Muscle Tissue

D Ndhlovu-Chikwanda

- OBJECTIVES
- Describe the general features of muscular tissue.
- Compare the structure, location, and mode of control of skeletal, cardiac, and smooth muscle tissue.
- Describe the gross anatomy of a skeletal muscle.
- Explain the importance of connective tissue components, blood vessels, and nerves to skeletal muscles.
- Describe the microscopic anatomy of a skeletal muscle fiber.

- **Muscular tissue**
- consists of elongated cells - ***muscle fibers* or *myocytes***
- use ATP to generate force
- **Types of Muscular Tissue**
- 3 types of muscular tissue: **skeletal, cardiac** & **smooth**
- **1.Skeletal muscle tissue**
- skeletal muscles move bones of the skeleton
- few attach to structures other than bone, such as skin or other skeletal muscles
- *Is striated has* alternating light & dark protein bands (*striations*)
- Action is *voluntary:* its activity can be consciously (voluntarily) controlled

- **2. Cardiac muscle tissue**
- found in the heart, forms the heart wall
- *striated*, action is *involuntary*
- **3. Smooth muscle tissue**
- located in walls of blood vessels, airways, & most organs in the abdominopelvic cavity
- also attached to hair follicles in the skin
- *nonstriated* or *smooth*
- action is *involuntary*
- Both cardiac muscle & smooth muscle are regulated by neurons that are part of the autonomic (involuntary) division of the nervous system & hormones released by endocrine glands

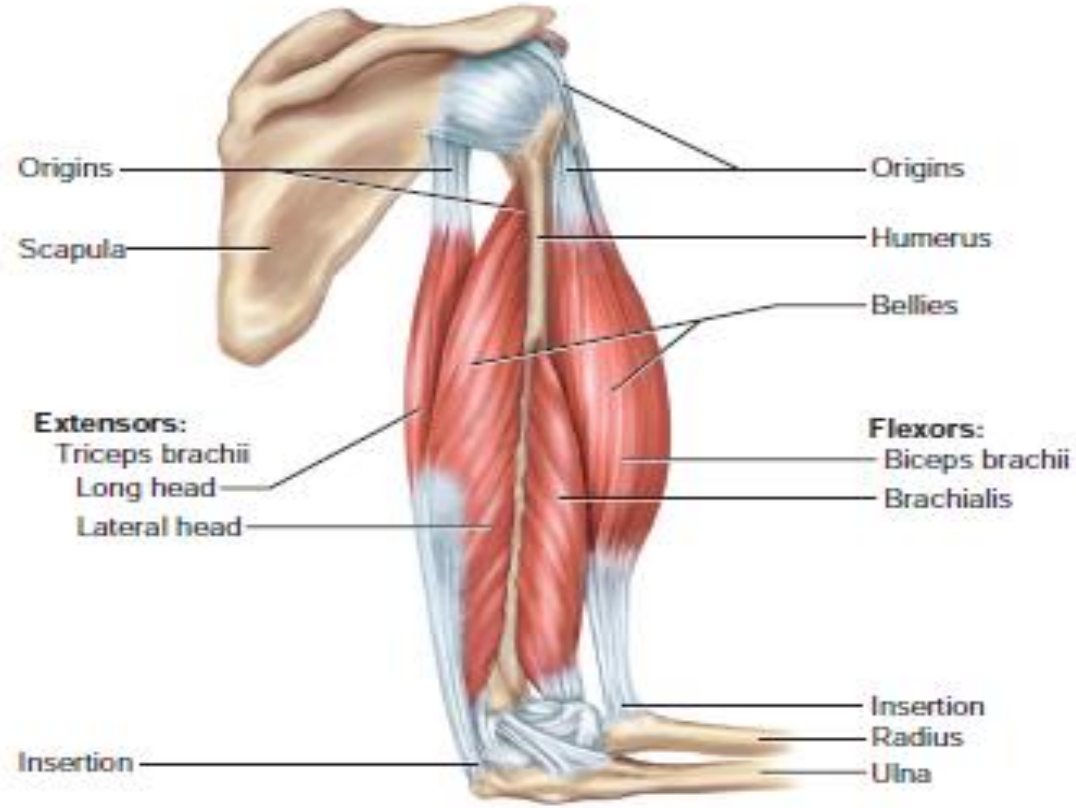
- **Functions**
- **1. Movement.**
- Skeletal muscle attaches to the skeleton & moves the body by moving the bones (move from place to place & move individual body parts)
- muscle in the walls of visceral organs produces movement by squeezing fluids and other substances through these hollow organs(circulation, digestion, defecation)Also communication-speech, facial expression, writing,body language)
- **2.Stabilizing body positions.**
- Skeletal muscle contractions stabilize joints & help maintain body positions, such as standing or sitting. Postural muscles contract continuously
- E.g. sustained contractions in neck muscles hold your head upright when you are listening intently to an anatomy lecture

- **3. Storing and moving substances within the body.**
- Sustained contractions of *sphincters* may prevent outflow of the contents of a hollow organ
- Temporary storage of food in the stomach or urine in the urinary bladder is possible because smooth muscle sphincters close off the outlets of these organs
- Cardiac muscle contractions pump blood through the body's blood vessels
- Peristalsis moves food in the intestines. Lymph in lower limbs is moved by muscles.
- **4. Producing heat.**
- contractions produce heat by **thermogenesis**
- heat released is used to maintain normal body temperature
- Involuntary contractions of skeletal muscles(shivering), can increase the rate of heat production.

- **Properties of Muscular Tissue**
- 4 properties that enable it to perform the functions
- **1.Electrical Excitability.**
- ability to respond to certain stimuli by producing electrical signals called **action potentials(impulses)**
- 2 main types of stimuli trigger action potentials: electrical & chemical
- *electrical signals(*Autorhythmic*)*- arise in muscular tissue itself, as in heart's pacemaker
- *Chemical stimuli-* neurotransmitters , hormones , local changes in pH, can trigger action potentials

- **2. Contractility**
- ability of muscular tissue to contract forcefully when stimulated by an action potential
- **3. Extensibility**
- ability of muscular tissue to stretch, within limits, without being damaged
- connective tissue within muscle limits range of extensibility
- **4. Elasticity**
- ability of muscular tissue to return to its original length & shape after contraction or extension

- **SKELETAL MUSCLE TISSUE**
- skeletal muscle is an organ composed of hundreds to thousands of skeletal muscle cells(**muscle fibers) have** elongated shapes
- Connective tissues surround muscle fibers & whole muscles, carry the blood vessels & nerves that exert their effects on individual muscle fibers

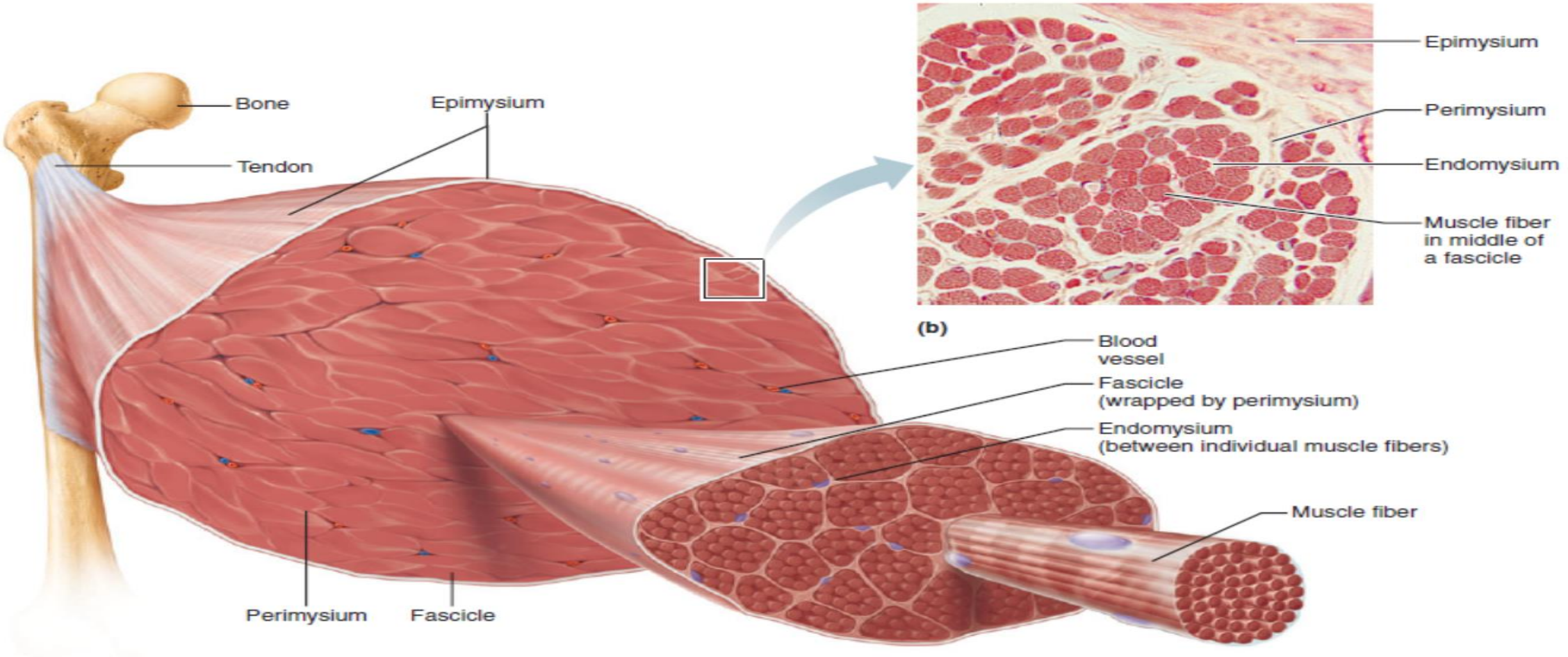


- **Structure of a Skeletal Muscle**
- consists of a muscle belly connected by tendons to the skeleton
- reddish appearance arises from well-vascularized muscle cells in the **muscle belly (body)** of the organ
- belly of the muscle has various shapes e.g. elongated, thick, round, triangular, rectangular , thin or flat
- **Tendons**
- tough, glistening white dense regular connective tissue structures
- attach muscle belly to the bones
- are minimally vascular, lack muscle cells
- consist primarily of parallel arrangements of collagen fibers
- variety of shapes: long, ropelike structures, others are flat sheets called **aponeuroses**

- **Clinical Application**
- **Tenosynovitis**
- inflammation of the tendons, tendon sheaths & synovial membranes surrounding certain joints
- tendons often affected are at the wrists, shoulders,elbows, finger joints, ankles, & feet
- affected sheaths become visibly swollen because of fluid accumulation
- Tenderness & pain are frequently associated with movement of the body part
- condition often follows trauma, strain, excessive exercise, or other stressors
- Gymnasts are prone to developing the condition as a result of chronic, repetitive, and maximum hyperextension at the wrists.
- Other repetitive movements involving activities such as typing, haircutting, carpentry, and assembly line work can also result in tenosynovitis

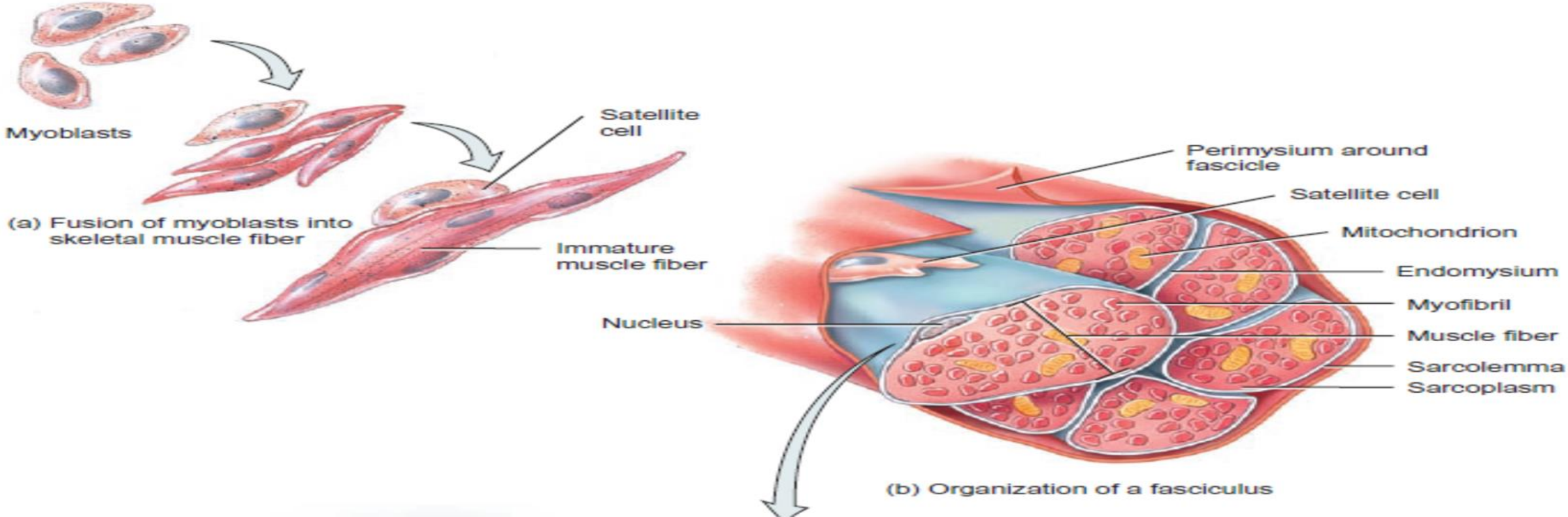
- **Connective Tissue Coverings**
- muscle belly consists of striated skeletal muscle fibers
- Surrounding each muscle fiber is a thin wrapping of reticular fibers called **endomysium**
- carries small blood vessels that supply the fibers with nutrients
- Groups of muscle fibers form bundles
- muscle fiber bundle is a **fascicle (** *fasciculus)*
- dense **irregular connective tissue** covering is called the **perimysium**
- helps to bind the muscle fibers together

- **epimysium** on periphery of the muscle is a thicker covering of dense irregular connective tissue
- binds all the fascicles together to form the muscle belly
- various skeletal muscles are further grouped together & protected by large dense irregular connective tissue sheets, called **fascia**



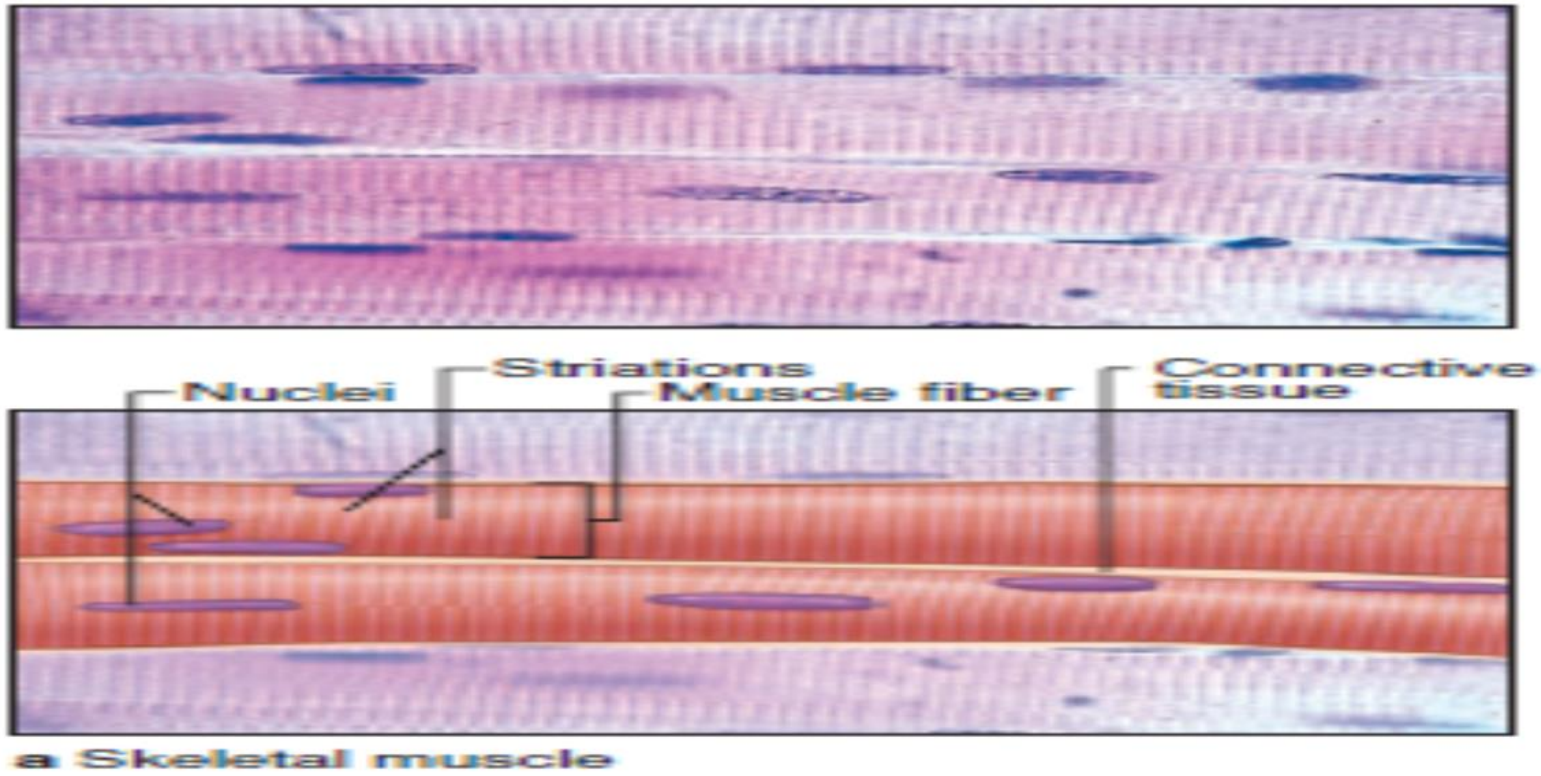
- **Nerve and Blood Supply**
- Skeletal muscles are well supplied with nerves & blood vessels
- Nerves enter muscle along with main blood vessels as a unit called a **neurovascular bundle**
- neurovascular bundles enter the muscle body near the origin then spread through the muscle via perimysium & endomysium
- **somatic motor neurons** stimulate skeletal muscle fibers to contract

