber
- Perimysium: surrounds each fascicle
- Epimysium: surrounds entire muscle
- Provide protection, location for blood vessels, nerves

Endomysium

- Innermost connective tissue layer
- Surrounds each muscle fiber
- Help bind together neighboring muscle fibers and
- Support capillaries near fibers



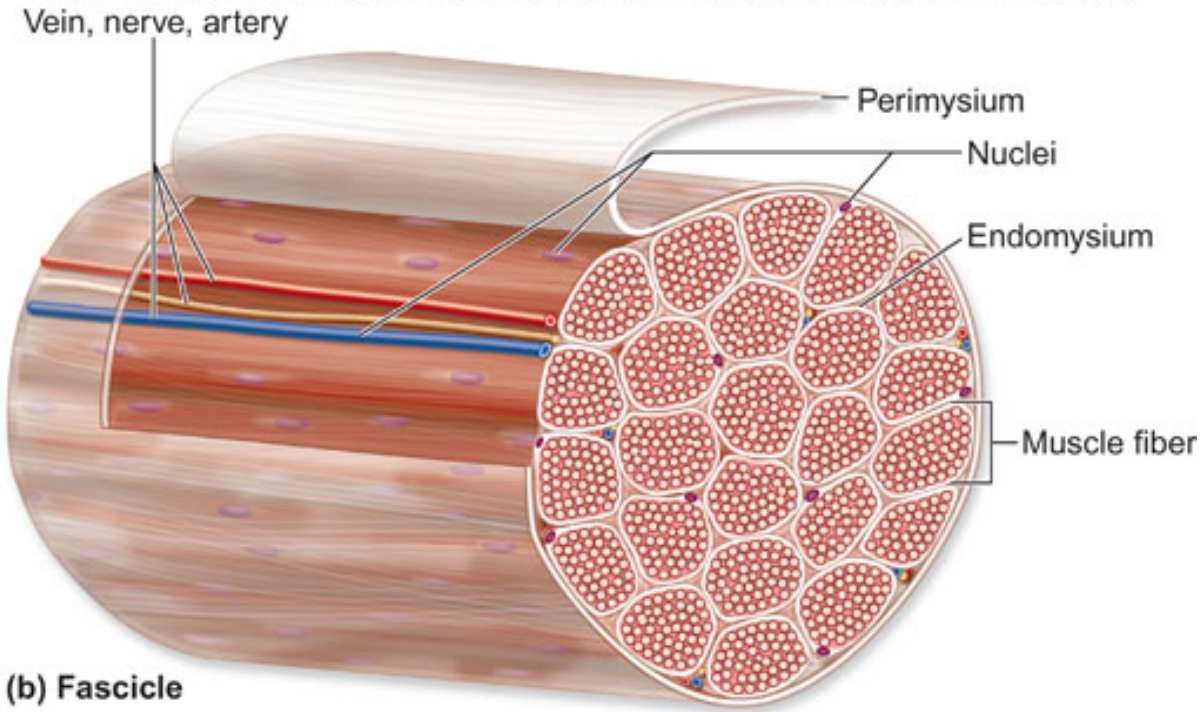
(b) Fascicle



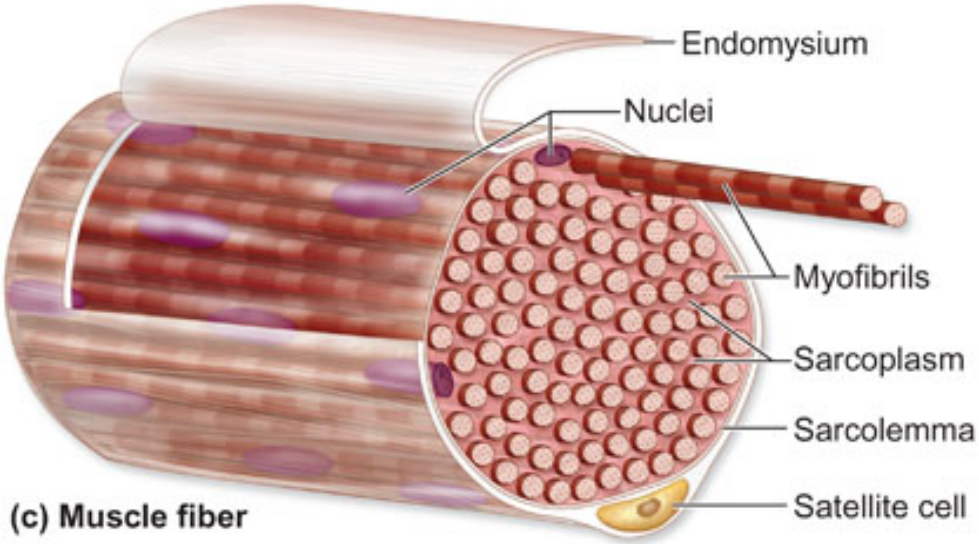
(c) Muscle fiber

Perimysium

- Surrounds the bundles of muscle fibers called fascicles.
- Has a dense irregular connective tissue sheath which contains extensive arrays of blood vessels and nerves that branch to supply each individual fascicle.



(b) Fascicle



(c) Muscle fiber

Epimysium

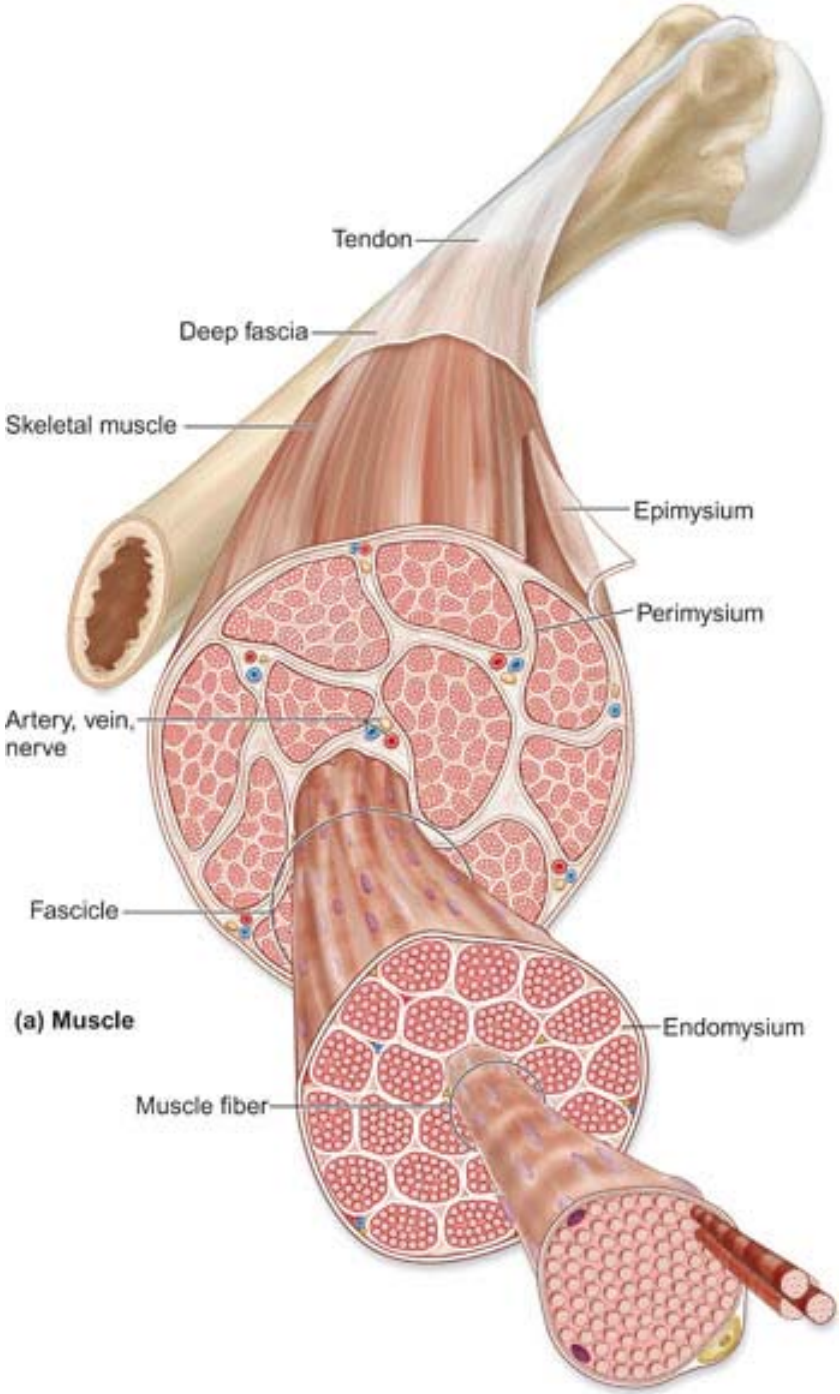
- A layer of dense irregular connective tissue that surrounds the whole skeletal muscle.

Deep Fascia

- An expansive sheet of dense irregular connective tissue
  - separates individual muscles
  - binds together muscles with similar functions
  - forms sheaths to help distribute nerves, blood vessels, and lymphatic vessels
  - fill spaces between muscles

Superficial Fascia

- An extensive sheet of areolar connective tissue and adipose
  - Also called subcutaneous tissue or hypodermis
  - Separates muscle from skin
  - Supeerficial to the deep fascia



Muscle Attachments

- Tendon attaches the muscle to bone, skin, or another muscle.
- Tendons usually have a thick, cordlike structure.
- Sometimes forms a thin, flattened sheet, termed an aponeurosis.

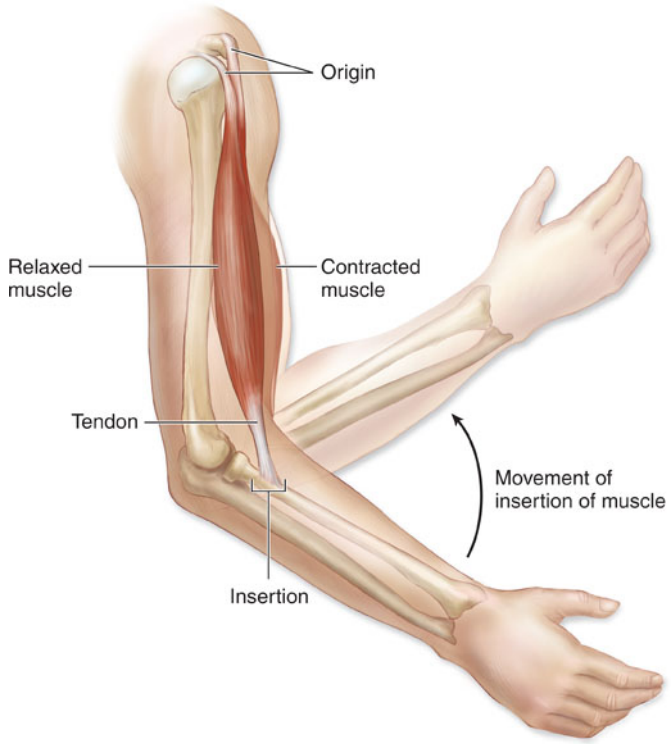
Muscle Origin and Insertion

- Most skeletal muscles extend between bones and cross at least one movable joint.
- Upon contraction, one of the bones moves while the other bone usually remains fixed.
- Less movable attachment of a muscle is called its origin.
- Origin typically lies proximal to the insertion.

Muscle Origin and Insertion

- More movable attachment of the muscle is its insertion.
- Insertion is pulled toward the origin.

Origin and Insertion



Blood Vessels and Nerves

- Extends through both the epimysium and perimysium.
- Blood vessels deliver to the muscle fibers both nutrients and oxygen needed for the production of ATP (adenosine triphosphate).
- Also remove waste products produced by the muscle fibers.

