Muscle Tissue

Muscle Tissue

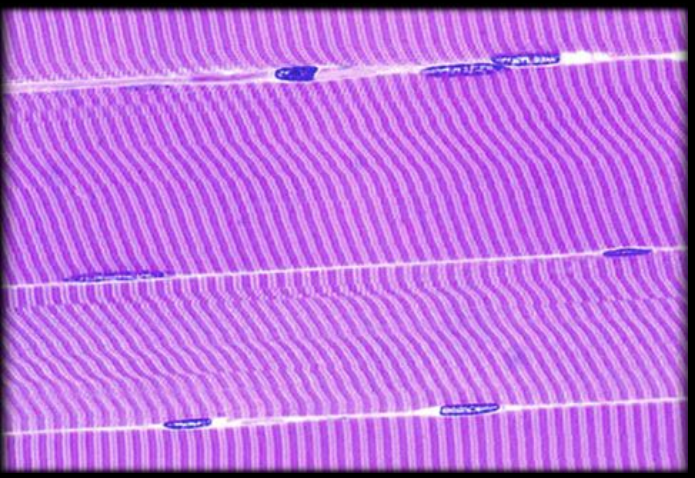
- Muscles tissue distributed almost everywhere
- Some functions of muscular tissue
  - Propels food we eat along gastrointestinal tract
  - Expels waste we produce
  - Changes amount of air that enters the lung
  - Pumps the blood to body tissues

Muscle Tissue

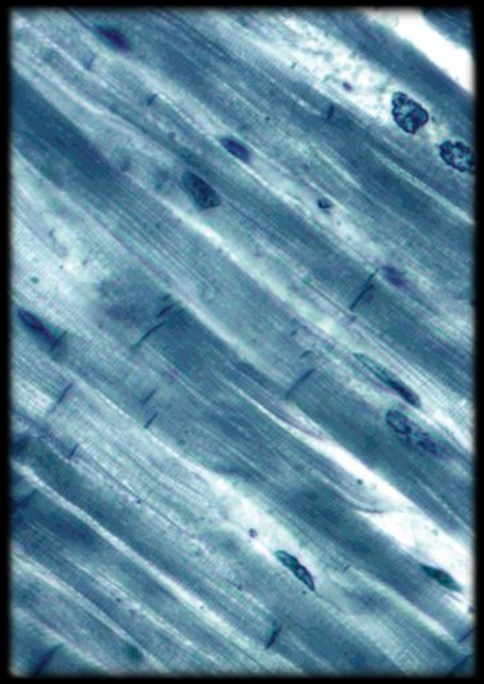
- Three types of muscle tissue:
  - Skeletal muscle, cardiac muscle, smooth muscle
  - Composes 40-50% of weight of the adult
- 700 skeletal muscles in the muscular system

3 Types of Muscle Tissue

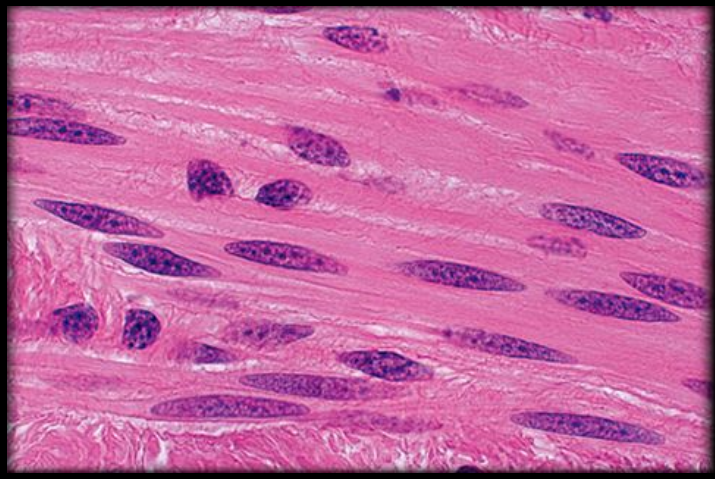
Skeletal



Cardiac



Smooth



Introduction to Skeletal Muscle: Functions of Skeletal Muscle

- Functions of Skeletal Muscle
  - **Body movement**
  - **Maintenance of posture**
  - **Protection and support**
  - **Storage and movement of materials**
    - **sphincters**,
  - **Heat production**
    - shiver when cold to generate heat

Introduction to Skeletal Muscle: Functions of Skeletal Muscle

What are the five major functions of skeletal muscle?

Body movement, maintenance of posture, protection and support, storage and movement of material, and heat production.

Introduction to Skeletal Muscle: Characteristics Skeletal Muscle Tissue

- Characteristics
  - **Excitability**
    - responsive to nervous system stimulation
    - neurons secreting neurotransmitters that bind to muscle cells
  - **Conductivity**
    - electrical change traveling along plasma membrane
    - initiated in response to neurotransmitter binding
  - **Contractility**
    - contractile proteins within muscle cells
    - slide past each other
    - tension used to pull on bones of skeleton

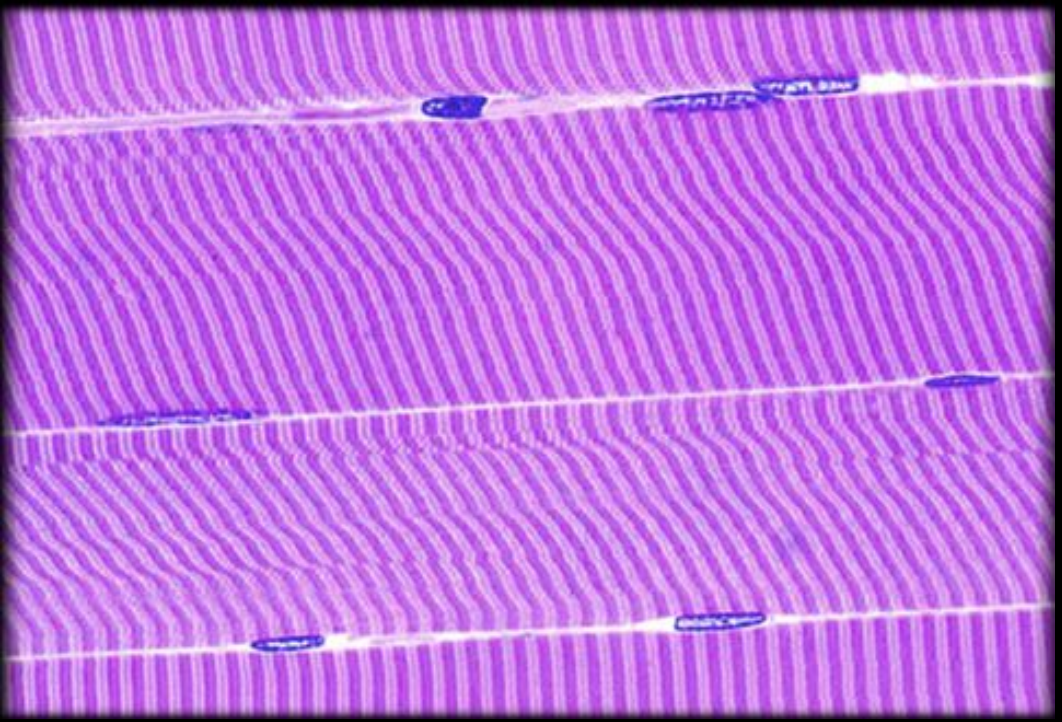
Introduction to Skeletal Muscle: Characteristics Skeletal Muscle Tissue

- Characteristics *(continued)*
  - **Elasticity**
    - due to protein fibers acting like compressed coils
    - when contraction ended, tension in proteins released
    - muscle returns to original length
  - **Extensibility**
    - lengthening of a muscle cell
    - e.g., extension of the triceps brachii when flex elbow joint

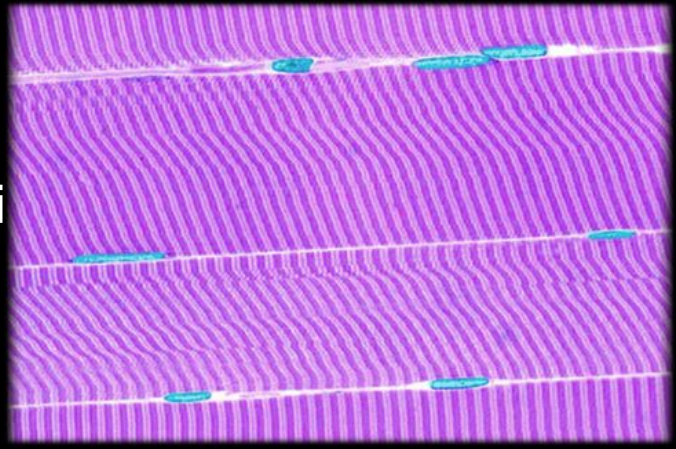
Anatomy of Skeletal Muscle: Gross Anatomy

- Skeletal muscle
  - Composed of thousands of muscle cells
  - Typically as long as the entire muscle
  - Often referred to as muscle fibers
  - Organized into bundles, termed **fascicles**
  - Muscle composed of fibers, connective tissue, blood vessels, nerves

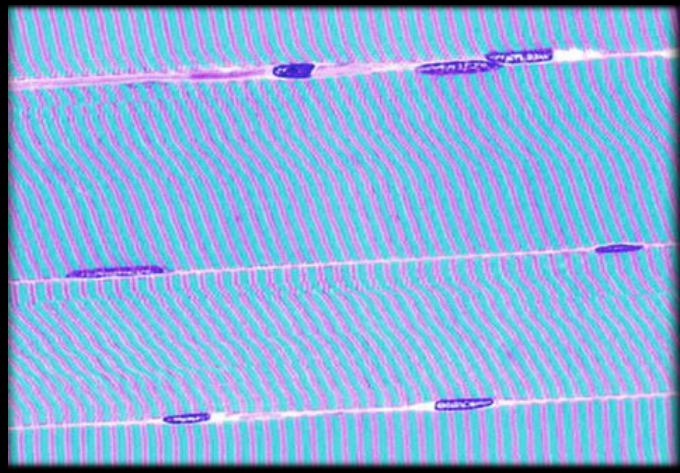
Skeletal Muscle
High Magnification



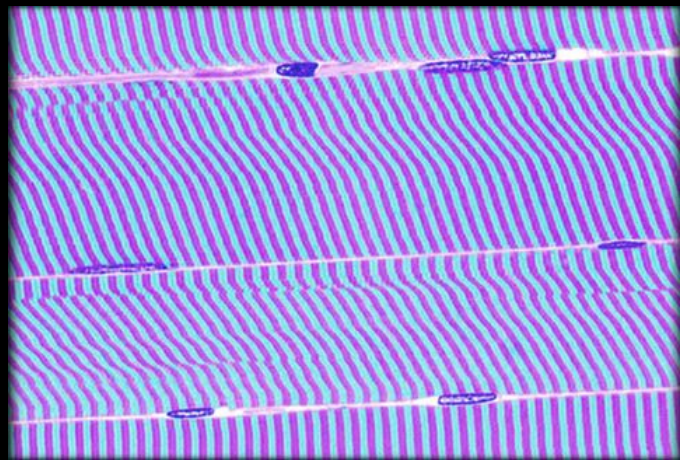
Nuclei



A band



I band



Anatomy of Skeletal Muscle: Gross Anatomy

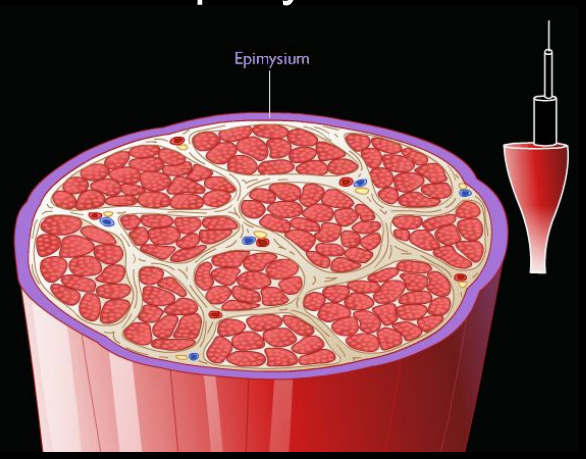
- **Connective tissue components**
  - Three concentric layers of connective tissue:
    - epimysium, perimysium, endomysium
  - Provide
    - protection
    - sites for blood vessel and nerve distribution
    - means of attachment to skeleton or other structures

Anatomy of Skeletal Muscle: Gross Anatomy

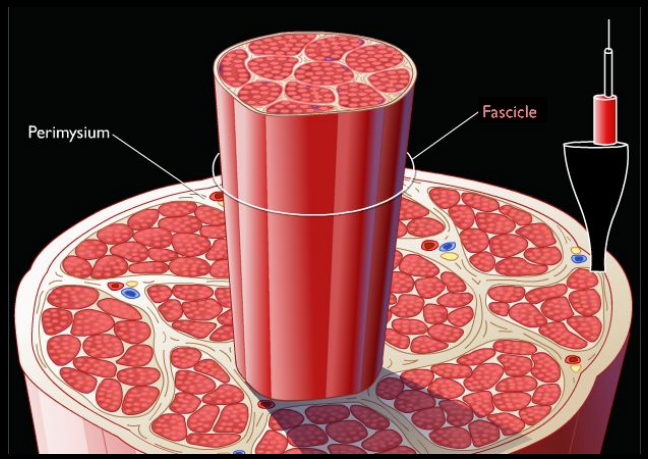
- **Connective tissue components *(continued)***
  - **Epimysium**
    - layer of dense irregular connective tissue
    - surrounds whole skeletal muscle
  - **Perimysium**
    - dense irregular tissue surrounding the fascicles
    - contains extensive blood vessels and nerves supplying fibers
  - **Endomysium**
    - innermost connective tissue layer
    - delicate areolar connective tissue
    - surrounds and electrically insulates each muscle fiber
    - contains reticular protein fibers
      - help bind together neighboring muscle fibers