- **Microscopic anatomy of a Skeletal Muscle Fiber (Cell)**
- important components of a skeletal muscle are **muscle fibers**
- Range from 10 to 100 μm* in diameter ,length is 10 cm to 30 cm
- During embryonic development, each skeletal muscle fiber arises from fusion of a hundred or more small mesodermal cells called *myoblasts*
- skeletal muscle fiber is a single cell with a hundred or more nuclei
- muscle fiber loses ability to undergo cell division after fusion



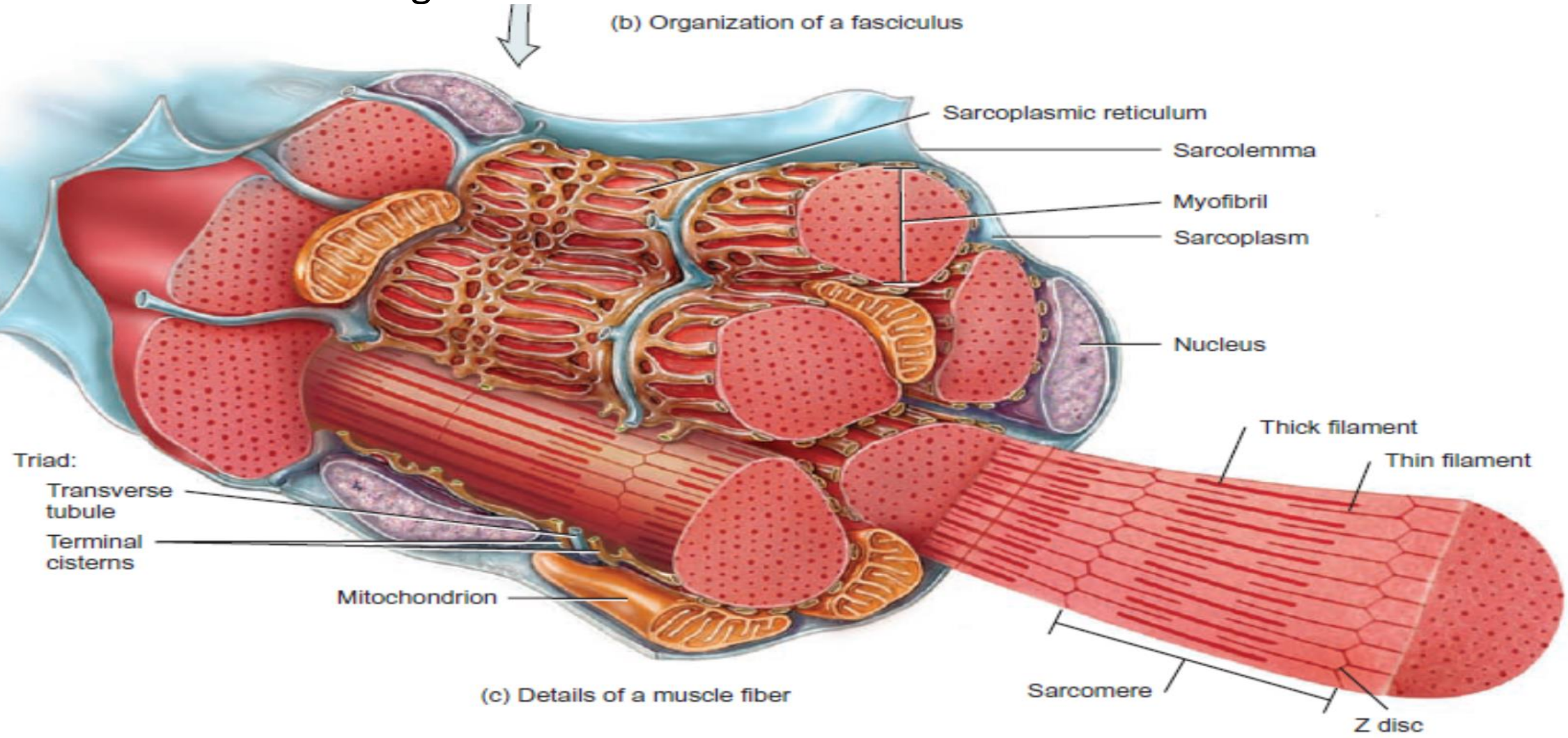
- few myoblasts do persist in mature skeletal muscle as *satellite cell*
- Have capacity to fuse with one another or with damaged muscle fibers to regenerate functional muscle fibers
- new skeletal muscle fibers are formed by satellite cells is not enough to compensate for significant skeletal muscle damage or degeneration
- skeletal muscle tissue undergoes **fibrosis(**the replacement of muscle fibers by fibrous scar tissue)
- regeneration of skeletal muscle tissue is limited

- muscle growth after birth occurs is by **hypertrophy (**enlargement of existing muscle fibers) **not hyperplasia(** an increase in the number of fibers)
- **Atrophy** (decrease in size of a muscle fiber)
- During childhood, human growth hormone & other hormones stimulate an increase in the size of skeletal muscle fibers
- Can also results from very forceful, repetitive muscular activity, such as strength training

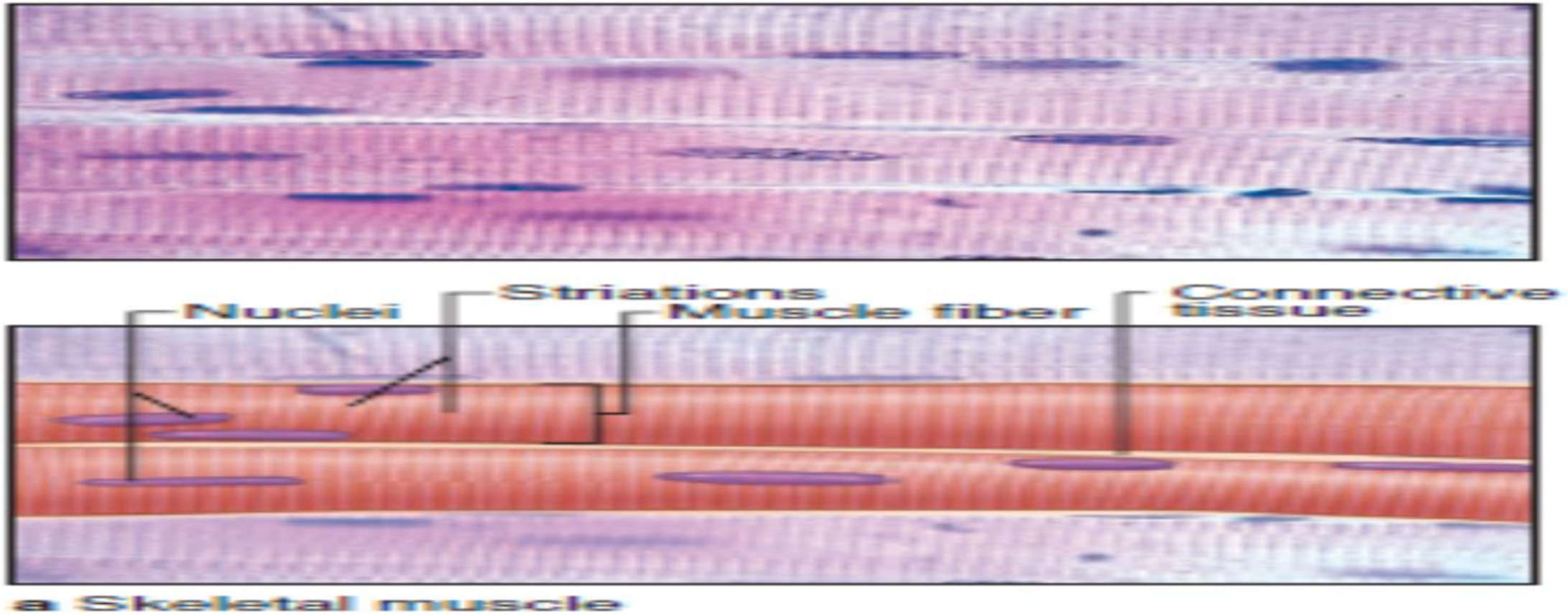


- ***Sarcolemma, T Tubules, and Sarcoplasm***
- multiple nuclei of a skeletal muscle fiber are located beneath the **sarcolemma(** plasma membrane**)**
- **transverse tubules** (*T tubules*)-Thousands of tiny invaginations of the sarcolemma (tunnel in from the surface toward the center of each muscle fiber)
- filled with interstitial fluid
- sarcolemma surrounds the **sarcoplasm (**cytoplasm of a muscle fiber)
- Sarcoplasm has glycogen-a chain of linked glucose molecules for ATP production
- **myoglobin** a red-colored protein found in sarcoplasm

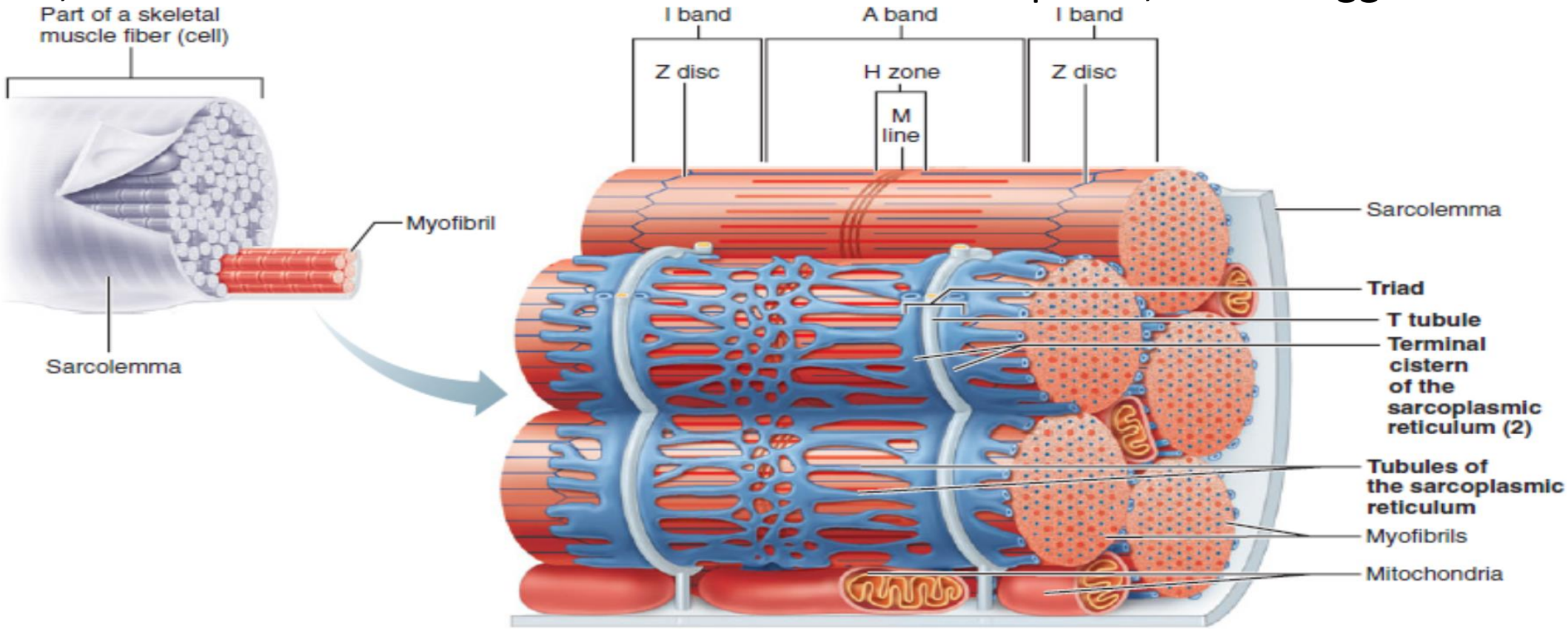
- myoglobin found only in muscle, binds oxygen molecules that diffuse into muscle fibers from interstitial fluid
- releases oxygen when mitochondria need it for ATP production
- mitochondria lie in rows throughout the muscle fiber



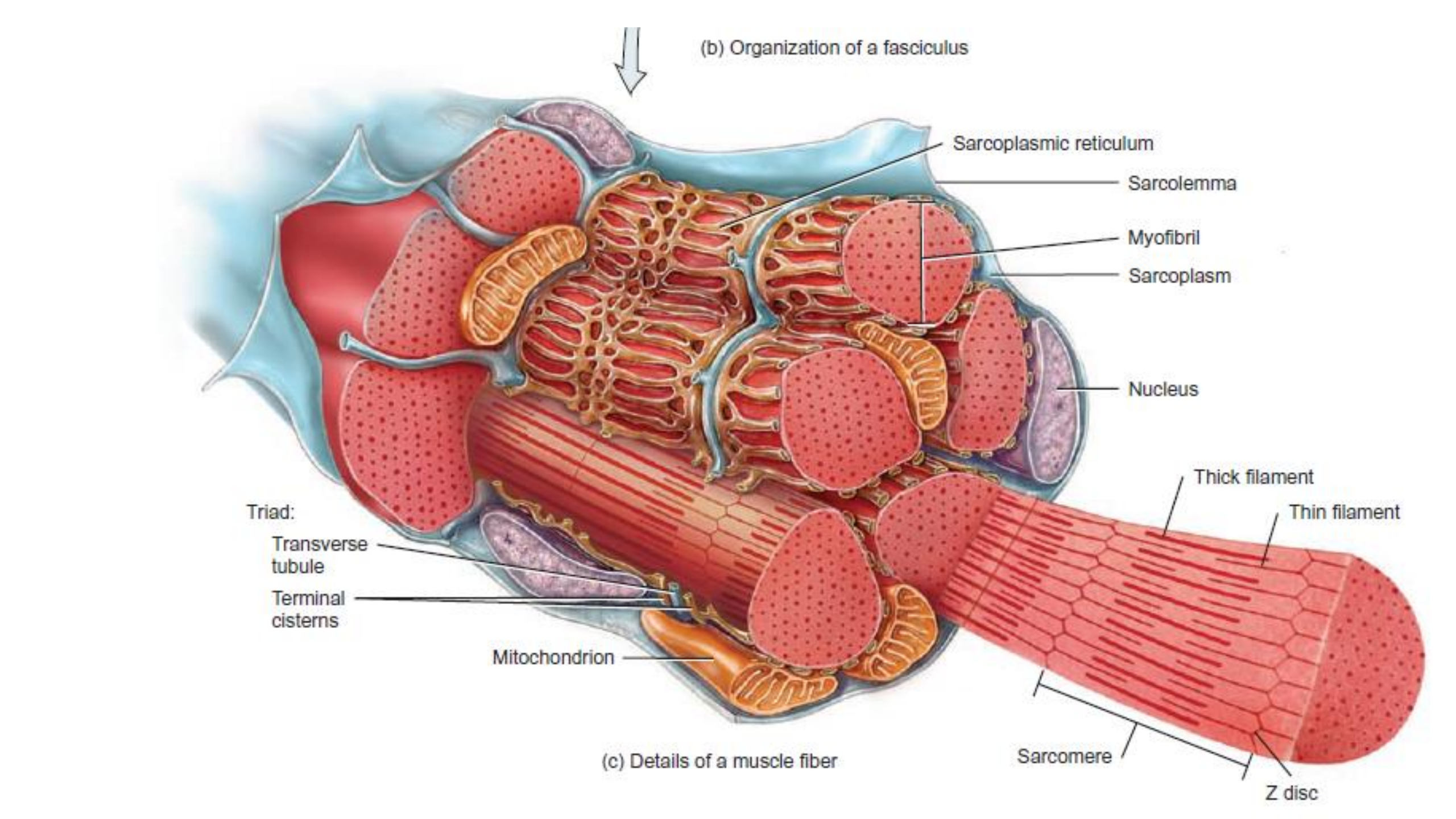
- ***Myofibrils and Sarcoplasmic Reticulum***
- At high magnification
- sarcoplasm appears stuffed with **myofibrils** (little threads)
- **myofibrils are** contractile elements of skeletal muscle**,** 2μm in diameter
- extend the entire length of the muscle fiber
- have striations that make the whole muscle fiber striped (striated)



- **sarcoplasmic reticulum (SR) (**smooth endoplasmic reticulum)**e**ncircles each myofibril
- Dilated end sacs of the sarcoplasmic reticulum called **terminal cisterns** are adjacent the transverse tubules from both sides
- 1 transverse tubule & 2 terminal cisterns on either side of it form a **triad**
- sarcoplasmic reticulum stores calcium ions (Ca2+) in relaxed muscle
- When triggered, releases Ca2+ from terminal cisterns to the sarcoplasm, which triggers muscle contraction

