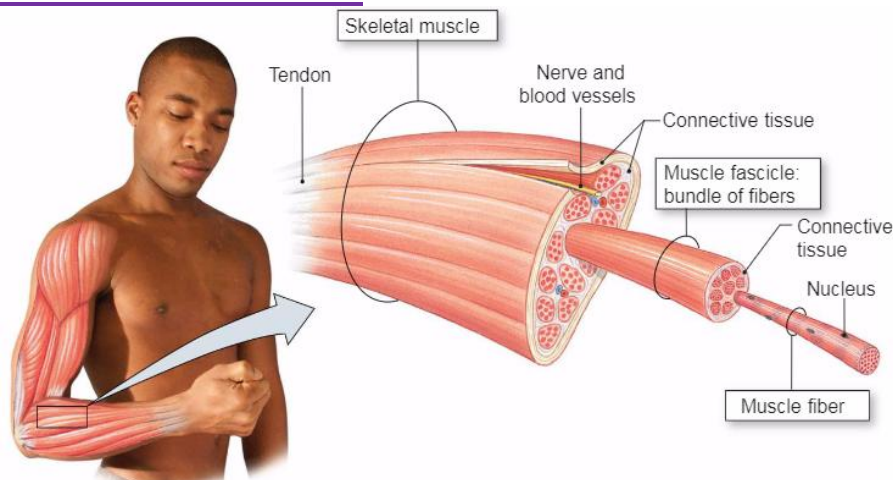
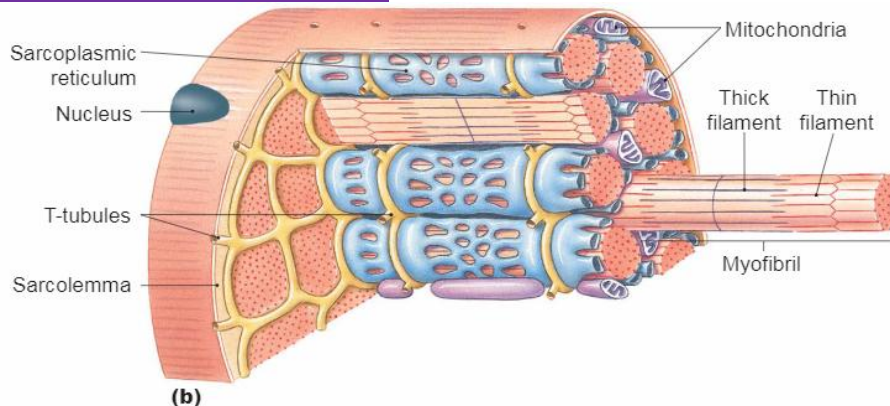




- Events at the neuromuscular junction which leads to an action potential in the muscle fiber plasma membrane:
 - An action potential will travel along a motor neuron.
 - Calcium will enter the nerve terminal through voltage-gated channels.
 - This will result in release of the neurotransmitter acetylcholine from the vesicles through exocytosis.
 - Acetylcholine will bind to its receptors found on the muscle membrane leading to influx of sodium and depolarization.
 - Propagated action potential in muscle plasma membrane.
 - Acetylcholine will be degraded from the neuromuscular junction via acetylcholine esterase.
- Excitation-contraction coupling:
 - A motor neuron will release acetylcholine at the neuromuscular junction.
 - There will be an influx of sodium initiating a muscle action potential (the threshold for the end-plate is -40 millivolts).
- Organization of the skeletal muscle:



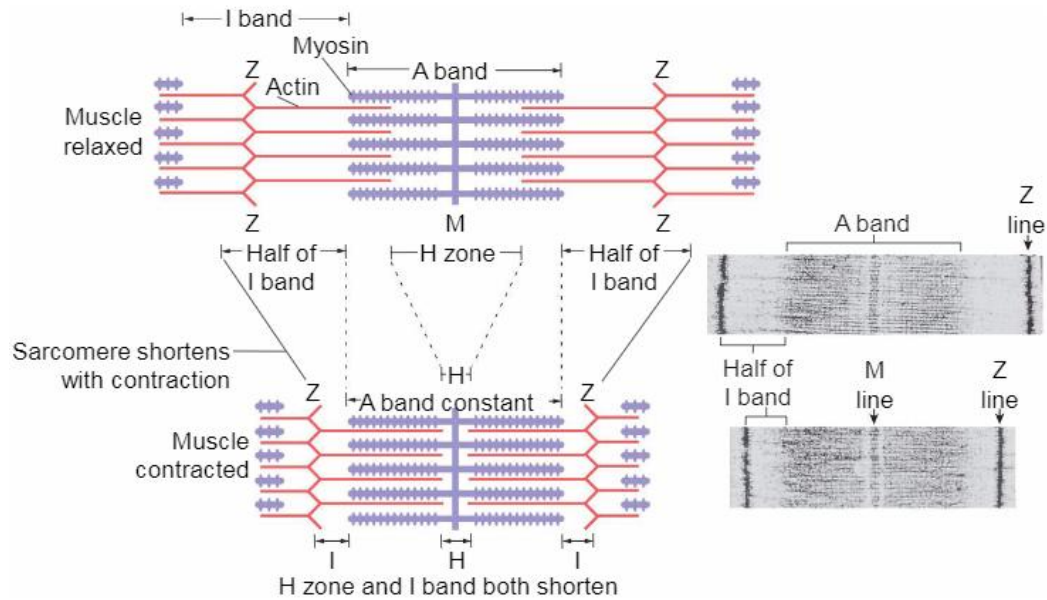
- Ultrastructure of the skeletal muscle:



- Myofibrils are composed of actin and myosin filaments:
 - Each myofibril is composed of about 1500 myosin filaments and 3000 actin filaments lying side by side. They are responsible for muscle contraction. Notice that the thick filaments are myosin and the thin filaments are actin.
 - **Light and dark bands:** light bands contain only actin filaments and are called I bands. The dark bands called A bands contain myosin filaments as well as the ends of the actin filaments.
 - **Cross-bridges:** the small projections from the sides of the myosin filaments are cross-bridges. Myosin cross-bridges interact with actin filaments causing contraction.



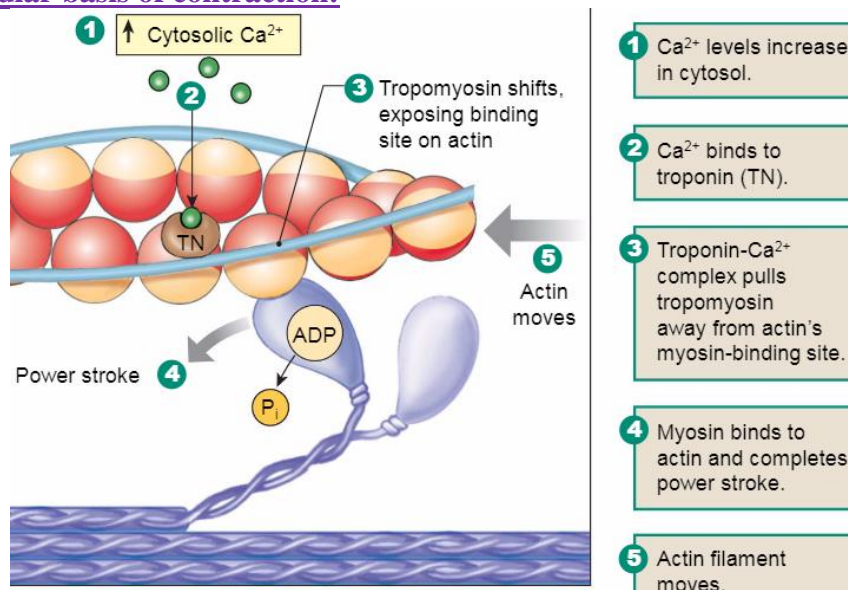
- **Z-disc:** the ends of the actin filaments are attached to Z-discs. The Z-disc passes across the myofibril and from one to another, attaching and aligning the myofibrils across the muscle fiber.
- **Sarcomere:** the portion of a myofibril that lies between two successive Z-discs.