Connective Tissue and Fascicles

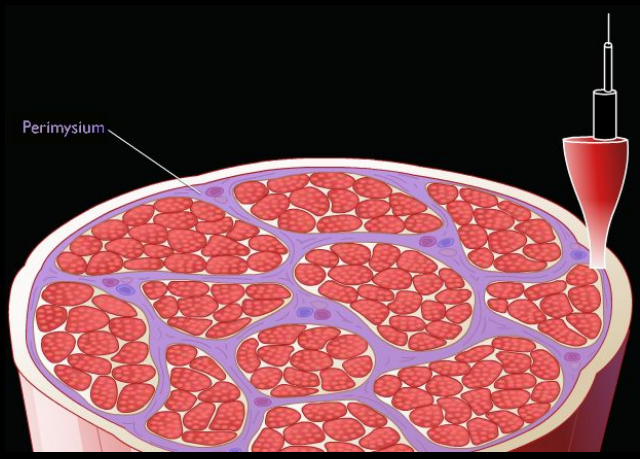
Epimysium



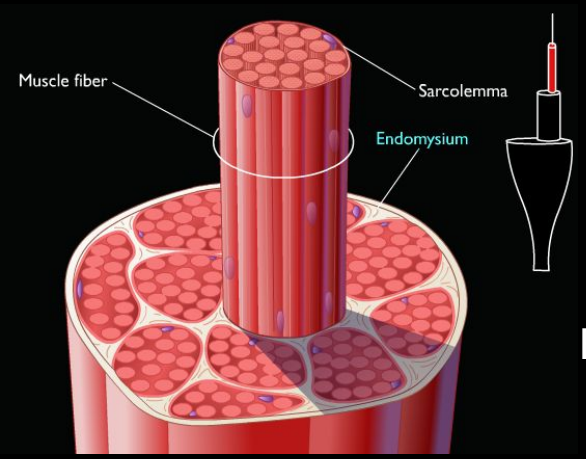
Fascicle



Perimysium



Endomysium

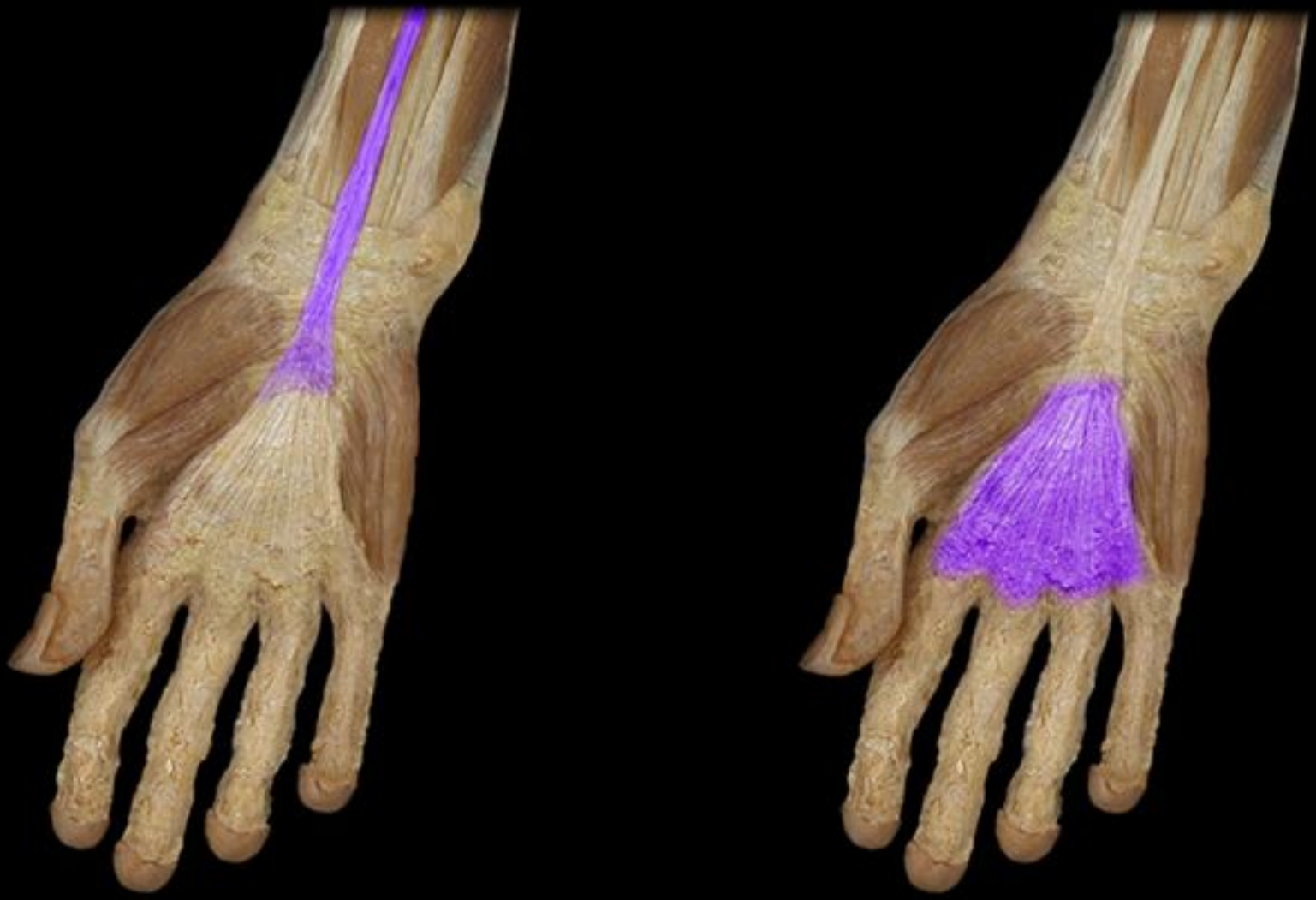


Epimysium + Perimysium + Endomysium = Tendon

Anatomy of Skeletal Muscle: Gross Anatomy

- **Connective tissue components *(continued)***
  - **Tendon**
    - cordlike structure composed of dense regular connective tissue
    - formed by the three connective tissue layers
    - attach the muscle to bone, skin or another muscle
  - **Aponeurosis**
    - thin, flattened sheet of dense irregular tissue
    - formed from the three connective tissue layers

Tendon and Aponeurosis of Palmaris Longus muscle

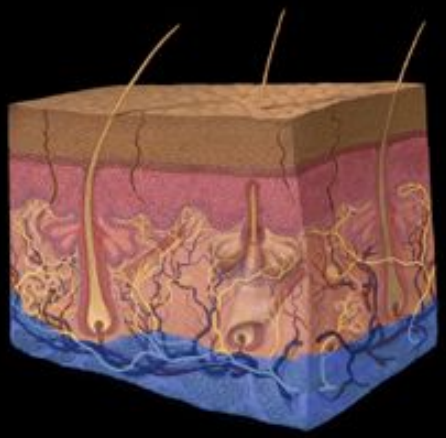


Anatomy of Skeletal Muscle: Gross Anatomy

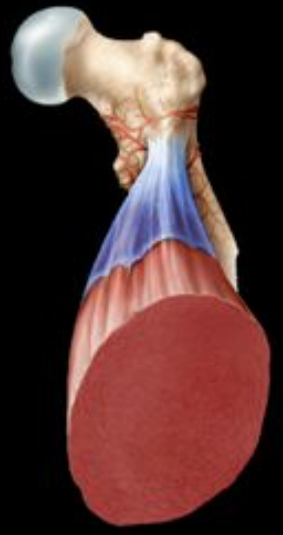
- **Connective tissue components *(continued)***
  - **Deep fascia**
    - additional sheet of dense irregular connective tissue
    - external to the epimysium
    - separates individual muscles
    - binds together muscles with similar functions
    - contains nerves, blood vessels, and lymph vessels
    - fills spaces between muscles

Superficial and Deep Fasciae

Superficial



Deep



Anatomy of Skeletal Muscle: Gross Anatomy

Connective tissue components *(continued)*

- **Superficial fascia**
  - superficial to deep fascia
  - composed of areolar and adipose connective tissue
  - separates muscles from skin

Skin

Superficial Fascia

Deep Fascia

Superficial Muscles

Deeper Muscles

Even Deeper Muscles

Yet Even Deeper Muscles

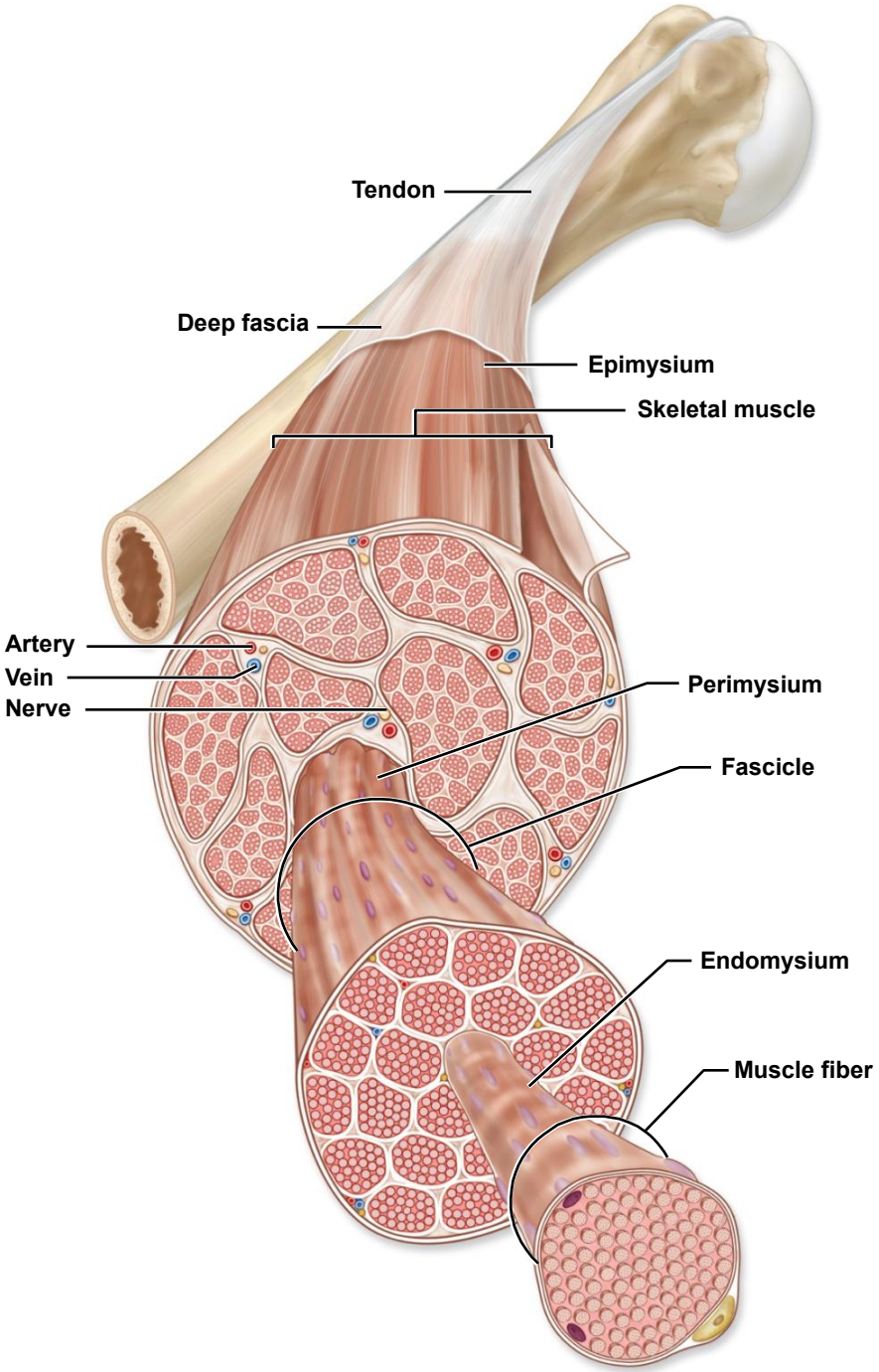
Soft Tissue and Bone

Bone

Anatomy of Skeletal Muscle: Gross Anatomy

- **Blood vessels and nerves**
  - Skeletal muscles vascularized by extensive blood vessels
    - Deliver oxygen and nutrients, removing waste products
  - Innervated by **motor neurons**
  - Axons
    - extend through connective layers
    - almost make contact with individual muscle fiber
    - junction termed the neuromuscular junction
  - Skeletal muscle termed **voluntary muscle**
    - because fibers consciously controlled by nervous system

Structural Organization of Skeletal Muscle (Figure 10.1)



Anatomy of Skeletal Muscle: Gross Anatomy

What are the locations of the endomysium, perimysium, and epimysium?

The endomysium is the layer of connective tissue surrounding the whole skeletal muscle and providing protection.

The perimysium surrounds the muscle fascicles and contains extensive blood vessels and nerves.

The endomysium is the innermost layer surrounding and electrically insulating muscle fibers.