Skeletal Muscle Contraction

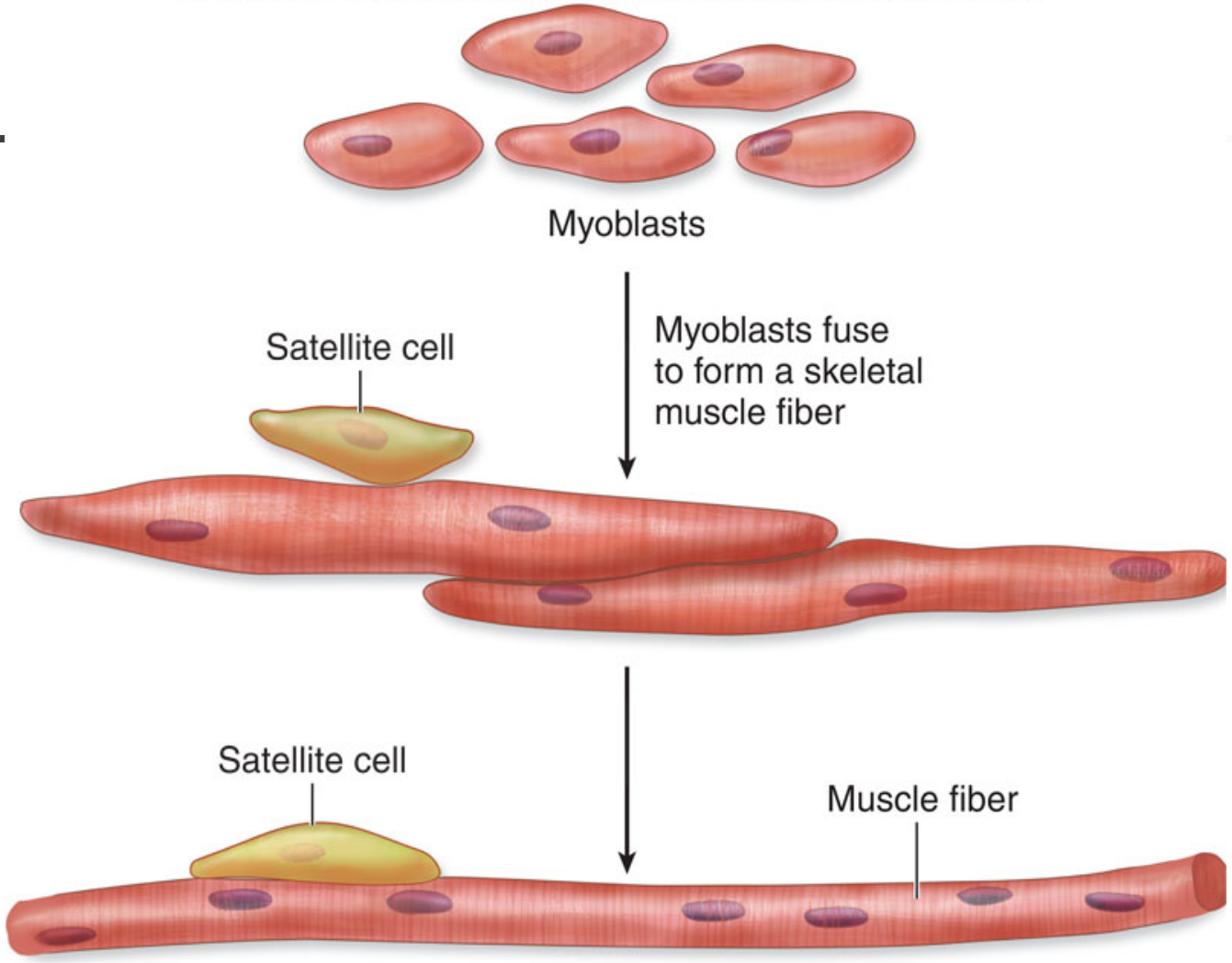
- Classified as voluntary: controlled by the somatic (voluntary) nervous system.
- The neurons that stimulate muscle contraction: motor neurons.
- Axon (or nerve fiber): transmits a nerve impulse to a muscle fiber.
- Axon travels through the epimysium and perimysium, and enters the endomysium, where it sends a nerve impulse to an individual muscle fiber.

Microscopic Anatomy

- Specialized terms/structures
  - Sarcolemma
  - Sarcoplasm
  - About 300 mitochondria
- Unique structures:
  - Transverse tubules: deep invaginations of the sarcolemma
  - Sarcoplasmic Reticulum
    - Terminal cisternae (lateral sacs)
  - Triad: T-tubule, 2 lateral sacs

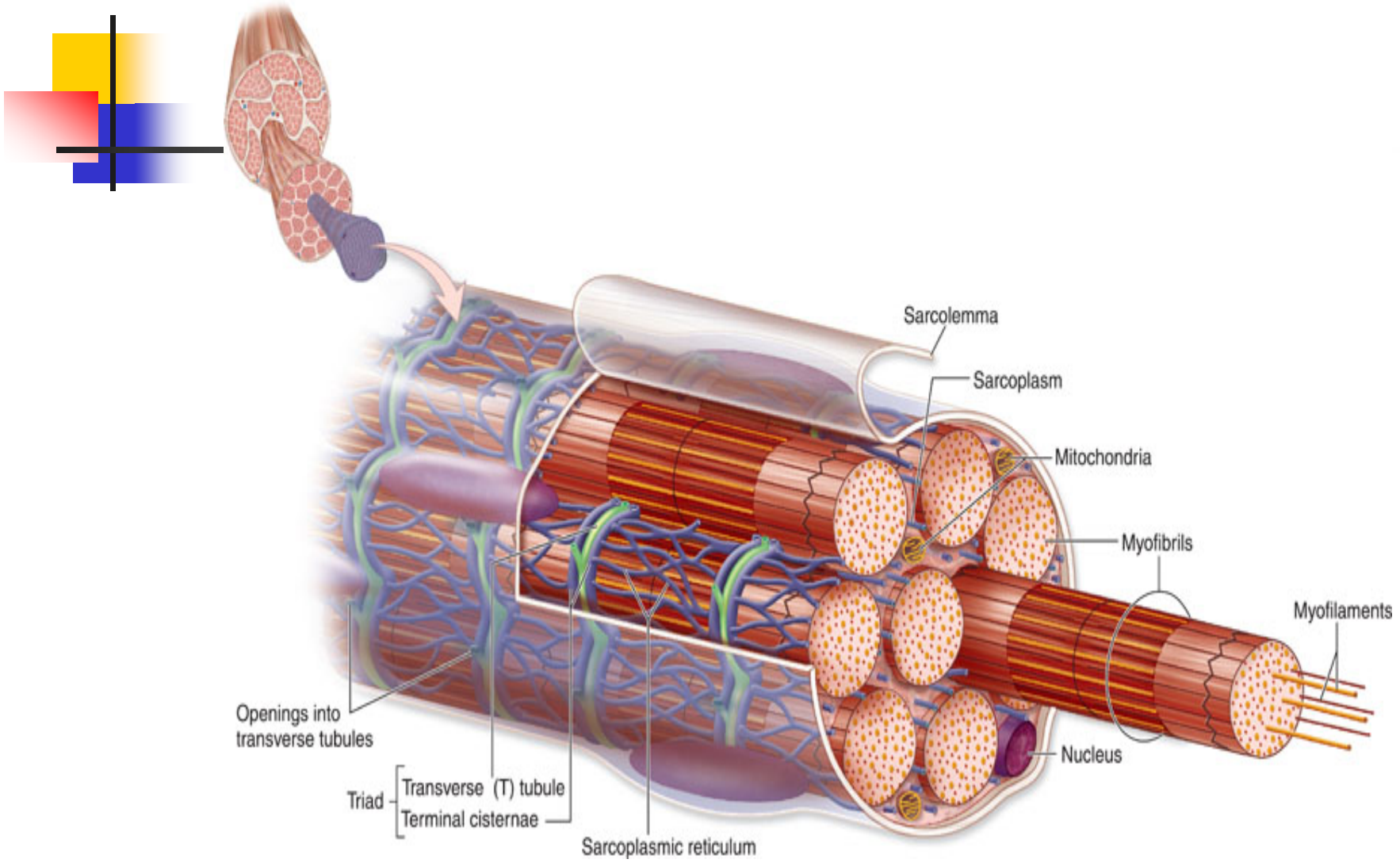
Microscopic Anatomy

- Multinucleated cells
  - Occurs during development
  - Myoblasts: embryonic cells
  - Most fuse into one cell
- Satellite cells
  - Myoblasts that do nor fuse
  - can aid in repair and regeneration in adults



Myofibrils and Myofilaments

- Myofibrils:
  - Long cylindrical organelles
  - About 1-2 micrometers in diameter
  - Extend length of muscle fiber
  - Shorten during contraction
  - Contain myofilaments

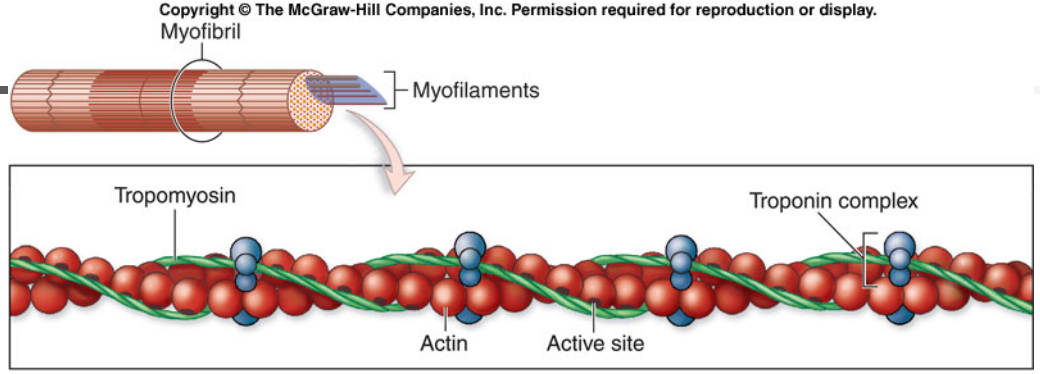


Thin and Thick Myofilaments

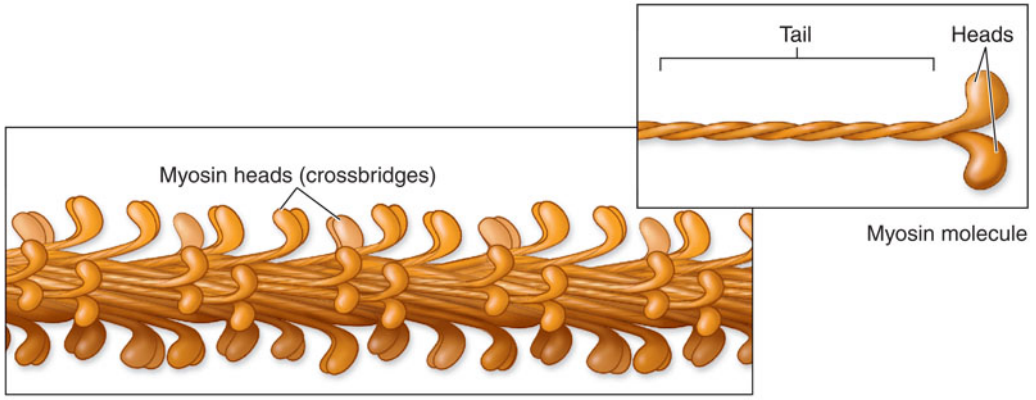
- Thin filaments
  - Actin
  - Two entwined strands of globular protein
  - Active site for myosin
  - Regulatory proteins
    - Troponin
    - Tropomyosin

Thin and Thick Myofilaments

- Thick filaments
  - Myosin
  - Myosin molecule: globular head, tail
    - Tails point to the middle of the filament
    - Heads called crossbridges



