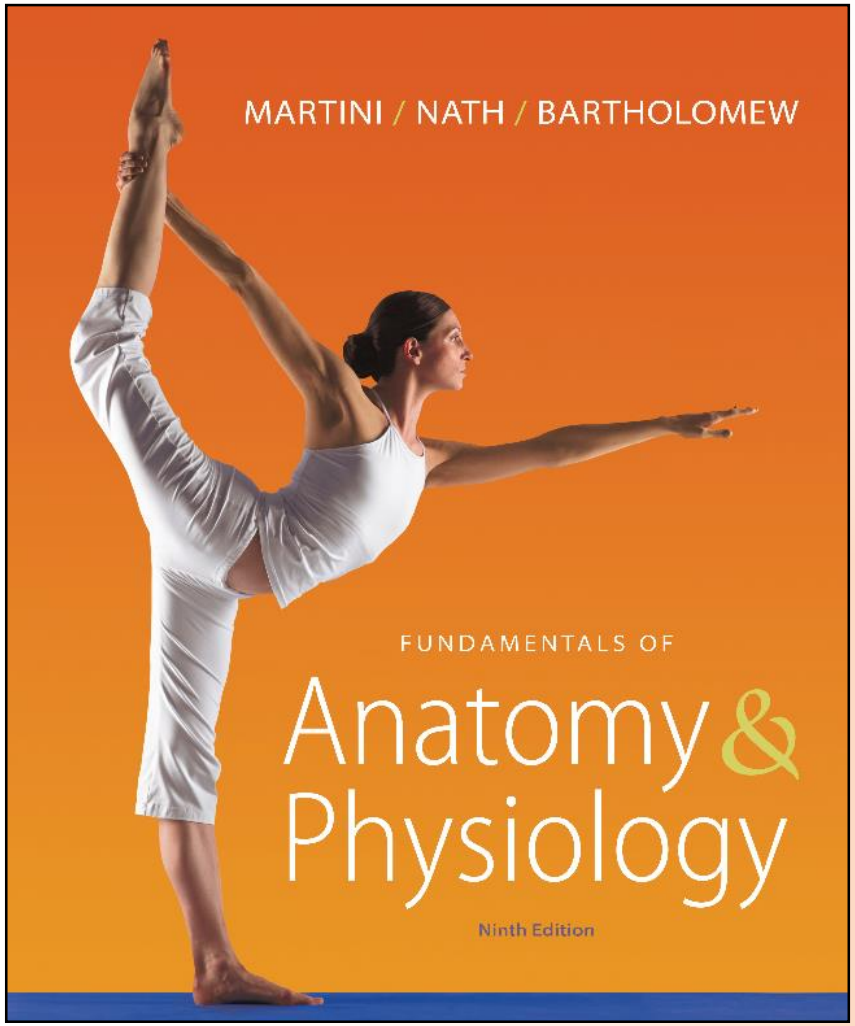


10

Muscle Tissue

PowerPoint® Lecture Presentations prepared by Jason LaPres

Lone Star College—North Harris

10-1 An Introduction to Muscle Tissue

- Learning Outcomes
  - **10-1** Specify the functions of skeletal muscle tissue.
  - **10-2** Describe the organization of muscle at the tissue level.
  - **10-3** Explain the characteristics of skeletal muscle fibers, and identify the structural components of a sarcomere.
  - **10-4** Identify the components of the neuromuscular junction, and summarize the events involved in the neural control of skeletal muscle contraction and relaxation.

10-1 An Introduction to Muscle Tissue

- Learning Outcomes
  - **10-8** Identify the structural and functional differences between skeletal muscle fibers and cardiac muscle cells.
  - **10-9** Identify the structural and functional differences between skeletal muscle fibers and smooth muscle cells, and discuss the roles of smooth muscle tissue in systems throughout the body.

An Introduction to Muscle Tissue

- What are some functions of skeletal muscle tissue?
  - Think, pair, share!

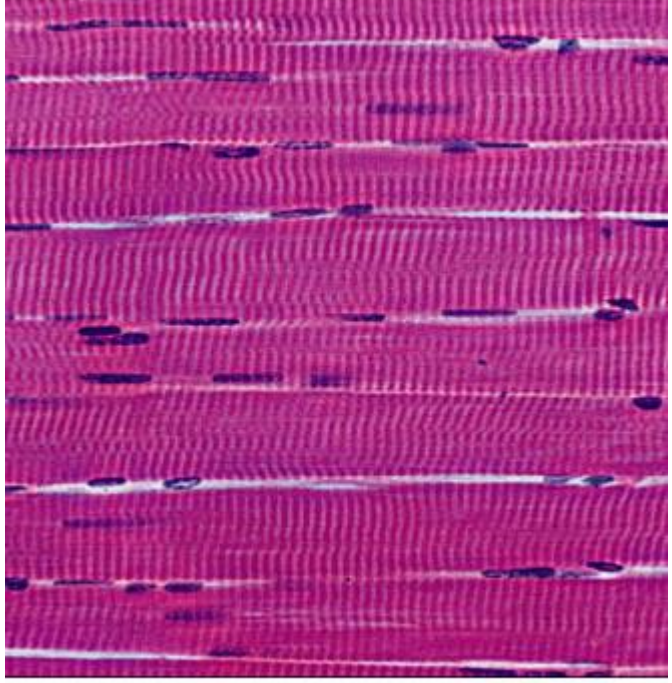
An Introduction to Muscle Tissue

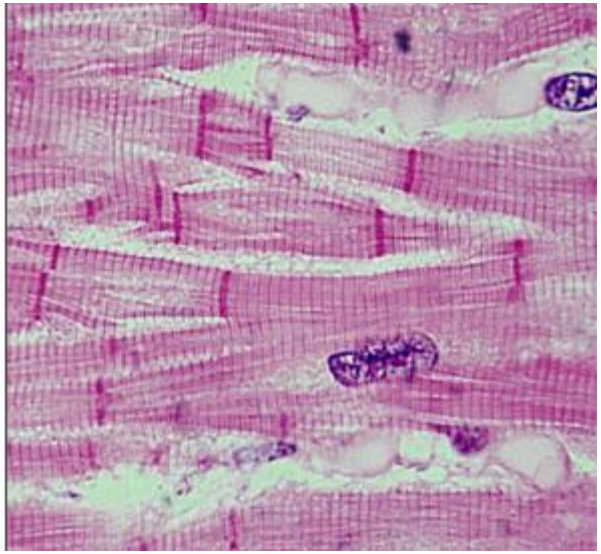
Define striated and voluntary.

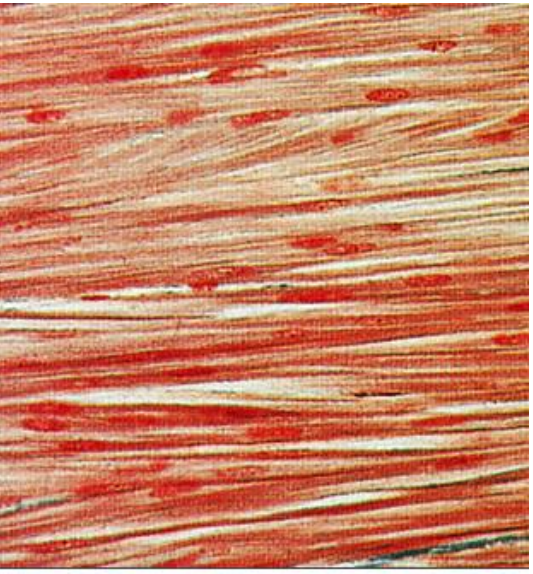
- Muscle Tissue
  - A primary tissue type, divided into:
    - **Skeletal** muscle tissue (striated, voluntary)
    - **Cardiac** muscle tissue (striated, involuntary)
    - **Smooth** muscle tissue (non-striated, involuntary)

Divided based on:
- how the contractile machinery is organized
- how the nervous system figures in its control.

Skeletal, Cardiac, or Smooth?







Where are these tissues normally found?

- Skeletal Muscle
  - voluntary, striated muscle attached to one or more bones, long, threadlike cells – muscle fibers
    - **voluntary** – conscious control over skeletal muscles
    - **striations** - alternating light and dark transverse bands , results from an overlapping of internal contractile proteins
    - contains **multiple nuclei** adjacent to plasma membrane

10-1 Functions of Skeletal Muscle Tissue

- Six Functions of Skeletal Muscle Tissue
  1. Produce skeletal movement
  2. Maintain posture and body position
  3. Support soft tissues
  4. Guard entrances and exits
  5. Maintain body temperature
  6. Store nutrient reserves

