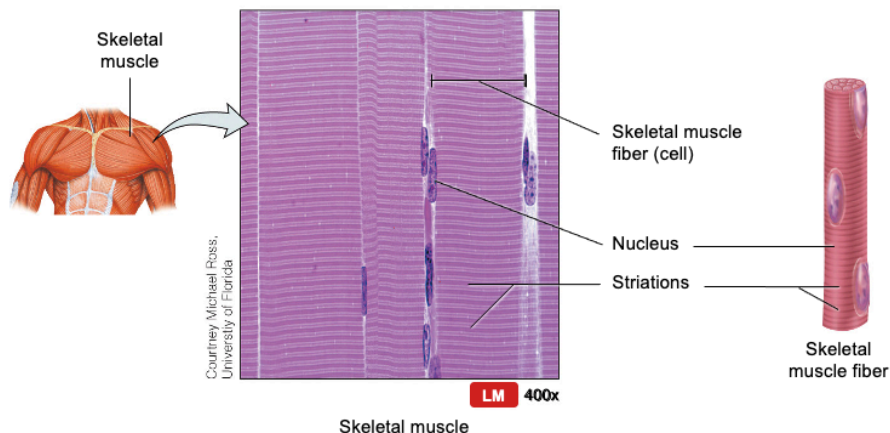


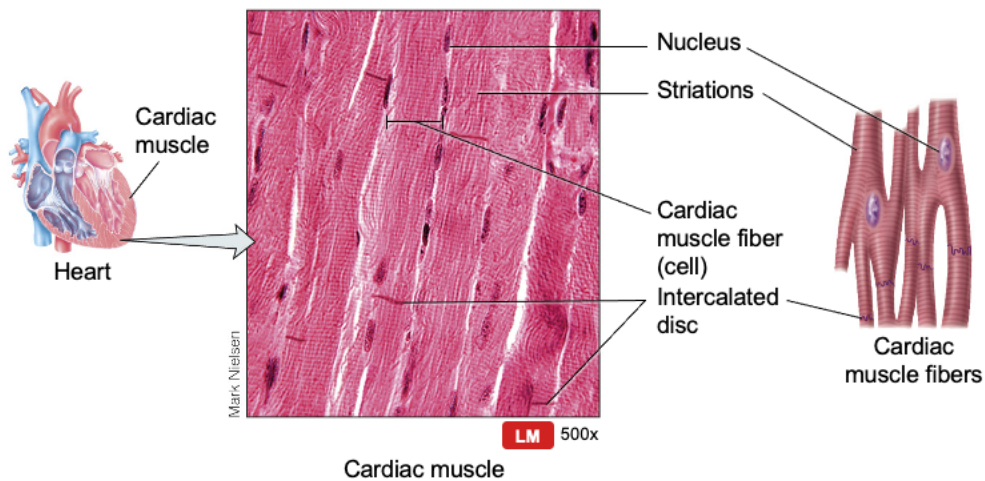
Muscle Lab Supplemental Resource**I. Types of Muscle****1. Three exist in the body****A. Skeletal muscle**

- Cells are long, cylindrical, striated, and multinucleate
- Voluntary
 - ◇ Its activity can be consciously controlled by motor neurons that are part of the somatic nervous system. Many skeletal muscles are also controlled subconsciously to some extent. For example, your diaphragm continues to alternately contract and relax without conscious control so that you don't stop breathing. In addition, the skeletal muscles that maintain posture or stabilize body position contract without conscious control. Together, all the skeletal muscles of the body comprise the muscular system.
- Attached to bone

**B. Cardiac muscle**

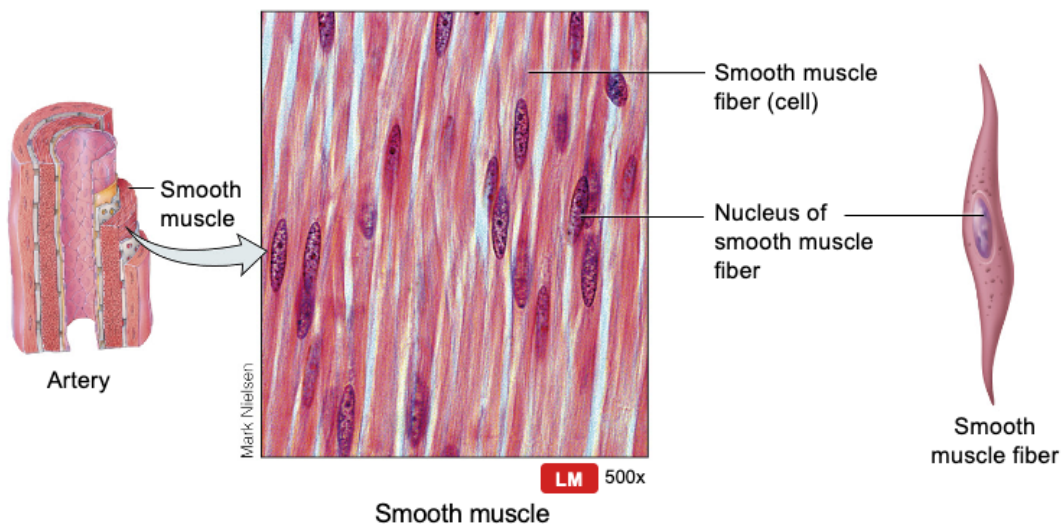
- Cells are short, branched, and striated
- Usually with single nucleus
- Cells interconnected by intercalated discs
- Involuntary
 - ◇ Its contractions are not under conscious control. Instead, the heart beats because it has a pacemaker that initiates each contraction. This built-in rhythm is termed autorhythmicity. Several neurotransmitters and hormones can adjust heart rate by speeding up or slowing down the pacemaker.

- Located in the heart



C. Smooth muscle

- Cells are short, spindle-shaped, non-striated (lack striation = smooth), with a single, central nucleus
- Involuntary
 - ◇ some smooth muscle tissue, such as the muscles that propel food through your gastrointestinal tract, has autorhythmicity. Both cardiac muscle and smooth muscle are regulated by motor neurons that are part of the autonomic nervous system and by hormones released by endocrine glands.
- Located in the walls of hollow organs
 - ◇ Blood vessels, airways, stomach, intestines, and uterus



II. Muscle Functions – through sustained contraction or alternating contraction and relaxation**1. Producing body movements.**

- Walking and running, and localized movements
- Rely on the integrated functioning of skeletal muscles, bones, and joints

2. Stabilizing body positions.

- Skeletal muscle contractions
- Stabilize joints and maintain body positions, such as standing or sitting.
- Postural muscles contract continuously when you are awake
 - Ex. sustained contractions of your neck muscles hold your head upright.

