

Temperature Regulation

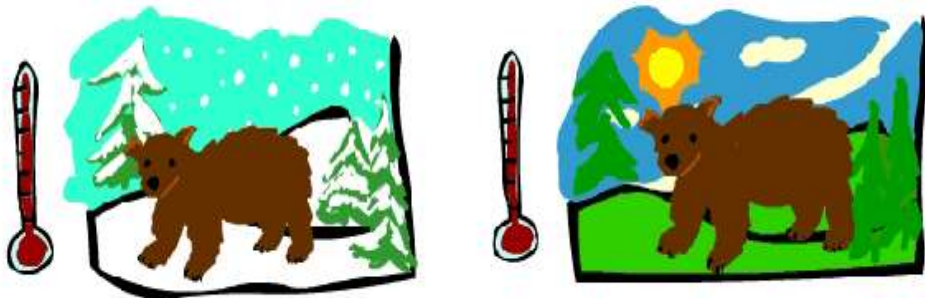


Lec.Dr.Ruwaidah F. Khaleel

Temperature Regulation

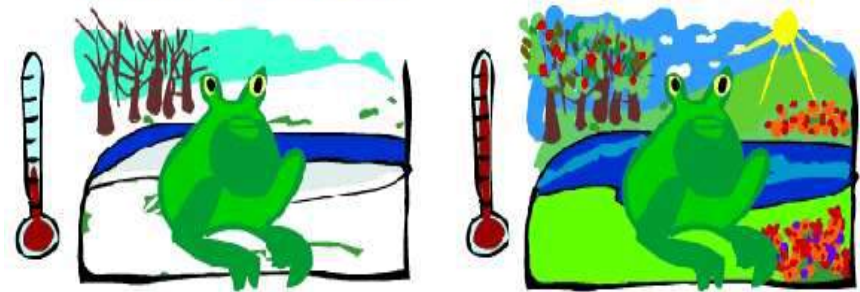
- On the basis of body temperature animals are classified as:
 - Warm blooded (homeothermic) animals which are capable of maintaining a relatively constant body temperature in spite of great variations of external temperature.
 - Cold blooded (poikilothermic) animals in which the body temperature varies with that of the environment. Poikilotherms include invertebrates and aquatic animals like **fishes and amphibians**.

Warm-blooded ANIMALS



Body temperature stays the same when its cold or hot outside.

Cold-blooded ANIMALS



Body temperature depends on whether its cold or hot outside.

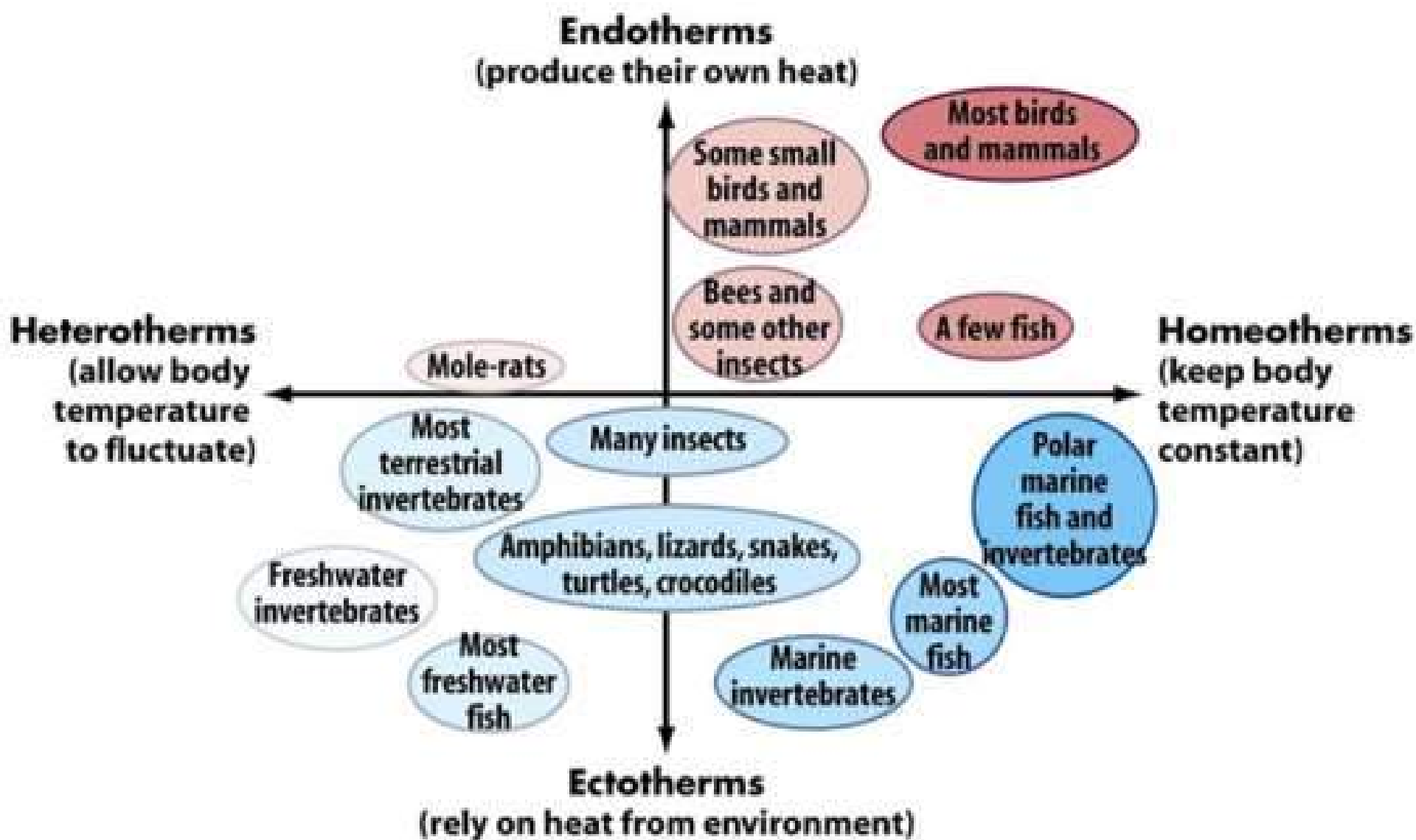
| Endothermic | Ectothermic |
|--|---|
| Warm-blooded animals | Cold blooded |
| Includes birds and mammals Maintain, a nearly constant internal temperature | Include fish, amphibians, and reptiles. Having internal body temperature that changes with the temperature of the environment. |
| Do not change with the temperature or environment | تكسب الحرارة They must gain heat to perform internal activities |
| When the outside temperature is too hot an endothermic animal can cool off | If the environment is cold, ectothermic animals become slow moving and sluggish |
| Example: sweating, panting, changing position and changing location Sweating and panting generates heat loss through evaporating water. Changing position and location allow the animal to find a cooler environment in the shade or shelter الظل أو المأوى | (for ex: digestion) تمتع بدفء الشمس Some animals must bask in the sun (for examples snakes or lizards) or move to a warmer area (for ex: some fish) before they can move about to hunt for food. If the temperature gets too hot ectothermic animals will need to find a cooler temperature or burrow in the ground to keep its body cool تحفر في الأرض |

heterothermic animals

- Which do not maintain constant body temperature, but during activity they show endothermic regulation, they are also called **facultative endotherms** since they are capable of regulating physiological temperature at certain time only.
- it is used as a way to dissociate the fluctuating metabolic rates seen in some small mammals and birds (e.g. [bats](#) and [hummingbirds](#)),

طريقة لفصل معدلات الأيض المتقلبة





The habitats of animals can be divided into

1. Animals living in terrestrial environment have an acute problem of temperature because of the radiant heat of the sun. Also air has a low specific heat and so it gains or loses heat rapidly.
2. Animals living in aquatic habitats do not face acute thermal problems because water has a high specific heat and it gains or loses heat slowly, thus making little changes in temperature.
3. Aerial animals like birds have a higher limit of thermal tolerance (35°C - 42°C) due to higher rate of metabolism.



Body Temperature

- The normal range of human body temperature is (**36 C° to 38C°**), with an average oral temperature of (**37C°**).
- Within a **24-hour** period, an individual's temperature fluctuates from **1C° to 2C°**,
- With the lowest temperatures-occurring **during sleep**.
- At either end of the **age spectrum**, however, temperature regulation may not be as **precise** as it is In older children or younger adults.
- Infants have more surface- area (skin) relative to volume and are likely to lose heat more rapidly.



- In the **elderly**, the mechanisms that maintain body temperature may not function as efficiently as they once did, and changes in environmental temperature may not be compensated for as quickly or effectively. قد لا يتم تعويضهم.
- This is especially important to remember when caring for patients who are very young or very old.



Heat Production

- **Cell respiration**: the process that releases energy from food to produce ATP, also produces heat as one of its energy products.
 - Although cell respiration takes place constantly, ^{بإستمرار} many factors influence the rate of this process:
 1. **The hormone thyroxin (and T3)**: produced by the thyroid gland, increases the rate of cell respiration and heat production. The secretion of thyroxin is regulated by the body's rate of energy production,
 - The metabolic rate
 - When the metabolic rate decreases
- ↓
- the thyroid gland is stimulated to secrete more thyroxin.
- ↓
- As thyroxin increases the rate of cell respiration,
- ↓
- a negative feedback mechanism ^{يمنع المزيد من إفراز} inhibits further secretion until metabolic rate decreases again.



2. In stress situations

- Epinephrine and norepinephrine are secreted by the adrenal medulla



- The sympathetic nervous system becomes more active.



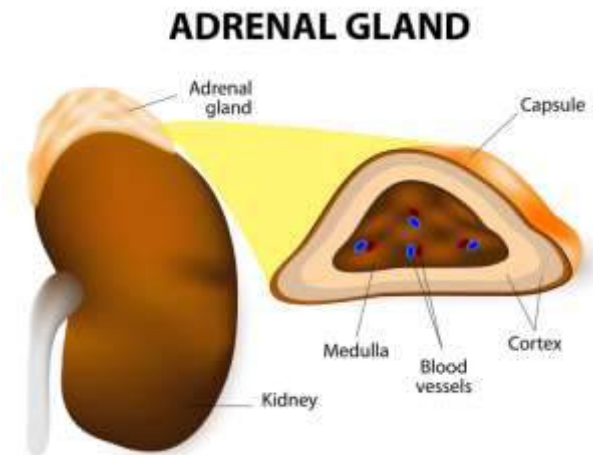
- Epinephrine increases the rate of cell respiration, especially in organs such as the **heart, skeletal muscles, and liver.**



- Sympathetic stimulation also increases the activity of these organs.



- The increased production of ATP ^{لتلبية المطالب} to meet the demands ^{حالة الاجهاد} of the stress situation also means that more heat will be produced.



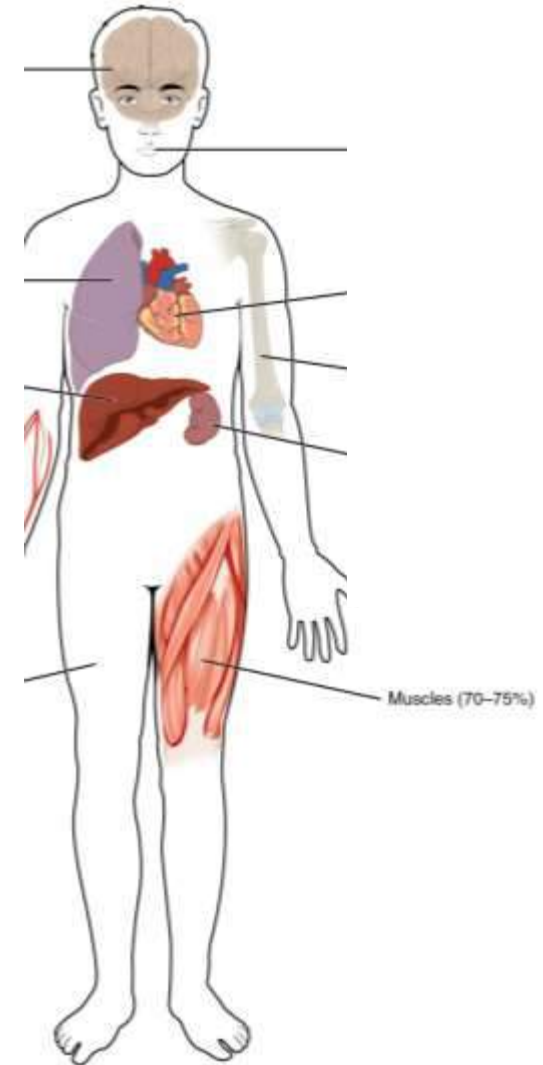
3. Organs that are normally active

(producing ATP) هي مصادر هامة للحرارة
are significant

sources of heat when the body is at rest. for example:

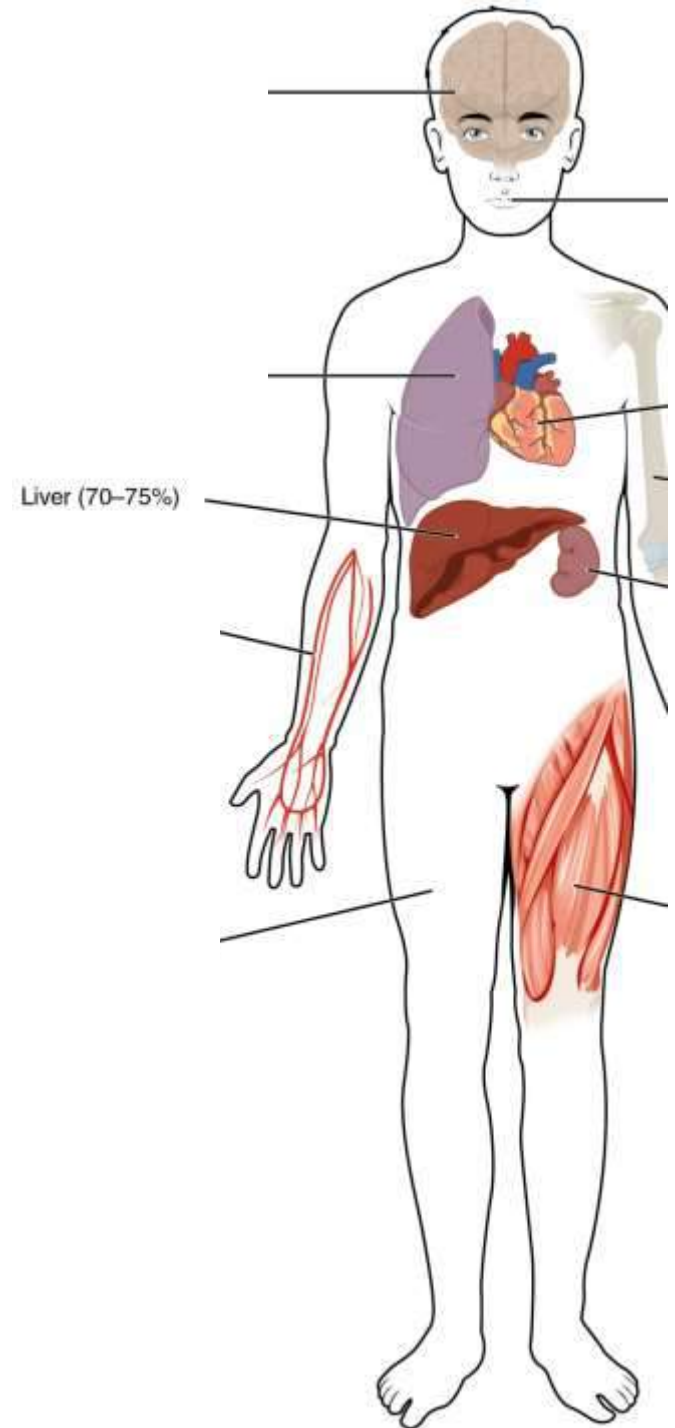
1. The skeletal muscles: are usually
In a state of slight contraction
called muscle tone.

- Because even slight contraction requires ATP, the muscles are also producing heat.
- This amounts to about 25% of the total body heat at rest and much more during exercise, when more ATP is produced.



2. The liver

- Is another organ that is continually active, producing ATP to supply energy for its many functions. As a result, the liver produces as much as **20%** of the total body heat at rest. The heat produced by these active organs is dispersed throughout the body by the blood. في جميع أنحاء



4. The intake of food also increases heat production, because:

- A. The metabolic activity of the digestive tract is increased.
- B. Heat is generated as the digestive organs produce ATP for ^{الحركة الدودية} **peristalsis** and for the **synthesis of digestive enzymes**.

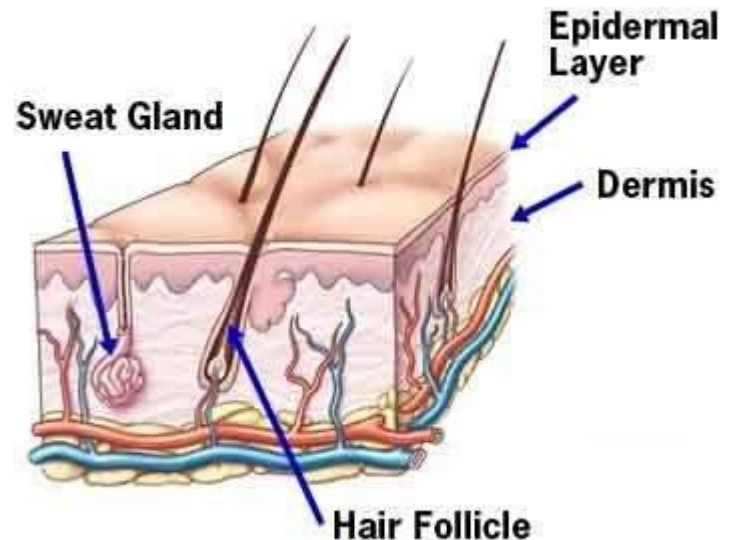


5. Changes In body temperature also have an effect on metabolic rate and heat production. This becomes clinically Important when a person has a fever, an abnormally high body temperature.

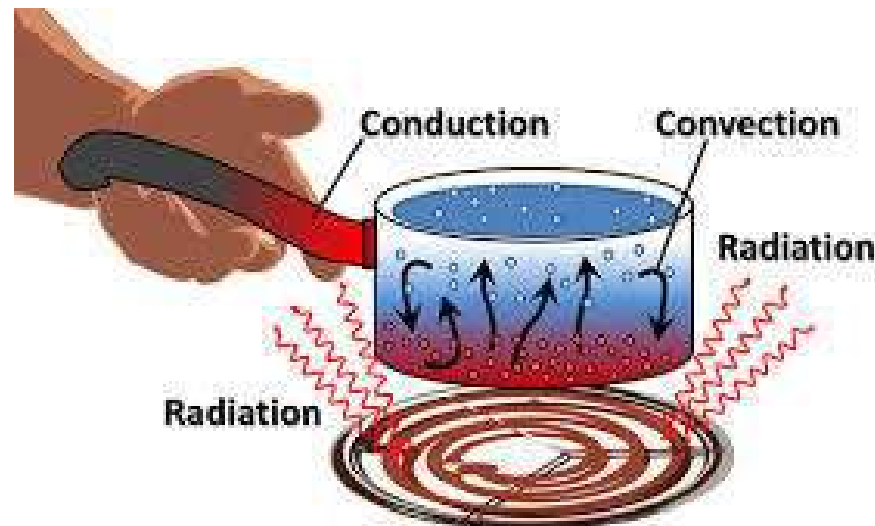


Heat Loss through the Skin

- Because the skin covers the body, most body heat is lost from the skin to the environment.
- When the environment is cooler than body temperature (as it usually is), heat loss is unavoidable. لا مفر منه
- **The amount of heat that is lost is determined by:**
 1. Blood flow through the skin that influences the amount of heat lost by the processes of radiation, conduction, and convection.
 2. The activity of sweat glands.



- **Radiation** means that heat from the body is transferred to cooler objects not touching the skin.
- **Conduction** is the loss of heat to cooler air or objects, such as clothing, that touch the skin.
- **Convection**^{الحمل الحراري} means that air currents move the warmer air away from the skin surface and facilitate the loss of heat.

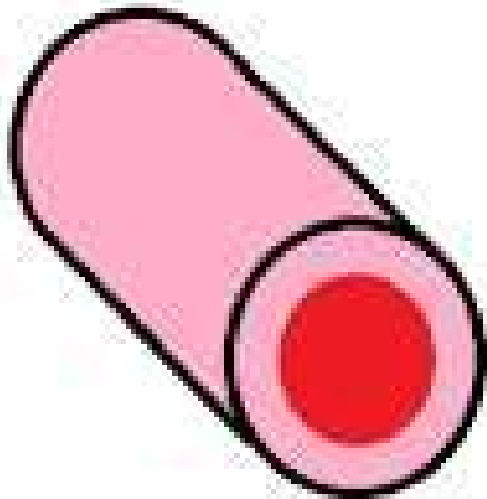


تضييق الوعاء

- In a cold environment, **vasoconstriction** decreases blood flow through the dermis and thereby decreases heat loss.

توسيع الوعاء

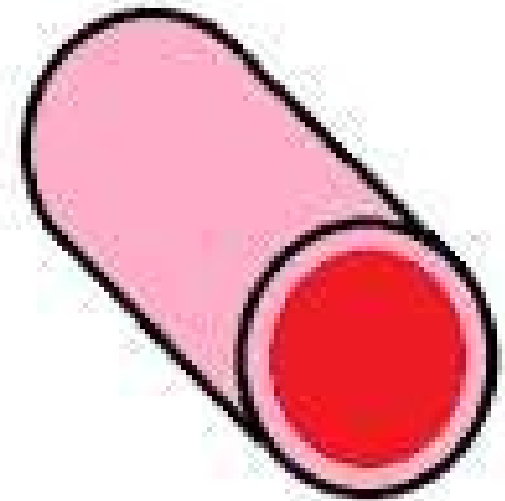
- In a warm environment, **vasodilation** in the dermis increases blood flow to the body surface and loss of heat to the environment.



Normal Cross Section

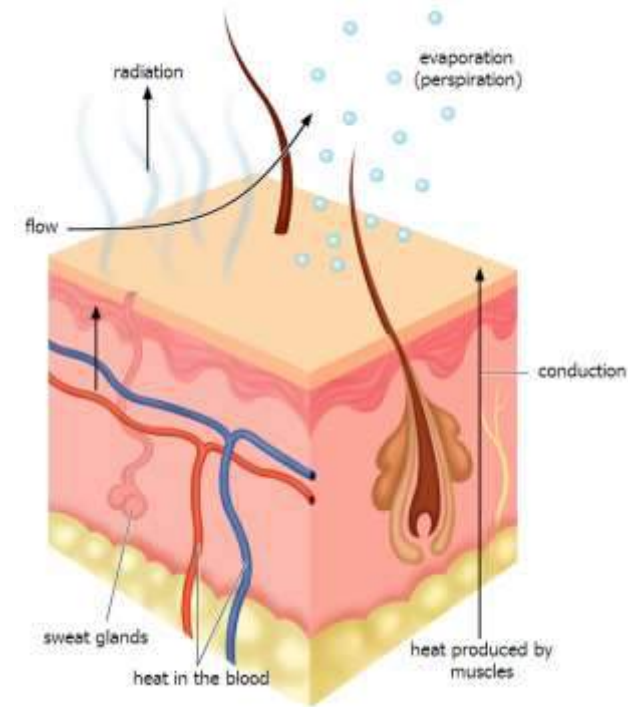


Vasoconstriction



Vasodilation

- The other mechanism by which heat is lost from the skin is sweating.
- The **sweat glands** secrete sweat (water) onto the skin surface and ^{زيادة حرارة الجسم} excess body heat evaporates the sweat.
- Sweating is most efficient when the humidity of the surrounding air is low.
- **Humidity:** ^{الرطوبة} is the percentage of the maximum amount of water vapor the atmosphere can contain.
- **A humidity reading of 90%** means that the air is already 90% saturated with water vapor and can hold little more. In such a situation, sweat does not readily evaporate, but instead remains on the skin even as more sweat is secreted.
- **If the humidity is 40%,** however, the air can hold a great deal more water vapor, and sweat evaporates quickly from the skin surface, removing excess body heat.
- **In air that is completely dry,** a person may tolerate a temperature of 75C ° for nearly 1 hour.



Heat Loss through the Respiratory Tract

- Heat is lost from the respiratory tract as the warmth of the respiratory mucosa evaporates some water from the living epithelial surface. The water vapor formed is exhaled, and a small amount of heat is lost.
- Animals such as **dogs** that do not have numerous sweat glands often pant in warm weather.

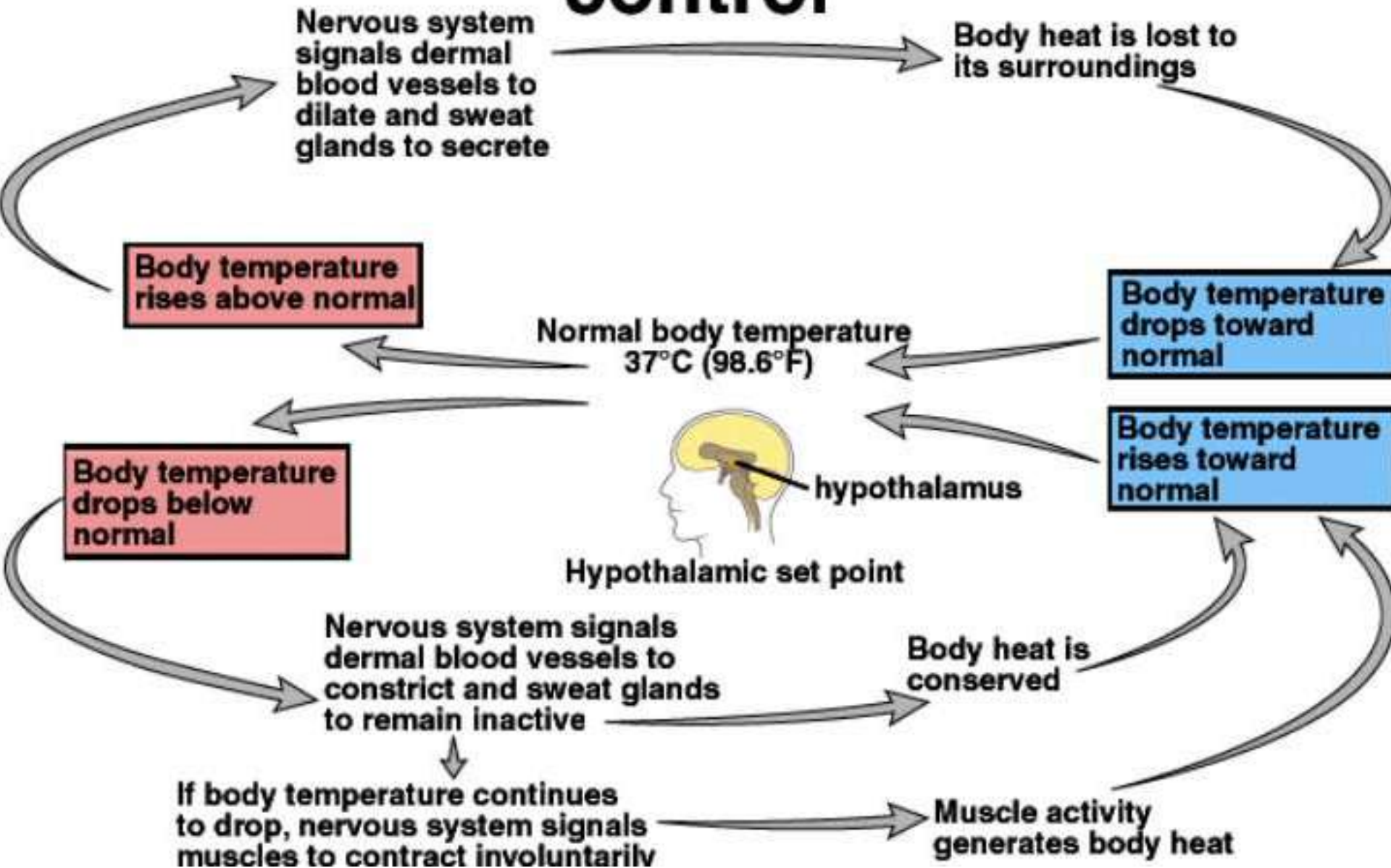


Heat loss through the Urinary and Digestive Tracts

- When excreted, urine and feces are at body temperature, and their elimination results in a very small amount of heat loss.



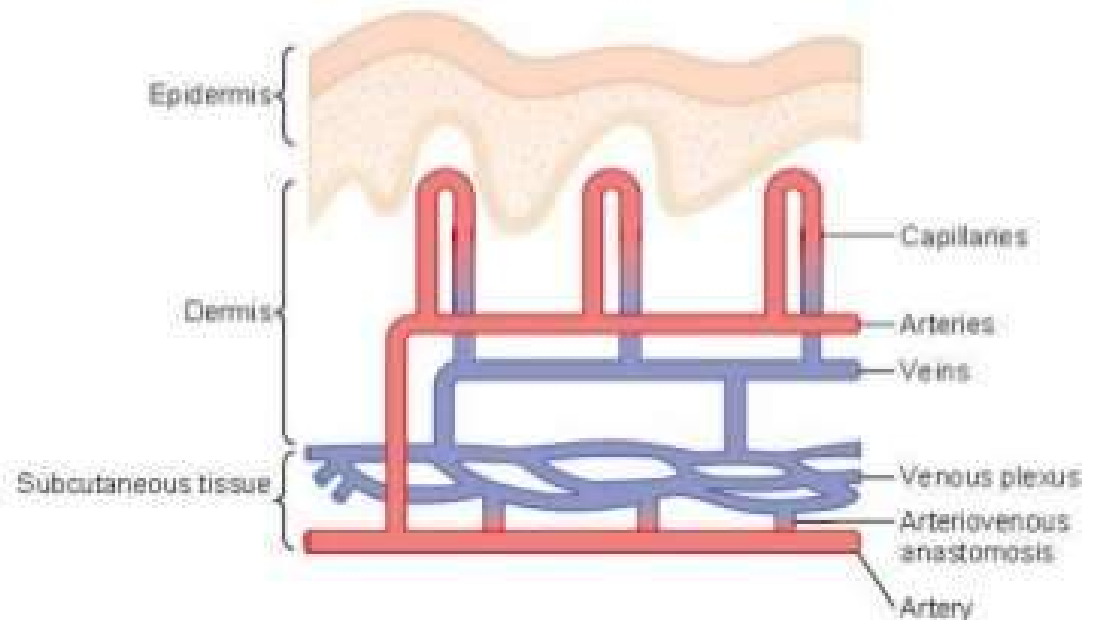
Homeostasis and temperature control



آلية كسب الحرارة

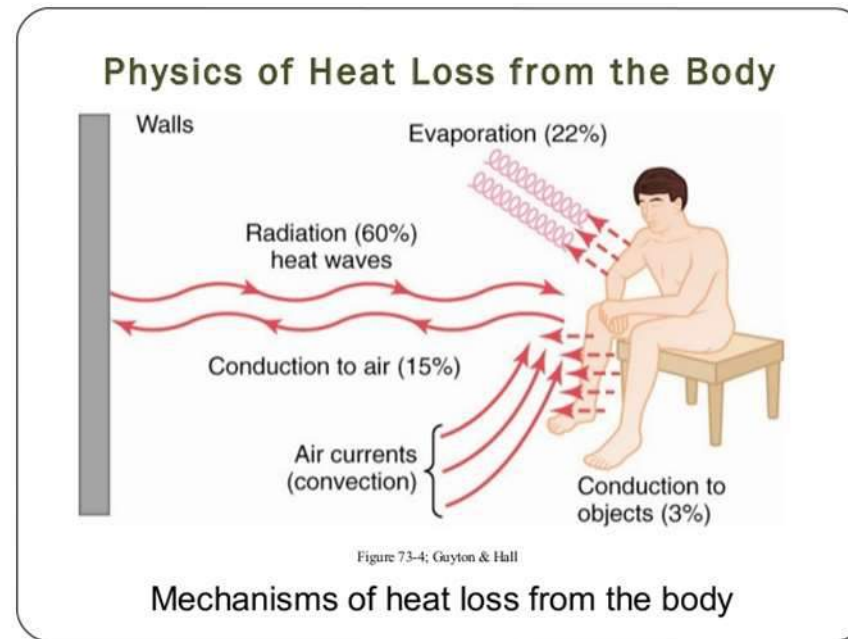
Heat gain mechanism

- Shivering رجفة
- Increase in metabolism by epinephrine, nor-epinephrine and thyroxin
- Cutaneous vasoconstriction



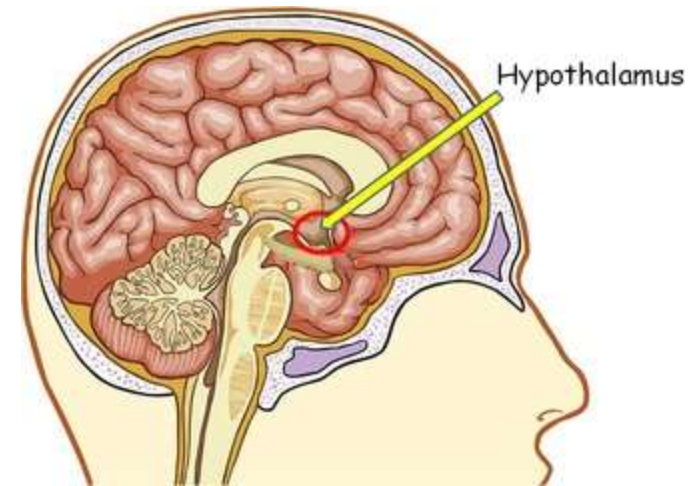
Heat loss mechanism

- Evaporation of sweat
- Radiation
- Conduction and convection
- Cutaneous vasodilation
- Decrease in metabolism through respiration