- **Mechanism of muscle contraction:**

1. An action potential travels along a motor nerve to its endings on muscle fibers, and each nerve ending secretes a small amount of the neurotransmitter substance acetylcholine.
2. The acetylcholine acts on a local area of the muscle membrane to open acetylcholine-gated cation channels, which allows mainly sodium ions but also calcium ions to flow into the muscle fiber causing a local depolarization. The local depolarization in turn leads to opening of voltage-gated sodium channels resulting in an action potential.
3. The action potential travels along the muscle fiber membrane, causing the sarcoplasmic reticulum to release calcium ions into the myofibrils that have been stored in the sarcoplasmic reticulum.
4. The calcium ions initiate attractive forces between the actin and myosin filaments, causing them to slide together; this is the contractile process.
5. The calcium ions are continually pumped back into the sarcoplasmic reticulum, where they remain stored until a muscle action potential arrives; this removal of calcium ions from the myofibrils causes contraction to cease.

- **The molecular basis of contraction:**



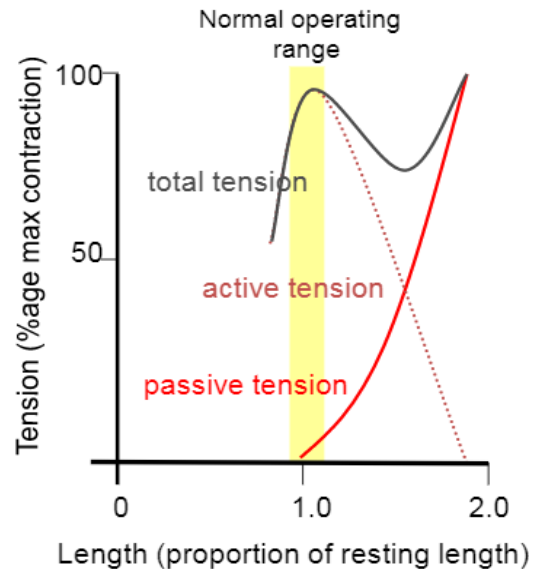


- **Isotonic vs isometric muscle contractions:**

- **Isotonic contraction (the muscle has the same tone but its length will change):** a weight/ load can be moved.
- **Isometric contraction (the muscle has the same length but the tone can be changed):** no movements occurs (maintenance of posture and supports objects in a fixed position).

- **Length-tension relation foe skeletal muscle:**

- Active tension cannot be measured directly.
- **What can be measured?**
 - ✓ Passive tension: tension needed to extend a resting muscle.
 - ✓ Total tension: active and passive tensions combined together.
 - ✓ Therefore, active tension = total tension – passive tension
 - ✓ Notice that active tension falls away linearly with increasing length.



- **Tension as a function of sarcomere length:**

- Stress is used to compare tension (force) generated by different sized muscles.
- In skeletal muscles, maximal active stress is developed at normal resting length (2mm).
- At longer lengths, stress declines.
- At shorter lengths, stress also declines.
- Cardiac muscle normally operates at lengths below optimal length.

- **Load vs velocity of contraction:**

no afterload: →

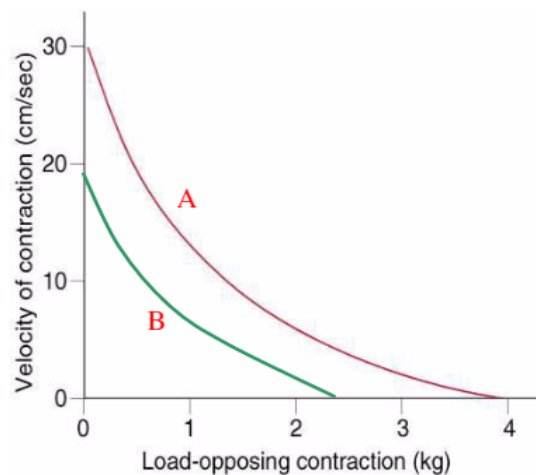
- maximum velocity at minimum load

increased afterload: →

- contraction velocity decreases

contraction velocity is zero →

when afterload = max force of contraction



A: larger, faster muscle (white muscle)

B: smaller, slower muscle (red muscle)

- **Speed of twitch contraction:**

- **Speed of contraction determined by V_{max} of myosin ATPase:**

- ✓ Fast, white muscle fibers (high V_{max}):
 - ❖ Rapid cross-bridge cycling.
 - ❖ Rapid rate of shortening.
- ✓ Slow, red muscle fibers (low V_{max}):
 - ❖ Slow cross bridge cycling.
 - ❖ Slow rate of shortening.