10-2 Organization of Muscle

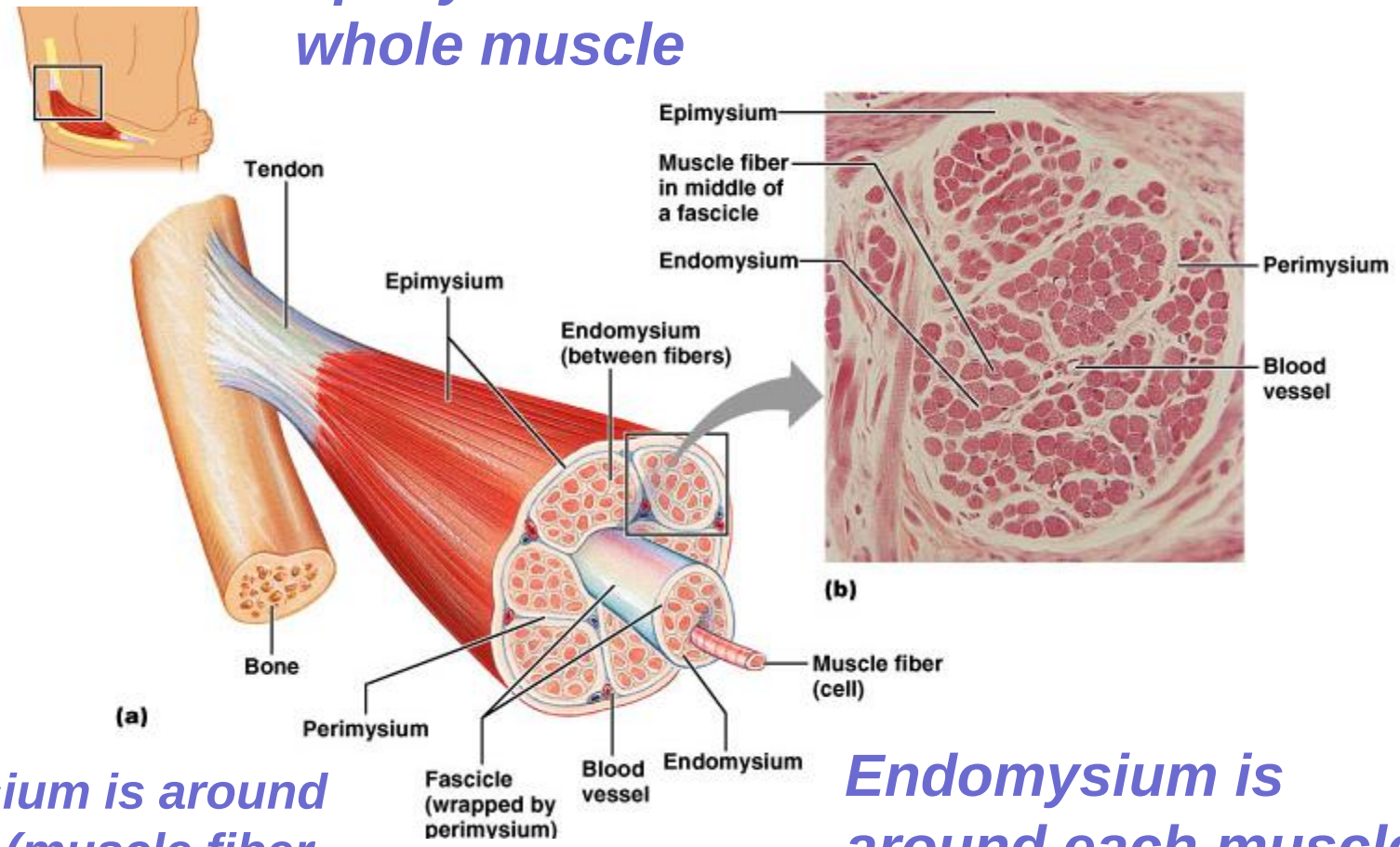
- Skeletal Muscle
  - **Connective tissues**
  - Nerves
  - Blood vessels
  - Muscle tissue (muscle cells or fibers)

10-2 Organization of Muscle

- Organization of Connective Tissues
  - Muscles have three layers of connective tissues
    1. **Epimysium**
    2. **Perimysium**
    3. **Endomysium**

Connective Tissue of Muscle

Epimysium: surrounds whole muscle



Perimysium is around fascicle (muscle fiber bundles)

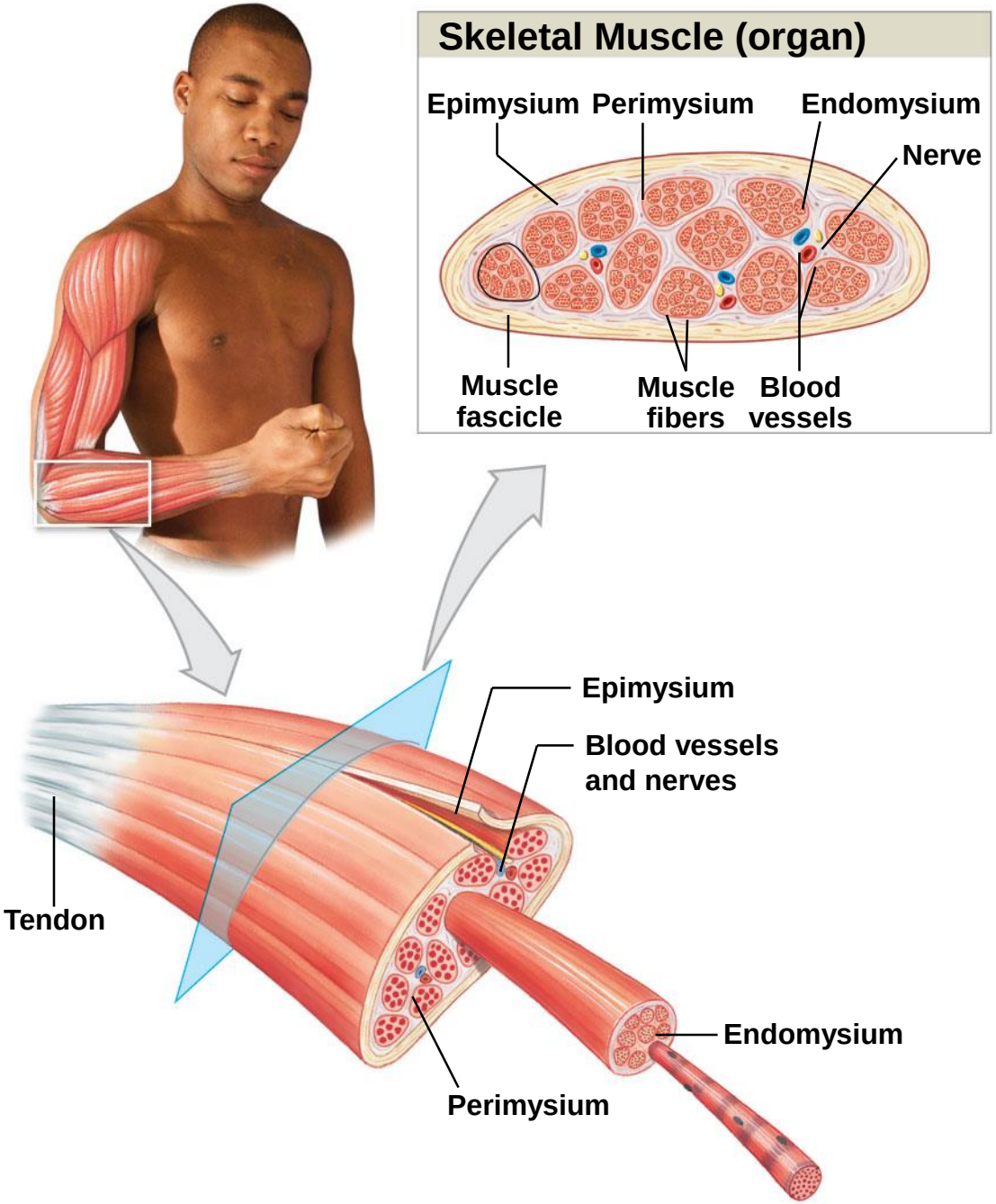
Endomysium is around each muscle fiber

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

- **Perimysium**
  - Surrounds muscle fiber bundles (fascicles)
  - Contains blood vessel and nerve supply to fascicles

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

Figure 10-1 The Organization of Skeletal Muscles



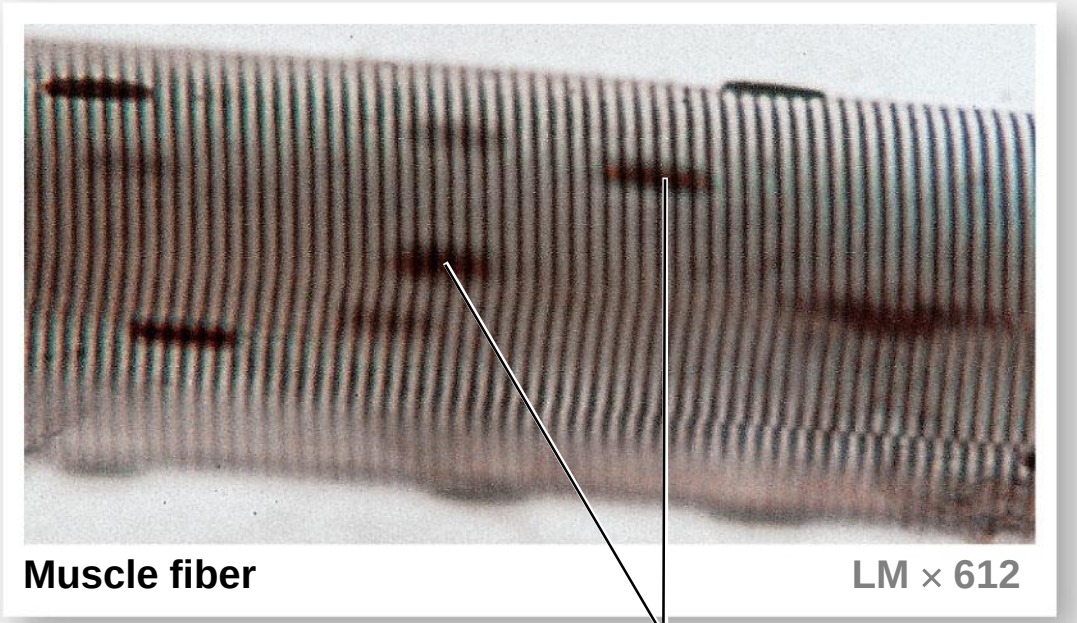
- Organization of Connective Tissues
  - Muscle Attachments
    - Endomysium, perimysium, and epimysium come together:
      - At ends of muscles
      - To form connective tissue attachment to bone matrix
      - I.e., **tendon** (bundle) or **aponeurosis** (sheet)