3. Storing and moving substances within the body.

- A. Storage is accomplished by sustained contractions of ring-like bands of smooth muscle called sphincters, which prevent outflow of the contents of a hollow organ.
 - Temporary storage of food in the stomach or urine in the urinary bladder
- B. Cardiac muscle contractions of the heart pump blood through the blood vessels of the body.
 - Contraction and relaxation of smooth muscle in the walls of blood vessels help adjust blood vessel diameter and thus regulate the rate of blood flow.
- C. Smooth muscle contractions move food and substances such as bile and enzymes through the gastrointestinal tract, push gametes (sperm and oocytes) through the passageways of the reproductive systems, and propel urine through the urinary system.
- D. Skeletal muscle contractions promote the flow of lymph and aid the return of blood to the heart

4. Generating heat.

- A. As muscle contracts, it produces heat.
 - This process is known as thermogenesis.
- B. Much of the heat generated by muscle is used to maintain normal body temperature.
- C. Involuntary contractions of skeletal muscles, known as shivering, can increase the rate of heat production.

III. Muscle Properties

1. Electrical excitability

- A. A property of both neurons and muscle cells
- B. Ability to respond to certain stimuli by producing action potentials.
- C. For muscle cells, two main types of stimuli trigger action potentials:
 - One is chemical stimuli, such as neurotransmitters released by neurons and hormones distributed by the blood.
 - The other is autorhythmic electrical signals arising in the muscle tissue itself, as in the heart's pacemaker.

2. Contractility

- A. Ability of muscle to contract forcefully when adequately stimulated
- B. When a muscle contracts, it generates tension (force of contraction)
 - If the tension generated is great enough to overcome the resistance of the object to be moved, the muscle shortens, and movement occurs.

3. Extensibility

- A. Ability of muscle to stretch without being damaged
 - allows a muscle to contract forcefully even if it is already stretched. Normally, smooth muscle is subject to the greatest amount of stretching. For example, each time your stomach fills with food, the muscle in its wall is stretched. Cardiac muscle is also stretched each time the heart fills with blood.

4. Elasticity

- A. Ability of muscle to return to its original length and shape after contraction or extension.

IV. Organization of Skeletal Muscle

1. Connective Tissue of Muscle – each skeletal muscle has three concentric layers, or wrappings, of connective tissue: an outer epimysium, a central perimysium, and an inner endomysium

A. Epimysium

- Layer of dense irregular connective tissue that surrounds the entire skeletal muscle
- Separates the muscle from surrounding tissues and organs

B. Perimysium

- These connective tissue fibers divide the muscle into a series of internal compartments, each containing a bundle of muscle fibers called a fascicle
- Contains numerous blood vessels and nerves that branch to supply each individual fascicle

C. Endomysium

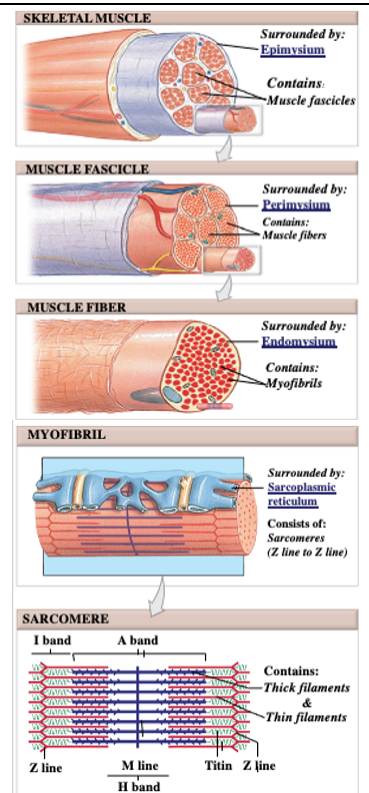
- Surrounds each skeletal muscle fiber, binds each muscle fiber to its neighbor, and supports capillaries that supply individual fibers
- Consists of a delicate network of reticular fibers
- Scattered myosatellite stem cells lie between the endomysium and muscle fibers

◊ These stem cells function in regeneration and repair of damaged muscle tissue

2. Microscopic structure of muscle

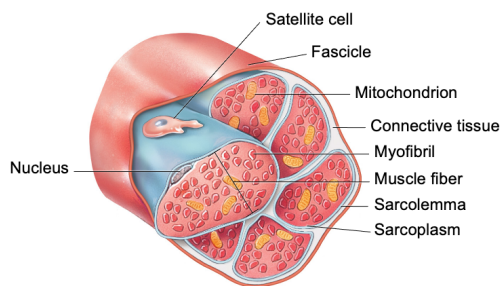
A. Sarcomere arrangement

- Single file arrangement along the myofibril
- The multiple nuclei of a skeletal muscle fiber are located just beneath the sarcolemma, the plasma membrane of a muscle fiber. Thousands of tiny invaginations of the sarcolemma, called transverse (T) tubules, tunnel in from the surface toward the center of each muscle fiber. Because T tubules are open to the outside of the fiber, they are filled with extracellular fluid. Muscle action potentials travel along the sarcolemma and through the T tubules, quickly spreading throughout the muscle fiber. This arrangement ensures that an action potential excites all parts of the muscle fiber at essentially the same instant.
- The sarcolemma surrounds the sarcoplasm, the cytoplasm of a muscle fiber. Within the sarcoplasm are mitochondria, which produce large amounts of ATP for muscle contraction. The sarcoplasm also contains glycogen, a large polysaccharide consisting of thousands of glucose molecules covalently linked together. Glycogen serves as a storage form of glucose. It can be broken down into individual glucose molecules that can be used to synthesize ATP. Also present in the sarcoplasm are molecules of myoglobin, a red-colored, oxygen-

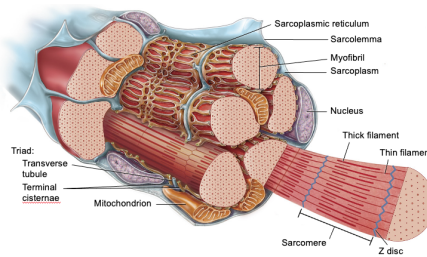


binding protein that is found only in muscle. Myoglobin stores oxygen until it is needed by mitochondria to generate ATP.

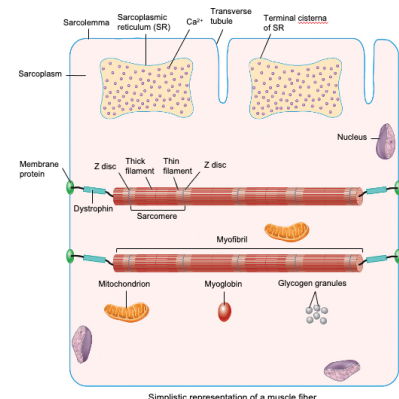
- Extending throughout the sarcoplasm are myofibrils, the contractile elements of the skeletal muscle fiber. Within myofibrils are smaller structures called filaments, which can have either a thin or thick diameter. Thin filaments are 8 nm in diameter and 1–2 μm long, while thick filaments are 16 nm in diameter and 1–2 μm long. Both thin and thick filaments are directly involved in the contraction process.
- A fluid-filled system of membranous sacs called the sarcoplasmic reticulum (SR) encircles each myofibril. This elaborate system is similar to the smooth endoplasmic reticulum in nonmuscular cells. Dilated end sacs of the sarcoplasmic reticulum called terminal cisternae (also known as lateral sacs) butt against a T tubule from both sides. A transverse tubule and the two terminal cisternae on either side of it form a triad (tri- = three). In a relaxed muscle fiber, the sarcoplasmic reticulum stores calcium ions (Ca^{2+}). Release of Ca^{2+} from the terminal cisternae of the sarcoplasmic reticulum triggers muscle contraction.



