MUSCULAR TISSUE

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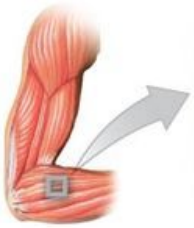
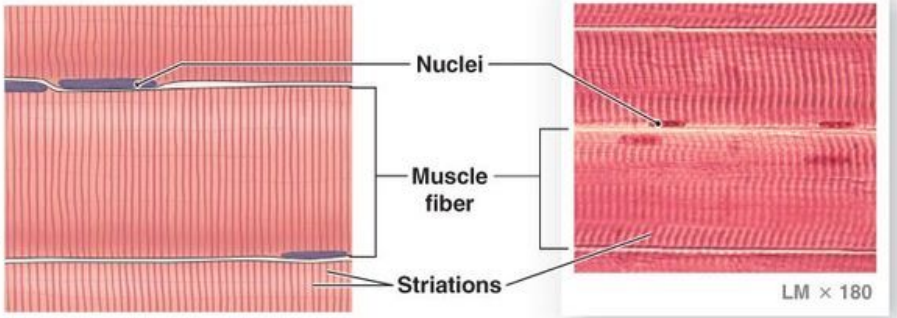
Types of Muscular Tissue

- There are three types of muscular tissue:
  - Skeletal
  - Cardiac
  - Smooth

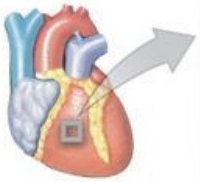
- These three types share some properties, but differ in their microscopic anatomy, location, and how they are controlled by the nervous and endocrine systems.

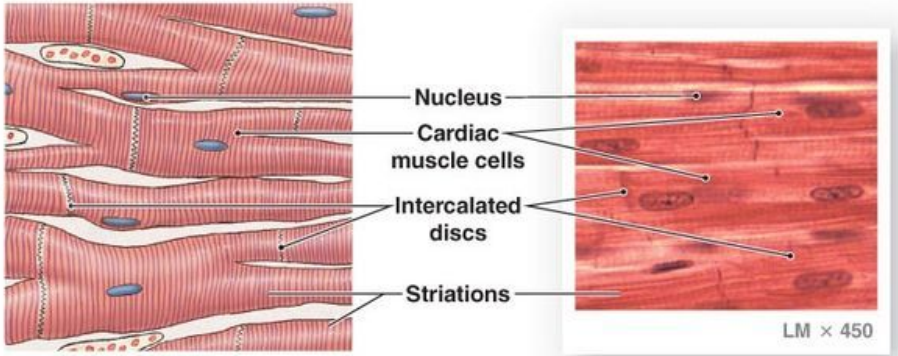
The structure and function of the three types of muscle tissue



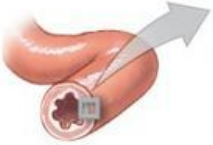


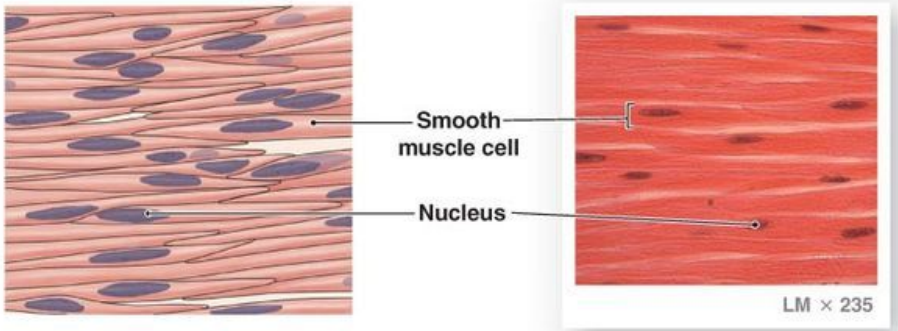
Skeletal muscles move or stabilize the position of the skeleton; guard entrances and exits to the digestive, respiratory, and urinary tracts; generate heat; and protect internal organs.





Cardiac muscle moves blood and maintains blood pressure.





Smooth muscle moves food, urine, and reproductive tract secretions; controls diameter of respiratory passageways and regulates diameter of blood vessels.

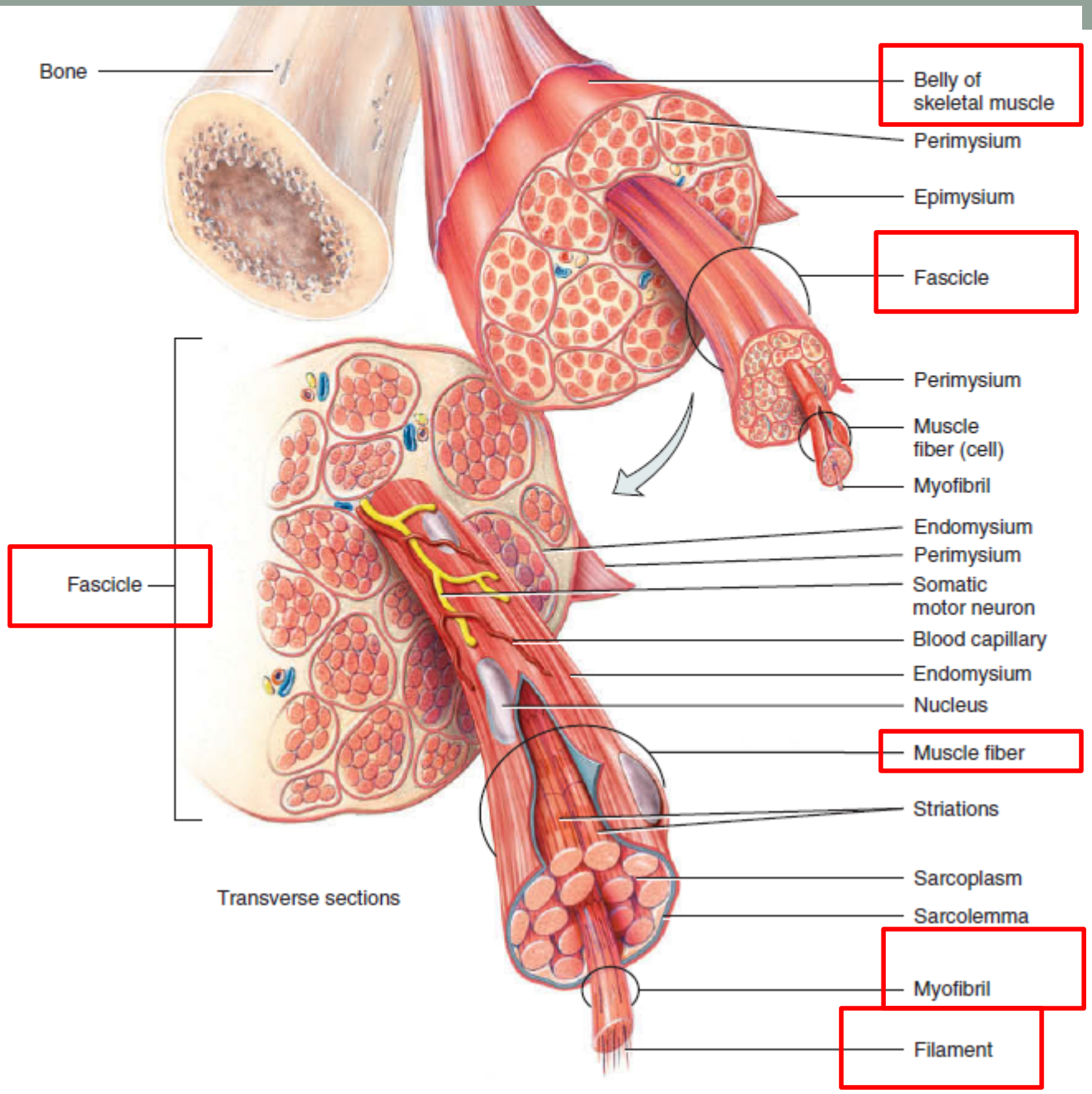
Skeletal muscle tissue

- Striated: Alternating light and dark protein bands are seen microscopically
- Work mainly in a voluntary manner.
- Controlled by neurons that are part of the somatic (voluntary) division of the nervous system.

Functions of Skeletal Muscular Tissue

1. Produces body movements.
2. Stabilizes body positions
3. Generates heat “Thermogenesis”.

SKELETAL MUSCLE TISSUE


Bone
Belly of skeletal muscle
Perimysium
Epimysium
Fascicle
Perimysium
Muscle fiber (cell)
Myofibril
Endomysium
Perimysium
Somatic motor neuron
Blood capillary
Endomysium
Nucleus
Muscle fiber
Striations
Sarcoplasm
Sarcolemma
Myofibril
Filament
Fascicle
Transverse sections

The Muscle Fiber

- Each skeletal muscle is composed of hundreds to thousands of cells, which are called **muscle fibers**
- Muscle fiber = muscle cell.

- Connective tissue surrounds and protects muscular tissue. It provides a pathway for nerves, blood vessels, and lymphatic vessels to enter and exit muscles.

Microscopic Anatomy of a Skeletal Muscle Fiber

- Each mature skeletal muscle fiber has a hundred or more nuclei.

- **Sarcolemma** the plasma membrane of a muscle cell.
- **Sarcoplasm** the cytoplasm of a muscle fiber.

- **Ttransverse (T) tubules:** tiny invaginations of the sarcolemma that extend from the surface toward the center of each muscle fiber. They are open to the outside of the fiber and are filled with interstitial fluid.

- The sarcoplasm contains large amounts of glycogen, myoglobin and mitochondria.

- **Myofibrils** are the **contractile organelles** they extend the entire length of a muscle fiber. They have prominent striations.

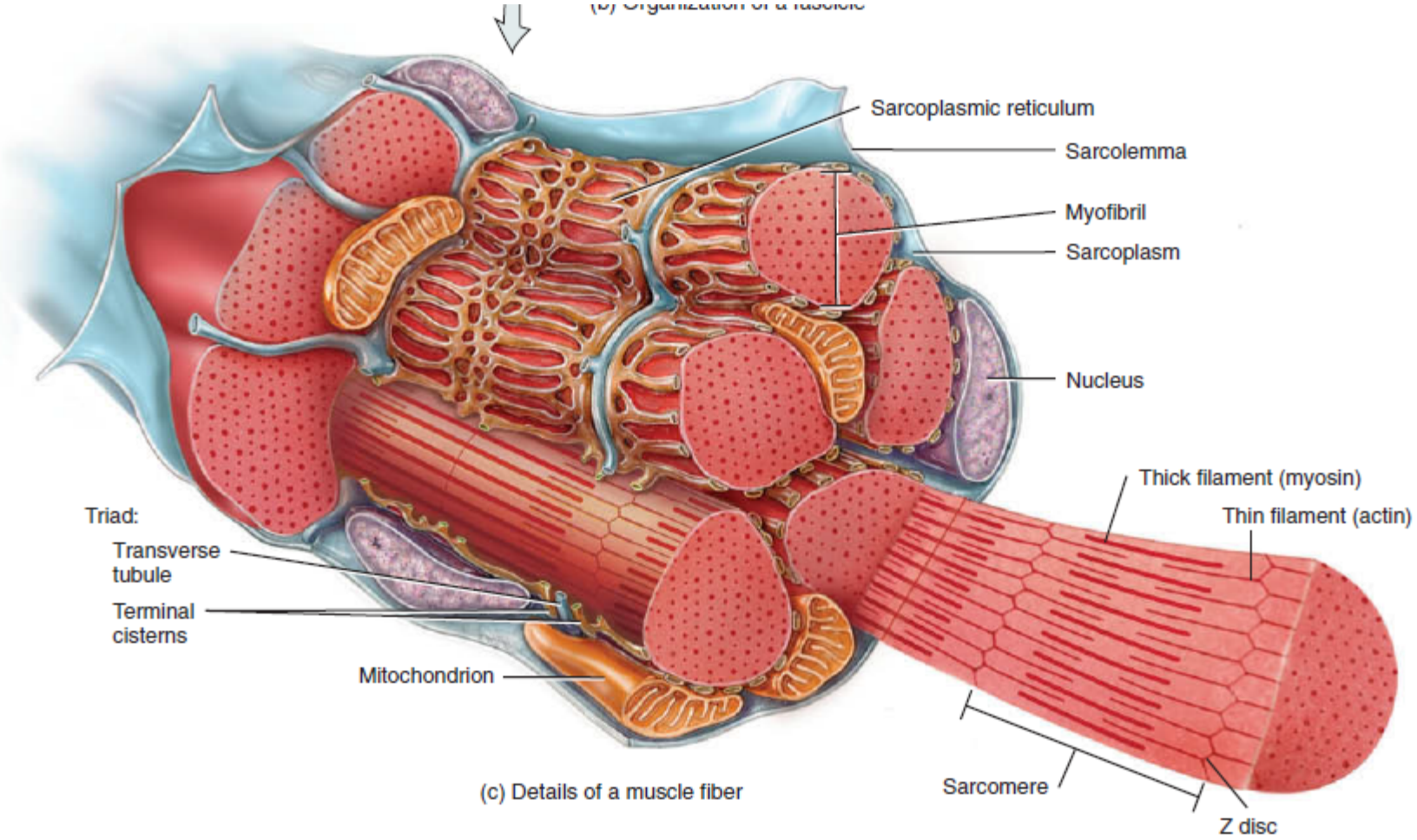
- Each is surrounded by a membranous sac called the sarcoplasmic reticulum (SR).

- In a relaxed muscle fiber, the sarcoplasmic reticulum stores huge amounts of calcium ions (Ca^{+2}).