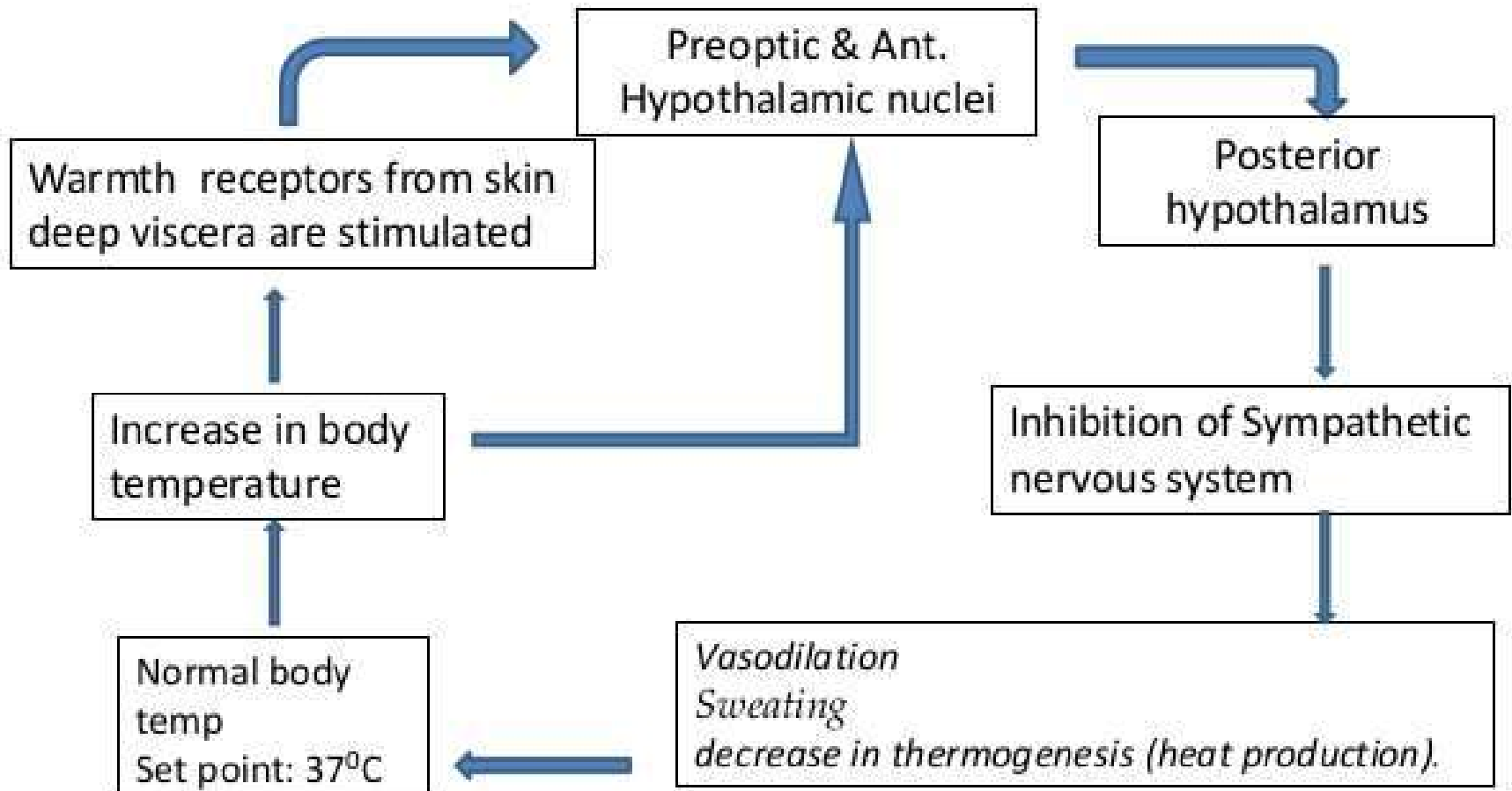


Regulation of Body Temperature - Role of the Hypothalamus

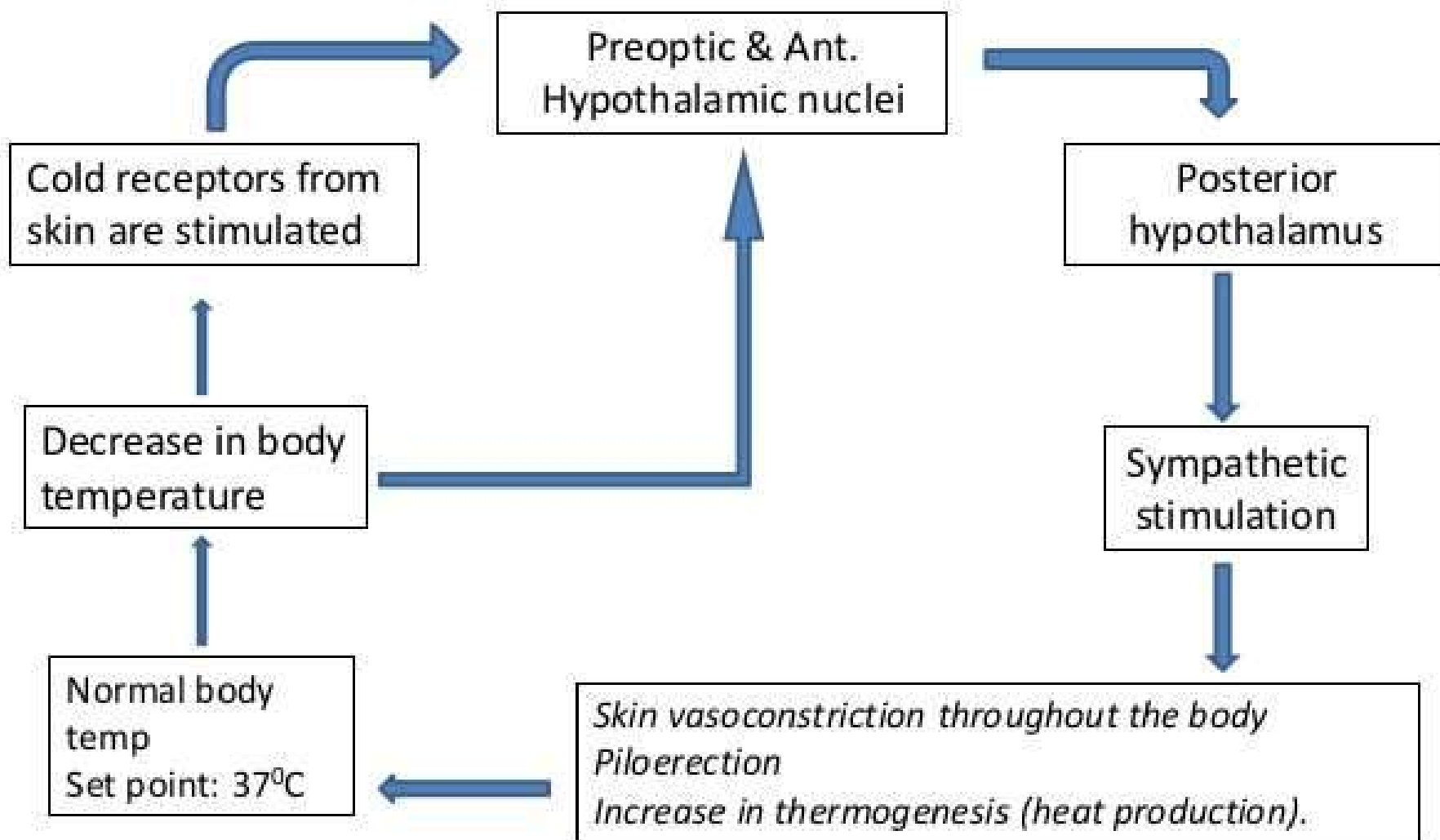
- **Receptors:** warmth & cold receptors from skin, deep tissues, spinal cord and hypothalamus
- **Heat loss center** - Preoptic & Anterior hypothalamic nuclei
- **Heat gain center** - Posterior hypothalamus
- Set point: 37°C in hypothalamus
- $\pm 0.1^{\circ}\text{C}$ cause hypothalamus to activate heat loss or heat gain mechanism



Temperature-decreasing mechanisms when the body is too hot



Temperature-increasing mechanisms when the body is too cold



Abnormalities of body temperature regulation

Hypothermia: decrease in body temp below normal range

Hyperthermia: increase in body temp above normal range



ضربة الشمس

Heatstroke

- Occurs when body temp rises beyond the critical temprature ranges from 105 to 108°F
- Symptoms:
 1. Dizziness اضطراب في البطن
 2. Abdominal distress,
 3. Vomiting
 4. Delirium هذيان
 5. Loss of consciousness
 6. Circulatory shock
 7. Death



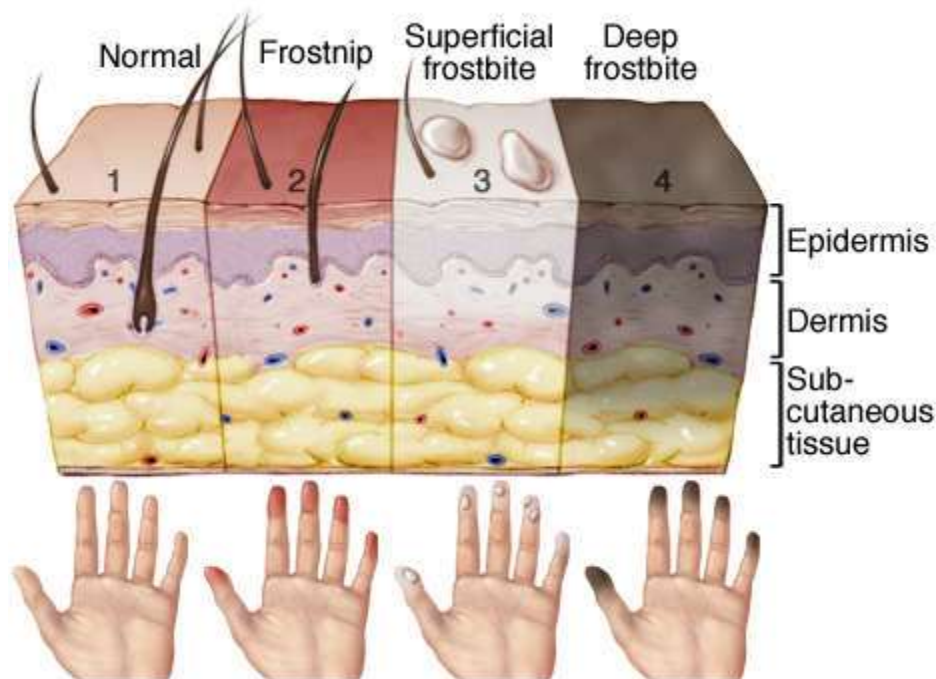
Hypothermia

- Person who is immersed in ice water for **20 to 30 minutes** ordinarily dies because of **heat fibrillation** الرجفان الحراري
- The body temperature has fallen below **85 F°**, the ability of the hypothalamus to regulate temperature is lost



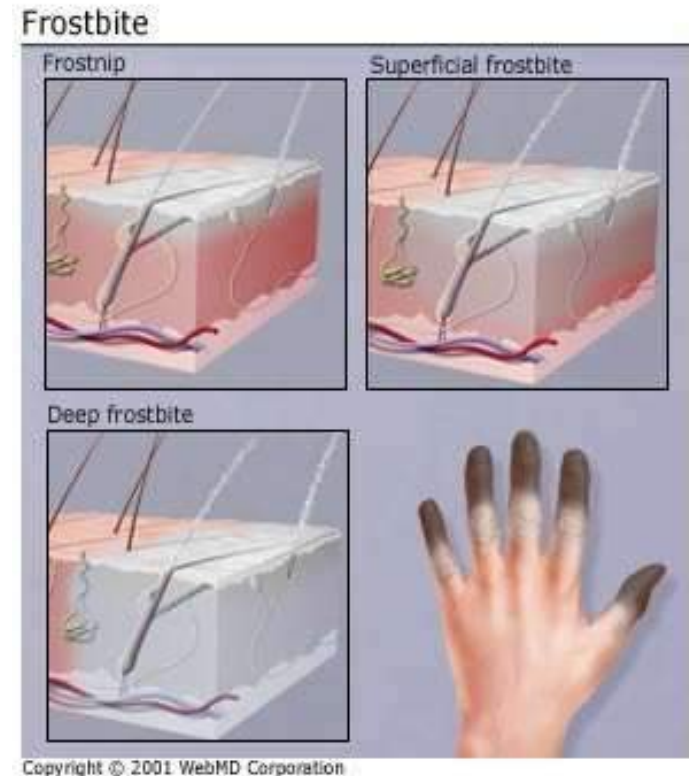
لسعة البرد Frostbite

- When the body is exposed to extremely low temperature, surface areas can freeze, the freezing called **frostbite**.
- Especially in the lobes of the ears and in the digits of the hand and feet



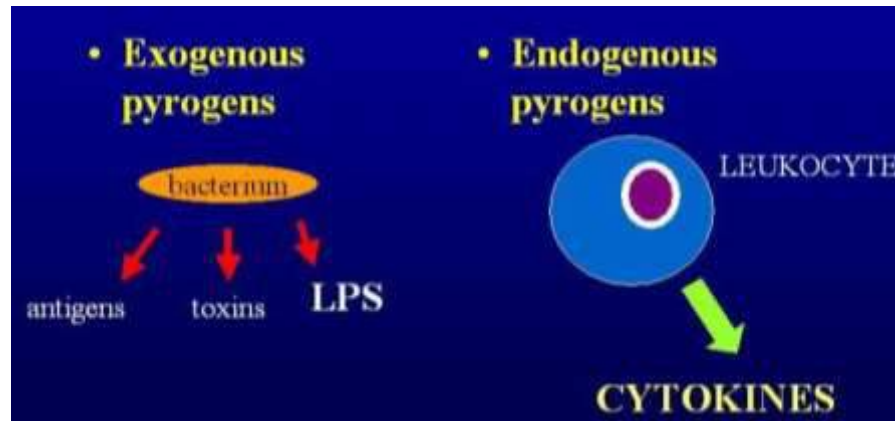
Low temperature effects

- **The protoplasm can exist in living state and freezes a few degrees below zero. Freezing causes:**
 1. Formation the ice crystals in the cell and disturbs the cell organization.
 2. Metabolism is greatly lowered and as such the rate of oxygen consumption is also very low because the diffusion of O₂ and CO₂ through the ice is very low.
 3. The enzymes become inactive.

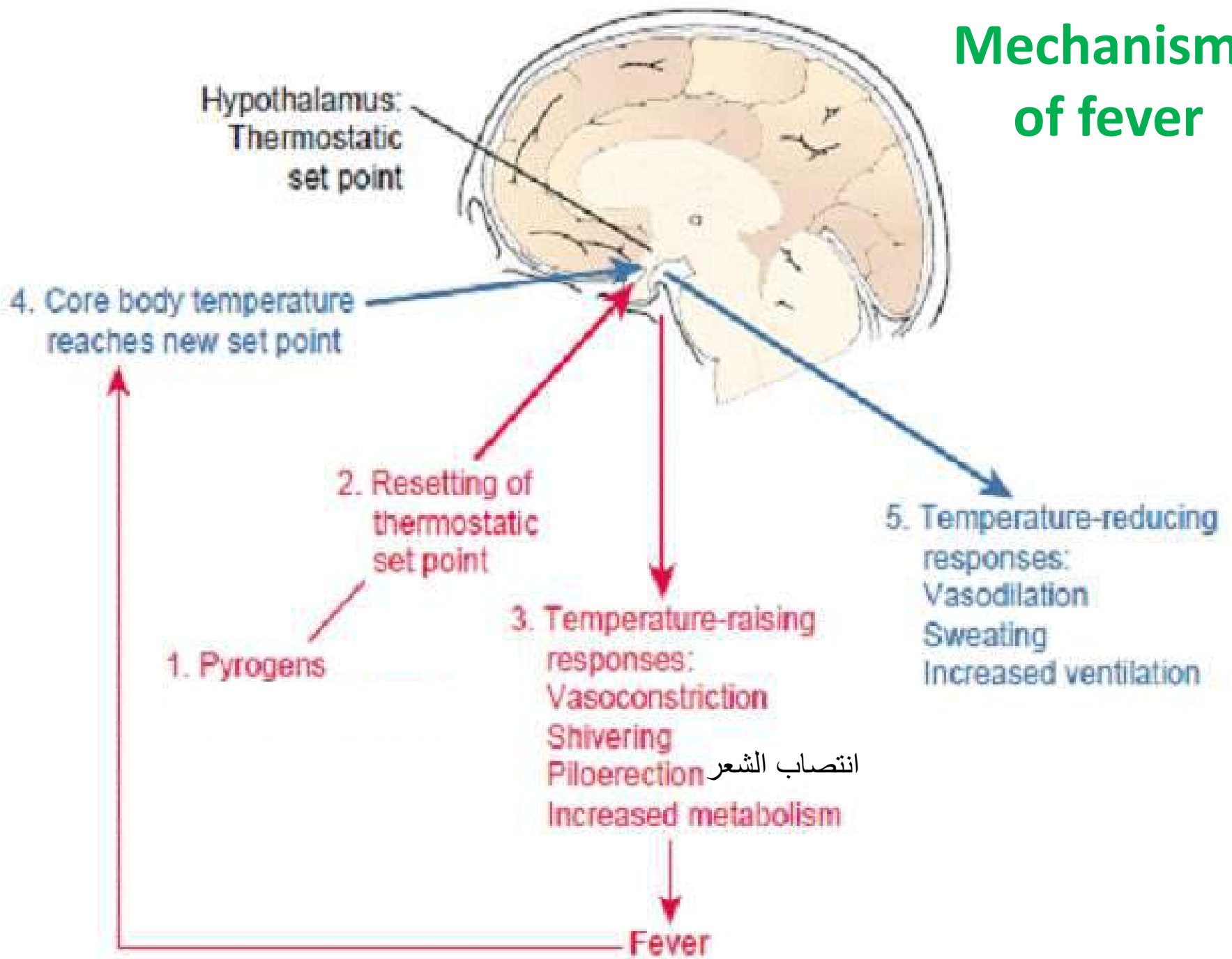


Fever

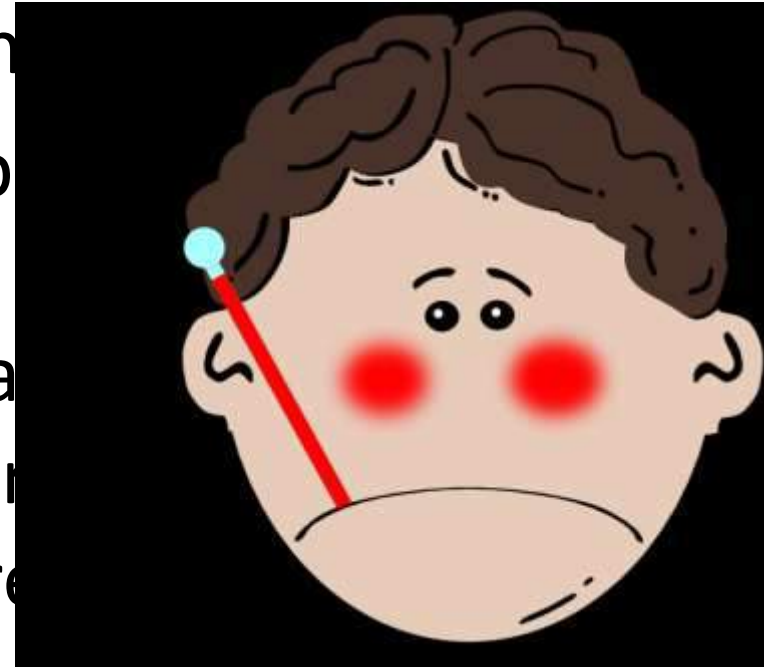
- **A fever** is an abnormally high body temperature and may accompany **infectious diseases, extensive physical trauma, cancer, or damage to the CNS.**
- **Pyrogens:** Is The substances that may cause a fever and include **bacteria, foreign proteins, and chemicals released during inflammation.**
- These inflammatory chemicals are called **endogenous pyrogens**. It is believed that pyrogens chemically affect the hypothalamus and “raise the setting” of the hypothalamic thermostat.



Mechanisms of fever



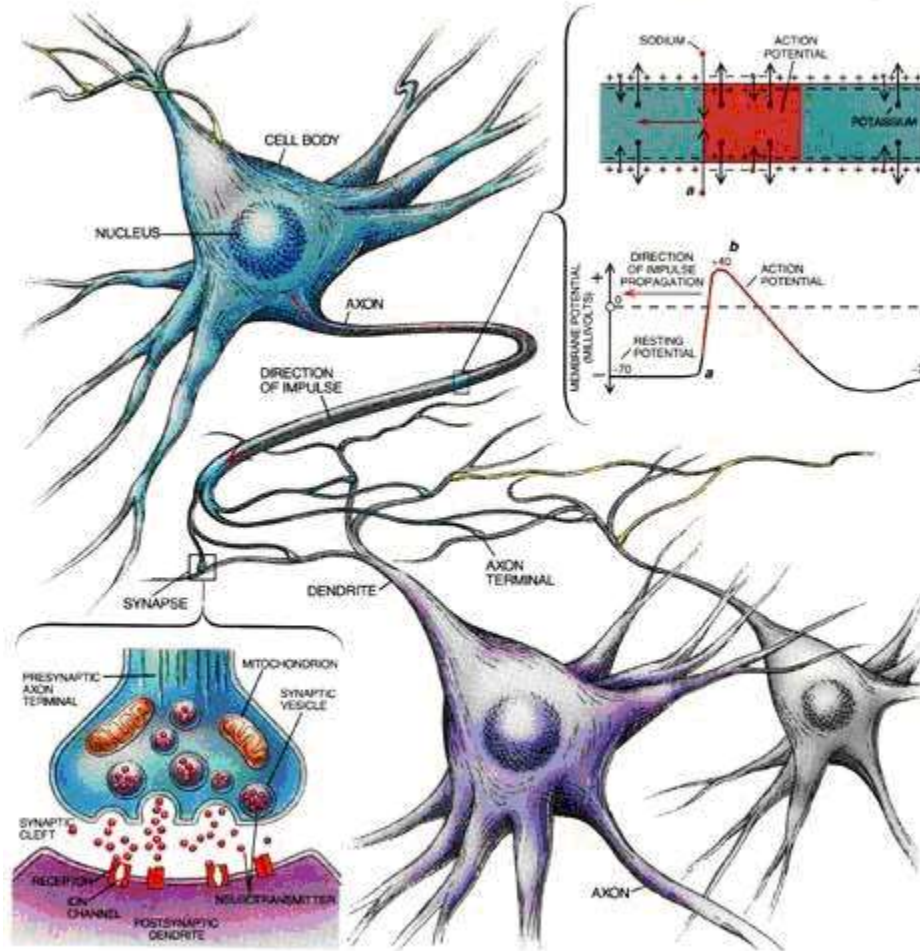
- Fever may be beneficial in that it may shorten the duration of an infection by accelerating the destruction of the pathogen ^{تعجل}
- A fever increases the metabolic rate, which increases heat production, which in turn raises body temperature even more. When the body temperature rises above 39.7°C , the hypothalamus begins to lose its ability to regulate temperature.



- A medication such as **aspirin** is called an **antipyretic** because it lowers a fever, probably by affecting the **hypothalamic thermostat**.



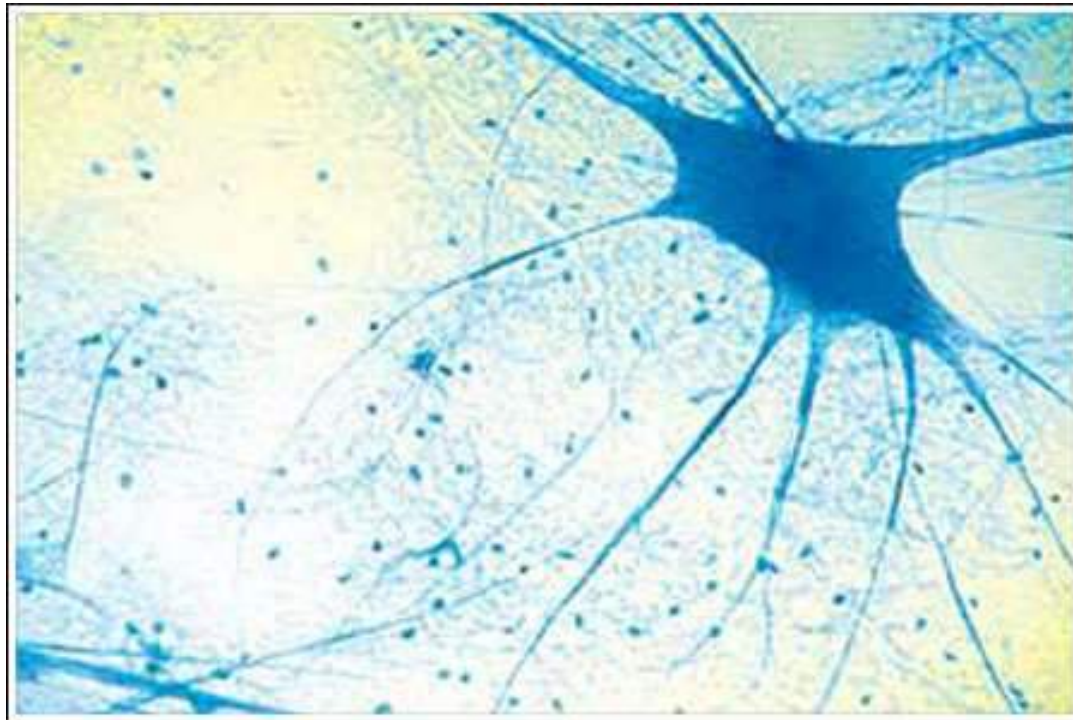
Nerve physiology



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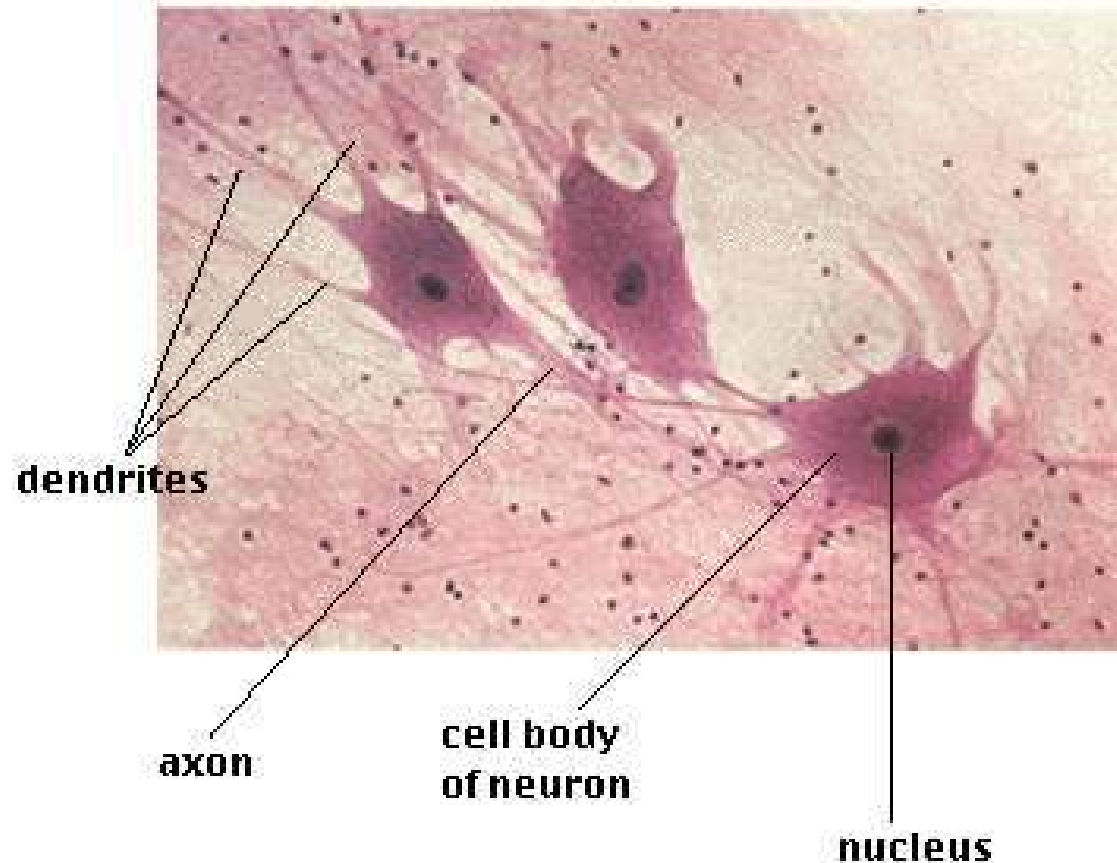
Nerve physiology

- The nervous system is one of regulating system. Electrochemical impulses of the nervous system make it possible to maintain homeostasis.
- **The functions of the nervous system:**
 1. To detect changes and feel sensations
 2. To initiate appropriate responses to changes
 3. To organize information for immediate use and store it for future use

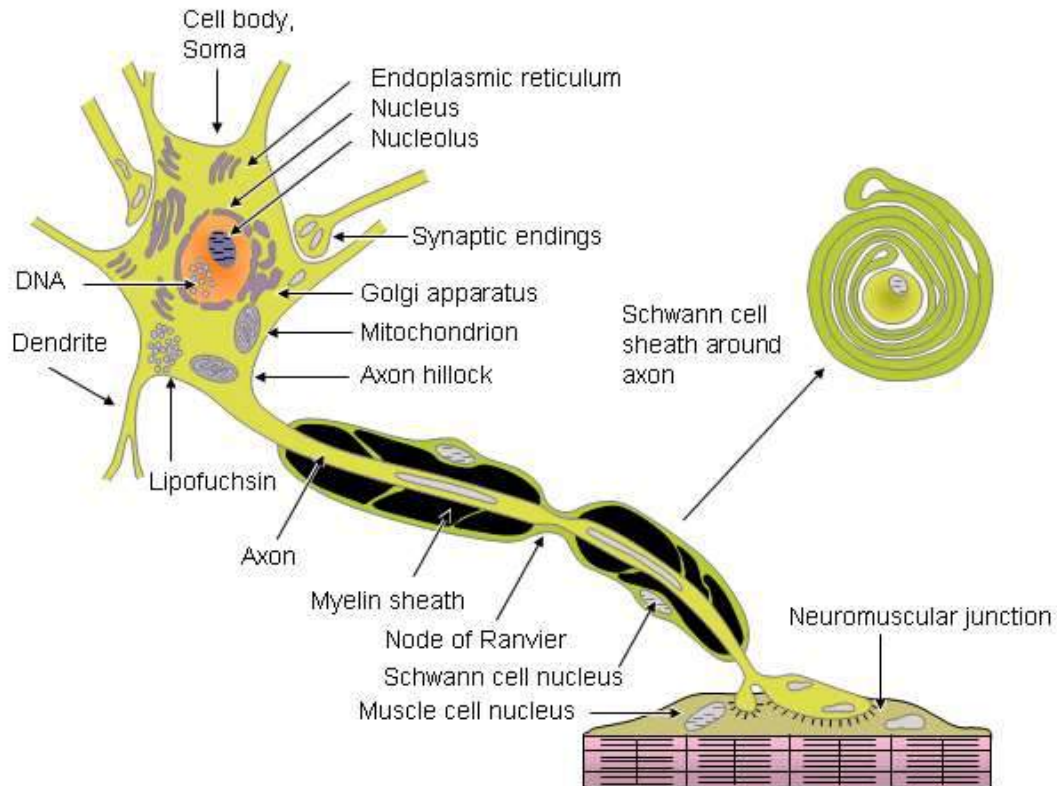


Nerve tissue

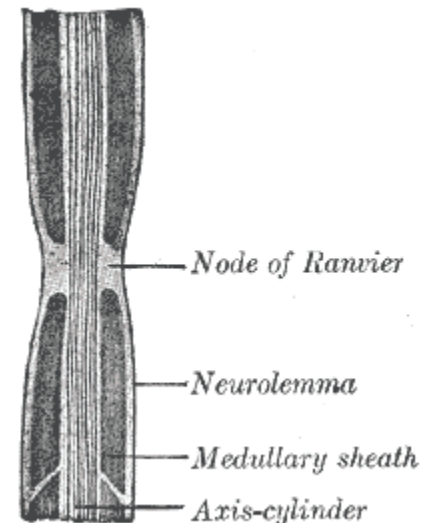
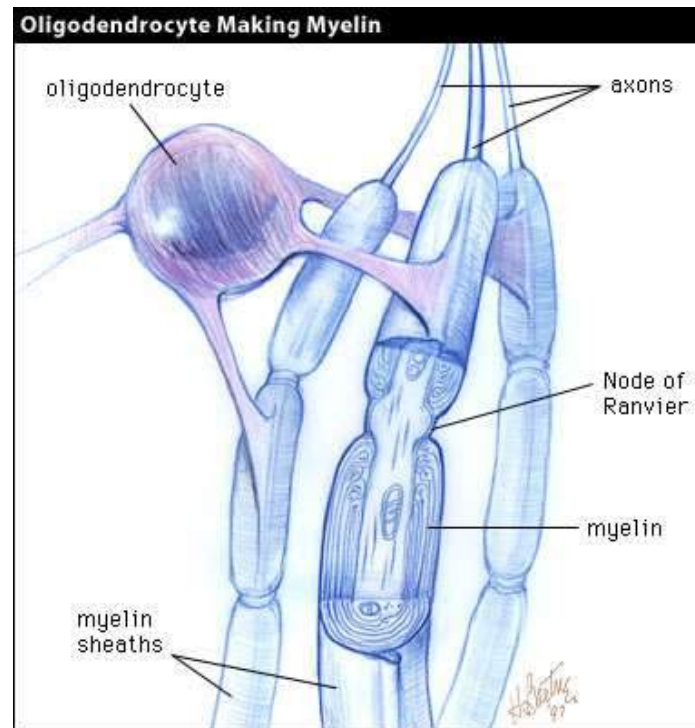
- Nerve cells are called neurons, the cell body contains the nucleus, dendrites are processes (extensions) that transmit impulses toward the cell body. The one axon of neuron transmits impulses away from the cell body.



- The one axon of neuron transmits impulses away from the cell body, and axon that carries the electrical nerve impulses. In PNS, axons and dendrites are (wrapped) in specialized cells called **schwann cells**, enclosing them in several layers of schwann cell membrane. These layers are the **myelin sheath**;
- **myelin** is phospholipid that electrically insulates neurons from one another.

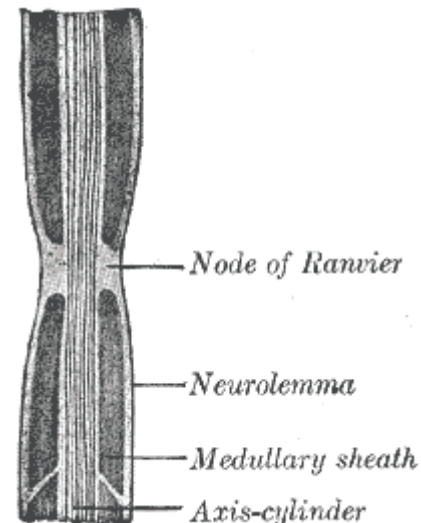
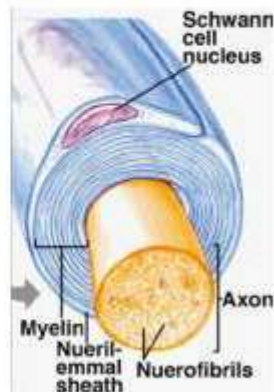
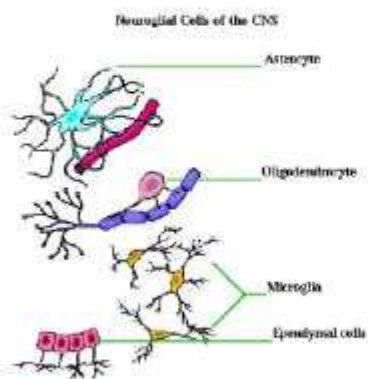


- The spaces between adjacent schwann cells **nodes of Ranvier**.
- These nodes are the parts of the neuron cell membrane that depolarize when an electrical impulse is transmitted.