Organization of a fascicle

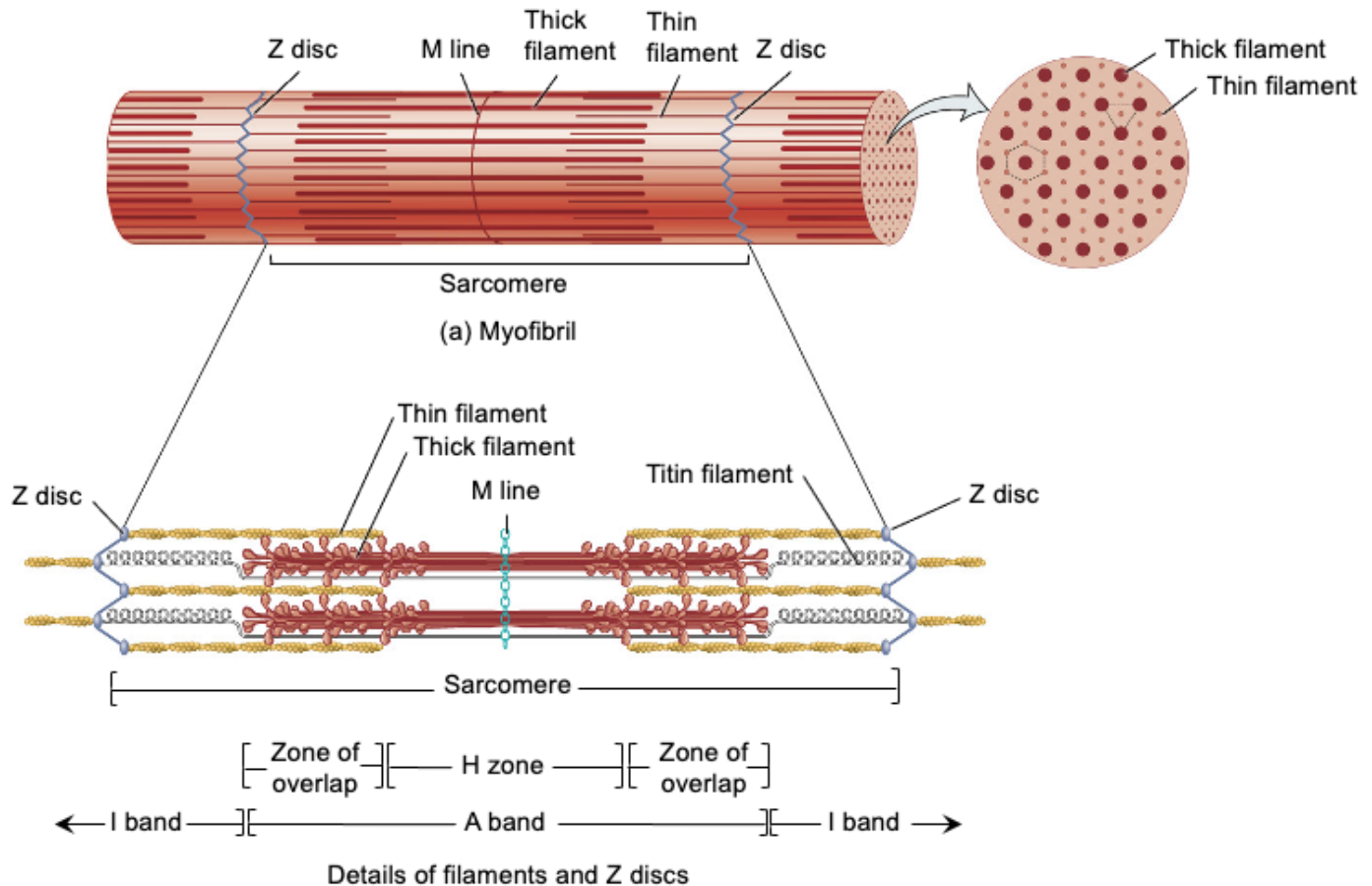


Details of a muscle fiber



Schematic representation of a muscle fiber

- The thin and thick filaments inside a myofibril do not extend the entire length of a muscle fiber. Instead, they are arranged in compartments called sarcomeres, which are the repeating units of a myofibril. Narrow, plate-shaped regions of dense protein material called Z discs (Z for the German word *zwichenscheibe* = between discs) separate one sarcomere from the next. Thus, a sarcomere extends from one Z disc to the next Z disc.



3. There Are Three Types of Muscle Proteins

A. Contractile proteins – Proteins that generate force during muscle contractions.

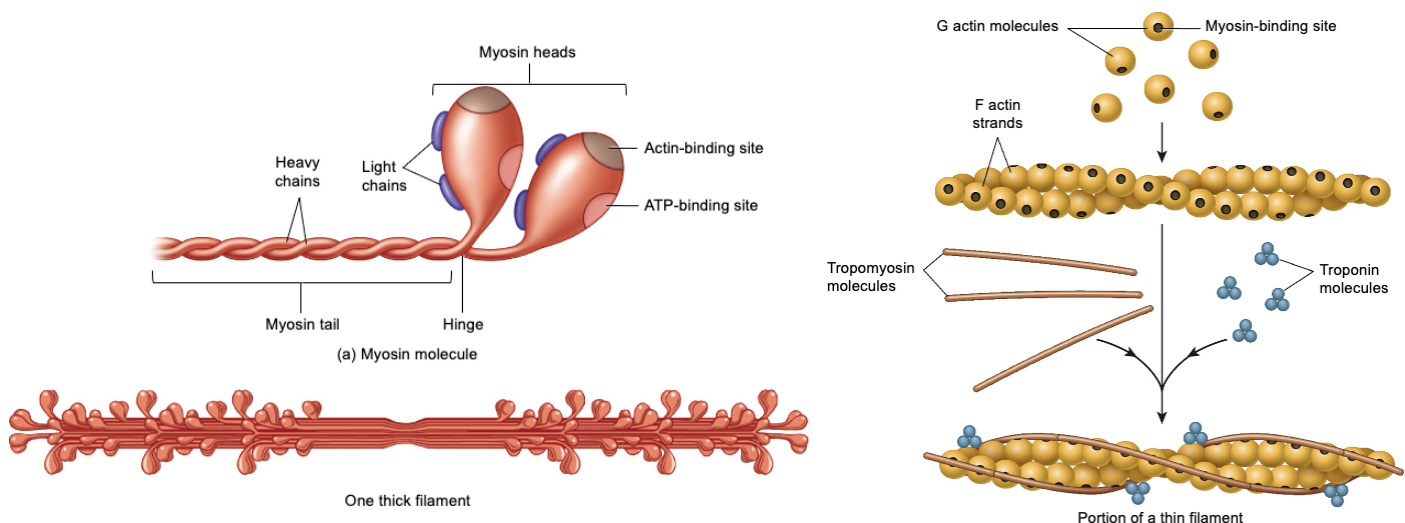
- I. Myosin – A contractile protein that makes up the thick filament. A myosin molecule consists of a tail and two myosin heads, which bind to myosin-binding sites on actin molecules of a thin filament during muscle contraction.
- II. Actin – A contractile protein that is the main component of the thin filament. Each actin molecule has a myosin-binding site to which a myosin head of a thick filament binds during muscle contraction.