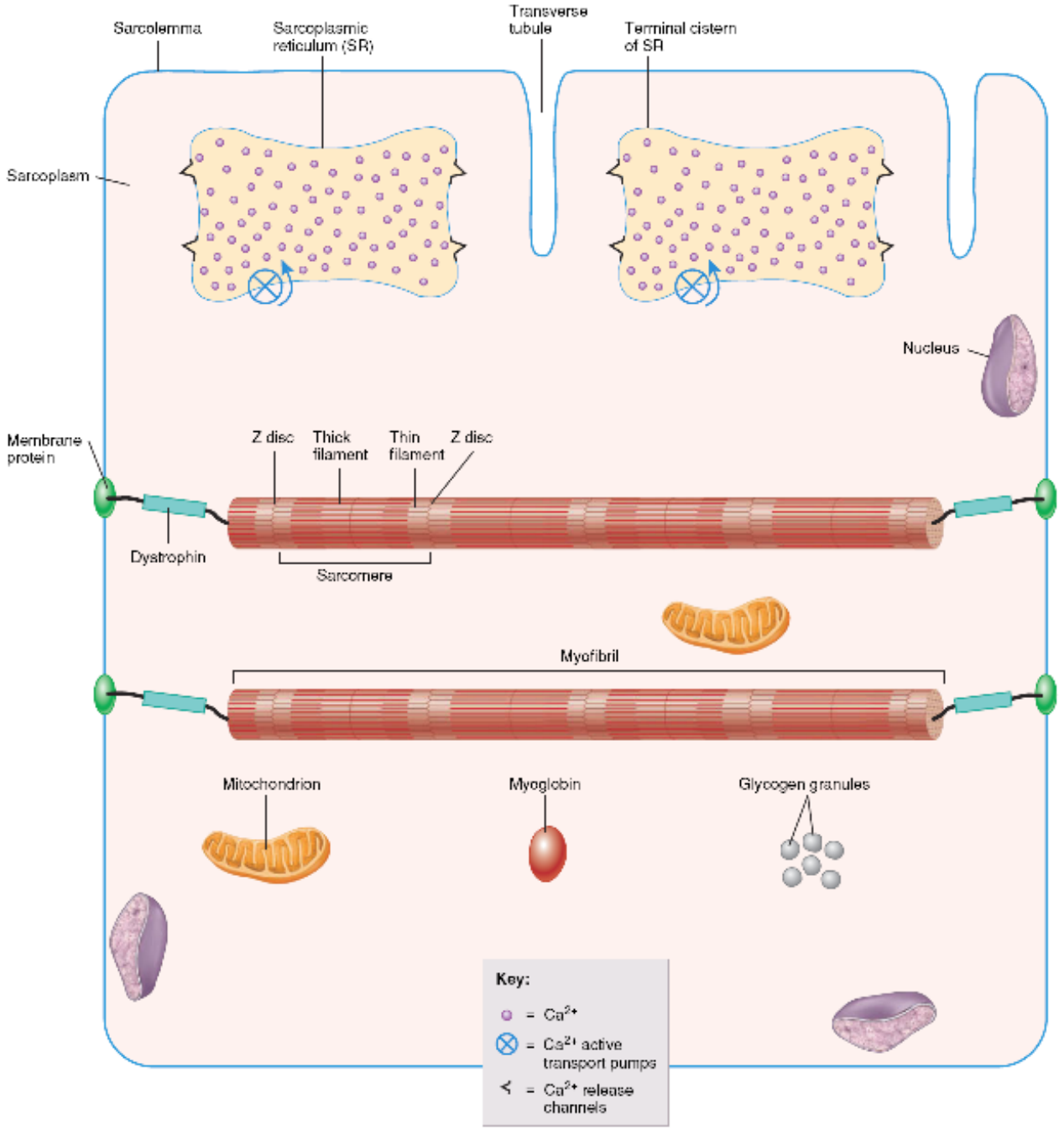
- Terminal cisterns are the dilated end sacs of the sarcoplasmic reticulum.
- A transverse tubule and the two terminal cisterns on either side of it form a **triad.**

Muscle Proteins

- Myofibrils are built from three kinds of proteins:
  1. Contractile proteins: myosin and actin.
  2. Regulatory proteins: tropomyosin and troponin
  3. Structural proteins: titin, a-actinin, myomesin, Nebulin, Dystrophin.



(c) Details of a muscle fiber

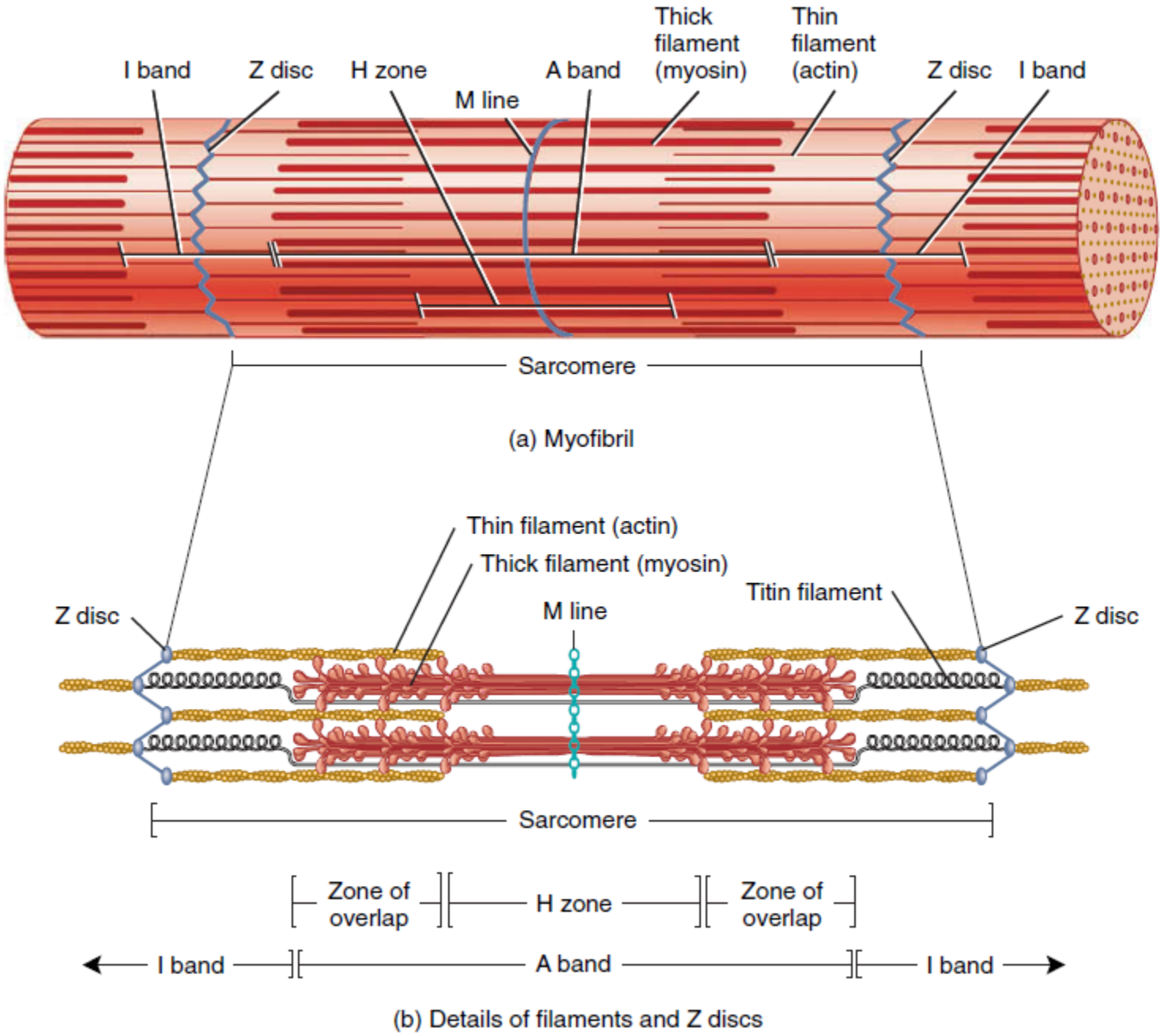


(d) Simplistic representation of a muscle fiber

Filaments and the Sarcomere

- Within myofibrils are smaller protein structures called filaments or myofilaments. They are directly involved in the contractile process. There are two types:
  1. Thin filaments are composed mainly of the protein **actin**
  2. Thick filaments are composed of the protein **myosin**.

- There are two thin filaments for every thick filament in the regions of filament overlap.
- The extent of overlap of the thick and thin filaments depends on whether the muscle is contracted, relaxed, or stretched.
- Each filament is made of several sacromeres.


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

Sacromeres

- Z discs: narrow, plate-shaped regions of dense protein material that separate one sarcomere from the next.
- A band: The darker middle part of the sarcomere, which extends the entire length of the thick filaments.
- I band: a lighter, less dense area that contains the rest of the thin filaments but no thick filaments.
- H zone: is the center of each A band it contains thick but not thin filaments.
- M Line: supporting proteins that hold the thick filaments together at the center of the H zone

Myosin

- About 300 molecules of myosin form a single thick filament. It is a made of a tail and two heads.
- Each myosin molecule is shaped like two golf clubs twisted together.
- The myosin tail points toward the M line in the center of the sarcomere.
- Tails of neighboring myosin molecules lie parallel to one another, forming the shaft of the thick filament.
- The two projections of each myosin are called myosin heads.
- Each head has an Actin binding site and an ATP-binding site

Actin

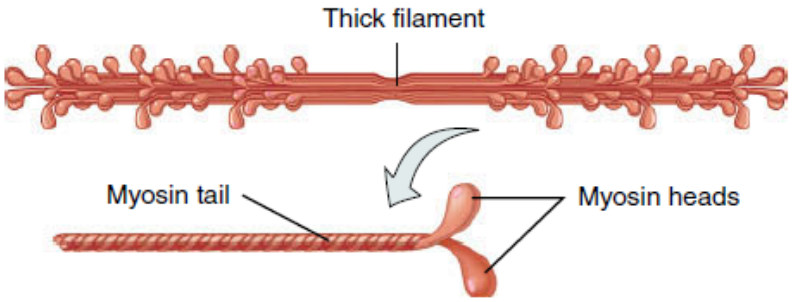
- Individual globular actin molecules join to form an actin filament that is twisted into a helix
- On each actin molecule is a myosin-binding site, where a myosin head can attach.
- Thin filaments are anchored to Z discs

Tropomyosin

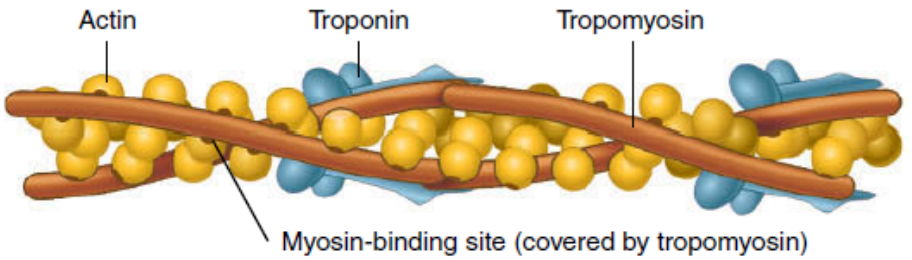
- A component of thin filament, forms a strand.
- When a skeletal muscle fiber is relaxed, tropomyosin covers myosin binding sites on actin molecules, thereby preventing myosin from binding to actin.

Troponin

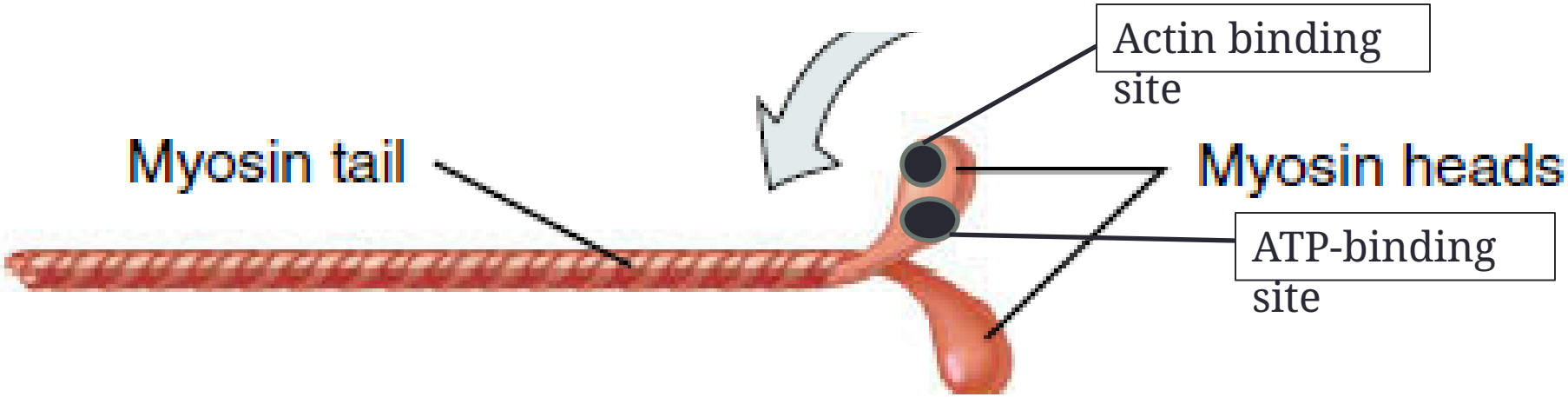
- A component of thin filament
- When calcium ions bind to troponin, it changes shape; this will cause tropomyosin to move away from myosin-binding sites on actin molecules, and muscle contraction subsequently begins as myosin binds to actin.



(a) A thick filament and a myosin molecule

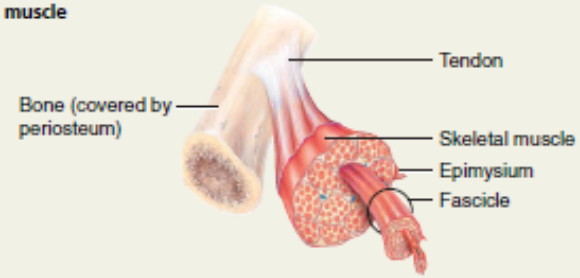
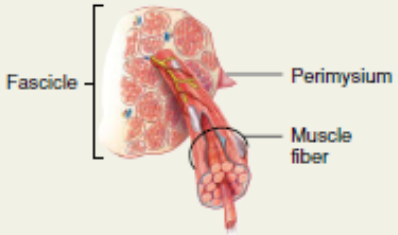
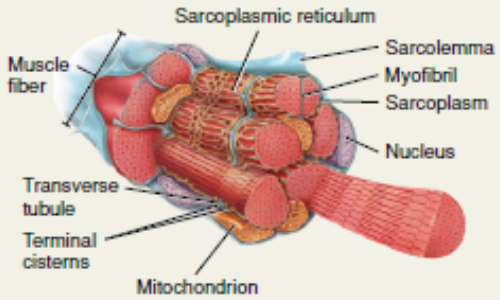
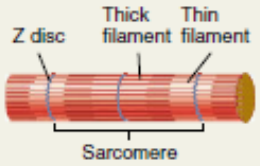
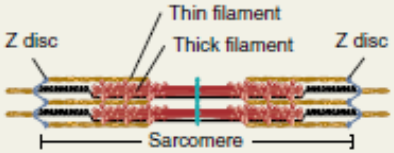


(b) Portion of a thin filament



(a) A thick filament and a myosin molecule

Levels of Organization within a Skeletal Muscle

LEVEL	DESCRIPTION
Skeletal muscle 	Organ made up of fascicles that contain muscle fibers (cells), blood vessels, and nerves; wrapped in epimysium.
Fascicle 	Bundle of muscle fibers wrapped in perimysium.
Muscle fiber (cell) 	Long cylindrical cell covered by endomysium and sarcolemma; contains sarcoplasm, myofibrils, many peripherally located nuclei, mitochondria, transverse tubules, sarcoplasmic reticulum, and terminal cisterns. The fiber has a striated appearance.
Myofibril 	Threadlike contractile elements within sarcoplasm of muscle fiber that extend entire length of fiber; composed of filaments.
Filaments (myofilaments) 	Contractile proteins within myofibrils that are of two types: thick filaments composed of myosin and thin filaments composed of actin, tropomyosin, and troponin; sliding of thin filaments past thick filaments produces muscle shortening.