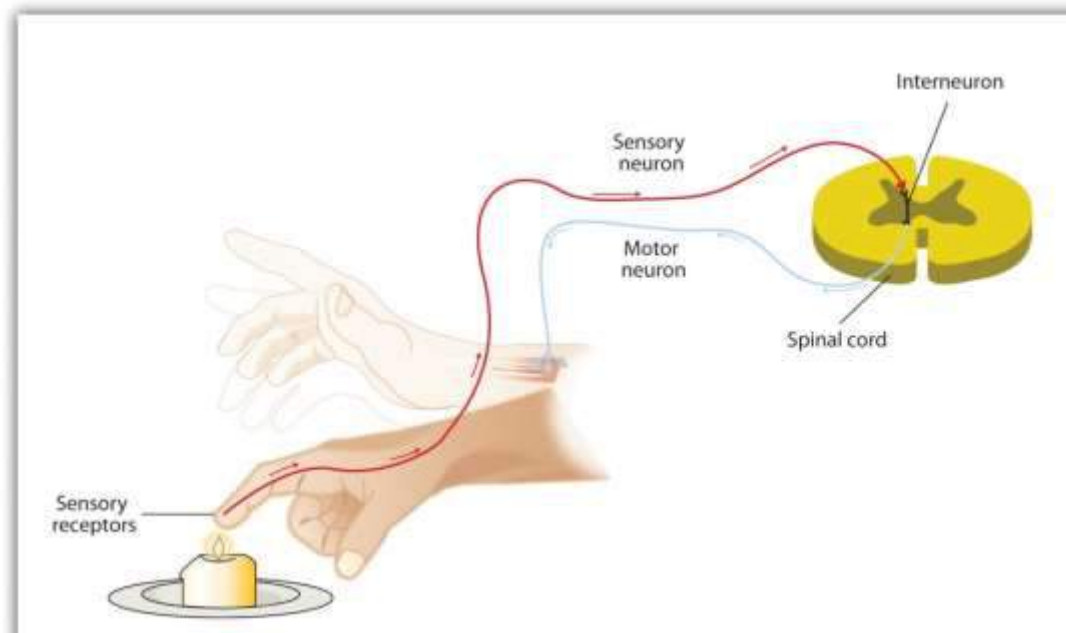
- The nuclei and cytoplasm of the schwann cells are wrapped around the outside of the myelin sheath and are called the **neurolemma**, in the CNS; the myelin sheaths are formed by **oligodendrocytes**, one of the **neuroglia**

Neuroglia



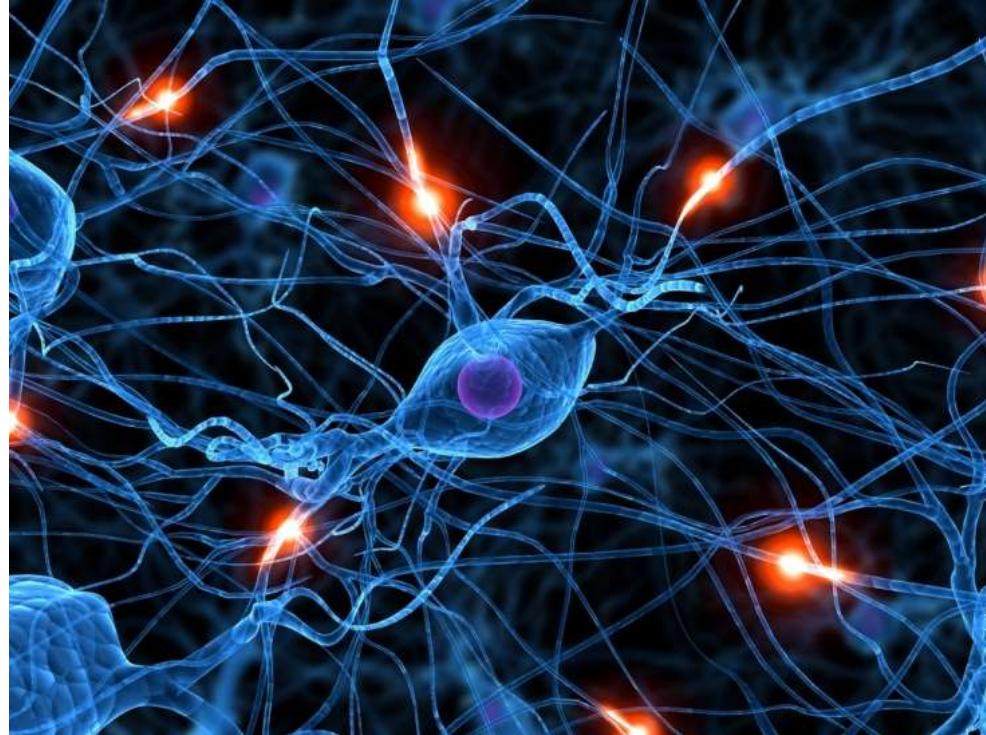
Types of neurons:

- Neurons may be classified into three groups:
 1. sensory neurons (or afferent neurons) carry impulses from CNS. **Receptors detect external or internal changes and send the information to the CNS in the form of impulses by way of the afferent neurons.**
 2. Motor neurons (or efferent neurons) carry impulses from the central nervous system to **effectors**.
 3. Interneuron is found entirely within the CNS.



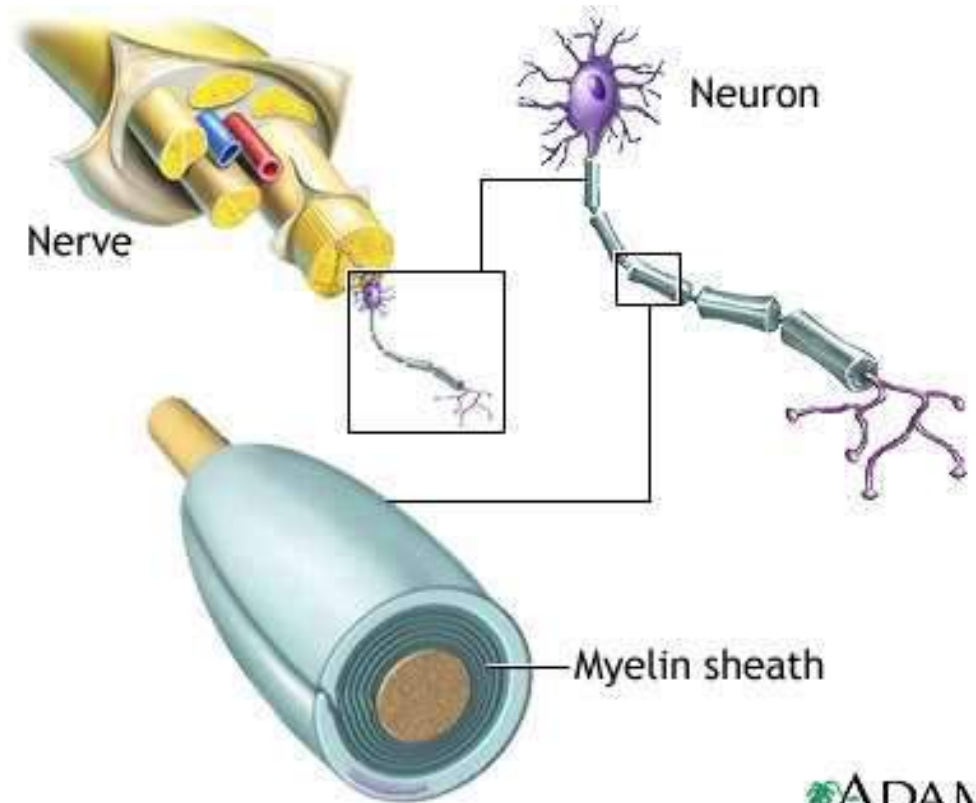
Nerves

- A nerve is a group of axons and/or dendrites of many neurons, with blood vessels and connective tissue. **Sensory nerves, motor nerves, and mixed nerve** the three types of nerves.



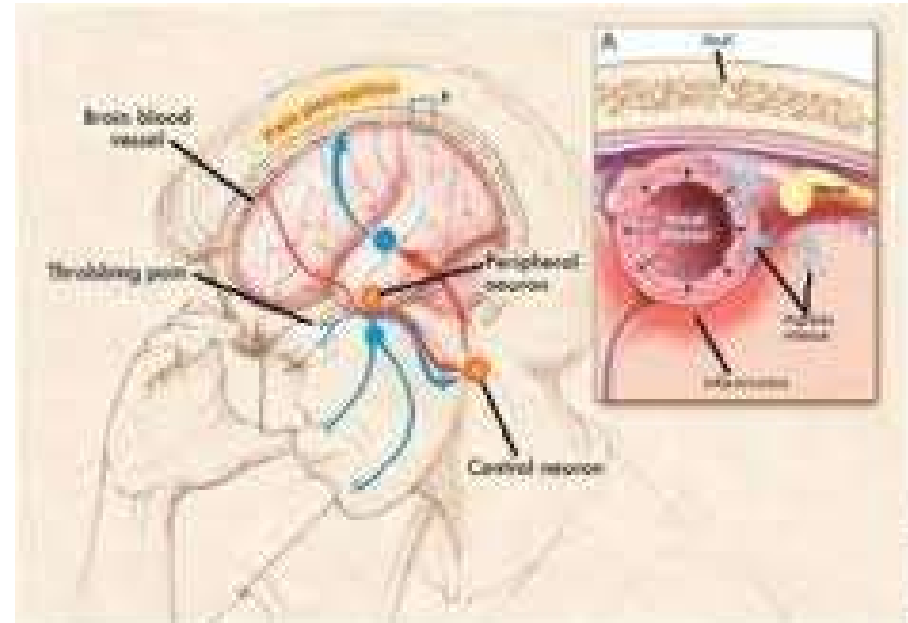
The main physiological activities of the nerve fiber are:

1. **Generation of nerve impulse.**
2. **Conduction of nerve impulse.**
3. **Transmission of impulse at the synapse.**



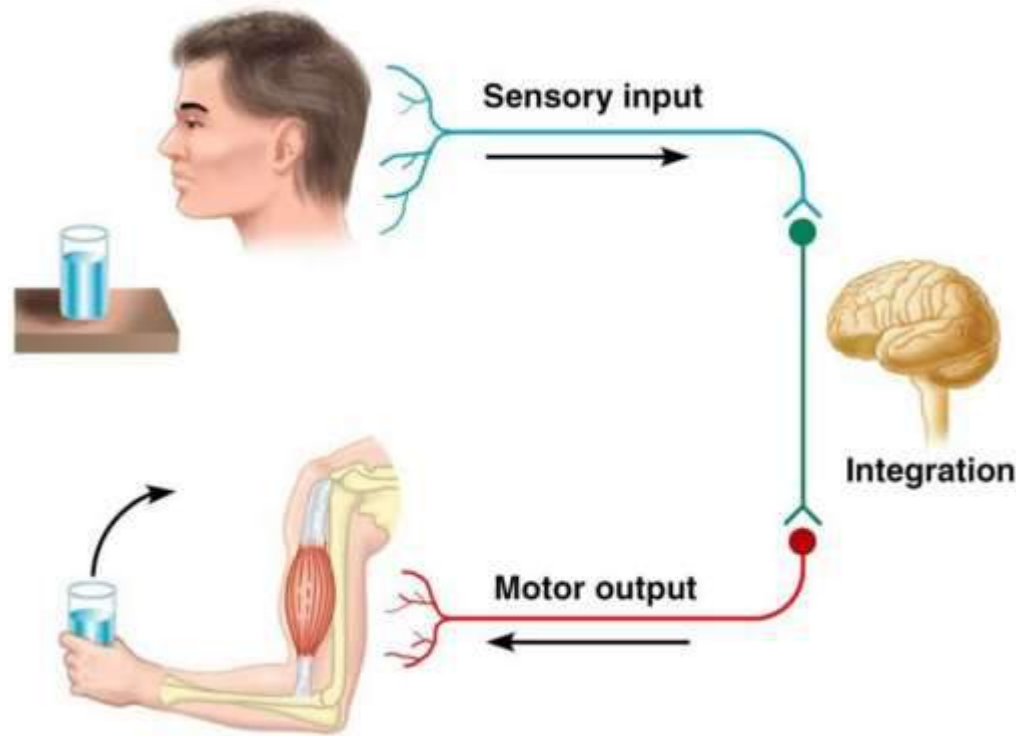
Generation of nerve impulse:

- **Excitability**
- Excitability is that property of the nerve fiber by virtue of which it responds by generating a nerve signal (electrical impulses or the so called **action potentials**) when it is stimulated by a suitable stimulus which may be **mechanical, thermal, chemical or electrical.**



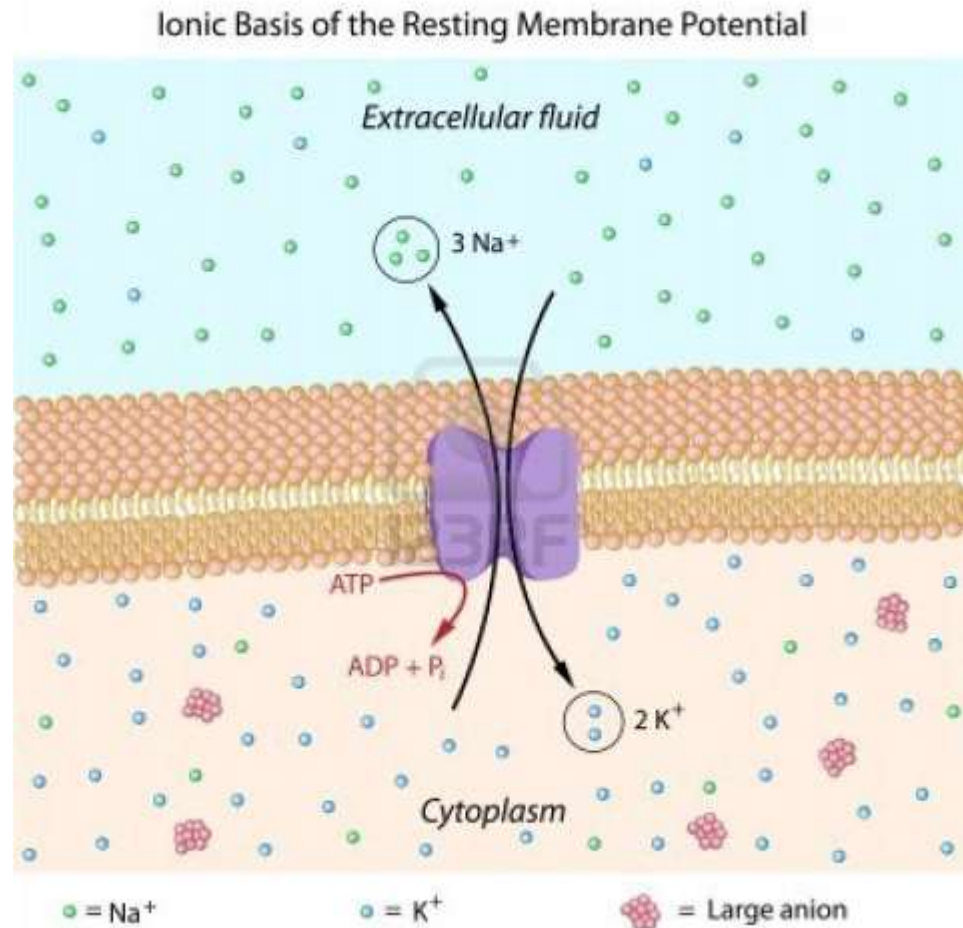
Resting membrane potential:

- A steady potential difference of **-70 mV** (inside negative) is observed in the nerve fiber. This is the **resting membrane potential (RMP)** and indicate the resting state of cell, also called state of **polarization**.

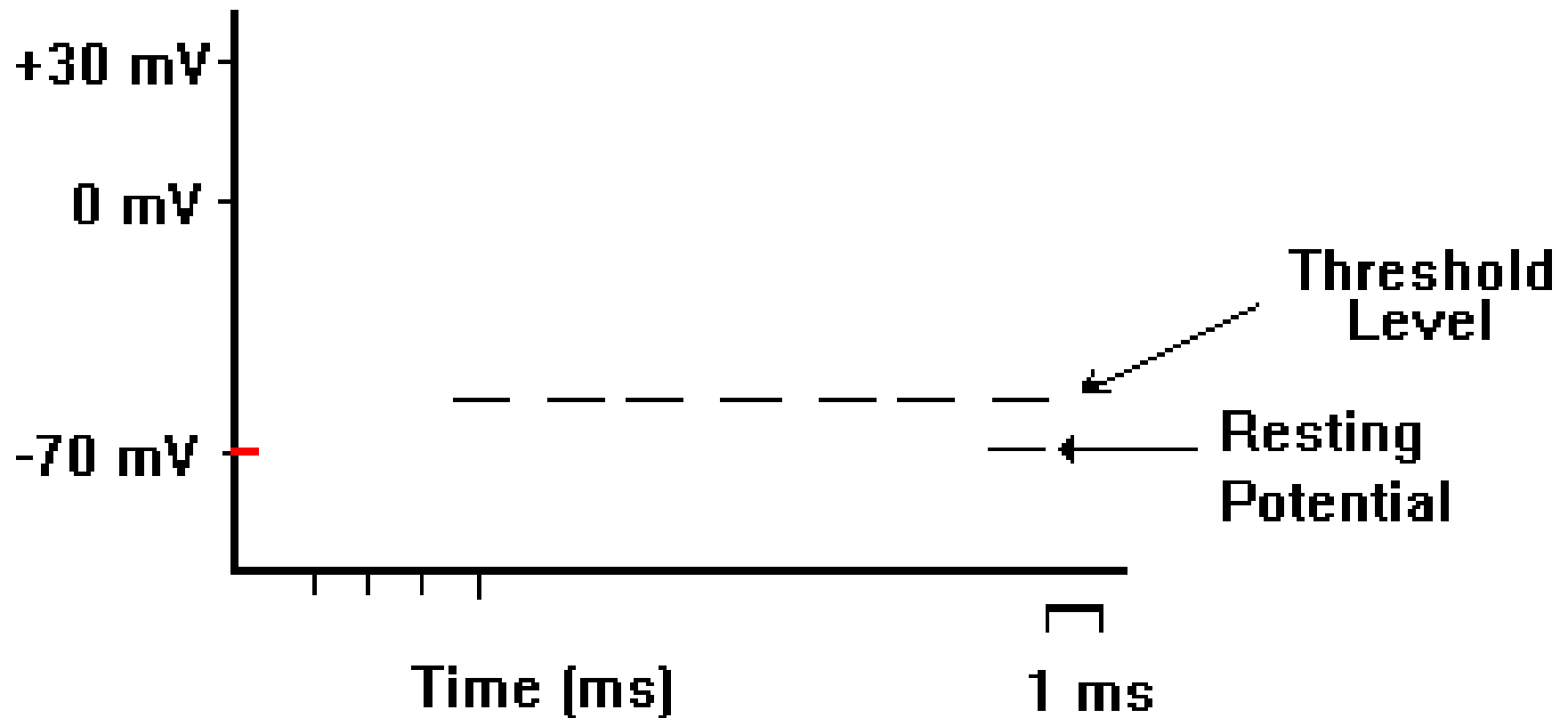


Action potential

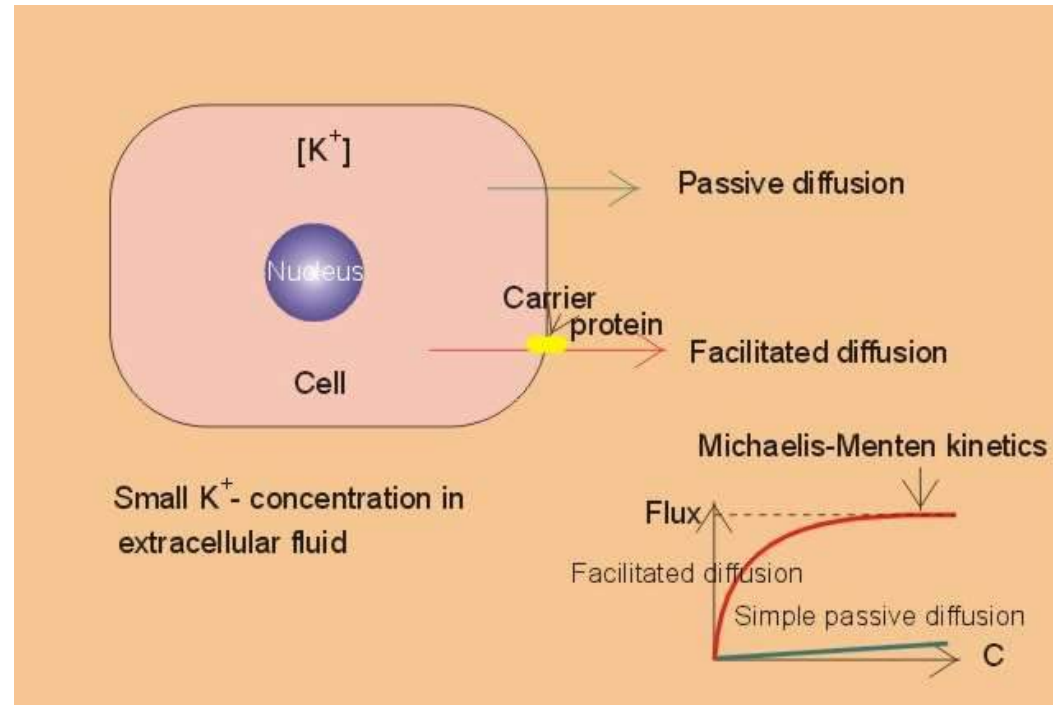
- **The action potential** may be defined as the brief sequence of changes which occur in the **resting membrane potential** when stimulated by threshold stimulus.



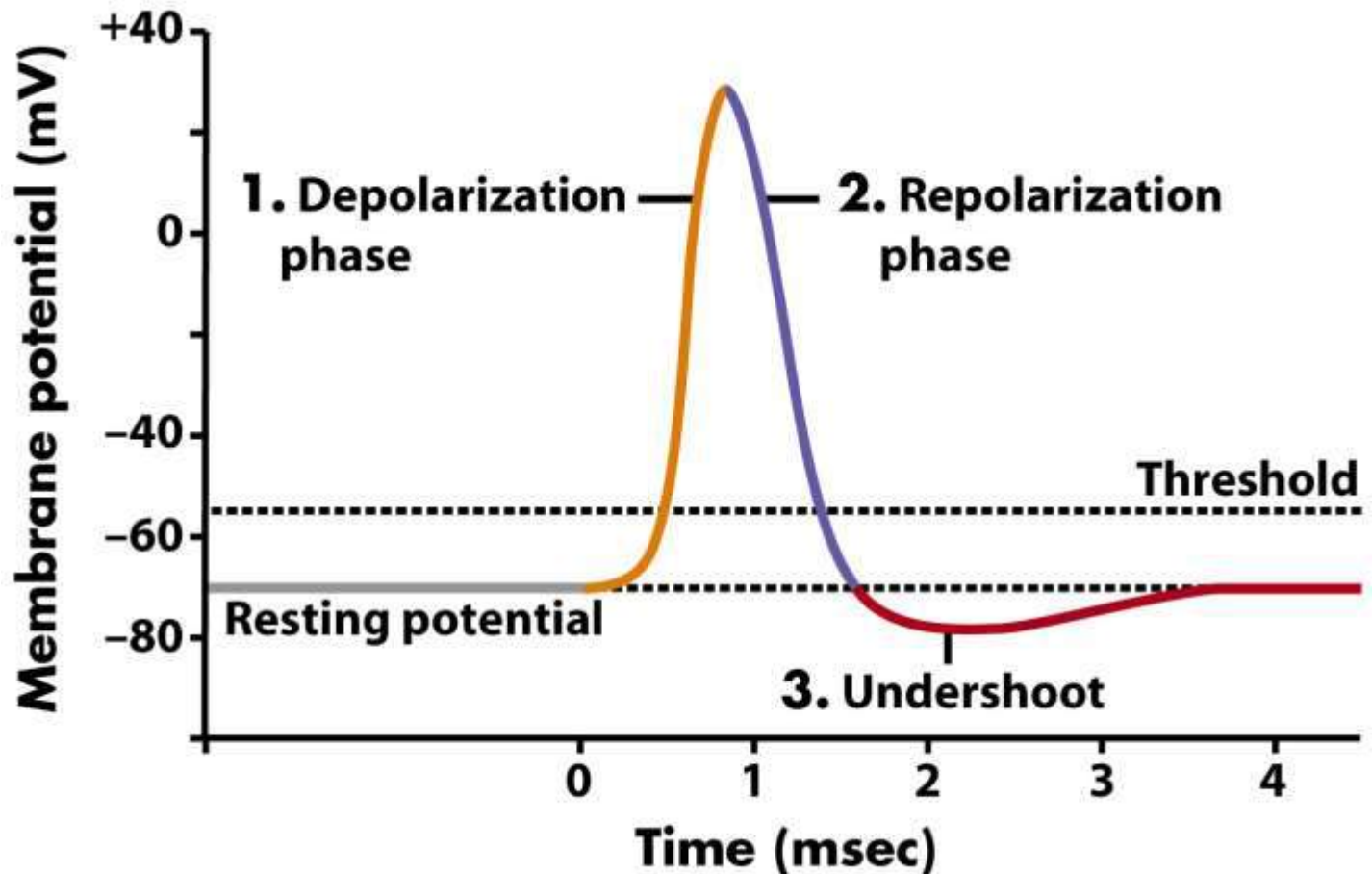
- When the stimulus is sub minimal or sub threshold, **it does not produce action potential**, but does produce some changes in the RMP.



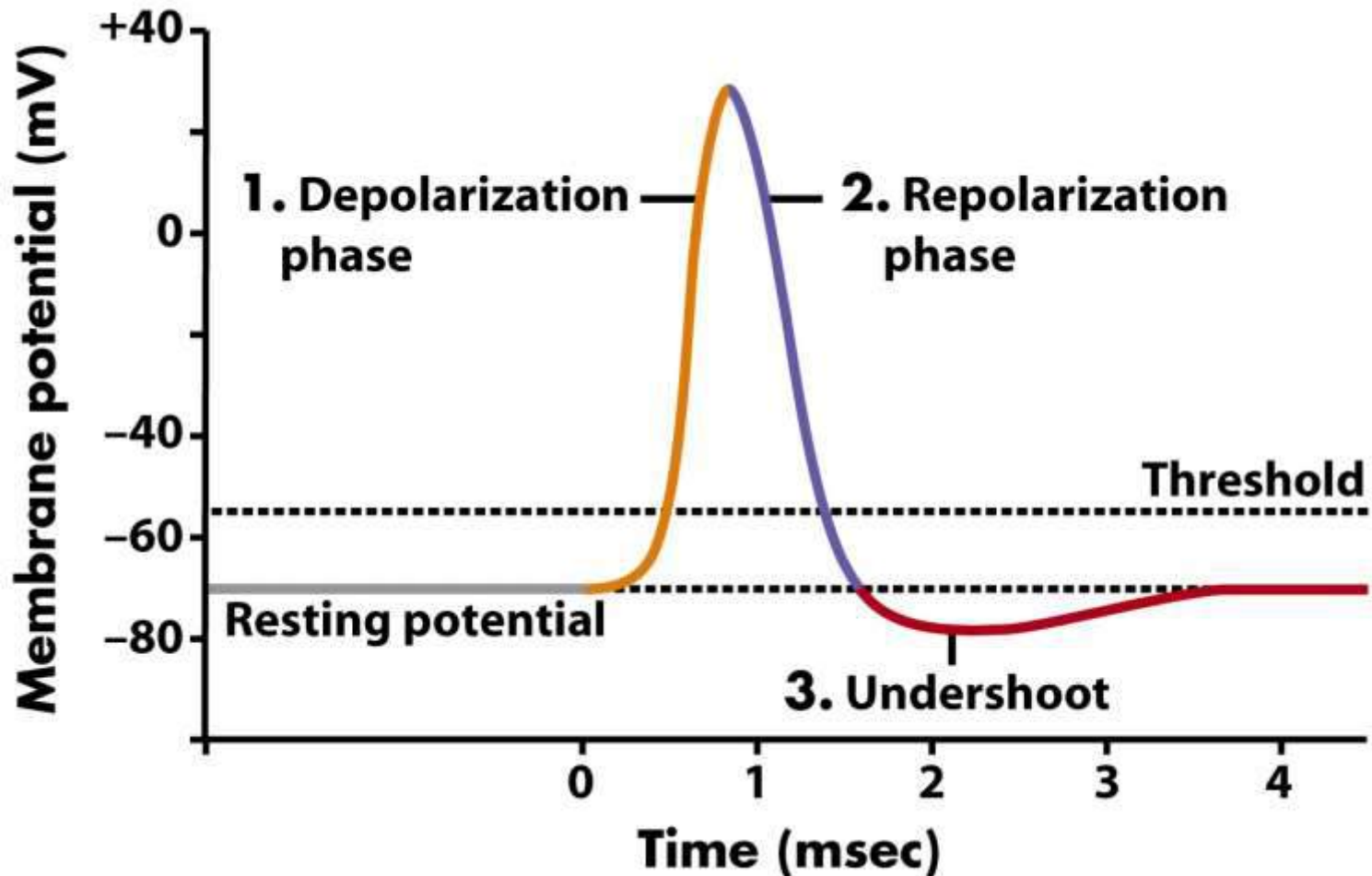
- There is slight depolarization for about **7 mV** which cannot be propagated, since propagation occurs only if the depolarization reaches a firing level of **15 mV (-55 mV)**.



- Once the firing level is reached, there occurs action potential there occurs abrupt depolarization with propagation (action potential).



- The adequate strength of stimulus necessary for producing the action potential in a nerve fiber is known as **threshold** or **minimal stimulus**.



Phases of action potential

- The action potential basically occurs in two phase:
- **Depolarization** and **repolarization**

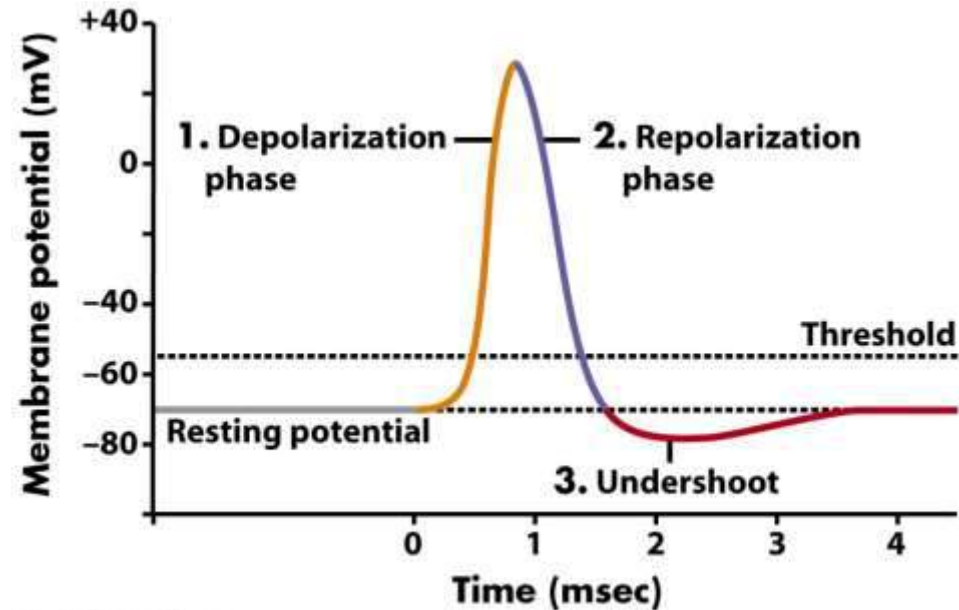
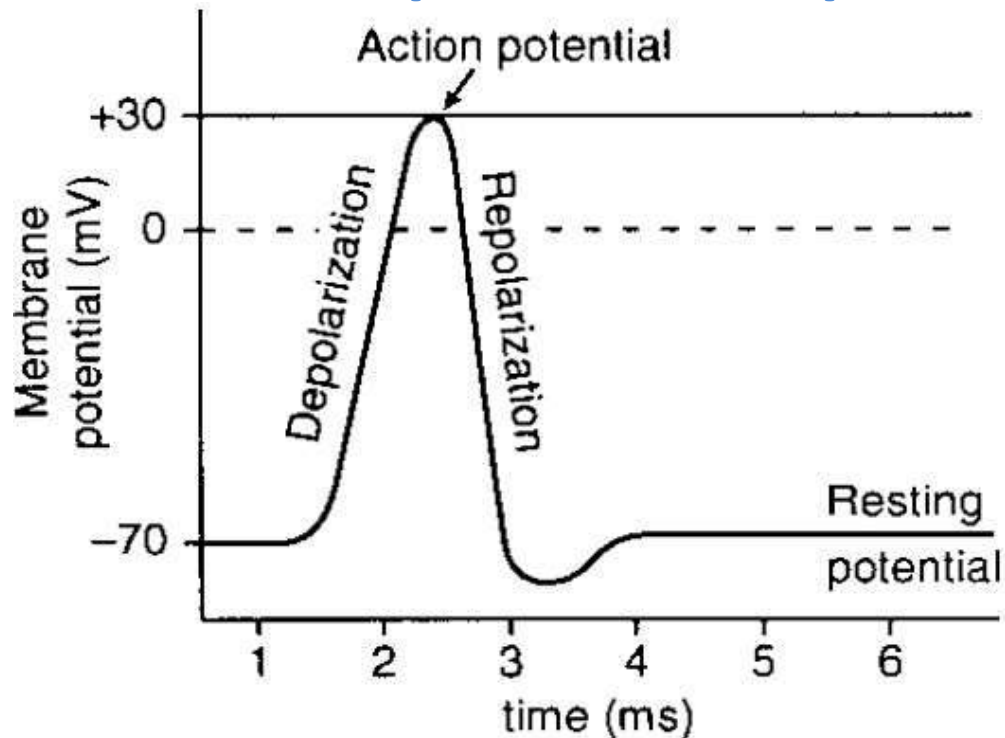


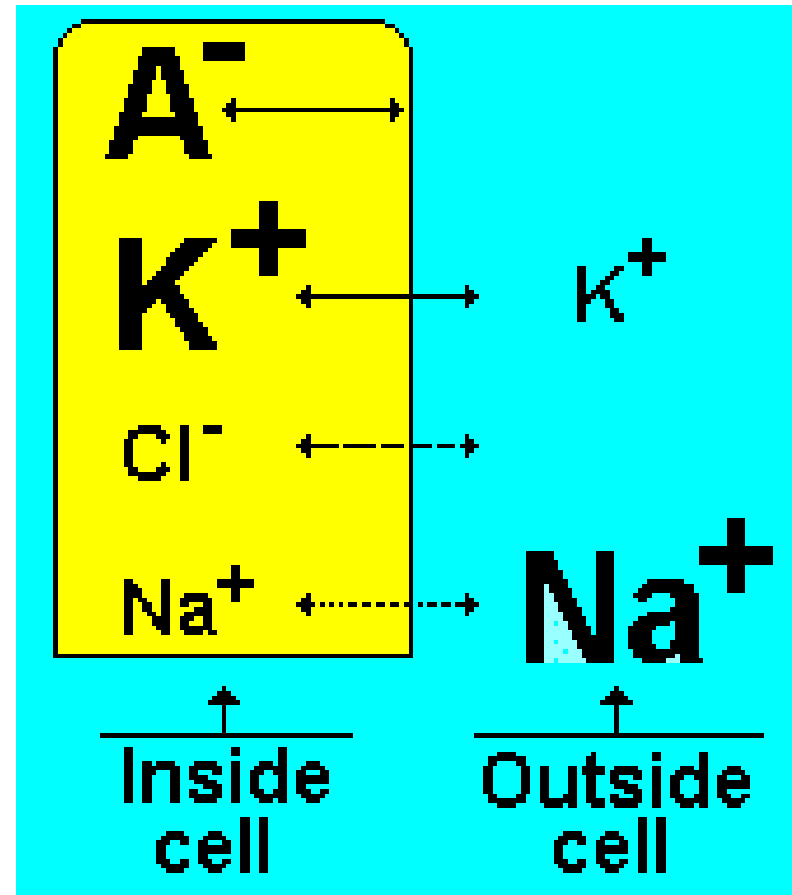
Figure 45-5 Biological Science, 2/e
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- When the nerve is stimulated, the polarized state (**-70 mV**) is altered, i.e. RMP is abolished and the interior of the nerve becomes positive (**+35 mV**) as compared to the exterior. This is called **depolarization phase**.
- Within no time there occurs several to the nearly original potential and this second phase of action potential is called **repolarization phase**.