Anatomy of Skeletal Muscle: Microscopic Anatomy

- **Sarcoplasma**
  - Cytoplasm of muscle fibers (cells comprising muscle)
  - Contains typical cellular structures
    - e.g., Golgi apparatus, ribosomes, vesicles
  - Has specialized cellular structure

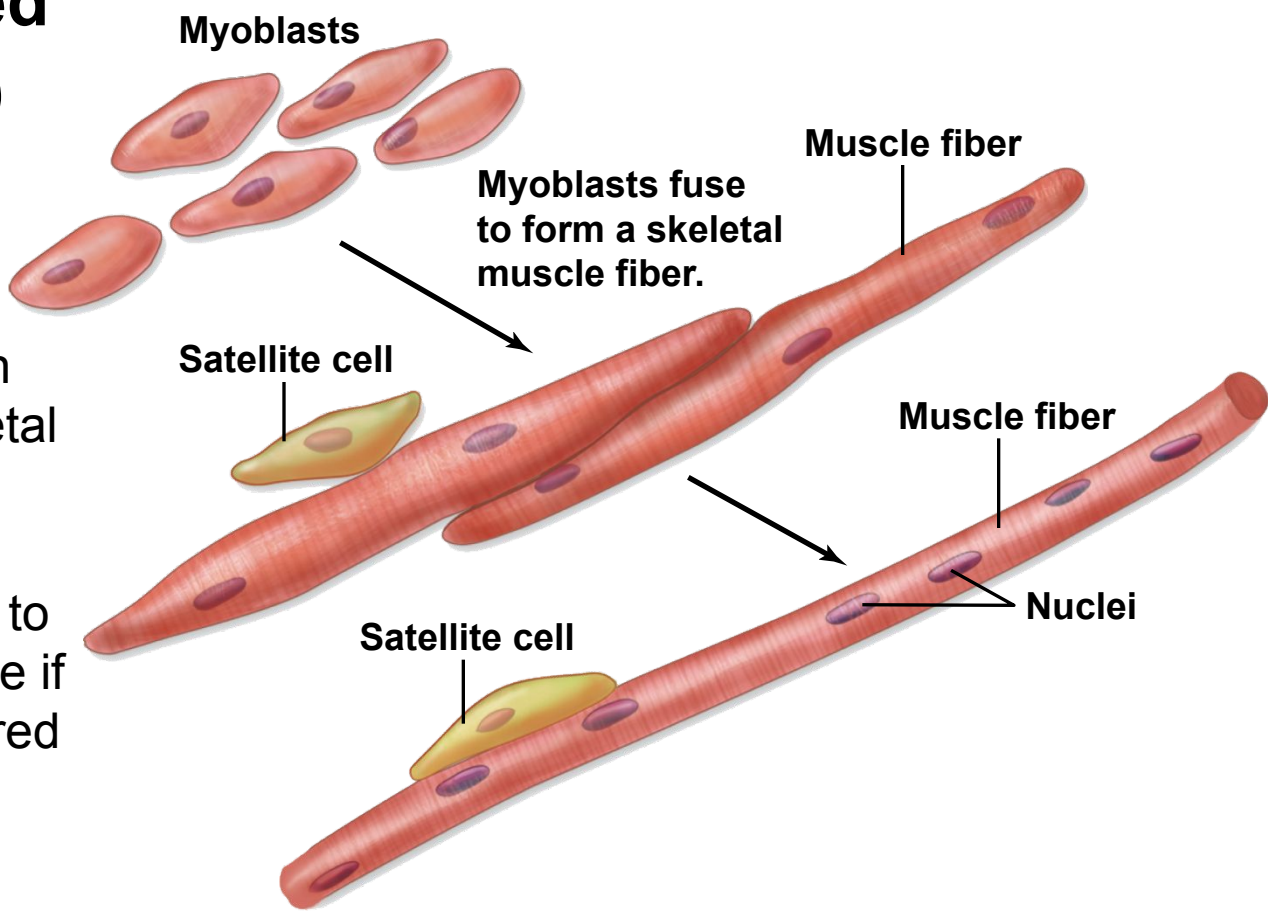
Anatomy of Skeletal Muscle: Microscopic Anatomy

- **Multinucleated cell**
  - Elongated cells extending length of muscle
  - **Myoblasts**
    - embryonic cells which fuse
    - form single skeletal muscle fibers during development
    - each contributing a nucleus to total nuclei
  - Thus fibers multinucleated cells

Anatomy of Skeletal Muscle: Microscopic Anatomy

- **Multinucleated cell *(continued)***
  - **Satellite cells**
    - myoblasts remaining, unfused, in adult skeletal tissue
    - may be stimulated to differentiate if tissue injured

(Figure 10.2)



Anatomy of Skeletal Muscle: Microscopic Anatomy

- **Sarcolemma and T-tubules**
  - Plasma membrane of a skeletal muscle fiber
    - **sarcolemma**
  - Invaginations of the sarcolemma
    - **T-tubules**, or **transverse tubules**

Anatomy of Skeletal Muscle: Microscopic Anatomy

Sarcolemma and T-tubules *(continued)*

- Na^+/ K^+ pumps along sarcolemma and T-tubules
  - create concentration gradients for Na^+ and K^+
  - three Na^+ pumped out while two K^+ pumped in
  - resting membrane potential maintained by pumps
    - inside of cell relatively negative in comparison to outside
    - responsible for excitability of skeletal muscle fibers

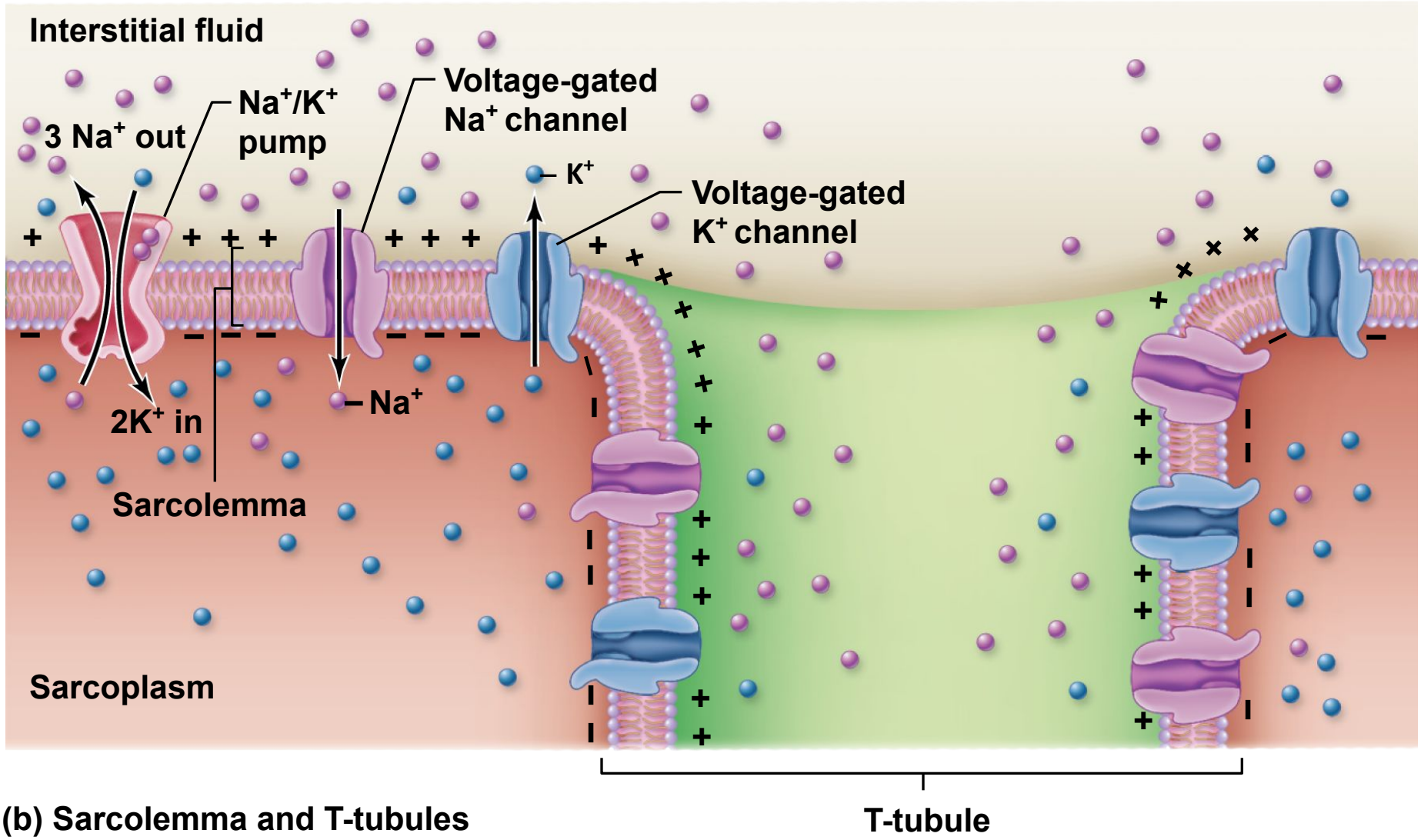
Anatomy of Skeletal Muscle: Microscopic Anatomy

- **Sarcolemma and T-tubules *(continued)***
  - Voltage-gated Na^+ channels and voltage-gated K^+ channels
    - also present
    - necessary for propagation of electrical change along sarcolemma

Anatomy of Skeletal Muscle: Microscopic Anatomy

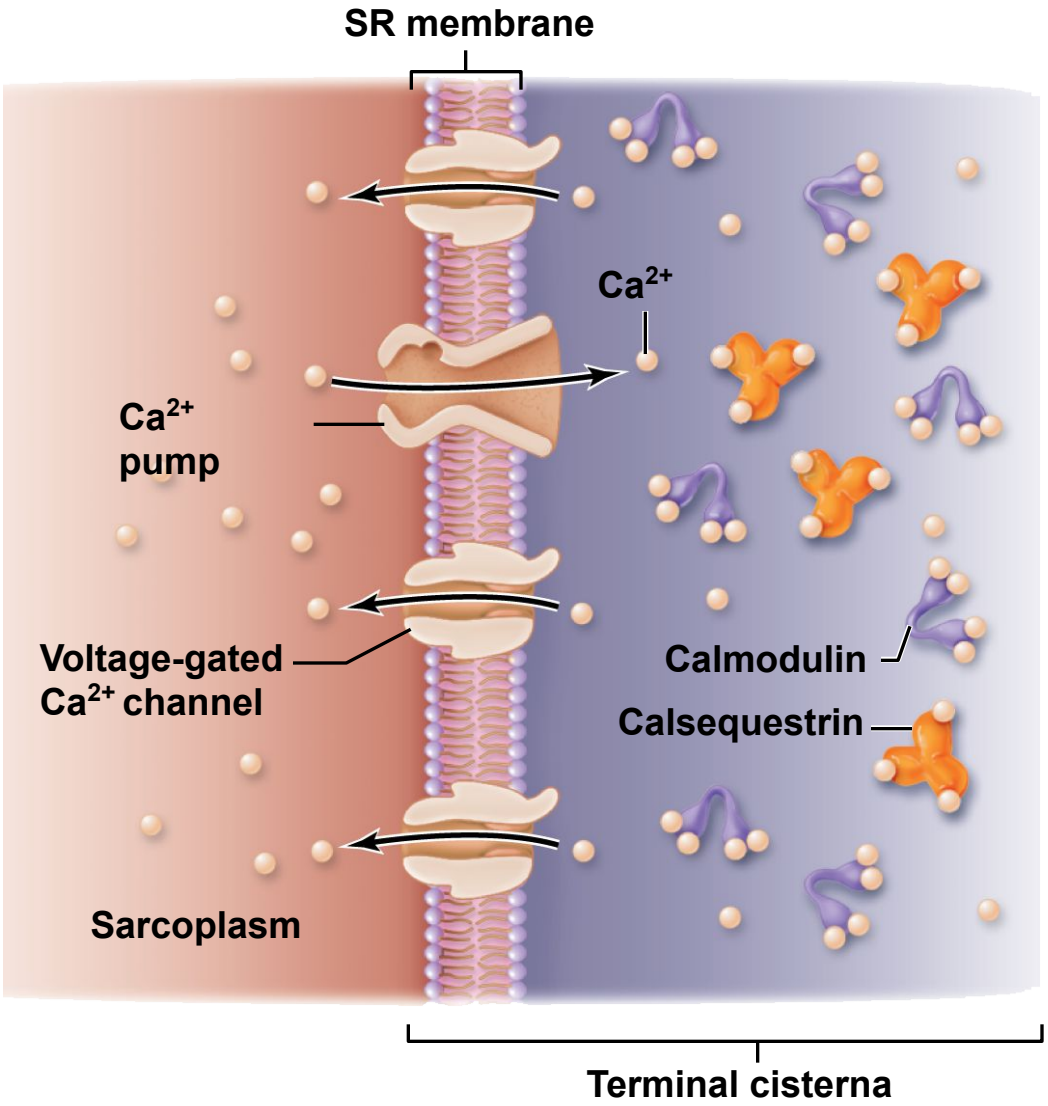
- **Sarcoplasmic reticulum**
  - Internal membrane complex
  - Similar to smooth endoplasmic reticulum
  - Surround bundles of contractile proteins
  - **Terminal cisternae**
    - blind sacs of sarcoplasmic reticulum
    - serve as reservoirs for calcium ions
    - combine in twos with central T-tubule to form **triads**

Structure and Organization of a Skeletal Muscle Fiber: Sarcolemma and T-Tubules (Figure 10.3 b)



(b) Sarcolemma and T-tubules

- **Sarcoplasmic reticulum *(continued)***
  - Ca^{2+} pumps embedded in sarcoplasmic reticulum
    - move Ca^{2+} into sarcoplasmic reticulum
    - stored bound to specialized proteins, **calmodulin** and **calsequestrin**
  - Voltage-gated Ca^{2+} channels
    - open to release Ca^{2+} from sarcoplasmic reticulum into sarcoplasm
    - causes muscle contraction