(a) Thin myofilament



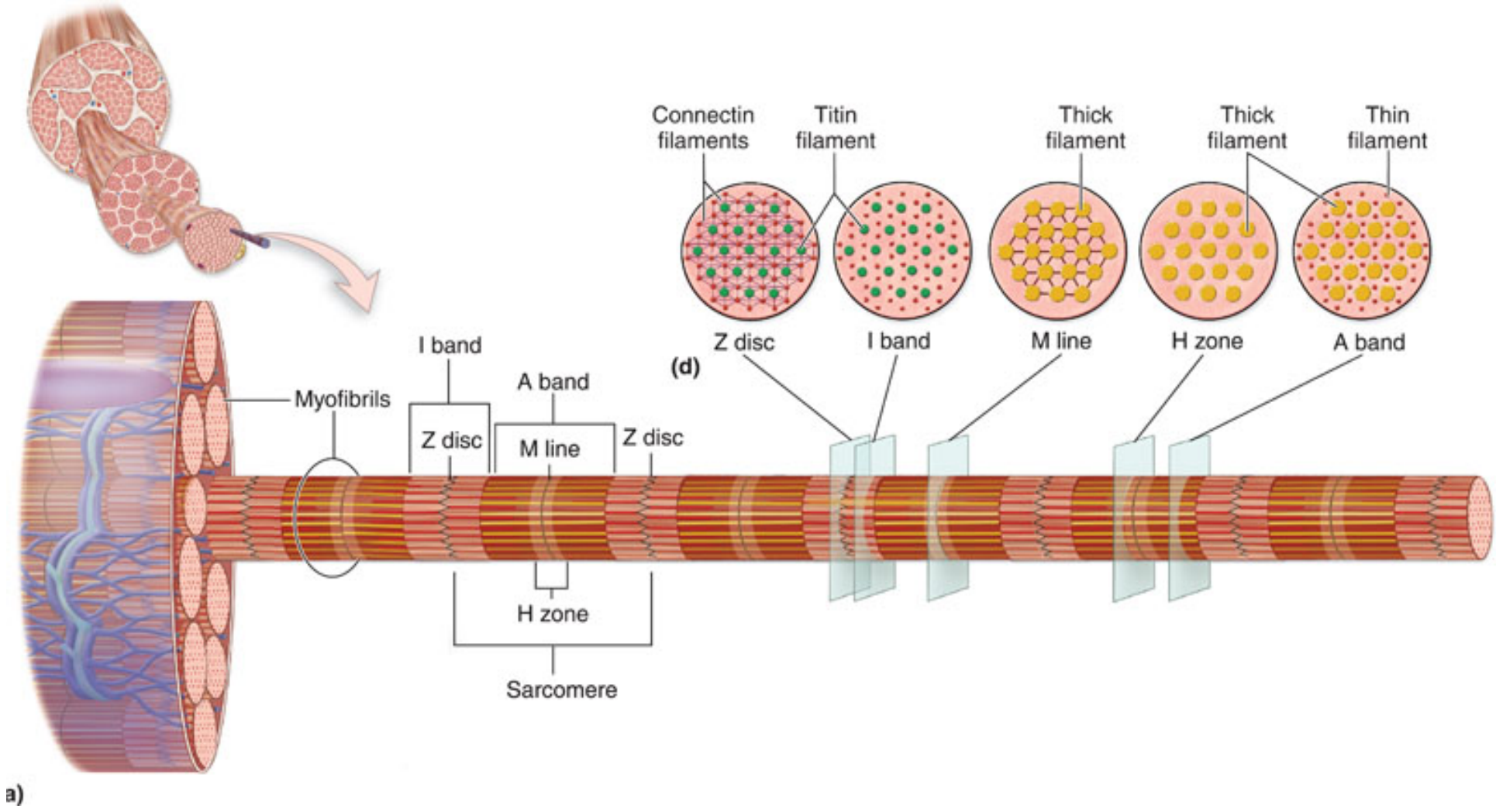
(b) Thick myofilament

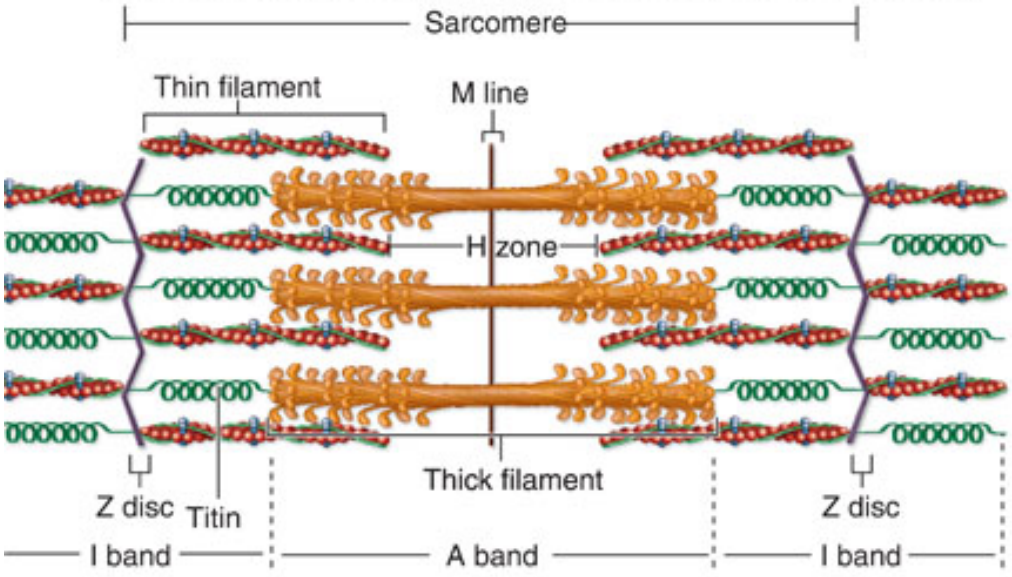
Thin and Thick Myofilaments

- Banding
  - I-band: light band
    - Actin filaments
    - Bisected by z-line
  - A-band: dark band
    - Overlap of actin and myosin myofilaments
    - Bisected by H-band
  - H-band (zone)
    - no actin here in relaxed fiber

Thin and Thick Myofilaments

- Banding
  - M-line:
    - Middle of H-band (zone) in relaxed fiber
    - Thin protein meshwork
    - Attachment for thick filaments
  - Z-line (Z-disc)
    - Thin protein structure
      - Connectins: anchor thin filaments
      - Titin: attach thin, thick filaments to z-disc
    - Attachment for thin filaments





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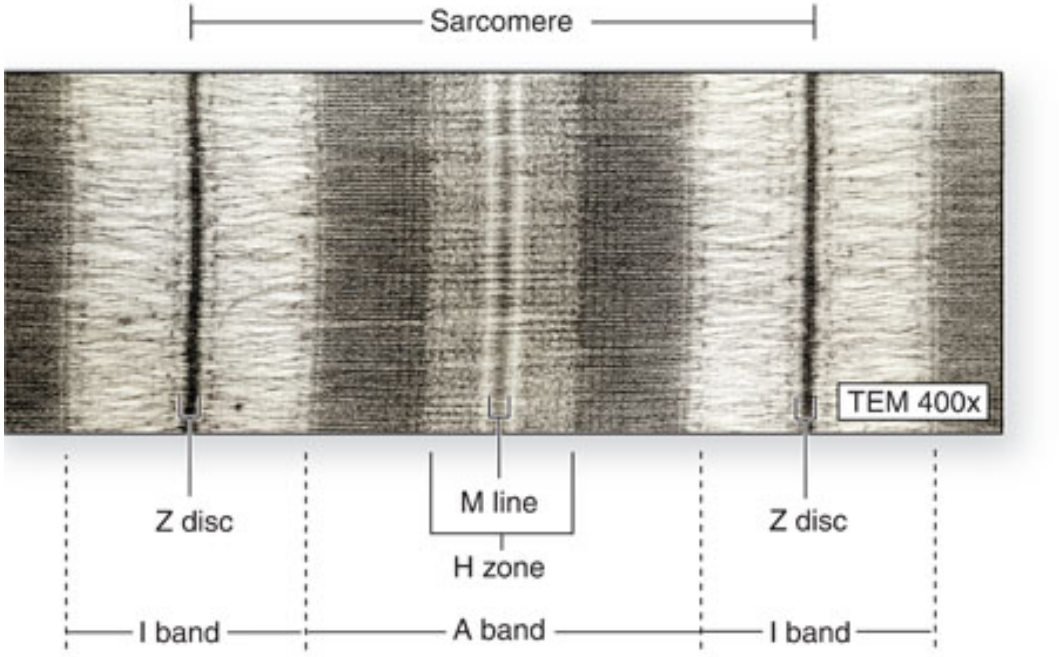

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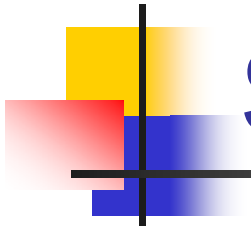
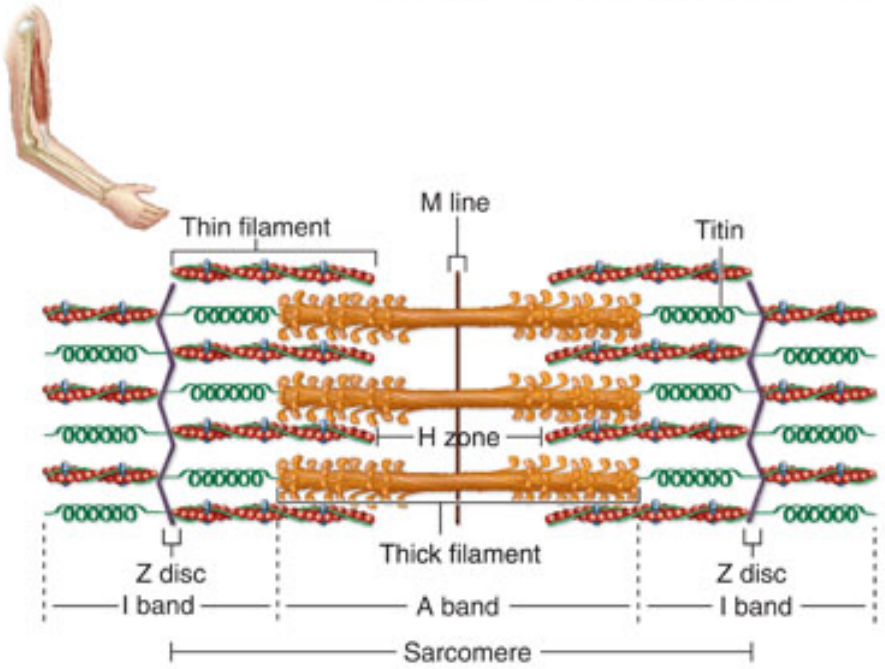


Sarcomere

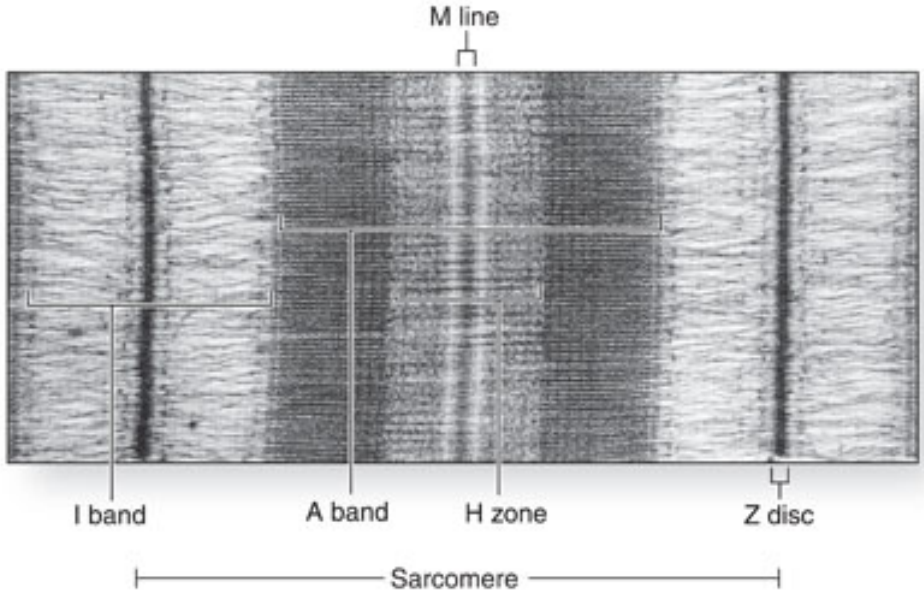
- The functional contractile unit of a skeletal muscle fiber.
- Defined as the distance from one Z disc to the next adjacent Z disc.
- Myofibrils contain multiple Z discs
- Numerous sarcomeres in each myofibril.
- Each shortens as the muscle fiber contracts.

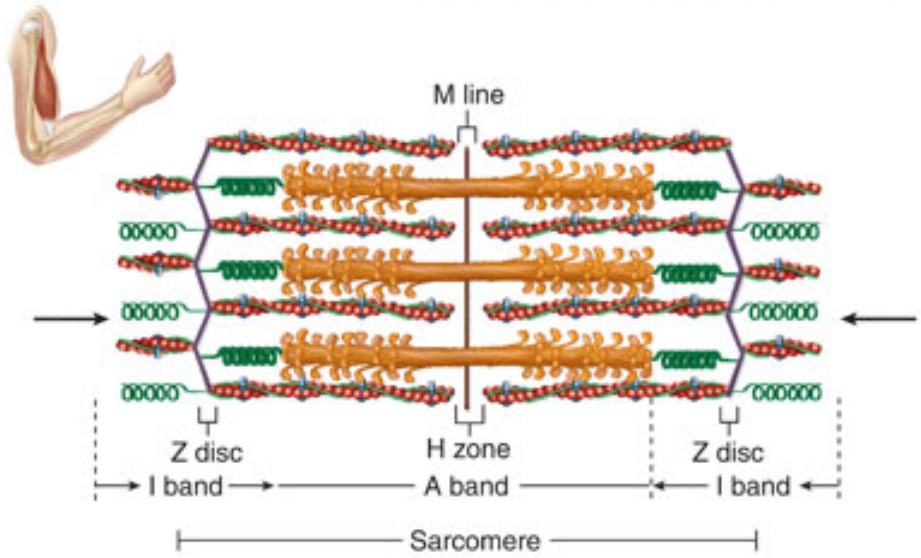
The Sliding Filament Theory

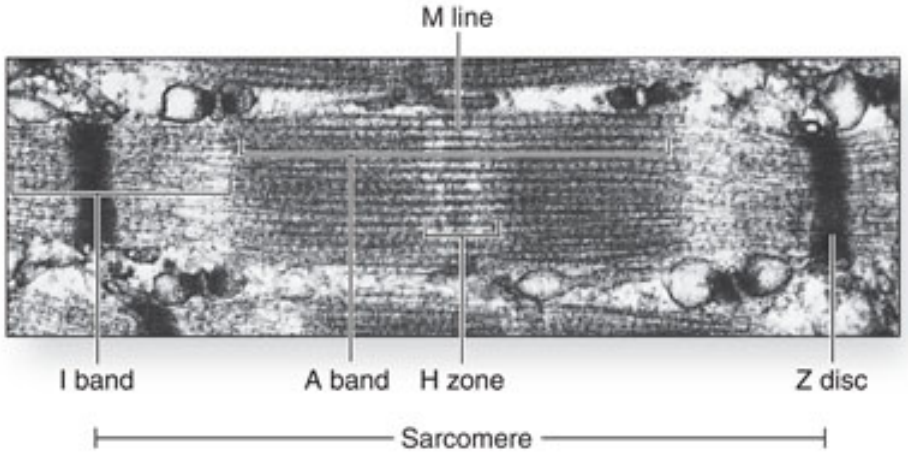
- The thin and thick filaments slide past each other
- This change in relative position results in the shortening of the sarcomere
  - I-band narrows
  - H-band disappears