Structural Proteins

- Contribute to the alignment, stability, elasticity, and extensibility of myofibrils.
- Titin: connects Z disc to M line of sarcomere, thereby stabilize thick filament position
- α –actinin: attaches to actin and to titin molecules
- Myomesin: binds to titin molecules and connects adjacent thick filaments to one another
- Nebulin: anchor thin filaments to Z discs
- Dystrophin: links thin filaments to integral membrane proteins in sarcolemma

Contraction And Relaxation Of Skeletal Muscle Fibers

Skeletal muscle contraction

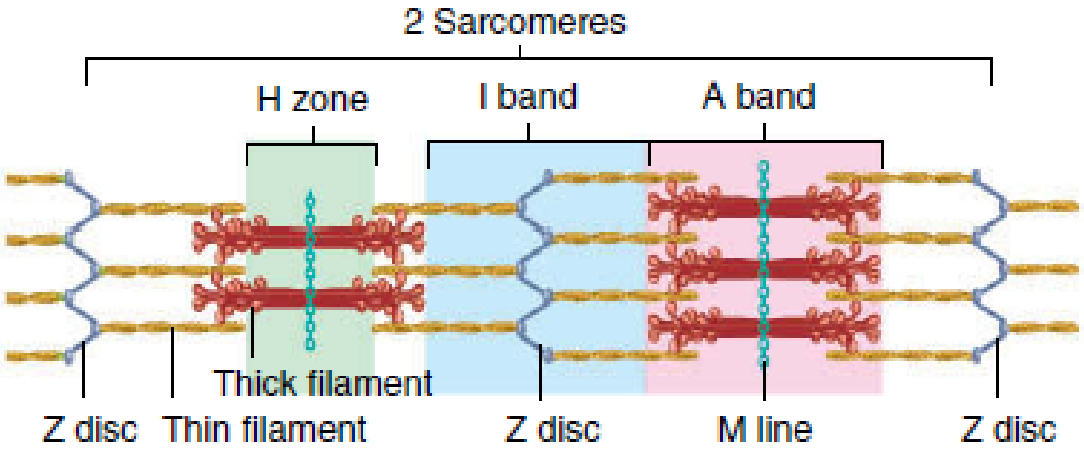
- During skeletal muscle contraction the muscle becomes shorter.
- The length of thin and thick filaments dosn't change during contraction.
- Skeletal muscle shortens during contraction because the thick and thin filaments slide past one another. This sliding will **shorten the sacromere.**
- This is called the **sliding filament mechanism**.

The Sliding Filament Mechanism

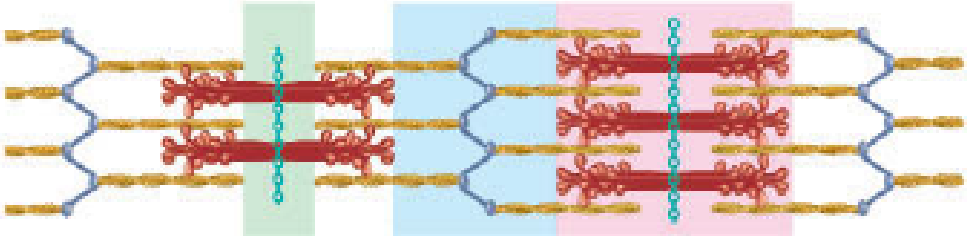
- Muscle contraction occurs because myosin heads attach to and “walk” along the thin filaments at both ends of a sarcomere, progressively pulling the thin filaments toward the M line.

- As the thin filaments slide inward, the I band and H zone narrow and eventually disappear altogether when the muscle is maximally contracted.

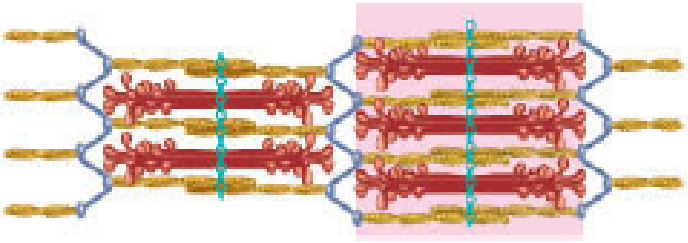
- However, the width of the A band and the individual lengths of the thick and thin filaments remain unchanged.



(a) Relaxed muscle



(b) Partially contracted muscle



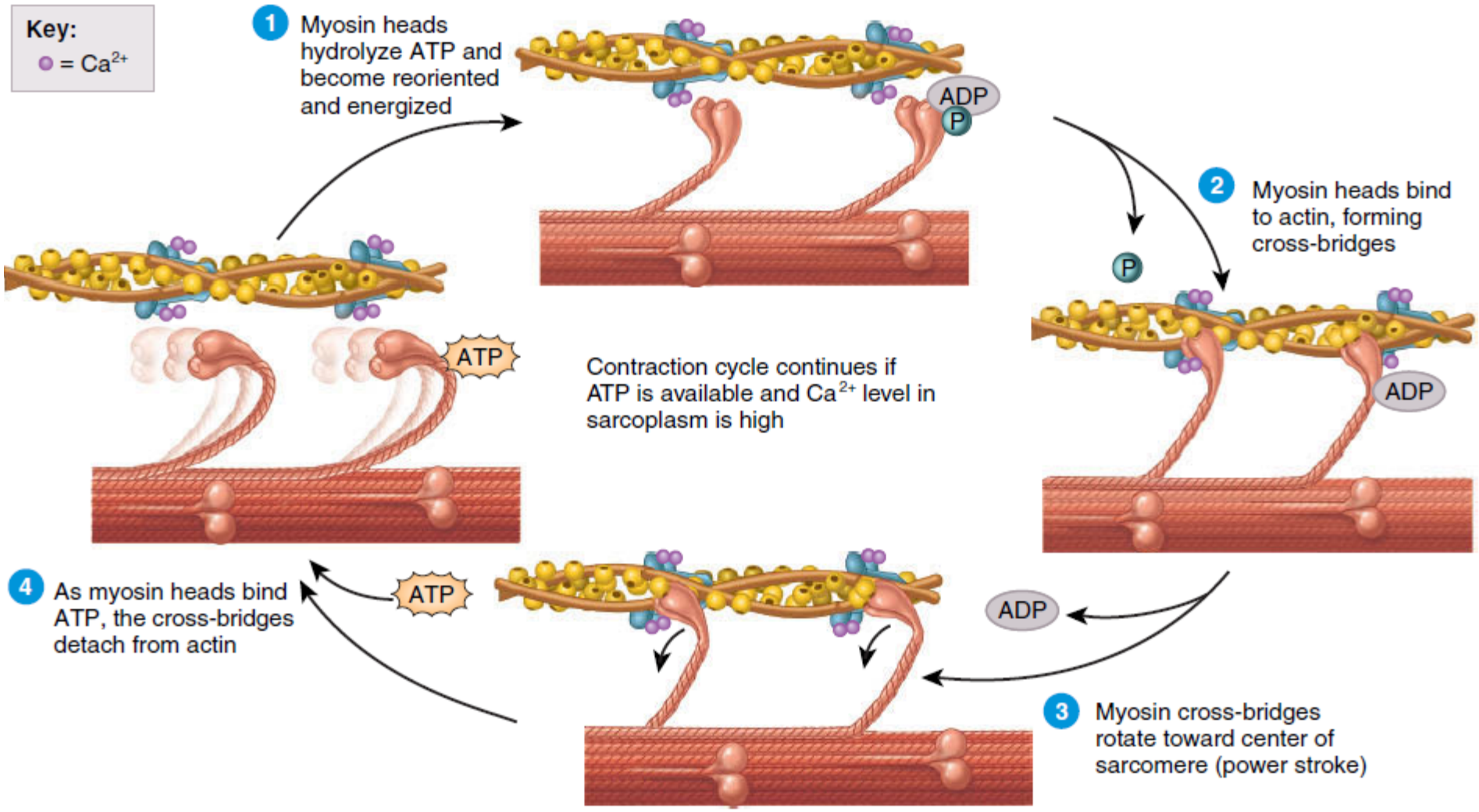
(c) Maximally contracted muscle

The Contraction Cycle

- At the onset of contraction:
  1. The sarcoplasmic reticulum releases calcium ions into the sarcoplasm.
  2. Calcium ions bind to troponin.
  3. Troponin then moves tropomyosin away from the myosin binding sites on actin.
  4. The **contraction cycle** begins.

- The contraction cycle is the repeating sequence of events that causes the filaments to slide. It consists of four steps.

The Contraction Cycle



1. ATP hydrolysis
   - The myosin head includes an ATP-binding site and an ATPase, ATP is hydrolyzed into ADP and a phosphate group (remain attached to the myosin head)
   - The myosin head reorients and energizes.

2. Attachment of myosin to actin to form cross-bridges.
   - Releases the phosphate group.

3. Power stroke.
   - The cross-bridge rotates toward the center of the sarcomere and releases the ADP.
   - The thin filament slides past the thick filament toward the M line

4. Detachment of myosin from actin.
   - ATP binds to the ATP binding site on the myosin head, the myosin head detaches from actin.

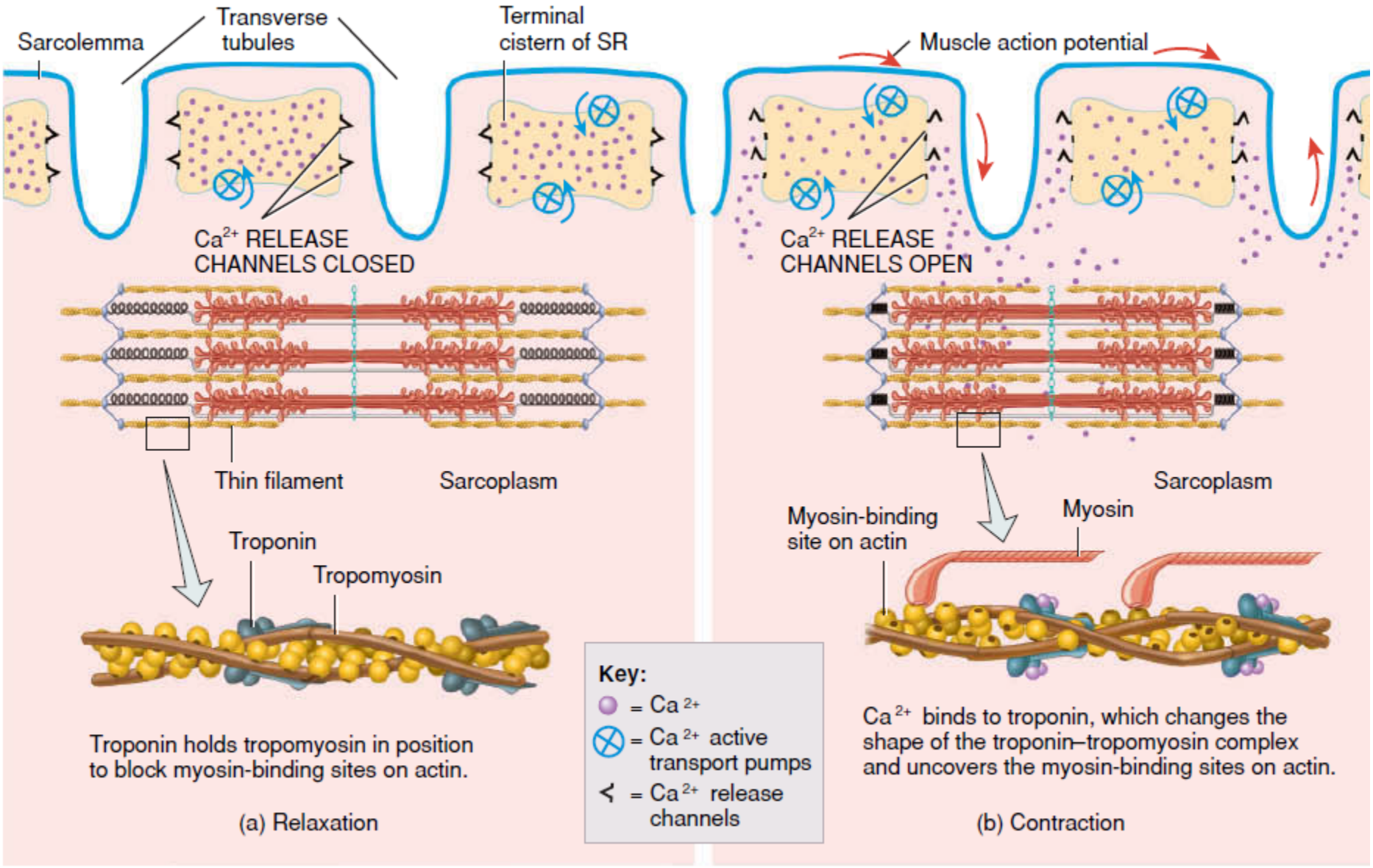
Excitation–Contraction Coupling

- The steps that connect excitation (a muscle action potential propagating along the sarcolemma and into the T tubules) to contraction (sliding of the filaments).

- The sarcoplasmic reticulum membrane contains Ca^{+2} **active transport pumps** that use ATP to move Ca^{+2} **constantly** from the sarcoplasm into the SR.