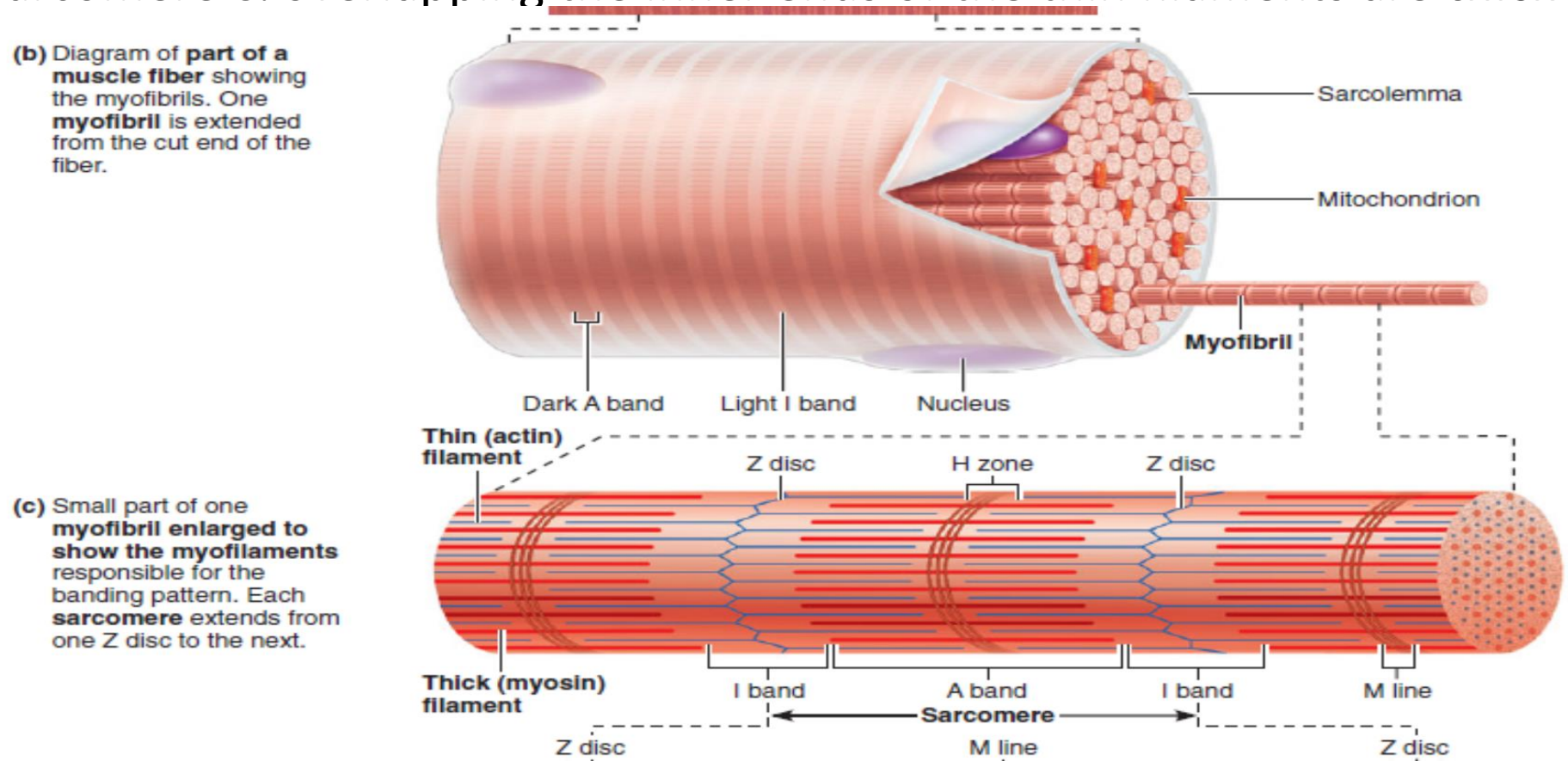


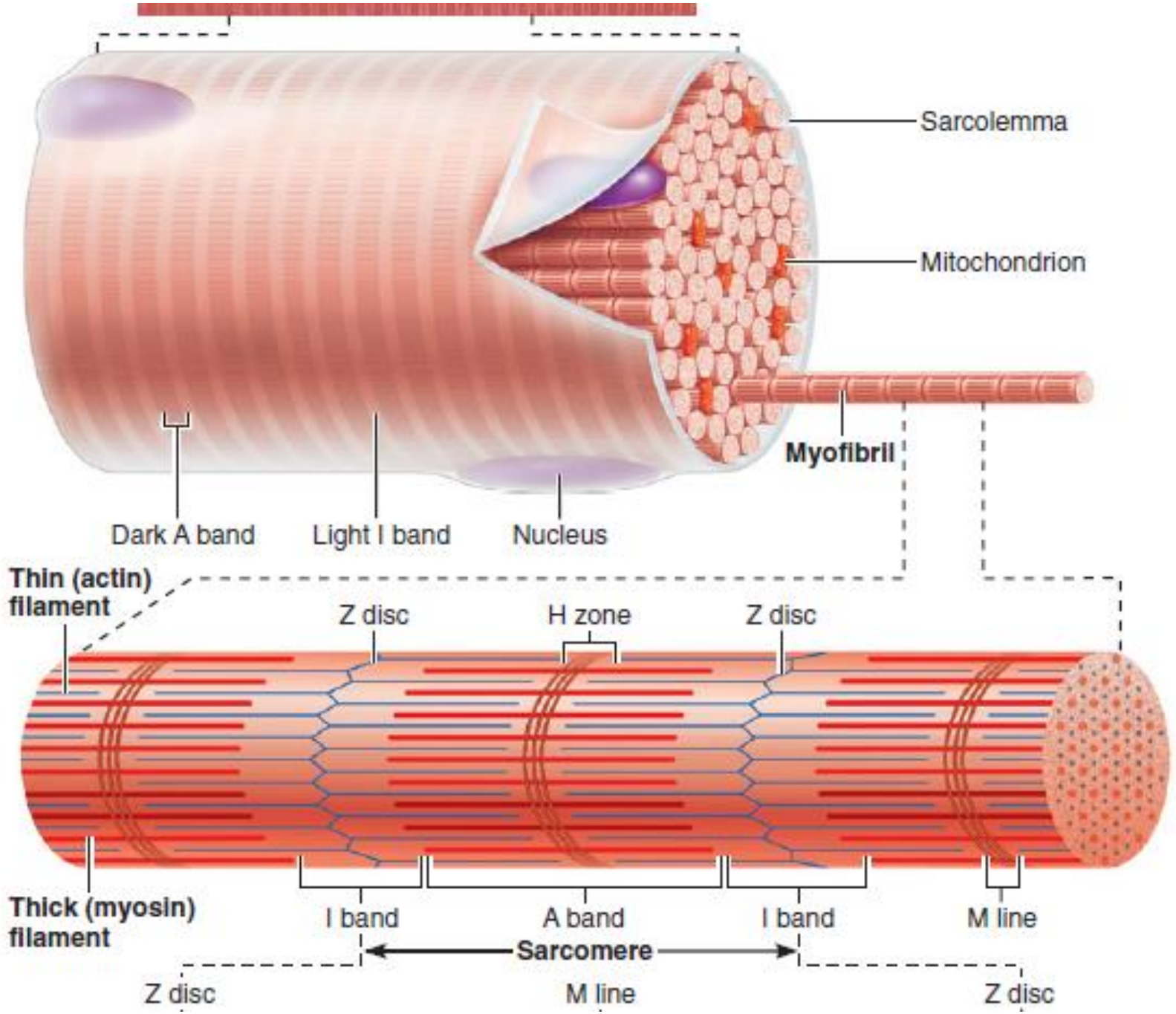
IGURE 10.6 **Sarcoplasmic reticulum and T tubules in the skeletal muscle fiber.**


(b) Organization of a fasciculus
Sarcoplasmic reticulum
Sarcolemma
Myofibril
Sarcoplasm
Nucleus
Thick filament
Thin filament
Triad:
Transverse tubule
Terminal cisterns
Mitochondrion
Sarcomere
Z disc
(c) Details of a muscle fiber

- ***Filaments and the Sarcomere***
- Within myofibrils are protein structures called **filaments** or ***myofilaments***
- ***Thin filaments*** are 8 nm† in diameter composed of protein **actin**
- ***Thick filaments*** are 16 nm in diameter composed of protein **myosin**
- Both are involved in the contractile process
- Filaments inside a myofibril do not extend the entire length
- Are arranged in compartments called **sarcomeres(t**he basic functional units of a myofibril)
- a sarcomere extends from one Z disc to the next Z disc

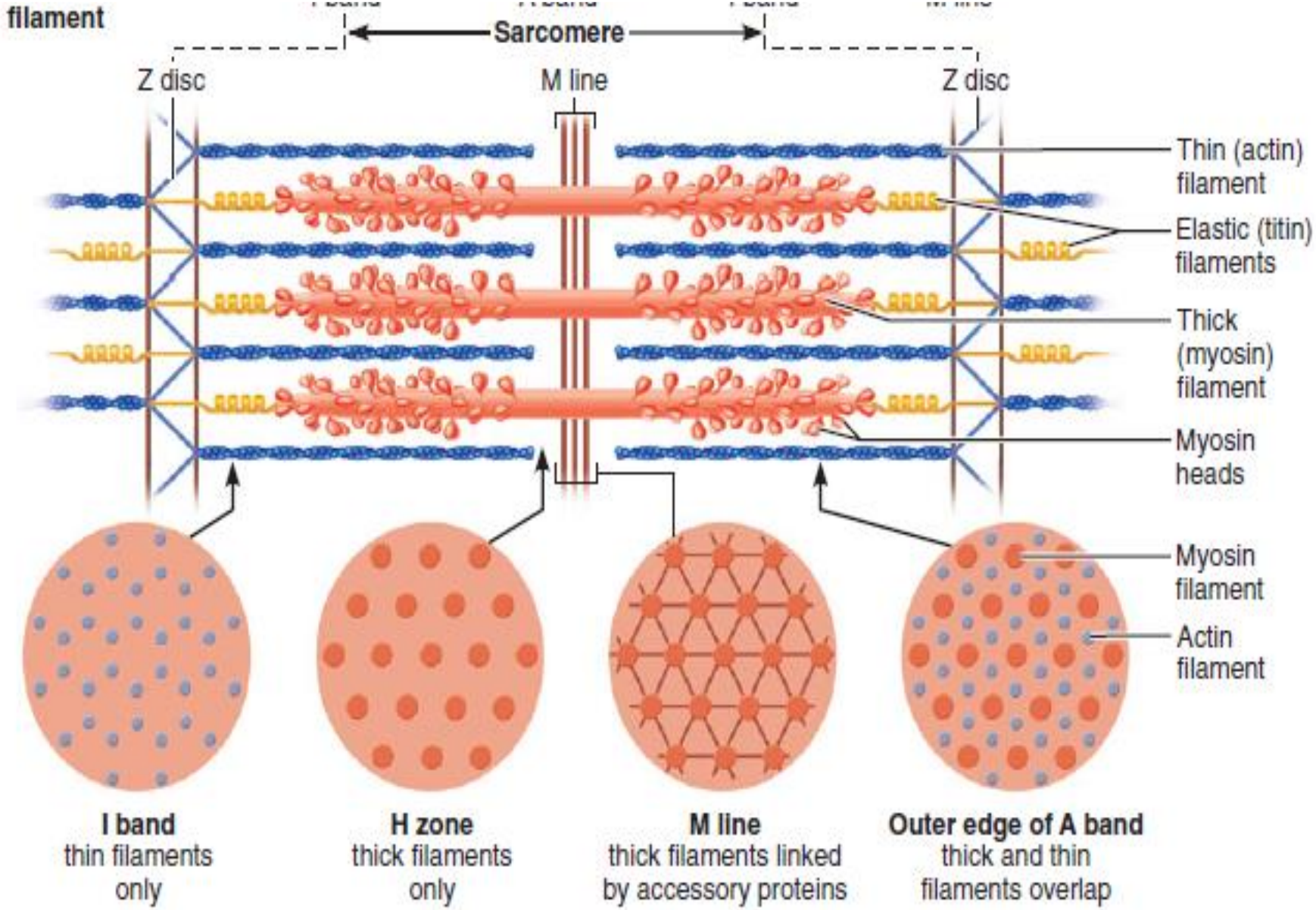
- A myofibril is a long row of repeating segments called **sarcomeres**
- sarcomere is the basic unit of contraction in skeletal muscle
- The boundaries at the 2 ends of each sarcomere are called **Z discs** (**Z lines**)
- Attached to each Z disc and extending toward the center of the sarcomere are myofilaments called **thin (actin) filaments**
- In the center of the sarcomere & overlapping the inner ends of the thin filaments are **thick (myosin) filaments**





(b) Diagram of **part of a muscle fiber** showing the myofibrils. One **myofibril** is extended from the cut end of the fiber.

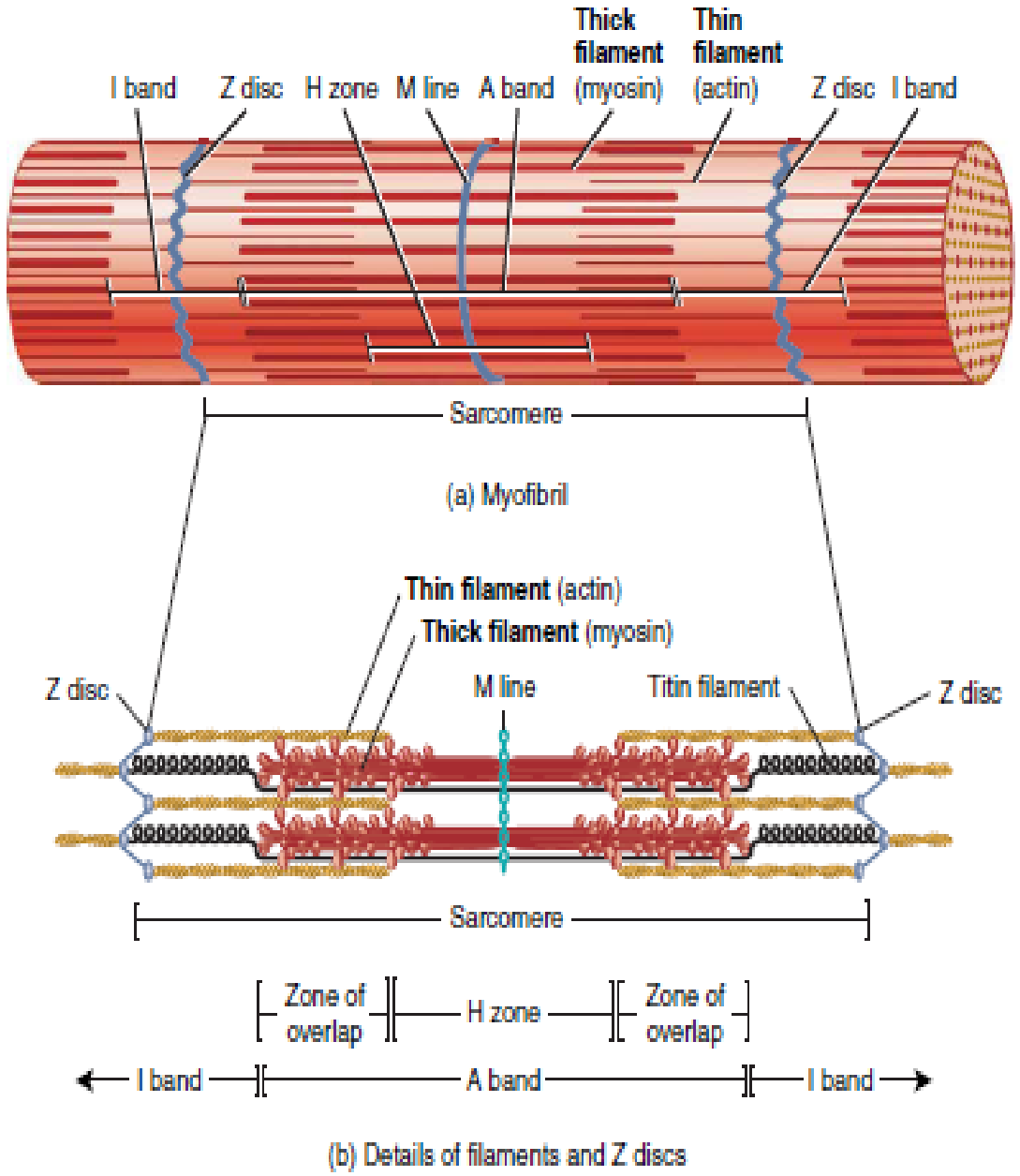
(c) Small part of one **myofibril enlarged to show the myofilaments** responsible for the banding pattern. Each **sarcomere** extends from one Z disc to the next.