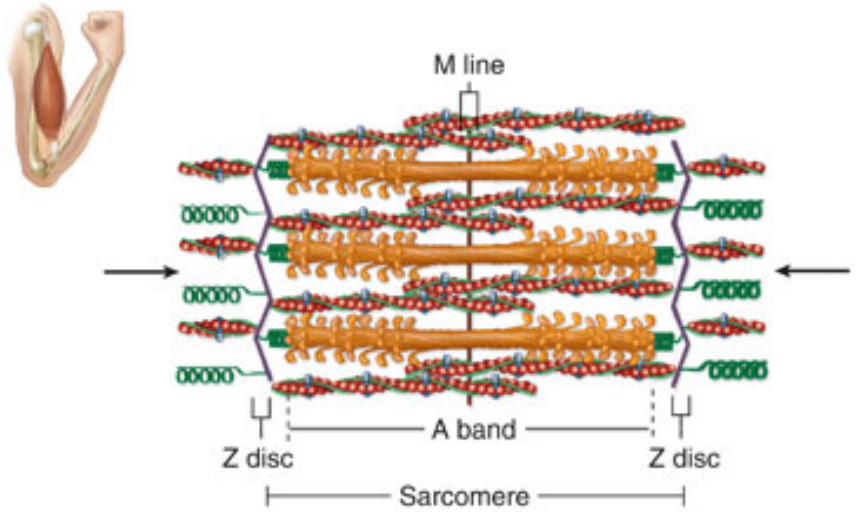
(a) Relaxed muscle
Sarcomere, I band, and H zone at an expanded/relaxed length. Note: The thick and thin filaments do not change length when the muscle contracts.

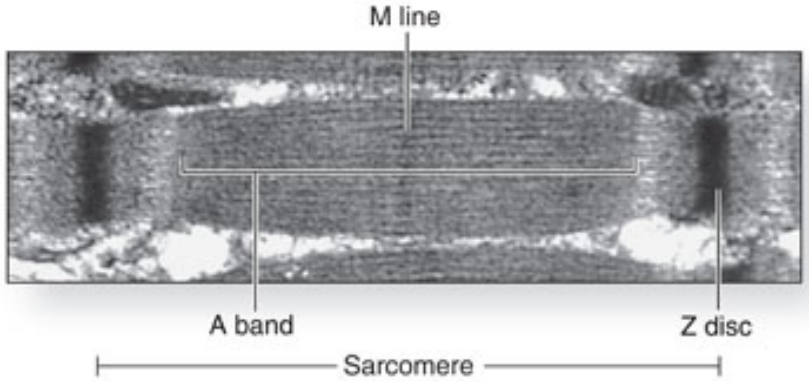






(b) Partially contracted muscle
Thick and thin filaments start to slide past one another. The sarcomere, I band, and H zone are narrower and shorter.

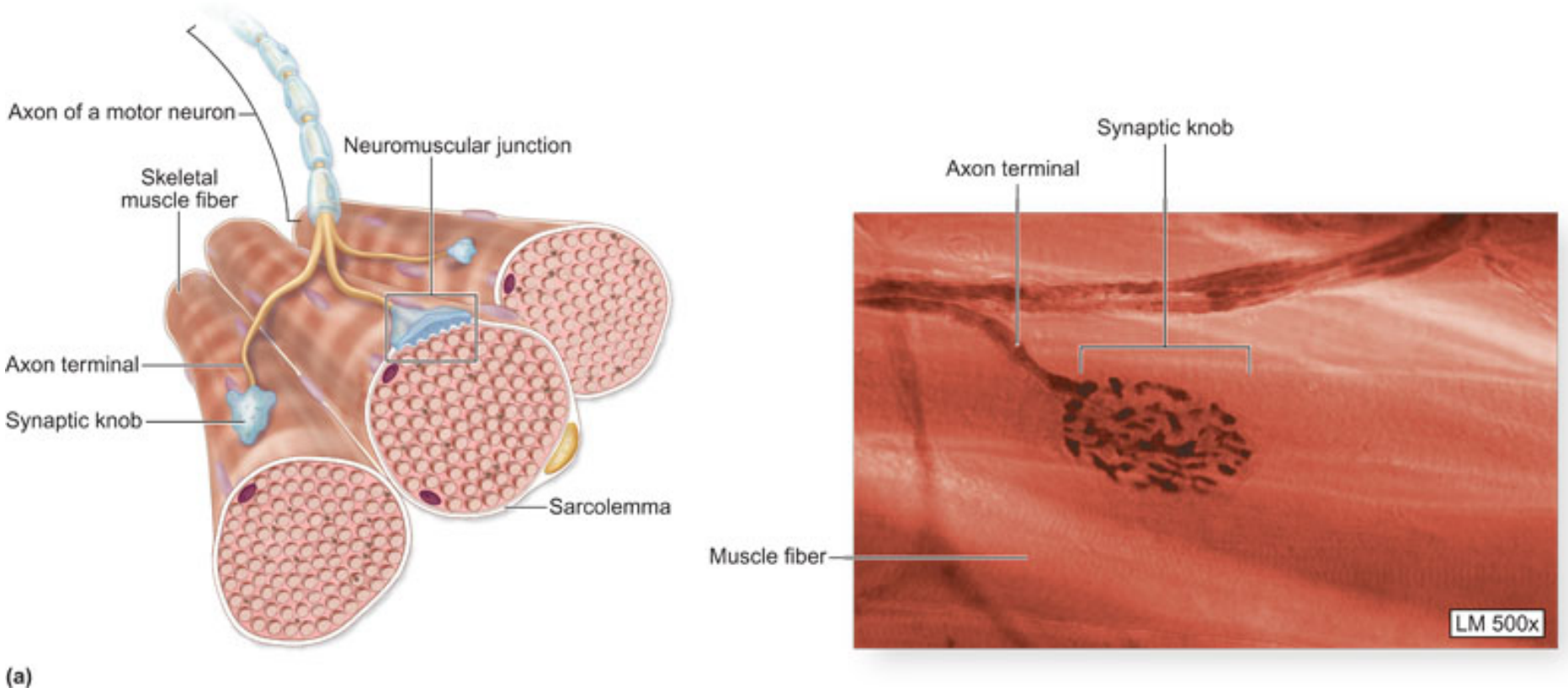


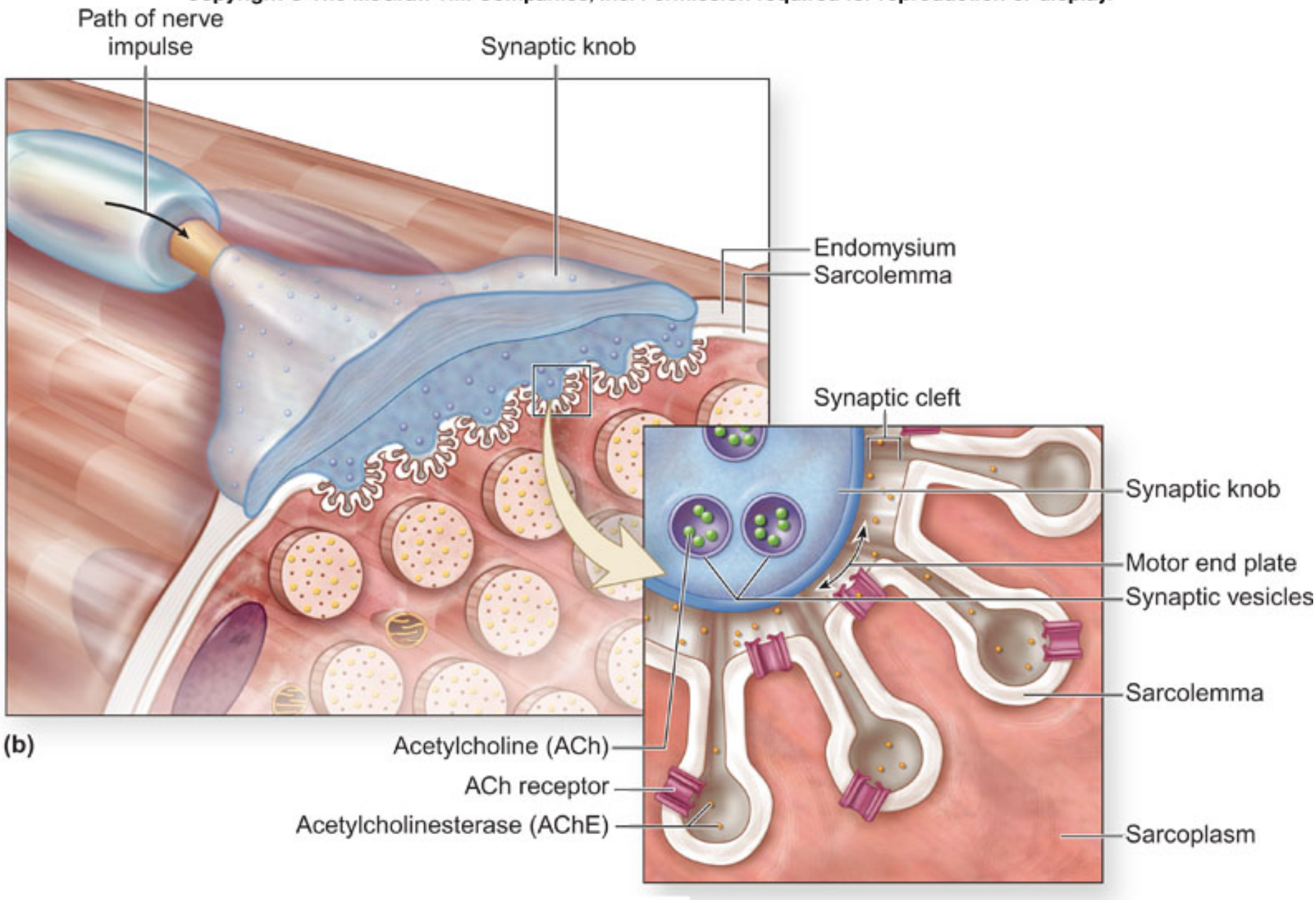


(c) Fully contracted muscle
The H zone and I band disappear, and the sarcomere is at its shortest length. Note: The length of the thick and thin filaments does not change.

Neuromuscular Junction

- Where motor neuron meets muscle fiber
- Components
  - Synaptic knob
  - Synaptic vesicles
    - Acetylcholine (ACh)
  - Motor end plate
    - ACh receptors
  - Synaptic cleft
    - acetylcholinesterase



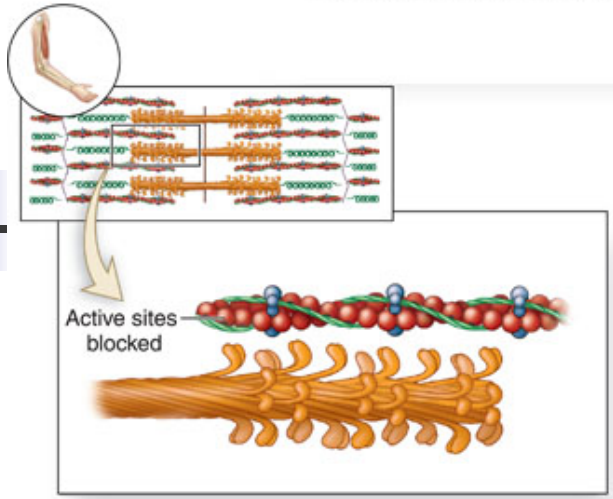


Mechanism of contraction

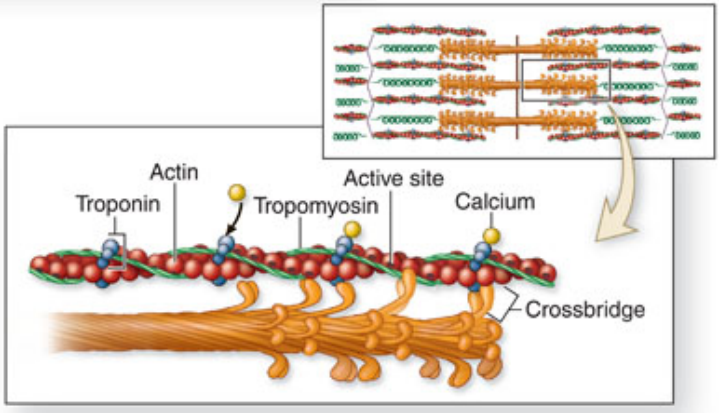
- Neuromuscular Junction:
  - Impulse causes release of Ach into synaptic cleft
  - Ach plugs into receptors
  - Initiates impulse in motor end plate
  - Acetylcholinesterase breaks down ACh
- Impulse travels on sarcolemma, then down T-tubule.
- Impulse reaches lateral sacs
  - Causes release of calcium ion
- Calcium ion bonds to troponin
  - Causes tropomyosin to move off of the myosin bonding site