- As a muscle action potential propagates along the sarcolemma and into the T tubules, it causes **Ca^{+2} release channels** in the SR membrane to open, then Ca^{+2} flow into the sarcoplasm more rapidly than they are transported back by the pumps.

- Ca^{+2} concentration in the sarcoplasm rises tenfold and the contraction cycle begins


Sarcolemma
Transverse tubules
Terminal cistern of SR
Ca2+ RELEASE CHANNELS CLOSED
Thin filament
Sarcoplasm
Troponin
Tropomyosin
Troponin holds tropomyosin in position to block myosin-binding sites on actin.
(a) Relaxation
Key:
= Ca 2+
= Ca 2+ active transport pumps
= Ca 2+ release channels
Muscle action potential
Ca2+ RELEASE CHANNELS OPEN
Sarcoplasm
Myosin-binding site on actin
Myosin
Ca 2+ binds to troponin, which changes the shape of the troponin–tropomyosin complex and uncovers the myosin-binding sites on actin.
(b) Contraction

The Neuromuscular Junction

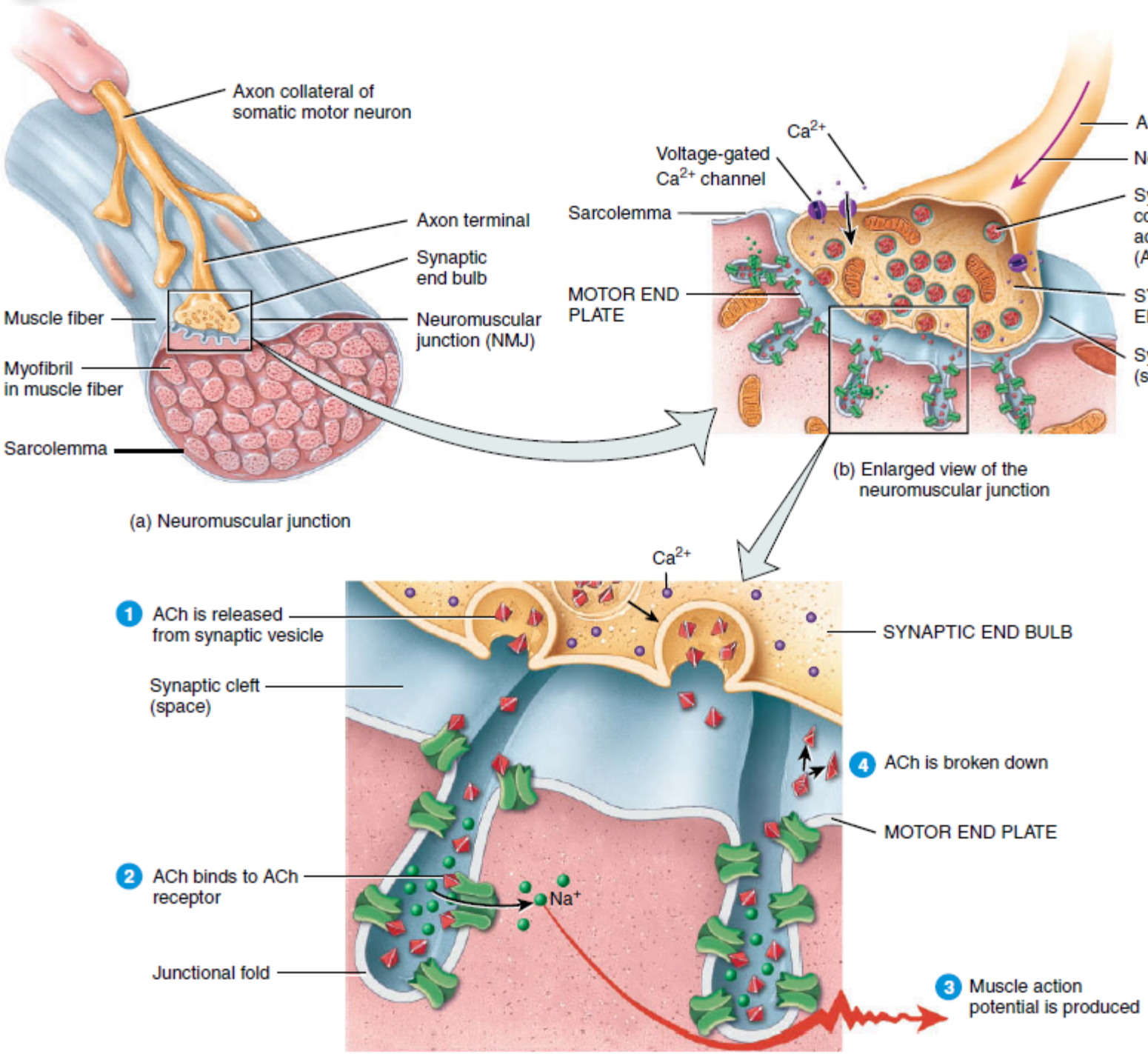
- Each somatic motor neuron has a threadlike axon that extends from the brain or spinal cord to a group of skeletal muscle fibers.
- Muscle action potentials arise at the neuromuscular junction (NMJ).
- NMJ is the region between a somatic motor neuron and a skeletal muscle fiber where communication occurs.
- The NMJ usually is near the midpoint of a skeletal muscle fiber.
- The two cells communicate through a neurotransmitter called acetylcholine(Ach)

Synaptic end bulbs and motor end plate

- Axon terminal is the end of the motor neuron. It divides into a cluster of synaptic end bulbs. Each synaptic end bulb has hundreds of membrane-enclosed sacs called synaptic vesicles that contain Ach.

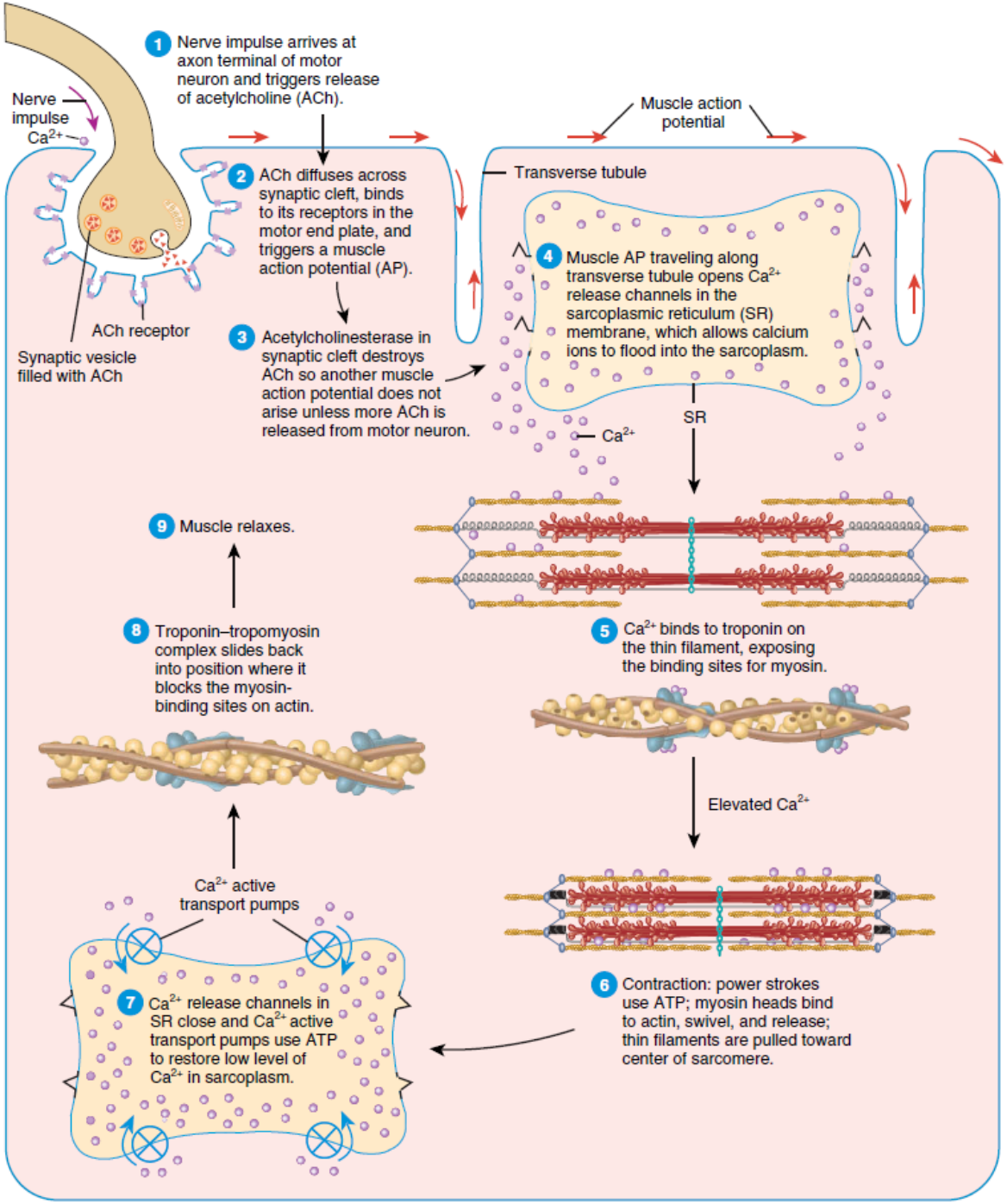
- Synaptic cleft is a small gap that separates the two cells.

- Motor end plate is the region of the sarcolemma opposite the synaptic end bulbs. It contains millions of acetylcholine receptors.
- Ach receptors are integral transmembrane proteins they function as **ligand-gated ion channels**


Axon collateral of somatic motor neuron
Axon terminal
Synaptic end bulb
Muscle fiber
Neuromuscular junction (NMJ)
Myofibril in muscle fiber
Sarcolemma
(a) Neuromuscular junction
Ca2+
Voltage-gated Ca2+ channel
Sarcolemma
MOTOR END PLATE
Axon terminal
Nerve impulse
Synaptic vesicle containing acetylcholine (ACh)
SYNAPTIC END BULB
Synaptic cleft (space)
(b) Enlarged view of the neuromuscular junction
Ca2+
1 ACh is released from synaptic vesicle
SYNAPTIC END BULB
Synaptic cleft (space)
4 ACh is broken down
MOTOR END PLATE
2 ACh binds to ACh receptor
Na+
Junctional fold
3 Muscle action potential is produced

- A nerve impulse (nerve action potential) elicits a muscle action potential in the following way:

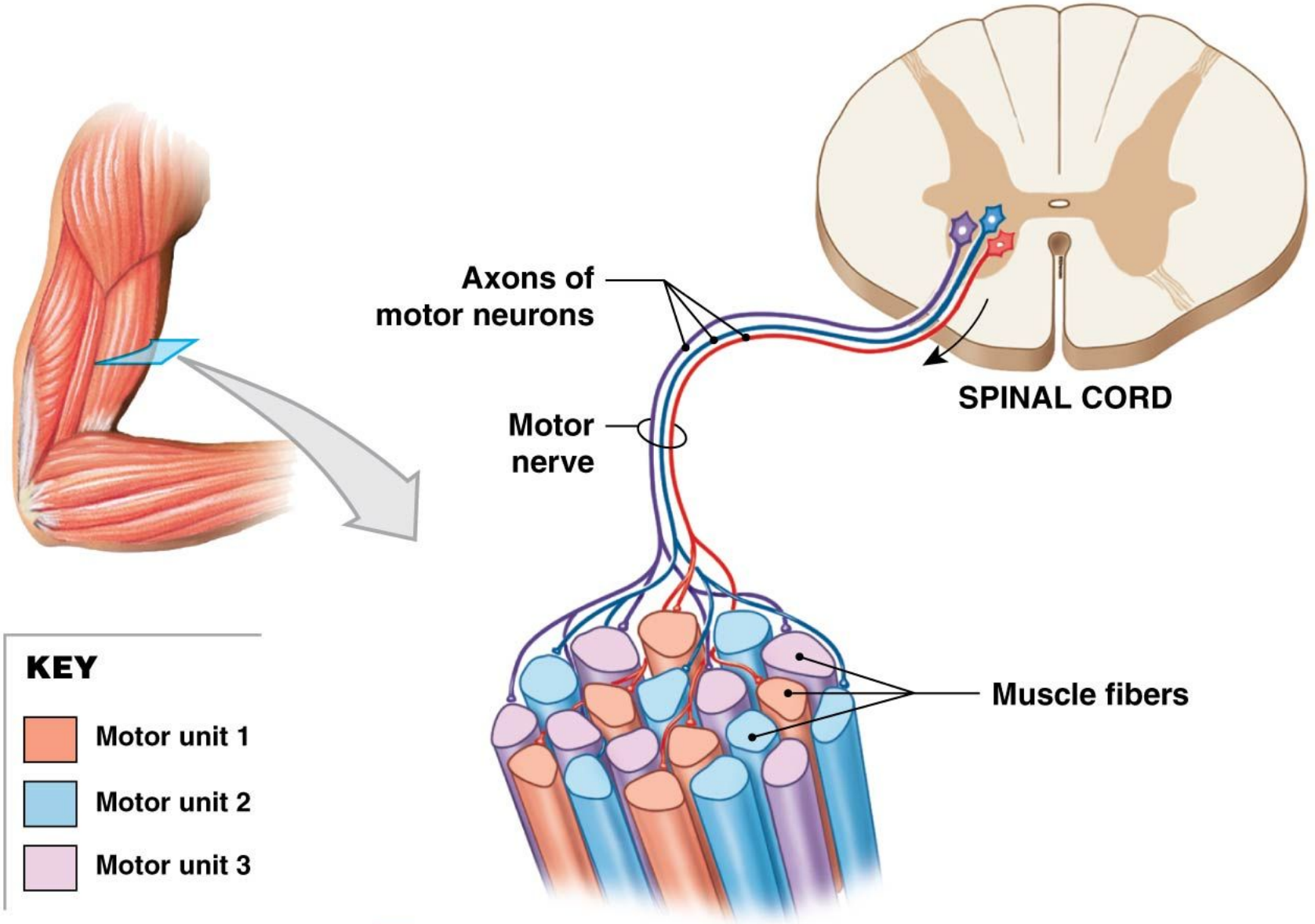
1. Release of acetylcholine
   - The nerve impulse leads to opening of voltage gated Ca^{+2} channels
   - Increased Ca^{+2} concentration causes exocytosis of Ach vesicles
2. Activation of ACh receptors
   - Binding of two molecules of ACh to the receptor opens the ion channel which allows Na^{+} to enter the muscle fiber
3. Production of muscle action potential
   - The inflow of Na^{+} triggers a muscle action potential.
   - The muscle action potential then propagates along the sarcolemma into the system of T tubules.
4. Termination of ACh activity
   - ACh is rapidly broken down by an enzyme called **acetylcholinesterase (AChE)**


1 Nerve impulse arrives at axon terminal of motor neuron and triggers release of acetylcholine (ACh).
Nerve impulse
Ca^{2+}
2 ACh diffuses across synaptic cleft, binds to its receptors in the motor end plate, and triggers a muscle action potential (AP).
ACh receptor
Synaptic vesicle filled with ACh
3 Acetylcholinesterase in synaptic cleft destroys ACh so another muscle action potential does not arise unless more ACh is released from motor neuron.
Muscle action potential
Transverse tubule
4 Muscle AP traveling along transverse tubule opens Ca^{2+} release channels in the sarcoplasmic reticulum (SR) membrane, which allows calcium ions to flood into the sarcoplasm.
SR
Ca^{2+}
5 Ca^{2+} binds to troponin on the thin filament, exposing the binding sites for myosin.
Elevated Ca^{2+}
6 Contraction: power strokes use ATP; myosin heads bind to actin, swivel, and release; thin filaments are pulled toward center of sarcomere.
7 Ca^{2+} release channels in SR close and Ca^{2+} active transport pumps use ATP to restore low level of Ca^{2+} in sarcoplasm.
Ca^{2+} active transport pumps
8 Troponin–tropomyosin complex slides back into position where it blocks the myosin-binding sites on actin.
9 Muscle relaxes.