B. Regulatory proteins – Proteins that help switch the muscle contraction process on and off.

- I. Tropomyosin – A regulatory protein that is a component of the thin filament. In a relaxed skeletal muscle fiber, tropomyosin covers the myosin-binding sites on actin molecules, preventing myosin from binding to actin.
- II. Troponin – A regulatory protein that is a component of the thin filament. When calcium ions (Ca^{2+}) bind to troponin, troponin undergoes a conformational

change that moves tropomyosin away from myosin-binding sites on actin molecules, and muscle contraction subsequently begins as myosin binds to actin.

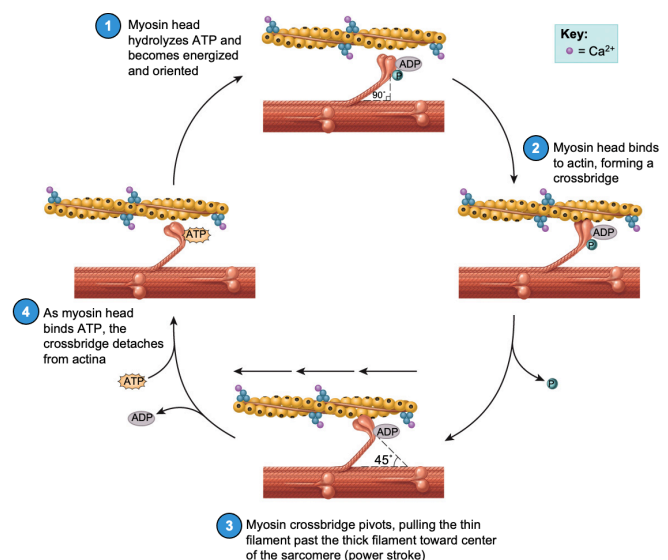
- C. Structural proteins – Proteins that keep the thick and thin filaments of the myofibrils in proper alignment, give the myofibrils elasticity and extensibility, and link the myofibrils to the sarcolemma and extracellular matrix.
- ◇ Titin – A structural protein that connects a Z disc to the M line of the sarcomere, helping to stabilize the position of the thick filament. Because it can stretch and then spring back unharmed, titin accounts for much of the elasticity and extensibility of myofibrils.
 - ◇ Alpha-actinin – A structural protein of the Z discs that attaches to actin molecules of thin filaments and to titin molecules.
 - ◇ Myomesin – A structural protein that forms the M line of the sarcomere; it binds to titin molecules and connects adjacent thick filaments to one another.
 - ◇ Nebulin – A structural protein that wraps around the entire length of each thin filament; it helps anchor the thin filaments to the Z discs and regulates the length of the thin filaments during development.
 - ◇ Dystrophin – A structural protein that links the thin filaments of the sarcomere to integral membrane proteins in the sarcolemma, which are attached in turn to proteins in the connective tissue matrix that surrounds muscle fibers. It is thought that dystrophin helps reinforce sarcolemma and helps transmit tension generated by sarcomeres to tendons.



V. Contraction and Relaxation of Skeletal Muscle Fibers

1. Sliding Filament Mechanism

- A. **ATP hydrolysis** – a myosin head includes an ATP-binding site that functions as an ATPase—an enzyme that hydrolyzes ATP into ADP (adenosine diphosphate) and a phosphate group. The energy generated from this hydrolysis reaction is stored in the myosin head for later use during the contraction cycle. The myosin head is said to be energized when it contains stored energy. The energized myosin head assumes a “cocked” position, like a stretched spring. In this position, the myosin head is perpendicular (at a 90° angle) relative to the thick and thin filaments and has the proper orientation to bind to an actin molecule. Notice that the products of ATP hydrolysis—ADP and a phosphate group—are still attached to the myosin head.
- B. **Attachment of myosin to actin** – The energized myosin head attaches to the myosin-binding site on actin and releases the previously hydrolyzed phosphate group. When a myosin head attaches to actin during the contraction cycle, the myosin head is referred to as a crossbridge. Although a single myosin molecule has a double head, only one head binds to actin at a time.
- C. **Power stroke** – After a crossbridge forms, the myosin head pivots, changing its position from a 90° angle to a 45° angle relative to the thick and thin filaments. As the myosin head changes to its new position, it pulls the thin filament past the thick filament toward the center of the sarcomere, generating tension (force) in the process. This event is known as the power stroke. The energy required for the power stroke is derived from the energy stored in the myosin head from the hydrolysis of ATP. Once the power stroke occurs, ADP is released from the myosin head.
- D. **Detachment of myosin from actin** – At the end of the power stroke, the crossbridge 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.