10-2 Blood Vessels and Nerves

- Blood Vessels and Nerves
  - Muscles have extensive vascular systems that:
    - Supply large amounts of oxygen
    - Supply nutrients
    - Carry away wastes
  - Skeletal muscles are voluntary muscles, controlled by nerves of the central nervous system (brain and spinal cord)

Figure 10-2b The Formation of a Multinucleate Skeletal Muscle Fiber

10-3 Skeletal Muscle cells and fibers



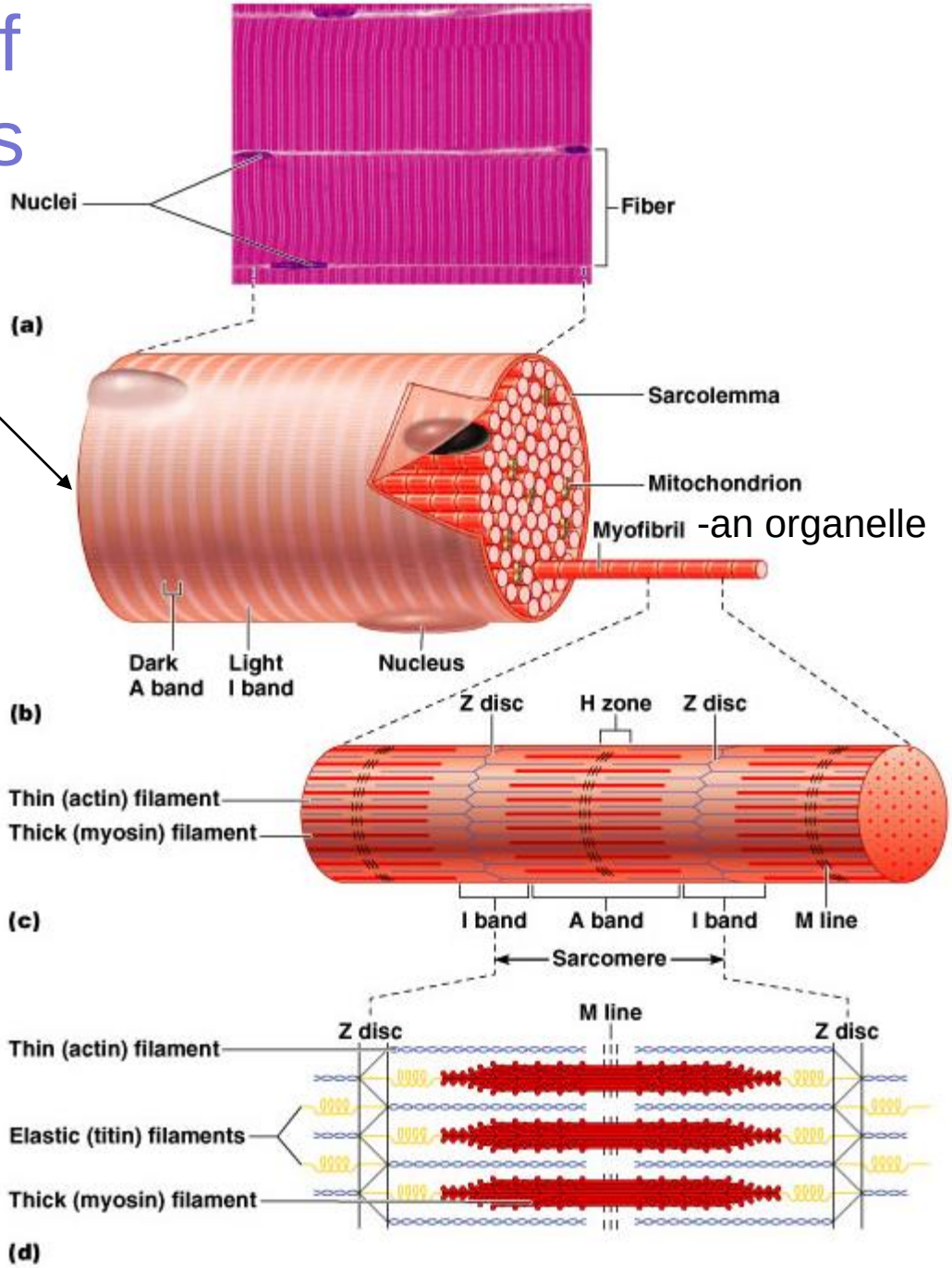
b A diagrammatic view and a micrograph of one muscle fiber.

Muscle Fibers

- **sarcolemma** – plasma membrane of a muscle fiber
- **sarcoplasm** – cytoplasm of a muscle fiber
- **mitochondria** – packed in spaces between myofibrils
- **sarcoplasmic reticulum** (SR) - smooth ER that forms a network around each myofibril – **calcium reservoir**
- The repeating unit of a skeletal muscle fiber is the sarcomere

10-3 Characteristics of Skeletal Muscle Fibers

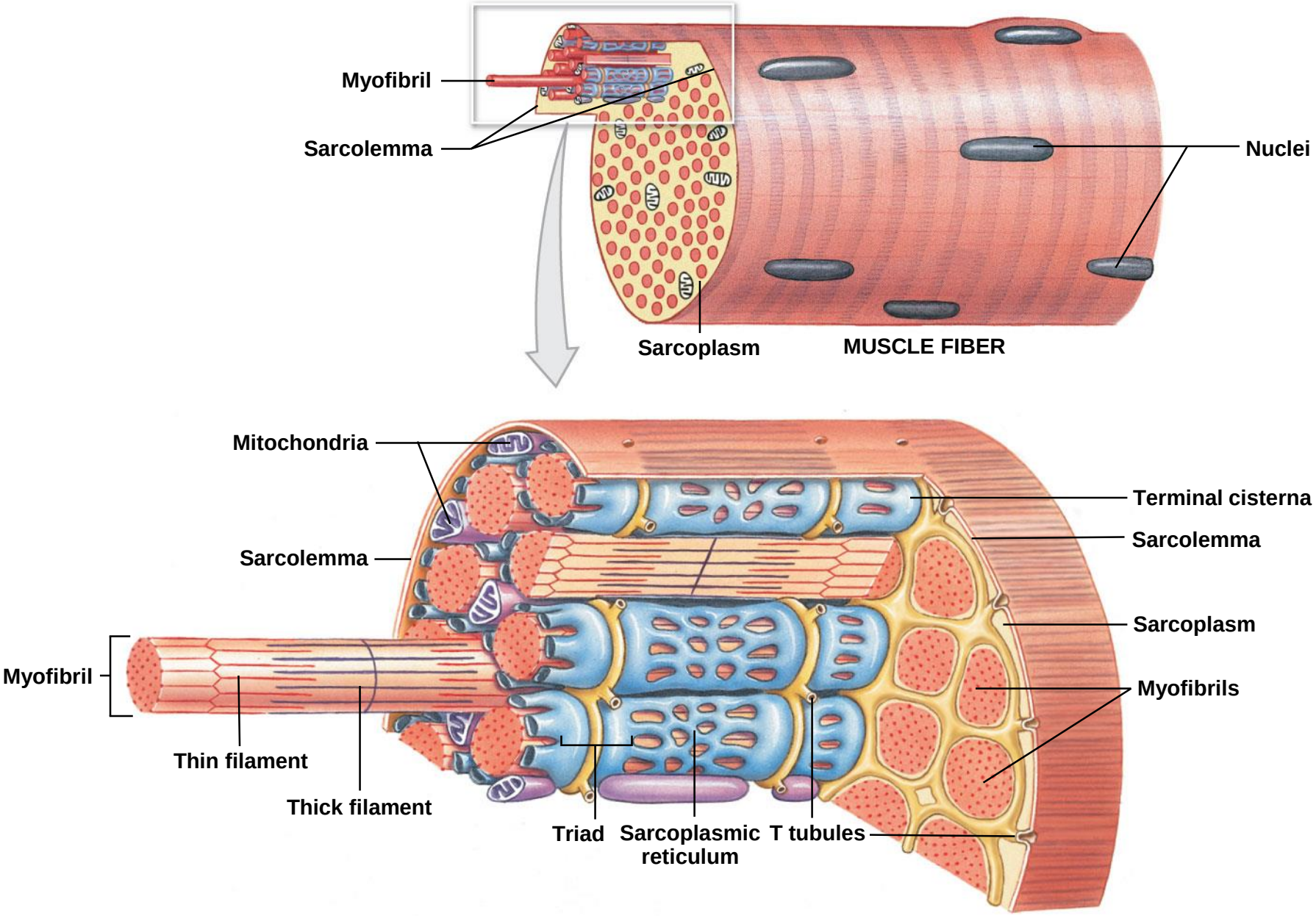
- ***Fibers*** (each is one cell) have striations
- ***Myofibrils*** are organelles of the cell: these are made up of ***myofilaments***
- ***Sarcomere***
  - Basic unit of contraction
  - ***Myofibrils*** are long rows of repeating sarcomeres
  - Boundaries: ***Z discs*** (or lines)



10-3 Characteristics of Skeletal Muscle Fibers

- **Myofibrils**
  - Lengthwise subdivisions within muscle fiber
  - Made up of bundles of protein filaments (**myofilaments**)
  - Myofilaments are responsible for muscle contraction
  - Types of myofilaments:
    - **Thin filaments**
      - Made of the protein actin
    - **Thick filaments**
      - Made of the protein myosin

Figure 10-3 The Structure of a Skeletal Muscle Fiber



10-3 Structural Components of a Sarcomere

- Sarcomeres
  - The contractile units of muscle
  - Structural units of myofibrils
  - Form visible patterns within myofibrils
  - A striped or striated pattern within myofibrils
    - Alternating dark, thick filaments (**A bands**) and light, thin filaments (**I bands**)