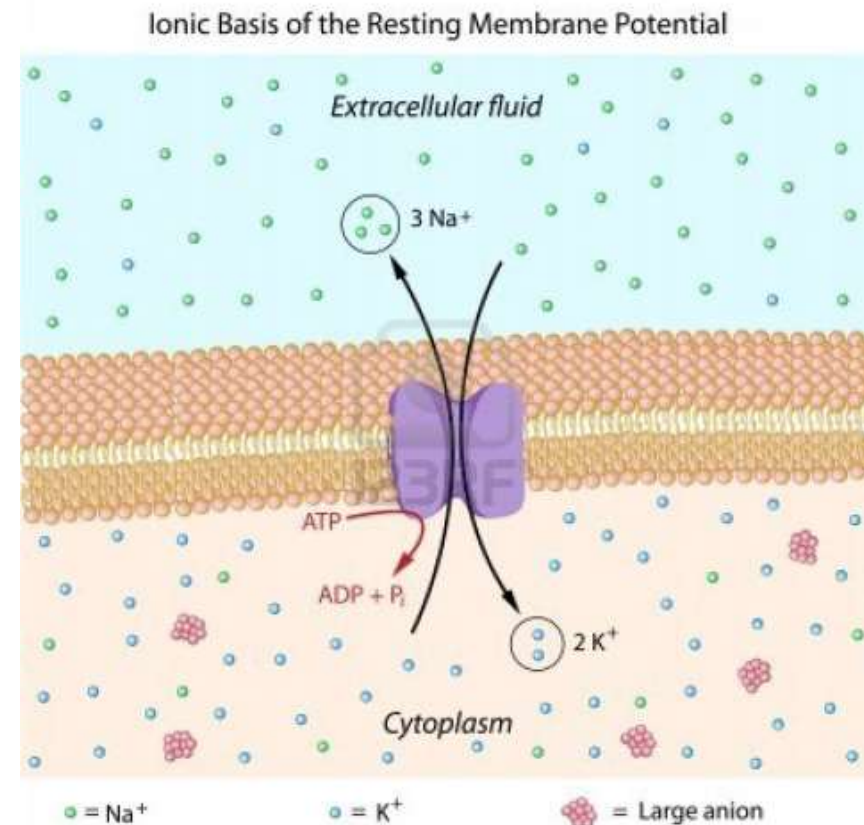


According to Hodgkin-Huxley theory, the sequence of events are:

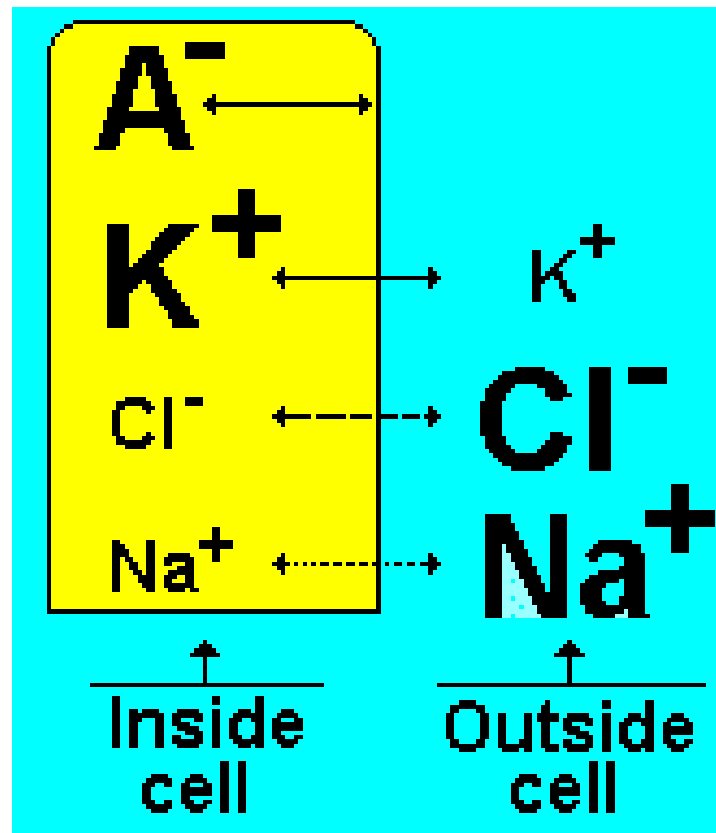
- 1. Polarization phase.** Resting membrane potential (-70 mV) is due to distribution of more cations outside the cell membrane and more anions inside the cell membrane, with Na^+ ions more abundant outside the cell, and K^+ ions and negative ions more abundant inside.
 - Na^+ Cannot enter the cell due to the impermeability of the membrane.



- **2. Depolarization phase.**
When threshold stimulus is applied to the cell membrane, at the point of stimulation the permeability of the membrane for **Na⁺ ions increase.**
- There occurs a rapid influx of **Na⁺ ions into the cell.**
- This rapid entry of Na⁺ leads to **depolarization.**

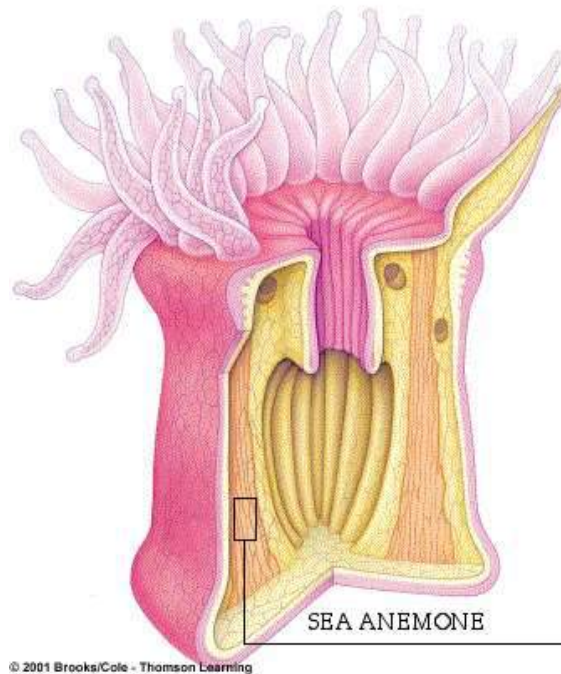


3. Repolarization phase. Repolarization occurs due to **decrease in further Na⁺ influx and K⁺ efflux** through the **voltage-gated K⁺ channels** which open later than Na⁺ channel but remain activated for prolonged period.

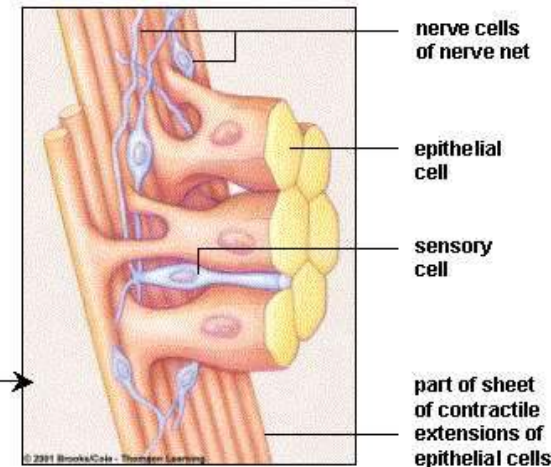


- Decrease in Na^+ influx and efflux of K^+ causes **net transfer** of positive charge out of the cell that serves to complete the repolarization.
- Then the sodium and potassium pumps return Na^+ ions outside and K^+ ions inside, and the neuron is ready to respond.

Nerve Net



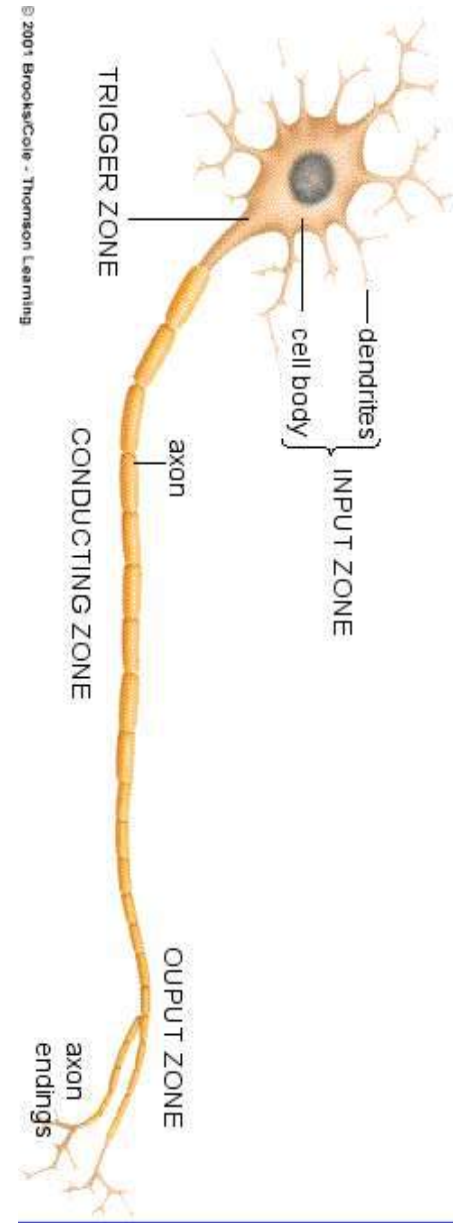
- Diffuse mesh of nerve cells that take part in simple reflex pathways
- Nerve cells interact with sensory and contractile cells



Main characteristics of nerve excitability

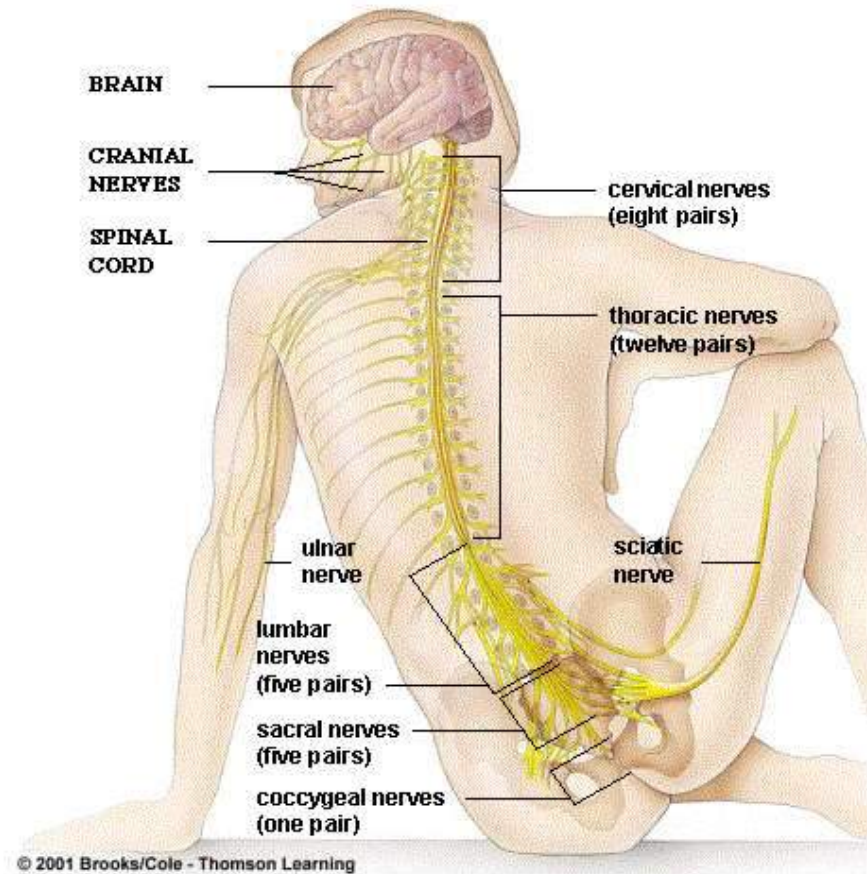
1. **All or none response.** A single nerve fiber always obeys **all or none law**, that is:

- When a stimulus of **subthreshold** intensity is applied to the axon, then no action potential is produced (**none response**)
- A response in the form of **spike** of action potential is observed when the stimulus is of **threshold** intensity;
- There occurs no increase in the magnitude of action potential when the strength of stimulus is **more than the threshold level (all response)**. This all or none relationship observed between the strength of stimulus and the response achieved is known as (all or none law).

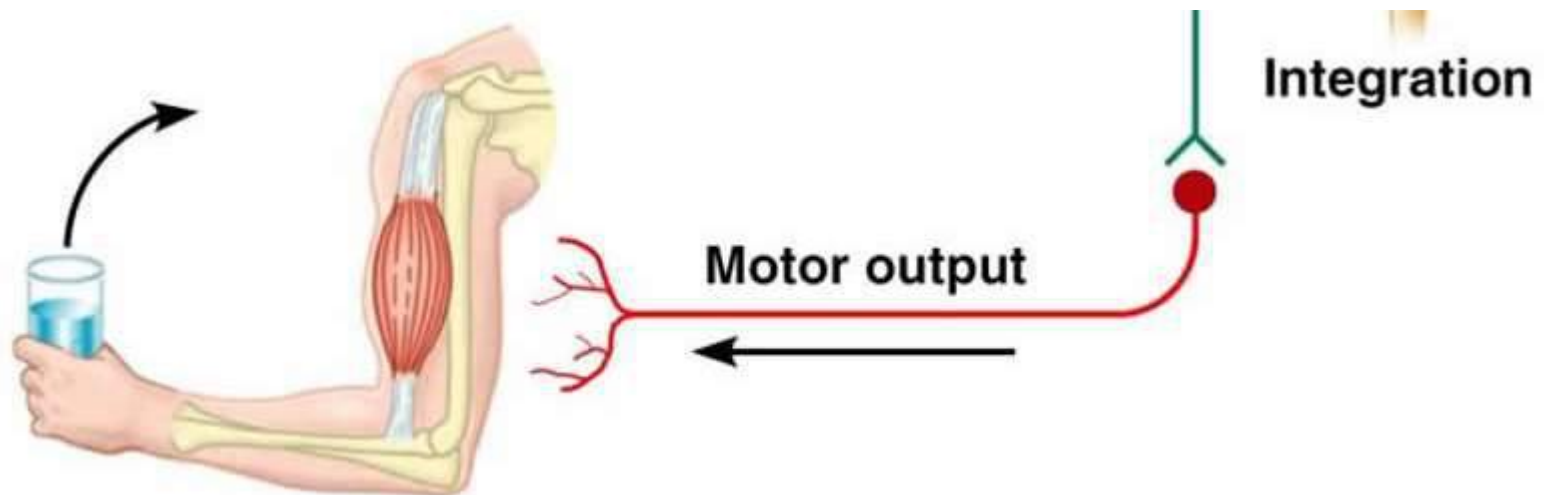


2. Refractory period.

Refractory period refers to the period following action potential (produced by a threshold stimulus) during which a nerve fiber either does not respond or responds sub normally to a stimulus of threshold intensity or greater than threshold intensity.

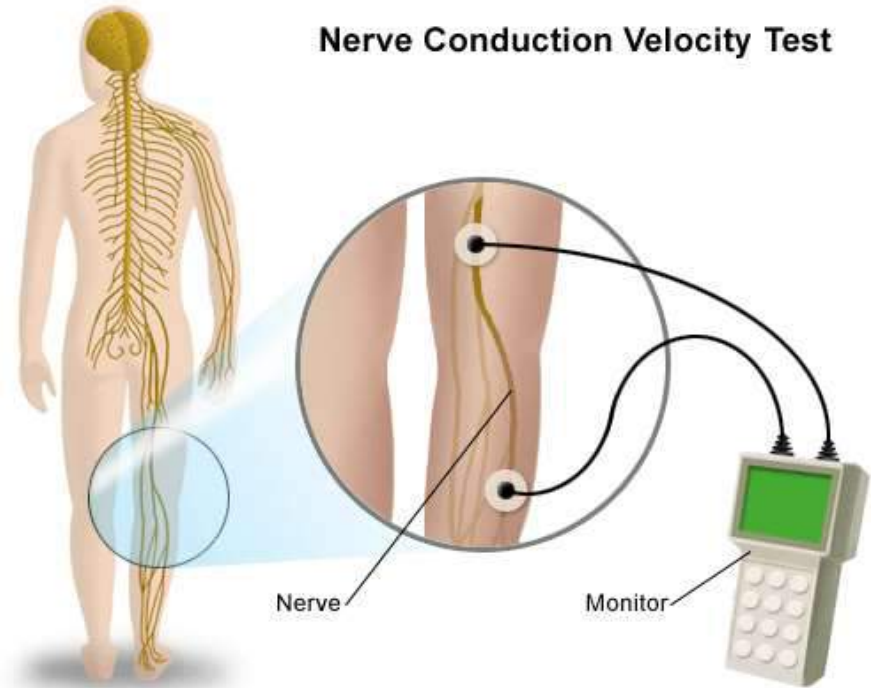


- It is of two types:
 - A. Absolute refractory period (ARP):** it is a short period following action potential during which **second stimulus**, no matter how strong it may be, cannot evoke any response (another action potential). **In other words during absolute refractory period the nerve fiber completely loses its excitability.**
 - B. Relative refractory period (RRP):** it is a short period during which the nerve fiber shows response if the strength of stimulus is **more than normal.**



Conduction of nerve impulse

- **Conductivity** refers to propagation of nerve impulse (action potential) in the form of a wave of depolarization through the nerve fiber.
- Normally, in the body the action potential is transmitted through fiber in one direction



Propagation of action potential in an unmyelinated axon are summarized:

1. In the resting phase (polarized state) the axonal membrane is outside positive and inside negative

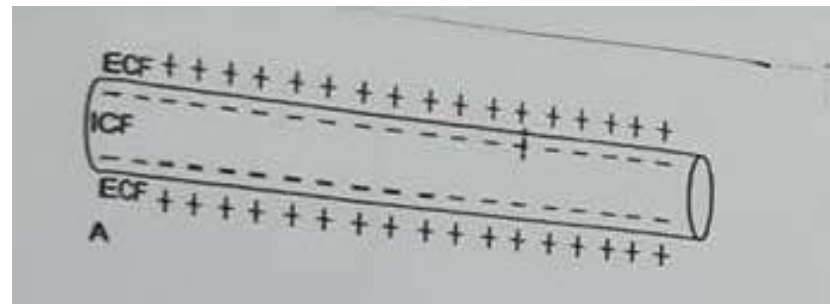
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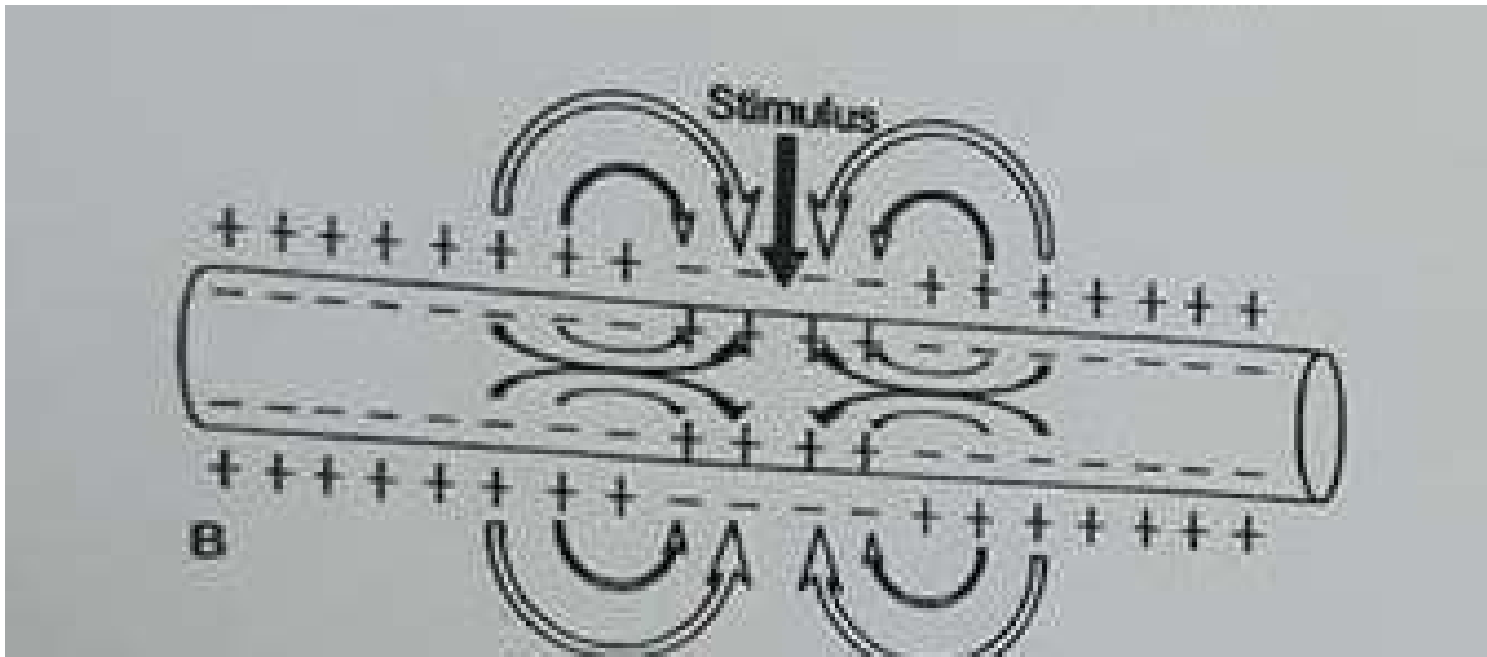
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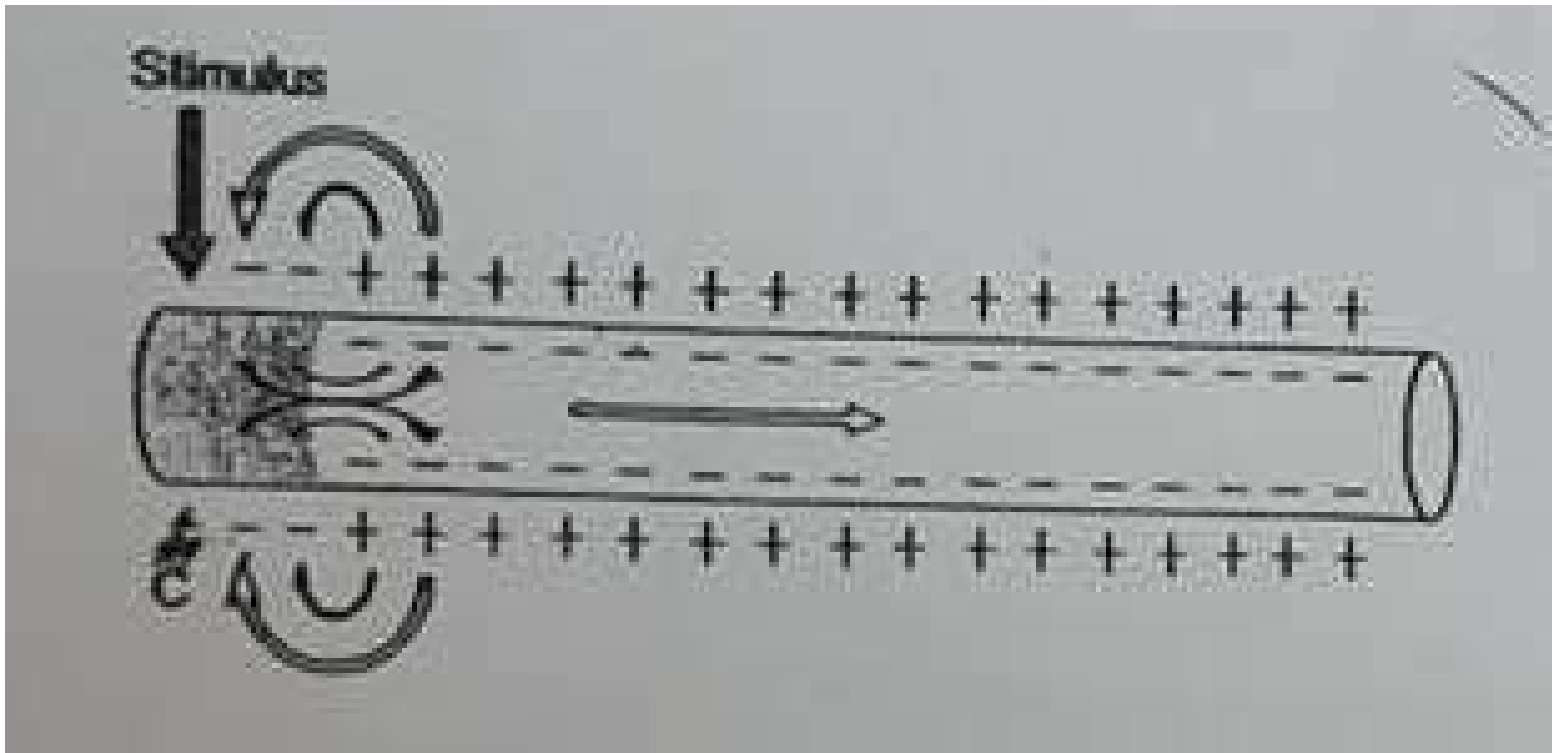
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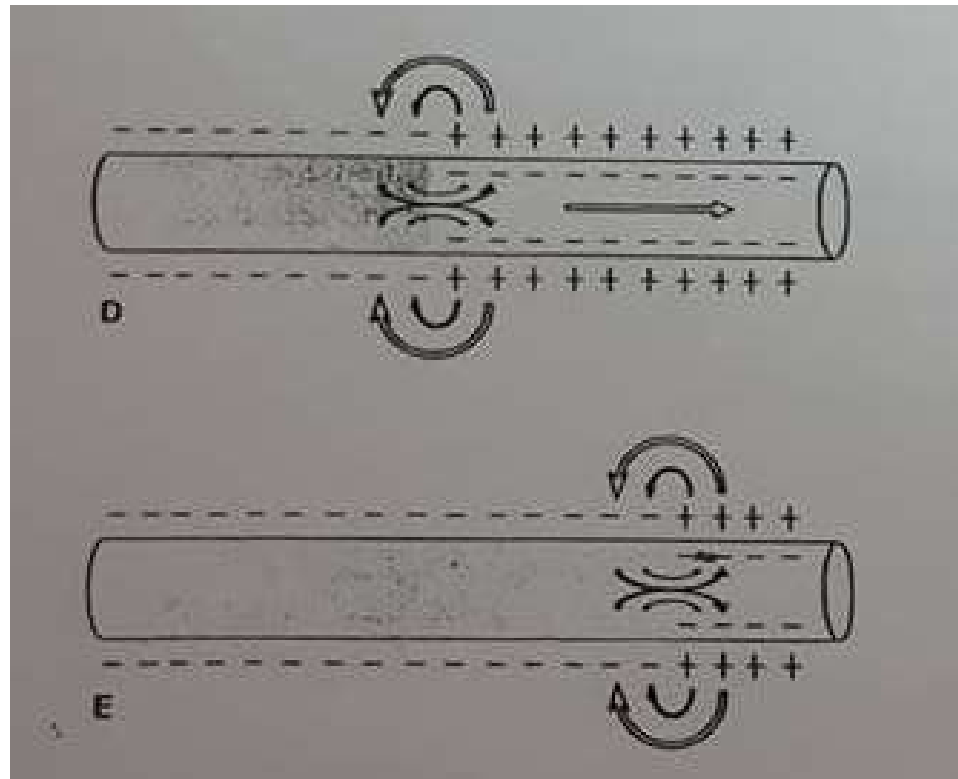
2. When an unmyelinated axon is stimulated at one site by a threshold stimulus, there occurs action potential at that site outside membrane become negative and inside positive (**reversal of polarity**) but the neighbouring areas until now remain in polarized state.



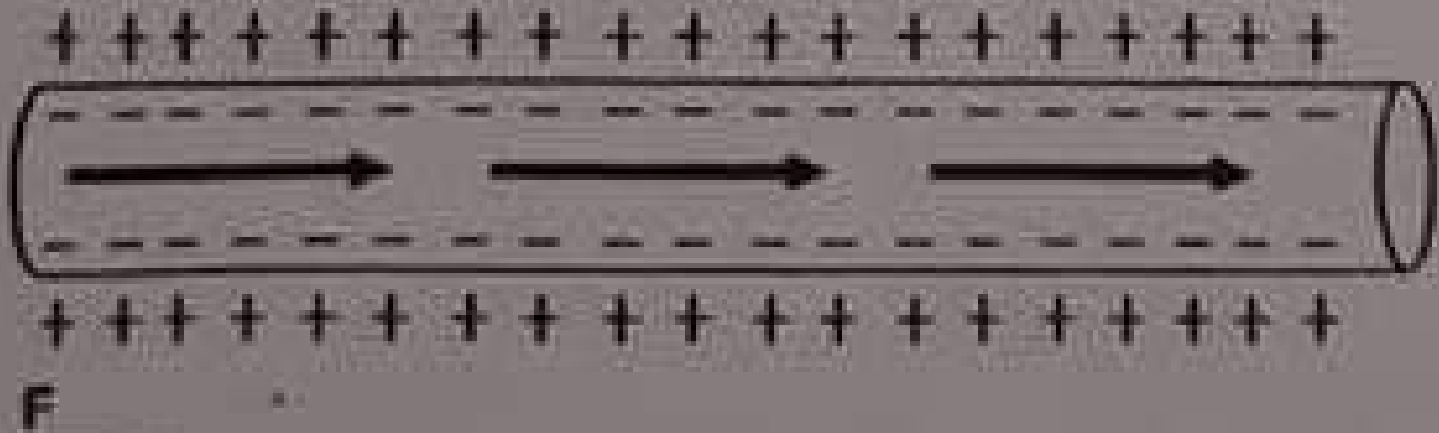
3. As ECF and ICF are both conductive to electricity, a current will flow from positive polarized area to negative activated area through ECF and in the reverse direction in ICF. Thus, a **local circuit current** flow between the resting polarized site to the depolarized site of the membrane (current sink).



4. This circular current flow depolarizes the neighboring area of the membrane up firing level and a new action potential is produced which in turn depolarizes the neighboring area ahead. Thus, due to successive depolarization of the neighboring area, the action potential is propagated along the entire length of the axon.

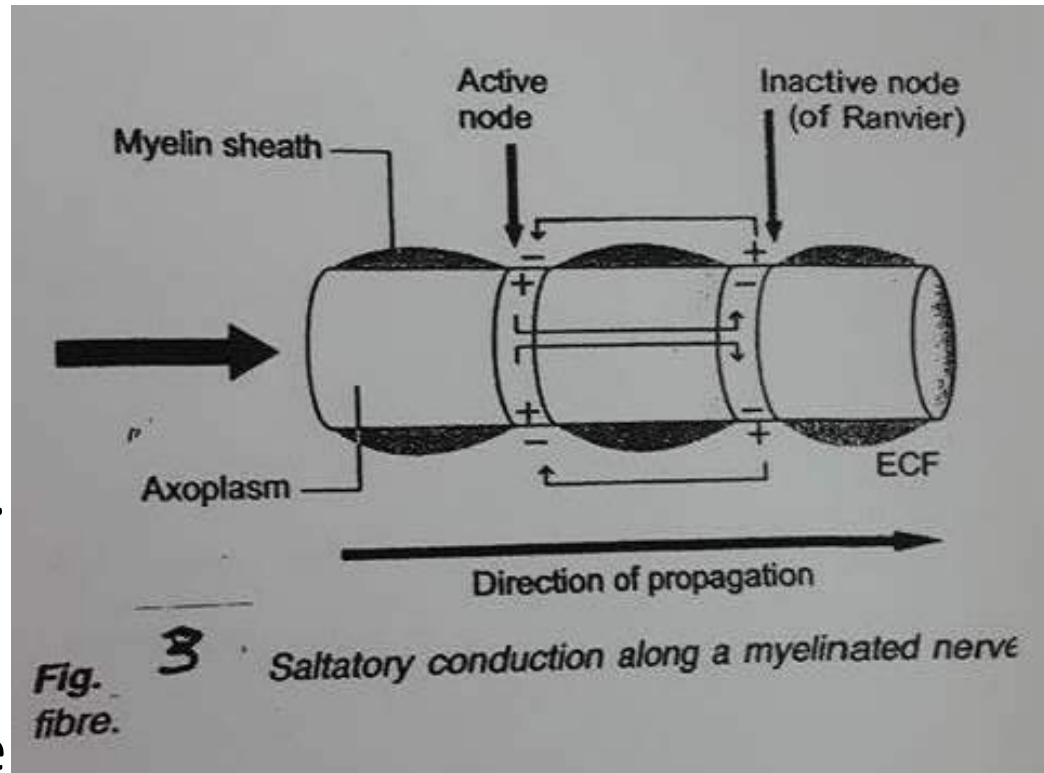


The portion which depolarizes first also repolarizes first. Thus repolarization also follows the same direction as depolarization.

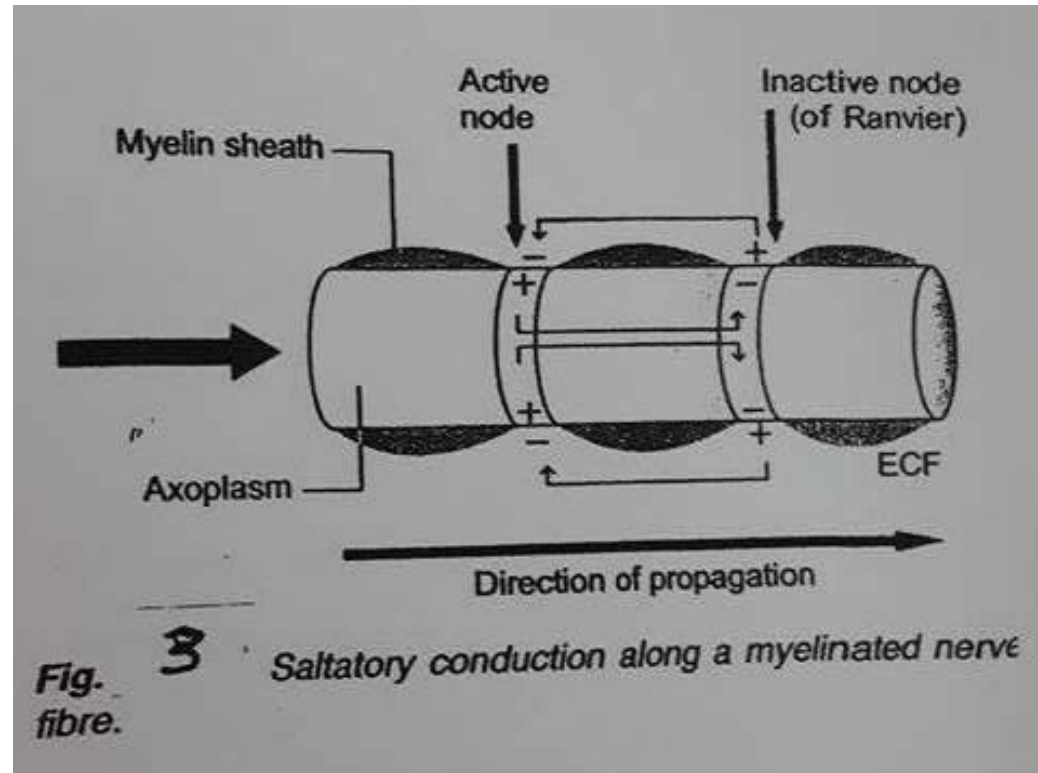


Propagation of action potential in a myelinated axon

- The myelinated nerve fibers have a wrapping of myelin sheath with gaps at regular intervals which are devoid of myelin sheath (nodes of Ranvier). The axonal membrane in the naked area (nodes of Ranvier) bears densely packed ion channels. The myelin sheath acts as an insulator and does not allow the current flow. Therefore, in myelinated nerve fiber the local circuit of current flow only occurs from one node of Ranvier to the adjacent node.

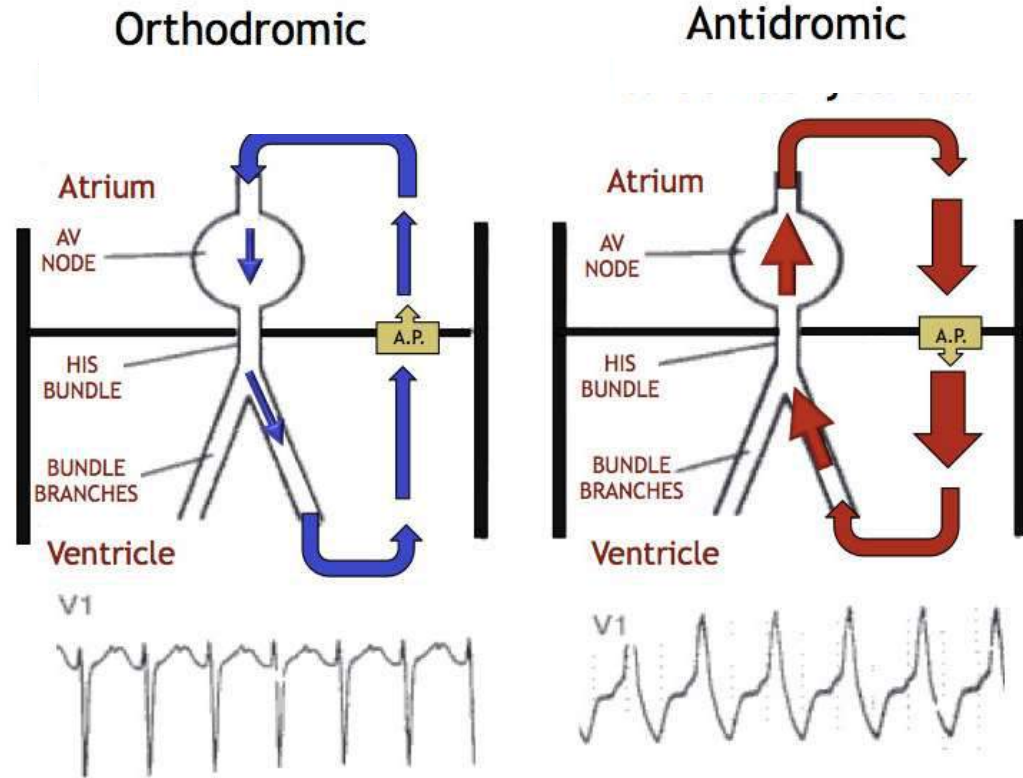


- That is the impulse (action potential) jumps from one node of Ranvier to next. This is known as **saltatory conduction**. Since the impulse jumps from one node to other, the speed of conduction in myelinated fibers is much rapid (50-100 times faster) than the unmyelinated fiber.