Mechanism of contraction

- Myosin head bonds to actin, pushes actin to middle of sarcomere
- Myosin released from actin
  - Need ATP to release
- As long as calcium is in cytoplasm, will continue to contract
- Return to relaxed condition

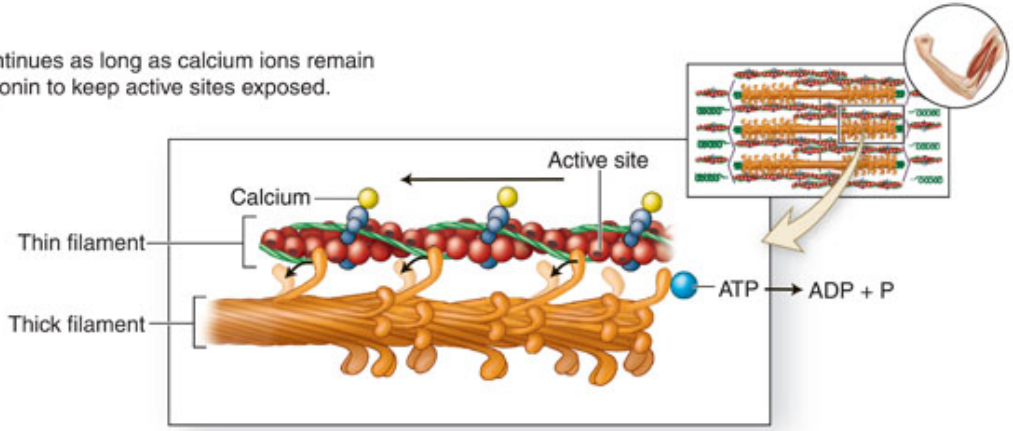


⑥ When the impulse stops, calcium ions return to the terminal cisternae, tropomyosin re-covers active sites, and filaments passively slide back to their relaxed state.



③ Calcium ions bind to troponin. Troponin changes shape, moving tropomyosin to expose active sites on actin molecules of thin filaments. Myosin heads of thick filaments attach to exposed active sites to form crossbridges.

⑤ The cycle continues as long as calcium ions remain bound to troponin to keep active sites exposed.



④ Myosin heads pivot, moving thin filaments toward the sarcomere center. ATP binds myosin heads, which detach from thin filaments and return to their pre-pivot position. The repeating cycle of *attach–pivot–detach–return* slides thick and thin filaments past one another. The sarcomere shortens and the muscle contracts.

Motor Neuron

- Initiates muscle contraction in a single muscle fiber.
- A single motor neuron typically controls numerous muscle fibers in a muscle.
- Has a neuromuscular junction with each muscle fiber it controls.

Motor Unit

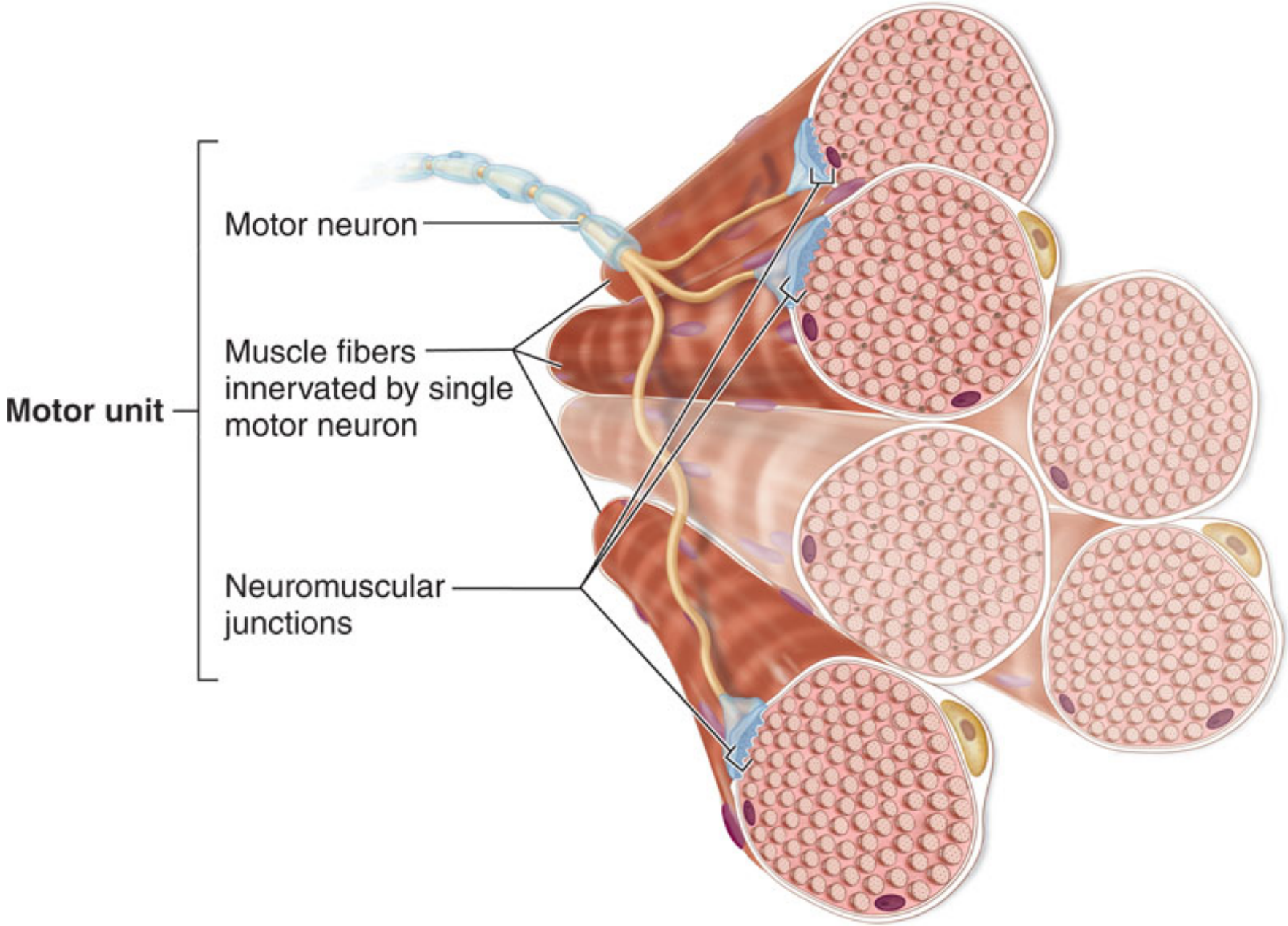
- Composed of a single motor neuron, the muscle fibers it controls, and the neuromuscular junctions between the motor neuron and the muscle fibers.
- Typically controls only some of the muscle fibers in an entire muscle.
- Most muscles have many motor units.
  - many motor neurons are needed to innervate an entire muscle

All-Or-None Principle

- All-or-none principle: A muscle fiber either contracts completely or does not contract at all.
- When a motor unit is stimulated, all its fibers contract at the same time.
- The total force exerted by the muscle depends on the number of activated motor units.

Muscle Tone

- Some motor units are always active, even when a muscle is at rest.
- The motor units cause the muscle to become tense, but do not produce enough tension to cause movement.
- Muscle tone is the resting tension in a skeletal muscle.

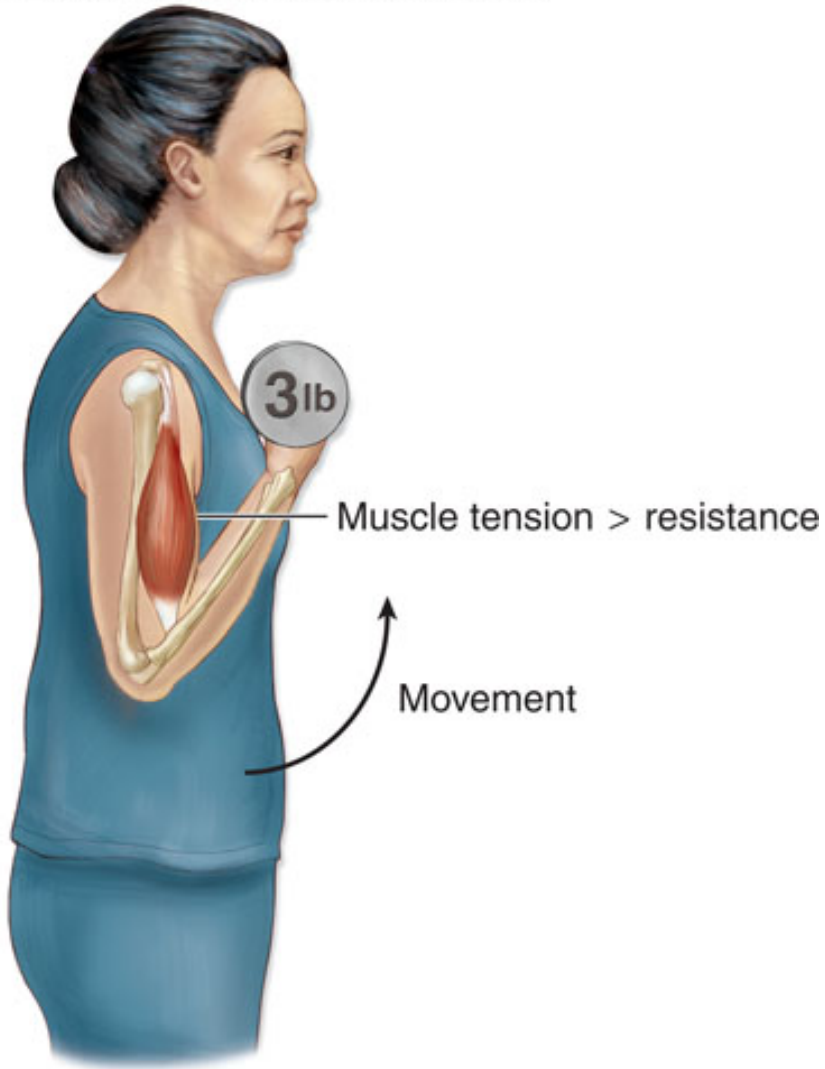


Contraction

- Isometric
  - length of the muscle does not change because the tension produced never exceeds the resistance (load)
  - tension is generated, but not enough to move the load
- Isotonic
  - tension produced exceeds the resistance (load), and the muscle fibers shorten, resulting in movement

(a) Isometric contraction

Muscle tension is less than the resistance; muscle does not shorten, and no movement occurs.



(b) Isotonic contraction

Muscle tension is greater than the resistance; muscle shortens, and movement occurs.

Muscle Atrophy

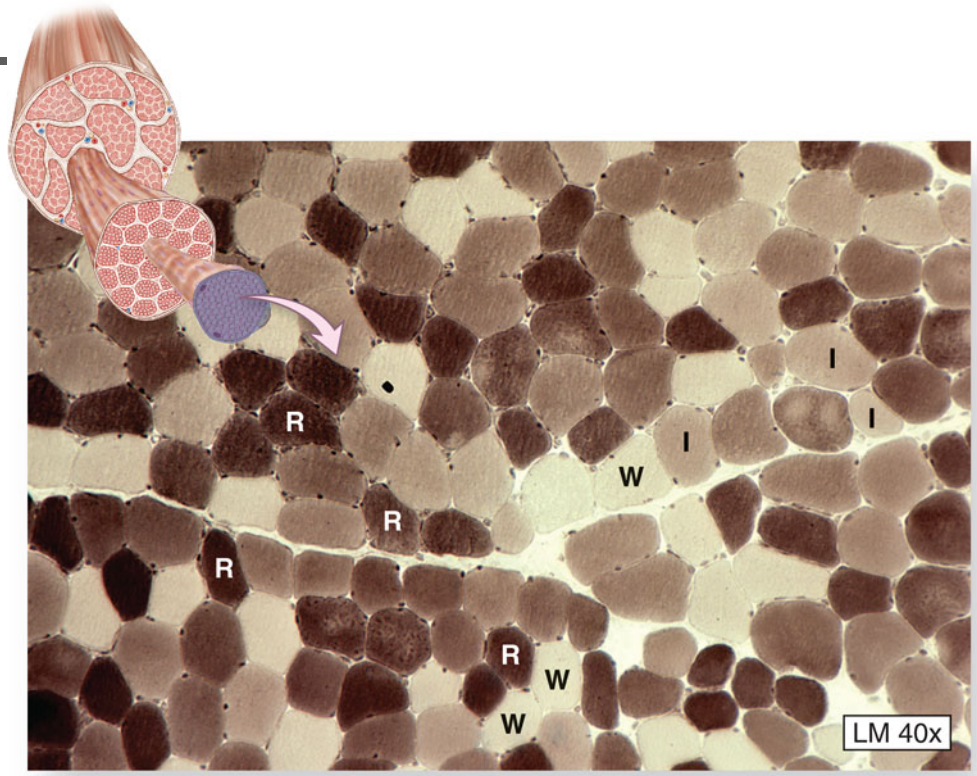
- Reduction in muscle size, tone, and power.
- Due to reduced stimulation, it loses both mass and tone.
- Muscle becomes flaccid, and its fibers decrease in size and become weaker.
- Even a temporary reduction in muscle use can lead to muscular atrophy.