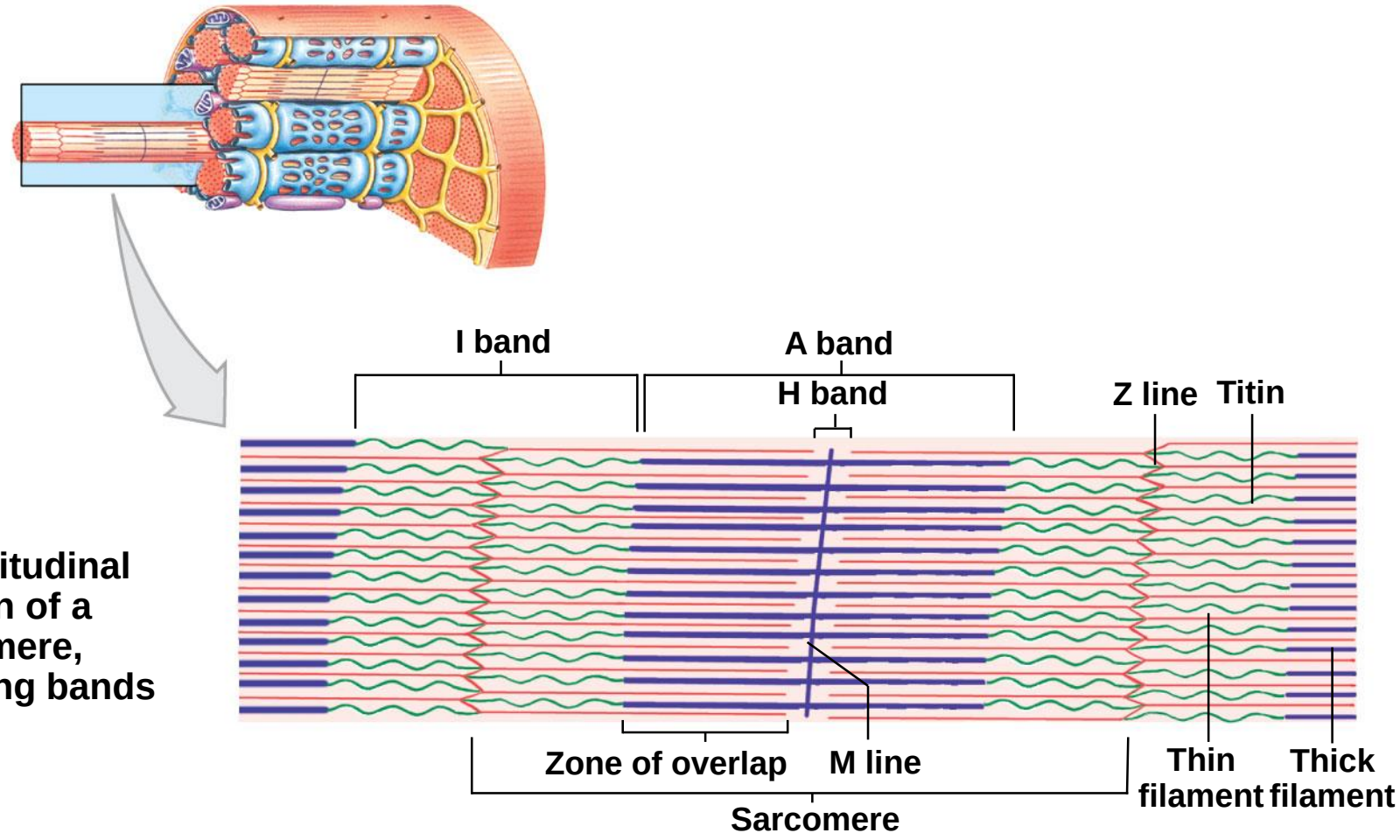
10-3 Structural Components of a Sarcomere

- Sarcomeres
  - The A Band
    - **M line**
      - The center of the A band
      - At midline of sarcomere
    - The **H Band**
      - The area around the M line
      - Has thick filaments but no thin filaments
    - **Zone of overlap**
      - The densest, darkest area on a light micrograph
      - Where thick and thin filaments overlap

10-3 Structural Components of a Sarcomere

- Sarcomeres
  - The I Band
    - **Z lines**
      - The centers of the I bands
      - At two ends of sarcomere
    - **Titin**
      - Are strands of protein
      - Reach from tips of thick filaments to the Z line
      - Stabilize the filaments

Figure 10-4a Sarcomere Structure, Part I



a A longitudinal section of a sarcomere, showing bands

Figure 10-4b Sarcomere Structure, Part I

b **A corresponding view of a sarcomere in a myofibril from a muscle fiber in the gastrocnemius muscle of the calf**

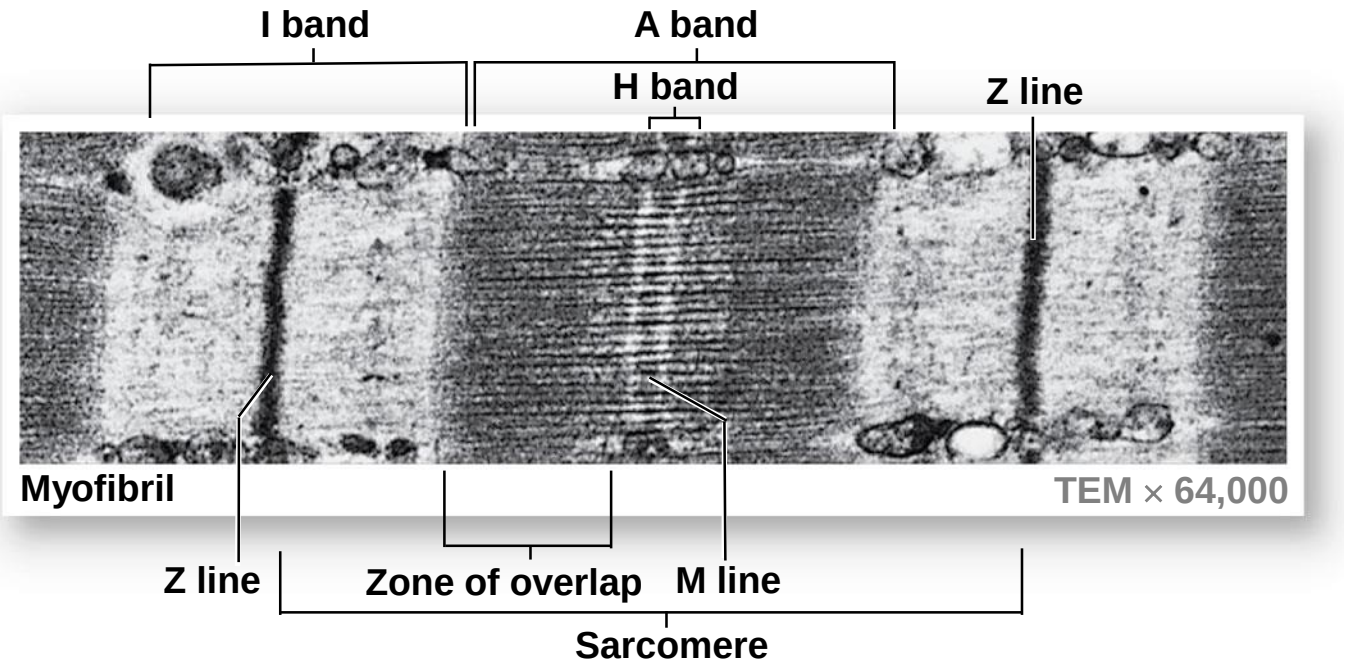
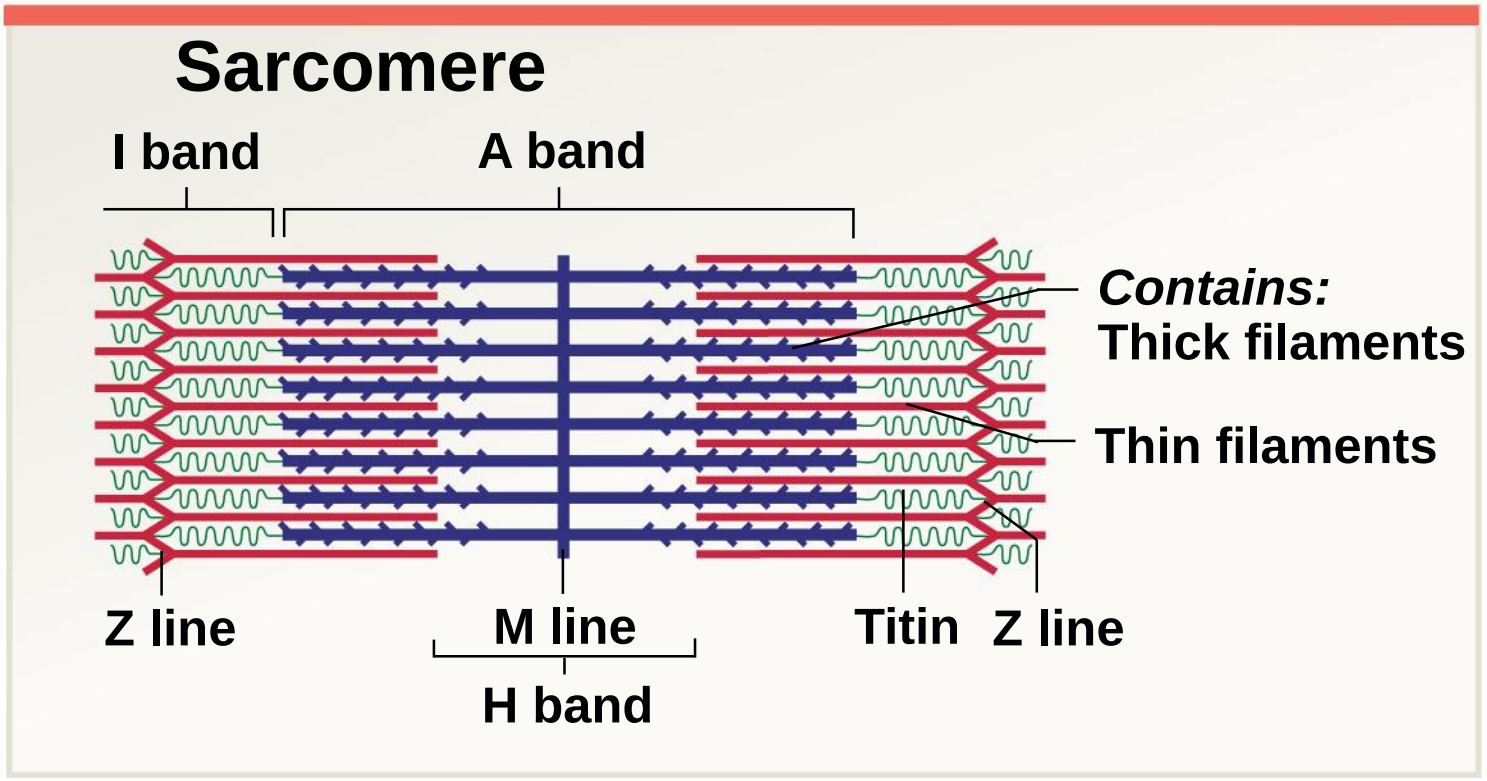