- Concentration difference of ions across a selectively permeable membrane creates membrane potential (diffusion potential):

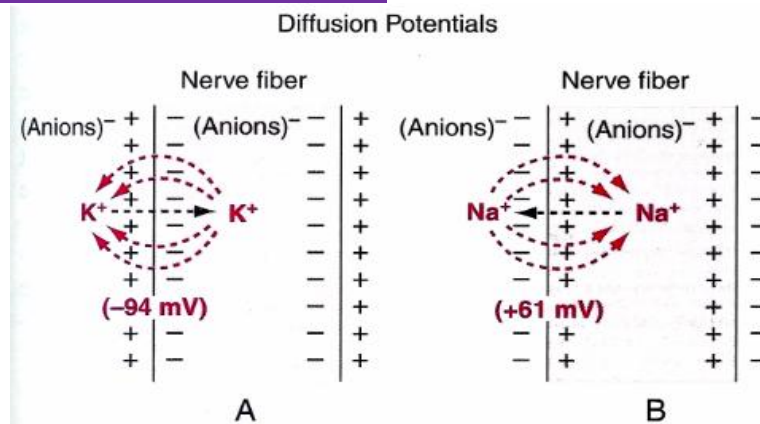


FIGURE 5 - 1

A, Establishment of a diffusion potential across a cell membrane, caused by diffusion of potassium ions from inside the cell to the outside through a membrane selectively permeable only to potassium.
 B, Establishment of a diffusion potential when the membrane is permeable only to sodium ions. Note that the internal membrane potential is negative when potassium ions diffuse and positive when sodium ions diffuse because of opposite concentration gradients of these two ions.

- Electrical signals: Nernst equation

- It describes the membrane potential that a single ion would produce if the membrane is permeable to only that ion:

$$\checkmark E = \pm 61 \times \log \frac{(\text{Concentration inside})}{(\text{Concentration outside})}$$

- Membrane potential is influenced by:
 - ✓ Concentration gradient of ions.
 - ✓ Membrane permeability to those ions.

- Electrical signals: GHK equation

- Predicts membrane potential that results from the contribution of all ions that can cross the membrane:

$$\checkmark V_m = 61 \log \frac{P_K[K^+]_{out} + P_{Na}[Na^+]_{out} + P_{Cl}[Cl^-]_{in}}{P_K[K^+]_{in} + P_{Na}[Na^+]_{in} + P_{Cl}[Cl^-]_{out}}$$

- Electrical signals: myelinated axons

- Saltatory conduction: action potentials appear to jump from one node of Ranvier to the next. Notice that only the nodes have Na⁺ voltage-gated channels.

- Electrical signals: action potential

- Speed of action potential in neuron is influenced by:

- ✓ Diameter of axon: larger axons are faster.
- ✓ Resistance of axon membrane to ion leakage out of the cell: myelinated axons are faster.

- Graded potentials:

- ✓ Local change in membrane potential that cause the change in the permeability of ions.
- ✓ Small; specialized areas of membrane; non-propagated.
- ✓ Examples are: post-synaptic potentials, receptor potential, end-plate potential, pacemaker potential and slow-wave potentials.
- ✓ Graded potentials decrease in strength as they spread out from the point of origin.

**TABLE 8-3****Comparison of Graded Potential and Action Potential in Neurons**

	GRADED POTENTIAL	ACTION POTENTIAL
Type of signal	Input signal	Regenerating conduction signal
Occurs where?	Usually dendrites and cell body	Trigger zone through axon
Types of gated ion channels involved	Mechanically, chemically, or voltage-gated channels	Voltage-gated channels
Ions involved	Usually Na ⁺ , Cl ⁻ , Ca ²⁺	Na ⁺ and K ⁺
Type of signal	Depolarizing (e.g., Na ⁺) or hyperpolarizing (e.g., Cl ⁻)	Depolarizing
Strength of signal	Depends on initial stimulus; can be summed	All-or-none phenomenon; cannot be summed
What initiates the signal?	Entry of ions through channels	Above-threshold graded potential at the trigger zone
Unique characteristics	No minimum level required to initiate	Threshold stimulus required to initiate
	Two signals coming close together in time will sum	Refractory period: two signals too close together in time cannot sum
	Initial stimulus strength is indicated by frequency of a series of action potentials	