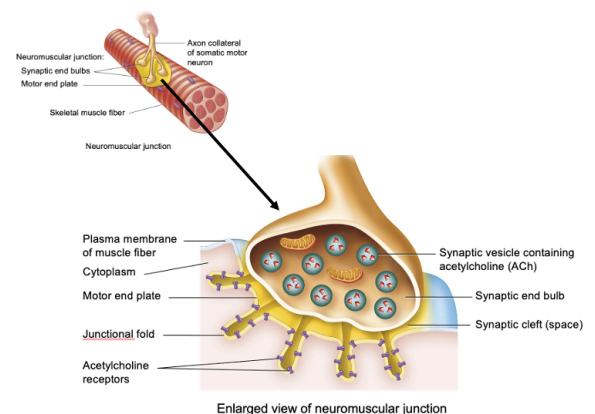


2. The Neuromuscular Junction

A. Synapse Between a Somatic Motor Neuron and a Skeletal Muscle Fiber

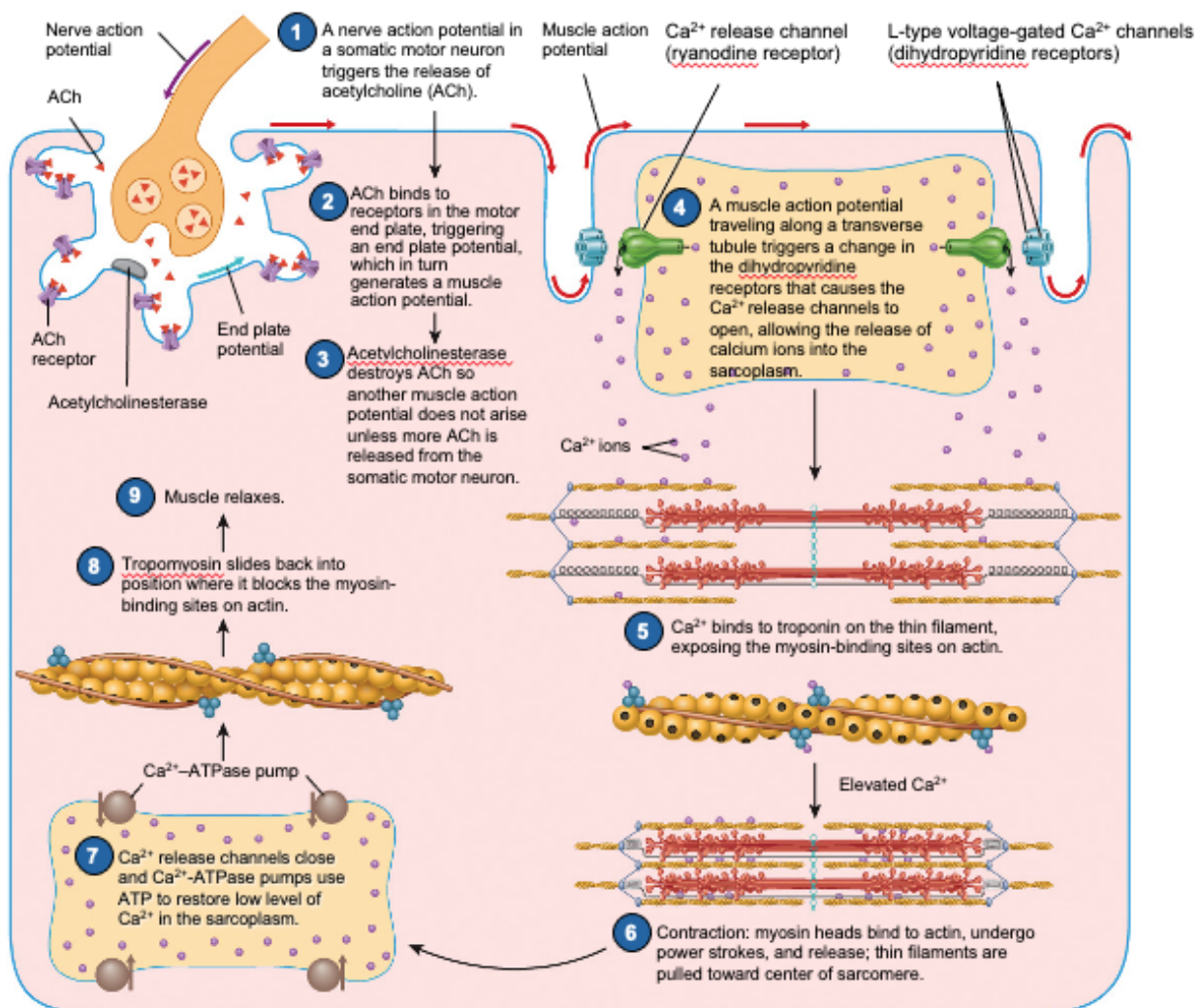
B. Motor end plate

- Before a skeletal muscle fiber can contract, it must be stimulated by a somatic motor neuron. The synapse between a somatic motor neuron and a skeletal muscle fiber is known as the neuromuscular junction (NMJ). Recall that the NMJ has three components: (1) synaptic end bulbs of a terminal branch of the somatic motor neuron; (2) a synaptic cleft; and (3) motor end plate, the region of muscle fiber membrane opposite the synaptic end bulbs. Neurotransmitter released at the NMJ, acetylcholine (ACh), has an excitatory effect on neuromuscular transmission: When an action potential occurs in a somatic motor neuron, it releases ACh molecules stored in synaptic vesicles of synaptic end bulbs. ACh then diffuses across synaptic cleft and binds to nicotinic ACh receptors on motor end plate, generating a depolarizing graded potential called: end plate potential (EPP). A single EPP is typically large enough to depolarize adjacent regions of sarcolemma to threshold, resulting in generation of a muscle action potential. Because NMJ is usually near the midpoint of muscle fiber, once muscle action potential arises, it propagates through muscle fiber membrane in both directions away from the NMJ toward ends of fiber. As muscle action potential passes through the membrane (sarcolemma and T tubules), it triggers a chain of events that ultimately leads to contraction of muscle fiber. Thus, a single action potential in a somatic motor neuron elicits a single action potential in a skeletal muscle fiber, which in turn causes skeletal muscle fiber to contract. Events just described repeat as long as nerve action potentials continue to occur in somatic motor neuron, causing the release of ACh. Once nerve action potentials in somatic motor neuron cease, ACh is no longer released and enzyme acetylcholinesterase (AChE), located on end plate membrane, breaks down any ACh that is present in synaptic cleft. Without ACh, end plate potentials are not generated, and production of muscle action potentials ends.



3. Excitation–Contraction Coupling – refers to the sequence of events that connects the muscle action potential to muscle contraction.

- 1) Somatic motor neuron delivers action potential
- 2) ACh is released from the axon terminal onto the motor end plate
- 3) ACh binds nicotinic receptors
- 4) Action potential is conducted along the muscle membrane
- 5) Sarcoplasmic reticulum is triggered to release Ca^{2+}
- 6) Ca^{2+} binds to troponin
- 7) Tropomyosin moves away from the binding site on actin
- 8) Cross-bridges are formed
- 9) Contraction occurs



Summary of the events of contraction and relaxation in a skeletal muscle fiber.

VI. ATP Production in Skeletal Muscle – Unlike most cells of the body, skeletal muscle fibers often switch between a low level of activity, when they are relaxed and using only a modest amount of ATP, and a high level of activity, when they are contracting and using ATP at a rapid pace. A huge amount of ATP is needed to power the contraction cycle, to pump Ca^{2+} into the sarcoplasmic reticulum, and for other metabolic reactions involved in muscle contraction. However, the ATP present inside muscle fibers is enough to power contraction for only a few seconds. If muscle contractions continue past that time, the muscle fibers must make more ATP. Skeletal muscle fibers have three ways to produce ATP: (1) from creatine phosphate, (2) by anaerobic glycolysis, and (3) by aerobic respiration

1. Creatine Phosphate

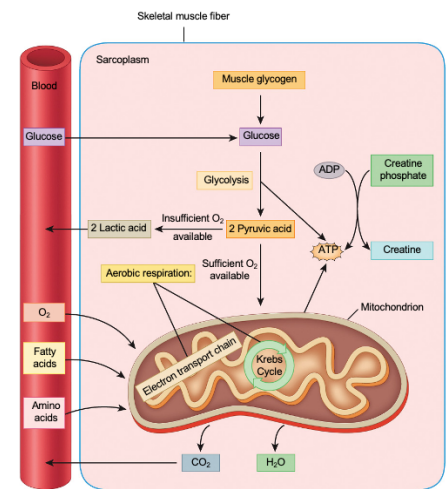
- A. First Source of ATP During Muscle Contraction
- B. This is due to the very rapid formation of ATP from creatine phosphate

2. Anaerobic Glycolysis

- A. Produces ATP When Oxygen Levels Are Low

3. Aerobic Respiration

- A. Generates ATP When Sufficient Oxygen Is Available



VII. Muscle Fatigue

1. The inability of a muscle to maintain force of contraction after a prolonged activity
2. Reasons:
 - A. Central fatigue – associated with the nervous system
 - B. Muscle physiology – energy availability, calcium, etc.