Figure 10-6 Levels of Functional Organization in a Skeletal Muscle



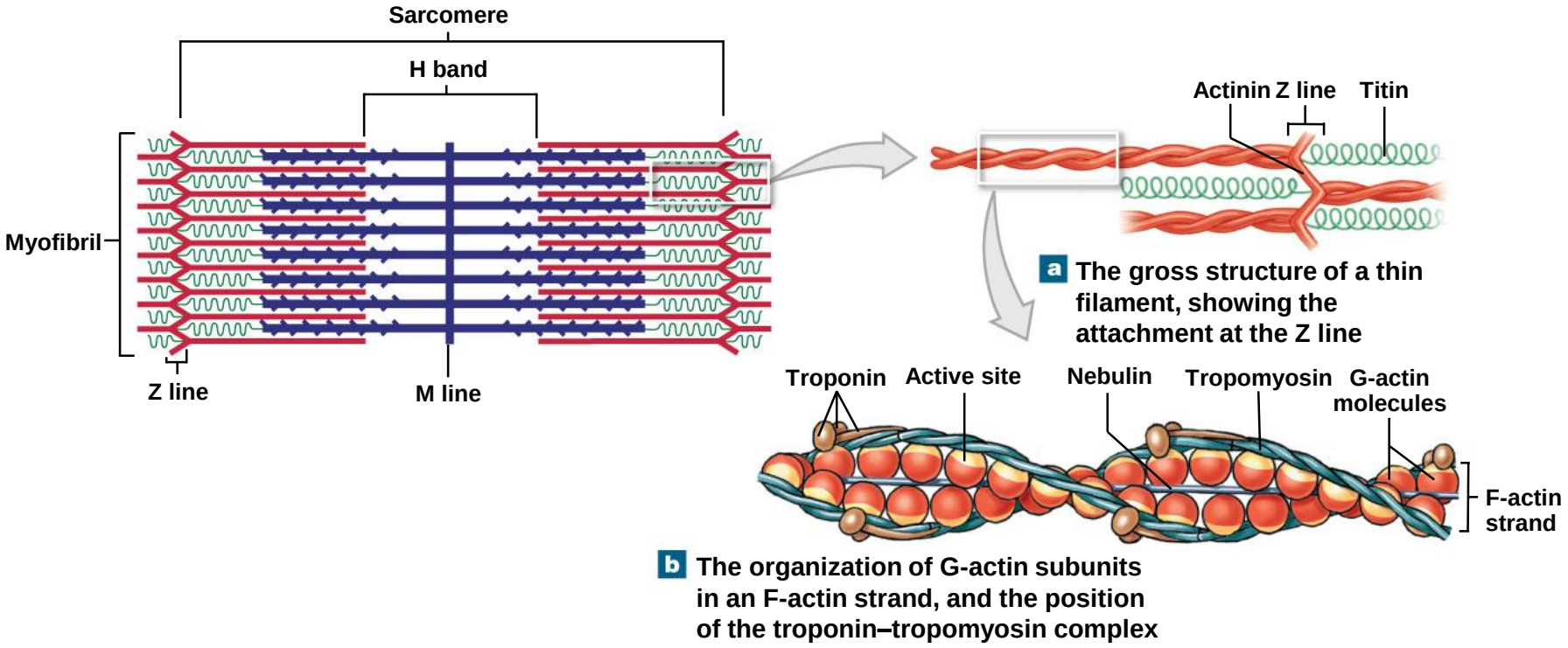
10-3 Structural Components of a Sarcomere

- Thin Filaments
  - **F-actin (filamentous actin)**
    - Is two twisted rows of globular G-actin
    - The active sites on G-actin strands bind to myosin
  - **Nebulin**
    - Holds F-actin strands together

10-3 Structural Components of a Sarcomere

- Thin Filaments
  - **Tropomyosin**
    - Is a double strand
    - Prevents actin–myosin interaction
  - **Troponin**
    - A globular protein
    - Binds tropomyosin to G-actin
    - Controlled by Ca^{2+}

Figure 10-7ab Thick and Thin Filaments



10-4 Skeletal Muscle Contraction

- The **Contraction Cycle**
  1. Contraction Cycle Begins
  2. Active-Site Exposure
  3. Cross-Bridge Formation
  4. Myosin Head Pivoting
  5. Cross-Bridge Detachment
  6. Myosin Reactivation

PLAY A&P FLIX The Cross Bridge Cycle

In other words…

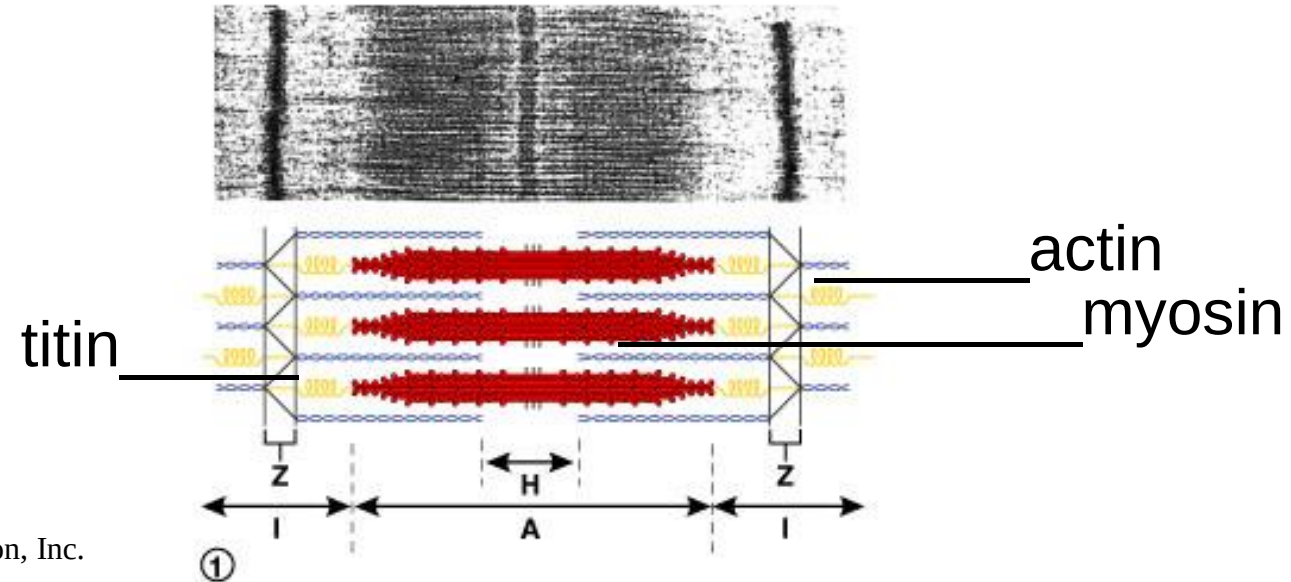
- Myosin heads sticking off the thick filaments use ATP to pull the actin filaments toward the middle of the A band, shortening the sarcomeres and thus pulling on an external load.