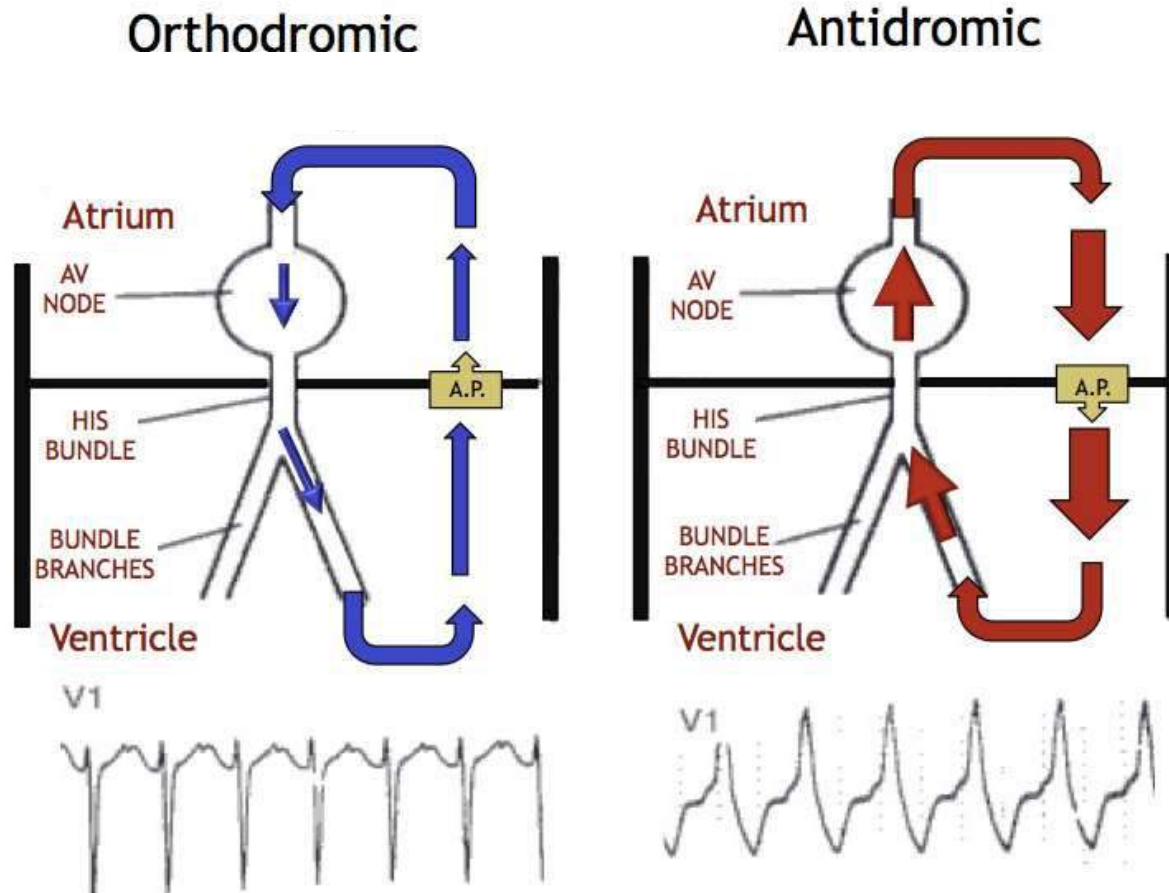


Orthodromic versus antidromic conduction

- Normally, the action potential is propagated in one direction. That is, usually the nerve impulse from the receptors or synaptic junctions travels along the entire length of axon to their termination. This type of conduction is called **orthodromic conduction**.

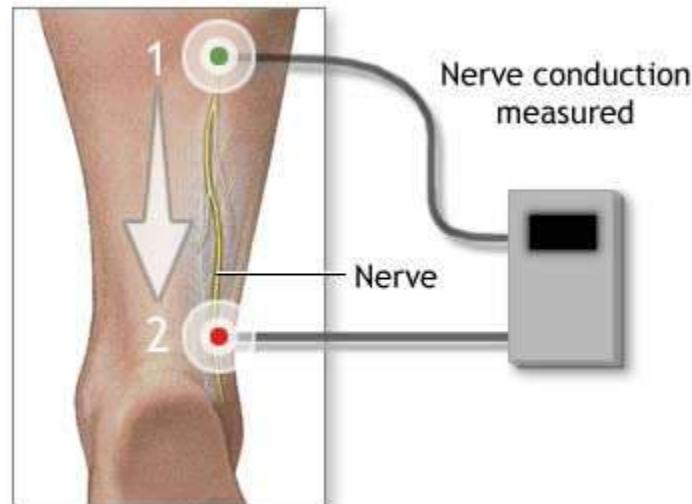


- The conduction of nerve impulse in the opposite direction, as seen in the sensory nerve supplying the blood vessels, is called **antidromic conduction**.



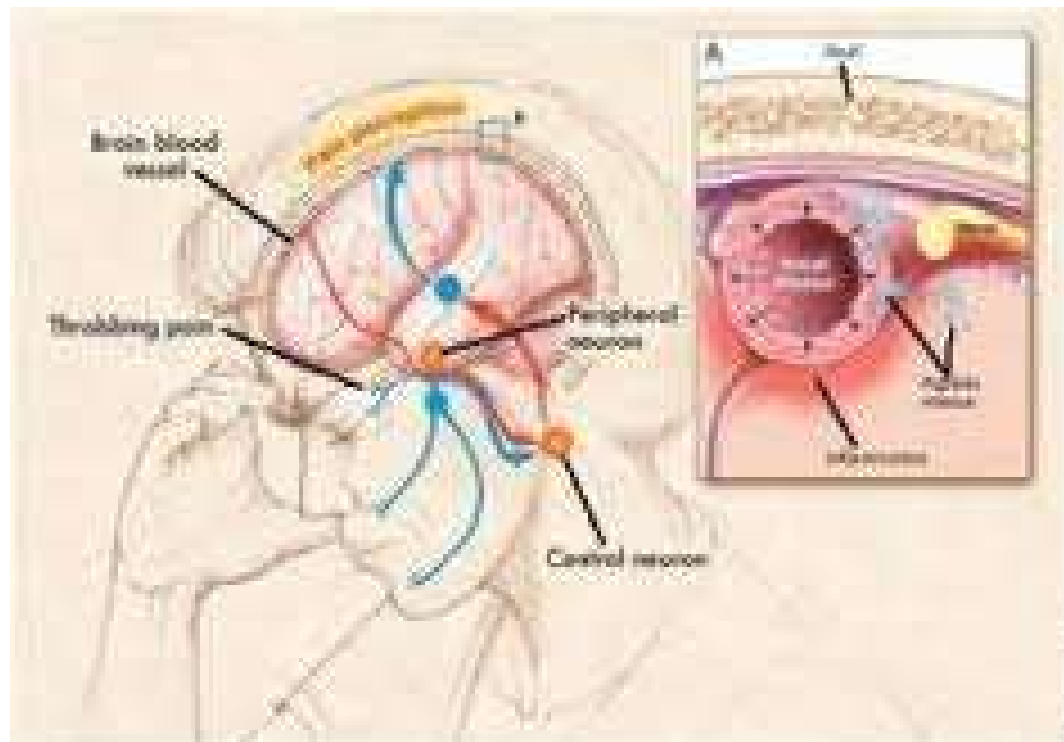
Factors affecting conduction velocity

- The velocity of conduction in nerve fiber varies from as little as 0.25 m/sec in very small unmyelinated fiber to as high as 100 m/sec in very large myelinated fiber.

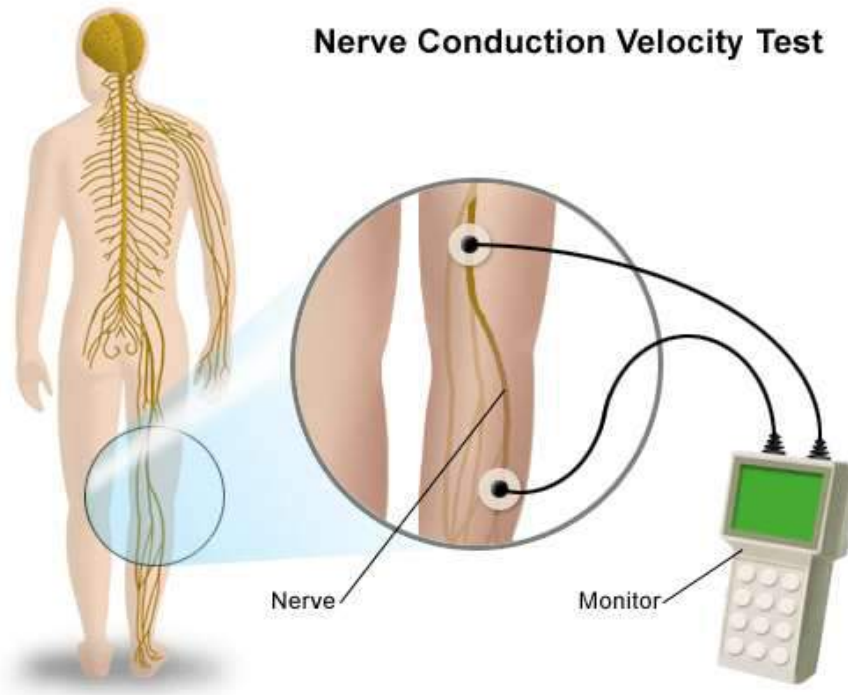


In general the factors affecting conducting velocity are:

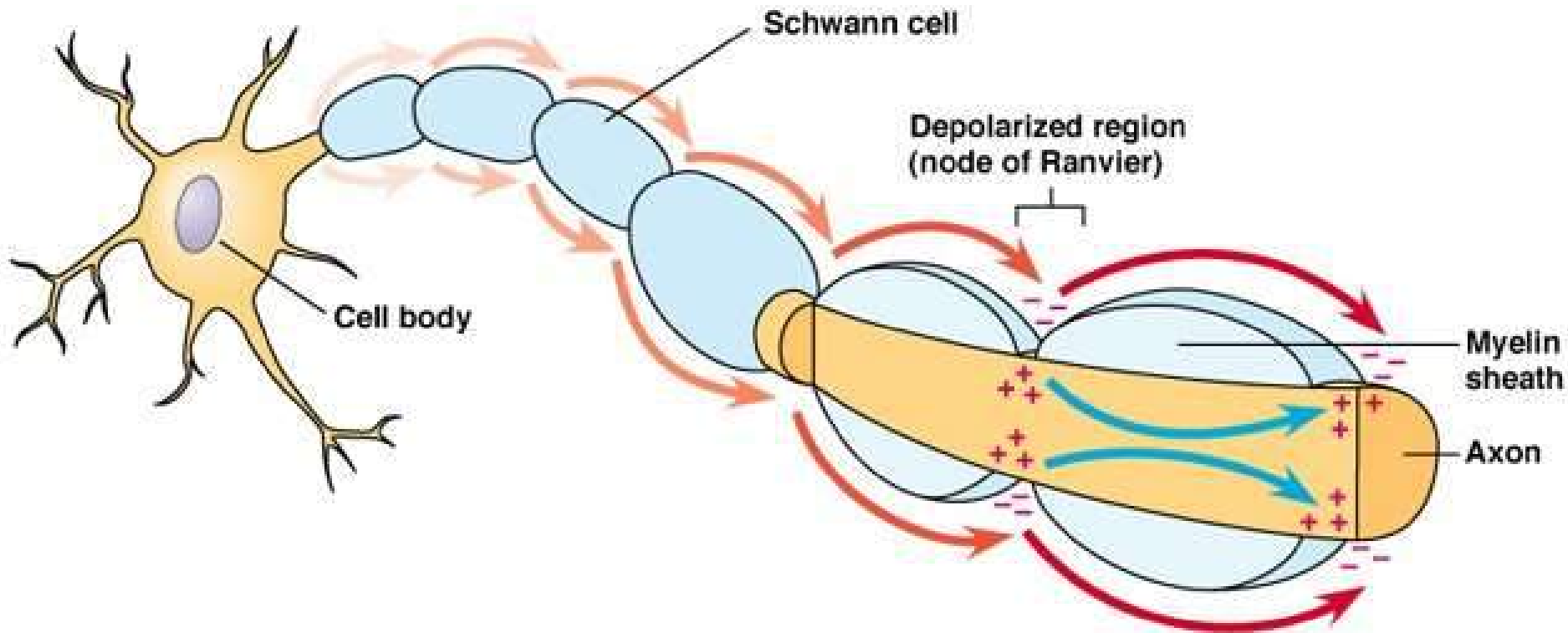
- 1. Temperature:** a decrease in temperature delays conduction i.e. slows down the conduction velocity



2. Axon diameter: affects the conduction velocity through the resistance offered by the axoplasm (R.) to the flow of axoplasmic current. If the diameter of the axon is greater, the axoplasmic resistance (K) is lesser and hence the velocity of conduction is higher.

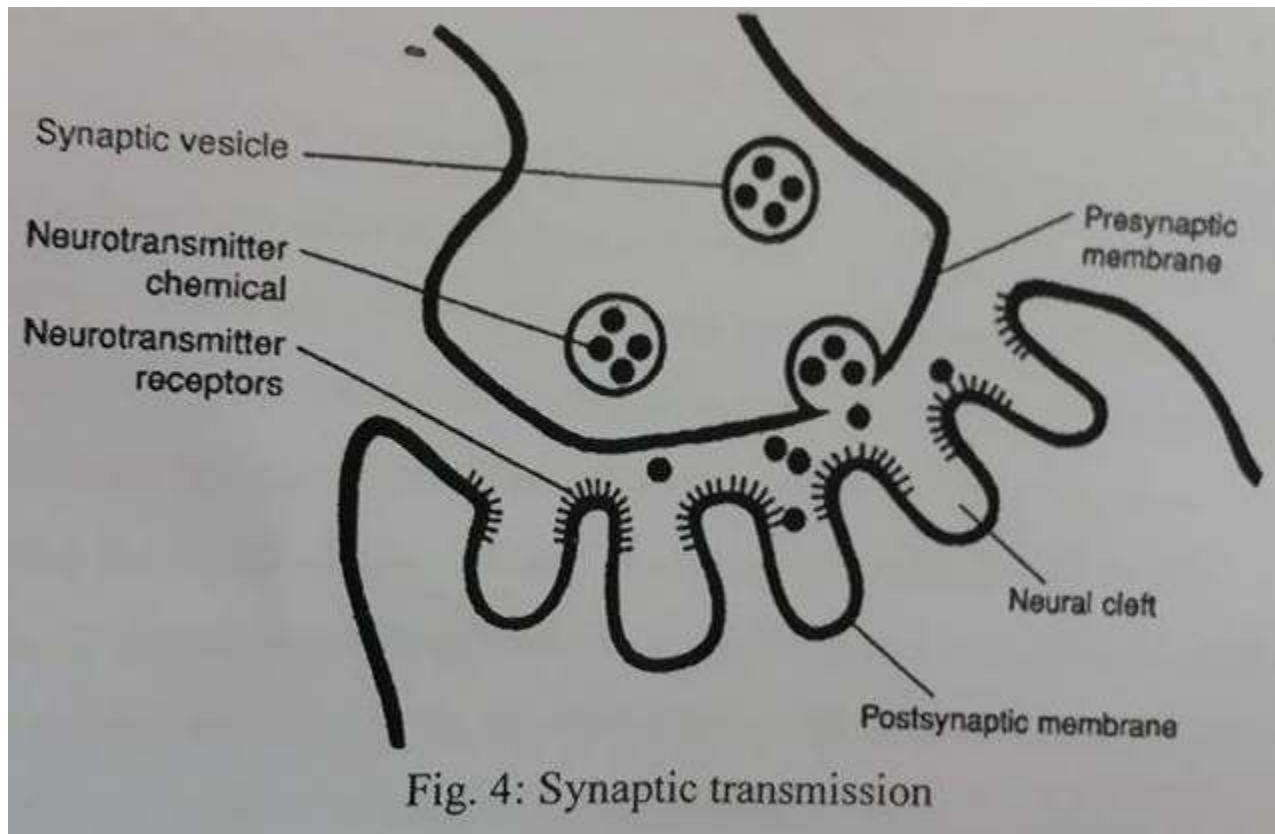


3. Myelination: increases conduction velocity by increases the axon diameter, and by the salutatory conduction produced due to its insulating effect.



Synapse

- Neurons that transmitted impulses to other neurons do not actually touch one another. The small gap or space between the axon of one neuron and the dendrites or cell body of the next neuron is called the **synapse**.



- Within the synaptic knob (terminal end) of the presynaptic axon is a chemical **neurotransmitter** that is released into the synapse by the arrival of an electrical nerve impulse.

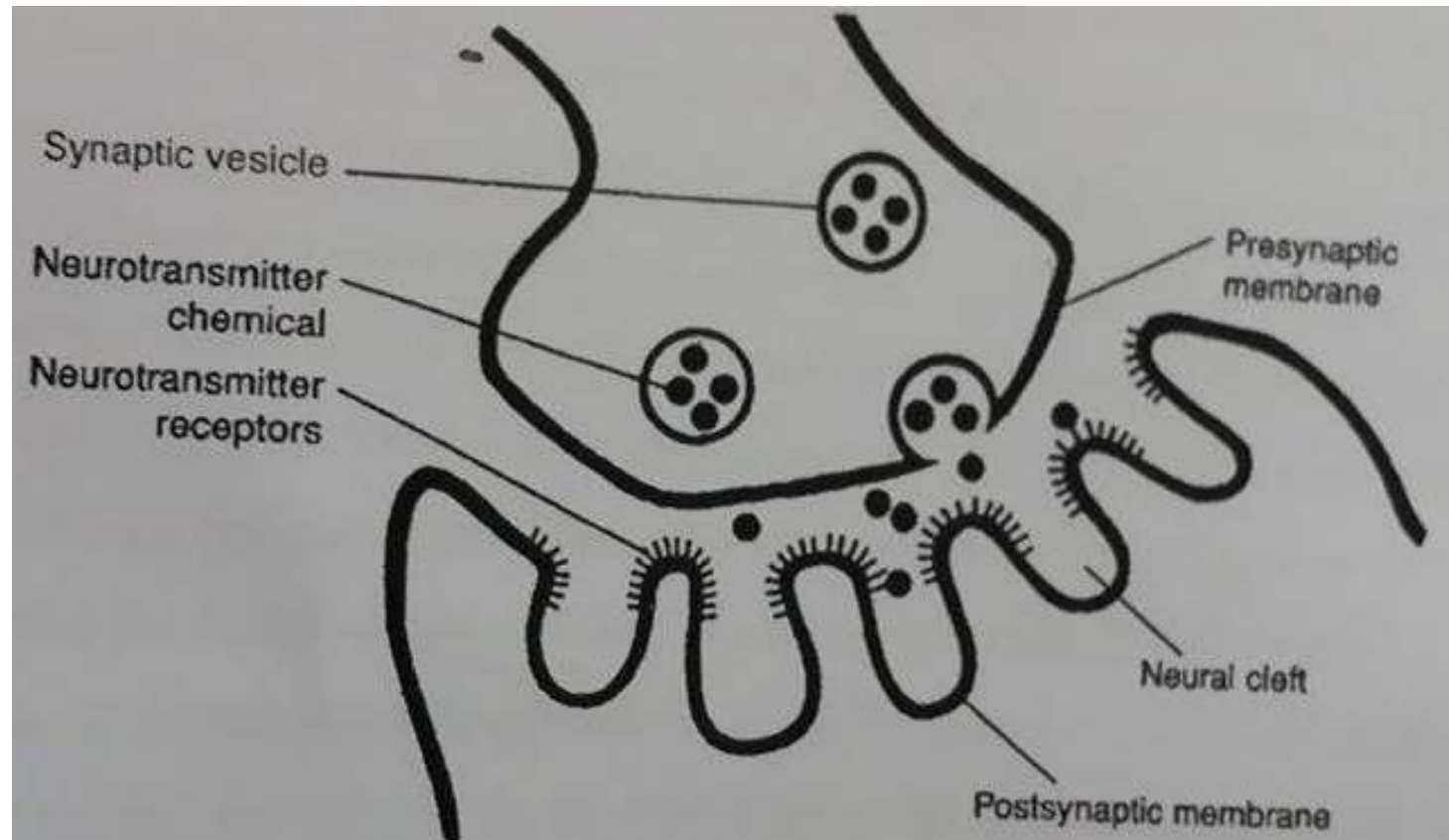
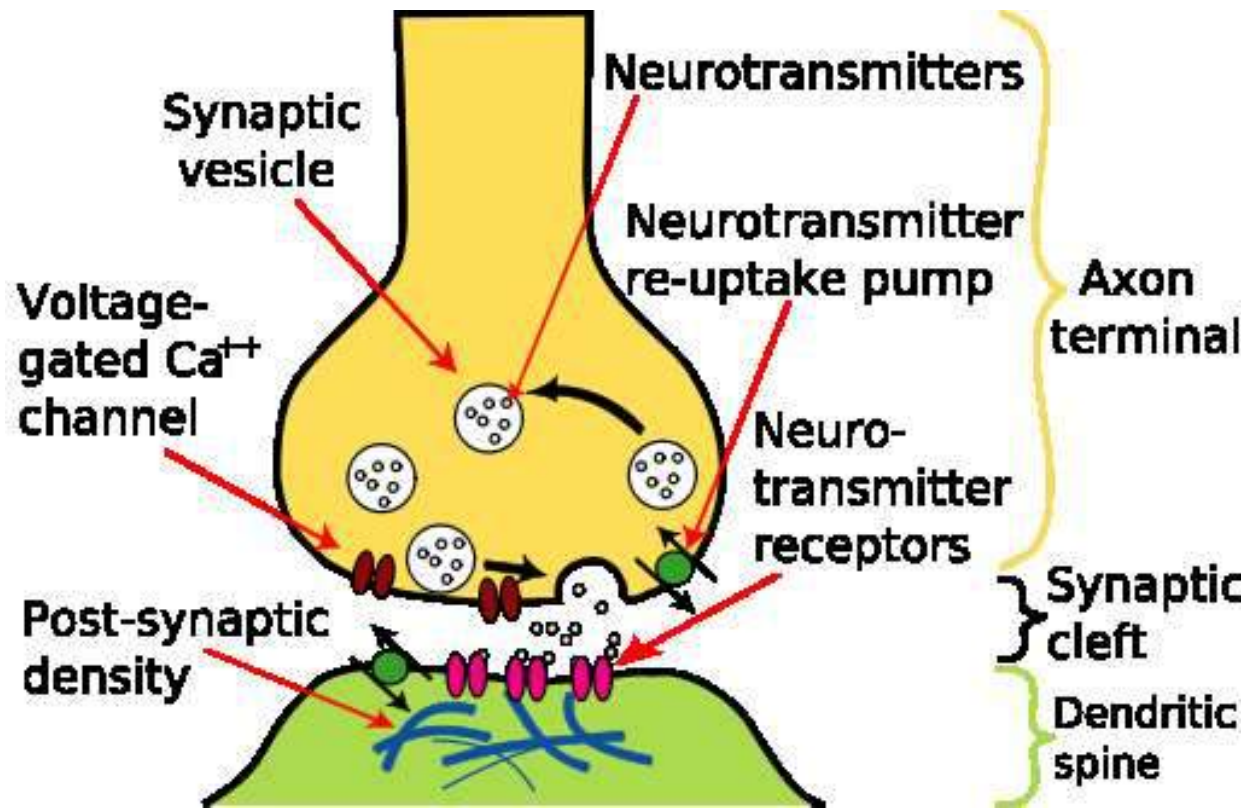
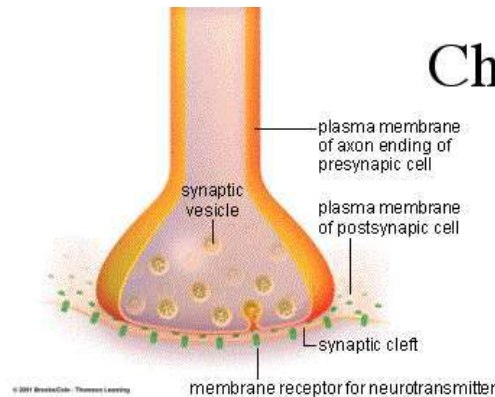


Fig. 4: Synaptic transmission

- The neurotransmitter diffuse across the synapse, combines with specific receptor sites on the cell membrane of the postsynaptic neuron, and there generates an electrical impulse that is, in turn, carried by this neurons axon to the next synapse, and so forth.

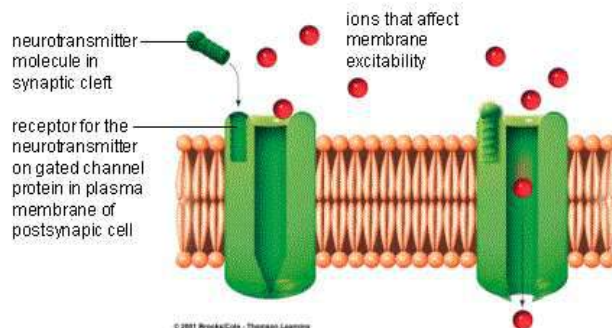


- A chemical in activator at the cell body or dendrite of the post synaptic neuron quickly inactivates in neurotransmitter. This prevents unwanted, continuous impulses, unless a new impulse from the first neuron releases more neurotransmitter.

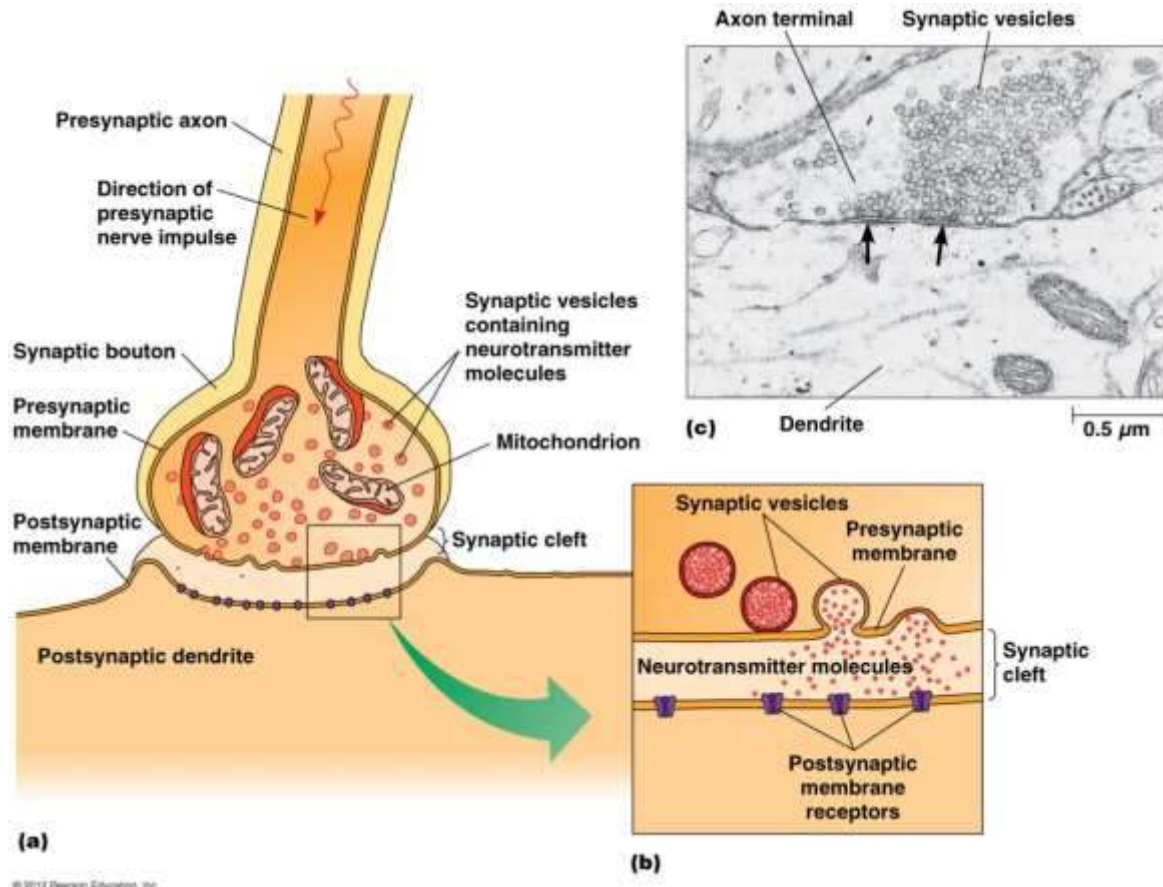


Chemical Synapse

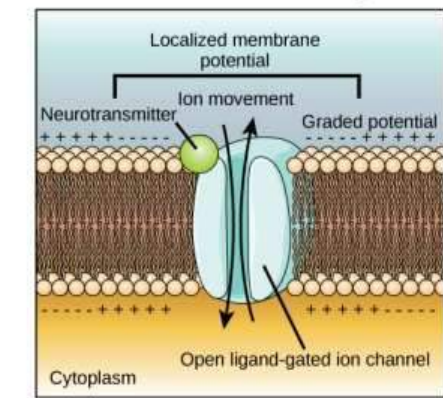
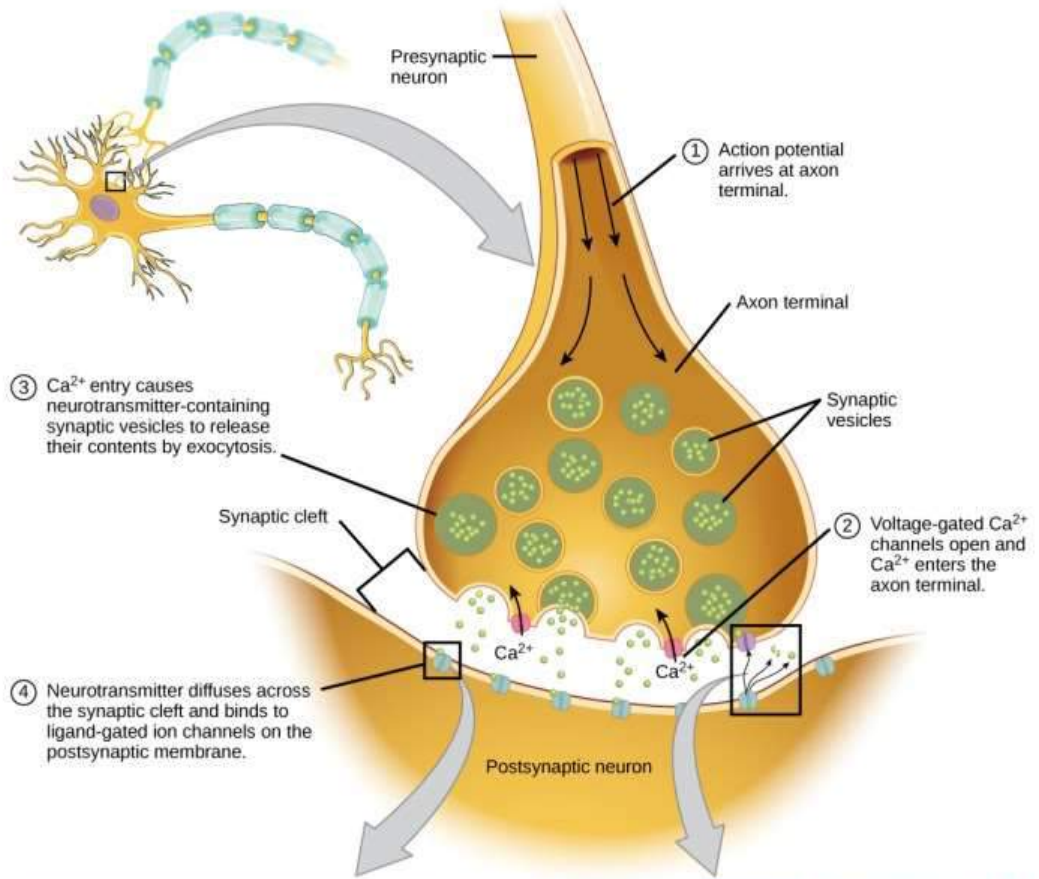
Gap between the terminal ending of an axon and the input zone of another cell



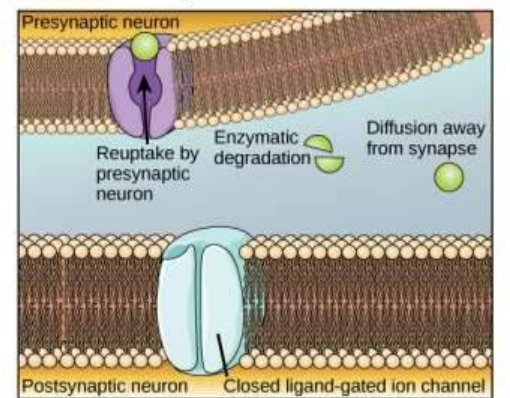
- **Many synapses are termed excitatory**
- because the neurotransmitter causes the postsynaptic neurons to depolarize (become more negative outside as Na^+ ions enter the cell) and transmit an electrical impulse to another neuron, muscle cell, or gland.



- Some synapses, however, are **inhibitory**, meaning that the neurotransmitter causes the postsynaptic neuron to hyperpolarize (become even more positive outside as K^+ ions have the cell or Cl^- ions inter the cell) and therefore not transmit an electrical impulse.

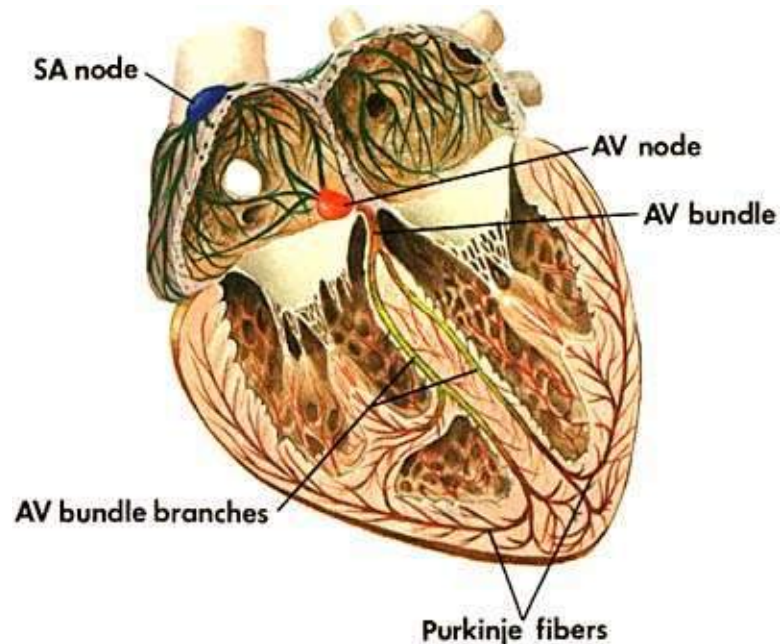


⑤ Binding of neurotransmitter opens ligand-gated ion channels, resulting in graded potentials.



⑥ Reuptake by the presynaptic neuron, enzymatic degradation, and diffusion reduce neurotransmitter levels, terminating the signal.