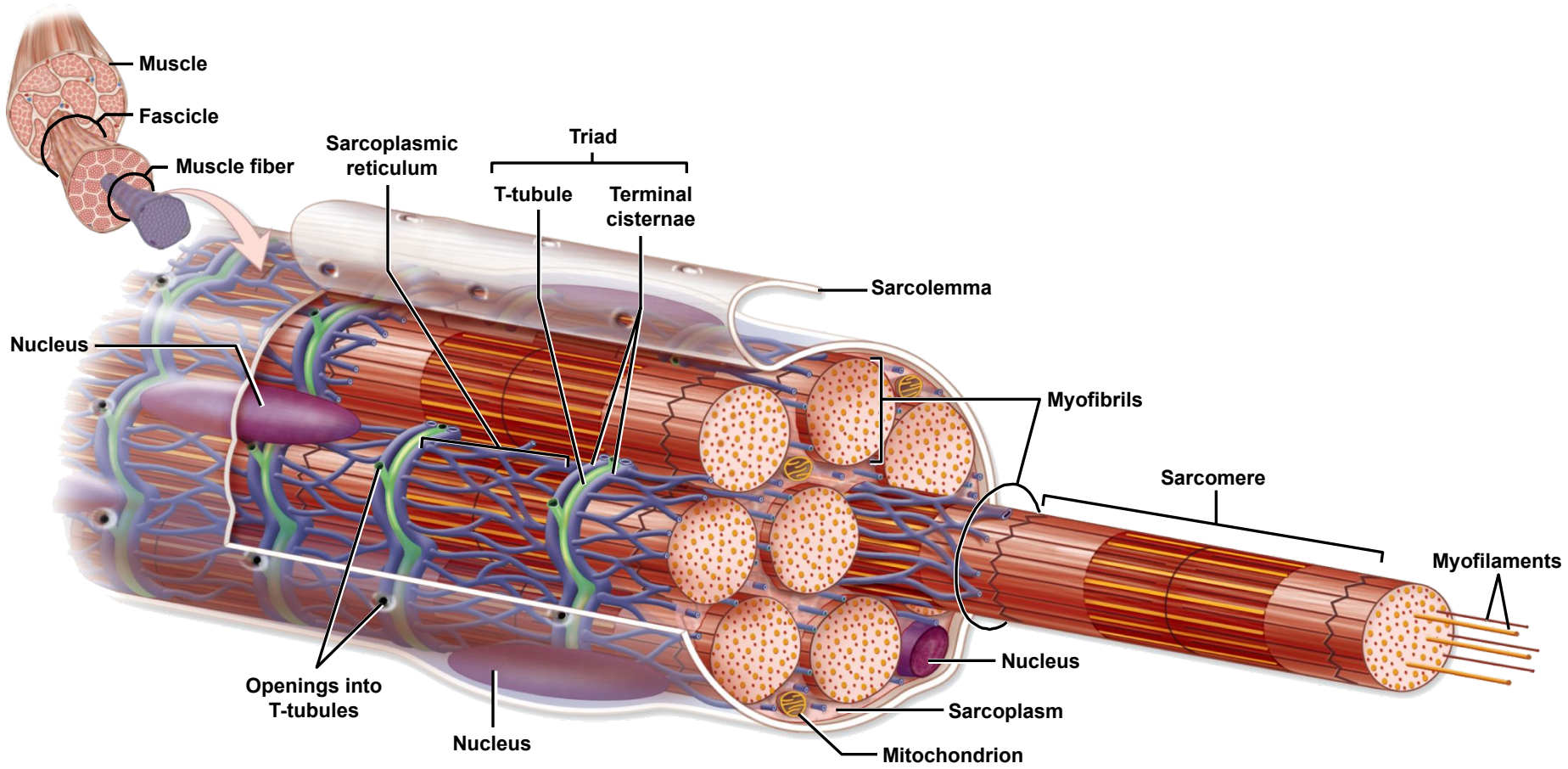
(c) Sarcoplasmic reticulum

(Figure 10.3c)

Anatomy of Skeletal Muscle: Microscopic Anatomy

- **Muscle fibers and myofibrils**
  - **Myofibrils**
    - long cylindrical structures
    - extend length of muscle fiber
    - compose 80% of volume of muscle fiber
    - each fiber with hundreds to thousands
  - **Myofilaments**
    - bundles of protein filaments
    - takes many to extend length of myofibril
    - two types: thick and thin

Structure and Organization of a Skeletal Muscle Fiber (Figure 10.3 a)



(a) Skeletal muscle fiber

Anatomy of Skeletal Muscle: Microscopic Anatomy

Muscle fibers and myofibrils *(continued)*

- **Thick filaments**
  - Assembled from bundles of protein molecules, **myosin**
    - each myosin protein with two intertwined strands
    - each strand with a globular head and elongated tail
    - tails pointing toward center of thick filaments
    - heads pointing toward edges of thick filaments
    - head with a binding site for actin (thin filaments)
    - head with site where ATP attaches and is split

Anatomy of Skeletal Muscle: Microscopic Anatomy

Muscle fibers and myofibrils *(continued)*

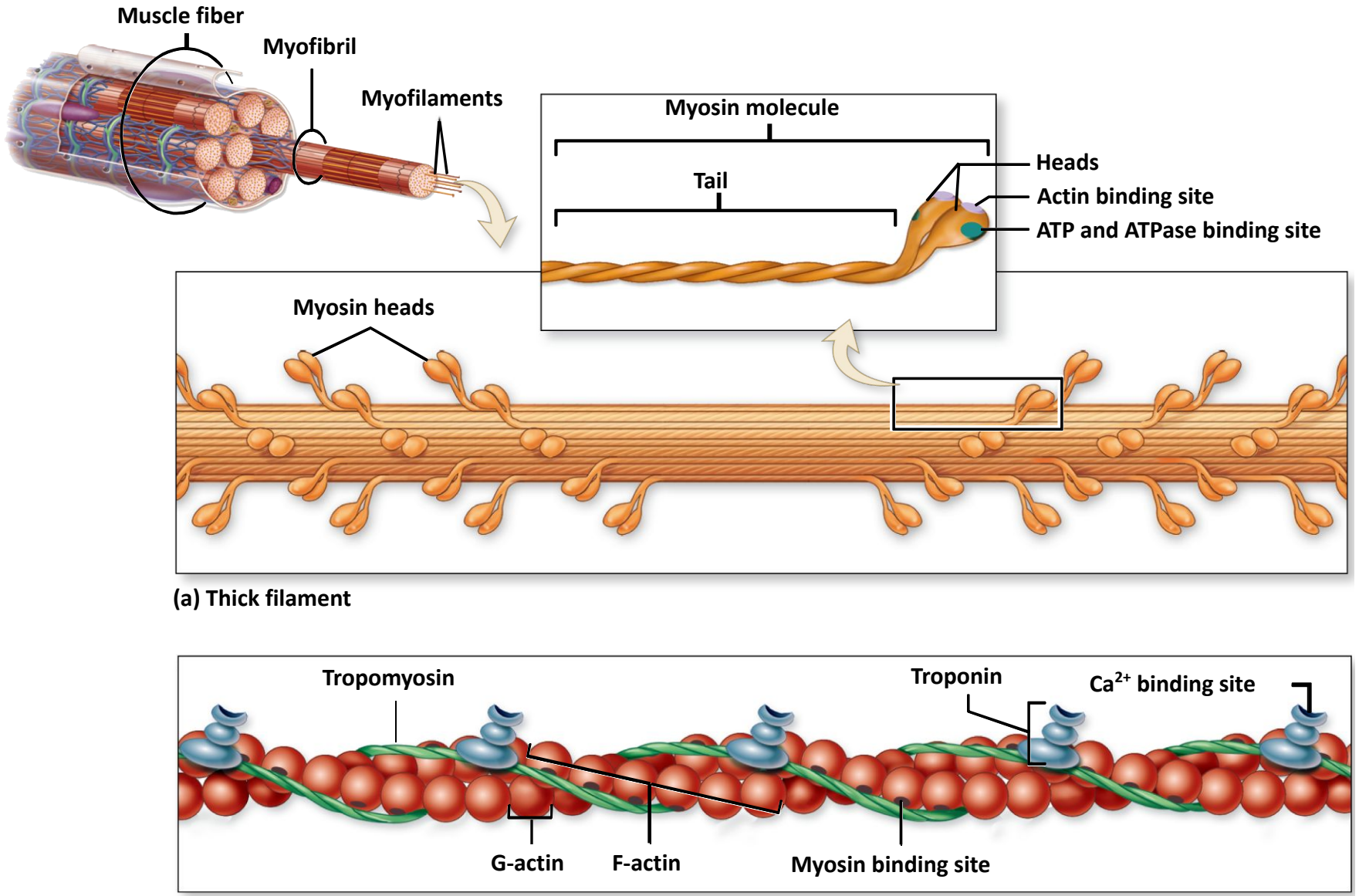
- **Thin filaments**
  - Primarily composed of two strands of protein, **actin**
  - Two strands twisted around each other
  - Many small spherical molecules, globular actin
  - Connected to form a fibrous strand, filamentous actin
  - Globular actin with **myosin binding site**
    - where myosin head attaches during contraction

Anatomy of Skeletal Muscle: Microscopic Anatomy

Muscle fibers and myofibrils

- **Thin filaments *(continued)***
  - **Tropomyosin**
    - twisted “stringlike” protein
    - cover small bands of the actin strands
    - covers myosin binding sites in a noncontracting muscle
  - **Troponin**
    - globular protein attached to tropomyosin
    - binding site for Ca^{2+}
    - together form troponin-tropomyosin complex

Molecular Structure of Thick and Thin Filaments (Figure 10.4)



Anatomy of Skeletal Muscle: Microscopic Anatomy

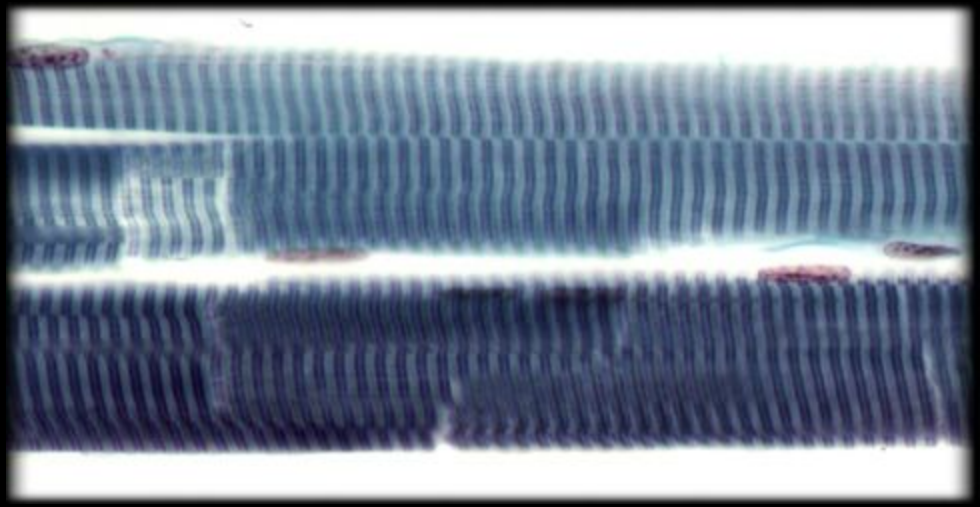
- **Organization of a sarcomere**
  - Myofilaments arranged in repeating units, **sarcomeres**
  - Number varies with length of myofibril
  - Composed of overlapping thick and thin filaments
  - Delineated at both ends by **Z discs**
    - specialized proteins perpendicular to myofilaments
    - anchors for thin filaments

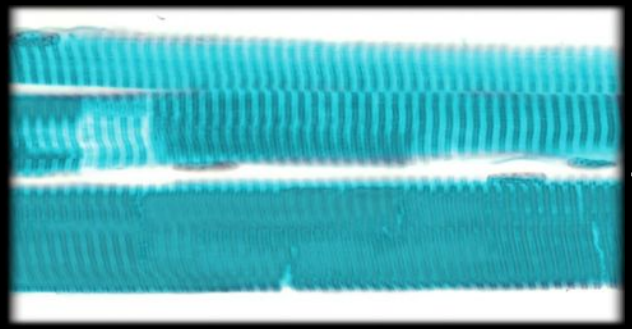
Anatomy of Skeletal Muscle: Microscopic Anatomy

Organization of a sarcomere

- Overlapping filaments (*continued*)
  - Form alternating patterns of light and dark regions
  - Appears striated under a microscope
    - due to size and density differences between thick and thin filaments
  - Each thin filament with three thick filaments
    - form triangle at its periphery

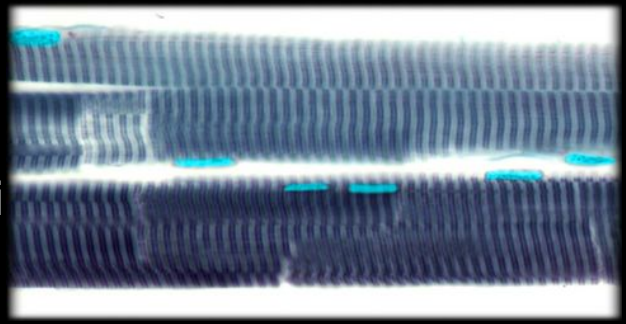
Skeletal Muscle (striations)