10-3 Structural Components of a Sarcomere

- Sliding Filaments and Muscle Contraction
  - **Sliding filament theory**
    - Thin filaments of sarcomere slide toward M line, alongside thick filaments
    - The width of A zone stays the same
    - Z lines move closer together

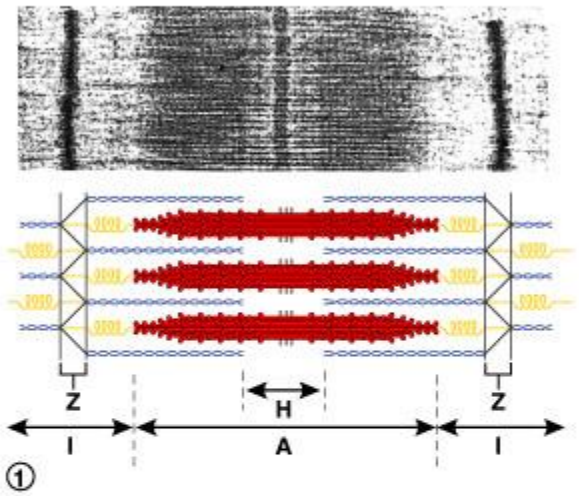
Myofibrils

- Made of three types of ***filaments*** **(or *myo*filaments)**:
  - Thick (***myosin***)
  - Thin (***actin***)
  - Elastic (***titin***)

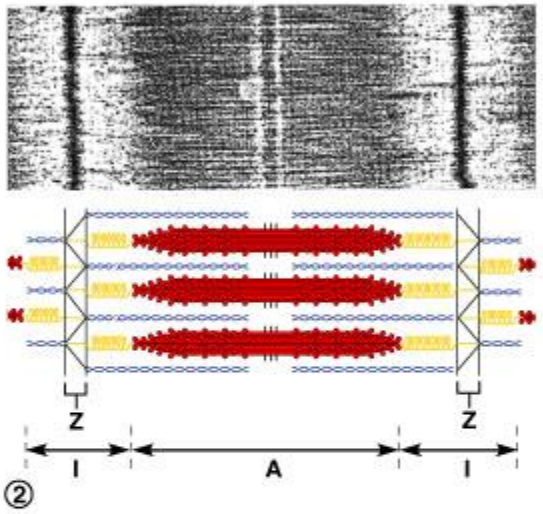


Sliding Filament Model

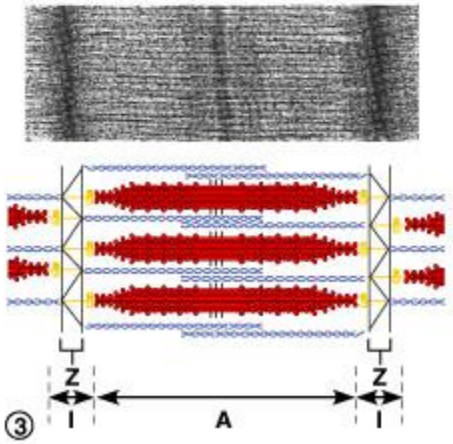
__relaxed sarcomere__



partly contracted



fully contracted

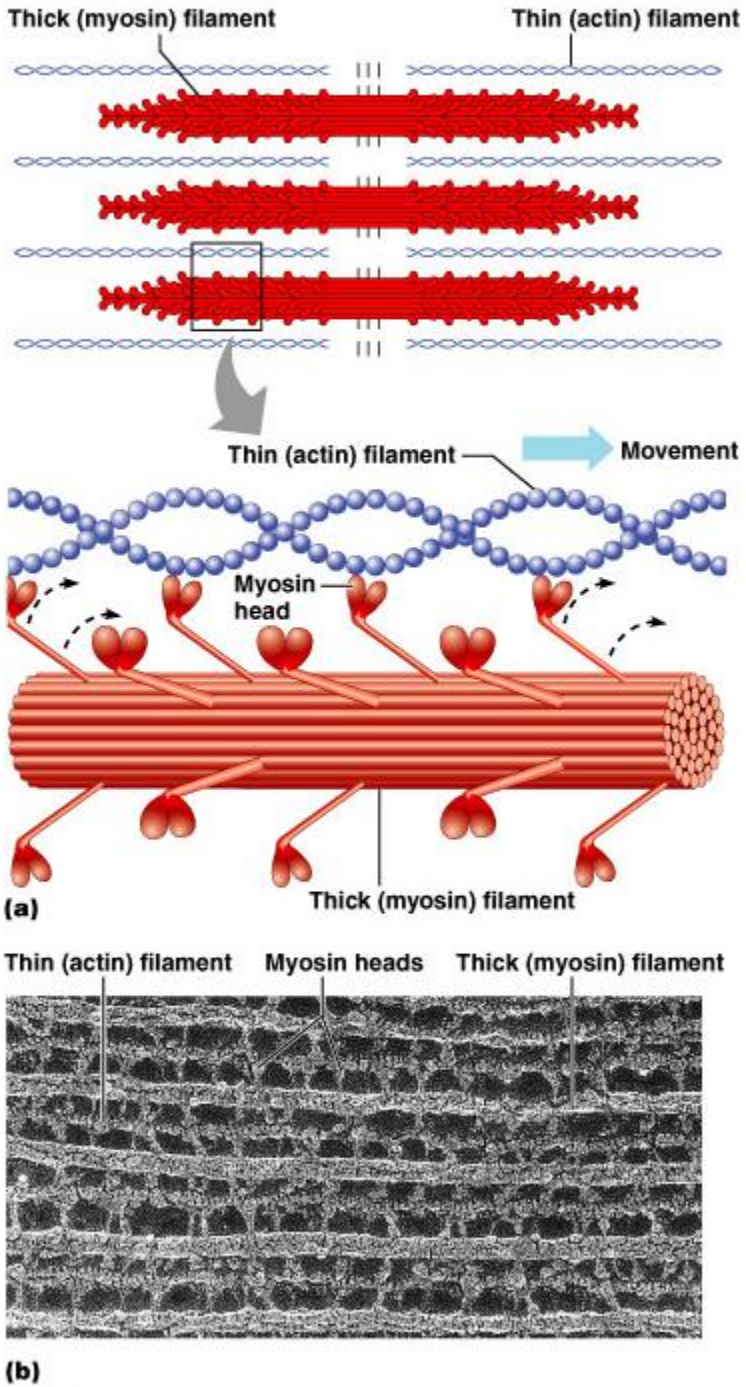


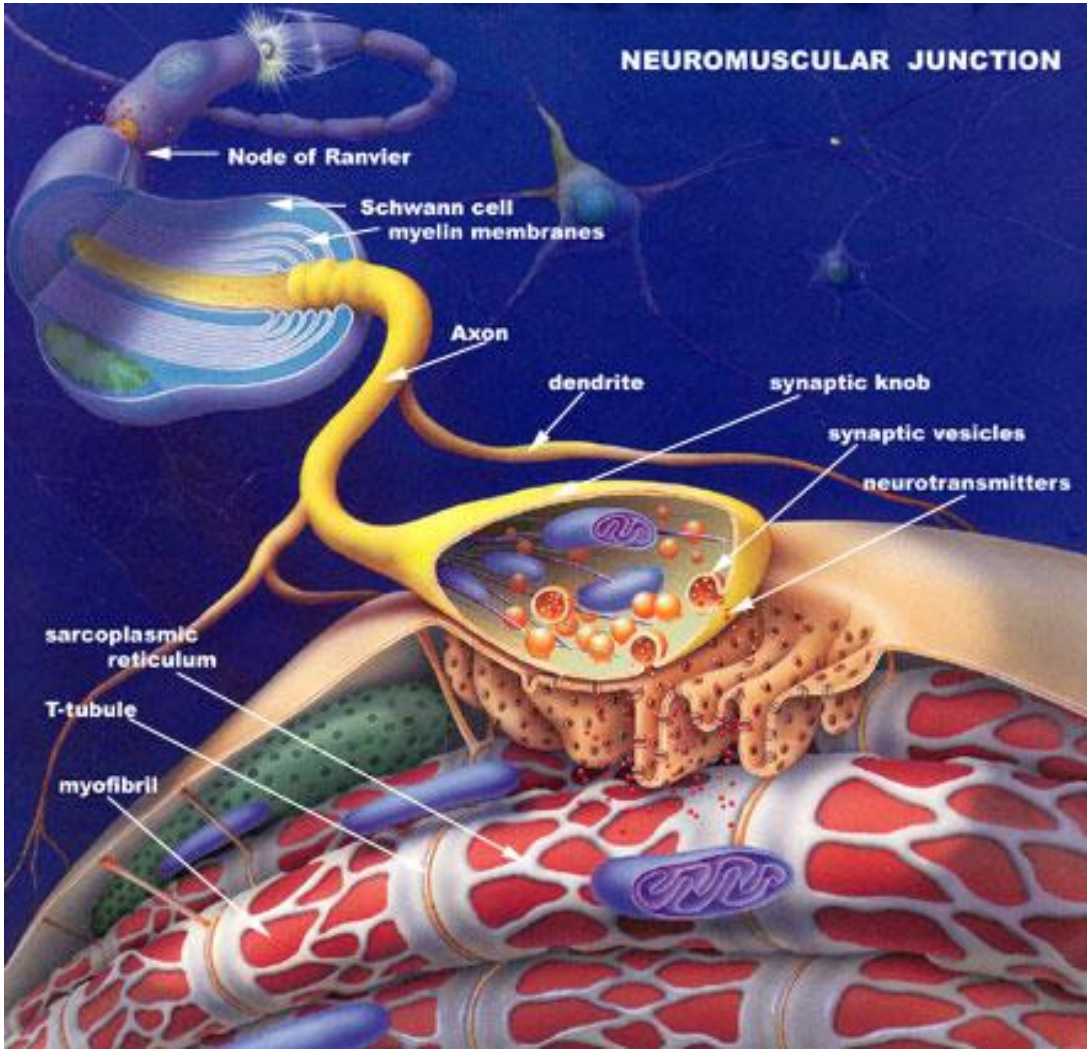
Sarcomere shortens because actin pulled towards its middle by myosin cross bridges