Motor Units

- A **motor unit** consists of a somatic motor neuron plus all of the skeletal muscle fibers it stimulates.

- Each skeletal muscle fiber has only a single neuromuscular junction.
- The axon of a somatic motor neuron branches out and forms neuromuscular junctions with ~150 skeletal muscle fibers.
- The number of fibers in one motor unit depends on the muscle's function.



a Muscle fibers of different motor units are intermingled, so the forces applied to the tendon remain roughly balanced regardless of which motor units are stimulated.

Types of muscle contraction

- Isotonic Contractions
- Isometric Contractions

Isotonic Contractions

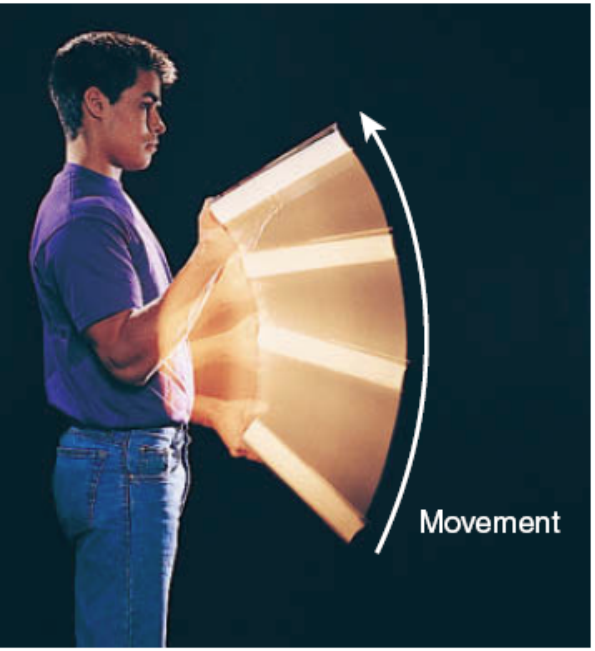
- Isotonic contraction: generate force by changing the length of the muscle while the tension developed in the muscle remains almost constant.
- They are used for body movements and for moving objects.

- There are two types:
  1. A concentric contraction causes muscles to shorten, thereby generating force.

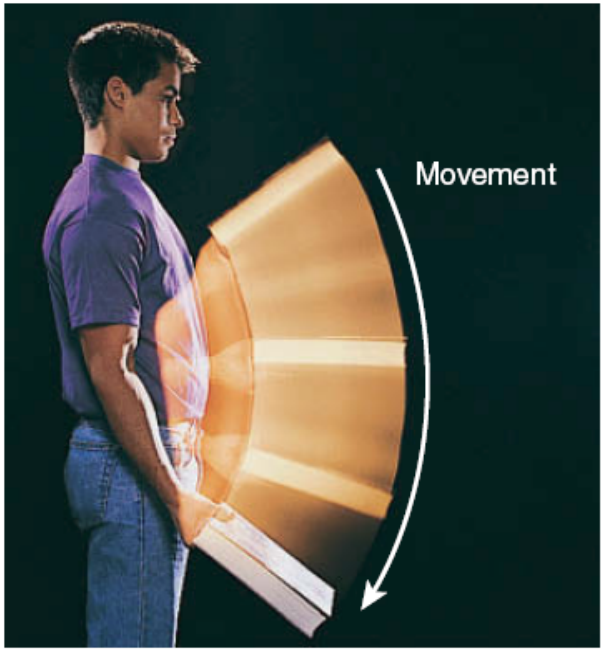
  2. Eccentric contractions cause muscles to elongate in response to a greater opposing force.

Isometric Contractions

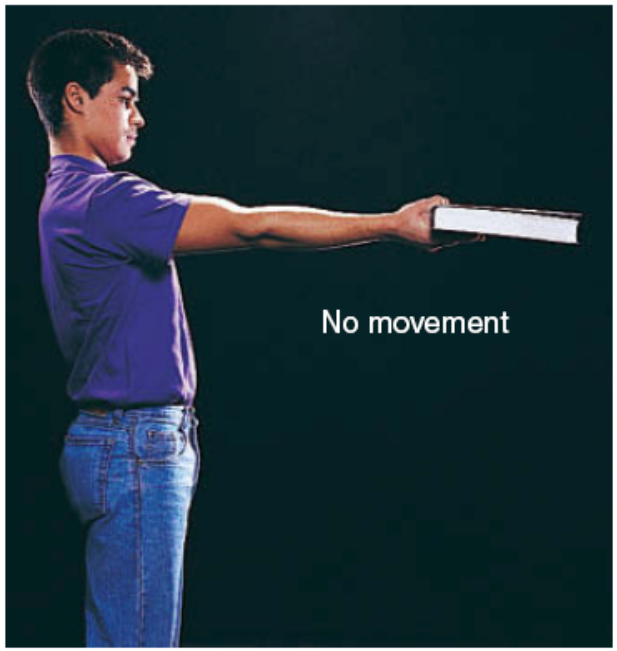
- Isometric contractions generate force without changing the length of the muscle.
- The tension generated is not enough to exceed the resistance of the object to be moved, and the muscle does not change its length.
- They are used for maintaining posture and for supporting objects in a fixed position.
- Most activities include both isotonic and isometric contractions.



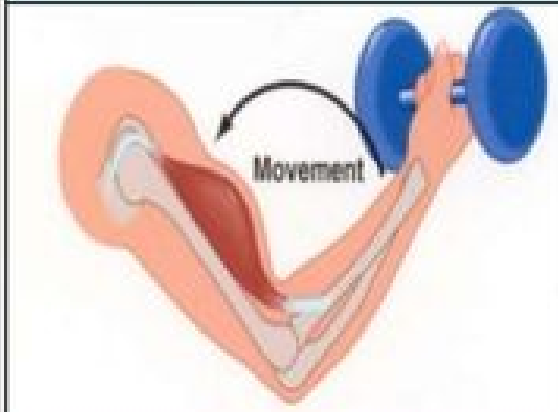
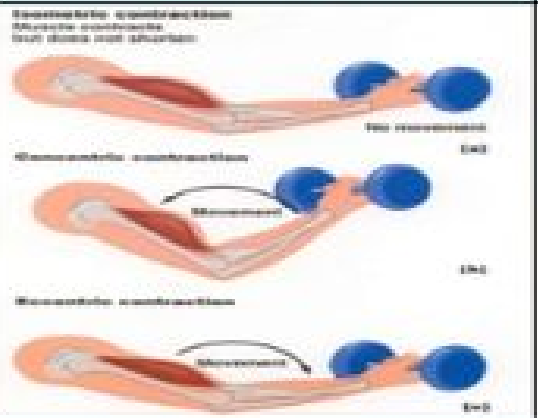
(a) Concentric contraction while picking up a book



(b) Eccentric contraction while lowering a book



(c) Isometric contraction while holding a book steady

Isotonic contraction		Isometric contraction
Concentric	**Eccentric**	
		
• Concentric contraction in the biceps brachii during the **upward phase** of exercise • Biceps brachii produces tension and **shortens** • It pulls the **forearm upwards to cause flexion** of the elbow	• Eccentric contraction in the biceps brachii during the **downward phase** of exercise • Biceps brachii produces tension and **lengthens** • It **slows the lowering of the forearm and controls extension of the elbow**	• Isometric contraction occurs in the biceps brachii when the muscle is **holding the weight still** • Biceps brachii develops tension and **stays the same length** •It **stops flexion and extension of the elbow**

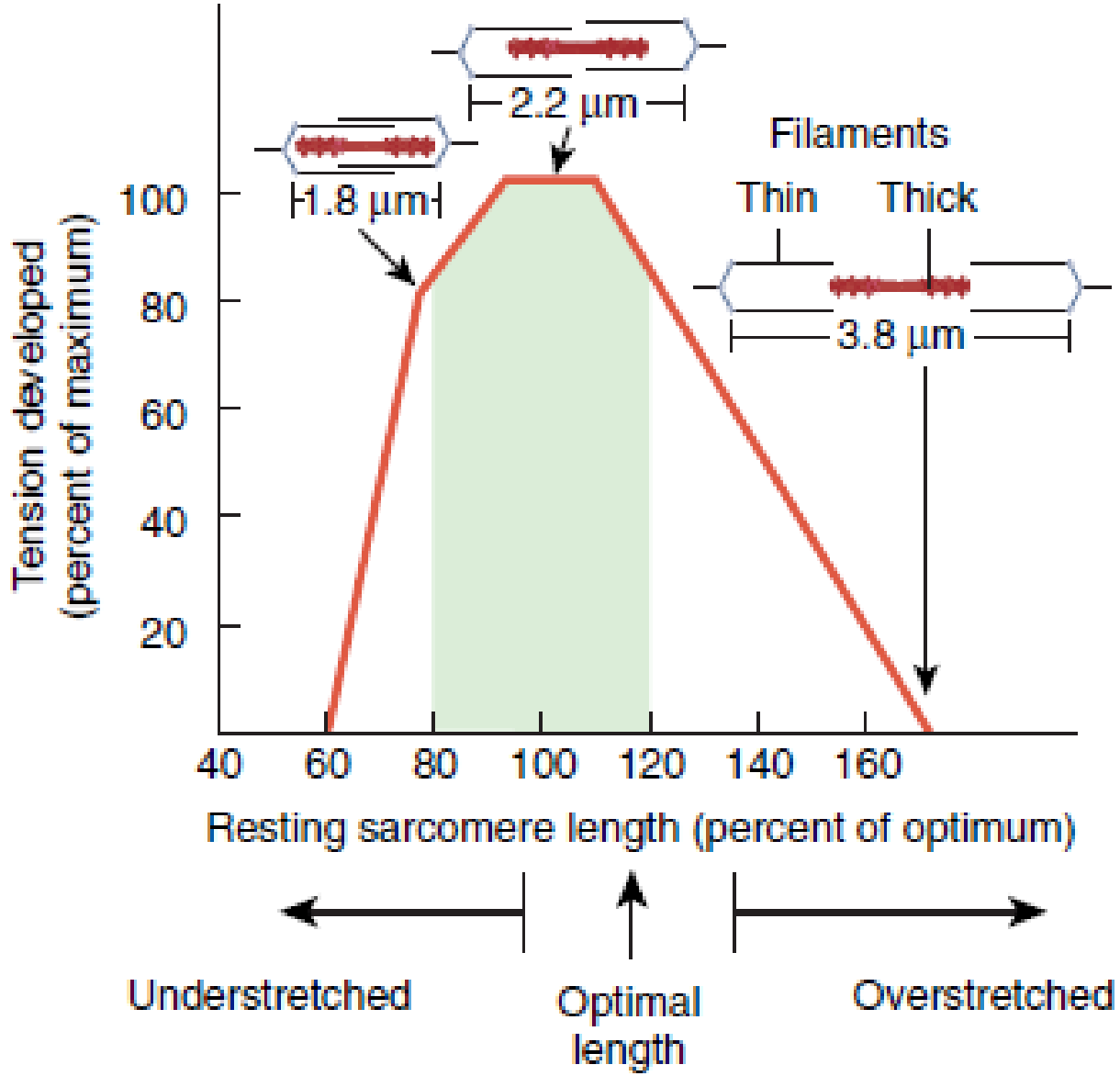
Control of Muscle Tension

- Action potentials always have the same size in a given neuron or muscle fiber.
- In contrast, the force of muscle fiber contraction does vary
- The total force (tension) that **a single muscle fiber** can produce depends mainly on the:
  1. Rate at which nerve impulses arrive at the neuromuscular junction (frequency of stimulation*)*.
  2. The amount of stretch before contraction
  3. The nutrient and oxygen availability.