VIII. Oxygen and muscle exercise

1. Oxygen consumption will increase for a while after exercise
 - A. Initially muscle is in an oxygen debt
 - It can recover in minutes to hours
 - Important for
 - ◇ Converting lactic acid to pyruvate
 - ◇ Tissue repair
 - ◇ Resynthesizing creatine phosphate
 - B. Instead refer to recovery oxygen uptake

- IX. Types of Skeletal Muscle Fibers** – Skeletal muscle fibers are not all alike in composition and function. For example, muscle fibers vary in their content of myoglobin, the red-colored protein that binds oxygen in muscle fibers. Skeletal muscle fibers that have a high myoglobin content are termed red muscle fibers and appear darker (the dark meat in chicken legs and thighs); those that have a low content of myoglobin are called white muscle fibers and appear lighter (the white meat in chicken breasts). Red muscle fibers also contain more mitochondria and are supplied by more blood capillaries.
- Skeletal muscle fibers also contract and relax at different speeds, vary in which metabolic reactions they use to generate ATP, and differ in how quickly they fatigue. For example, a fiber is categorized as either slow or fast depending on how rapidly the ATPase in its myosin heads hydrolyzes ATP. Based on all of these structural and functional characteristics, skeletal muscle fibers are classified into three main types: (1) slow oxidative fibers, (2) fast oxidative-glycolytic fibers, and (3) fast glycolytic fibers.

1. Slow oxidative (SO) fibers

- A. Smallest in diameter and thus are the least powerful type of muscle fibers
- B. Appear dark red because they contain large amounts of myoglobin and many blood capillaries
- C. Contain many large mitochondria, generating ATP mainly by aerobic respiration, which is why they are called oxidative fibers.
- D. Said to be “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. As a result, SO fibers have a slow speed of contraction. Their twitch contractions last from 100–200 msec, and they take longer to reach peak tension.
- E. Have a high resistance to fatigue and are capable of prolonged, sustained contractions for many hours.
- F. These slow-twitch, fatigue-resistant fibers are adapted for maintaining posture and for aerobic, endurance-type activities such as running a marathon.

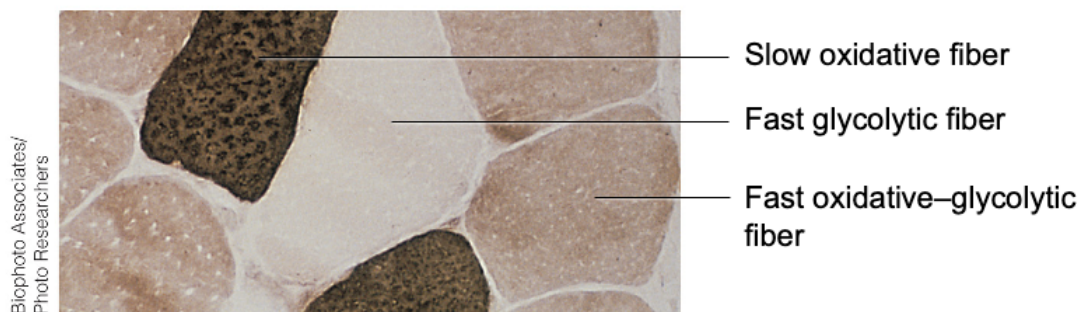
2. Fast oxidative-glycolytic (FOG) fibers

- A. Intermediate in diameter between the other two types of fibers
- B. Like slow oxidative fibers, they contain large amounts of myoglobin and many blood capillaries, giving them a dark red appearance
- C. FOG fibers can generate considerable ATP by aerobic respiration, which gives them a moderate resistance to fatigue.

- D. Because their intracellular glycogen level is high, they also generate ATP by anaerobic glycolysis.
- E. 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, which makes their speed of contraction faster. Thus, twitches of FOG fibers reach peak tension more quickly than those of SO fibers but are briefer in duration—less than 100 msec. FOG fibers contribute to activities such as walking and sprinting.

3. Fast glycolytic (FG) fibers

- A. Are largest in diameter and contain the most myofibrils.
- B. Hence, they can generate the most powerful contractions.
- C. FG fibers have low myoglobin content, relatively few blood capillaries, few mitochondria, and appear white in color.
- D. Contain large amounts of glycogen and generate ATP mainly by anaerobic glycolysis.
- E. Due to their large size and their ability to hydrolyze ATP rapidly, FG fibers contract strongly and quickly.
- F. These fast-twitch fibers are adapted for intense anaerobic movements of short duration, such as weight lifting or throwing a ball, but they fatigue quickly.
- G. Strength training programs that engage a person in activities requiring great strength for short times increase the size, strength, and glycogen content of fast glycolytic fibers.
- H. The FG fibers of a weight lifter may be 50% larger than those of a sedentary person or an endurance athlete. The increase in size is due to increased synthesis of muscle proteins. The overall result is muscle enlargement due to hypertrophy of the FG fibers. Low resistance to fatigue



LM 440x

Transverse section of three types of skeletal muscle fibers

4. Skeletal Muscle Fibers Are Distributed Differently and Recruited in a Certain Order

Most skeletal muscles are a mixture of all three types of skeletal muscle fibers; about half the fibers in a typical skeletal muscle are SO fibers. However, the proportions vary somewhat, 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. Muscles of the shoulders and arms, in contrast, are not constantly active but are used briefly now and then to produce large amounts of tension, such as in lifting and throwing. These muscles have a high proportion of FG fibers. Leg muscles, which not only support the body but are also used for walking and running, have large numbers of both SO and FOG fibers.

Within a particular motor unit, all of the skeletal muscle fibers are of the same type. The different motor units in a muscle are recruited in a specific order, depending on need. For example, if weak contractions suffice to perform a task, only SO motor units are activated. If more force is needed, the motor units of FOG fibers are also recruited. Finally, if maximal force is required, motor units of FG fibers are also called into action. Activation of various motor units is controlled by the brain and spinal cord.

Characteristic	Slow Oxidative (SO) Fibers	Fast Oxidative-Glycolytic (FOG) Fibers	Fast Glycolytic (FG) Fibers
Fiber diameter	Smallest.	Intermediate.	Largest.
Myoglobin content	Large amount.	Large amount.	Small amount.
Mitochondria	Many.	Many.	Few.
Capillaries	Many.	Many.	Few.
Color	Red.	Red-pink.	White (pale).
Capacity for generating ATP and method used	High capacity, by aerobic respiration.	Intermediate capacity, by both aerobic respiration and anaerobic glycolysis.	Low capacity, 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 the 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.