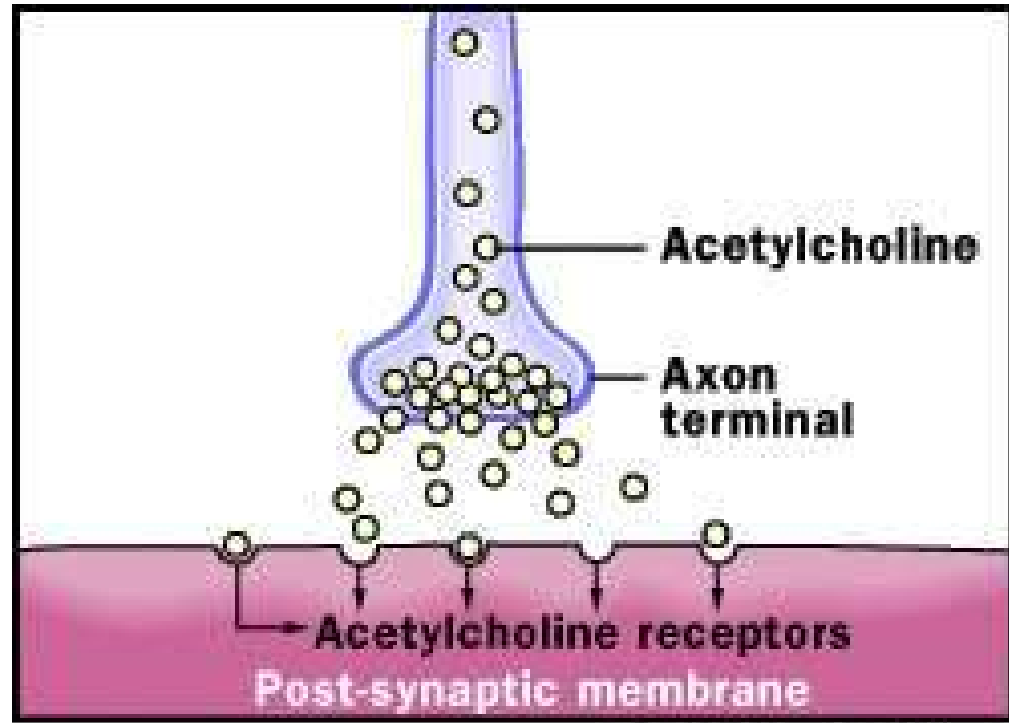
- Such inhibitory synapses are important, for example, for slowing the heart rate, and for balancing the excitatory impulses transmitted to skeletal muscles. With respect to the skeletal muscles, this inhibition prevents excessive contraction and is important for coordination.



- An example of neurotransmitter is **acetylcholine**, which is found at neuromuscular junctions, in the CNS, and in much of the peripheral nervous system.

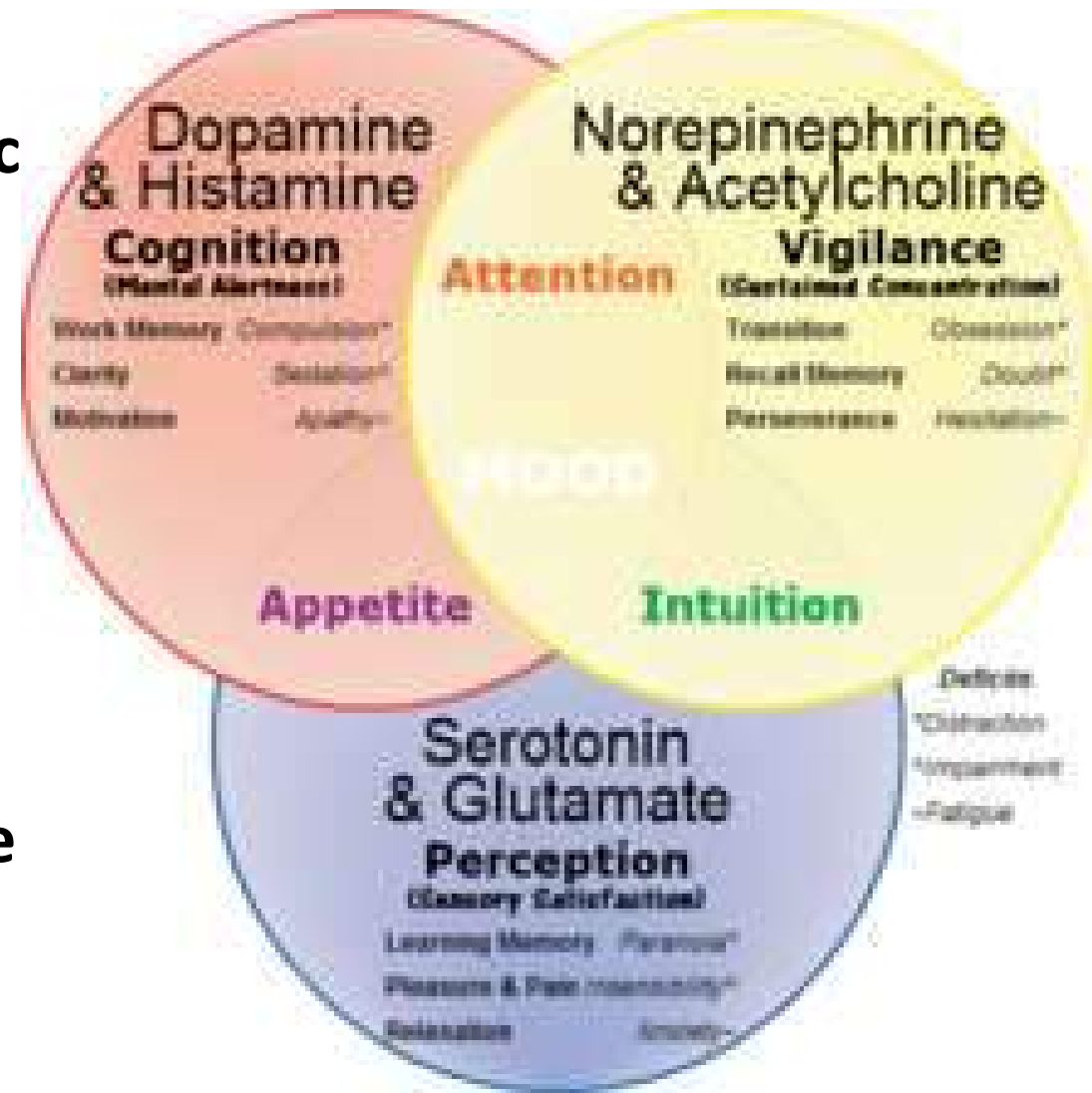
Acetylcholine usually makes a postsynaptic membrane more permeable to Na^+ ions, which brings about depolarization of the postsynaptic neuron.

Cholinesterase is the inactivator of acetylcholine.



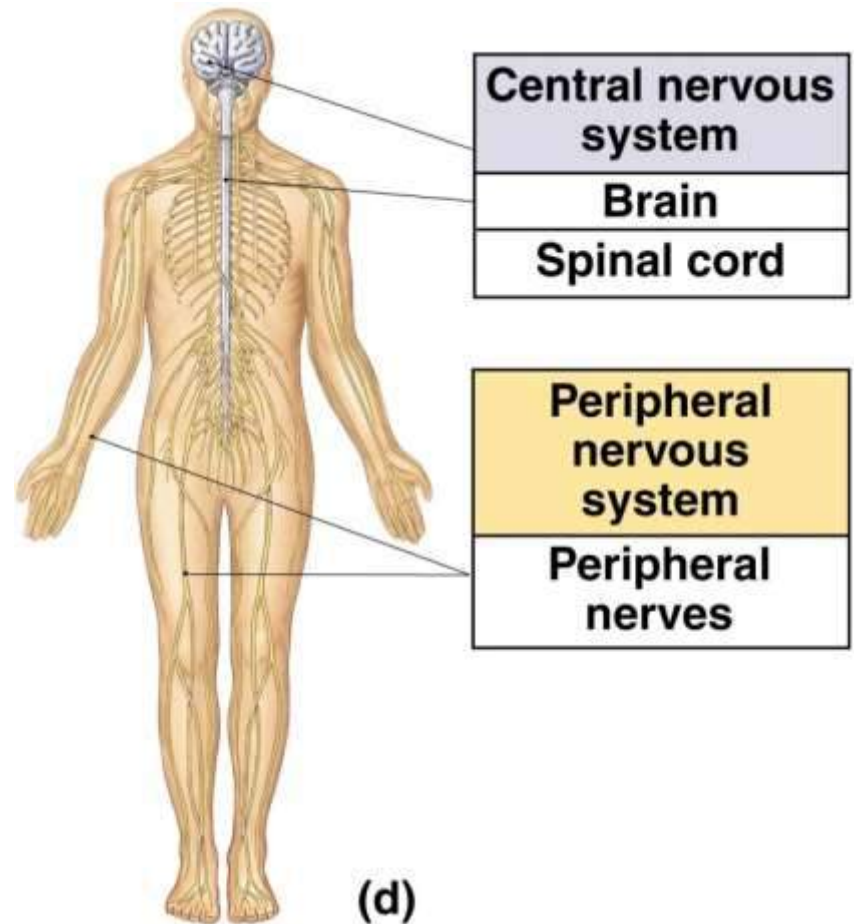
There are many other neurotransmitters, especially in the central nervous system. These include

- Dopamine
- gamma amino butyric acid (GABA)
- norepinephrine
- glutamate
- serotonin.
- Norepinephrine is inactivated by either catechol-o-methyltransferase (COMT) or monamine (MAO).



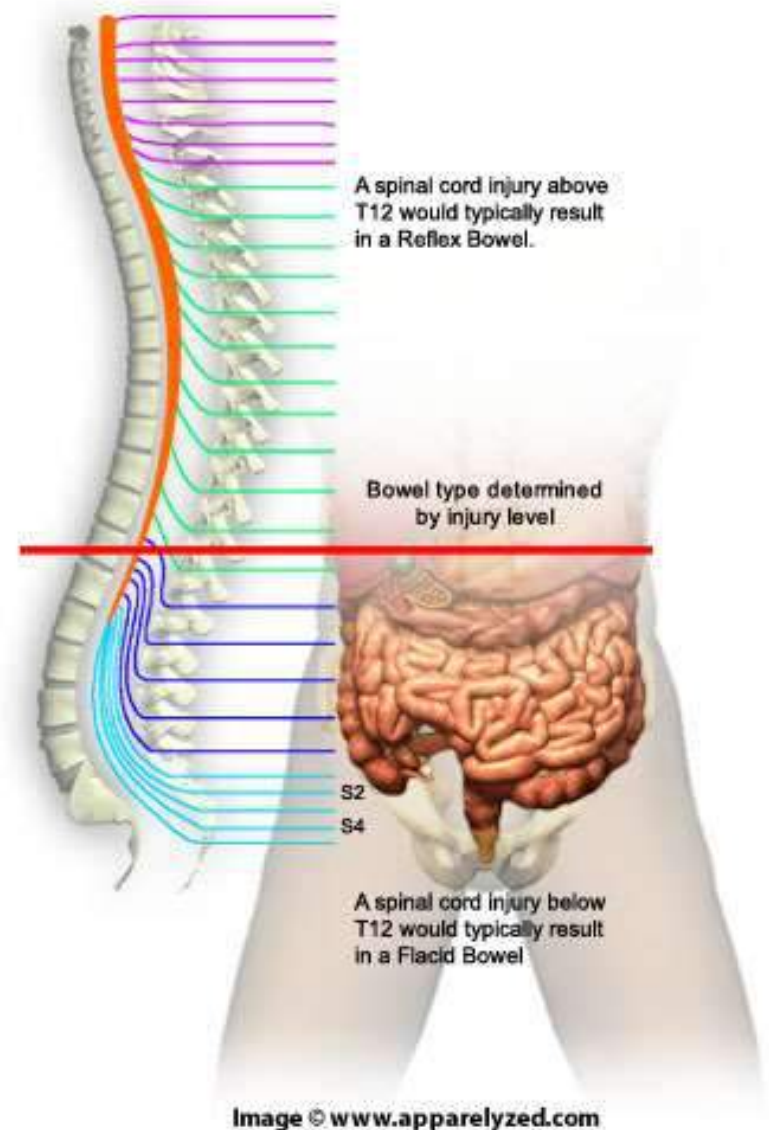
Nervous system divisions

- The nervous system has two divisions
 1. **The central nervous system (CNS):** consists of brain and spinal cord
 2. **The peripheral nervous system (PNS):** consists of cranial nerves and spinal nerves. The PNS includes the autonomic nervous system (ANS).



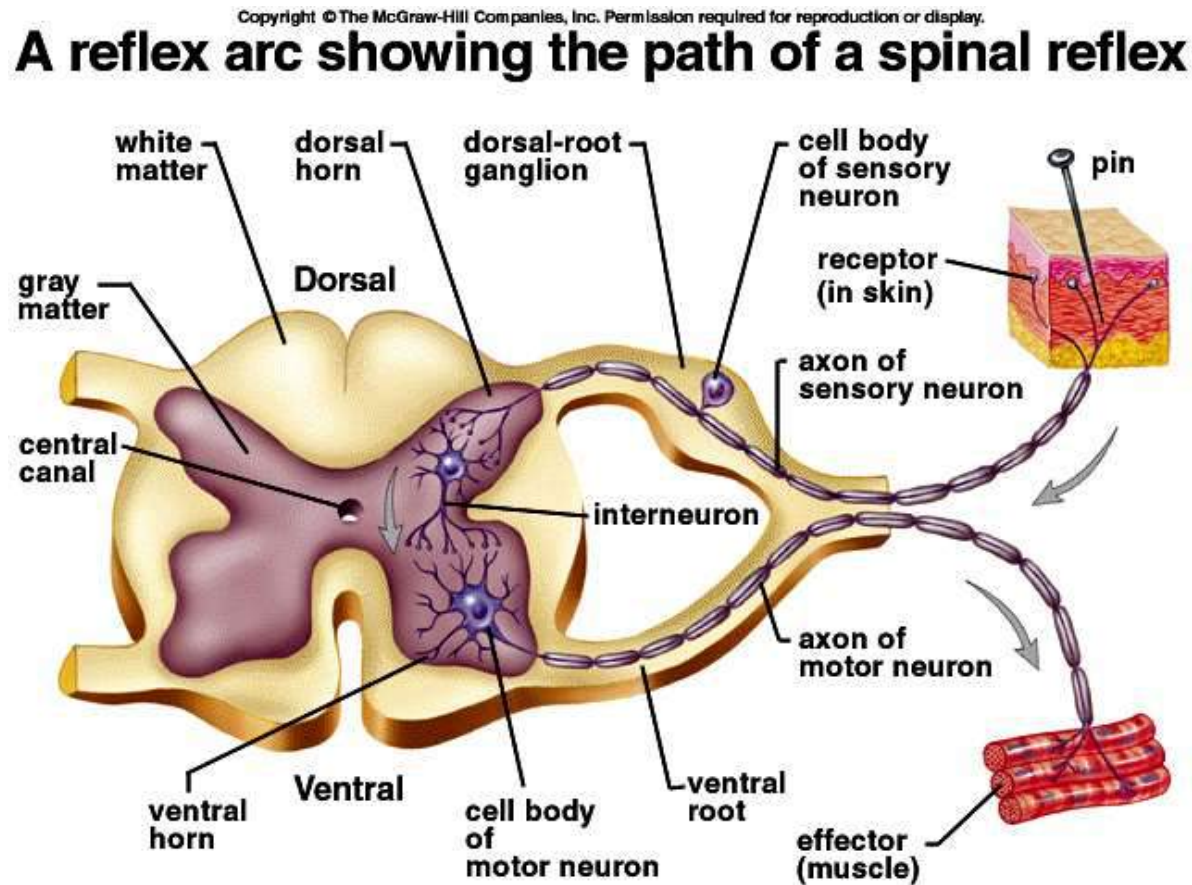
Spinal cord reflexes:

- A reflex is an involuntary response to a stimulus, that is, an automatic action stimulated by a specific change of some kind. Spinal cord reflexes are those that do not depend directly on the brain, although the brain may inhibit or enhance them.

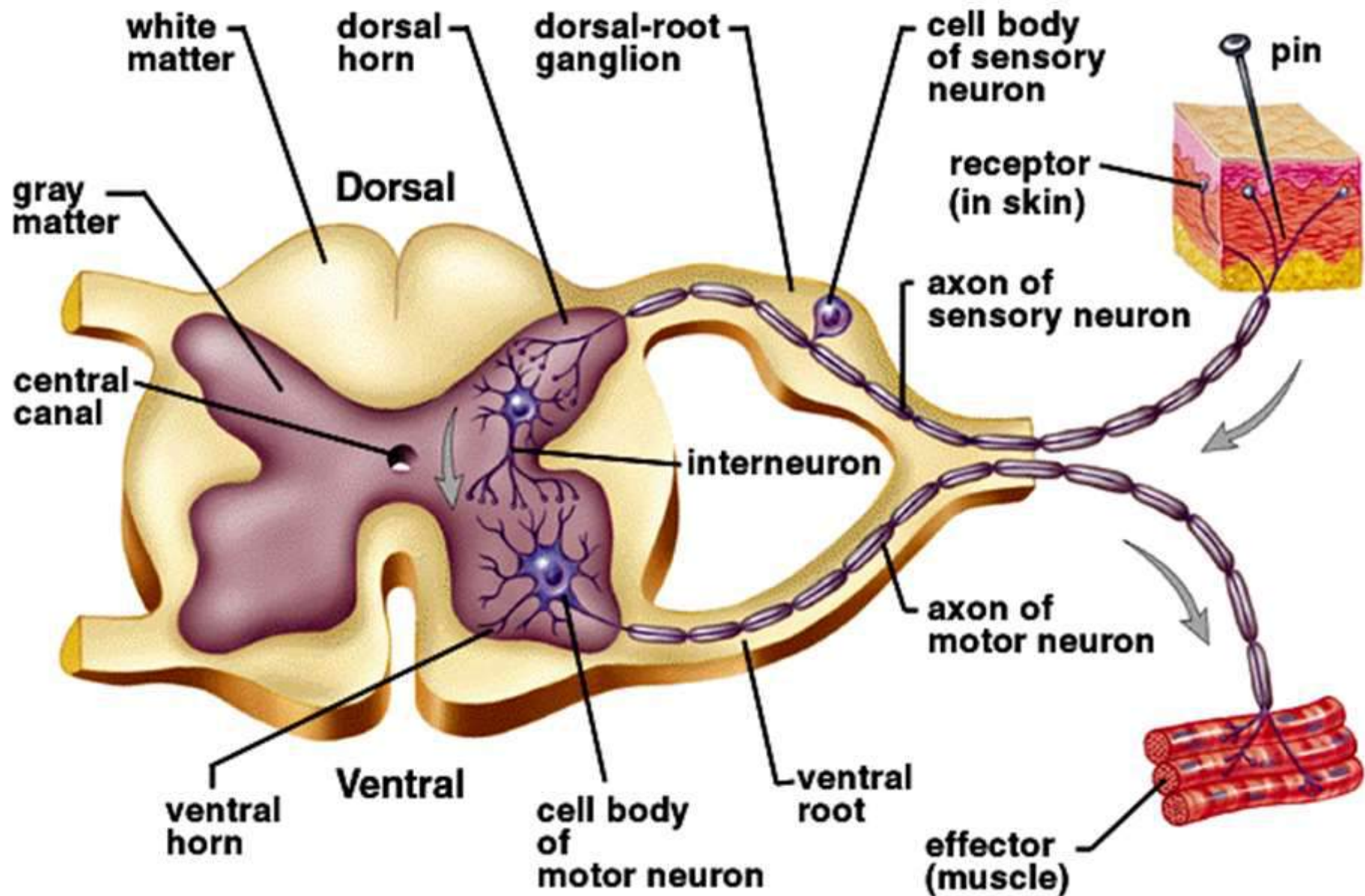


Reflex Arc

- **A reflex arc** is the pathway that nerve impulses travel when a reflex is elicited, and there are five essential parts:
 1. **Receptors**- detect a change (the stimulus) and generate impulses.
 2. **Sensory neurons**- transmit impulses from receptors to the CNS
 3. **Central nervous system**- contains one or more synapses (interneurons may be part of the pathway).
 4. **Motor neurons**- transmit impulses from the CNS to the effector.
 5. **Effector**- performs its characteristic action.



A reflex arc showing the path of a spinal reflex

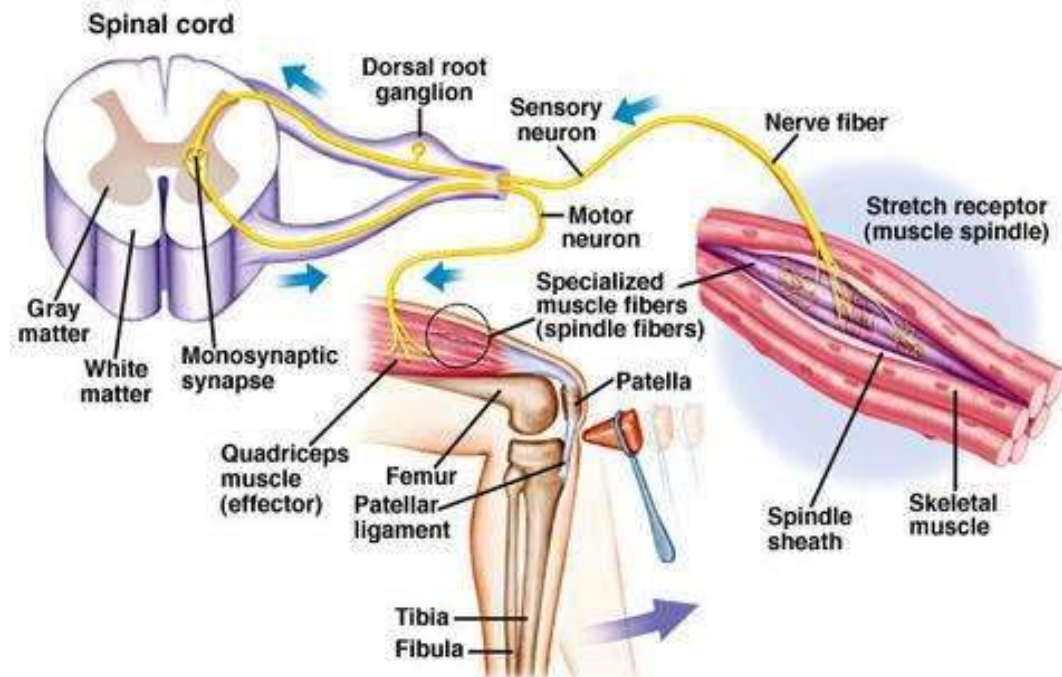


Patellar reflex or knee-jerk

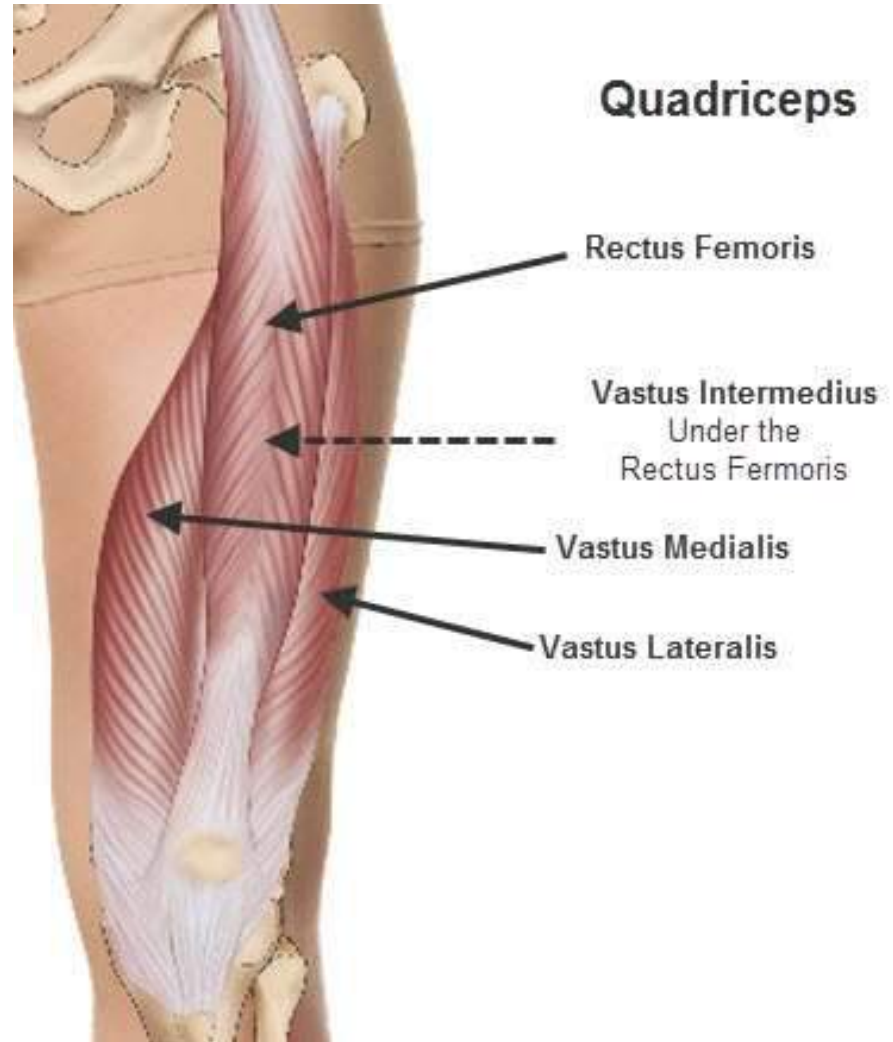
- In this reflex, a tap on the patellar tendon just below the kneecap causes extension of the lower leg. This is a **stretch reflex**, which means that a muscle that is stretched will automatically contract.

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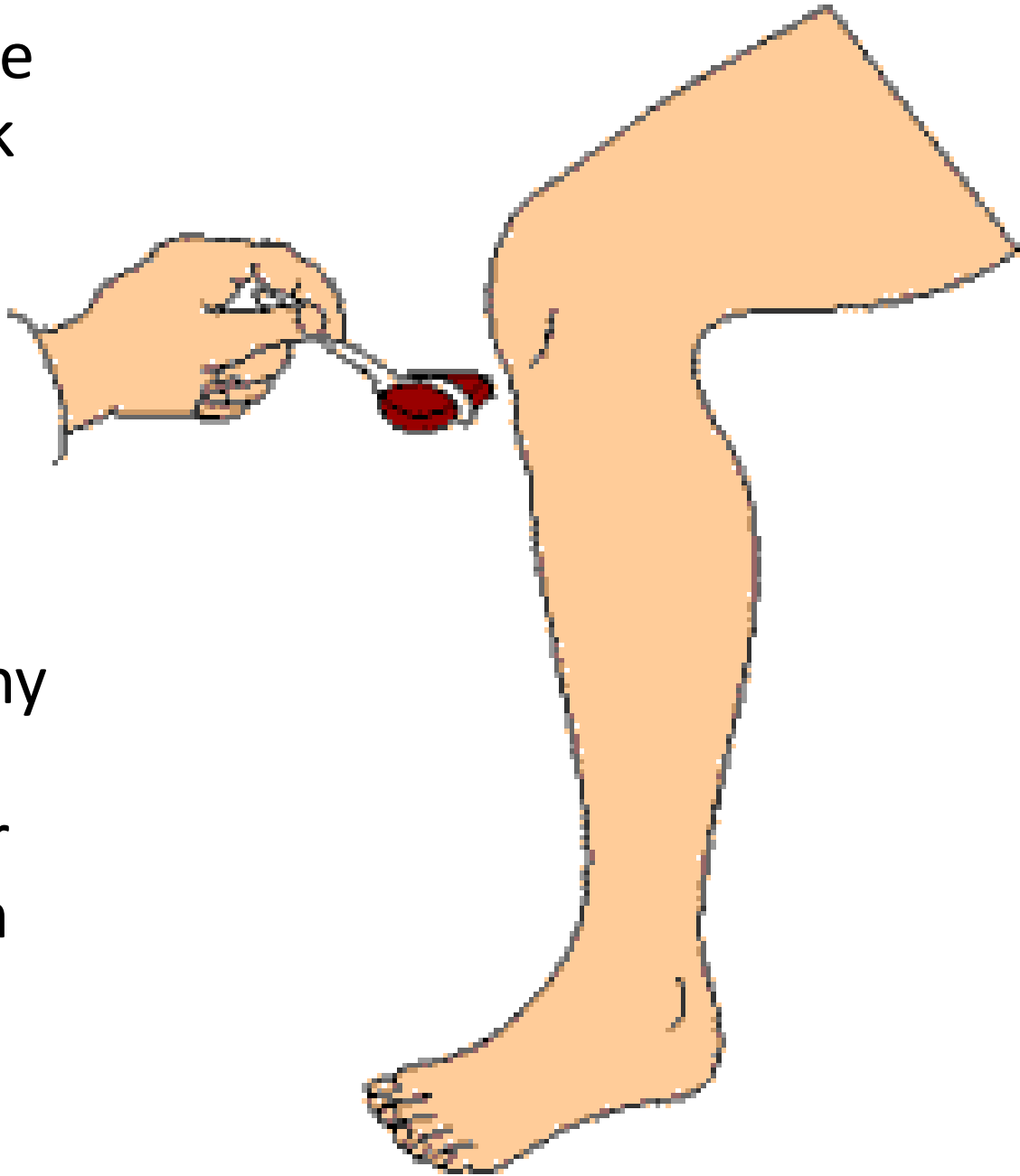
Knee-Jerk Reflex



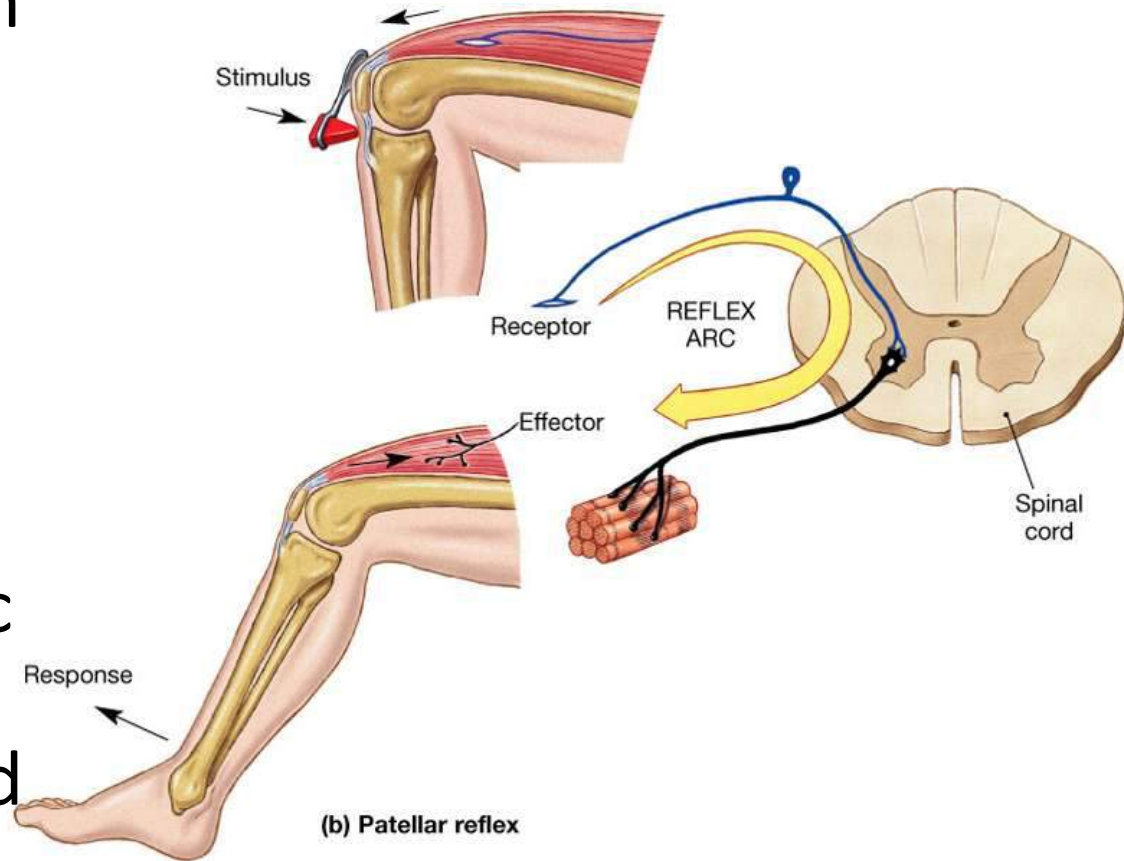
- In the quadriceps femoris muscle are stretch that detect stretching produced by striking the patellar tendon. These receptors generate impulses that are carried along sensory neurons in the femoral nerve to the spinal cord, in the spinal cord, the sensory neurons synapse with motor neurons (this is a two-neuron reflex).



- The motor neurons in the femoral nerve carry impulses back to the quadriceps femoris, the effector, which contracts and extends the lower leg. The patellar reflex is one of many used clinically to determine whether the nervous system is functionally properly.

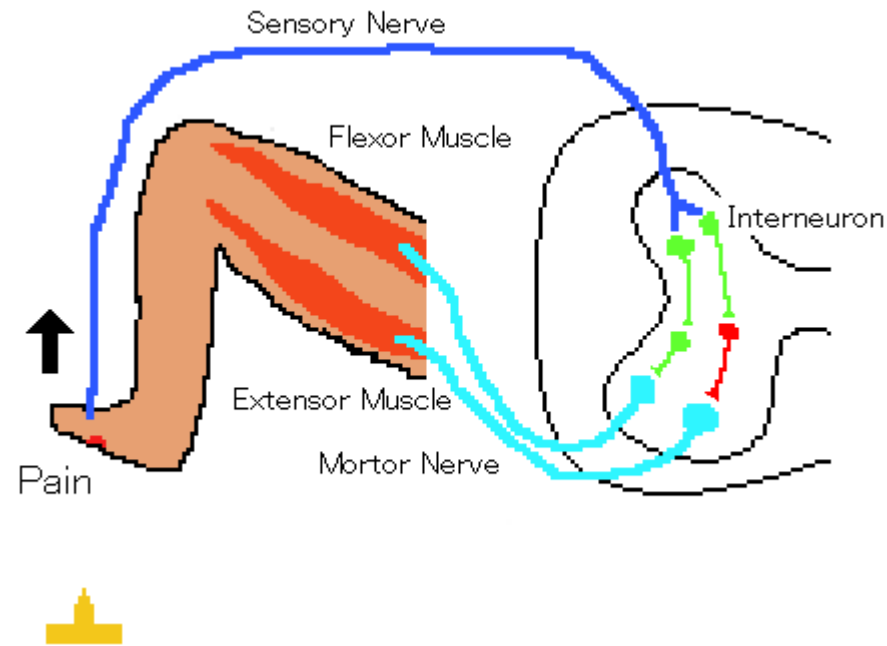


- If the patellar reflex were absent in a patient, the problem could be in the tight muscle, the femoral nerve, or the spinal cord. If the reflex is normal, however, that means that all part of the reflex arc are intact. Since these are spinal cord reflexes, the brain is not directly involved.