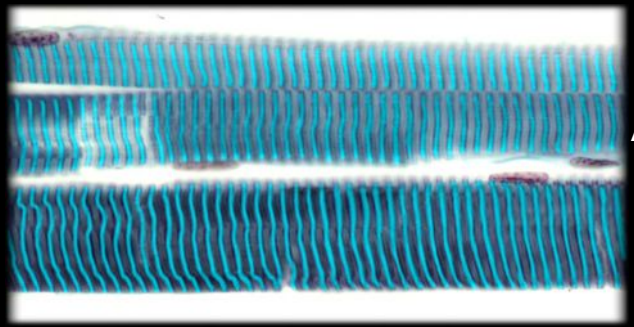




Skeletal muscle fiber

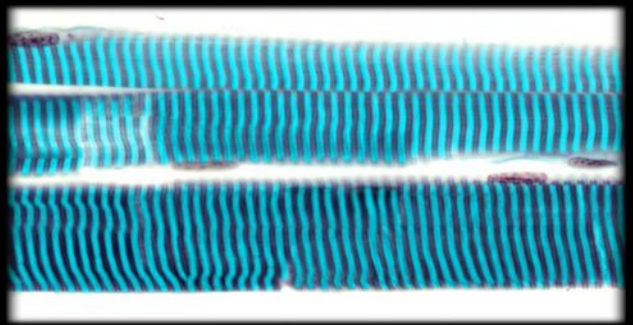
Nuclei





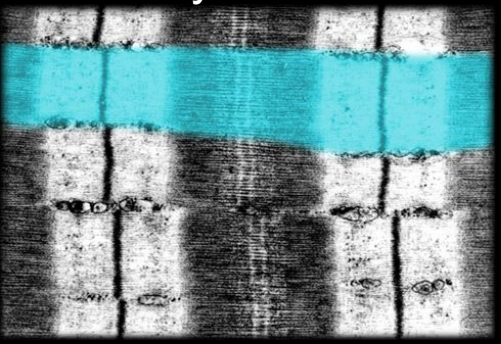
A band

I band

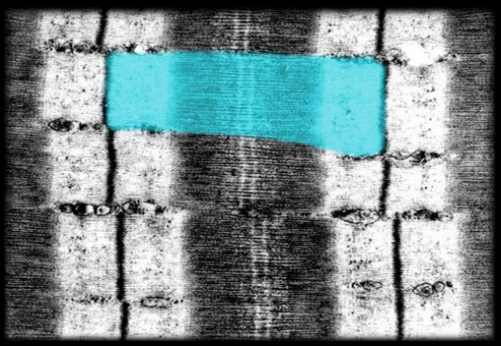


Sarcomere

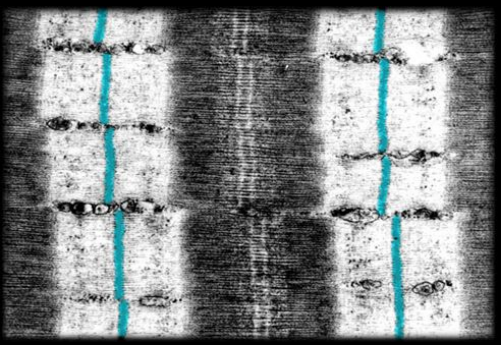
Myofibril

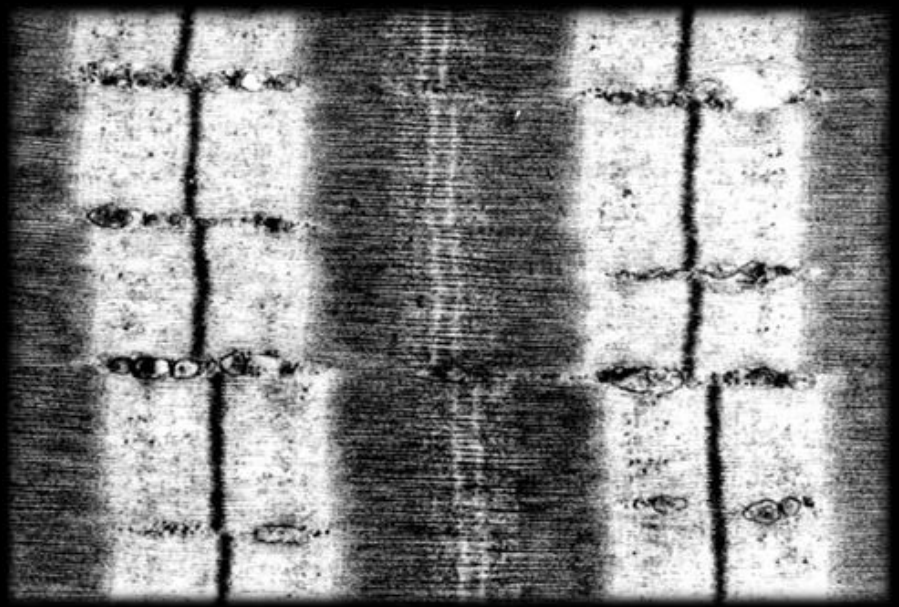


Sarcomere

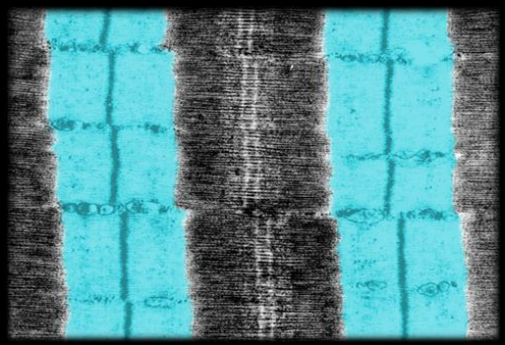


Z disc

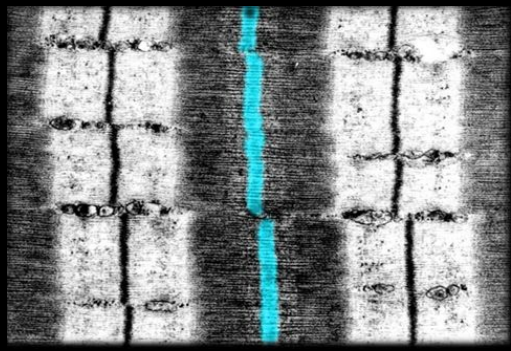




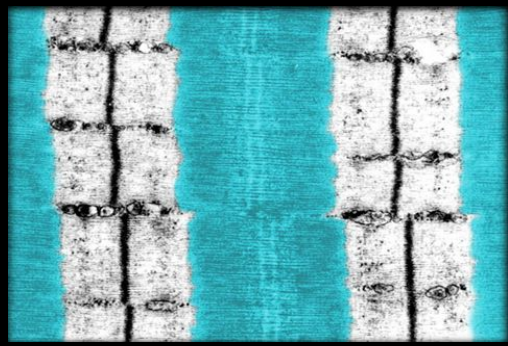
I band



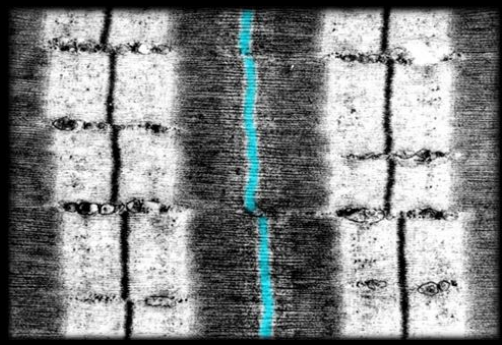
H band



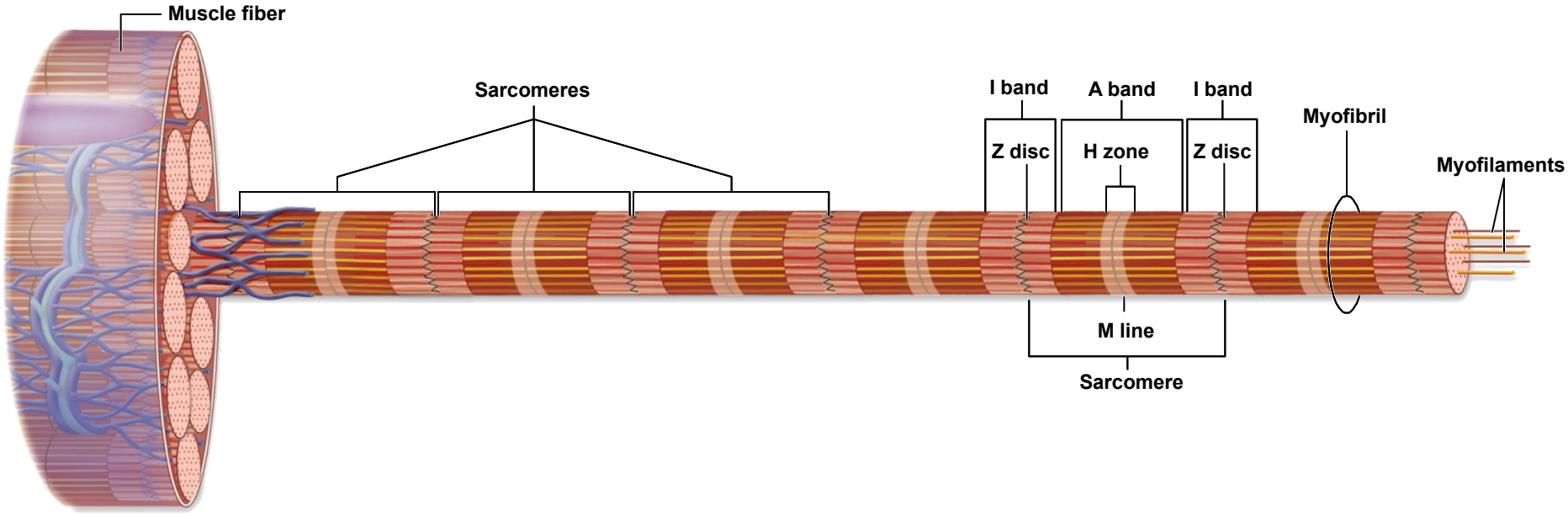
A band



M line



Structure of a Sarcomere (Figure 10.5 a)



(a)

Anatomy of Skeletal Muscle: Microscopic Anatomy

Organization of a sarcomere *(continued)*

- Overlapping filaments
  - **I bands**
    - region containing only thin filaments
    - extend from both directions of Z disc
    - bisected by Z disc
    - appear light under a microscope
    - disappear at maximal muscle contraction

Anatomy of Skeletal Muscle: Microscopic Anatomy

Organization of a sarcomere

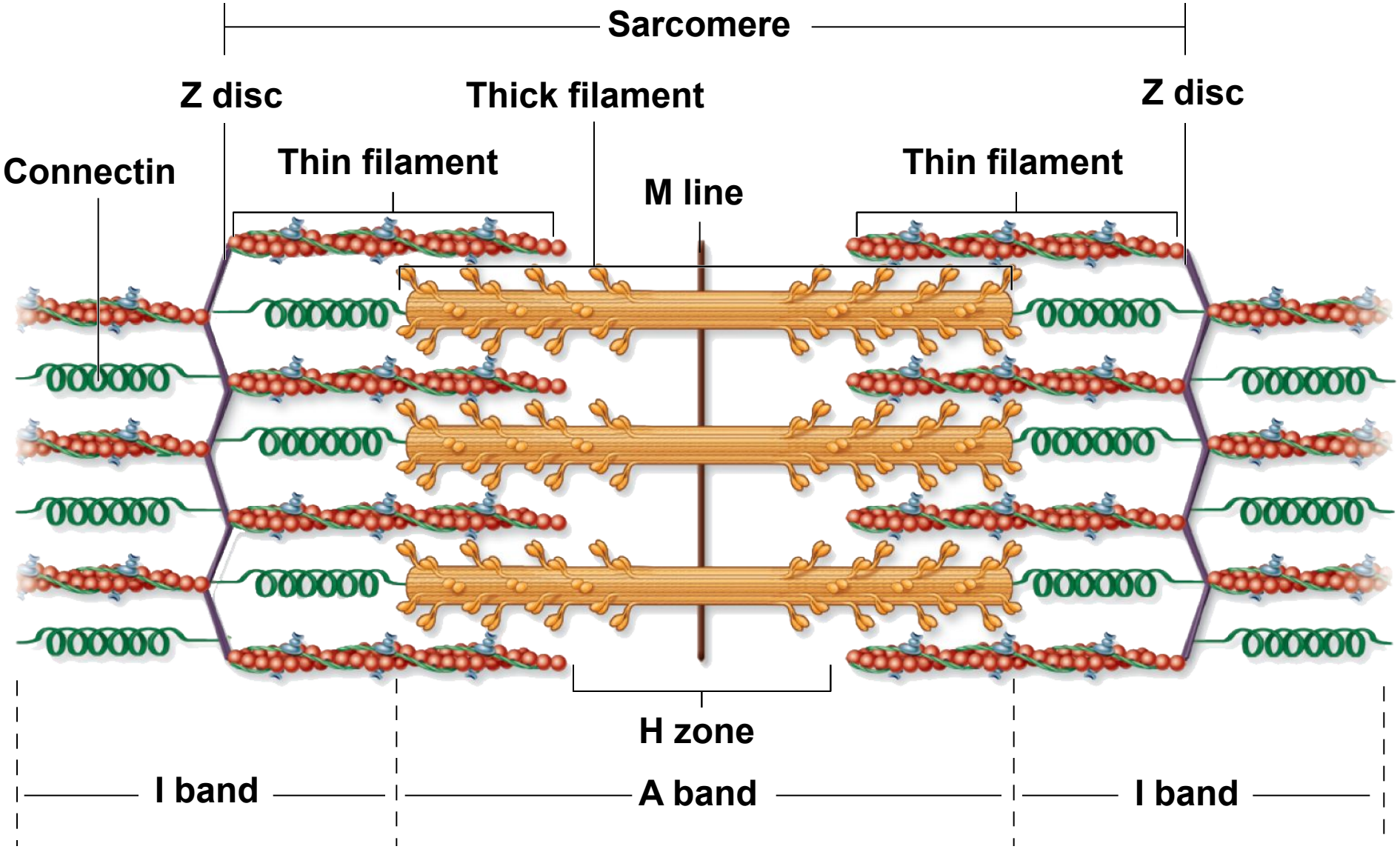
- Overlapping filaments *(continued)*
  - **A band**
    - central region of sarcomere
    - contains entire thick filament
    - contains partially overlapping thin filaments
    - appears dark under a microscope