Titin resists overstretching

“A” band constant because it is caused by myosin, which doesn’t change length

Another view





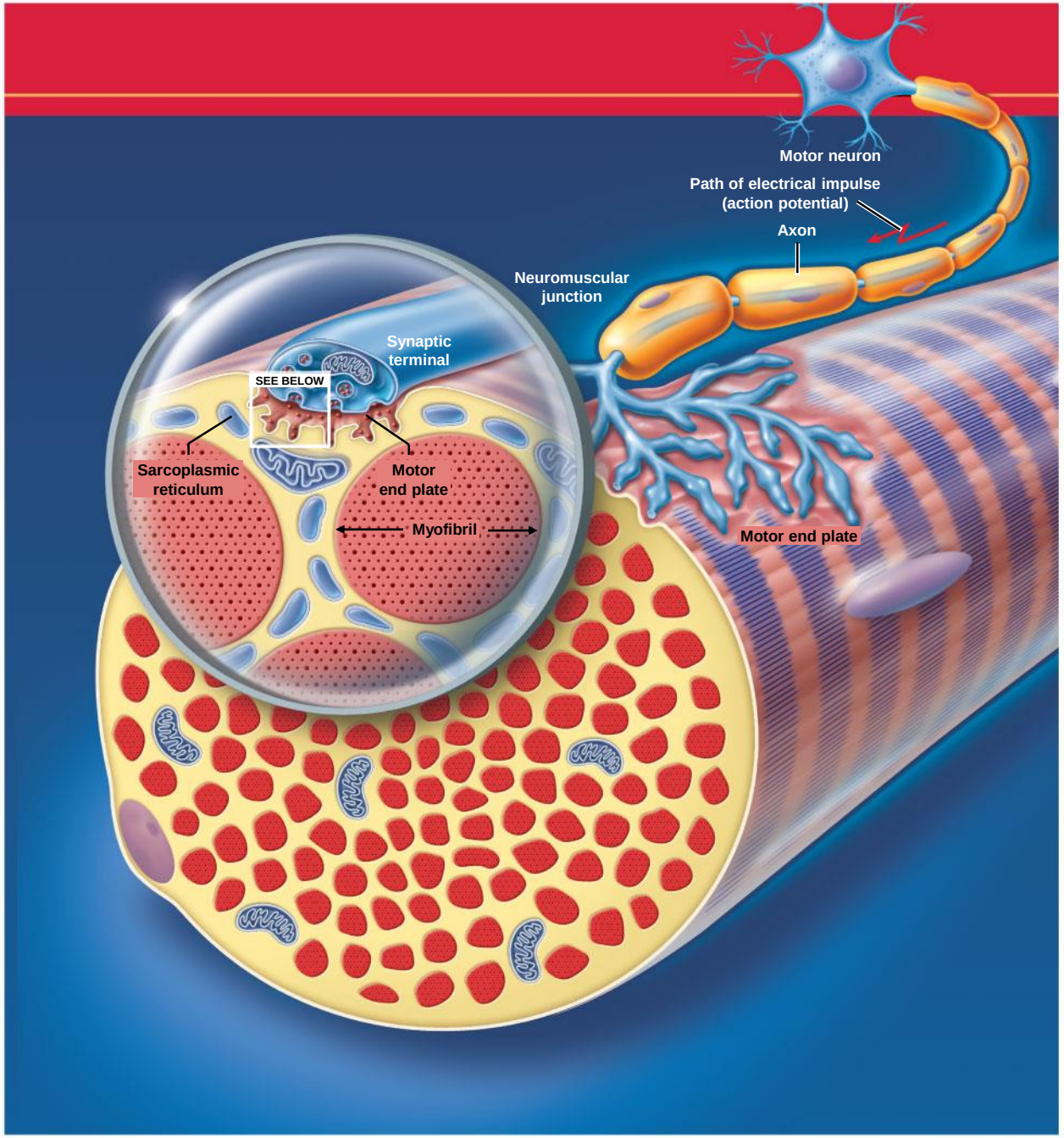
Neuromuscular Junction

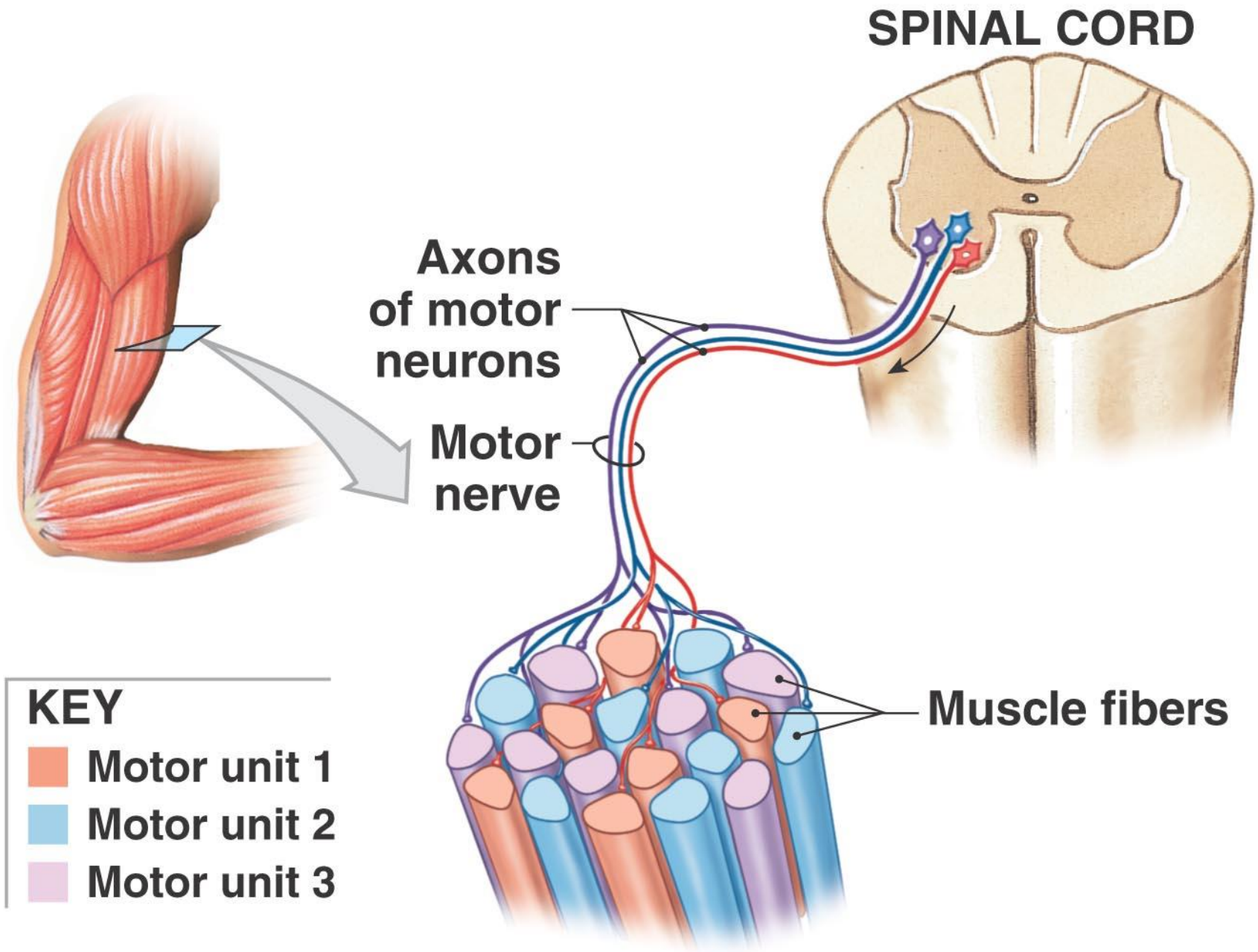
Motor neurons innervate muscle fibers
Motor end plate is where they meet
Neurotransmitters are released by nerve signal: this initiates calcium ion release and muscle contraction

Motor Unit: a motor neuron and all the muscle fibers it innervates (these all contract together)

- Average is 150, but range is four to several hundred muscle fibers in a motor unit
- The finer the movement, the fewer muscle fibers /motor unit
- The fibers are spread throughout the muscle, so stimulation of a single motor unit causes a weak contraction of the entire muscle

Figure 10-11 Skeletal Muscle Innervation





10-4 Skeletal Muscle Contraction and Relaxation

- Summary
  - Skeletal muscle fibers shorten as thin filaments slide between thick filaments
  - Free Ca^{2+} in the sarcoplasm triggers contraction
  - SR releases Ca^{2+} when a motor neuron stimulates the muscle fiber
  - Contraction is an active process
  - Relaxation and return to resting length are passive

10-5 Tension Production and Contraction Types

- Tension Production by Muscles Fibers
  - As a whole, a muscle fiber is either contracted or relaxed
  - Depends on:
    - The number of pivoting cross-bridges
    - The fiber's resting length at the time of stimulation
    - The frequency of stimulation

10-6 Energy to Power Contractions

- ATP Provides Energy For Muscle Contraction
  - Sustained muscle contraction uses a lot of ATP energy
  - Muscles store enough energy to start contraction
  - Muscle fibers must manufacture more ATP as needed

How does Rigor mortis relate to ATP depletion during death?

10-6 Energy to Power Contractions

- Energy Use and the Level of Muscular Activity
  - Skeletal muscles at rest metabolize fatty acids and store glycogen
  - During light activity, muscles generate ATP through the breakdown of carbohydrates, lipids, or amino acids
  - At peak activity, energy is provided by certain reactions that generate **lactic acid** as a byproduct

10-6 Energy to Power Contractions

- Muscle Fatigue
  - When muscles can no longer perform a required activity, they are **fatigued**
- Results of Muscle Fatigue
  - Depletion of metabolic reserves
  - Damage to sarcolemma and sarcoplasmic reticulum
  - Low pH (lactic acid)
  - Muscle exhaustion and pain

Why do we get sore muscles after a hard work out?