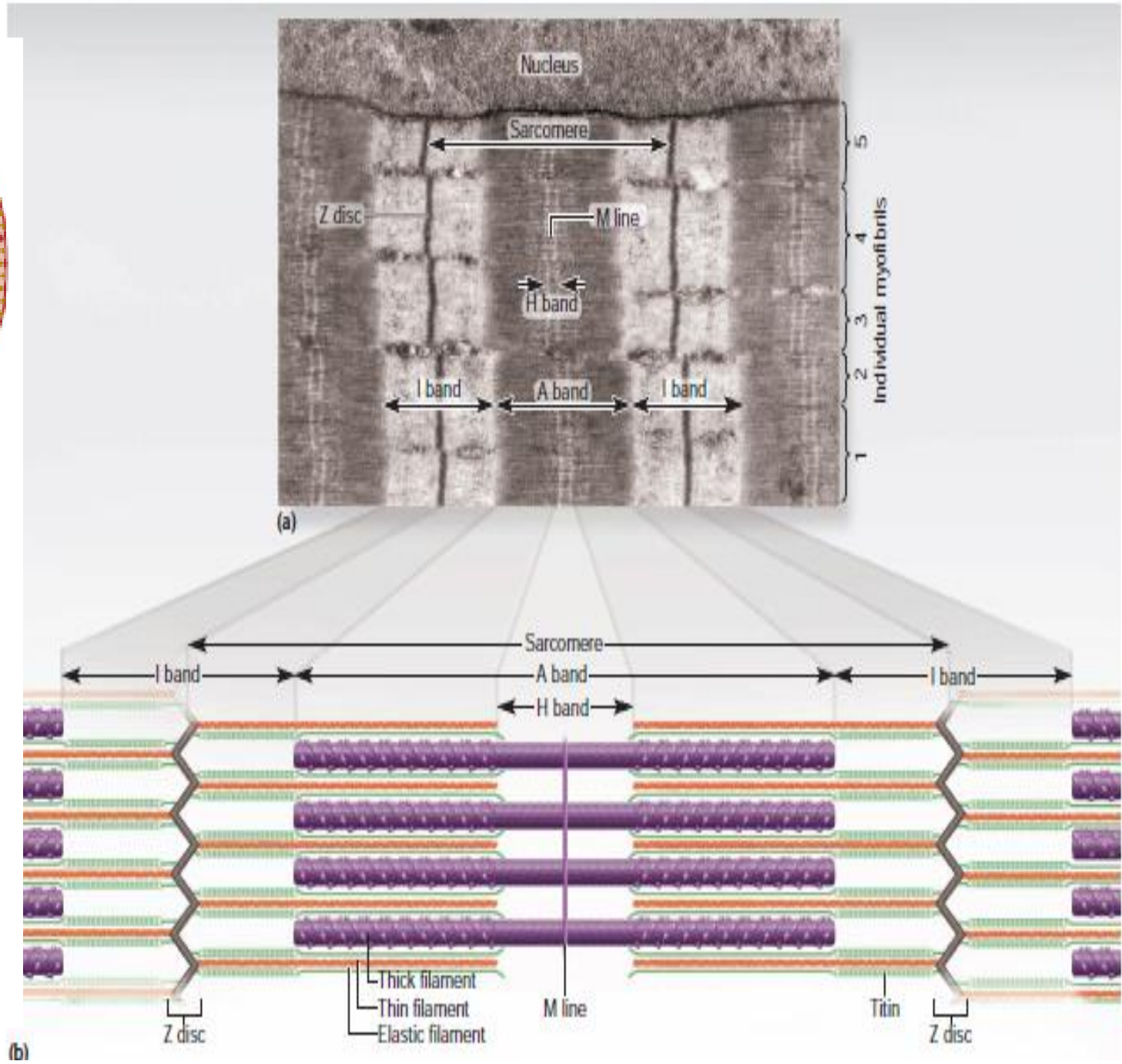


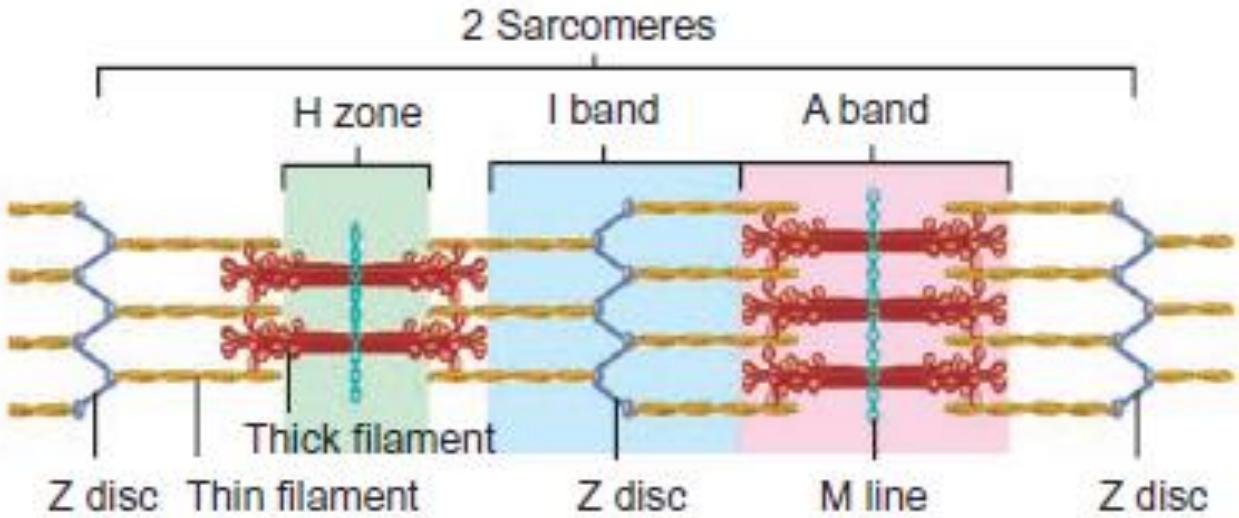
(d) Enlargement of one sarcomere (sectioned lengthwise). Notice the myosin heads on the thick filaments.

(e) Cross-sectional view of a sarcomere cut through in different locations.

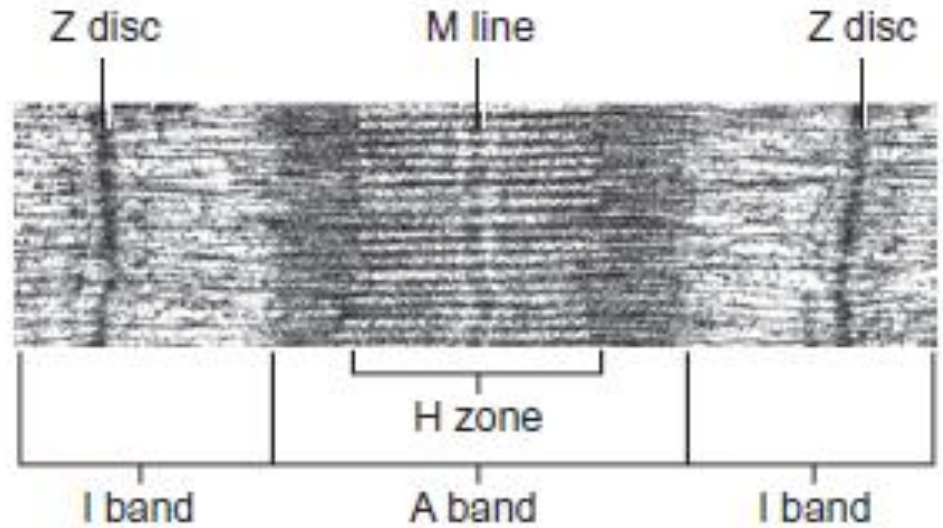
- sarcomere structure explains the pattern of striations in skeletal muscle fibers
- dark bands are created by the full length of the thick filaments in the sarcomeres, along with the inner ends of the thin filaments, which overlap the thick filaments
- region of each sarcomere is called the **A band**
- central part of an A band, where no thin filaments reach, is the **H zone** has only thick filaments
- **M line** in the center of the H zone contains tiny rods that hold the thick filaments together
- 2 regions on either side of the A band, regions that contain only thin filaments, are called the **I bands**
- each I band is part of 2 adjacent sarcomeres and has a Z disc running through its center


Thick filament (myosin)
Thin filament (actin)
I band
Z disc
H zone
M line
A band
Z disc
I band
Sarcomere
(a) Myofibril
Thin filament (actin)
Thick filament (myosin)
Z disc
M line
Titin filament
Z disc
Sarcomere
Zone of overlap
H zone
Zone of overlap
I band
A band
I band
(b) Details of filaments and Z discs


Nucleus
Sarcomere
Z disc
M line
H band
I band
A band
I band
Individual myofibrils
1
2
3
4
5
(a)
Sarcomere
I band
A band
I band
H band
Thick filament
Thin filament
Elastic filament
Z disc
M line
Titin
Z disc
(b)



(a) Relaxed muscle



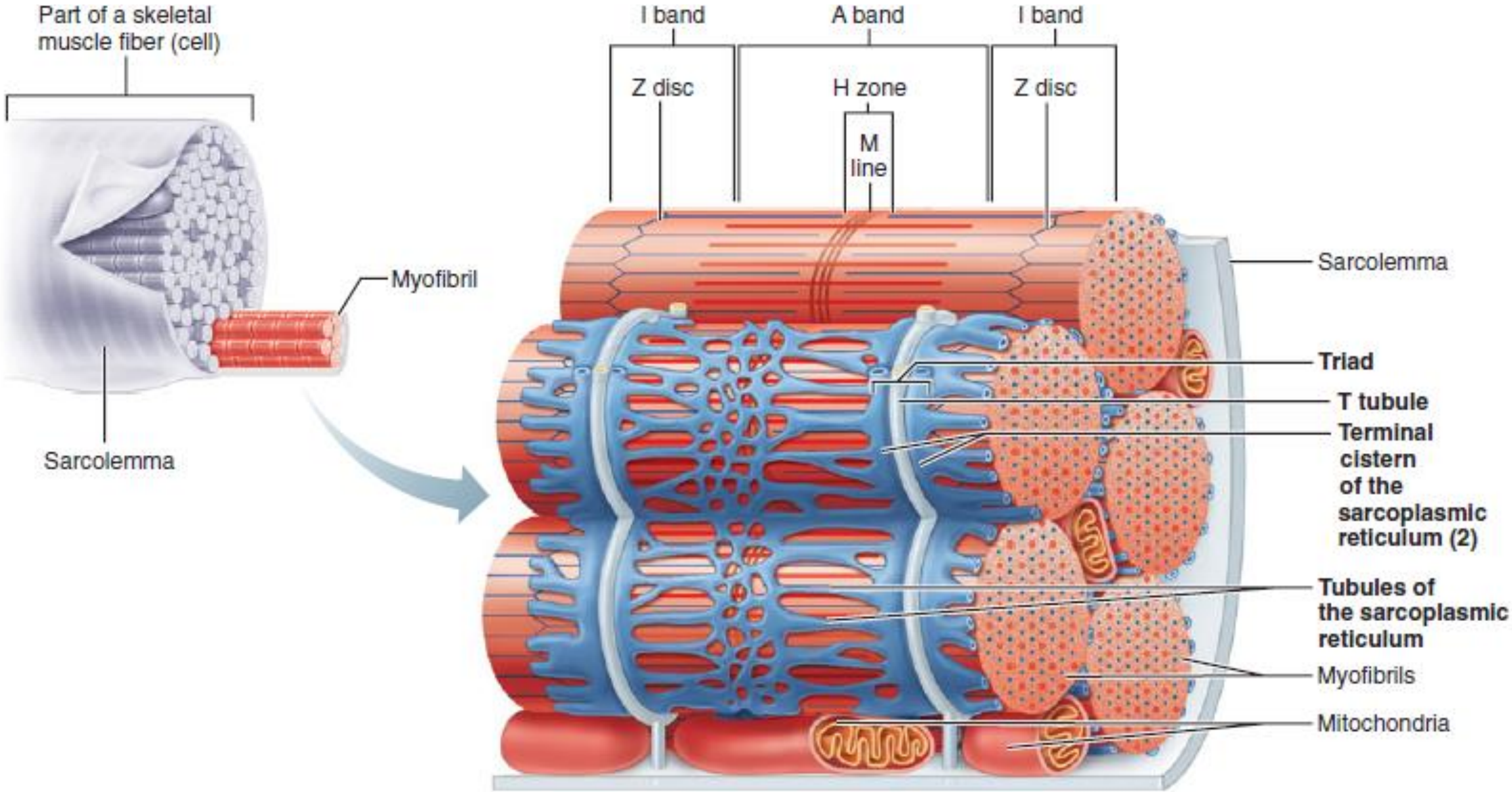
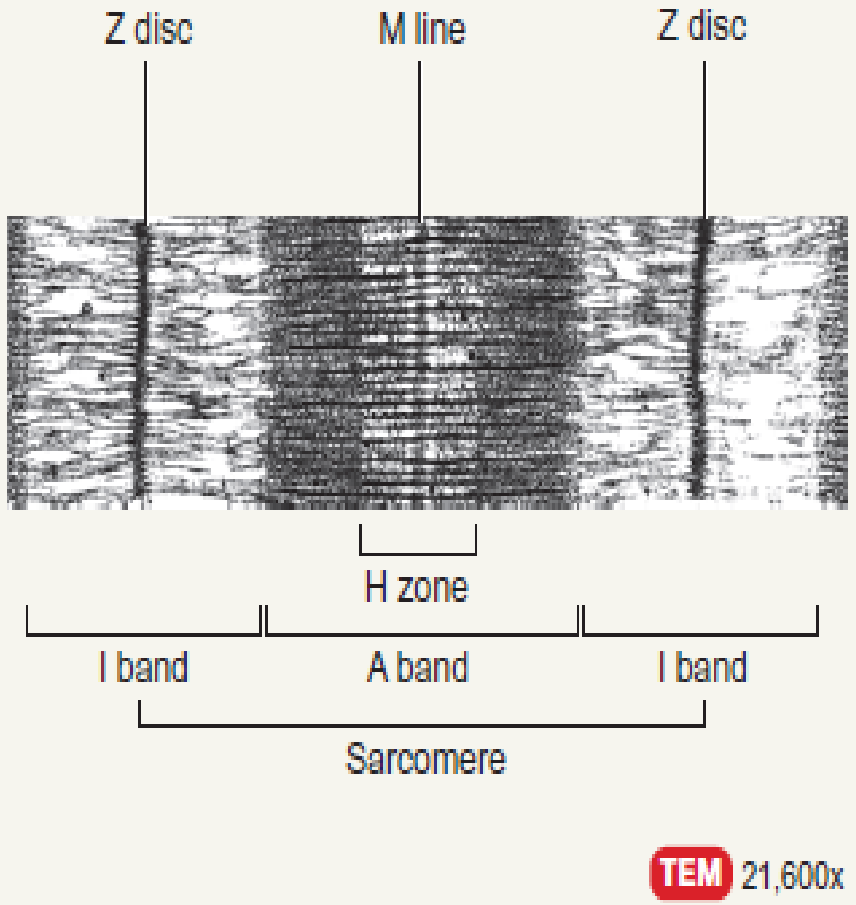


FIGURE 10.6 Sarcoplasmic reticulum and T tubules in the skeletal muscle fiber.

TABLE 10.1

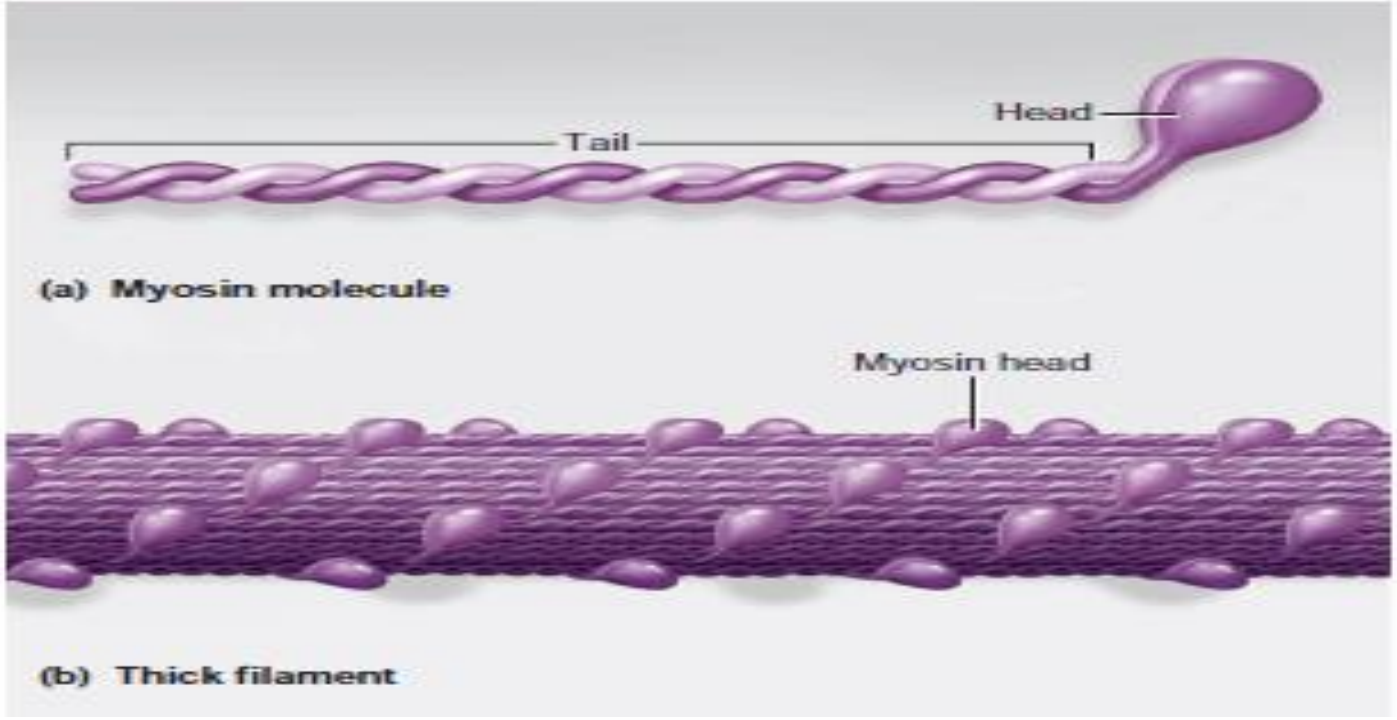
Components of a Sarcomere

COMPONENT	DESCRIPTION
Z discs	Narrow, plate-shaped regions of dense protein material that separate one sarcomere from the next
A band	The dark, middle part of the sarcomere that extends the entire length of the thick filaments and also includes those parts of the thin filaments that overlap with the thick filaments
I band	The lighter, less dense area of the sarcomere that contains the rest of the thin filaments but no thick filaments A Z disc passes through the center of each I band
H zone	A narrow region in the center of each A band that contains thick filaments but no thin filaments
M line	A region in the center of the H zone that contains proteins that hold the thick filaments together at the center of the sarcomere



- **Muscle Proteins**
- Myofibrils are built from 3 kinds of proteins:
- (1)contractile proteins, generate force during contraction
- (2)regulatory proteins, help switch the contraction process on & off
- (3)structural proteins
- keep the thick & thin filaments in the proper alignment
- give the myofibril elasticity & extensibility
- link the myofibrils to the sarcolemma & extracellular matrix