Anatomy of Skeletal Muscle: Microscopic Anatomy

Organization of a sarcomere

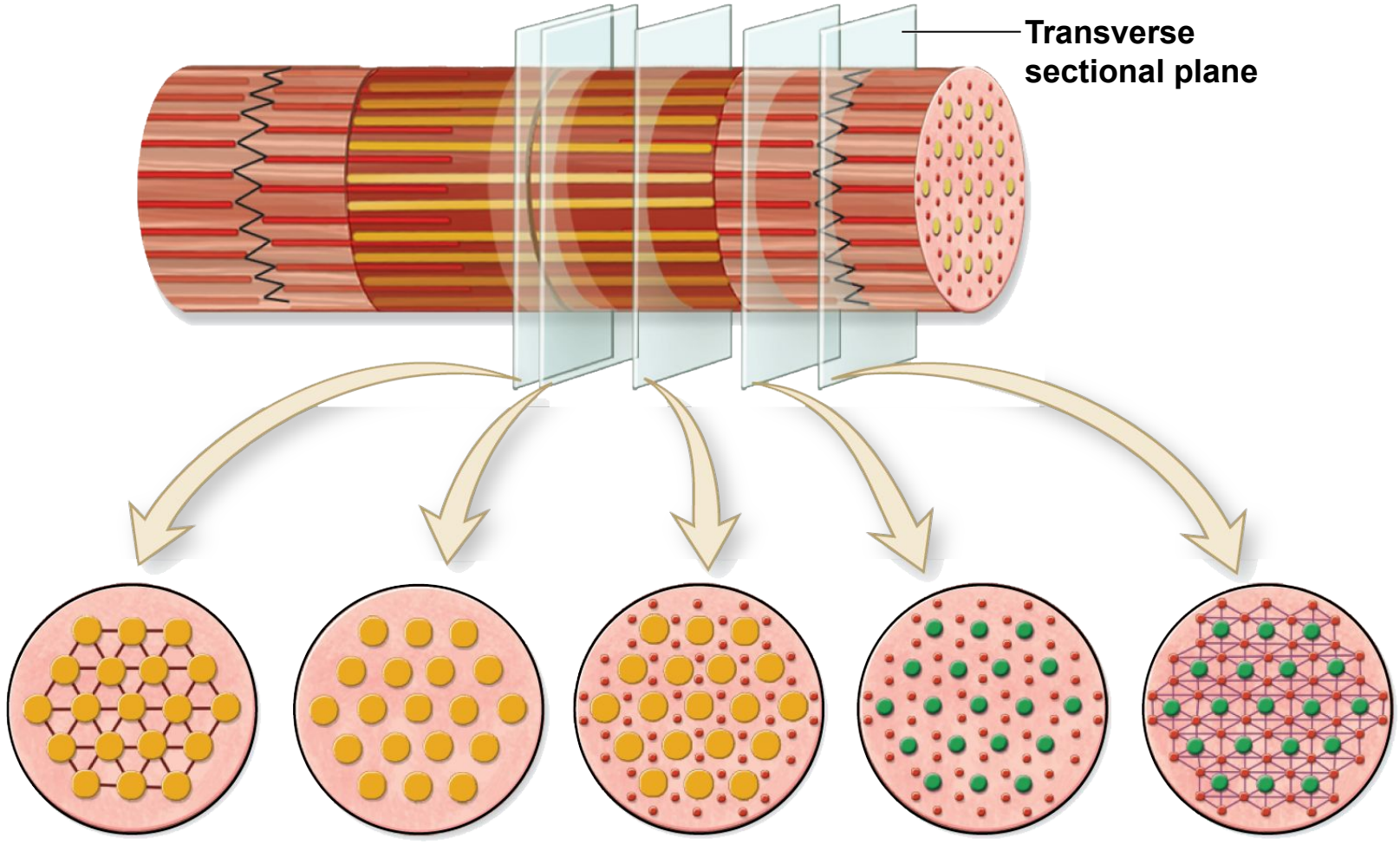
- Overlapping filaments *(continued)*
  - **H zone**
    - central portion of A band
    - thick filaments only present; no thin filament overlap
    - disappears during maximal muscle contraction
  - **M line**
    - protein meshwork structure at center of H zone
    - attachment site for thick filaments

Structure of a Sarcomere (Figure 10.5 b)



(b)

Structure of a Sarcomere (Figure 10.5 c)



(c)

Anatomy of Skeletal Muscle: Microscopic Anatomy

Organization of a sarcomere

- Other structural and functional proteins
  - **Connectin**
    - protein extending from Z discs to M line
    - extends through core of each thick filament
    - stabilizes the position of thick filaments
    - springlike to produce passive tension during contraction
    - during relaxation, passive tension released

Anatomy of Skeletal Muscle: Microscopic Anatomy

Organization of a sarcomere

- Other structural and functional proteins *(continued)*
  - **Nebulin**
    - actin-binding protein
    - part of I band of the sarcomere
    - plays possible role in creating orderly structure of sarcomere
  - **Dystrophin**
    - anchors myofibrils adjacent to sarcolemma to sarcolemma proteins
    - links internal myofilament proteins to external proteins
    - abnormal structure or amounts of proteins in *muscular dystrophy*

Anatomy of Skeletal Muscle: Microscopic Anatomy

- **Mitochondria and other structures associated with energy production**
  - Muscle with high ATP requirement
  - Abundant mitochondria for aerobic cellular respiration
  - Glycogen stores for immediate fuel molecule
  - Creatinine phosphate
    - molecule unique to muscle tissue
    - provides fibers means of supplying ATP anaerobically

Anatomy of Skeletal Muscle: Microscopic Anatomy

- **Mitochondria and other structures associated with energy production *(continued)***
  - **Myoglobin**
    - molecule unique to muscle tissue
    - reddish globular protein similar to hemoglobin
    - binds oxygen when muscle at rest
    - releases it during muscular contraction
    - provides additional oxygen to enhance aerobic cellular respiration

Anatomy of Skeletal Muscle: Microscopic Anatomy

What are the primary components of thick and thin filaments?

Thick filaments are composed of myosin protein.

Thin filaments are composed primarily of actin protein. Tropomyosin and tropin are associated regulatory proteins.

Anatomy of Skeletal Muscle: Microscopic Anatomy

In which band are there thick filaments only, with no thin filament overlap?

H zone

Anatomy of Skeletal Muscle: Innervation of Skeletal Muscle Fibers

- **Motor unit**
  - Motor neuron nerve cells
    - transmit nerve signals from brain or spinal cord
    - have axons that branch
    - individually innervate numerous skeletal muscle fibers
    - single motor neuron + fibers it controls = **motor unit**

Anatomy of Skeletal Muscle: Innervation of Skeletal Muscle Fibers

- **Motor unit *(continued)***
  - Varied number of fibers a neuron innervates
    - small motor units less than five muscle fibers
    - large motor units with several thousand
    - inverse relationship between size of motor unit and degree of control
      - e.g., small motor units innervating eye
      - need greater control
      - e.g., large motor units innervating lower limbs
      - need less precise control

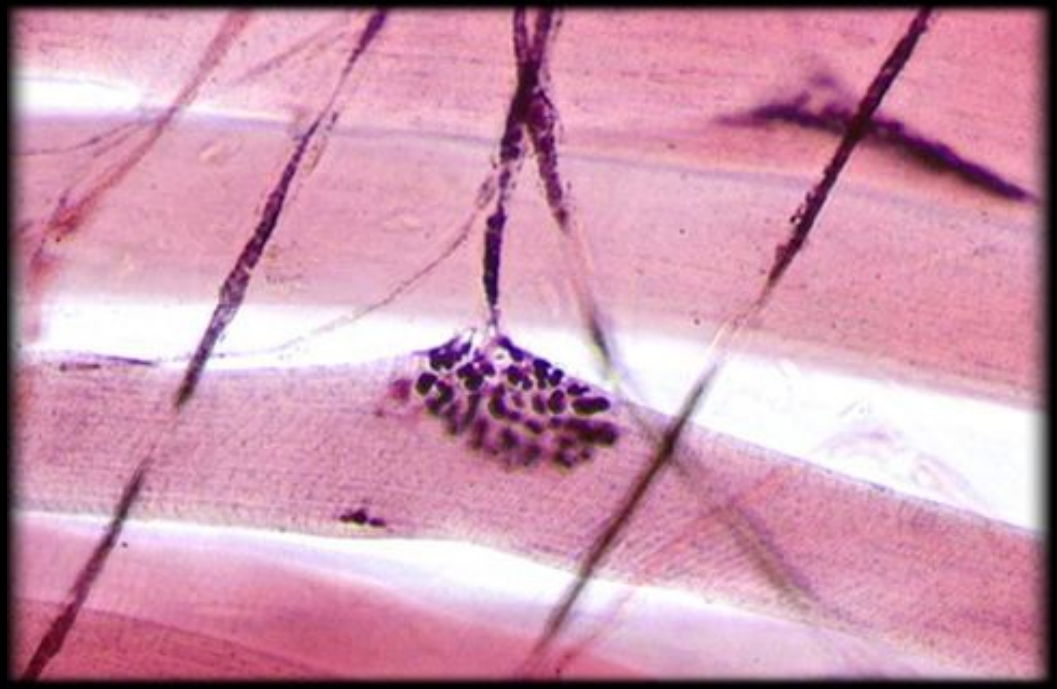
Anatomy of Skeletal Muscle: Innervation of Skeletal Muscle Fibers

- **Motor unit *(continued)***
  - Fibers dispersed throughout most of a muscle
  - Stimulation producing weak contraction over a wide area

Anatomy of Skeletal Muscle: Innervation of Skeletal Muscle Fibers

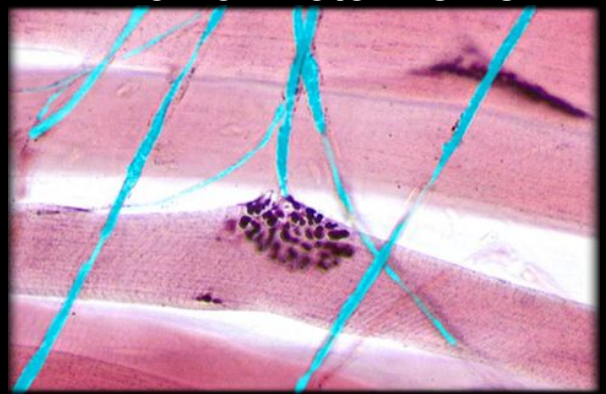
- **Neuromuscular junctions**
  - Location where motor neuron innervates muscle
  - Usually mid-region of muscle fiber
  - Has synaptic knob, motor end plate, synaptic cleft

Neuromuscular Junction
High Magnification

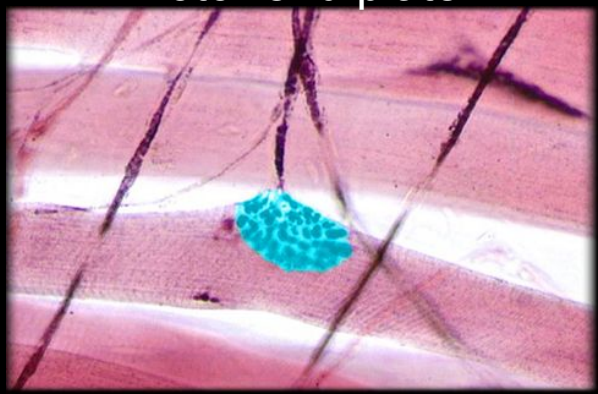


Skeletal muscle fiber

Axon of motor nerve



Motor end plate



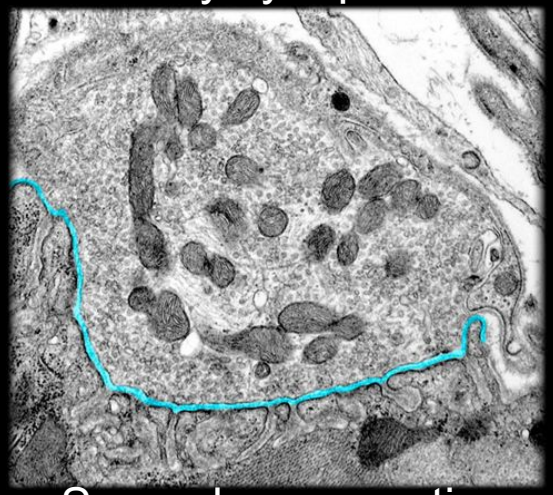
Anatomy of Skeletal Muscle: Innervation of Skeletal Muscle Fibers

Neuromuscular junctions *(continued)*

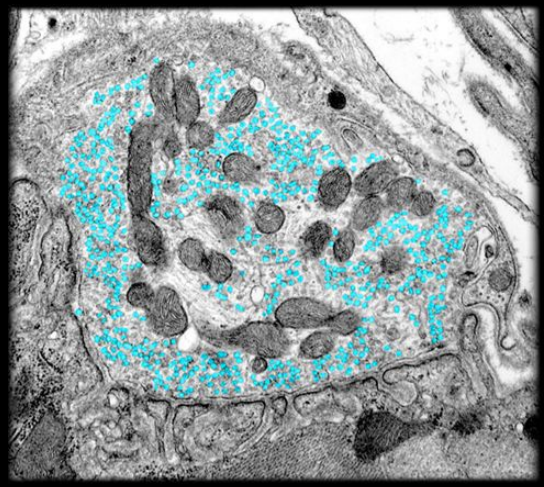
- **Synaptic knob**
  - The expanded tip of the axon
  - Axon enlarged and flattened in this region
  - Houses **synaptic vesicles**, small membrane sacs
    - filled with neurotransmitter, **acetylcholine** (**ACh**)
  - Has Ca^{2+} pumps embedded in plasma membrane
    - establish calcium gradient, with more outside the neuron