- The total tension **a whole muscle** can produce depends on the number of muscle fibers that are

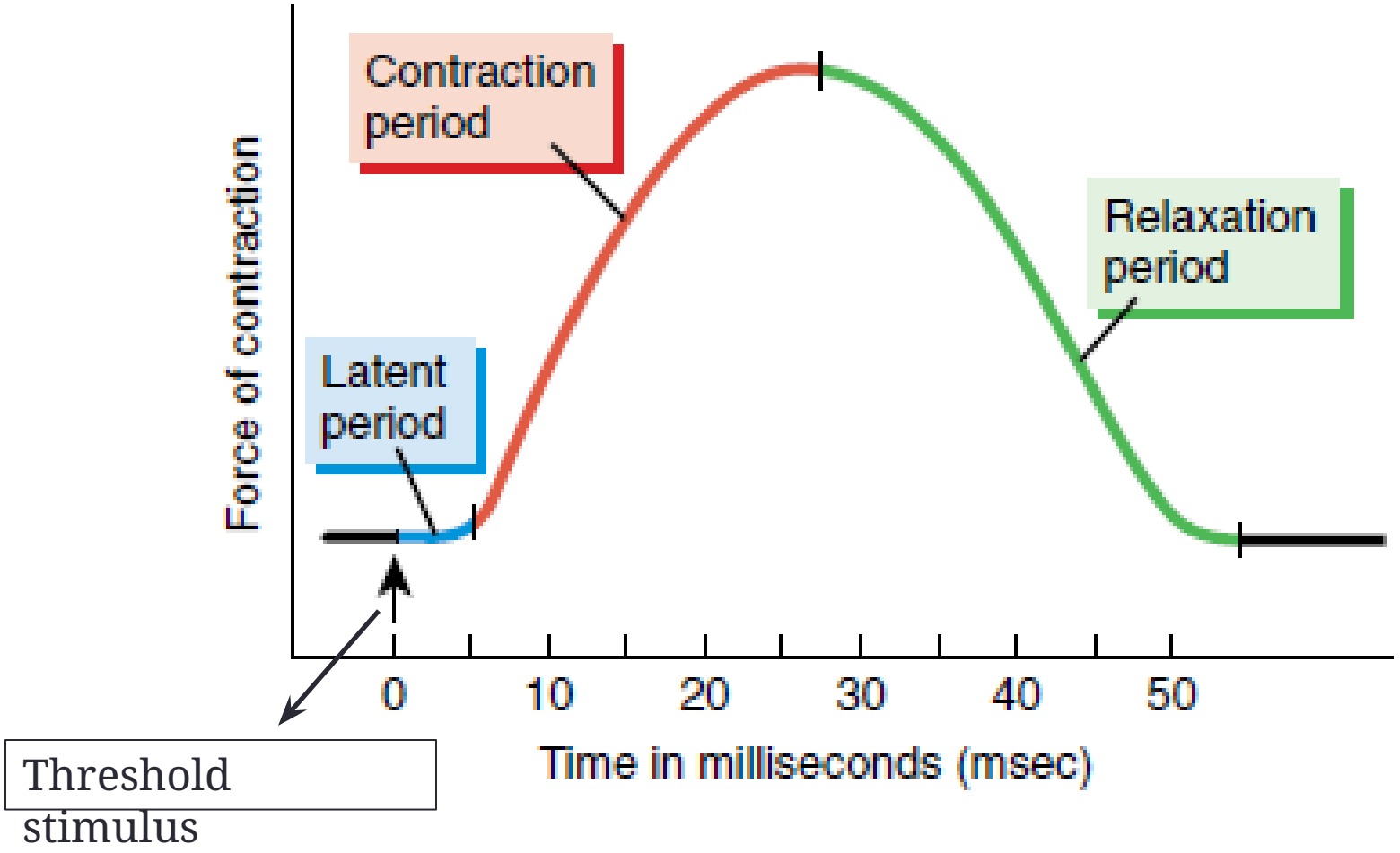
Length–Tension Relationship

- The strength of muscle contraction depends on the length of the sarcomeres within a muscle before contraction begins.
- At a sarcomere length of about 2.0–2.4 micro meter , the zone of overlap in each sarcomere is optimal, and the muscle fiber can develop maximum tension.
- Normally, resting muscle fiber length is held very close to the optimum by firm attachments of skeletal muscle to bones (via their tendons) and to other inelastic tissues.


2.2 µm
1.8 µm
Filaments
Thin
Thick
3.8 µm
Tension developed
(percent of maximum)
100
80
60
40
20
40
60
80
100
120
140
160
Resting sarcomere length (percent of optimum)
Understretched
Optimal
length
Overstretched

Twitch Contraction

- The brief contraction of all muscle fibers in a motor unit in response to a single action potential in its motor neuron.
- Twitches last anywhere from 20 to 200 msec depending on the type of the muscle.
- Consists of: latent period, contraction period and relaxation period
- The refractory period is the time during which a muscle fiber loses its excitability and cannot respond to any stimulus.
- Skeletal muscle has a short refractory period of about 1 msec



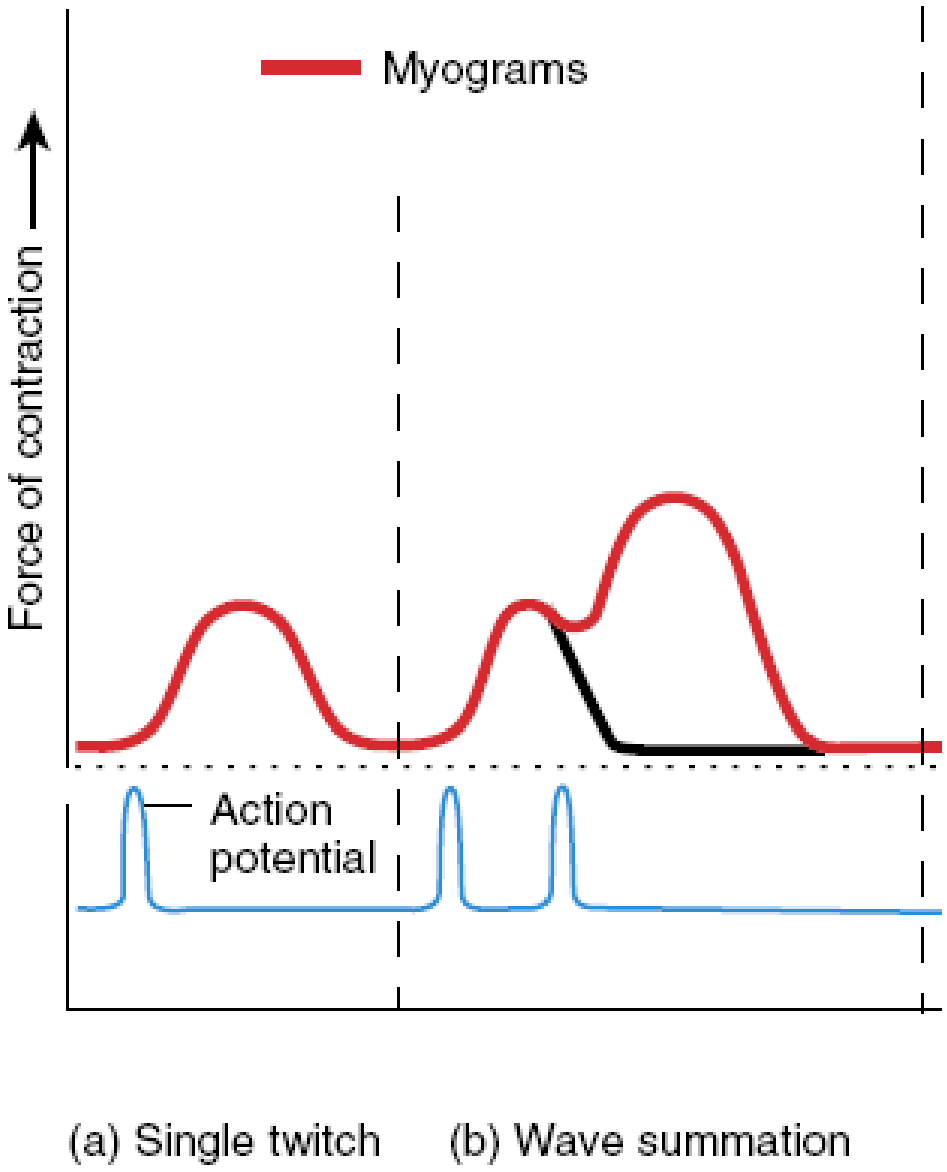
Myogram : a record of a muscle contraction

Wave summation and tetanization

- Wave Summation means the adding together of individual twitch contractions to increase the intensity of overall muscle contraction by increasing the frequency of stimulation.

- Tetanization occurs with higher frequency of stimulation whereby the successive contractions eventually become so rapid that they fuse together and the whole muscle contraction appears to be completely smooth and continuous

- They occur because additional Ca^{+2} is released from the sarcoplasmic reticulum by subsequent stimuli while the levels of Ca^{+2} in the sarcoplasm are still elevated from the first stimulus.
- Because of the buildup in the Ca^{+2} level, the peak tension generated during tetanus is 5 to 10 times larger than the peak tension produced during a single twitch.


Myograms
Force of contraction
Action potential
(a) Single twitch
(b) Wave summation

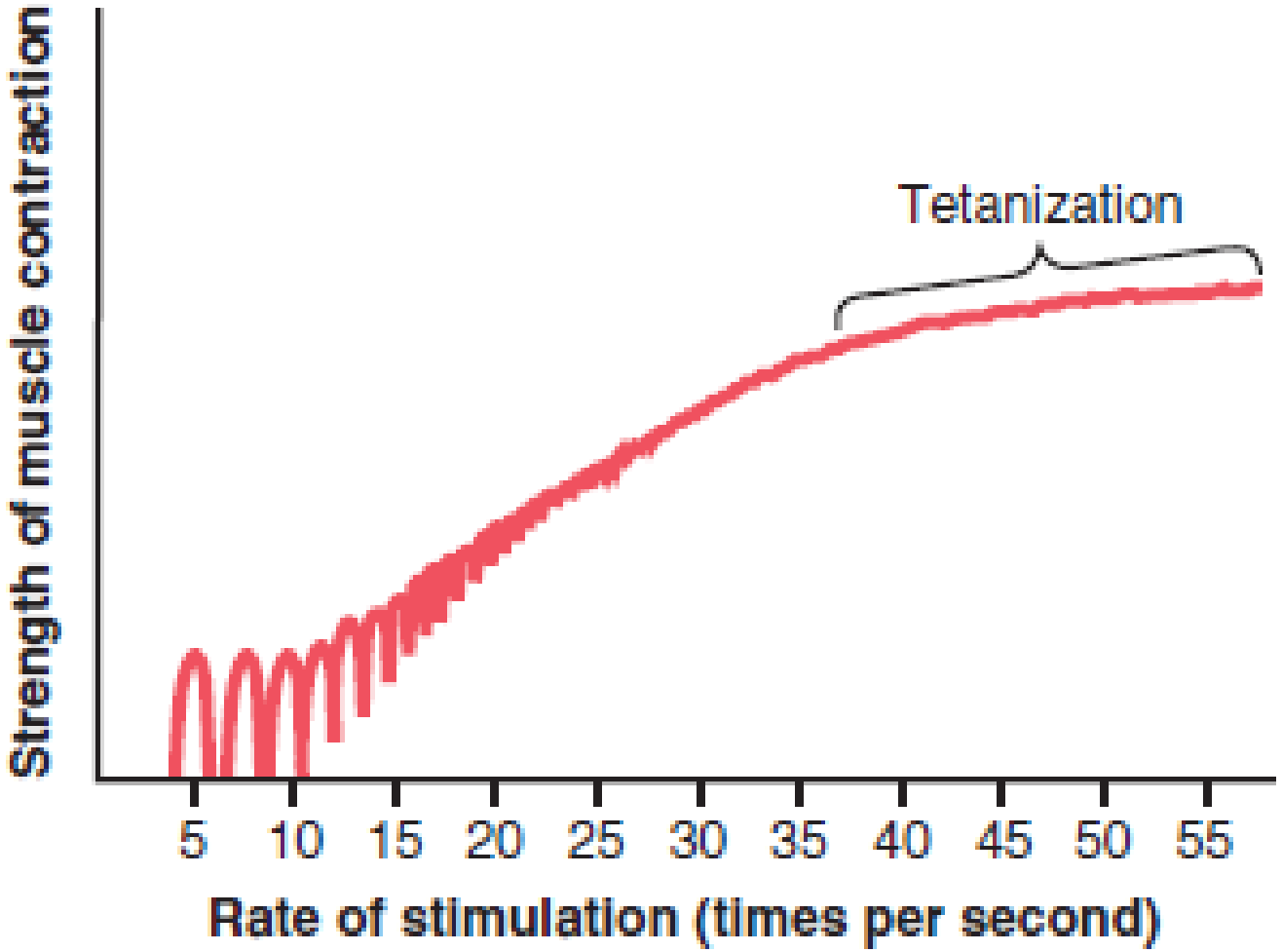
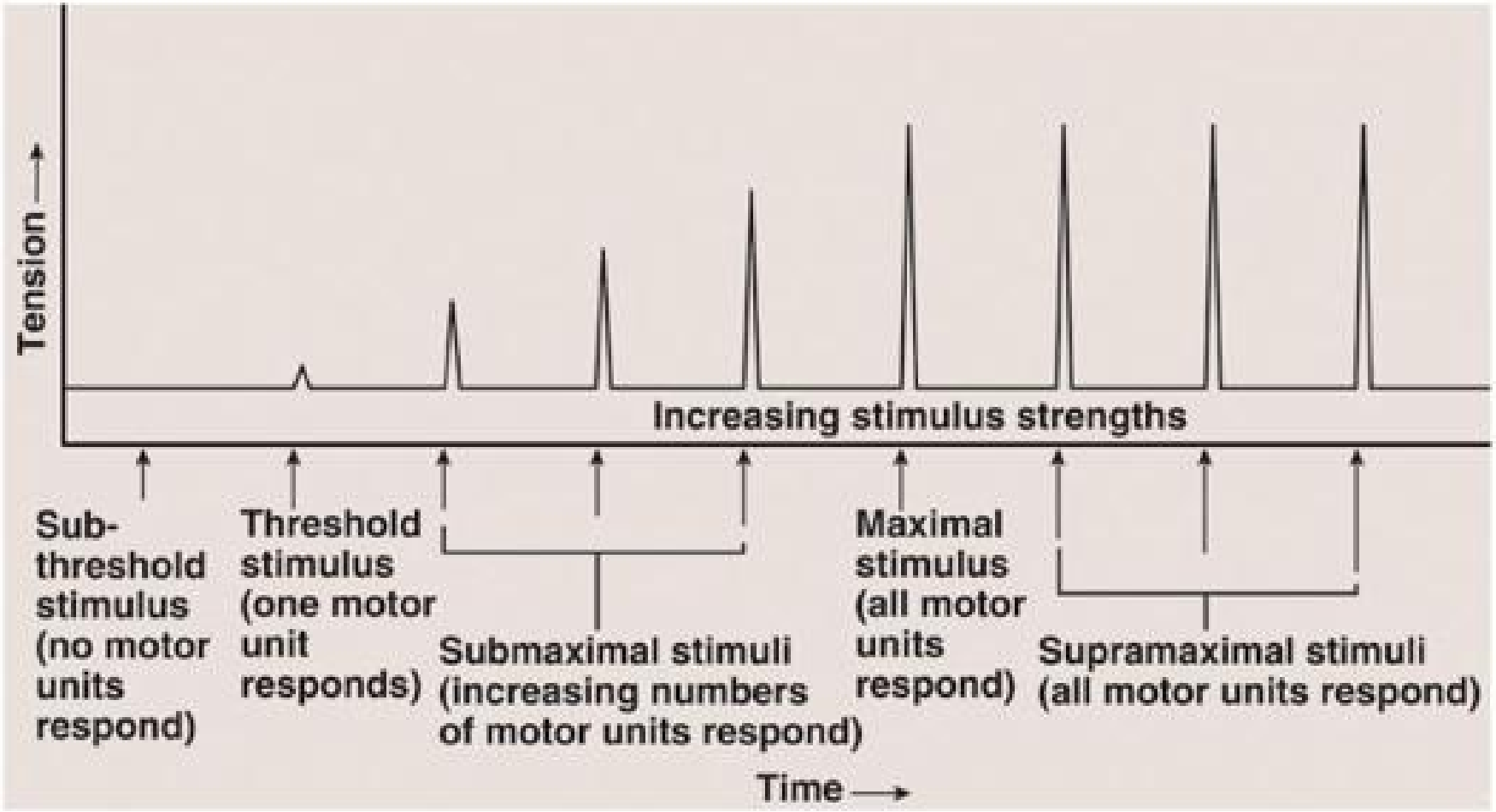


Figure 6-15. Frequency summation and tetanization.