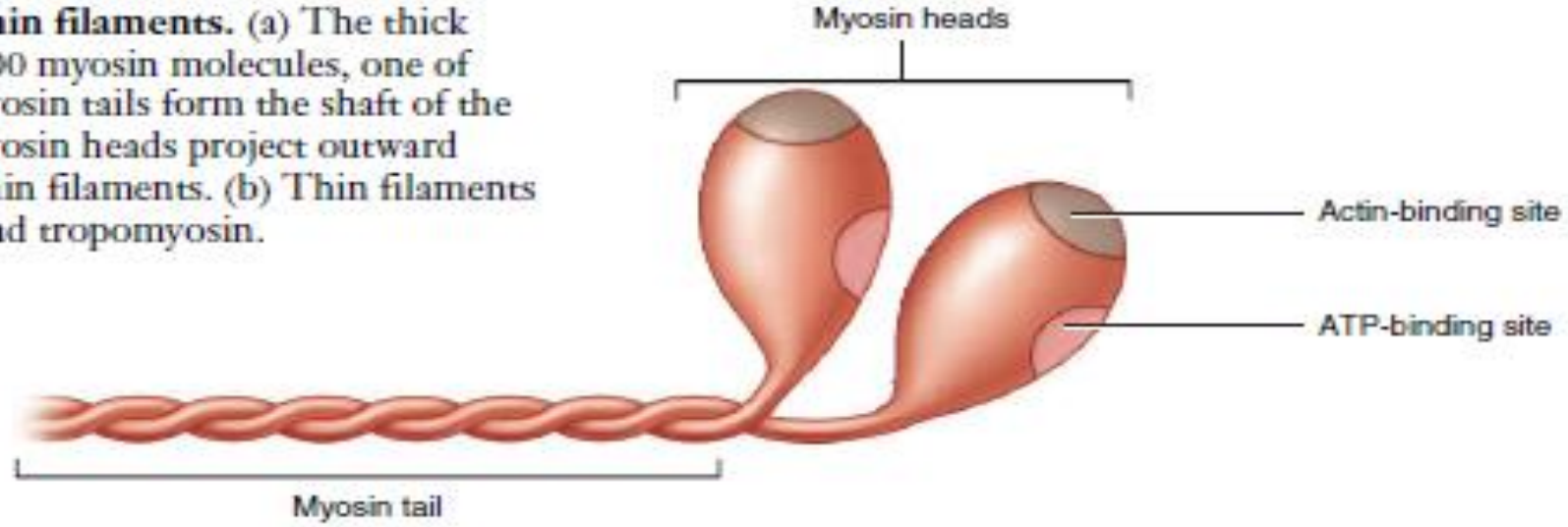
- **2 *contractile proteins*** - myosin & actin
- **Myosin** functions as a motor protein in all 3 types of muscle tissue
- *motor proteins* convert ATP's chemical energy into the mechanical energy of motion, that is, the production of force
- 300 molecules of myosin make 1 thick filament
- Each myosin molecule is shaped like 2 golf clubs twisted together
- *myosin tail* points toward the M line in the center of the sarcomere
- Tails of neighboring myosin molecules lie parallel to one another, form shaft of the thick filament



- 2 projections of each myosin molecule are called *myosin heads*
- Each myosin head has 2 binding sites:
- (1) an *actin-binding site*
- (2) an *ATP-binding site* -also functions as an *ATPase*—an enzyme that hydrolyzes ATP to generate energy for muscle contraction

Figure 10.4 Structure of thick and thin filaments. (a) The thick filament contains about 300 myosin molecules, one of which is pictured. The myosin tails form the shaft of the thick filament, and the myosin heads project outward toward the surrounding thin filaments. (b) Thin filaments contain actin, troponin, and tropomyosin.

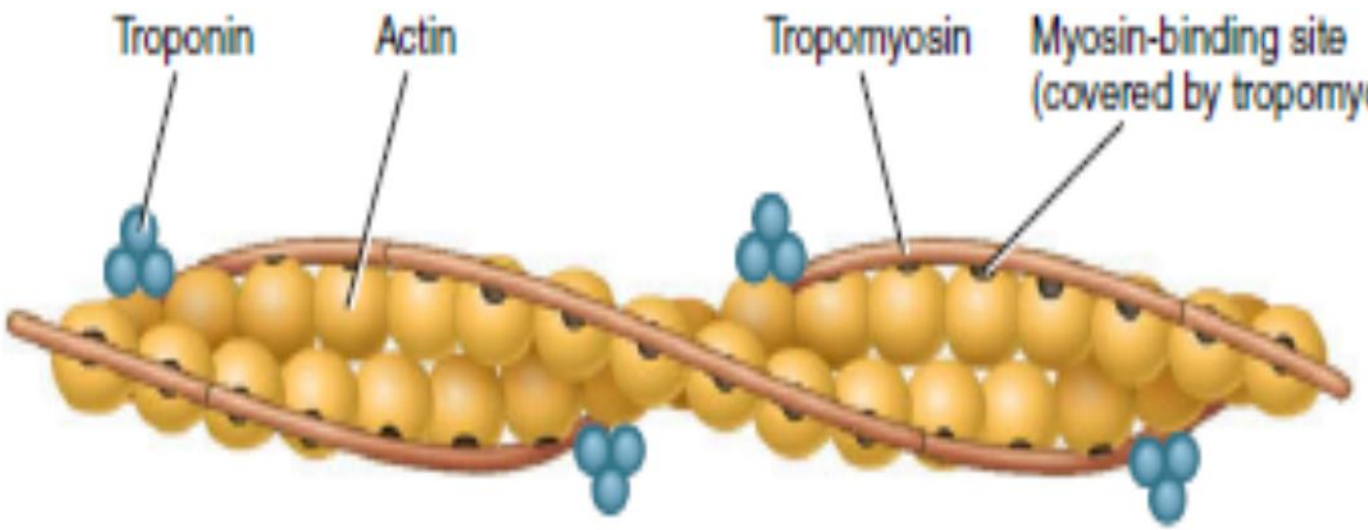
Contractile proteins (myosin and actin) generate force during contraction, and regulatory proteins (troponin and tropomyosin) help switch contraction on and off.



(a) Thick filament (below) and myosin molecule (above)

- Thin filaments extend from anchoring points within the Z discs
- main component is the protein **actin**
- Individual actin molecules join to form an actin filament that is twisted into a helix

(a) Thick filament (below) and myosin molecule (ab

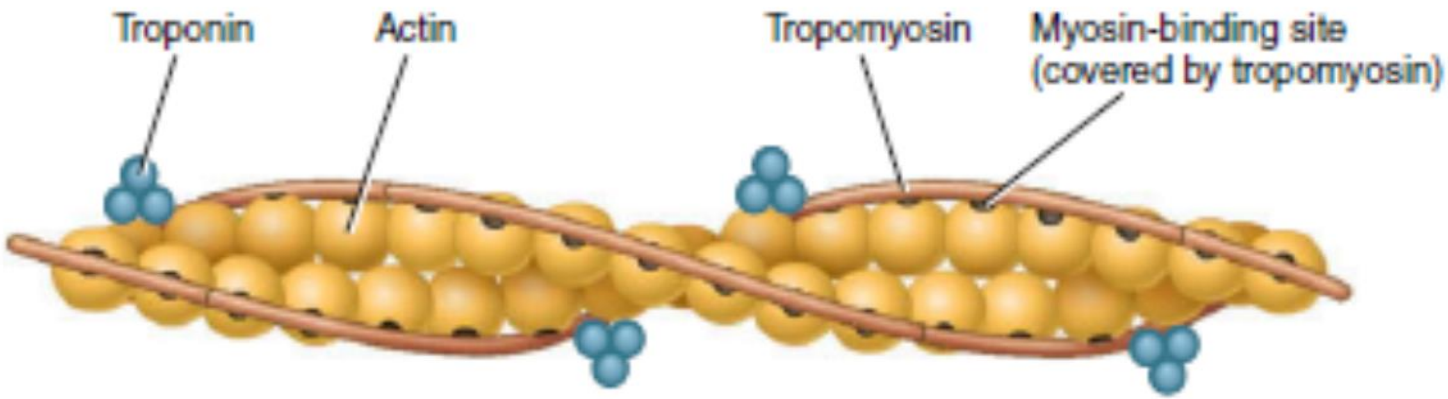


(b) Portion of a thin filament

? Which proteins
proteins are pr

- On each actin molecule is a *myosin-binding site*
- 2 *regulatory proteins*—**tropomyosin & troponin** —are part of the thin filament
- relaxed muscle, myosin is blocked from binding to actin because strands of tropomyosin cover the myosin-binding site on actin
- tropomyosin strand, is held in place by troponin molecules
- Calcium ions (Ca2+) bind to troponin, it undergoes a change in shape;
- this change moves tropomyosin away from myosin-binding sites on actin, allowing myosin to bind to actin and muscle contraction to begin

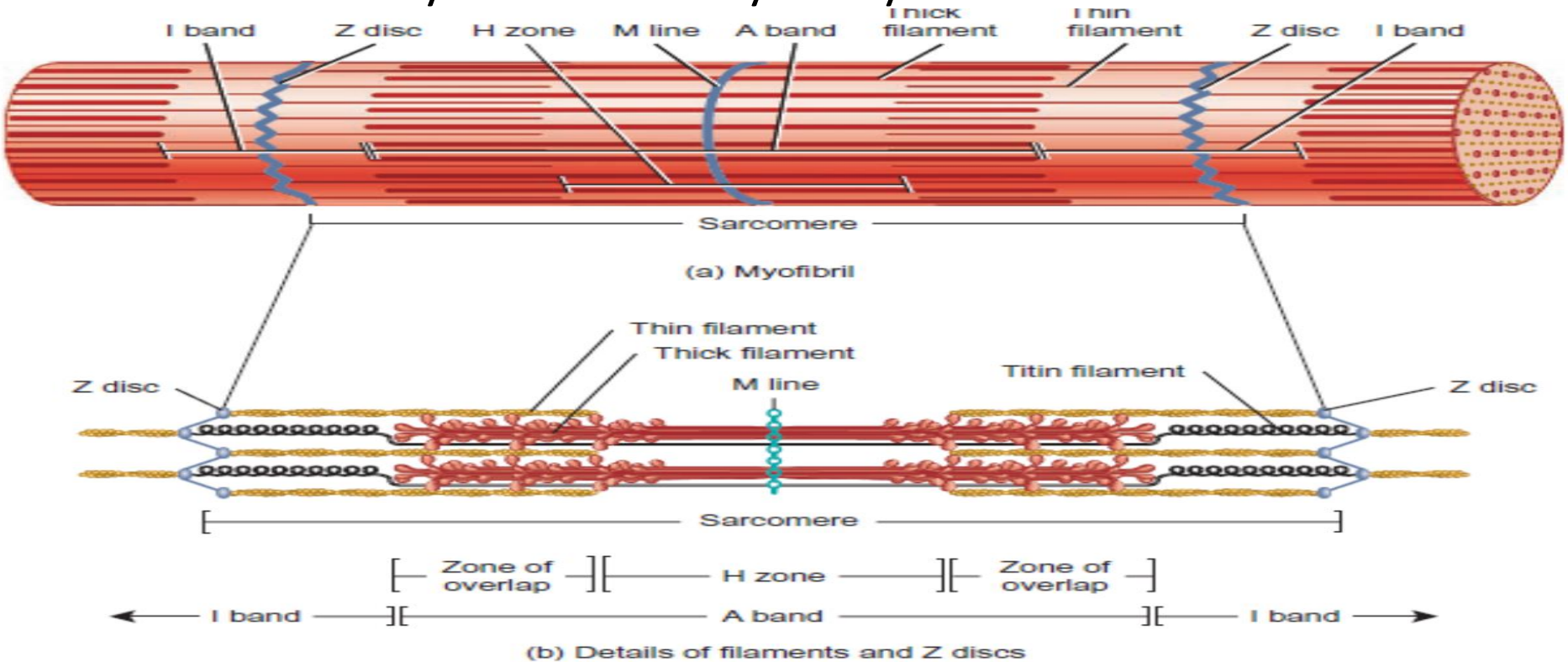
(a) Thick filament (below) and myosin molecule (ab•



(b) Portion of a thin filament

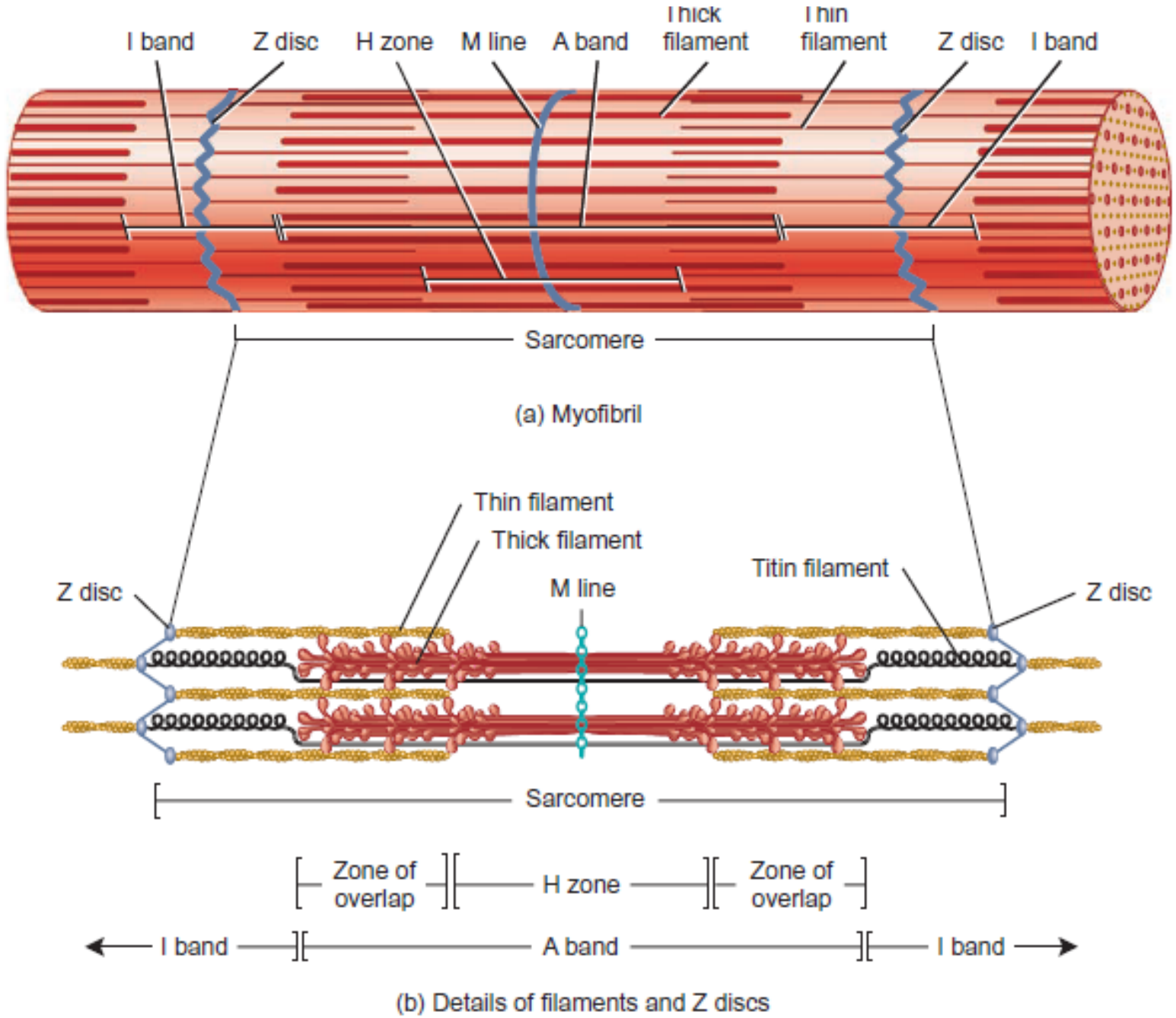
Which proteins
proteins are pr

- ***structural proteins***
- contribute to the alignment, stability, elasticity, and extensibility of myofibrils
- **Titin**
- is the 3rd most plentiful protein in skeletal muscle
- Anchors a thick filament to both a Z disc & M line
- helps stabilize the position of the thick filament
- accounts for much of the elasticity & extensibility of myofibrils