Muscle Hypertrophy

- An increase in muscle fiber size.
- Muscle size may be improved by exercising.
- Repetitive, exhaustive stimulation of muscle fibers results in more mitochondria, larger glycogen reserves, and an increased ability to produce ATP.
- Ultimately, each muscle fiber develops more myofibrils, and each myofibril contains a larger number of myofilaments.

Three Types of Skeletal Muscle Fibers

- Fast
  - are large in diameter
  - contain large glycogen reserves
  - densely packed myofibrils
  - relatively few mitochondria
  - called white fibers due to lack of myoglobin
  - majority of skeletal muscle fibers in the body
- Intermediate
  - resemble fast fibers; however
  - have a greater resistance to fatigue
- Slow
  - smaller and they
  - contract more slowly
  - called red fibers because due to myoglobin



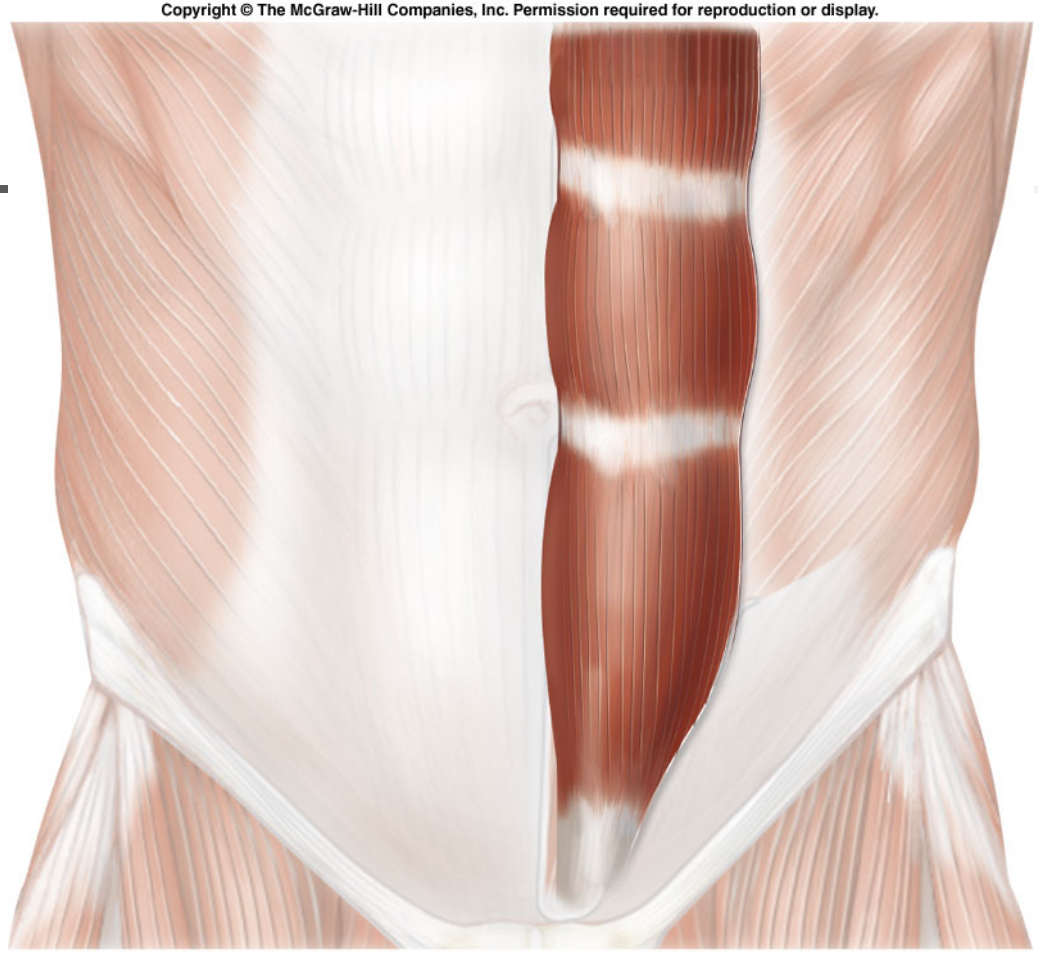
Red slow fibers (R) White fast fibers (W) Intermediate fast fibers (I)

Skeletal Muscle Has Striations

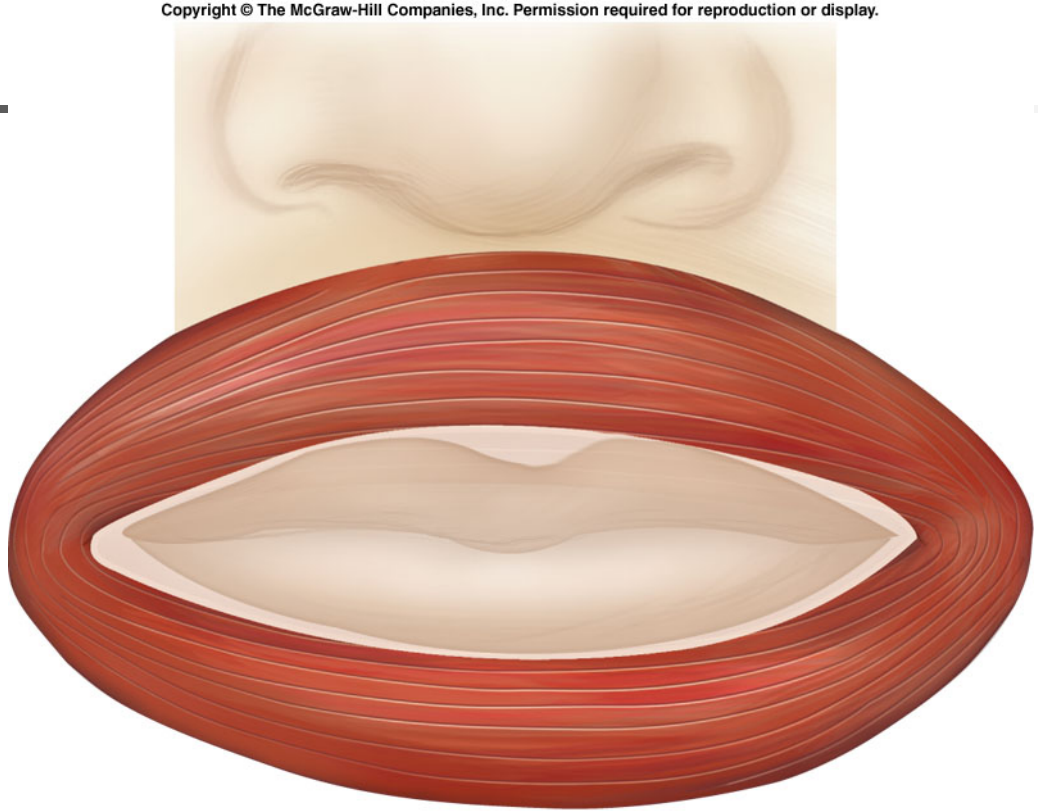
- Appearance is due to size and density differences between thick filaments and thin filaments.
- Under the light microscope, two differently shaded bands are present.
- The dark bands, called A bands, contain the entire thick filament.
- At either end of a thick filament is a region where thin filaments extend into the A band between the stacked thick filaments.
- Light bands, called I bands, contain thin filaments only.
- I band is lighter shaded than an A band because only the thin filaments occupy this region.

Four Organizational Patterns in Fascicles

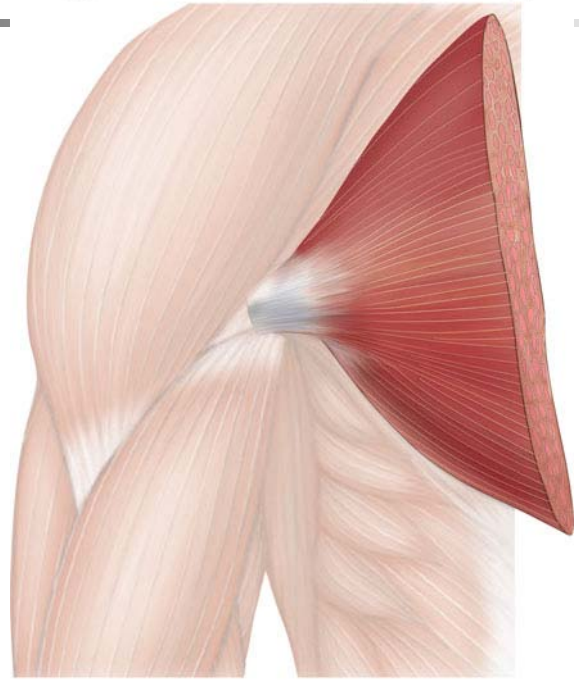
- Circular - muscle is also called a sphincter because contraction of the muscle closes off the opening.
- Convergent - muscle has widespread muscle fibers that converge on a common attachment site and are often triangular in shape.
- Parallel - fascicles run parallel to its long axis.
  - have a central body, called the belly, or gaster
- Pennate - have one or more tendons extending through their body, and the fascicles are arranged at an oblique angle to the tendon.



Rectus abdominis



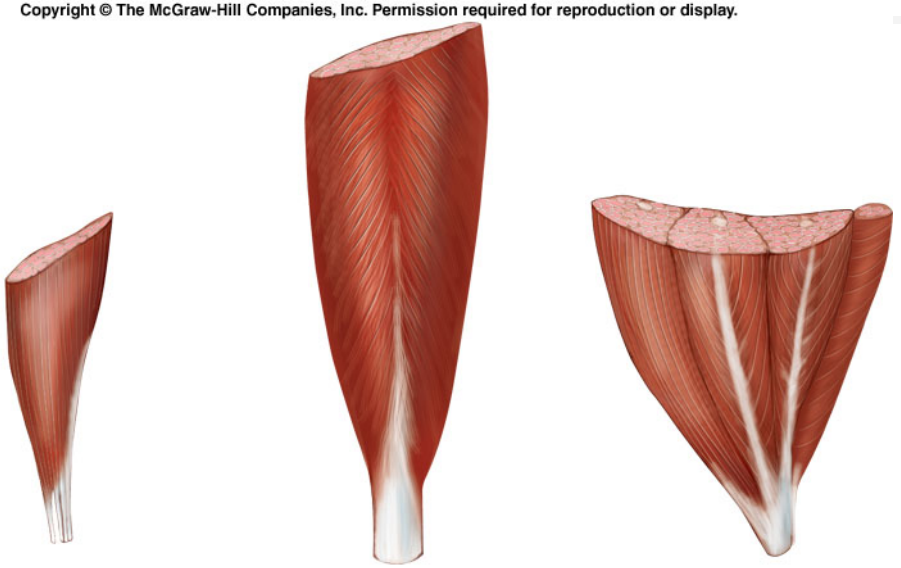
Orbicularis oris



Pectoralis major

3 Types of Pennate Muscles

- Unipennate muscle - all of the muscle fibers are on the same side of the tendon.
- Bipennate muscle - the most common type, has muscle fibers on both sides of the tendon.
- Multipennate muscle - has branches of the tendon within the muscle.