Neuromuscular Junction
TEM: High Magnification

Primary synaptic cleft

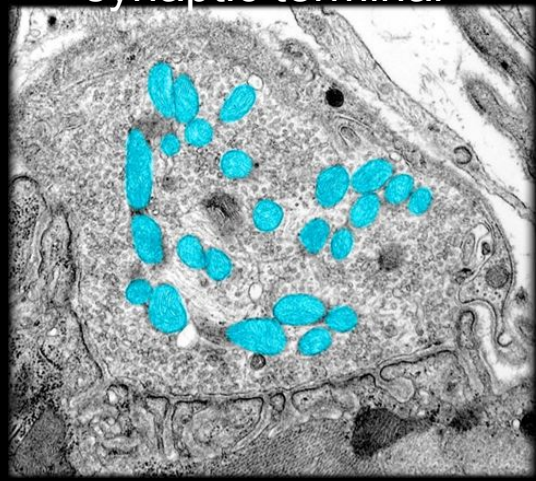


Synaptic vesicles of synaptic terminal



Secondary synaptic cleft (junctional folds)

Mitochondria of synaptic terminal



Anatomy of Skeletal Muscle: Innervation of Skeletal Muscle Fibers

Neuromuscular junctions

- Synaptic knob (*continued*)
  - Has voltage-gated Ca^{2+} channels in membrane
  - Ca^{2+} flowing down concentration gradient if opened
  - Vesicles normally repelled from membrane of synaptic knob
    - because both normally negatively charged

Anatomy of Skeletal Muscle: Innervation of Skeletal Muscle Fibers

Neuromuscular junctions

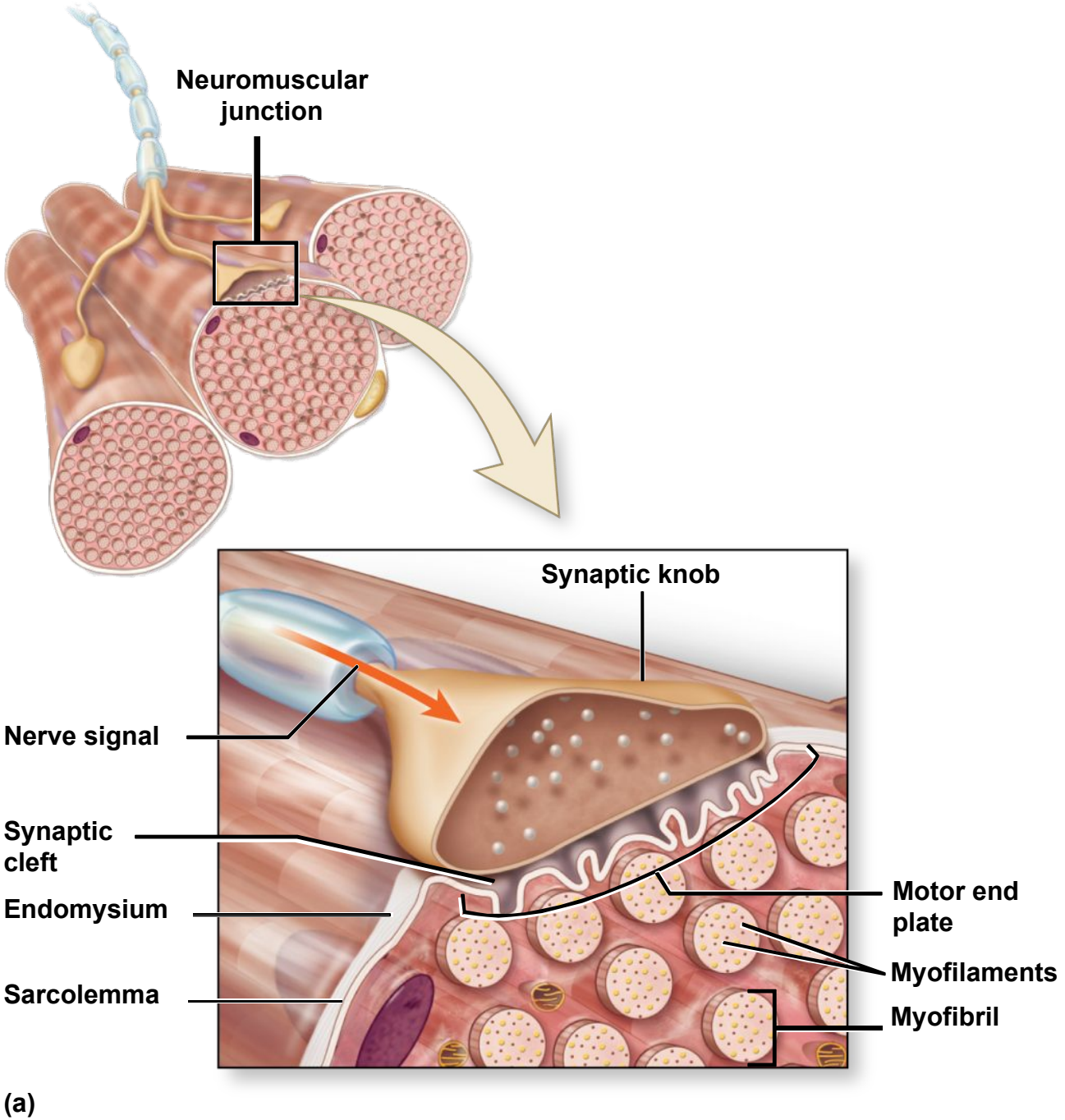
- **Motor end plate**
  - Specialized region of sarcolemma
  - Has numerous folds
    - increase surface area covered by knob
  - Has vast numbers of **ACh receptors**
    - plasma membrane protein channels
    - opened by binding of ACh
    - allow Na^+ entry and K^+ exit

Anatomy of Skeletal Muscle: Innervation of Skeletal Muscle Fibers

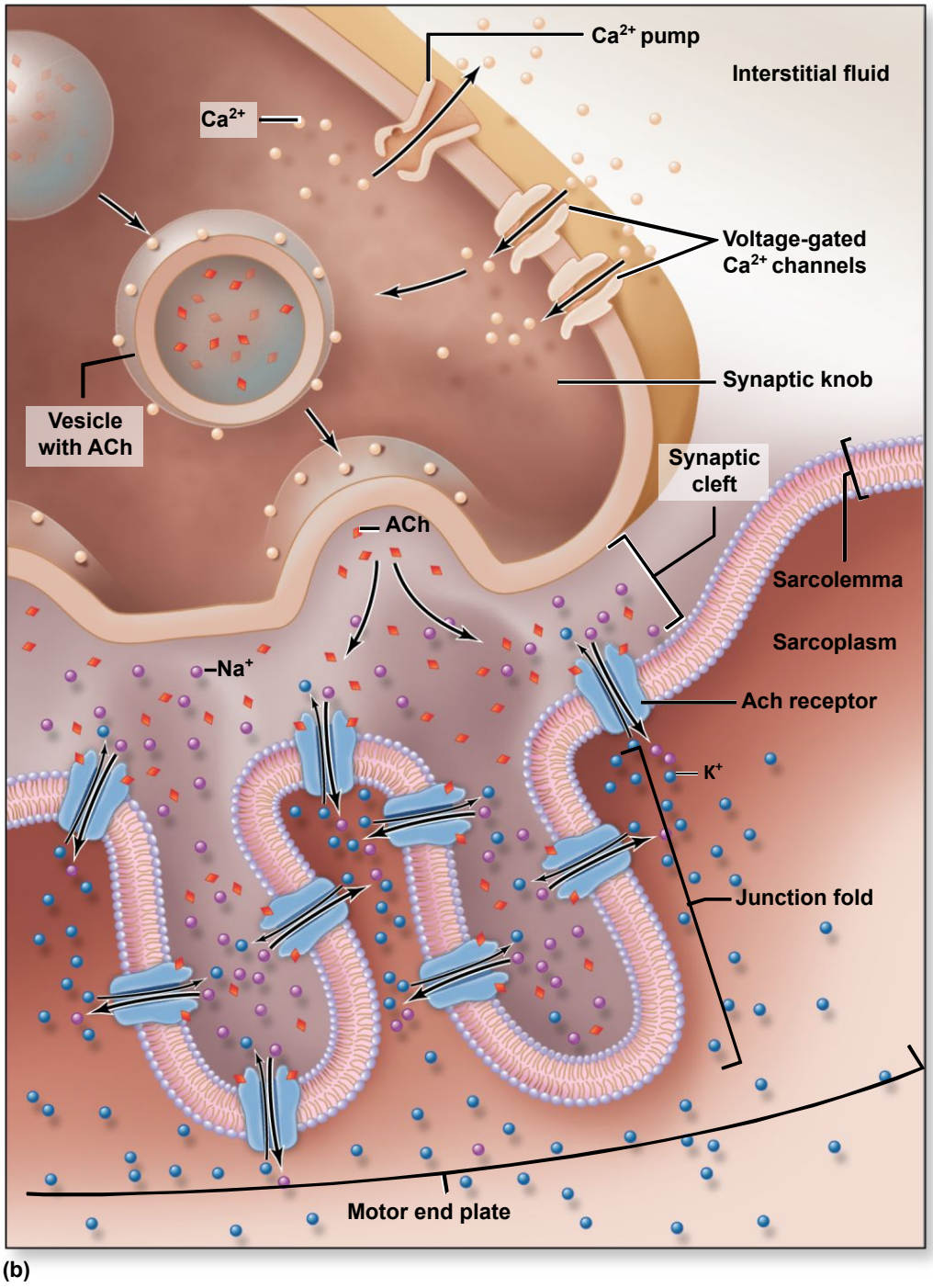
Neuromuscular junctions *(continued)*

- **Synaptic cleft**
  - Narrow fluid-filled space
  - Separates synaptic knob and motor end plate
  - **Acetylcholinesterase** residing here
    - enzyme that breaks down ACh molecules
    - after their release into synaptic cleft

Structure and Organization of a Neuromuscular Junction (Figure 10.7a)



Structure and Organization of a Neuromuscular Junction (Figure 10.7b)



(b)

Anatomy of Skeletal Muscle: Innervation of Skeletal Muscle Fibers

What is a motor unit, and why does it vary in size?

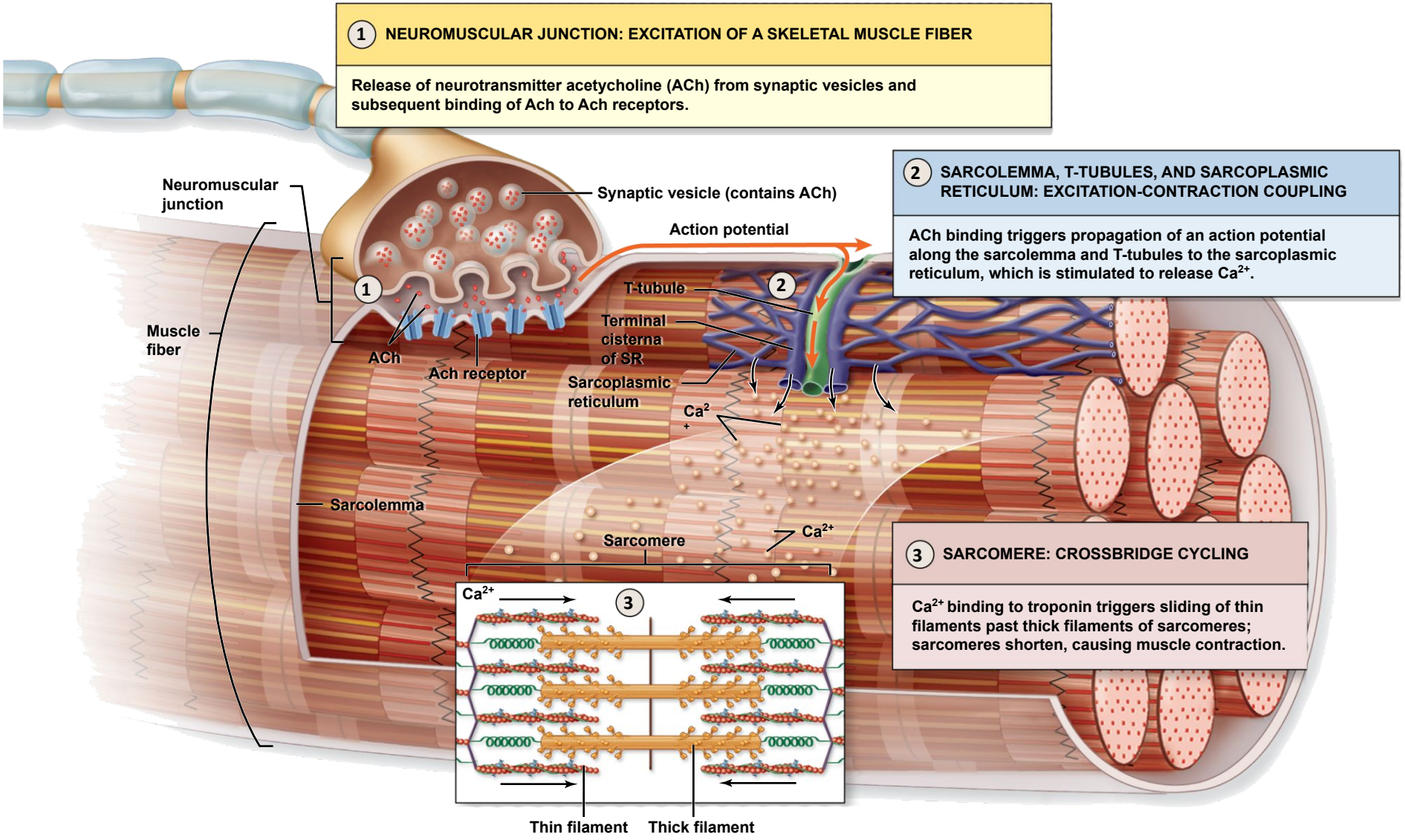
A motor unit is a single motor neuron and the muscle fibers it controls.