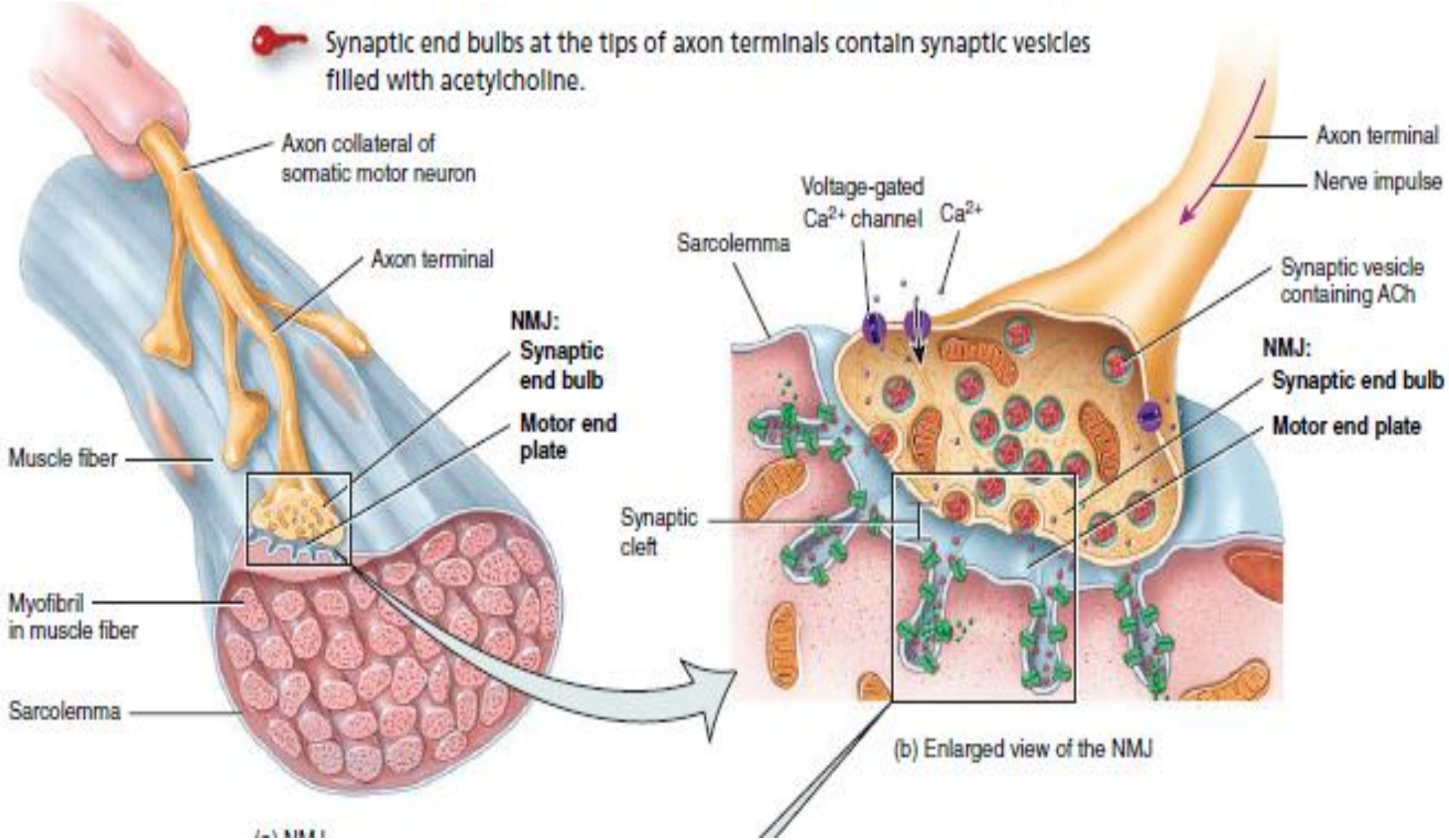
- **Myomesin**
- form the M line
- M line proteins bind to titin & connect adjacent thick filaments to one another
- holds the thick filaments in alignment at the M line
- **Nebulin**
- helps anchor thin filaments to Z discs and regulates the length of thin filaments during development
- **Dystrophin**
- links thin filaments of the sarcomere to integral membrane proteins of the sarcolemma
- membrane proteins attach to proteins in the connective tissue extracellular matrix that surrounds muscle fibers

- **Contraction and Relaxation of Skeletal Muscle Fibers**
- ***Sliding Filament Mechanism***
- Skeletal muscle shortens during contraction because the thick & thin filaments slide past one another
- model describing this process known as **sliding filament mechanism**
- Muscle contraction occurs because myosin heads attach to and “walk” along the thin filaments at both ends of a sarcomere, progressively pulling the thin filaments toward the M line
- Thin filaments slide inward & meet at the center of a sarcomere
- Z discs come closer together & sarcomere shortens
- lengths of the individual thick & thin filaments do not change

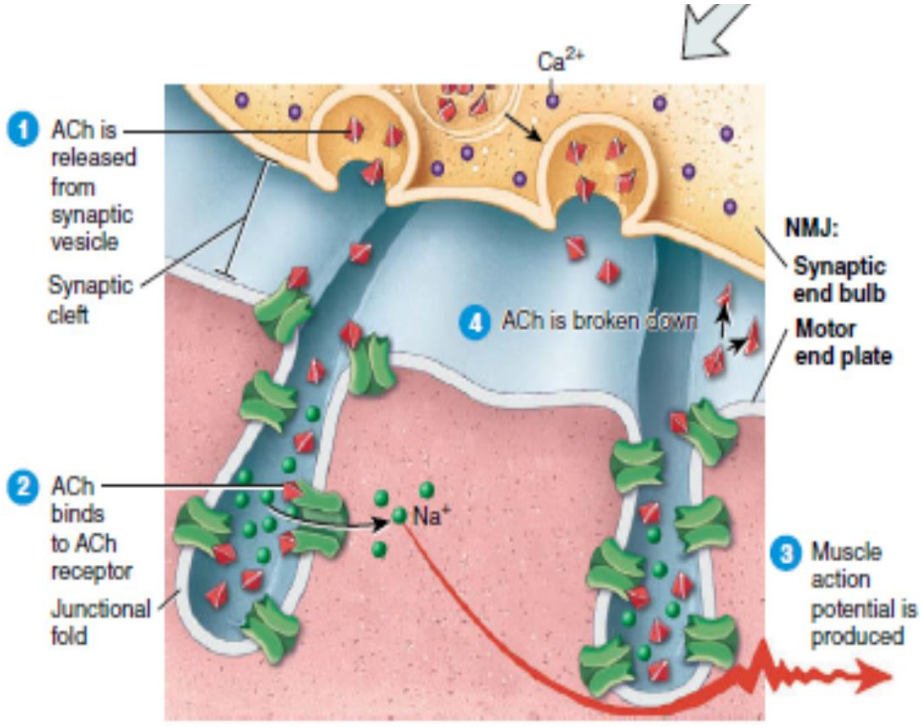


(b) Details of filaments and Z discs

- ***The Neuromuscular Junction***
- **Neuromuscular junction (NMJ)** the synapse between a somatic motor neuron & a skeletal muscle fiber
- **synapse** is a region where communication occurs between 2 neurons, or between a neuron and a target cell
- **synaptic cleft** small gap that separates the 2 cells
- At the NMJ:
- the end of the motor neuron, **axon terminal**, divides into a cluster of **synaptic end bulbs**(the *neural part* of the NMJ)
- In each synaptic end bulb are **synaptic vesicles**
- Inside each synaptic vesicle are **acetylcholine** the neurotransmitter released at the NMJ


Synaptic end bulbs at the tips of axon terminals contain synaptic vesicles filled with acetylcholine.
Axon collateral of somatic motor neuron
Axon terminal
NMJ:
Synaptic end bulb
Motor end plate
Muscle fiber
Myofibril in muscle fiber
Sarcolemma
Axon terminal
Nerve impulse
Voltage-gated Ca^{2+} channel
Ca^{2+}
Sarcolemma
Synaptic vesicle containing ACh
NMJ:
Synaptic end bulb
Motor end plate
Synaptic cleft
(b) Enlarged view of the NMJ

- region of the sarcolemma opposite the synaptic end bulbs is **motor end plate (** *muscular part)* of the NMJ
- motor end plate are 30 to 40 million **acetylcholine receptors**, integral transmembrane proteins that bind specifically to Ach(abundant in junctional folds)
- **Neuromuscular junction** includes all the synaptic end bulbs of a neuron on one side of the synaptic cleft, plus the motor end plate of the muscle fiber on the other side
- A somatic motor neuron plus all the skeletal muscle fibers it stimulates is called a **motor unit**



(c) Binding of acetylcholine to ACh receptors in the motor end plate

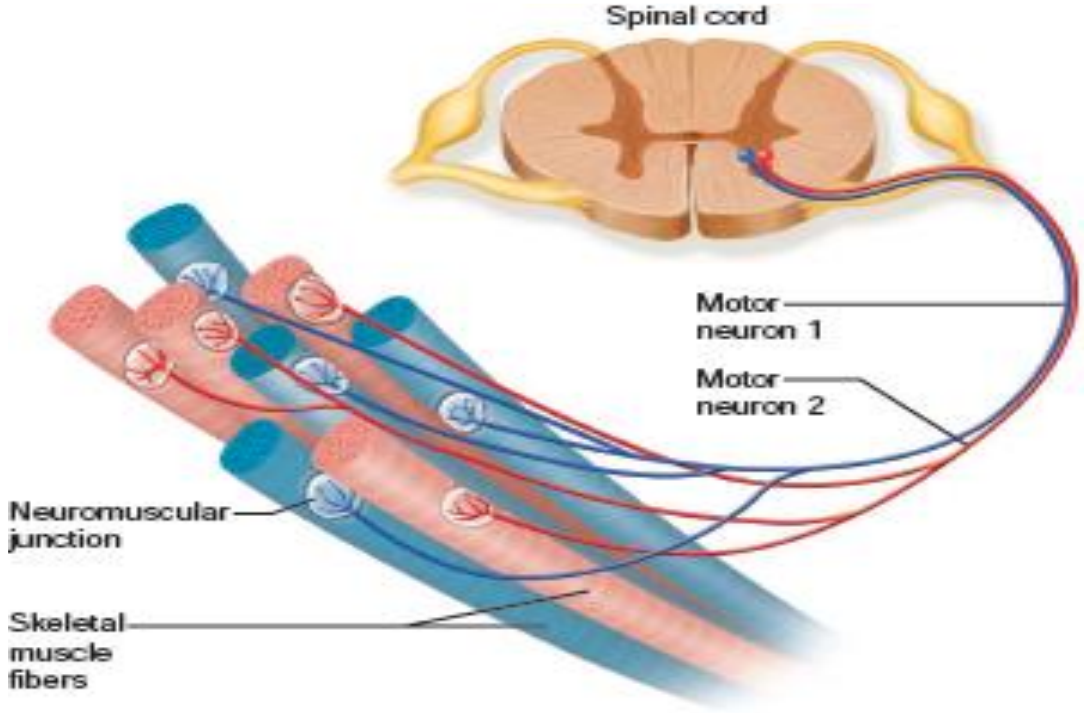
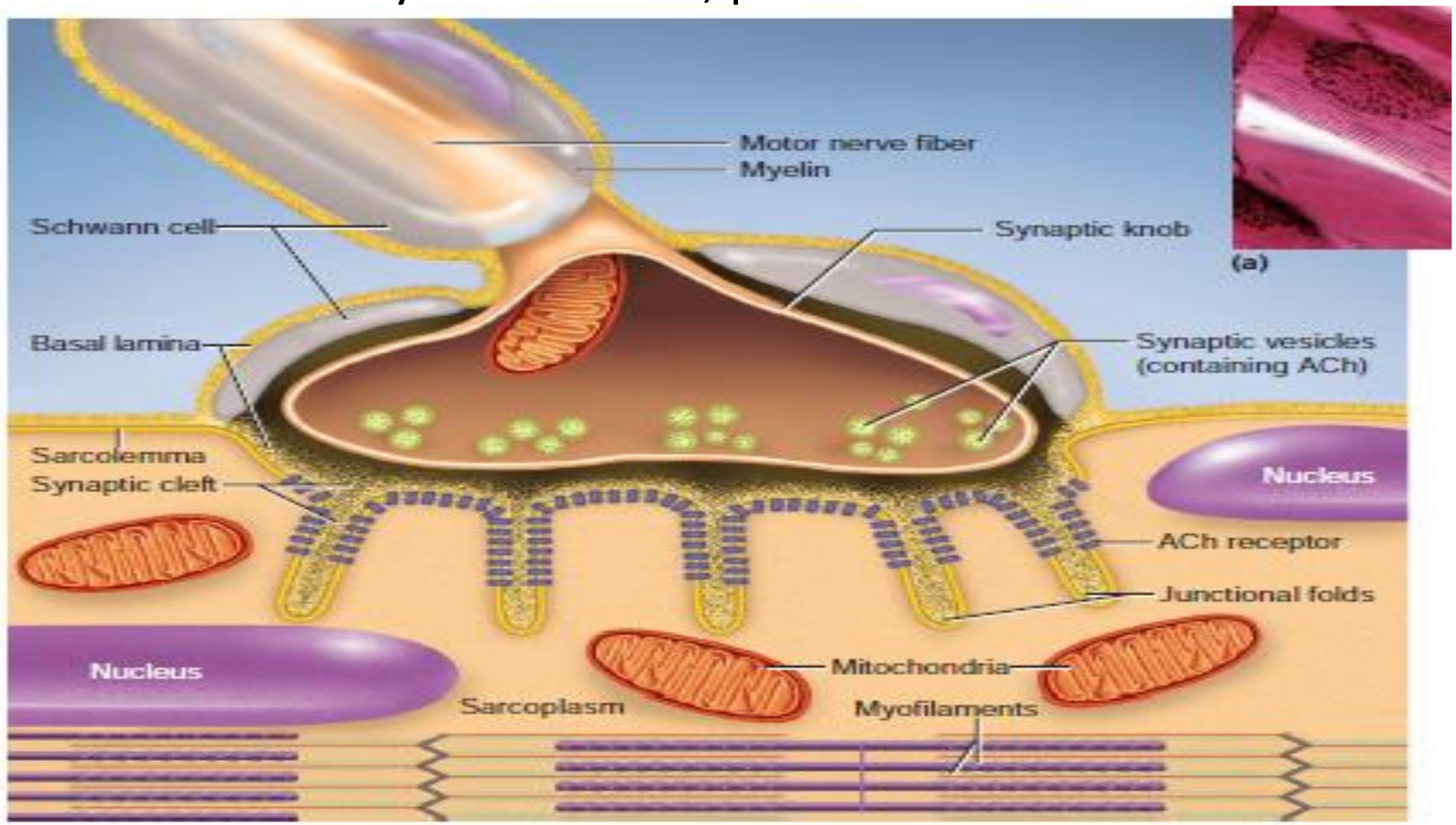


Figure 10.12 Motor Units. A motor unit consists of one motor neuron and all skeletal muscle fibers that it innervates. Two motor units

- nerve impulse (or nerve action potential) elicits a muscle action potential in the following way:
- ❶ ***Release of acetylcholine***
- nerve impulse at synaptic end bulbs stimulates voltage-gated channels to open, and Ca2+ enters the synaptic end bulbs
- Ca2+ stimulates synaptic vesicles to undergo exocytosis
- During exocytosis, the synaptic vesicles fuse with the motor neuron’s plasma membrane, liberating ACh into the synaptic cleft
- ACh then diffuses across the synaptic cleft between the motor neuron and the motor end plate

- ❷ ***Activation of ACh receptors***
- Binding of 2 molecules of ACh to the receptor on the motor end plate opens an ion channel in the ACh receptor
- Once the channel is open, small cations, most importantly Na+, can flow across the membrane
- ❸ ***Production of muscle action potential***
- inflow of Na+ triggers a muscle action potential
- muscle action potential then propagates along the sarcolemma into the system of T tubule
- causes the sarcoplasmic reticulum to release its stored Ca2+ into the sarcoplasm and the muscle fiber subsequently contracts.

- ❹ ***Termination of ACh activity***
- effect of ACh binding lasts only briefly because ACh is rapidly broken down by an enzyme called **acetylcholinesterase**
- This enzyme is attached to collagen fibers in the extracellular matrix of the synaptic cleft
- AChE breaks down ACh into acetyl and choline, products that cannot activate the ACh receptor



- **Myasthenia gravis**
- autoimmune disease that causes chronic, progressive damage of the neuromuscular junction
- immune system inappropriately produces antibodies that bind to & block some ACh receptors, thereby decreasing the number of functional ACh receptors
- As the disease progresses, more ACh receptors are lost
- muscles become increasingly weaker, fatigue more easily, and may eventually cease to function

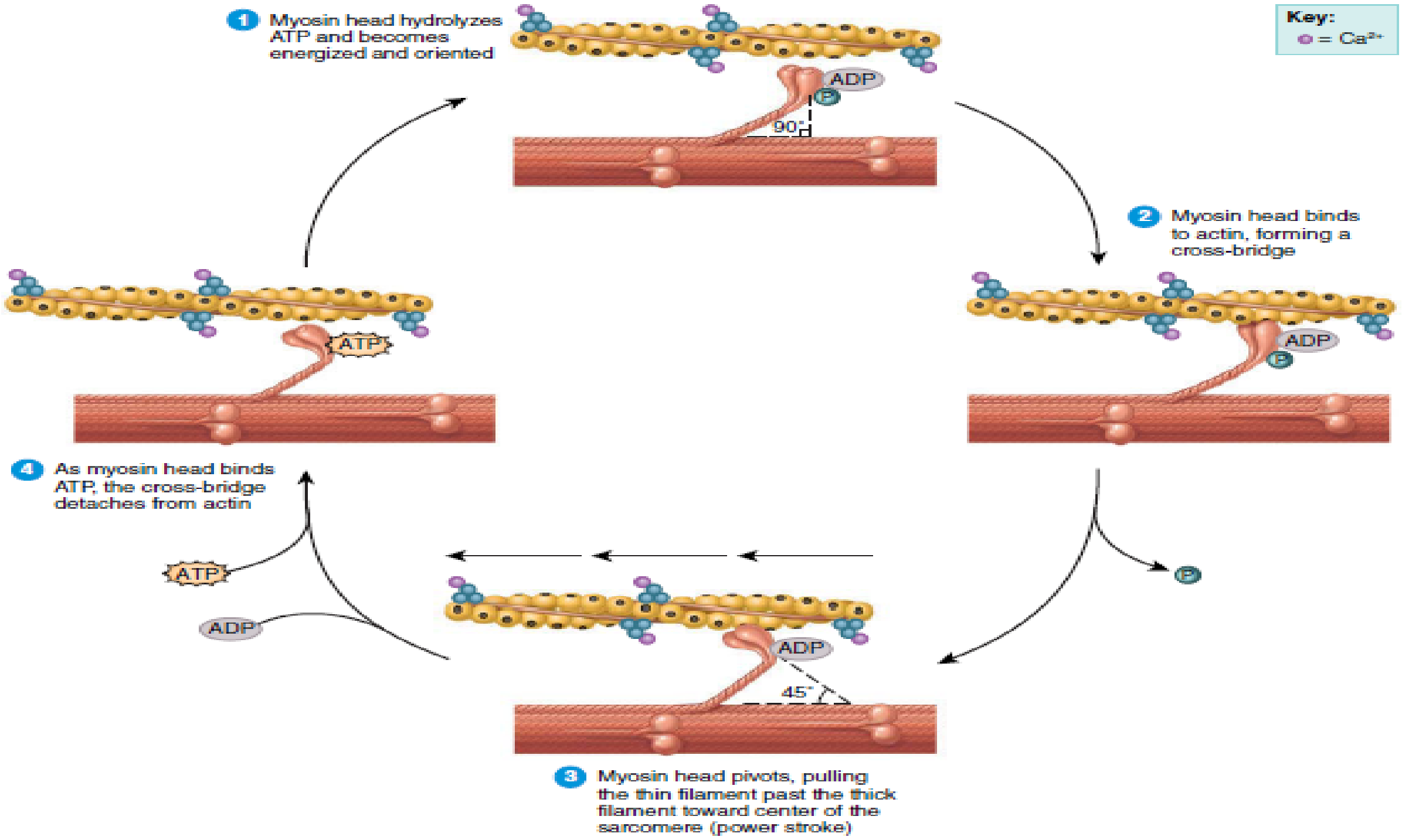
- muscles of the face and neck are most often affected
- Initial symptoms include weakness of the eye muscles, which may produce double vision, & weakness of the throat muscles that may produce difficulty in swallowing
- Later, the person has difficulty chewing & talking
- Eventually the muscles of the limbs may become involved.
- Death may result from paralysis of the respiratory muscles, but often the disorder does not progress to this stage
- Anticholinesterase drugs such as pyridostigmine (Mestinon.) or neostigmine, the first line of treatment, act as inhibitors of acetylcholinesterase,the enzyme that breaks down ACh.