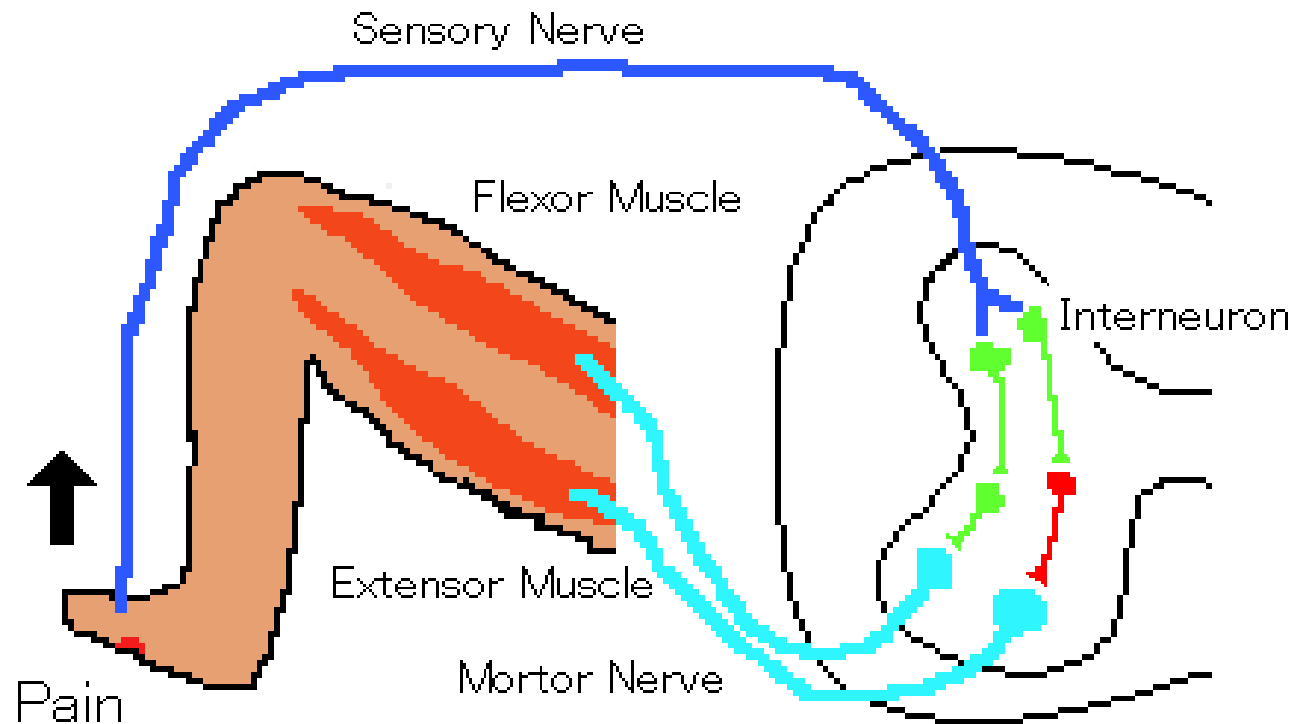


Flexor reflexes (or withdrawal reflexes)

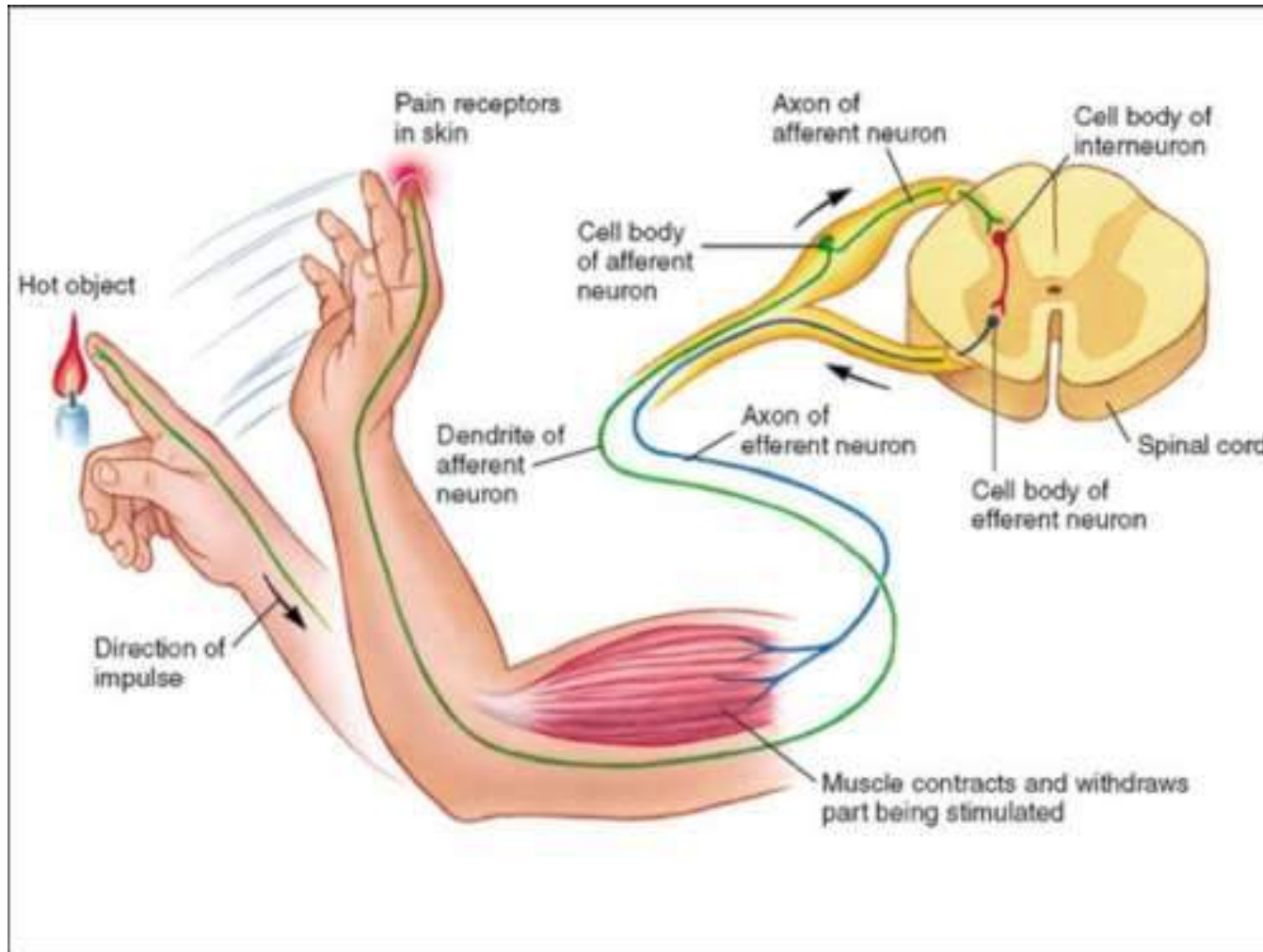
- In this reflex, the stimulus is something painful and potentially harmful and the response is to pull away from it. If you inadvertently touch a hot stove, you automatically pull your hand away.



- Flexor reflexes are three neuron reflexes, because sensory neurons synapse with interneurons in the spinal cord, which in turn synapse with motor neurons.

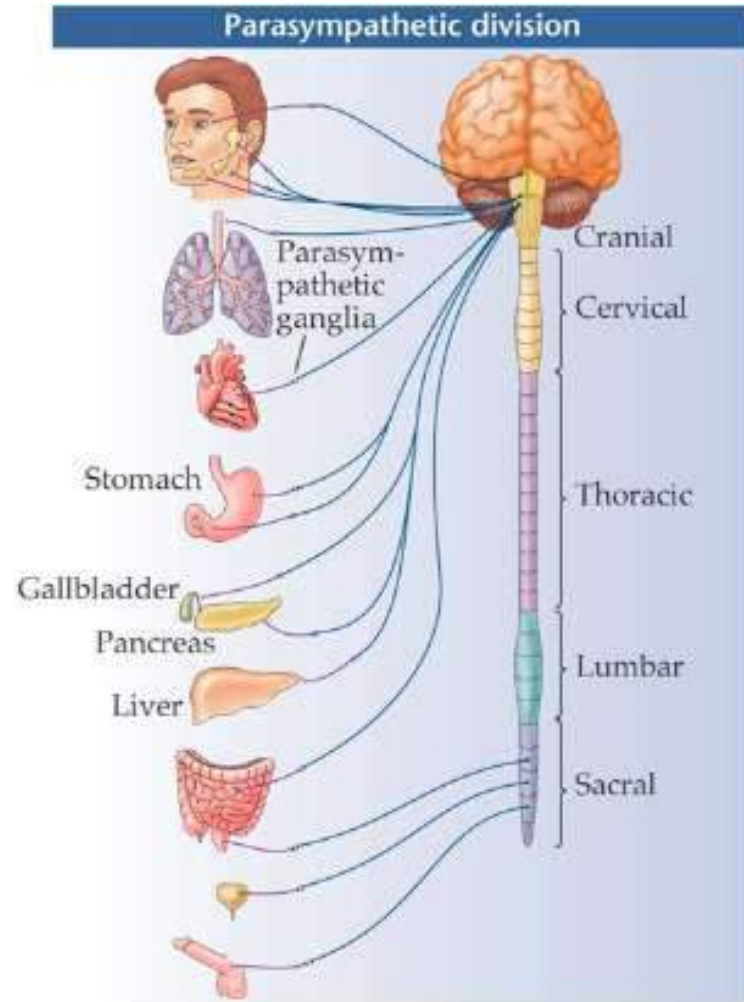
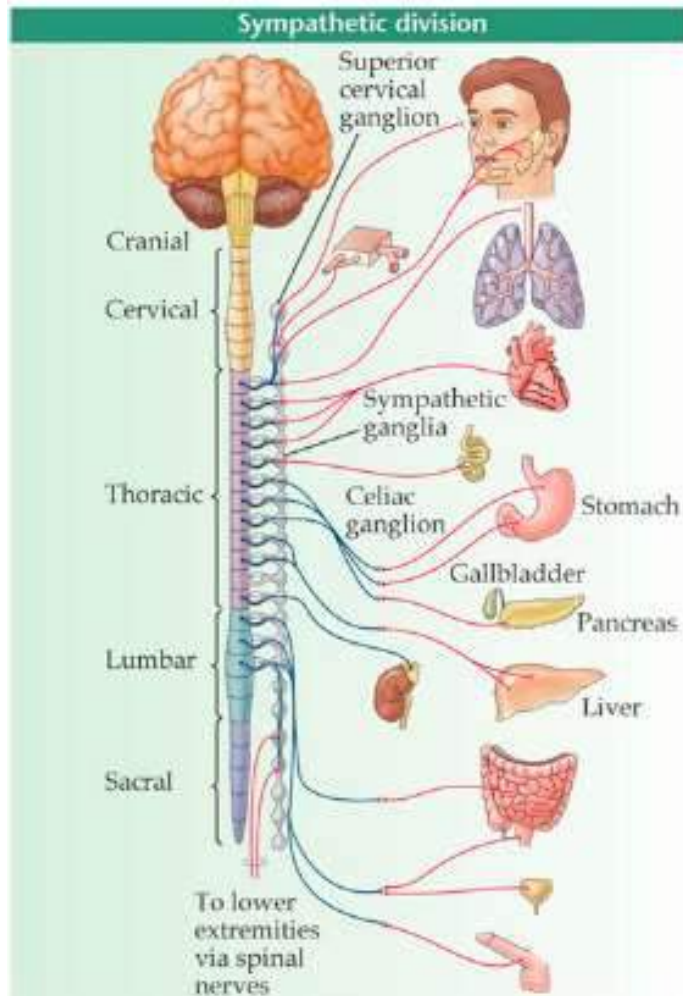


- Again, however, the brain does not have to make a decision to protect the body; the flexor reflex does that automatically.



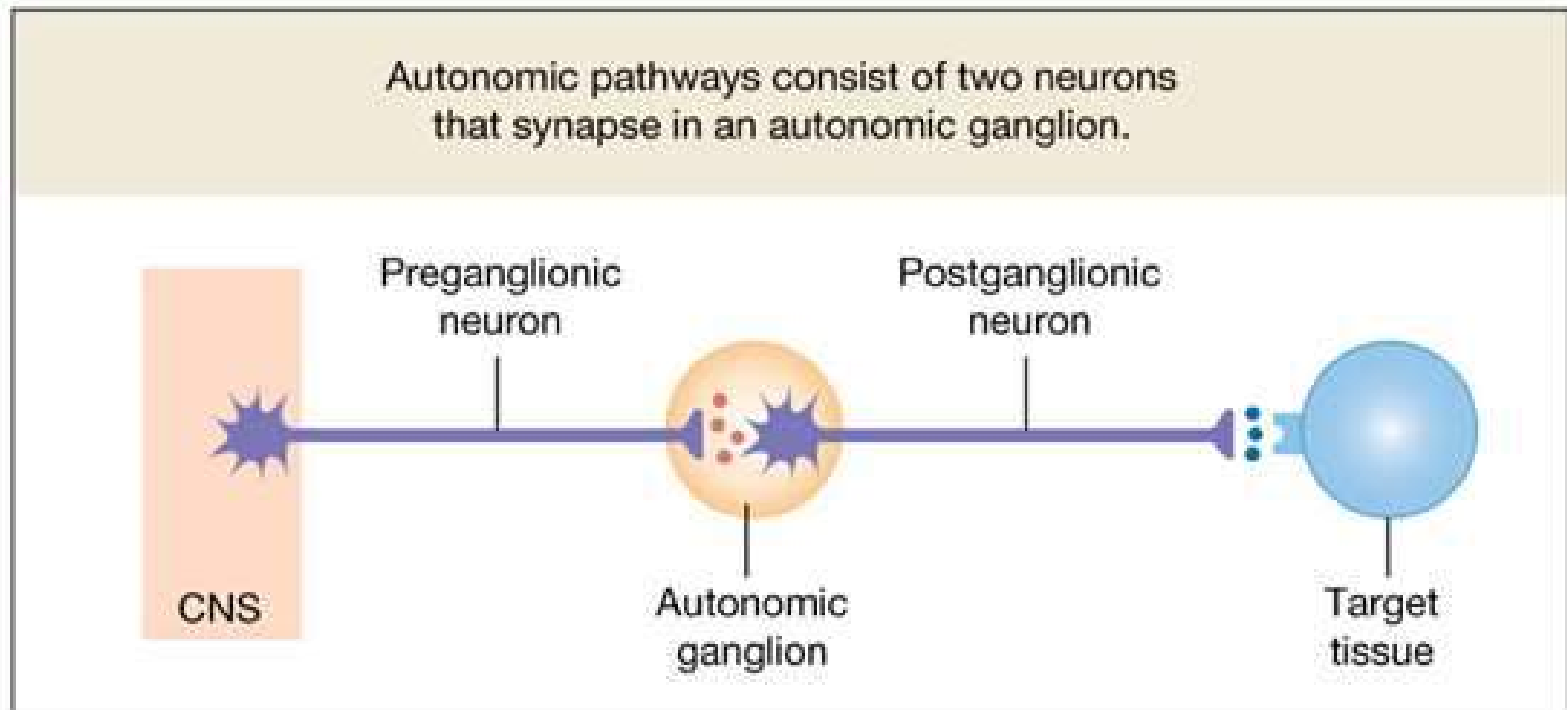
The autonomic nervous system

- The autonomic nervous system (ANS) is actually part of the peripheral nervous system in that it consists of motor portions of some cranial and spinal nerves.
- **The ANS has two divisions: sympathetic and parasympathetic.** Often, they function in opposition to each other.



Autonomic pathways

- Autonomic nerve pathway consist of two motor neurons that
 - The first neuron is called the preganglionic neuron**, from the CNS to the ganglion.
 - The second neuron is called the ganglionic neuron**, from the ganglion to the visceral effectors.



Sympathetic division:

- The sympathetic division brings about widespread responses in many organs.
- **The sympathetic division is dominant in stressful situations, which include**
 - ✓ **anger, fear, or anxiety, as well as exercise.**



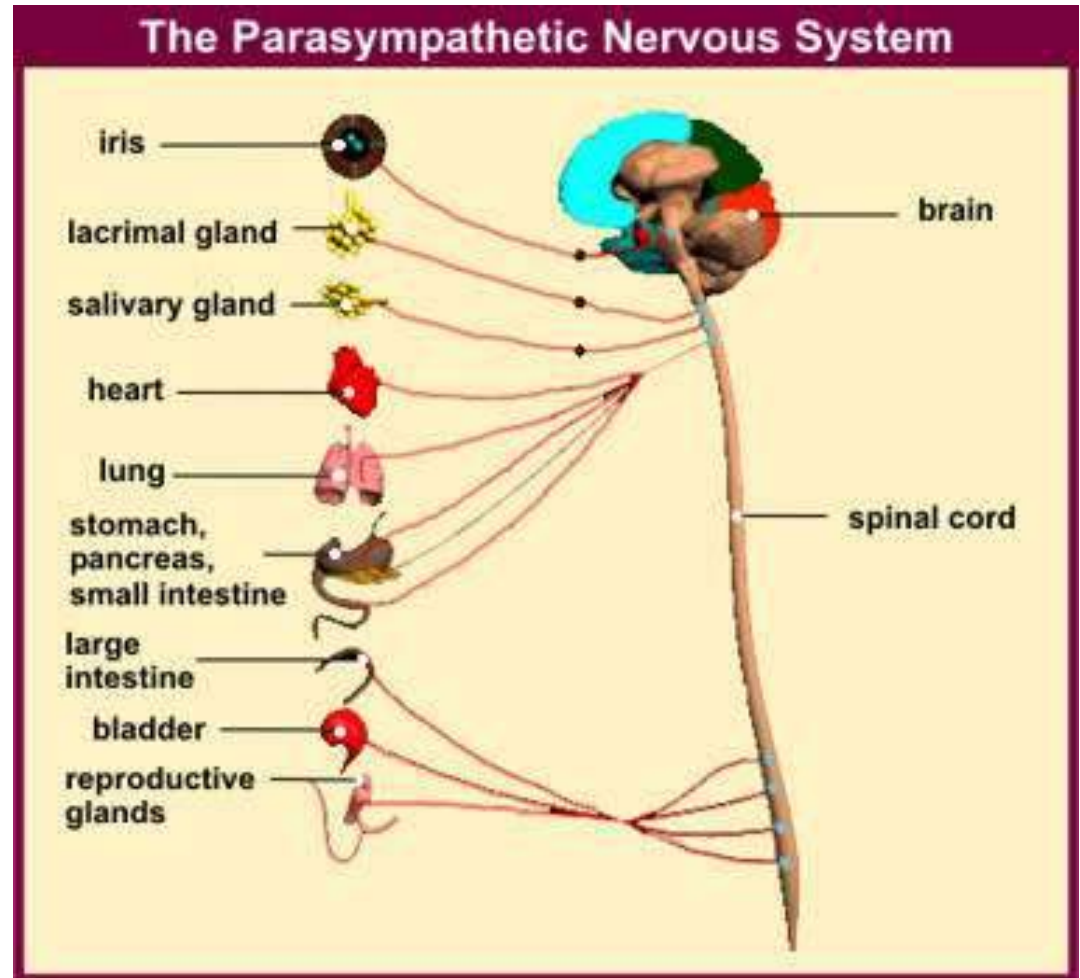
For our prehistoric ancestors, stressful situations often involved the need for intense physical activity- the (fight or flight response).

1. The heart rate increases,
2. vasodilation in skeletal muscles supplies them with more oxygen,
3. the bronchioles dilate to take in more air
4. the liver changes glycogen to glucose to supply energy.
5. At the same time digestive secretions decrease and peristalsis slows; these are not important in a stress situation.
6. Vasoconstriction in the skin
7. viscera shunts blood to more vital organs such as the heart, muscles, and brain.

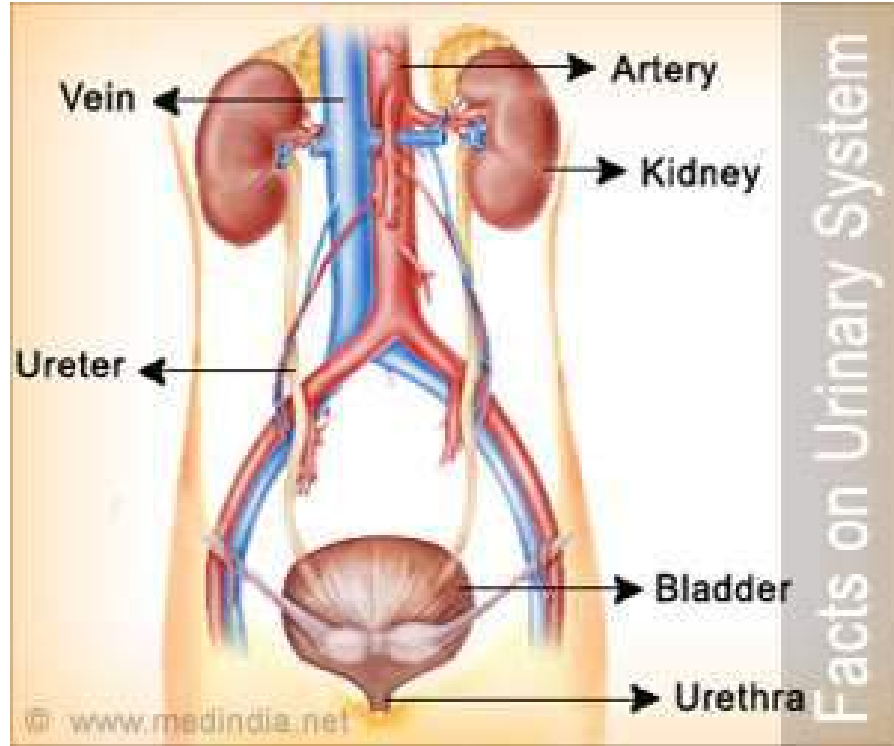


Parasympathetic division

- The parasympathetic division dominates in **relaxed (non-stress) situation** to promote normal functioning of several organ systems.

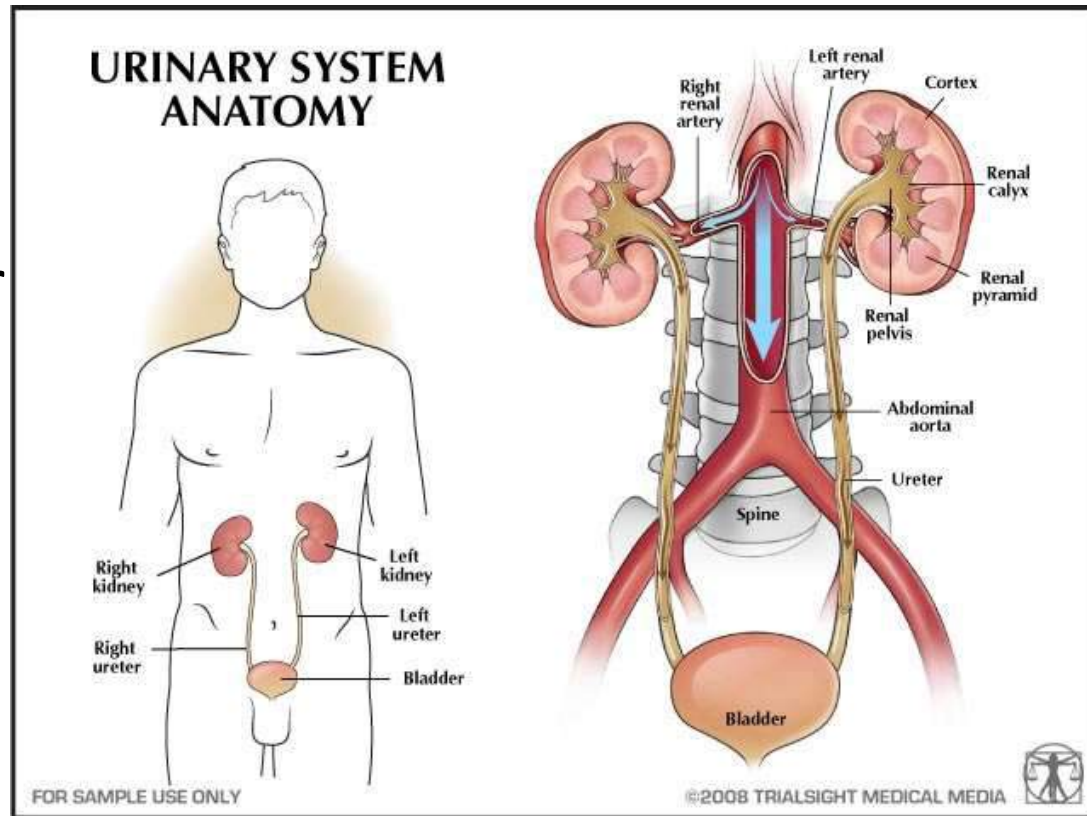


Urinary system



Urinary system

- Urinary System is a group of organs in the body concerned with filtering out excess fluid and other substances from the bloodstream.
- The substances are filtered out from the body in the form of **urine**.

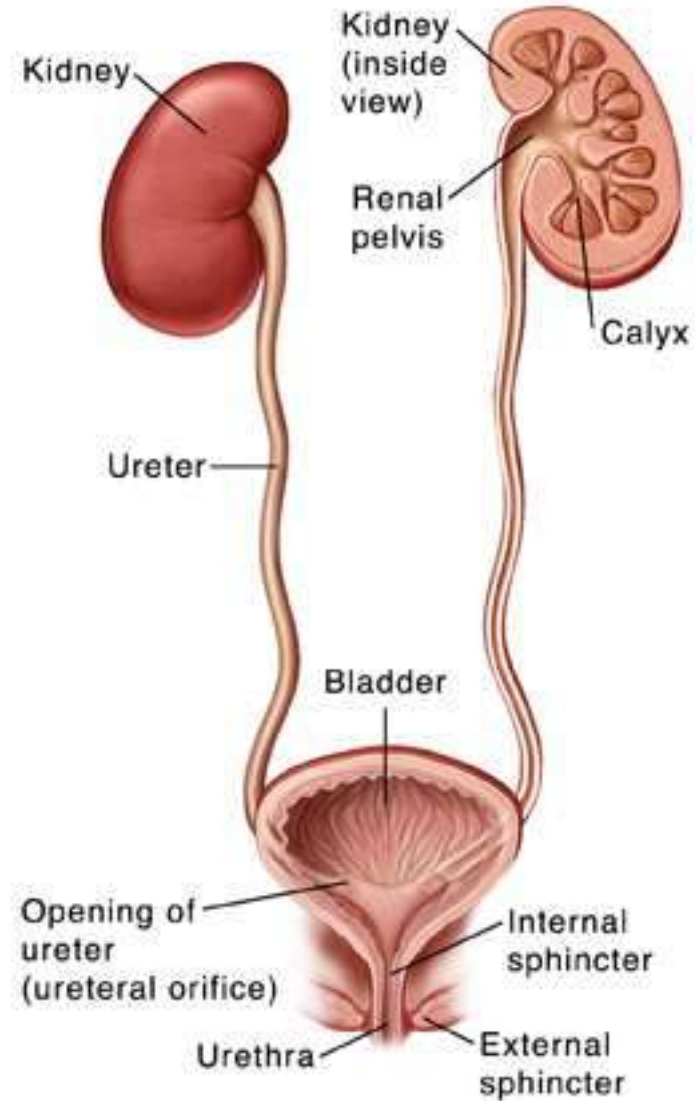


- **Urine** is a transparent yellow fluid containing unwanted wastes mostly excess water, salts, and nitrogen compounds (In general 95% water and 5% solutes).
- **Excretion** is the process of eliminating, from an organism, waste products of metabolism and other materials that are of no use.



- The kidneys are the most important excretory organ; they also accomplish several other functions:

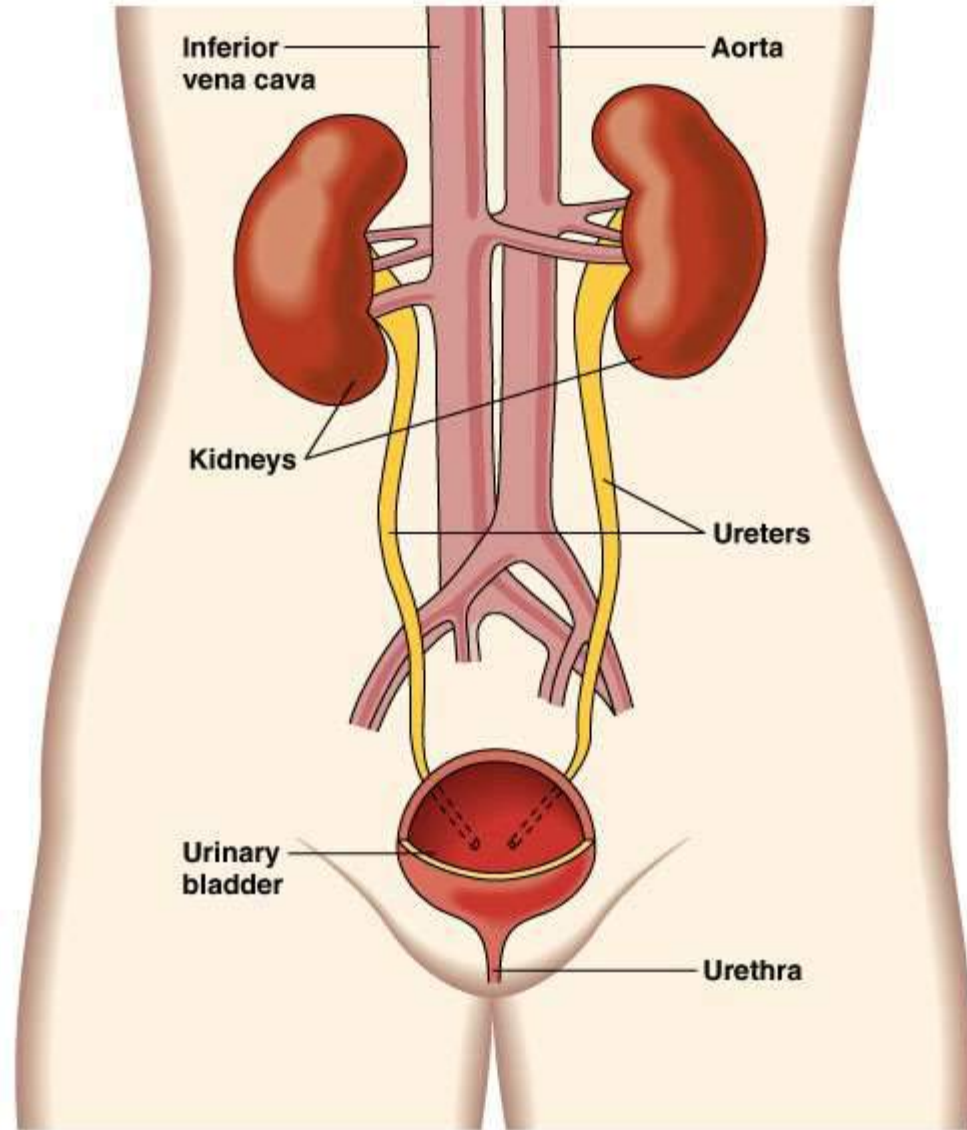
1. Regulation of plasma ionic composition such as **sodium, potassium, calcium, magnesium, chloride, bicarbonate, and phosphates**
2. Regulation of plasma osmolality
3. Regulation of plasma volume by controlling how much water a person excretes. ..
4. Regulation of plasma hydrogen ion concentration (pH) with the lungs (regulated the acid- base balance)
5. Removal of metabolic waste products and foreign substances from the plasma like nitrogenous waste (**urea, ammonia, creatinine and uric acid**)



- **Urea** comes from combines that **ammonia with carbon dioxide by the liver.**
- **Creatinine** comes from the metabolic breakdown of **creatine phosphate** (a high-energy phosphate in muscles).
- **Uric acid** comes from the breakdown of **nucleotides**. Uric acid is insoluble and too much uric acid in the blood will build up and form crystals that can collect in the joints and cause **gout**.

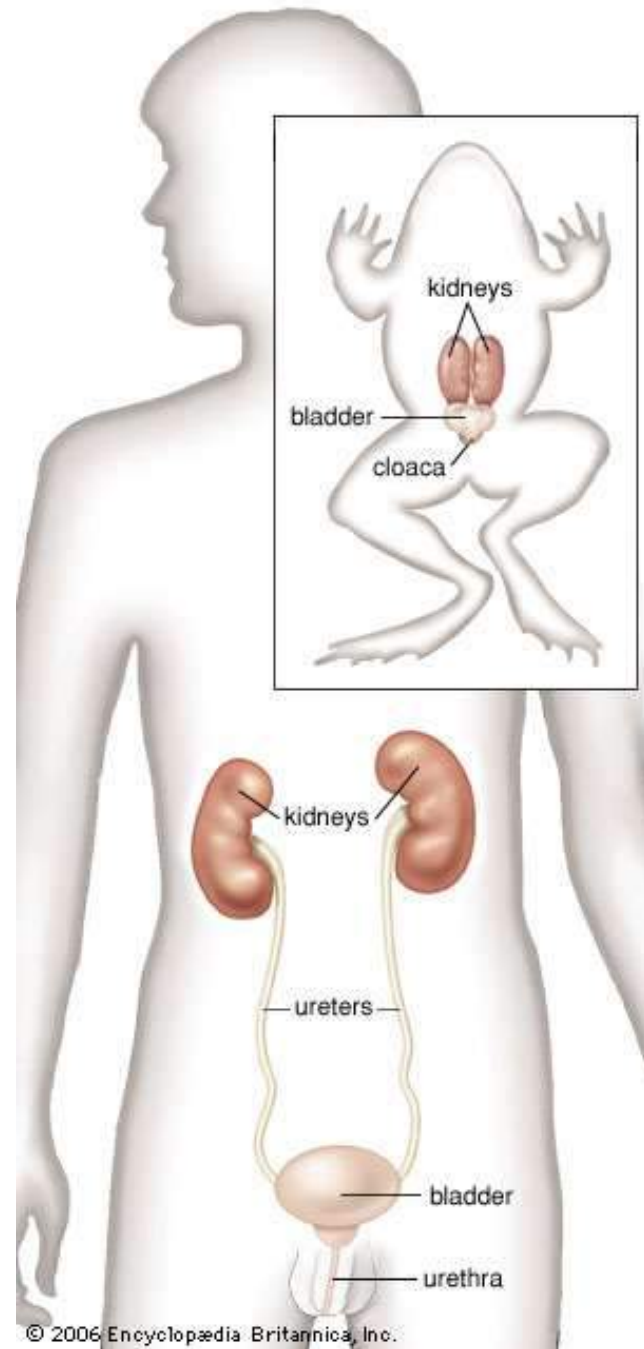


6. Secretion of hormones like **Renin**, it is needed to stimulate the secretion of aldosterone by the adrenal cortex which promotes the kidneys to reabsorb the **(Na⁺) ions**.
7. The kidneys also secrete **erythropoietin** when the blood doesn't have the capacity to carry oxygen; erythropoietin stimulates red blood cell production. Vitamin **D** from the skin is also activated with help from the kidneys. Calcium (Ca⁺) absorption from the digestive tract is promoted by vitamin **D**.



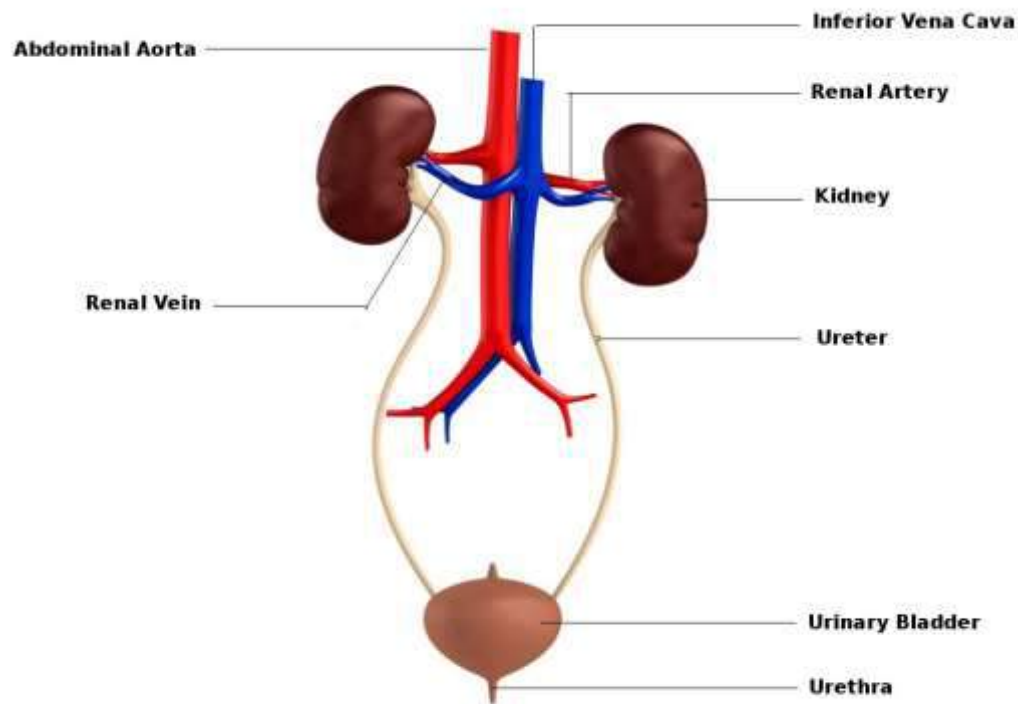
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- All vertebrates dispose of excess water and other wastes by means of kidneys.
- The kidneys of fish and amphibians are comparatively simple, while those of mammals are the most complex. Fish and amphibians absorb a great deal of water and, as a result, must excrete large quantities of urine in contrast, the urinary systems of birds and reptiles are designed to conserve water; these animals produce urine that is solid or semisolid.