There is an inverse relationship between size and degree of control. Muscles needing greater power but less control have bigger motor units.

Physiology of Skeletal Muscle Contraction

- During muscle contraction
  - Protein filaments within sarcomeres interact
  - Sarcomeres shorten
  - Tension is exerted on portion of skeleton where muscle attached
  - Contracting fiber decreases in length
  - Movement occurs

Overview of Events in Skeletal Muscle Contraction (Figure 10.8)



Skeletal Muscle Contraction—Neuromuscular Junction: Excitation of a Skeletal Muscle Fiber

- First physiological event
  - Muscular fiber excitation by motor neuron
  - Occurs at neuromuscular junction
  - Results in release of ACh and subsequent binding of ACh receptors

Skeletal Muscle Contraction—Neuromuscular Junction: Excitation of a Skeletal Muscle Fiber

- **Calcium entry at synaptic knob**
  - Nerve signal propagated down motor axon
  - Triggers opening of voltage-gated Ca^{2+} channels
  - Movement of calcium down concentration gradient
    - from interstitial fluid into synaptic knob
  - Binding of calcium with proteins on synaptic vesicles

Skeletal Muscle Contraction—Neuromuscular Junction: Excitation of a Skeletal Muscle Fiber

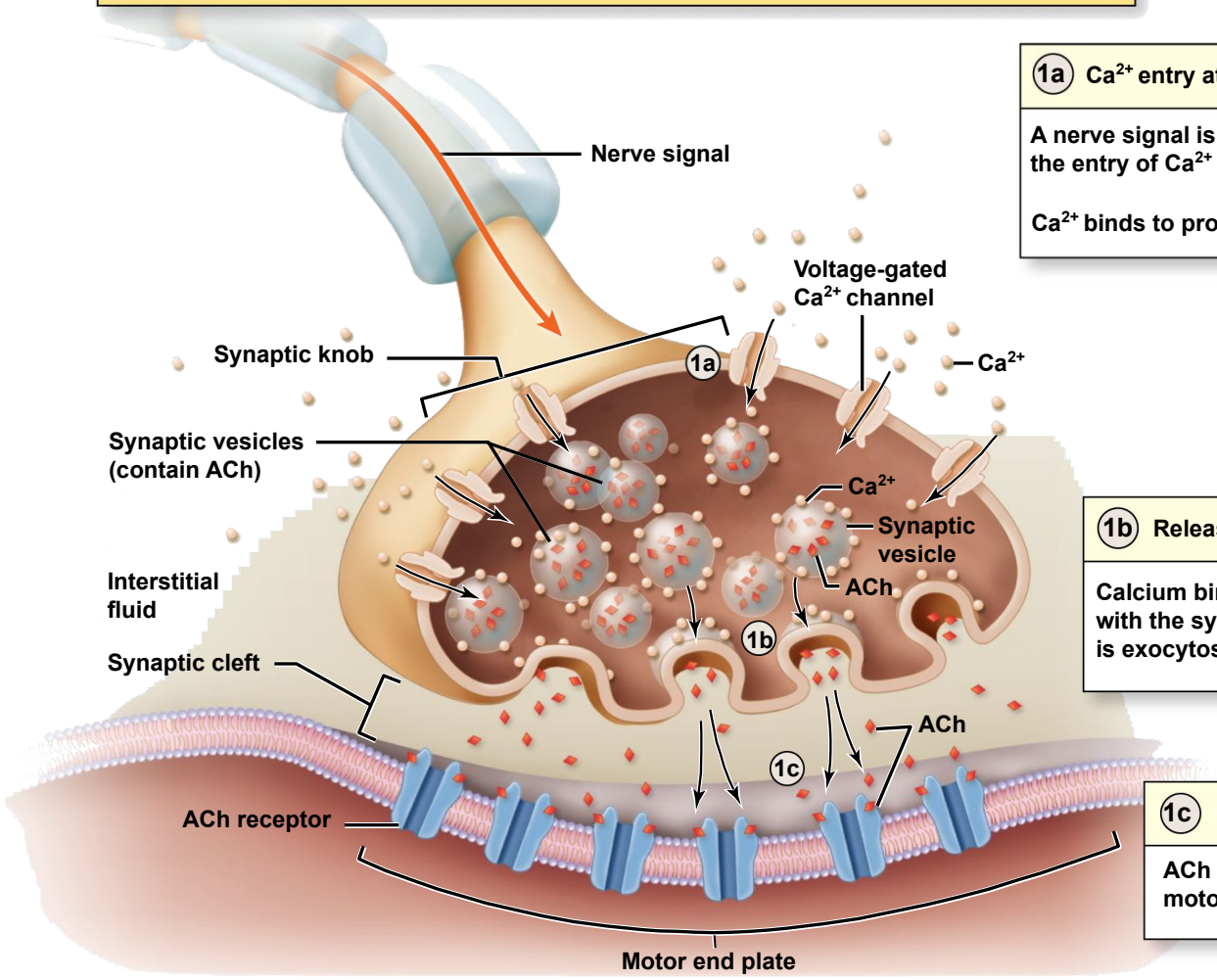
- **Release of ACh from synaptic knob**
  - Merging of synaptic vesicles with synaptic knob membrane
    - triggered by binding of Ca^{2+}
  - Exocytosis of ACh into synaptic cleft
  - About 300 vesicles per nerve signal

Skeletal Muscle Contraction—Neuromuscular Junction: Excitation of a Skeletal Muscle Fiber

- **Binding of ACh at motor end plate**
  - Diffusion of ACh across synaptic cleft
  - Binds with ACh receptors within motor end plate
  - Causes excitation of muscle fiber

Neuromuscular Junction: Excitation of a Skeletal Muscle Fiber (Figure 10.9)

1 NEUROMUSCULAR JUNCTION: EXCITATION OF A SKELETAL MUSCLE FIBER



1a Ca^{2+} entry at synaptic knob

A nerve signal is propagated down a motor axon and triggers the entry of Ca^{2+} into the synaptic knob.

Ca^{2+} binds to proteins in synaptic vesicle membrane.

1b Release of ACh from synaptic knob

Calcium binding triggers synaptic vesicles to merge with the synaptic knob plasma membrane and ACh is exocytosed into the synaptic cleft.

1c Binding of ACh to ACh receptor at motor end plate

ACh diffuses across the fluid-filled synaptic cleft in the motor end plate to bind with ACh receptors.

Skeletal Muscle Contraction—Neuromuscular Junction: Excitation of a Skeletal Muscle Fiber

What triggers the binding of synaptic vesicles to the synaptic knob membrane to cause exocytosis of ACh?

Nerve signal triggers the entry of calcium into the synaptic knob. Calcium binding to synaptic vesicles triggers the exocytosis of ACh.

Skeletal Muscle Contraction—Neuromuscular Junction: Excitation of a Skeletal Muscle Fiber

Clinical View: Myasthenia Gravis

- Autoimmune disease, primarily in women
- Antibodies binding ACh receptors in neuromuscular junctions
- Receptors removed from muscle fiber by endocytosis
- Results in decreased muscle stimulation
- Rapid fatigue and muscle weakness
- Eye and facial muscles often involved first
- May be followed by swallowing problems, limb weakness

Skeletal Muscle Contraction—Sarcolemma, T-Tubules, Sarcoplasmic Reticulum: Excitation-Contraction Coupling

- Second physiological event
  - Excitation-contraction coupling
  - Links skeletal muscle stimulation to events of contraction
  - Consists of three events:
    - development of end-plate potential at motor end plate
    - initiation and propagation of action potential along sarcolemma
    - release of Ca^{2+} from sarcoplasmic reticulum

Skeletal Muscle Contraction—Sarcolemma, T-Tubules, Sarcoplasmic Reticulum: Excitation-Contraction Coupling

- **Development of an end-plate potential at the motor end plate**
  - Binding of ACh to ACh receptors on motor end plate
  - Receptors stimulated to open
  - Allows Na^+ to rapidly diffuse into muscle fiber
  - Allows K^+ to slowly diffuse out

Skeletal Muscle Contraction—Sarcolemma, T-Tubules, Sarcoplasmic Reticulum: Excitation-Contraction Coupling

- **Development of an end-plate potential at the motor end plate *(continued)***
  - Net gain of positive charge inside fiber
  - Reverses electrical charge difference at motor end plate
    - reverse termed an **end plate potential (EPP)**
    - transient, localized at motor end plate
  - Can be stimulated again almost immediately

Skeletal Muscle Contraction—Sarcolemma, T-Tubules, Sarcoplasmic Reticulum: Excitation-Contraction Coupling

- **Initiation and propagation of action potential along the sarcolemma and T-tubules**
  - Action potential triggered by EPP
    - first, inside of sarcolemma becoming relatively positive
      - due to influx of Na^+ from voltage-gated channels
      - termed **depolarization**
    - then, inside of sarcolemma returning to resting potential
      - due to outflux of K^+ from voltage-gated channels
      - termed **repolarization**

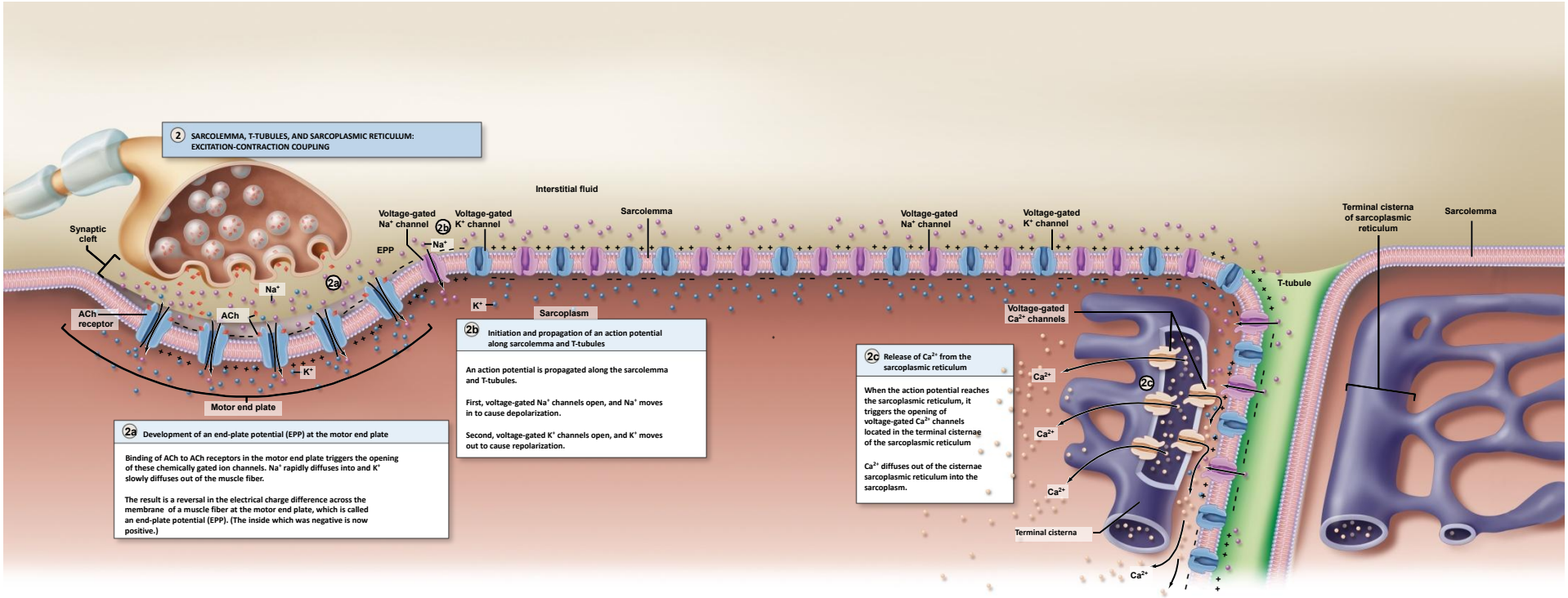
Skeletal Muscle Contraction—Sarcolemma, T-Tubules, Sarcoplasmic Reticulum: Excitation-Contraction Coupling

- **Initiation and propagation of action potential along the sarcolemma and T-tubules *(continued)***
  - Action potential propagated along sarcolemma and T-tubules
    - inflow of Na^+ at initial portion of sarcolemma
    - causes adjacent regions to experience electrical changes
    - initiate voltage-gated Na^+ channels in this region to open
    - action potential propagated down the sarcolemma and t-tubules
  - **Refractory period**
    - time between depolarization and repolarization
    - muscle unable to be restimulated

Skeletal Muscle Contraction—Sarcolemma, T-Tubules, Sarcoplasmic Reticulum: Excitation-Contraction Coupling

- **Release of calcium from the sarcoplasmic reticulum**
  - Opening of voltage-gated Ca^{2+} channels
    - found in terminal cisternae of sarcoplasmic reticulum
    - triggered by action potential
  - Diffusion of Ca^{2+} out of cisternae
  - Diffusion of Ca^{2+} into sarcoplasm
  - Now interacts with thick and thin filaments

Skeletal Muscle Fiber: Excitation-Contraction Coupling (Figure 10.10)



Skeletal Muscle Contraction—Sarcolemma, T-Tubules, Sarcoplasmic Reticulum: Excitation-Contraction Coupling

What two events are linked in the physiologic process call excitation-contraction coupling?

The events of skeletal muscle stimulation at the neuromuscular junction are coupled to the events of contraction caused by sliding myofilaments.