- Several plant products & drugs selectively block certain events at the NMJ
- *E.g. Botulinum toxin,* produced by the bacterium *Clostridium botulinum*
- one of the most lethal chemicals known
- blocks exocytosis of synaptic vesicles at the NMJ, ACh is not released, and muscle contraction does not occur
- first bacterial toxin to be used as a medicine (Botox®)
- Injections of Botox into the affected muscles can help patients who have strabismus (crossed eyes), blepharospasm (uncontrollable blinking), or spasms of the vocal cords that interfere with speech
- alleviates chronic back pain due to muscle spasms in the lumbar region
- a cosmetic treatment to relax muscles that cause facial wrinkles

- ***The Contraction Cycle***
- At the onset of contraction, sarcoplasmic reticulum releases calcium ions (Ca2+) into the sarcoplasm
- bind to troponin
- Troponin then moves tropomyosin away from the myosin-binding sites on actin
- Once the binding sites are “free," the **contraction cycle**—the repeating sequence of events that causes the filaments to slide—begins

- ❶ ***ATP hydrolysis***
- myosin head includes an ATP-binding site & an ATPase, an enzyme that breaks down ATP into ADP (adenosine diphosphate) & a phosphate group
- reaction reorients & energizes the myosin head
- ADP & a phosphate group are still attached to the myosin head
- ❷ ***Attachment of myosin to actin to form cross-bridges***
- energized myosin head attaches to the myosin-binding site on actin & releases the phosphate group
- When the myosin heads attach to actin during contraction, they are referred to as **cross-bridges**

- ❸ ***Power stroke***
- After the cross-bridges form, the power stroke occurs
- During the power stroke, the site on the cross-bridge where ADP is still bound opens
- As a result, the cross-bridge rotates & releases the ADP
- Crossbridge generates force as it rotates toward the center of the sarcomere, sliding the thin filament past the thick filament toward the M line
- ❹ ***Detachment of myosin from actin***
- At the end of the power stroke, the cross-bridge remains firmly attached to actin until it binds another molecule of ATP
- As ATP binds to the ATP-binding site on the myosin head, the myosin head detaches from actin


Key:
= Ca^{2+}
1 Myosin head hydrolyzes ATP and becomes energized and oriented
ADP
P
90°
2 Myosin head binds to actin, forming a cross-bridge
ADP
P
P
3 Myosin head pivots, pulling the thin filament past the thick filament toward center of the sarcomere (power stroke)
ADP
45°
4 As myosin head binds ATP, the cross-bridge detaches from actin
ATP
ADP
ATP

- **TYPES OF SKELETAL MUSCLE FIBERS**
- vary in their content of myoglobin, the red protein that binds oxygen in muscle fibers
- Those with a high myoglobin content are called **red muscle fibers**
- Those that have a low myoglobin content are called **white muscle fibers**
- Red muscle fibers also contain more mitochondria & are supplied by more blood capillaries than white muscle fibers
- Skeletal muscle fibers also contract & relax at different speeds
- Can be categorized as either slow or fast depending on how rapidly the ATPase in their myosin heads hydrolyzes ATP

- All of these structural and functional characteristics are taken into account in classifying a skeletal muscle fiber as one of 3 main types:
- (1) slow oxidative fibers,
- (2) fast oxidative-glycolytic fibers
- (3) fast glycolytic fibers

- **Slow Oxidative Fibers(** *type I fibers)*
- appear dark red because they contain large amounts of myoglobin and many blood capillaries
- have many large mitochondria, SO fibers generate ATP mainly by aerobic (oxygen-requiring) cellular respiration
- are “slow” because they use ATP at a slow rate
- slow speed of contraction
- resistant to fatigue and are capable of prolonged, sustained contractions for many hours
- fibers are adapted for maintaining posture and for aerobic, endurance-type activities such as running a marathon

- **Fast Oxidative-Glycolytic Fibers(** *type IIa fibers)*
- are the largest fibers
- large amounts of myoglobin & many blood capillaries, giving them a dark red appearance
- generate ATP by aerobic cellular respiration, gives them a moderately high resistance to fatigue
- intracellular glycogen level is high, they also generate ATP by anaerobic (oxygen-free) glycolysis
- are “fast” they use ATP at a fast rate, makes their speed of contraction faster
- FOG fibers contribute to activities such as walking and sprinting

- **Fast Glycolytic Fibers(***type IIb fibers)*
- low myoglobin content, few blood capillaries and few mitochondria, and appear white in color
- contain large amounts of glycogen and generate ATP mainly by anaerobic (nonoxygen-requiring) cellular respiration (glycolysis)
- use ATP at a fast rate, contract strongly and quickly
- are adapted for intense anaerobic movements of short duration, such as weight lifting or throwing a ball
- they fatigue quickly
- Most skeletal muscles are a mixture of all 3 types of skeletal muscle fibers

- **Clinical Application**
- **DISORDERS OF SKELETAL MUSCLE TISSUE**
- body’s skeletal muscle tissue experiences remarkably few disorders
- Given good nutrition and sufficient exercise, it is amazingly resistant to infection throughout life
- Noninfectious disorders of skeletal muscle include *muscular dystrophy, myofascial pain syndrome,* and *fibromyalgia*

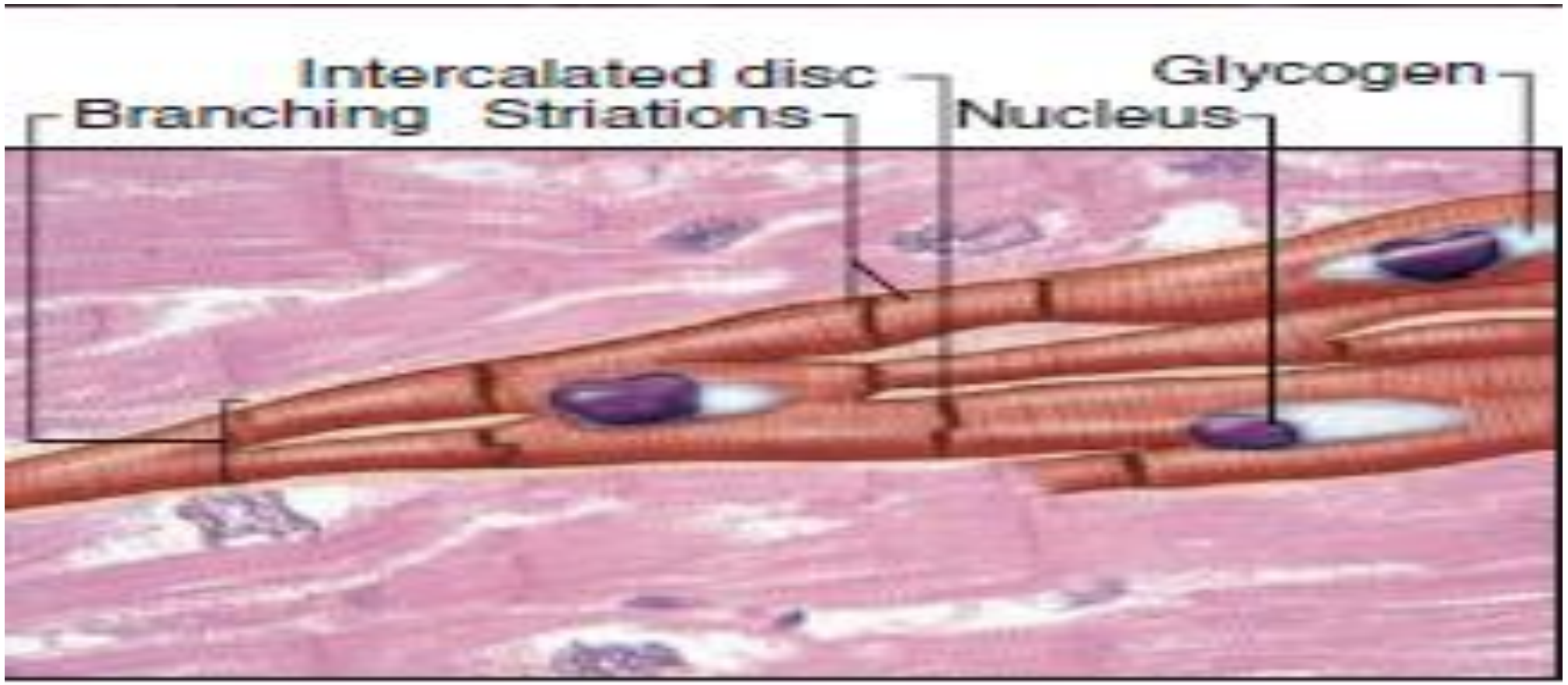
- **Muscular Dystrophy**
- a group of inherited muscle destroying diseases that generally appear in childhood
- affected muscles enlarge with fat & connective tissue while the muscle fibers degenerate
- Common and most serious form is **Duchenne muscular dystrophy,** which is inherited as a *sex-linked recessive disease*
- This means that females carry and transmit the abnormal gene, but it is expressed almost exclusively in males
- Diagnosed when the boy is between 2 and 10 years old
- Active, apparently normal children become clumsy and start to fall frequently as their muscles weaken.
- The disease progresses from the pelvic muscles to the shoulder muscles to the head and chest muscles.
- Victims rarely live past age 20 and usually die of respiratory infections or respiratory failure

- **Muscular atrophy**
- is a wasting away of muscles
- Individual muscle fibers decrease in size as a result of progressive loss of myofibrils
- Atrophy that occurs because muscles are not used is termed *disuse atrophy*
- Bedridden individuals and people with casts experience disuse atrophy because the flow of nerve impulses (nerve action potentials) to inactive skeletal muscle is greatly reduced
- the condition is reversible
- If instead the nerve supply to a muscle is disrupted or cut, the muscle undergoes *denervation atrophy*
- Over a period of from 6 months to 2 years, the muscle shrinks to about one-fourth its original size, and the muscle fibers are irreversibly replaced by fibrous connective tissue

- **Myofascial Pain Syndrome**
- pain is caused by tightened bands of muscle fibers that twitch when the skin over them is touched
- sensitive areas of skin are called trigger points
- mostly associated with overused or strained postural muscles, and the pain is often felt some distance from the trigger point, in predictable places called *reference zones*
- syndrome is very common, affecting up to half of all people, mostly those from 30 to 60 years old
- pain is treated with nonsteroidal anti-inflammatory drugs and by stretching the affected muscle.
- Massage also helps, and exercising the affected muscle can lead to long-term recovery

- **Fibromyalgia**
- mysterious chronic pain syndrome of unknown cause
- Symptoms include severe musculoskeletal pain, fatigue, sleep abnormalities, and headache
- affects about 2% of all people, mostly women
- common sites of pain are the lower back or neck, but for a condition to be identified as fibromyalgia, pain must be present in at least 11 of 18 standardized points that are spread widely over the body
- Treatment consists of stress reduction, regular exercise, application of heat, gentle massage, physical therapy, medication for pain, and a low-dose antidepressant to help improve sleep.

- **CARDIAC MUSCLE TISSUE**
- principal tissue in heart wall **,**striated like skeletal muscle, activity involuntarily
- display **auto rhythmicity** - ability to repeatedly self generate spontaneous action potentials
- action potentials cause alternating contraction & relaxation of the heart muscle fibers
- cardiac muscle fibers are shorter in length & less circular in transverse section
- exhibit branching



(b) Cardiac muscle

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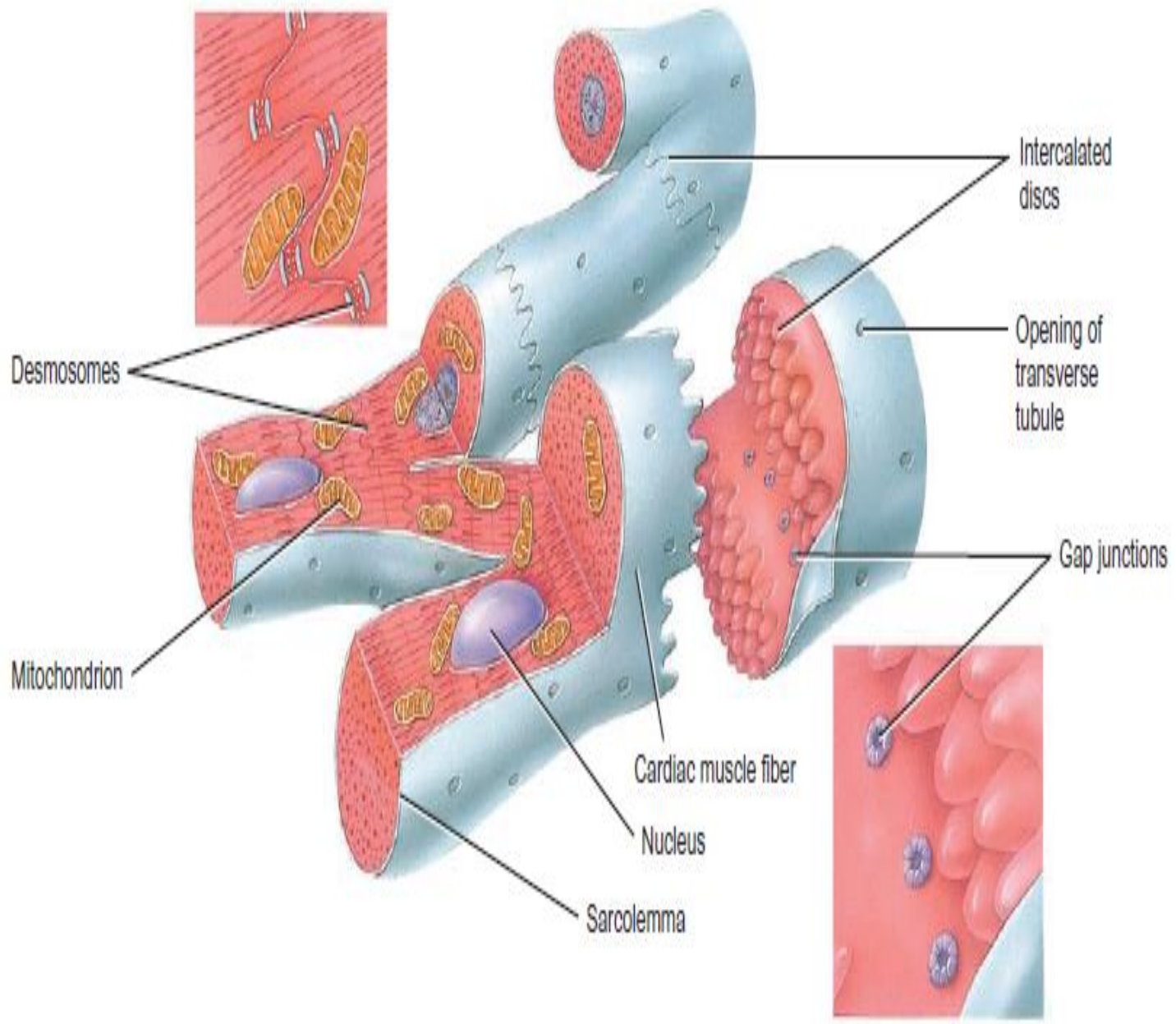
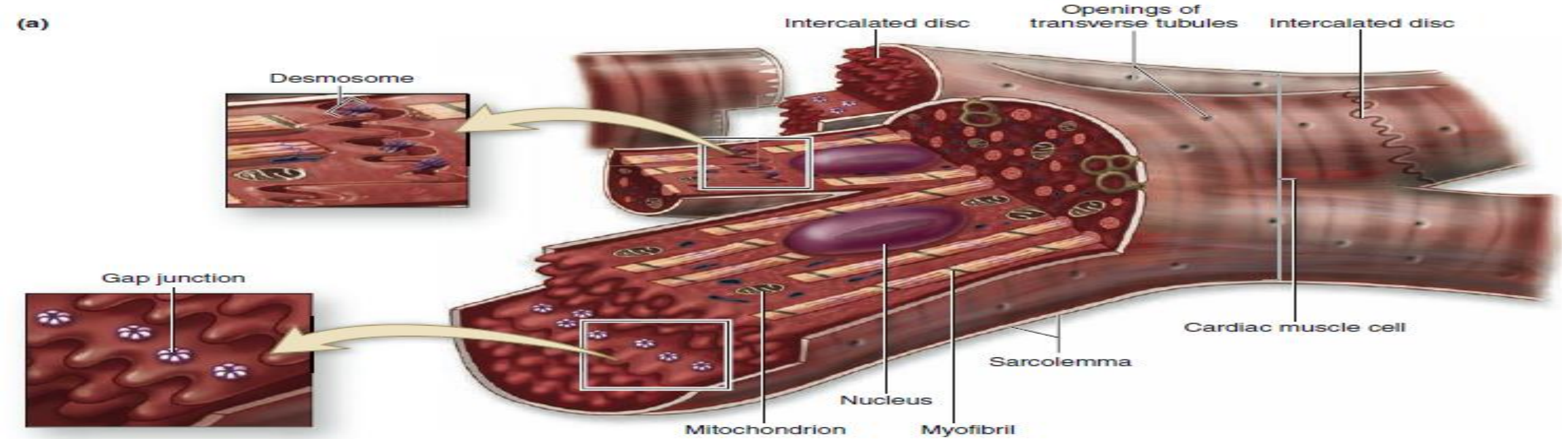
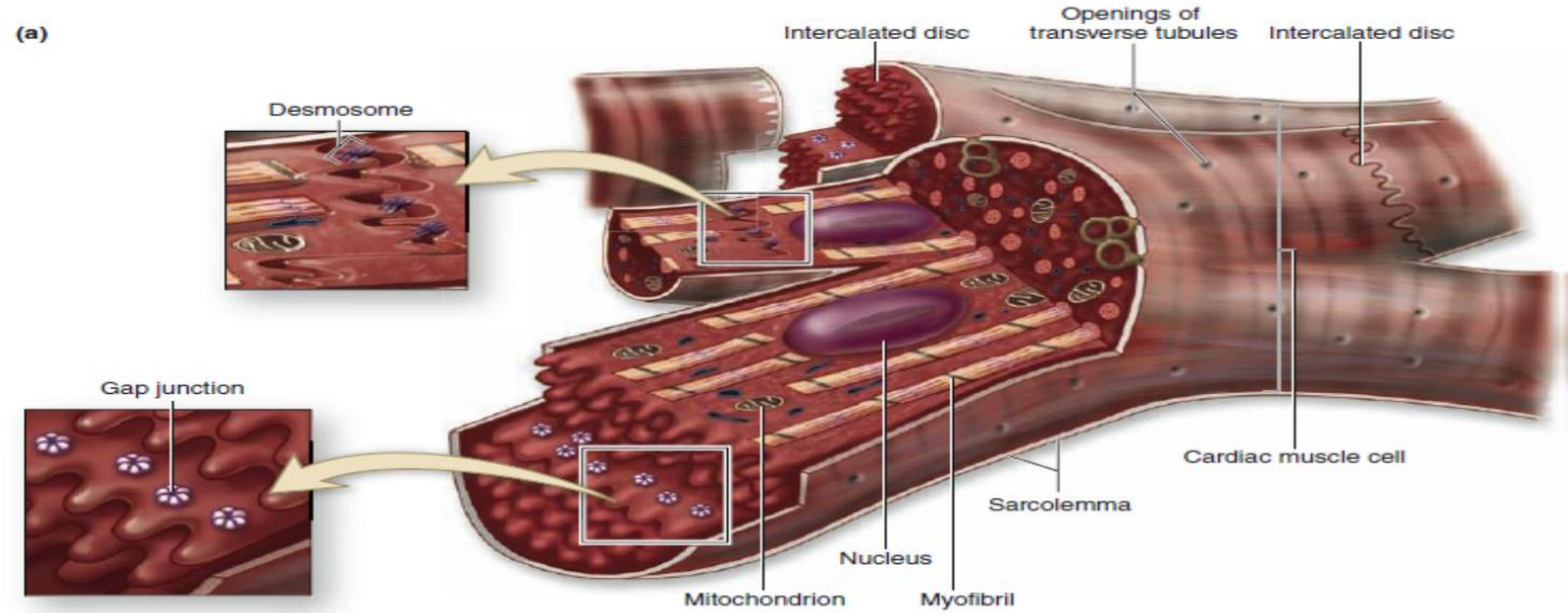