Motor Unit Recruitment

- When the central nervous system sends a weak signal to contract a muscle, the smaller motor units of the muscle may be stimulated in preference to the larger motor units Then, as the strength of the signal increases, larger and larger motor units begin to be excited as well.
- The different motor units of an entire muscle are not stimulated to contract at the same time. While some motor units are contracting, others are relaxed.
- The weakest motor units are recruited first, with progressively stronger motor units added if the task requires more force.



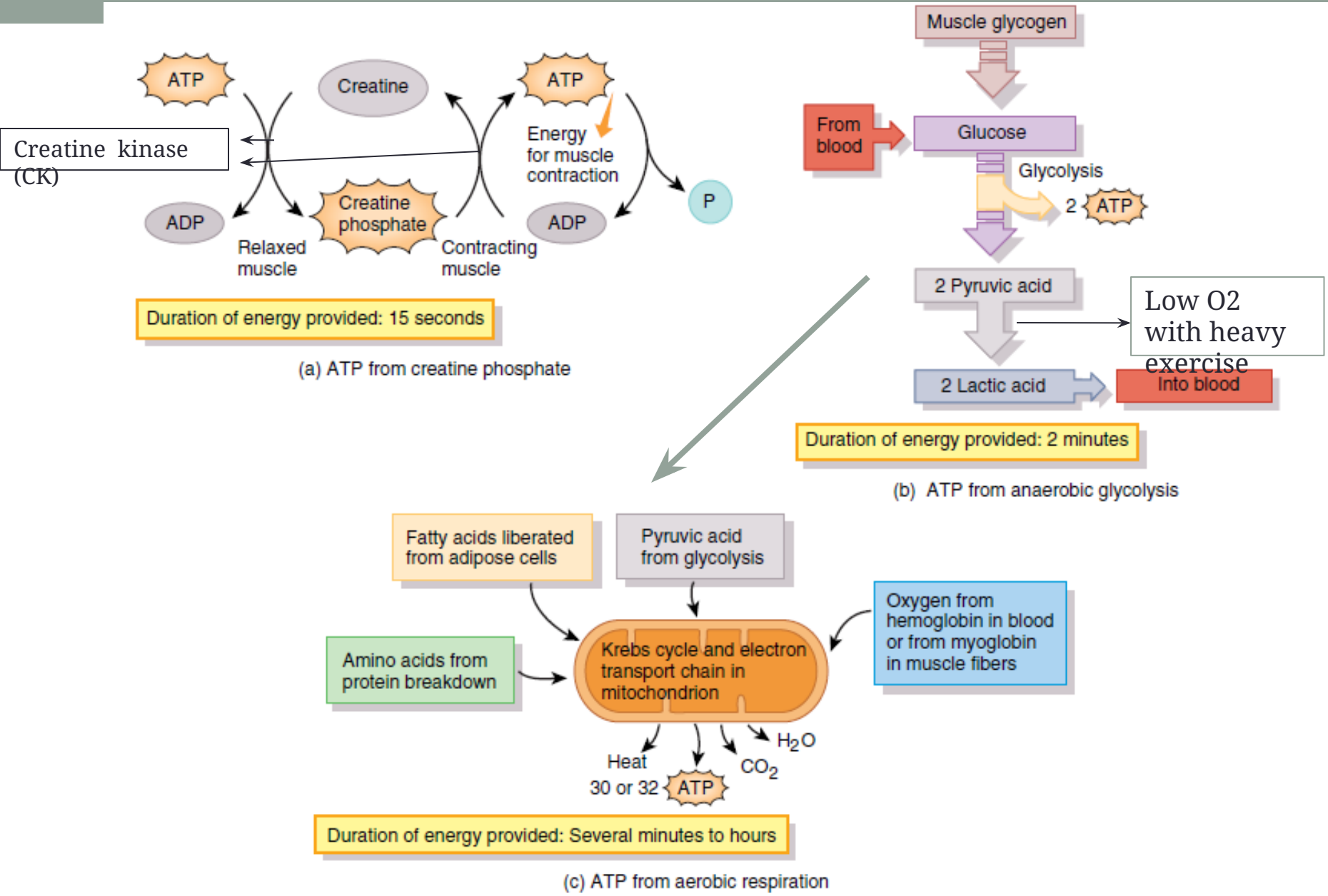
Muscle Fatigue

- The inability of a muscle to maintain force of contraction after prolonged activity.
- It is caused by:

1. Inadequate release of calcium ions from the SR
2. Depletion of creatine phosphate
3. Insufficient oxygen,
4. Depletion of glycogen and other nutrients,
5. Buildup of lactic acid and ADP
6. Failure of action potentials in the motor neuron to release enough acetylcholine.

Production of ATP in Muscle Fibers

- Skeletal muscle fibers switch between a low level of activity (relaxed and using little ATP), and a high level of activity (contracting)
- A huge amount of ATP is needed to power the contraction cycle.
- ATP synthesis occurs by three methods:
  1. From creatine phosphate: unique to muscle fibers, quickly generates new ATP molecules when the muscle starts contracting.
  2. By anaerobic glycolysis
  3. By aerobic respiration: slower but gives more ATP


ATP
Creatine
ATP
Creatine kinase (CK)
Energy for muscle contraction
ADP
Creatine phosphate
ADP
P
Relaxed muscle
Contracting muscle
Duration of energy provided: 15 seconds
(a) ATP from creatine phosphate
Muscle glycogen
From blood
Glucose
Glycolysis
2 ATP
2 Pyruvic acid
Low O2 with heavy exercise
2 Lactic acid
Into blood
Duration of energy provided: 2 minutes
(b) ATP from anaerobic glycolysis
Fatty acids liberated from adipose cells
Pyruvic acid from glycolysis
Oxygen from hemoglobin in blood or from myoglobin in muscle fibers
Amino acids from protein breakdown
Krebs cycle and electron transport chain in mitochondrion
H_2O
Heat
30 or 32 ATP
CO_2
Duration of energy provided: Several minutes to hours
(c) ATP from aerobic respiration

TYPES OF SKELETAL MUSCLE FIBERS

Slow Oxidative Fibers (SO)

- Called slow because the ATPase in the myosin heads hydrolyzes ATP relatively slowly and the contraction cycle proceeds at a slower pace than in “fast” fibers
- They are called oxidative because they have many large mitochondria so these fibers generate ATP mainly by aerobic respiration.
- Appear dark red because they contain large amounts of myoglobin and many blood capillaries.

- Very resistant to fatigue and are capable of prolonged, sustained contractions for many hours.
- Needed to maintain posture

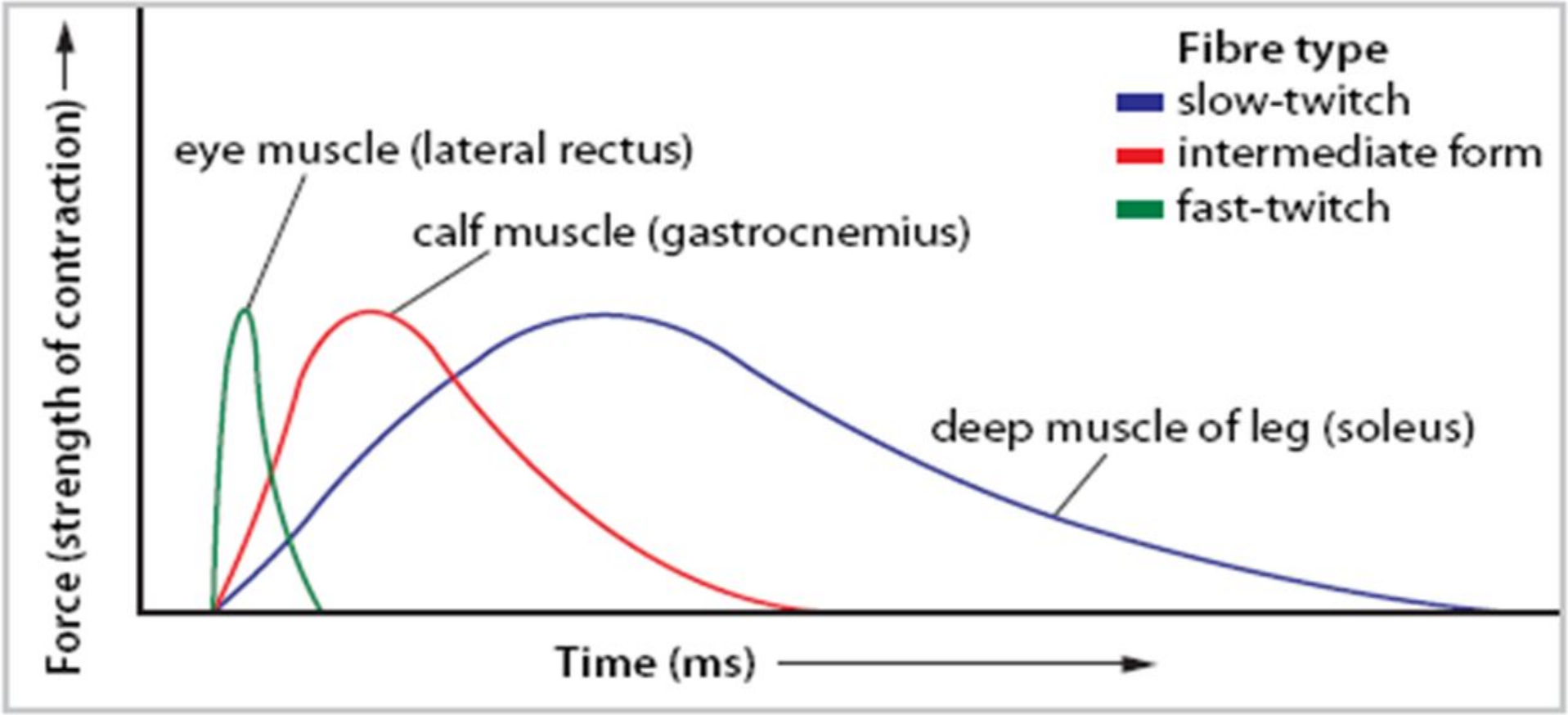
Fast Oxidative–Glycolytic Fibers (FOG)

- The largest fibers.
- They have dark red appearance because they contain large amounts of myoglobin and many blood capillaries.
- Can generate a lot of ATP by aerobic respiration and anaerobic glycolysis..
- They have moderately high resistance to fatigue.
- FOG fibers are “fast” because the ATPase in their myosin heads hydrolyzes ATP three to five times faster than the myosin ATPase in SO fibers, They contribute to activities such as walking and sprinting.

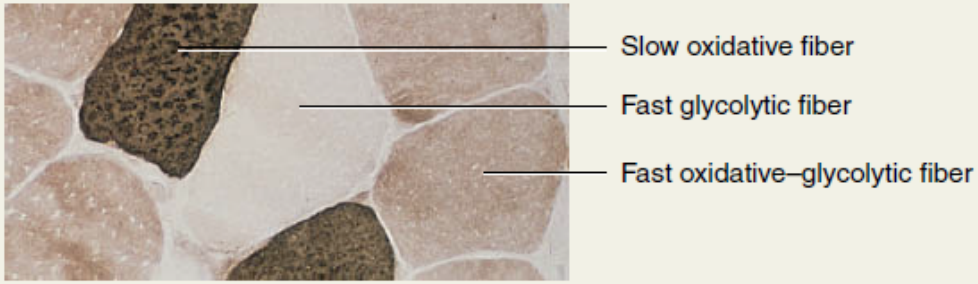
Fast Glycolytic Fibers (FG)

- Appear white in color since they have low myoglobin content, few blood capillaries and few mitochondria
- They contain large amounts of glycogen and generate ATP mainly by anerobic glycolysis.
- FG fibers contract strongly and quickly.
- They fatigue quickly.

Muscle twitch in different muscle types



Characteristics of the Three Types of Skeletal Muscle Fibers



Transverse section of three types of skeletal muscle fibers

	SLOW OXIDATIVE (SO) FIBERS	FAST OXIDATIVE–GLYCOLYTIC (FOG) FIBERS	FAST GLYCOLYTIC (FG) FIBERS
STRUCTURAL CHARACTERISTIC			
Myoglobin content	Large amount.	Large amount.	Small amount.
Mitochondria	Many.	Many.	Few.
Capillaries	Many.	Many.	Few.
Color	Red.	Red-pink.	White (pale).
FUNCTIONAL CHARACTERISTIC			
Capacity for generating ATP and method used	High, by aerobic respiration.	Intermediate, by both aerobic respiration and anaerobic glycolysis.	Low, by anaerobic glycolysis.
Rate of ATP hydrolysis by myosin ATPase	Slow.	Fast.	Fast.
Contraction velocity	Slow.	Fast.	Fast.
Fatigue resistance	High.	Intermediate.	Low.
Creatine kinase	Lowest amount.	Intermediate amount.	Highest amount.
Glycogen stores	Low.	Intermediate.	High.
Order of recruitment	First.	Second.	Third.
Location where fibers are abundant	Postural muscles such as those of neck.	Lower limb muscles.	Upper limb muscles.
Primary functions of fibers	Maintaining posture and aerobic endurance activities.	Walking, sprinting.	Rapid, intense movements of short duration.