X. Cardiac Muscle

1. Characteristics

A. Intercalated discs –

- Found at junction between two muscle cells

B. Functional syncytium –

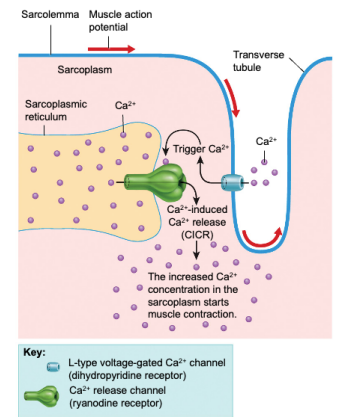
- All cells work together as a single unit

C. Autorhythmicity

- Electrical potentials are created within cardiac cells
- Does not require nervous stimulation

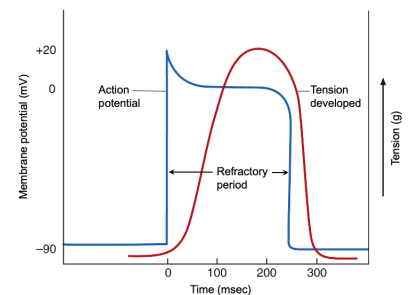
2. Excitation-contraction coupling

- Muscle action potential travels along the sarcolemma
- L-type voltage-gated Ca^{2+} open
- Ca^{2+} enters into the cell
- Triggers release of Ca^{2+} from the sarcoplasmic reticulum
 - This is referred to as a calcium induced calcium release
- Muscle contraction begins in the same way that skeletal muscle contraction occurs



3. Action potential and refractory period relationship

- Refractory period is very long
- Leads to the inability to create summation and tetany



XI. Smooth Muscle

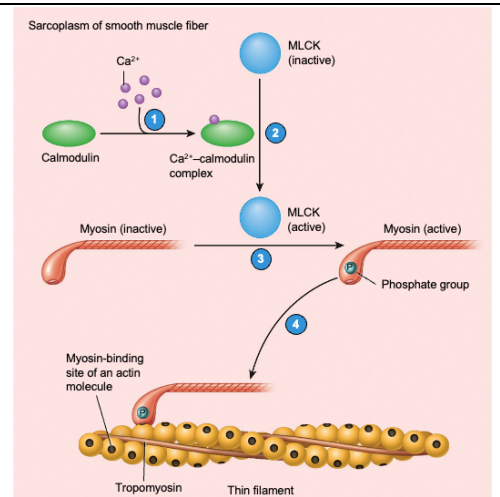
1. Contraction and relaxation in smooth muscle

- Ca^{2+} binds to calmodulin, a regulatory protein in the sarcoplasm that is similar in structure to troponin.
- The Ca^{2+} -calmodulin complex activates an enzyme called myosin light chain kinase (MLCK), which is also present in the sarcoplasm.
- Activated MLCK in turn phosphorylates (adds a phosphate group to) light chains in the myosin heads.
- The phosphorylated myosin heads bind to actin, and muscle contraction begins.

2. Contractions occur More Slowly Than in Striated Muscle

- There are several reasons why this is true
 - There are not transverse tubules in smooth muscle fibers, so it takes longer for Ca^{2+} to reach the filaments in the center of the fiber and trigger the contraction process.
 - Myosin light chain kinase works rather slowly.
 - The ATPase activity of myosin heads in smooth muscle is much slower than in striated muscle.

- The myosin heads in smooth muscle can enter a latch state, in which they stay attached to actin for a longer portion of the cross-bridge cycle compared to myosin heads in striated muscle. Although the latch state is poorly understood, it is important because it allows smooth muscle to maintain tension for long periods of time with minimal ATP consumption.



3. Autonomic nervous system regulates smooth muscle contraction

A. Done through the varicosities

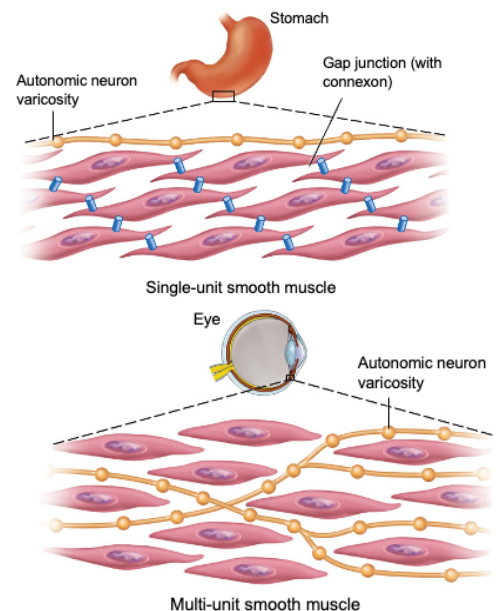
4. Two Forms of Smooth Muscle

A. Single unit

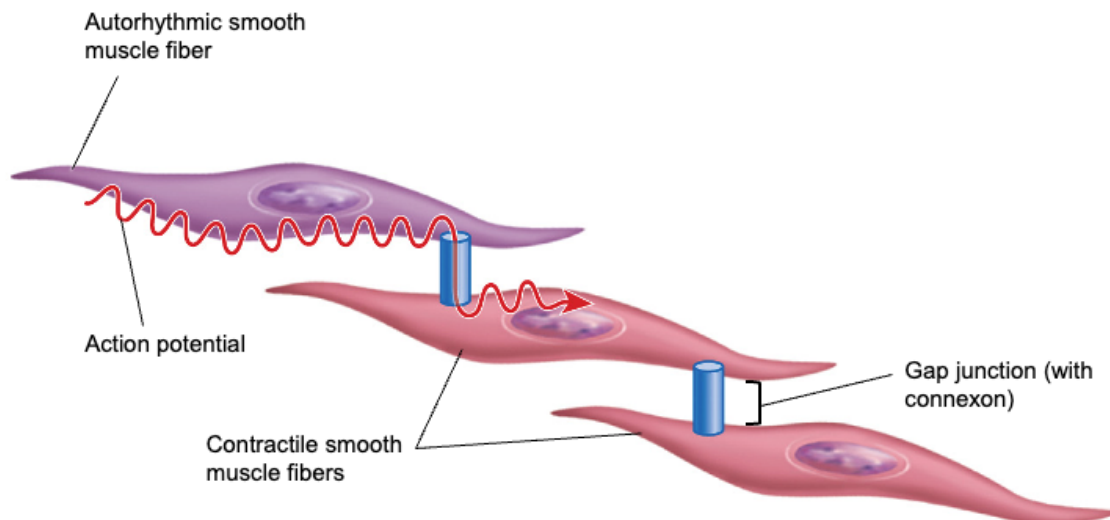
- Fibers contract together as one
- Ex. Visceral muscle