Unipennate (extensor digitorum)

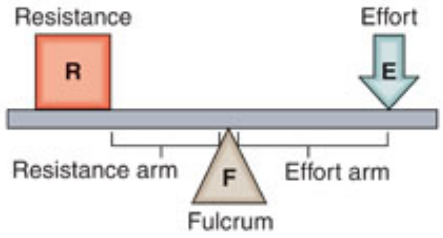
Bipennate (rectus femoris)

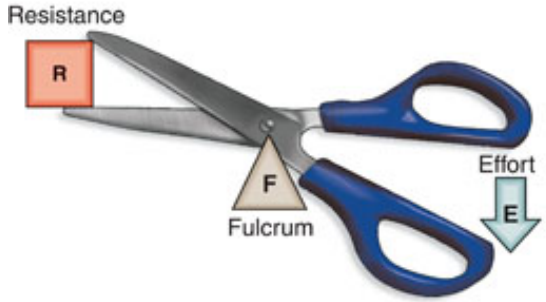
Multipennate (deltoid)

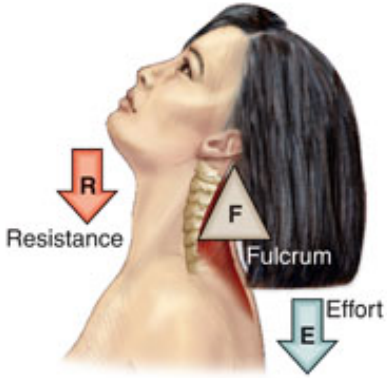
3 Classes of Levers in the Body

- In the body, a long bone acts as a lever, a joint serves as the fulcrum, and the effort is generated by a muscle attached to the bone.
- First-class
  - has a fulcrum in the middle, between the force and the resistance
- Second-class
  - resistance is between the fulcrum and the applied force
- Third-class
  - force is applied between the resistance and the fulcrum
  - the most common levers in the body

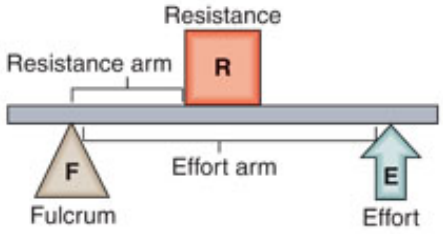
First-class lever

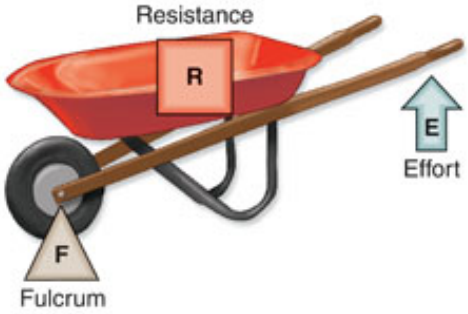


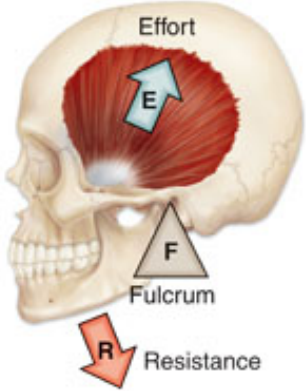




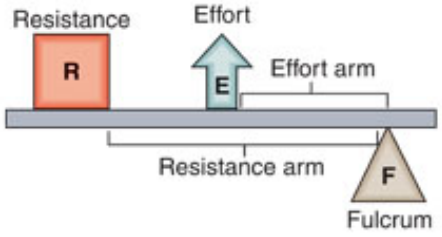
Second-class lever

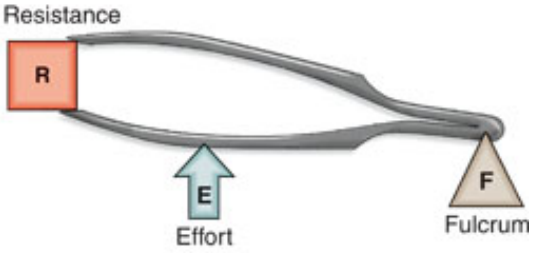


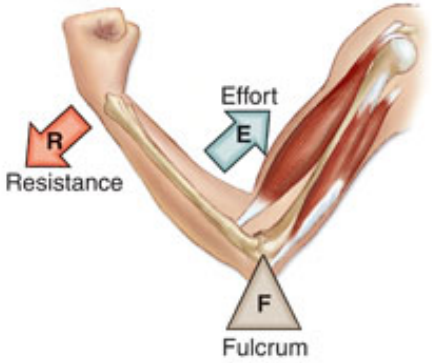




Third-class lever







Actions of Skeletal Muscles

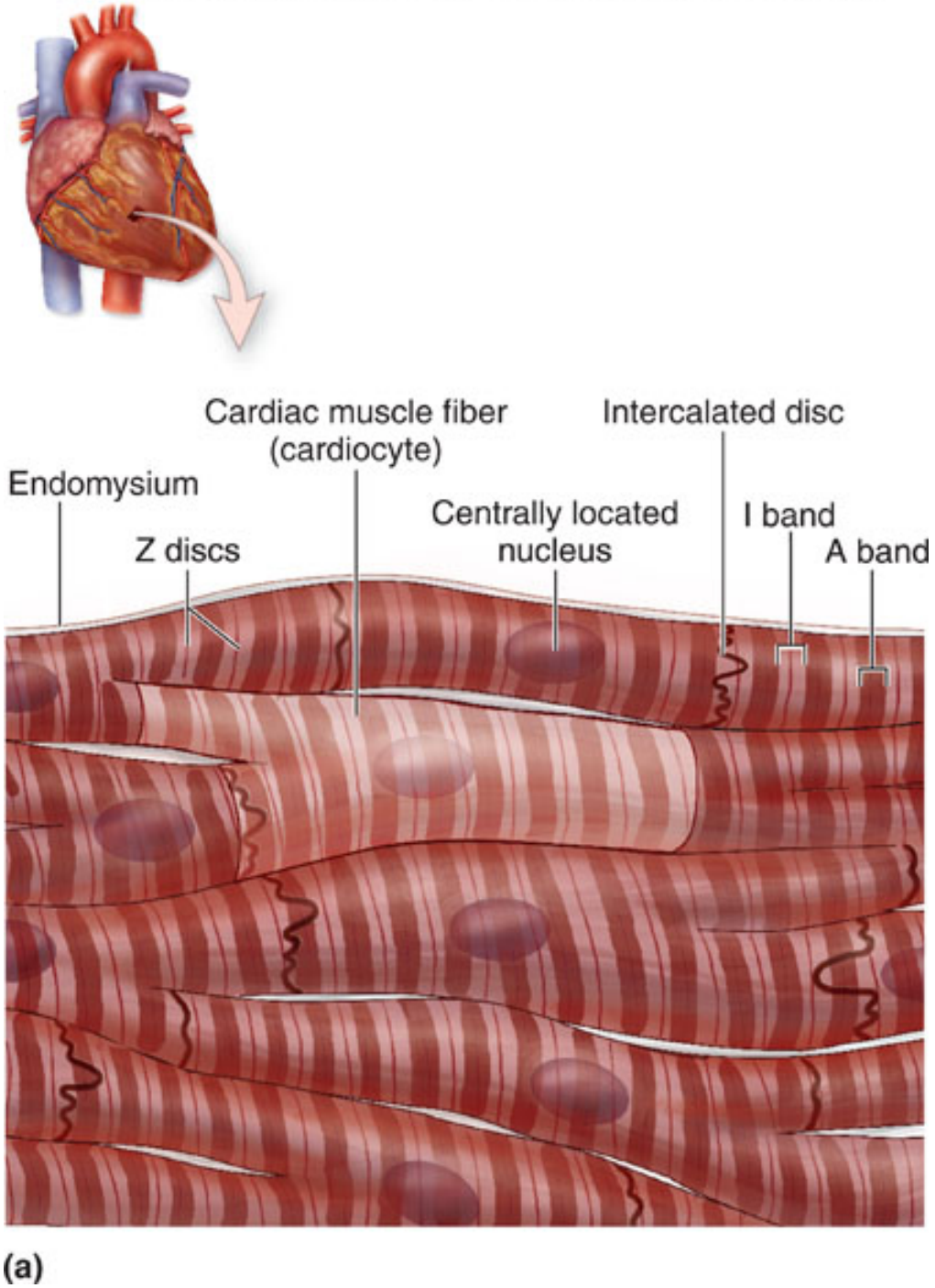
- Grouped according to their primary actions into three types:
- Agonists - also called a prime mover contracts to produce a particular movement
- Antagonists - actions oppose those of the agonist
- Synergists
  - assist the prime mover in performing its action.
  - the contraction contributes to tension exerted close to the insertion of the muscle or stabilizes the point of origin
  - may also assist an agonist by preventing movement at a joint and thereby stabilizing the origin of the agonist
  - called fixators

Criteria for Naming of Muscles

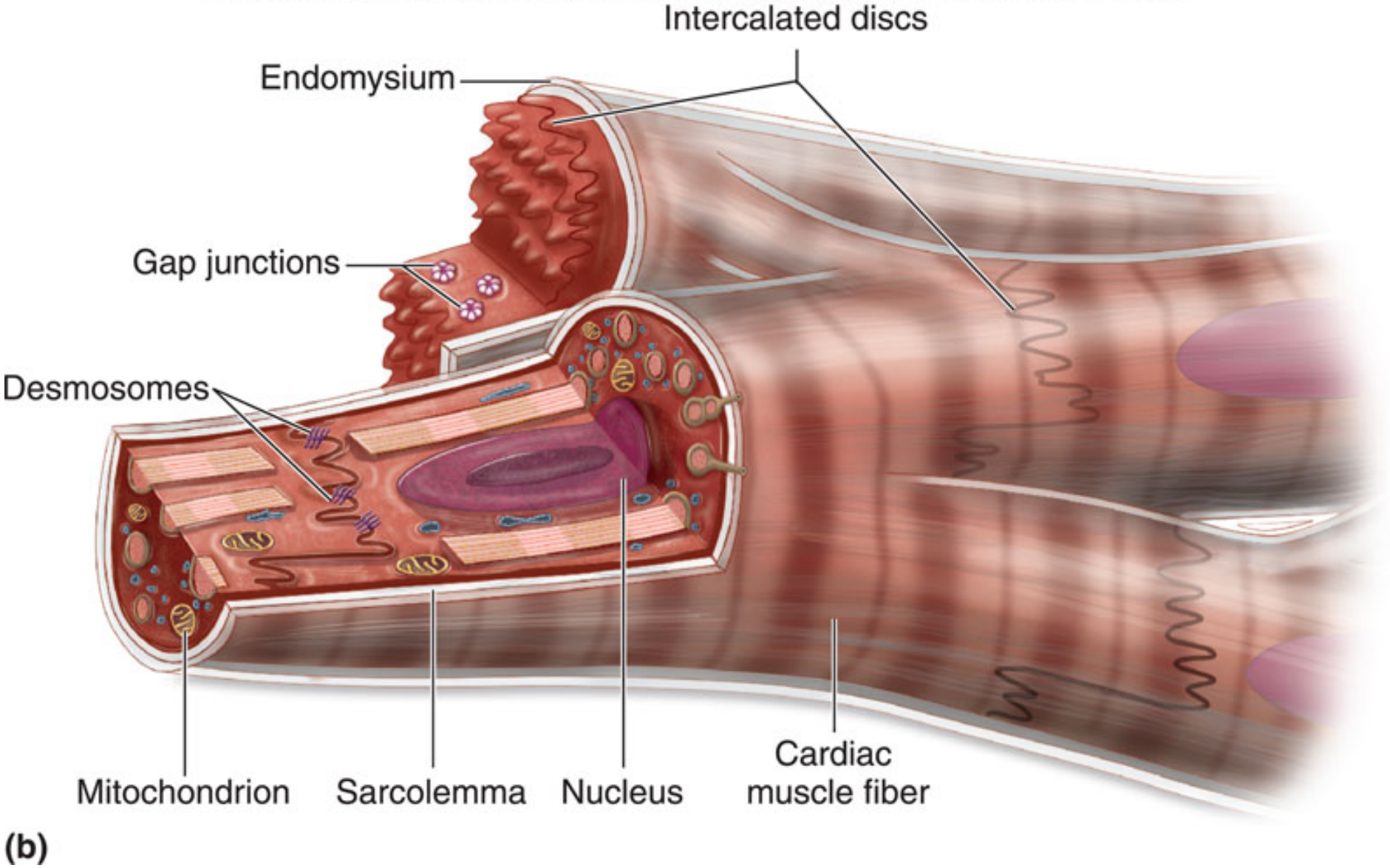
- Names incorporate appearance, location, function, orientation, and unusual features
- Names provide clues to their identification
  - orientation of muscle fibers
  - muscle attachments
  - specific body regions
  - muscle shape
  - muscle size
  - muscle heads/tendons of origin
  - muscle function or movement
  - muscle position at body surface

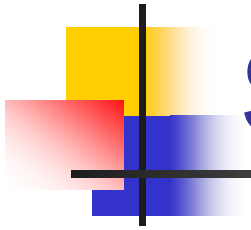
Cardiac Muscle

- Fibers are individual muscle fibers arranged in thick bundles within the heart wall.
- Fibers are striated like skeletal muscle fibers, but shorter and thicker, and they have only one or two nuclei.
- Fibers form Y-shaped branches and join to adjacent muscle fibers at junctions termed intercalated discs.
- Fibers are autorhythmic (can generate a muscle impulse without being stimulated).