10-6 Energy to Power Contractions

- The **Recovery Period**
  - The time required after exertion for muscles to return to normal
  - Oxygen becomes available
  - Mitochondrial activity resumes

10-6 Energy to Power Contractions

- Heat Production and Loss
  - Active muscles produce heat
  - Up to 70% of muscle energy can be lost as heat, raising body temperature

10-7 Types of Muscles Fibers and Endurance

- Muscle Performance
  - **Force**
    - The maximum amount of tension produced
  - **Endurance**
    - The amount of time an activity can be sustained
  - Force and endurance depend on:
    - The types of muscle fibers
    - Physical conditioning

10-7 Types of Muscles Fibers and Endurance

- Muscle **Hypertrophy**
  - Muscle growth from heavy training
    - Increases diameter of muscle fibers
    - Increases number of myofibrils
    - Increases mitochondria, glycogen reserves
- Muscle **Atrophy**
  - Lack of muscle activity
    - Reduces muscle size, tone, and power

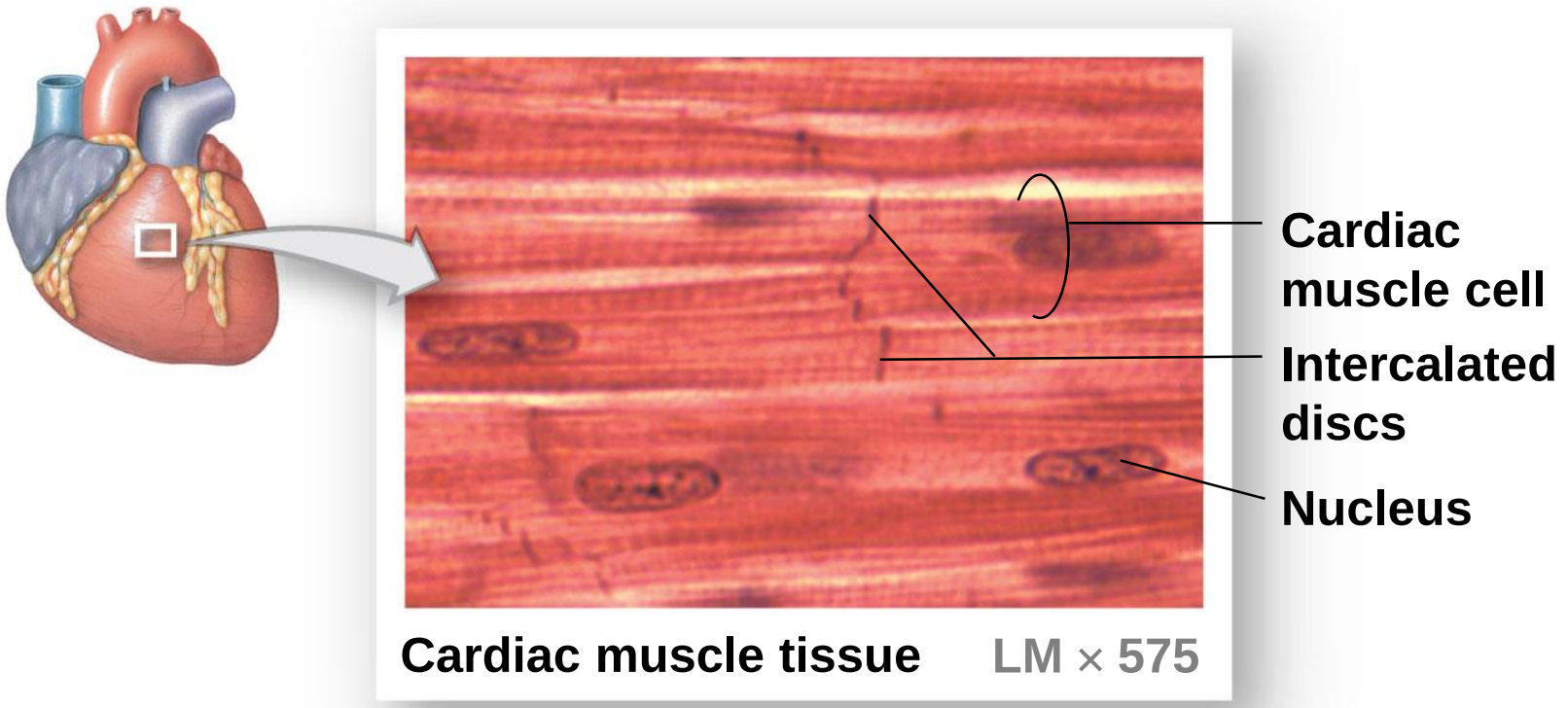
10-7 Types of Muscles Fibers and Endurance

- Importance of Exercise
  - What you don’t use, you lose
  - Muscle tone indicates base activity in motor units of skeletal muscles
  - Muscles become flaccid when inactive for days or weeks
  - Muscle fibers break down proteins, become smaller and weaker
  - With prolonged inactivity, fibrous tissue may replace muscle fibers

10-8 Cardiac Muscle Tissue

- Cardiac Muscle Tissue
  - limited to the heart
  - **myocytes** or **cardiocytes** are much shorter, branched, and notched at ends
  - contain **one centrally located nucleus** surrounded by light staining glycogen
  - **intercalated discs** join cardiocytes end to end
  - provide electrical and mechanical connection
  - **striated**, and **involuntary** (not under conscious control)

Figure 10-22a Cardiac Muscle Tissue

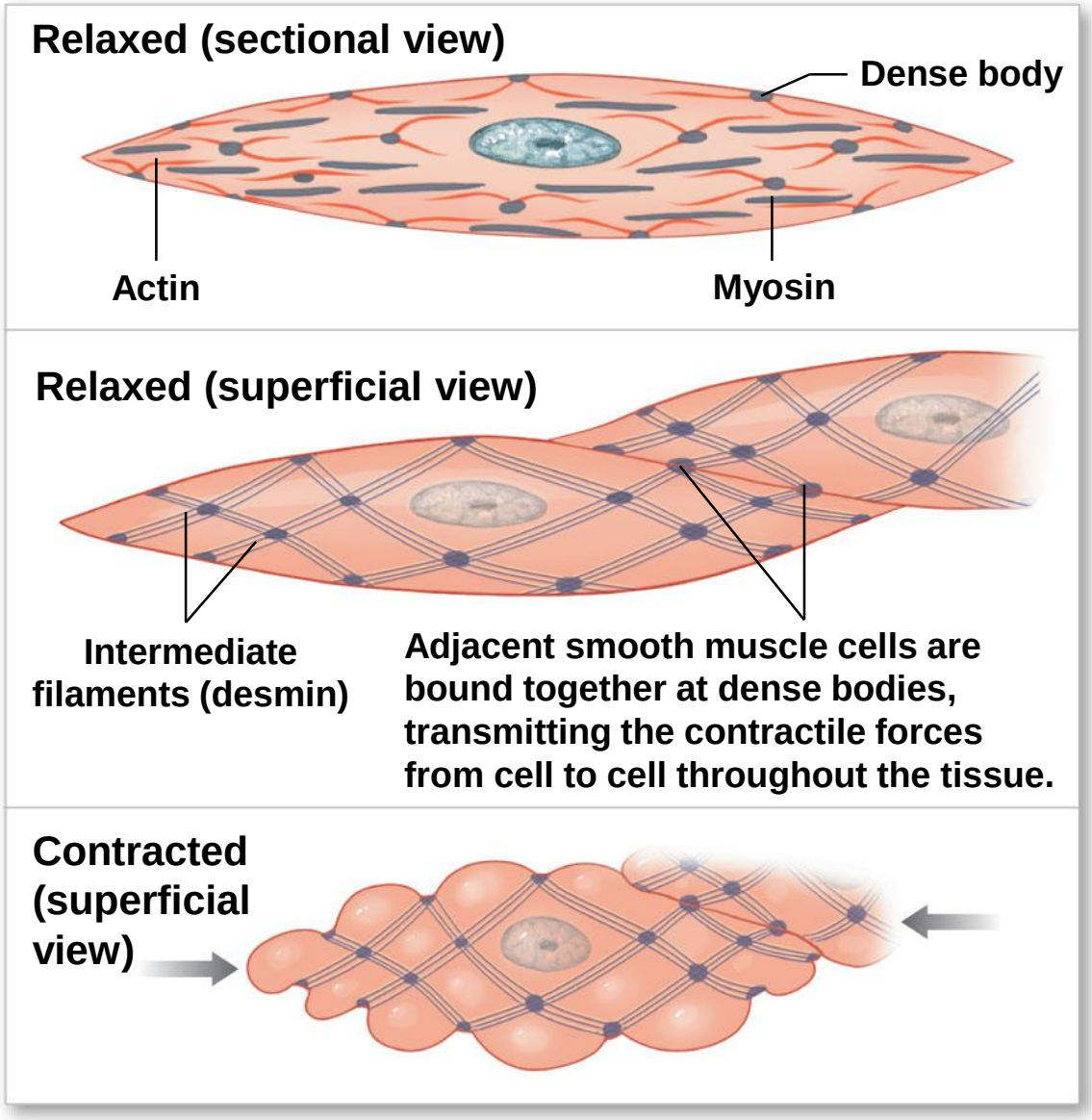


a **A light micrograph of cardiac muscle tissue.**

10-9 Smooth Muscle Tissue

- Smooth Muscle in Body Systems
  - Forms around other tissues
    - **lacks striations** and is **involuntary**
    - **visceral muscle** – forms layers of digestive, respiratory, and urinary tract: blood vessels, uterus and other viscera
    - propels contents through an organ, regulates diameter of blood vessels

Figure 10-23b Smooth Muscle Tissue



b **A single relaxed smooth muscle cell is spindle shaped and has no striations. Note the changes in cell shape as contraction occurs.**