(a) Cardiac muscle fibers

- cardiac muscle fiber is 50–100 um long & a diameter of 14 um
- one centrally located nucleus , may have 2 nuclei
- ends of cardiac muscle fibers connect to neighboring fibers by irregular transverse thickenings of the sarcolemma referred to as **intercalated discs**
- The discs contain:
- **Desmosomes-** hold the fibers together , anchoring(adherens) junctions
- **gap junctions-** allow muscle action potentials to spread from one muscle fiber to its neighbors
- Cardiac muscle tissue has an endomysium, but lacks a perimysium & epimysium



- Mitochondria are larger & numerous than in skeletal muscle fibers
- same arrangement of actin & myosin, same bands, zones & discs, as skeletal muscle fibers
- transverse (T) tubules are wider but less abundant than of skeletal muscle
- sarcoplasmic reticulum are smaller than SR of skeletal muscle fibers



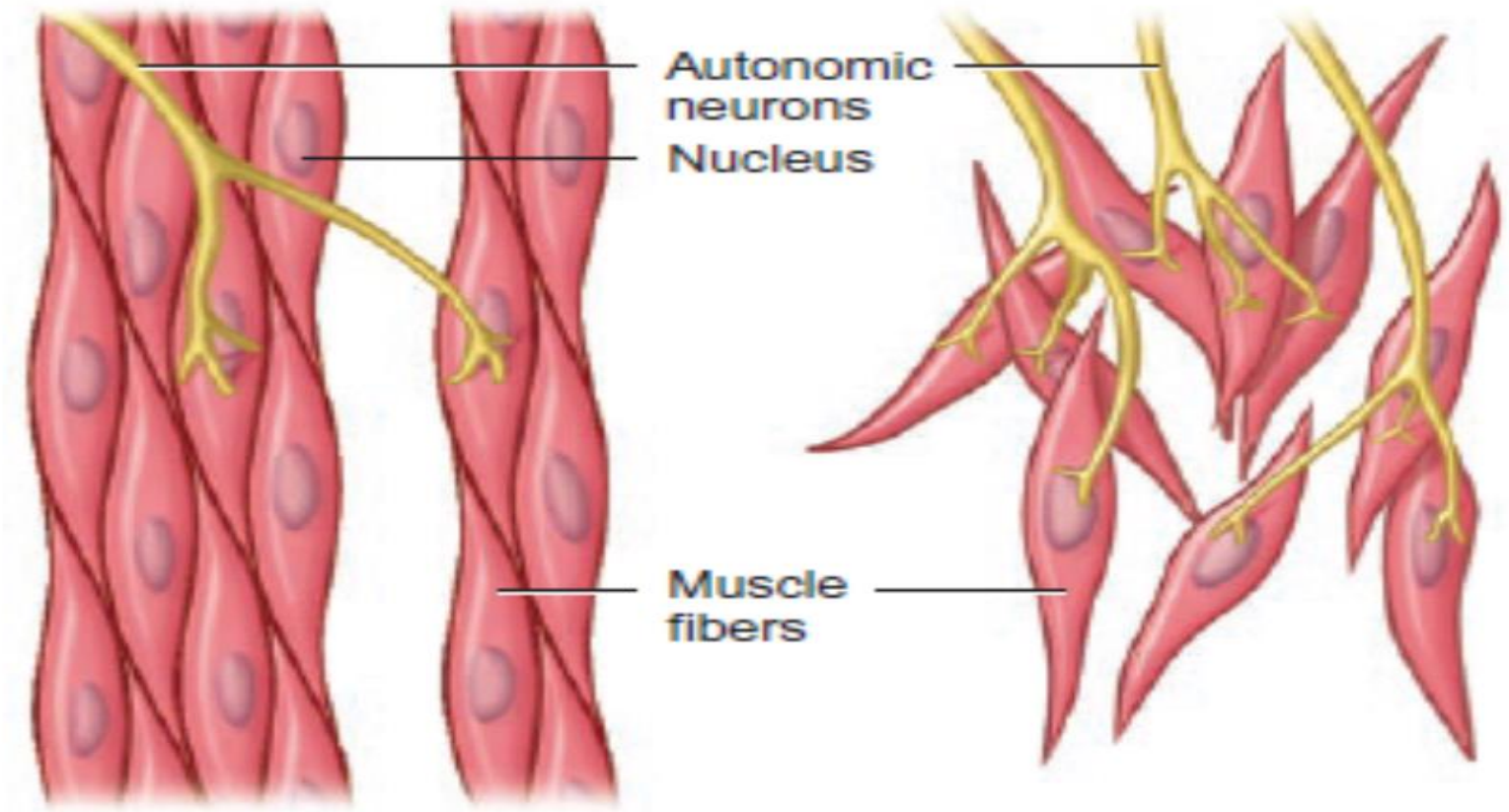
- normal resting conditions, cardiac muscle tissue contracts & relaxes about 75 times per minute
- Continuous, rhythmic activity is a major functional difference between cardiac & skeletal muscle tissue
- Skeletal muscle tissue contracts only when stimulated by acetylcholine released by an action potential in a somatic motor neuron
- cardiac muscle tissue can contract without extrinsic (outside) nervous or hormonal stimulation
- source of stimulation is a conducting network of specialized cardiac muscle fibers within the heart

- Like skeletal muscle, cardiac muscle fibers can undergo hypertrophy in response to an increased workload
- is a ***physiological enlarged heart*** & it is why many athletes have enlarged hearts
- a ***pathological enlarged heart*** is related to significant heart disease

- **SMOOTH MUSCLE TISSUE**
- **smooth muscle tissue** is activated involuntarily & not striated
- 2 types of smooth muscle tissue: **visceral (single-unit) smooth muscle tissue** & **multiunit smooth muscle tissue**
- **1. visceral (single-unit) smooth muscle tissue**
- more common type
- is found in:-
- skin
- walls of small arteries & veins
- walls of hollow viscera such as the stomach, intestines, uterus, & urinary bladder
- fibers connect to one another by gap junctions, muscle action potentials spread rapidly throughout the network

- when a neurotransmitter, hormone, or autorhythmic signal stimulates one fiber, the muscle action potential spreads to neighboring fibers, which then contract as a single unit

Smooth muscle fibers have thick and thin filaments but no transverse tubules and little sarcoplasmic reticulum.

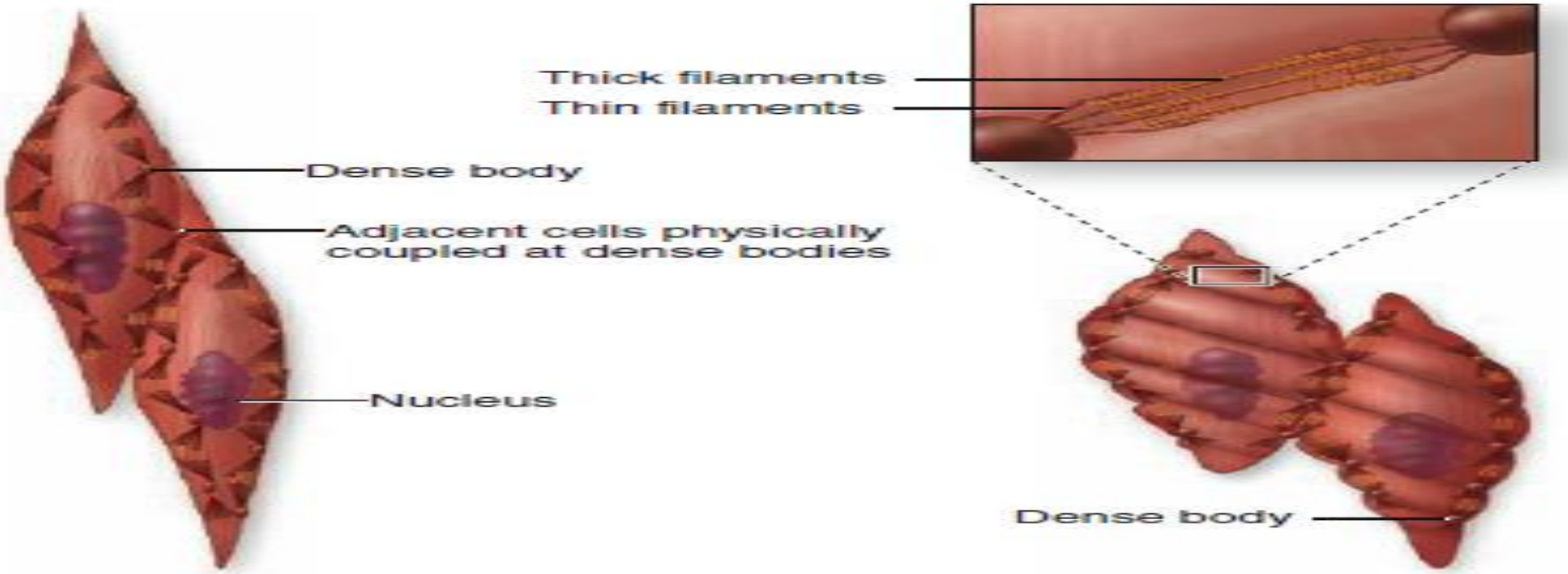


(a) Visceral (single-unit) smooth muscle tissue

(b) Multiunit smooth muscle tissue

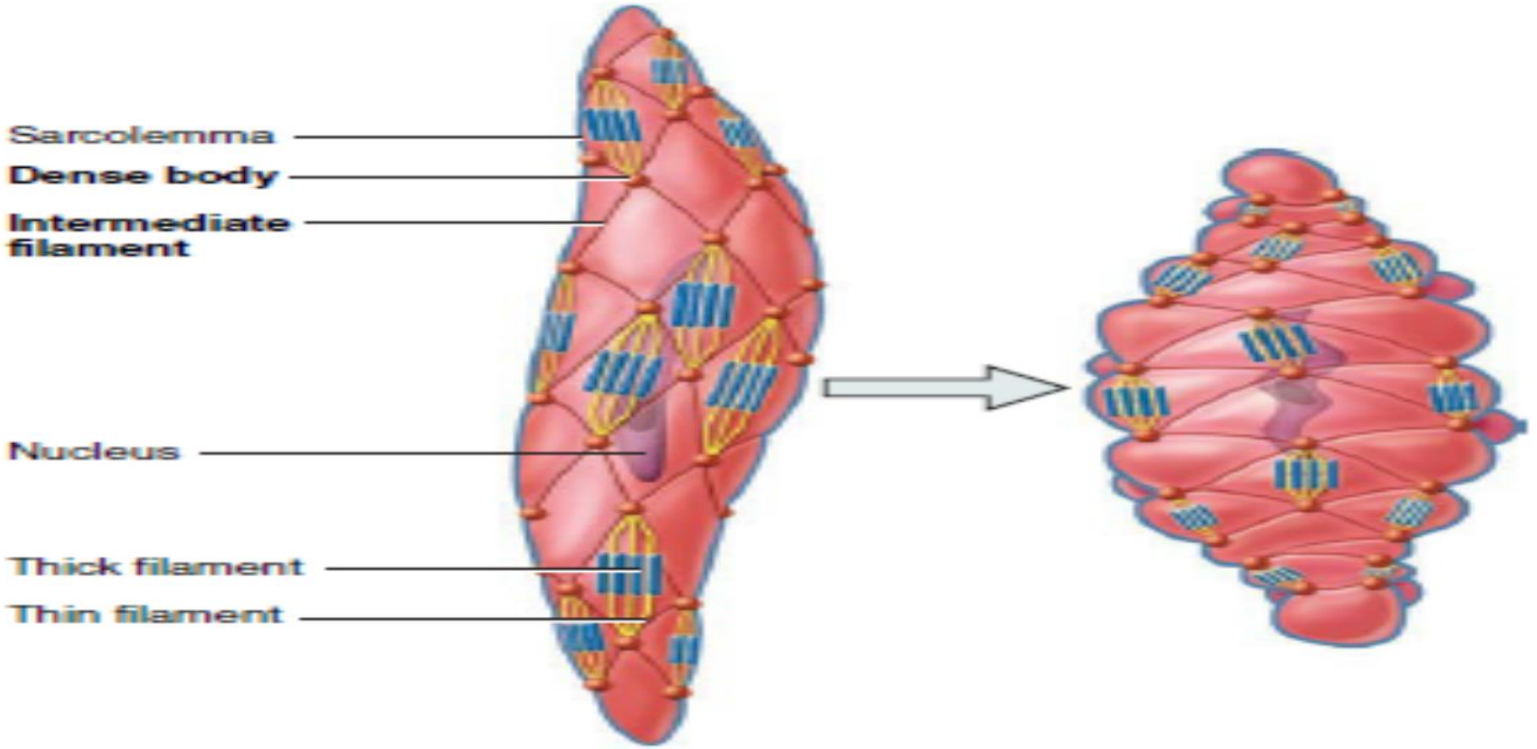
- **2. multiunit smooth muscle tissue**
- consists of individual fibers, each of which has its own motor neuron terminals
- stimulation of one multi-unit smooth muscle fiber causes contraction of that fiber only
- Found:-
- **walls of large arteries**
- **airways to the lungs**
- **arrector pili muscles that attach to hair follicles**
- **muscles of the iris that adjust pupil diameter**
- **ciliary body that adjusts focus of the lens in the eye**

- Smooth muscle fibers are smaller than skeletal muscle fibers
- tapered at each end
- has a single, oval, centrally located nucleus
- sarcoplasm contains both thick filaments & thin filaments, in ratios between about 1:10 & 1:15 respectively
- not arranged in orderly sarcomeres as in striated muscle
- contain **intermediate filaments**
- filaments, contain the protein desmin, have a structural rather than contractile role



- Does not exhibit striations
- lack transverse tubules & have little sarcoplasmic reticulum for storage of Ca2.
- has an endomysium, lacks a perimysium & epimysium
- intermediate filaments attach to structures called **dense bodies**, are functionally similar to Z discs in striated muscle fibers
- Some dense bodies are dispersed throughout the sarcoplasm; others are attached to the sarcolemma
- Bundles of intermediate filaments stretch from one dense body to another

- During contraction, tension generated by the thick and thin filaments in the sliding filament mechanism is transmitted to intermediate filaments
- These in turn pull on the dense bodies attached to the sarcolemma, causing a shortening of the muscle fiber
- When a smooth muscle fiber contracts, it turns like a corkscrew; when it relaxes, it rotates in the opposite direction



(c) Microscopic anatomy of a relaxed and contracted smooth muscle fiber