B. Multi-unit

- Fibers act independently of each other
- Ex. Pupillary muscles



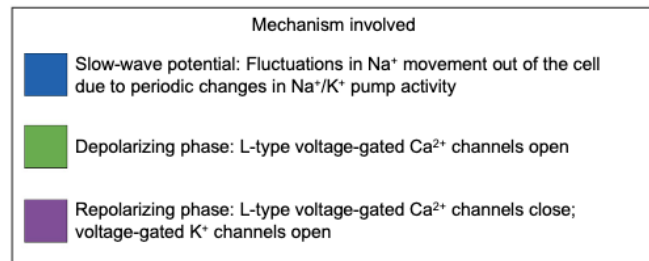
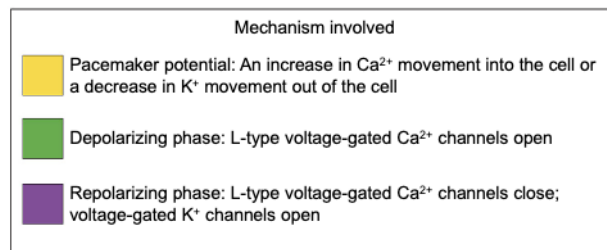
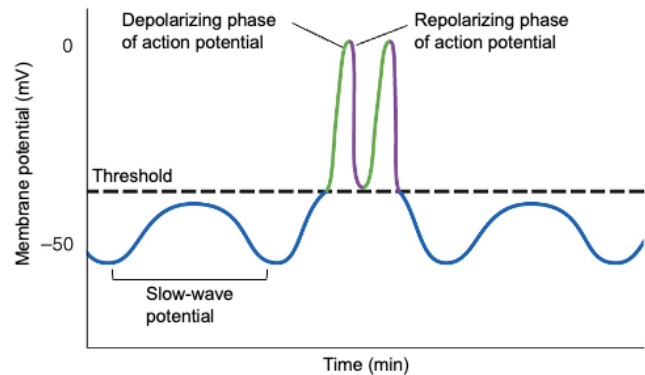
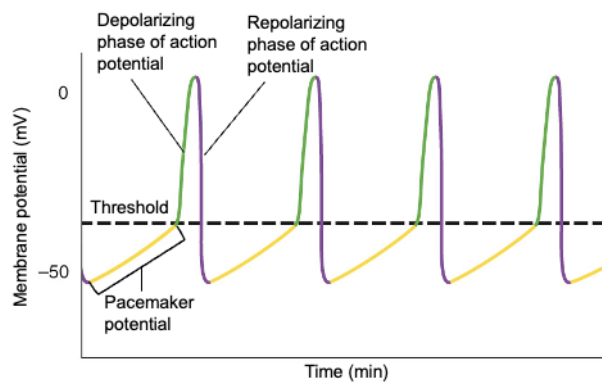
5. Smooth Muscle Can Exhibit Autorhythmicity



A. Two types of potentials exist in smooth muscles cells

▪ Pacemaker potentials

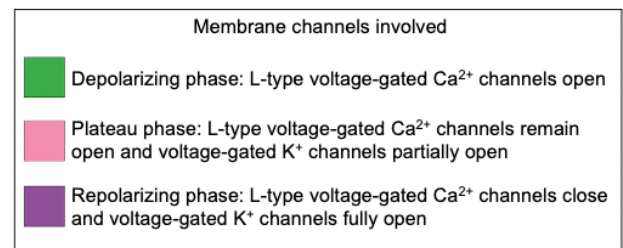
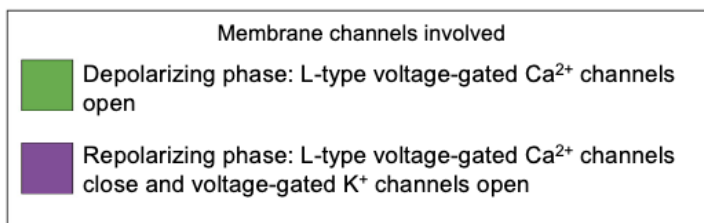
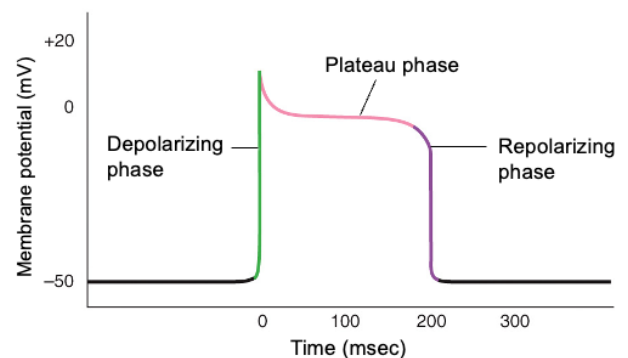
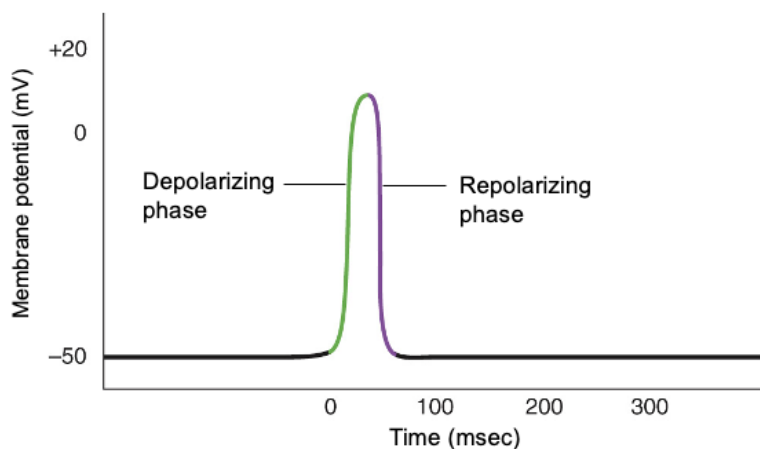
◇ Spontaneous potentials that always reach threshold



Pacemaker potential and action potential in an autorhythmic smooth muscle fiber Slow-wave potential and action potential in an autorhythmic smooth muscle fiber

▪ Slow wave potentials

◇ Constant depolarizations and repolarizations that do not necessarily reach threshold



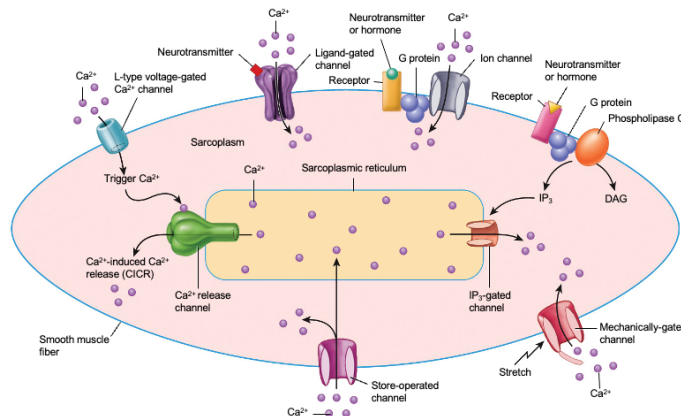
Spike potential in a contractile smooth muscle fiber

Action potential with plateau in a contractile smooth muscle fiber

6. Excitation–Contraction Coupling in Smooth

A. Variety of mechanisms all of which allow calcium to enter cell and bind to calmodulin

- Voltage-gated channels
- Ca^{2+} release channels
- Receptor-activated channels
- Inositol trisphosphate (IP_3)–gated channels
- Store-operated channels
- Mechanically-gated channels



7. Regulation

A. Autonomic nervous system

- Excitatory – promote contraction
- Inhibitory – promote relaxation

8. Stress–relaxation response

- ### A. Increased tension initially when stretched, but then after a minute or so will release the tension

XII. Regeneration of Muscle

1. Hypertrophy

- A. Enlargement of existing cells
- B. Occurs in all muscle types
- C. Can help repair damaged tissue

2. Hyperplasia

- A. Increase in the number of fibers
- B. Occurs via cell division
- C. Can occur in limited types of smooth muscle