Distribution of Different Types of Fibers

- Most skeletal muscles are a mixture of all three types of skeletal muscle fibers.
- The proportions vary depending on the action of the muscle, the person's training regimen and genetic factors.
- For example, the continually active postural muscles of the neck, back, and legs have a high proportion of SO fibers.

SMOOTH MUSCLE TISSUE

Smooth muscle tissue

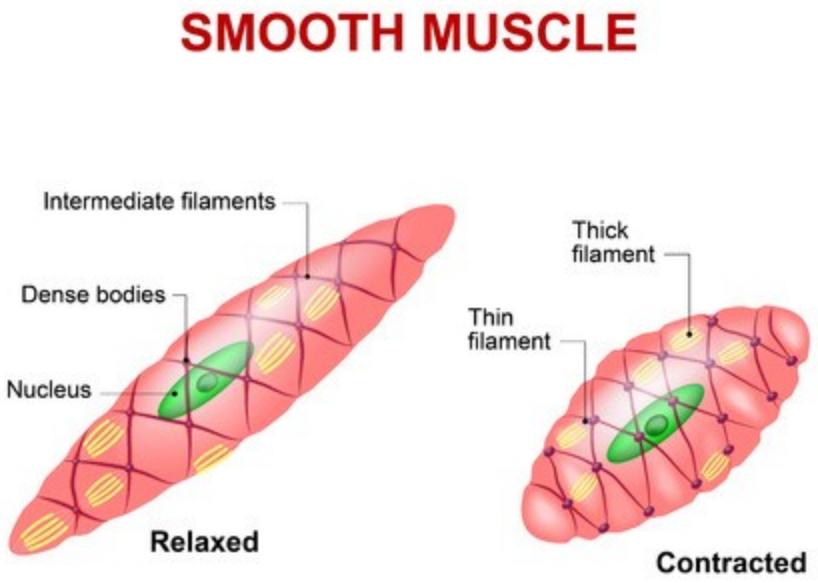
- Located in the walls of hollow internal structures, such as blood vessels, airways, and most organs in the abdominopelvic cavity.
-
- Under a microscope, it looks nonstriated.
- Their action is involuntary,
- Regulated by neurons that are part of the autonomic (involuntary) nervous system and by hormones.
- Some have autorhythmicity.

Microscopic Anatomy of Smooth Muscle Fiber

- Each fiber is thickest in the middle and tapers at each end
- Within each fiber is a single, oval, centrally located nucleus.
- The sarcoplasm contains thick and thin filaments, in a ratio of 1:10, but they are not arranged in sarcomeres.
- Thin filaments attach to structures called **dense bodies**.
- Dense bodies are dispersed in sarcoplasm or attached to the sarcolemma
- Contain **intermediate filaments** they stretch from one dense body to another

- Lack transverse tubules and have only a small amount of sarcoplasmic reticulum for storage of Ca^{+2}

- **Caveolae are s**mall pouchlike invaginations of the plasma membrane that contain extracellular Ca^{+2} that can be used for muscular contraction.



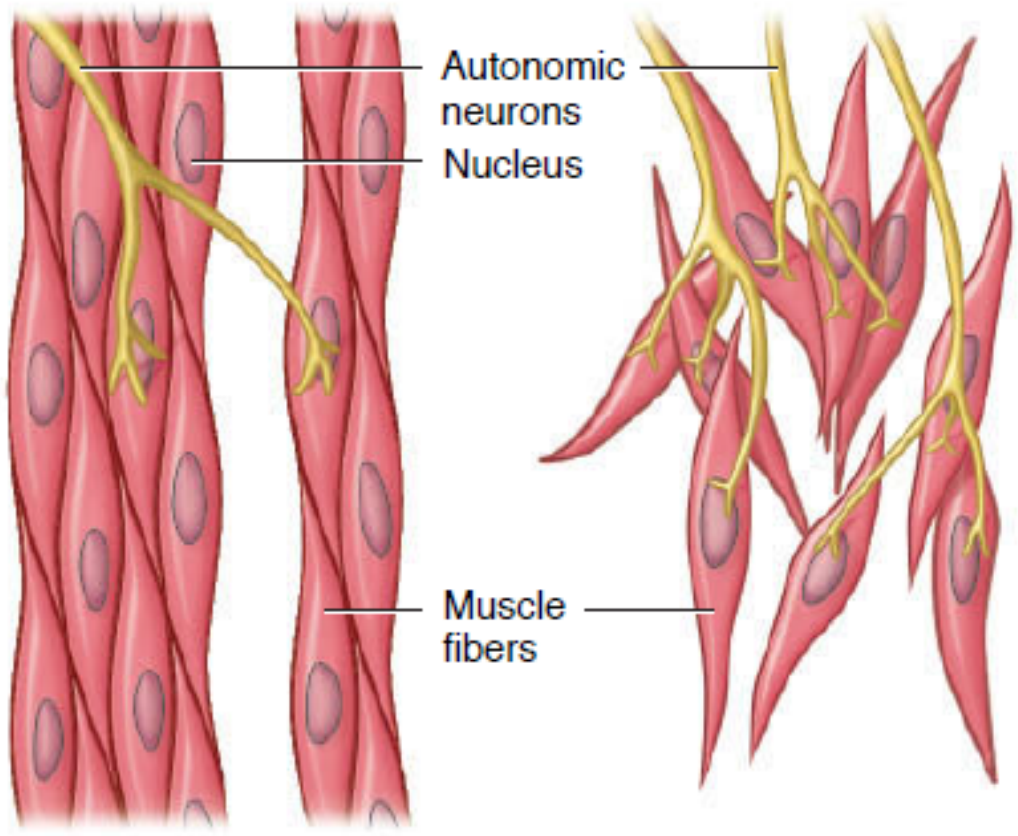
Smooth Muscle Tissue Types

1. **Visceral (single-unit) smooth muscle tissue**

- Most common type
- Found in the walls of small arteries and veins and the walls of hollow organs
- Extensive gap junctions
- Stimulation of one visceral muscle fiber causes contraction of many adjacent fibers.

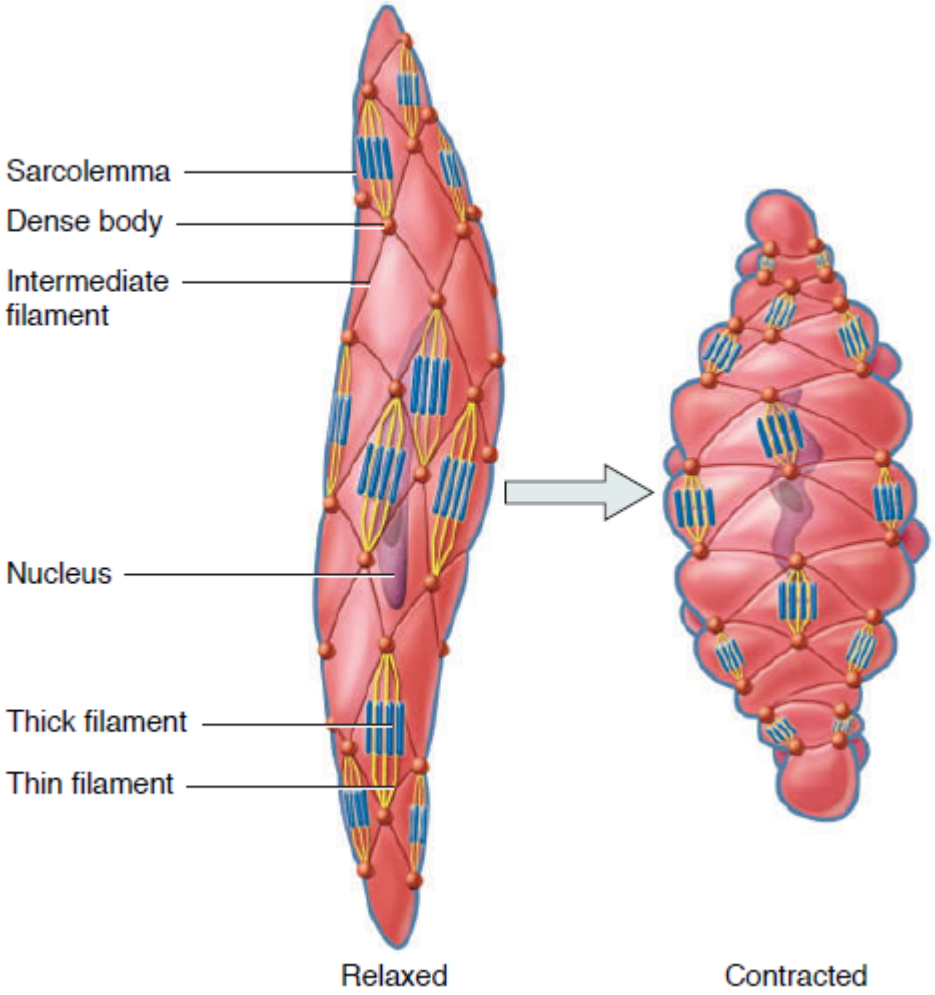
2. **Multiunit smooth muscle tissue**

- Found in the walls of large arteries & in the airways
- Few gap junctions
- Each fiber has its own motor neuron terminals
- Stimulation of one multiunit fiber causes contraction of that fiber only.



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

(b) Multiunit smooth muscle tissue



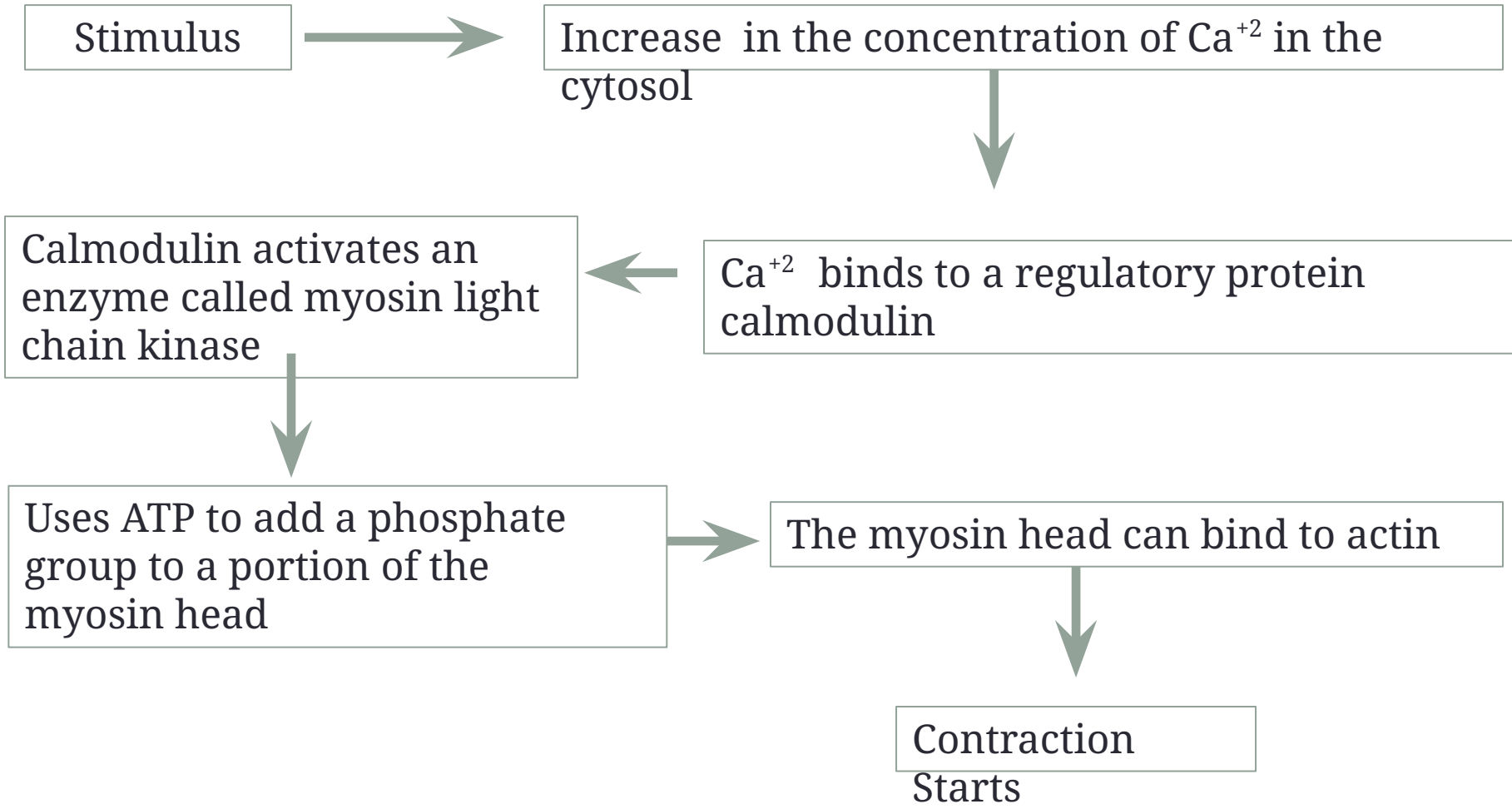
1. During contraction, the sliding filament mechanism involving thick and thin filaments generates tension

2. Tension is transmitted to intermediate filaments.

3. These filaments pull on the dense bodies attached to the sarcolemma, causing a lengthwise shortening of the muscle fiber.

4. As a smooth muscle fiber contracts, it rotates as a corkscrew turns.

5. The fiber twists in a helix as it contracts, and rotates in the opposite direction as it relaxes.



Contraction of Smooth Muscles

Physiology of Smooth Muscle (SM) contraction

- Contraction in a SM fiber starts more slowly and lasts much longer than skeletal muscle fiber contraction.
  - Slow entrance & exit of Ca^{+2}
  - Myosin light chain kinase works slowly

- SM can both shorten and stretch to a greater extent than the other muscle types.

Triggers for Contraction

- Autonomic nervous system stimulation.
- Stretching
- Hormones like epinephrine
- Local factors such as changes in pH, oxygen and carbon dioxide levels, temperature, and ion concentrations.