(a)



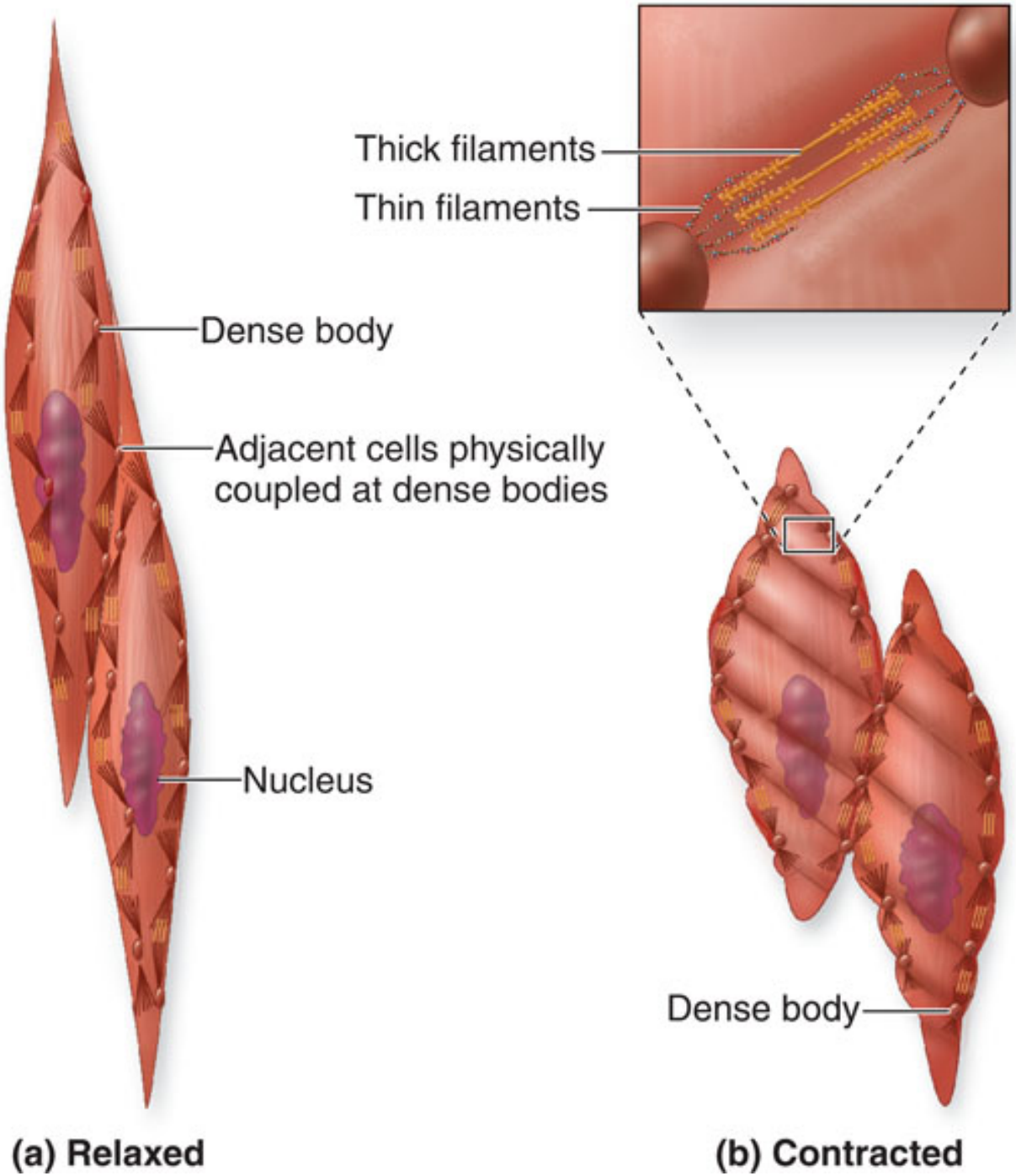


Smooth Muscle

- Composed of short muscle fibers that have a fusiform shape and single centrally located nucleus.
- Thick and thin filaments are not precisely aligned so no visible striations or sarcomeres are present.
- Z discs are absent - thin filaments are attached to dense bodies by elements of the cytoskeleton.

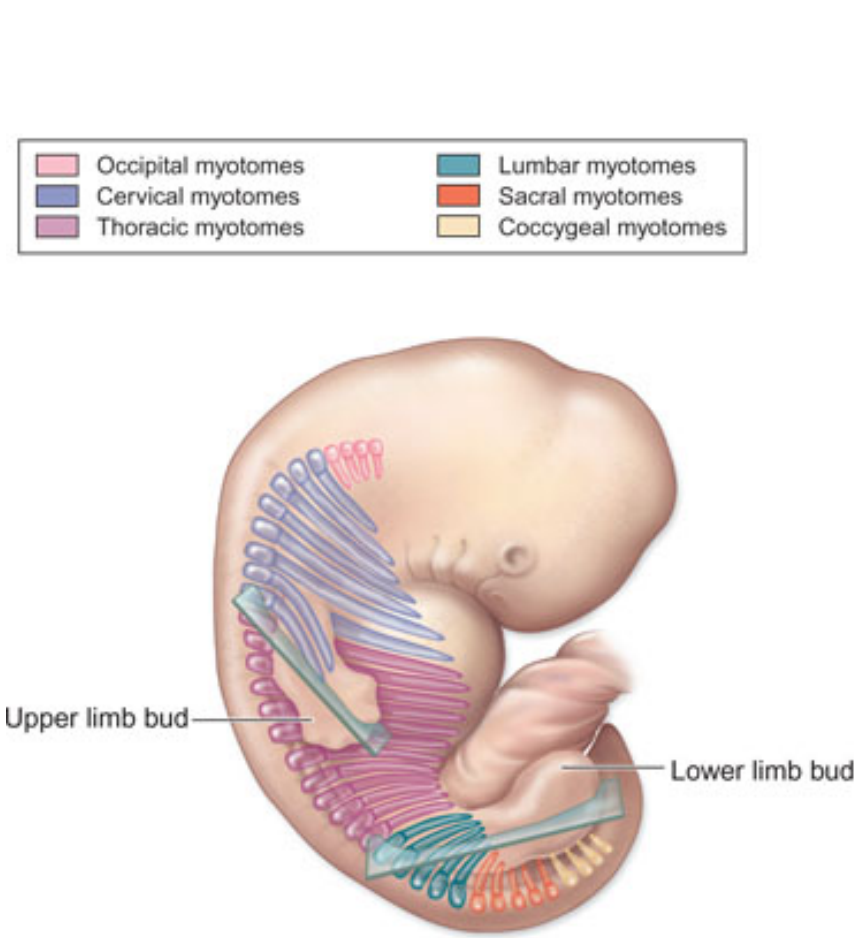
Smooth Muscle

- Sarcoplasmic reticulum is sparse.
- Transverse tubules are absent.
- Contraction is slow, resistant to fatigue, and usually sustained for an extended period of time.
- Takes longer than skeletal muscle to contract and relax.
- Contraction is under involuntary control.

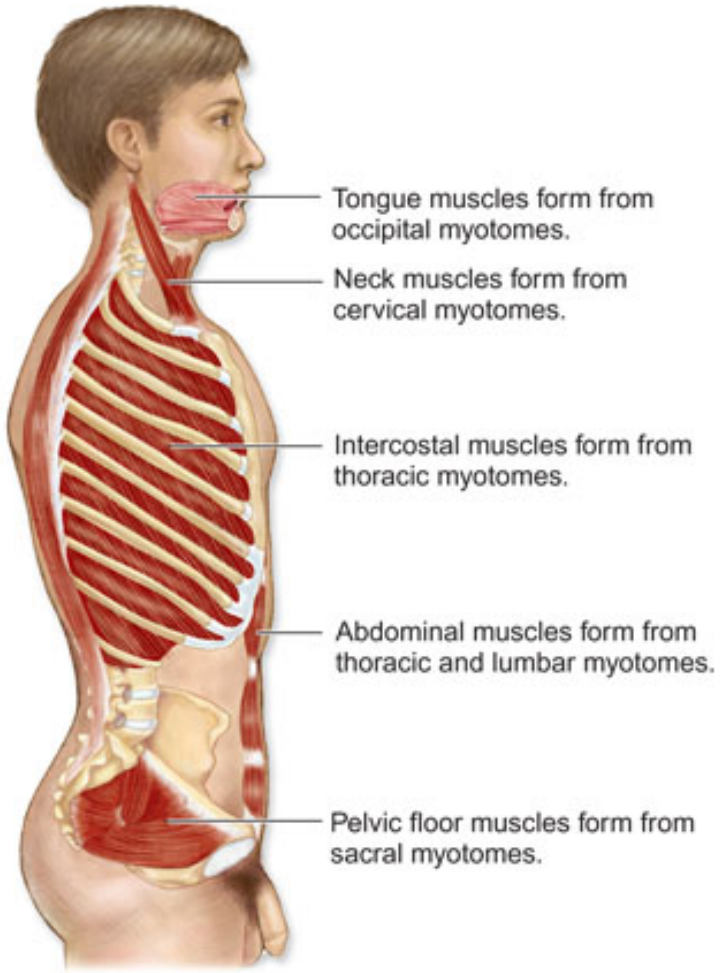


Development of Skeletal Muscle

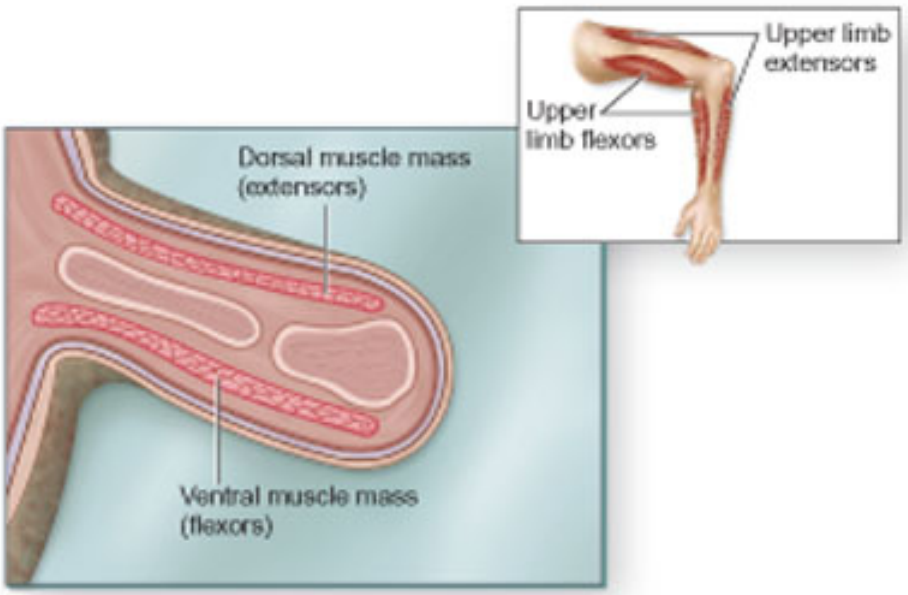
- Initiated during the fourth week of embryonic development when mesodermal cells form thick blocks along each side of the developing neural tube.
- Blocks, called paraxial mesoderm, form structures called somites.
  - sclerotome separates from the rest of the somite and gives rise to the vertebral skeleton
  - dermatome forms the connective tissue of the skin
  - myotome gives rise to the skeletal muscles



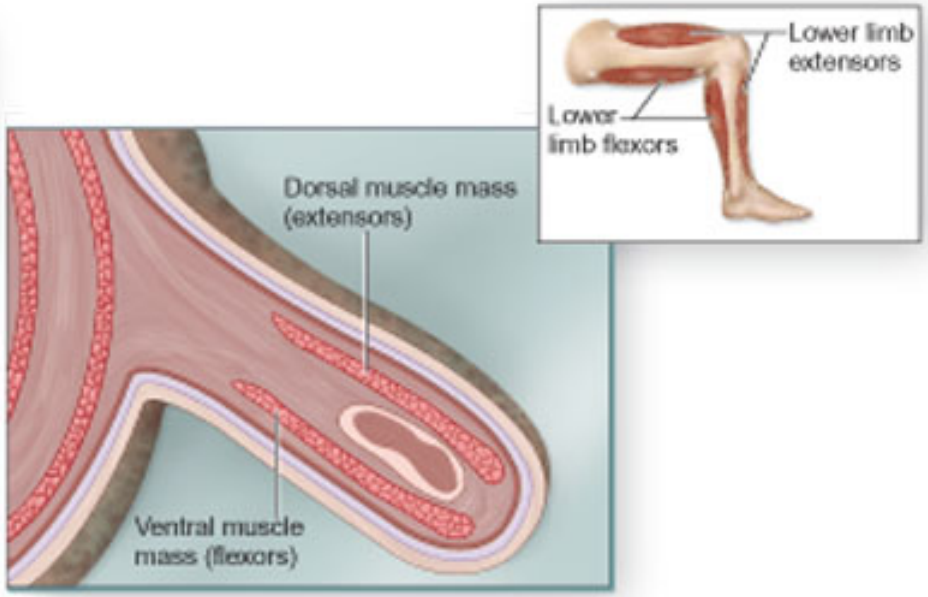
(a) 6-week embryo



(b) Selected axial musculature formed from myotomes



(c) Upper limb muscles, 6 weeks



(d) Lower limb muscles, 6 weeks

Effects of Aging on Skeletal Muscle

- Slow, progressive loss of skeletal muscle mass begins as a direct result of increasing inactivity.
- Size and power of all muscle tissues also decrease
- Lost muscle mass is replaced by either adipose or fibrous connective tissue.
- Muscle strength and endurance are impaired.
- Decreased cardiovascular performance thus.
- Increased circulatory supply to active muscles occurs much more slowly
- Tolerance for exercise decreases.
- Tendency toward rapid fatigue.
- Muscle tissue has a reduced capacity to recover from disease or injury.
- Elasticity of skeletal muscle also decreases.