- **Kidneys and Their Structure:-**

- The **kidneys** are pair of bean shaped, reddish brown organs, weights **140- 160 g**, they are covered by the renal capsule, which is a tough capsule of fibrous connective tissue.



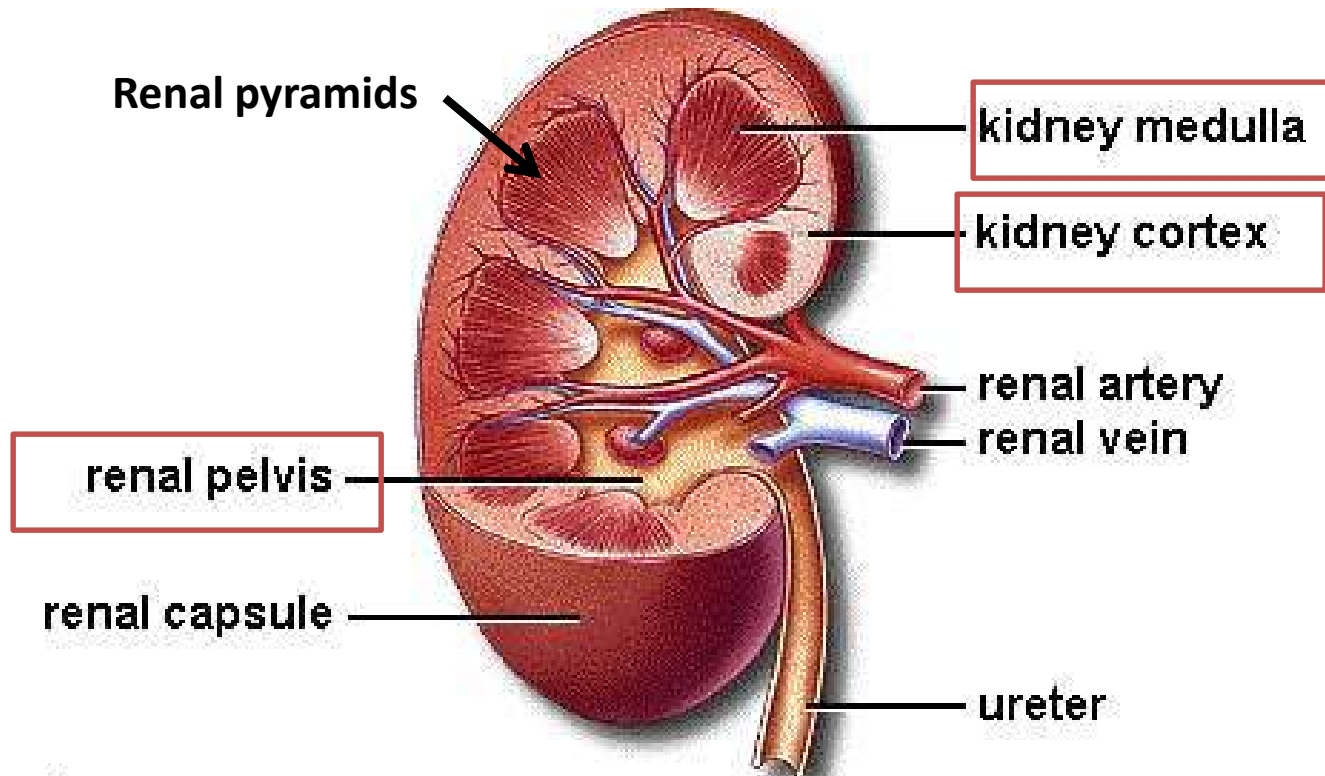
- Adhering to the surface of each kidney is two layers of fat to help cushion them. There is a concaved side of the kidney that has a depression where a renal artery enters, and a renal vein and a ureter exit the kidney. They are considered retroperitoneal, which means they lie behind the peritoneum.



- Each kidney has an indentation called the **hilum** on its medial side, at the hilum, the renal artery enters the kidney, and the renal vein and ureter emerge, the renal artery delivers over 1700 liters of blood to the kidneys each day, which these organs filter and return to the heart via the renal vein.

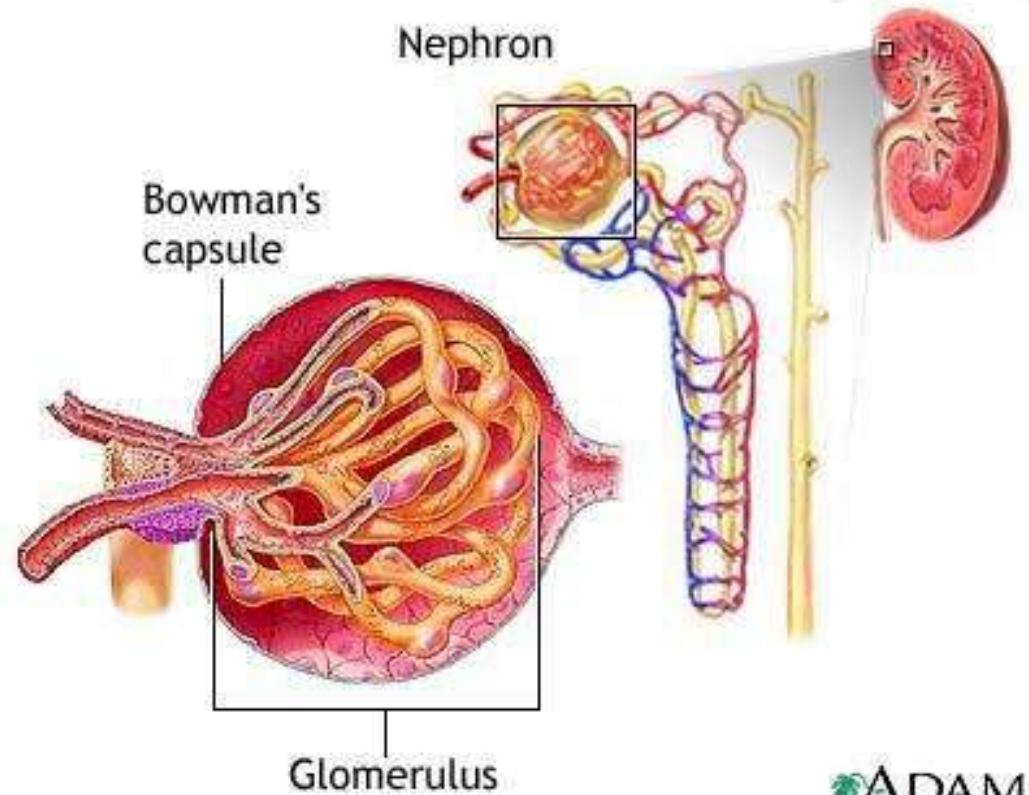


- There are three major regions of the kidney, **renal cortex**, **renal medulla** and the **renal pelvis**.
- The outer, granulated layer is the renal cortex; the cortex stretches down in between a radially striated inner layer.
- The inner radially striated layer is the renal medulla, this contains between 8 and 18 cone- shaped sections known as pyramids called the renal pyramids, separated by renal columns. The ureters are continuous with the renal pelvis and are the very center of the kidney.



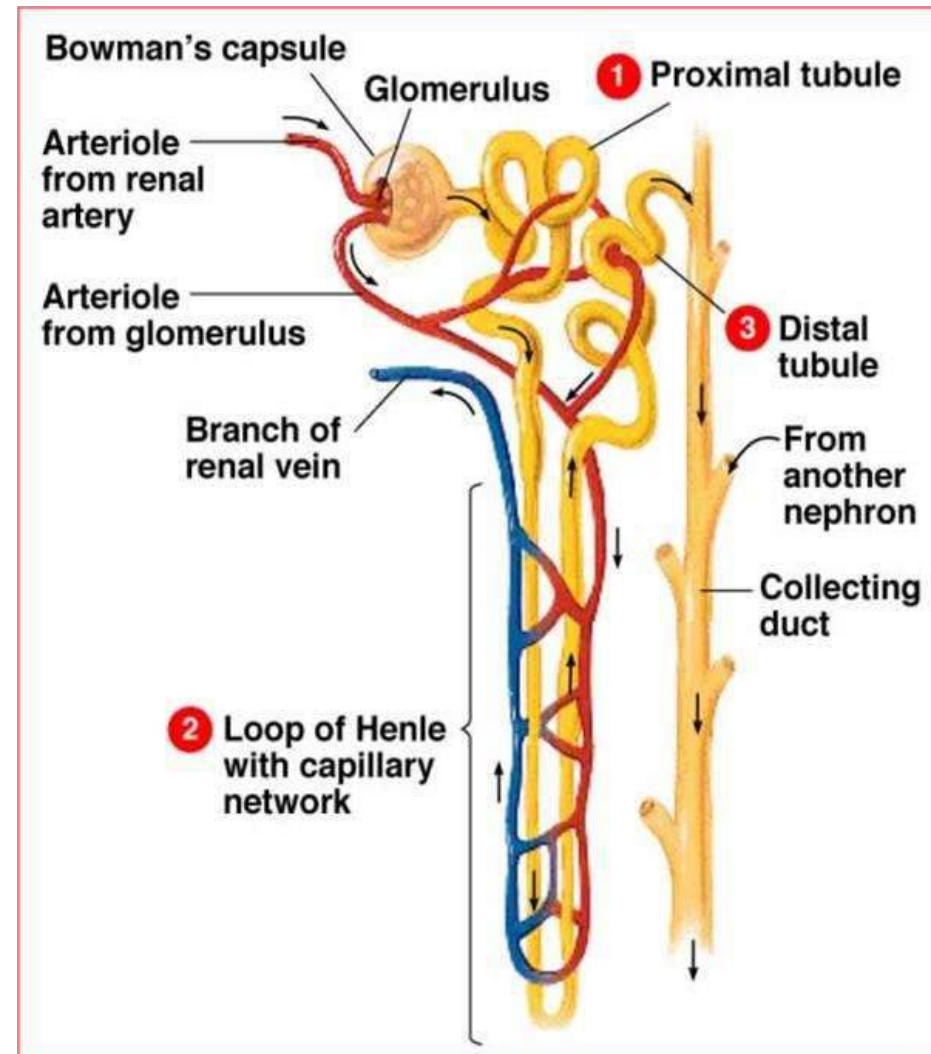
The Nephron:-

- The nephron is the structural and functional unit of the kidney; each kidney contains approximately 1 million nephrons. It is in the nephrons, with their associated blood vessels, that urine is formed.



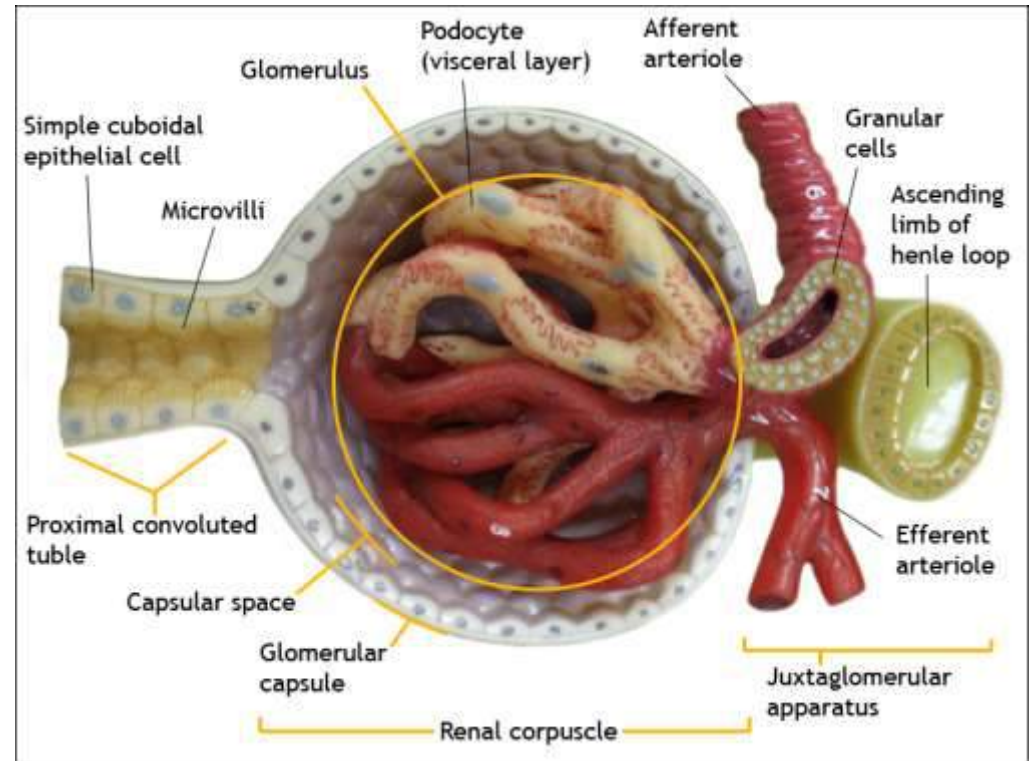
Each nephron has two major portions:

- Renal corpuscle
- Renal tubule
- Each of these major parts has further subdivisions.

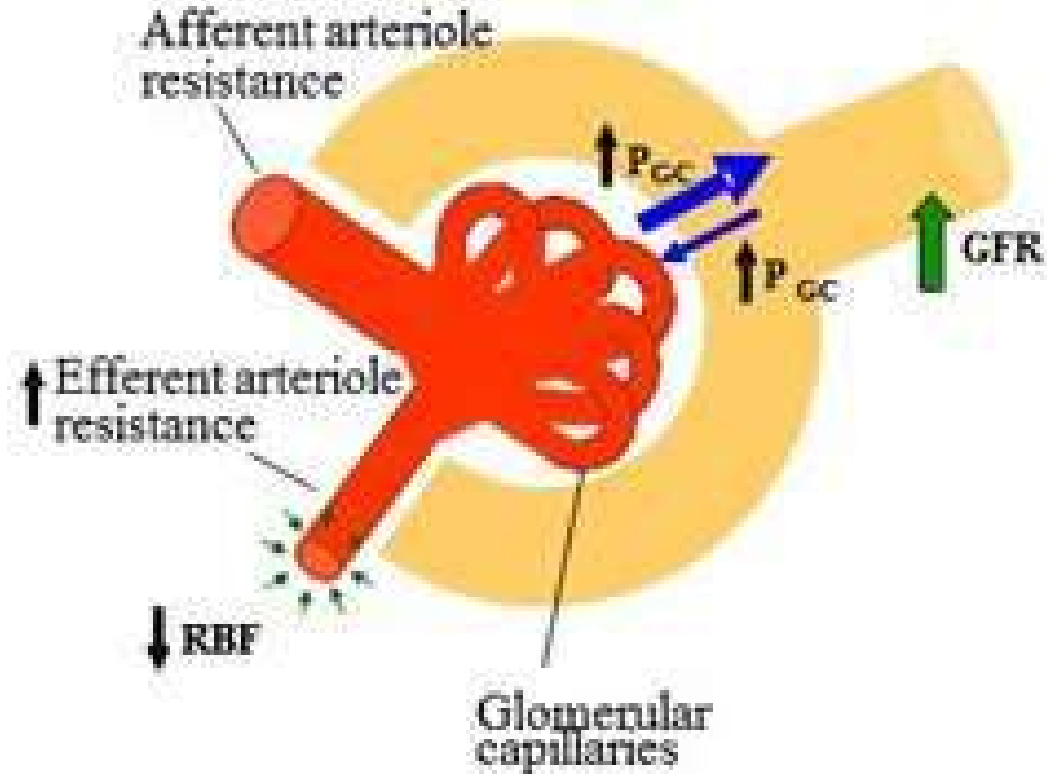


Renal Corpuscle:

- A **renal corpuscle** consists of a glomerulus surrounded by a Bowman's capsule.
- The **glomerulus** is a capillary network that arises from an **afferent arteriole** and empties into an **efferent arteriole**.

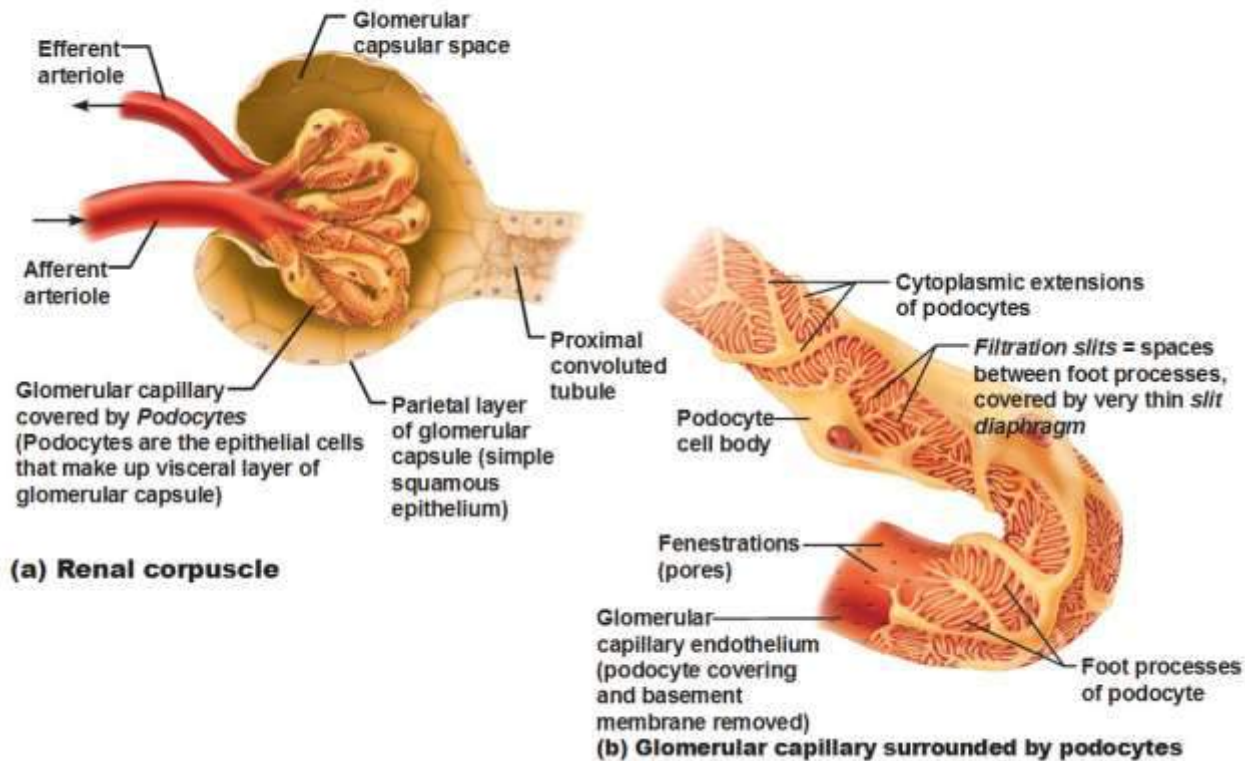


- The diameter of the efferent arteriole is smaller than that of the afferent arteriole, which helps maintain a fairly high blood pressure in the glomerulus.

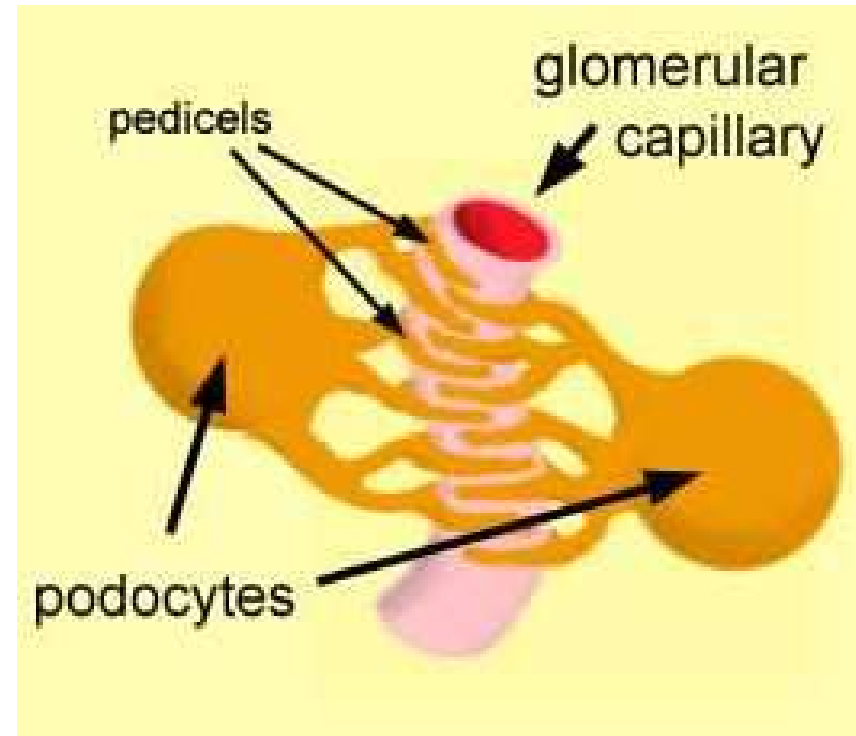


- **Bowman's capsule (or glomerular capsule)** is the expanded end of a renal tubule; it encloses the glomerulus.
- The inner layer of Bowman's capsule is made of **podocytes**; the name means “foot cells,” and the “feet” of the podocytes are on the surface of the glomerular capillaries.

Renal Corpuscle and the Filtration Membrane



- The arrangement of podocytes creates pores, spaces between adjacent “feet,” which make this layer very permeable.
- The space between the inner and outer layers of Bowman’s capsule contains **renal filtrate**, the fluid that is formed from the blood in the glomerulus and will eventually become urine.

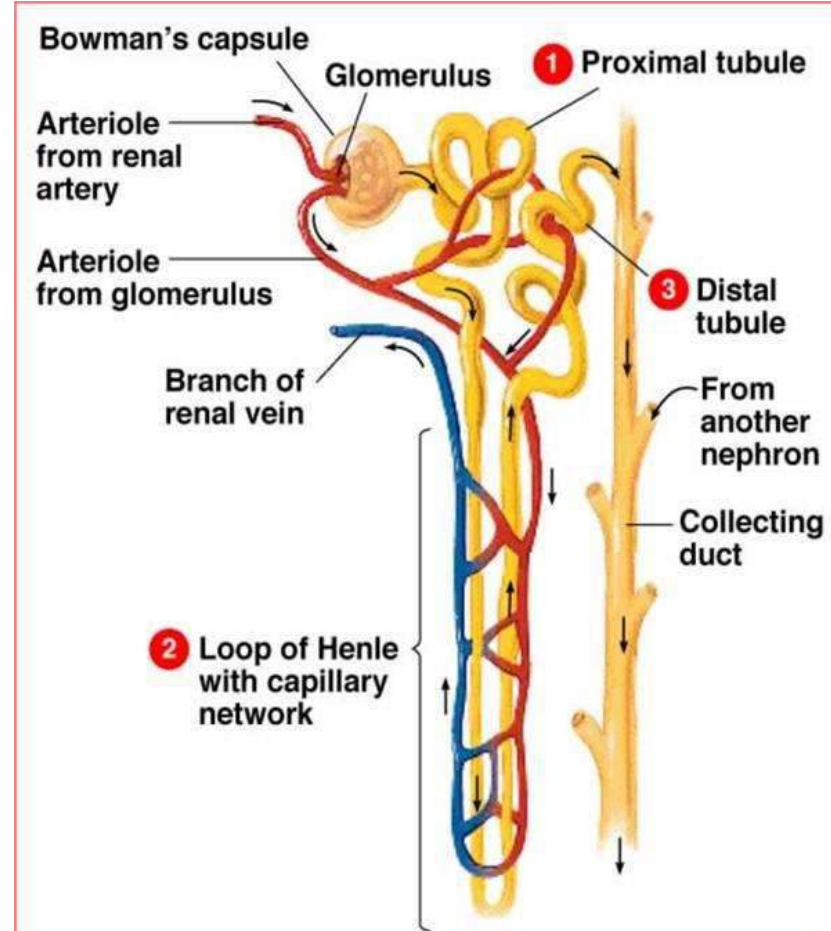


Renal Tubule:

- The **renal tubule** continues from Bowman's capsule and consists of the following parts:
 1. **Proximal convoluted tubule** (in the renal cortex and contains the microvilli),
 2. **Loop of Henle** (or loop of the nephron, in the renal medulla),
 3. **Distal convoluted tubule** (in the renal cortex).

The distal convoluted tubules from several nephrons empty into a **collecting tubule**.

- All parts of the renal tubule are surrounded by **peritubular capillaries**
- The peritubular capillaries will receive the materials reabsorbed by the **renal tubules**.



Blood Vessels of the Kidney:-

- The pathway of blood flow through the kidney

- (Renal blood flow about 21% of cardiac output).

- Blood from the abdominal aorta

- Enters the renal artery,

- Smaller arteries.

- Afferent arterioles in the renal cortex.

- Glomeruli (capillaries)

- Efferent arterioles

- peritubular capillaries

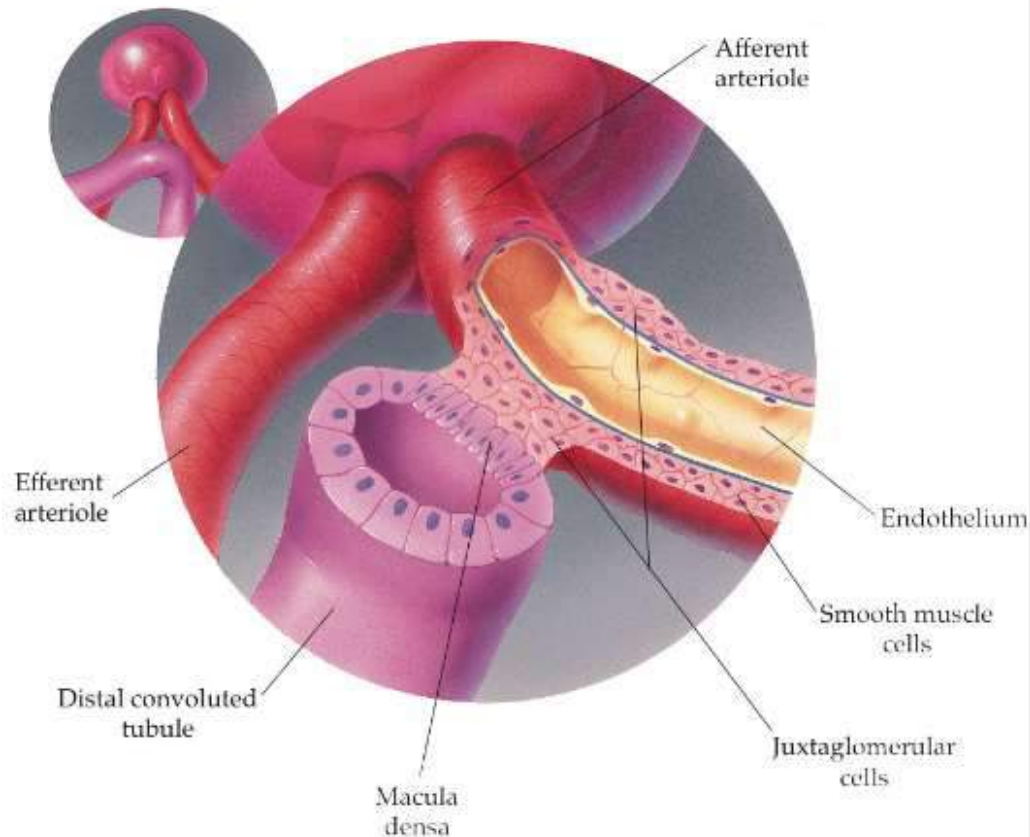
- Veins within the kidney

- The renal vein

- Finally to the inferior vena cava.

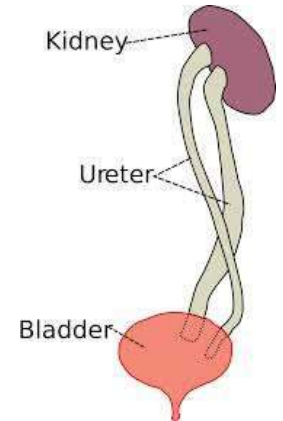
- The efferent arteriole drains the glomerulus. Between the two arterioles lies specialized cells called the **macula densa**.
- The **juxtaglomerular cells** and the macula densa collectively form the **juxtaglomerular apparatus**. It is in the juxtaglomerular apparatus cells that the enzyme **renin** is formed and stored.

Histology of Juxtaglomerular Apparatus



Ureters:

- **The ureters** are two tubes that drain urine from the kidneys to the bladder; each ureter is a muscular tube about (25 cm) long.



Muscles in the walls of the ureters



Send the urine in small spurts into the bladder.



After the urine enters the bladder from the ureters,



Small folds in the bladder mucosa act like valves preventing backward flow of the urine.



The outlet of the bladder is controlled by a sphincter muscle.



A full bladder stimulates sensory nerves in the bladder wall



Relax the sphincter and allow release of the urine.



Relaxation of the sphincter is also in part a learned response under voluntary control.

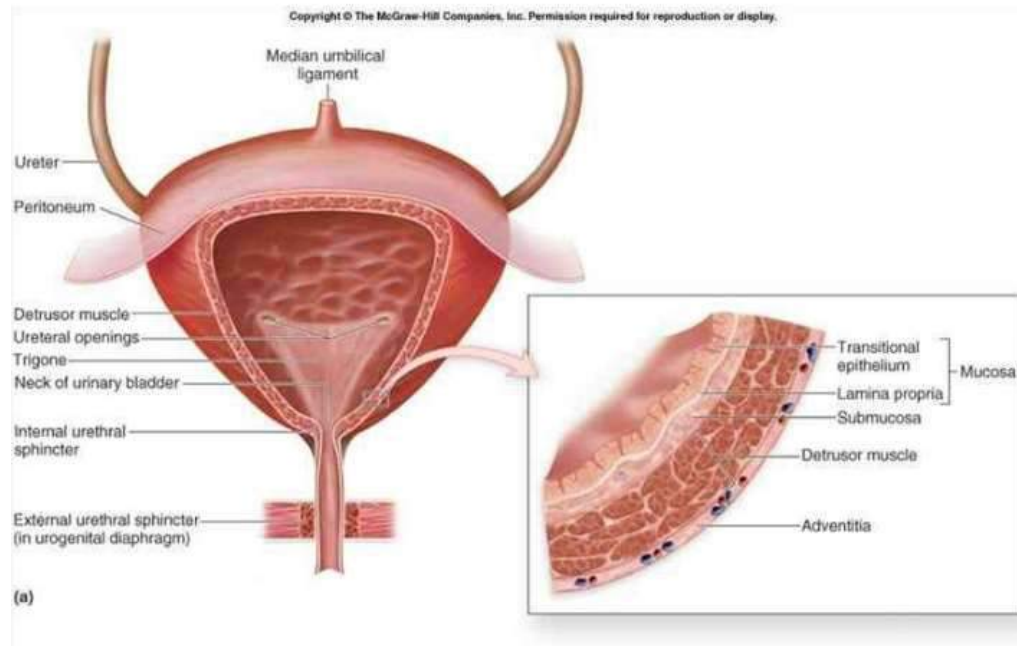


The released urine enters the urethra.

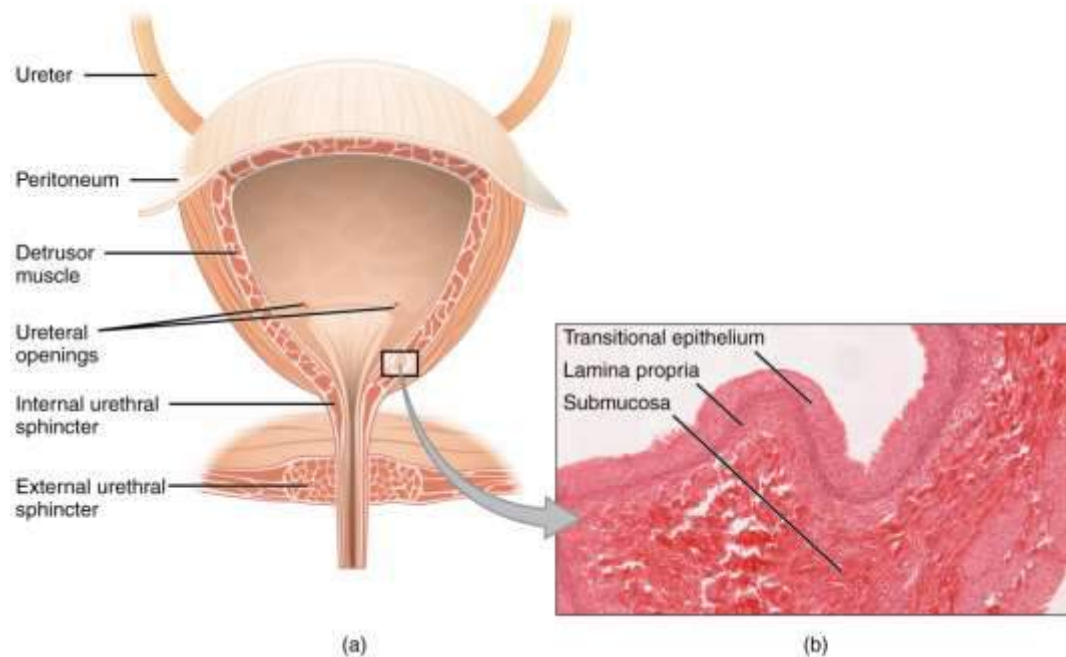
Urinary Bladder:

- The urinary bladder is a hollow, muscular and distensible or elastic organ that sits on the pelvic floor (superior to the prostate in males)
- On its anterior border lies the pubic symphysis and, on its posterior border, the vagina (in females) and rectum (in males).

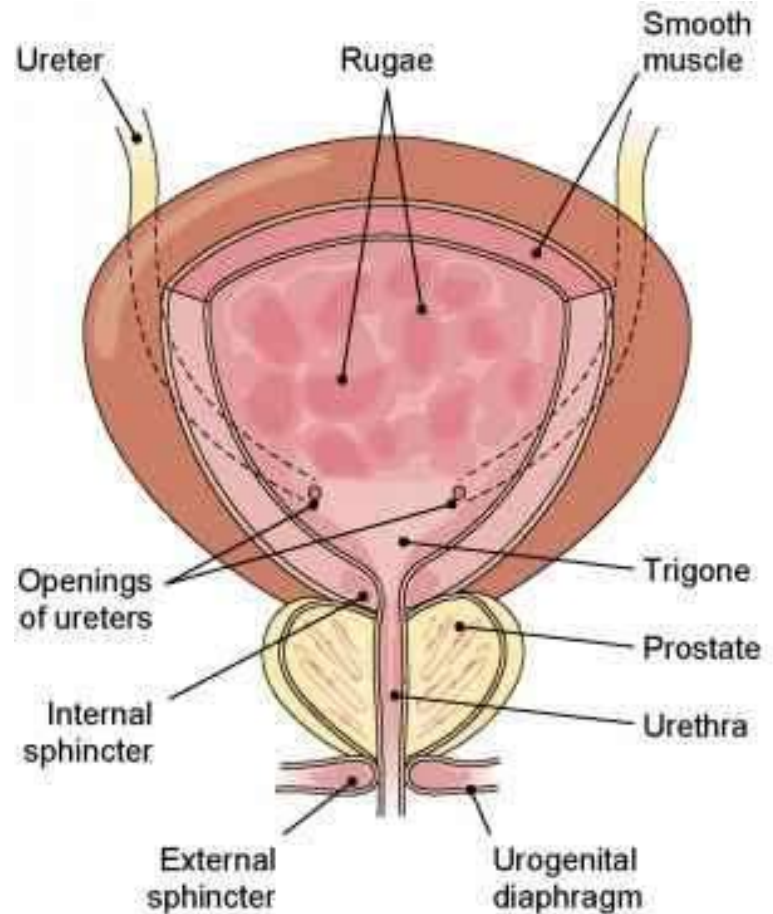
URINARY BLADDER



- The urinary bladder can hold approximately (500 to 530 ml) of urine; when the bladder fills with urine (about half full), stretch receptors send nerve impulses to the spinal cord, which then sends a reflex nerve impulse back to the sphincter (muscular valve) at the neck of the bladder, causing it to relax and allow the flow of urine into the urethra..

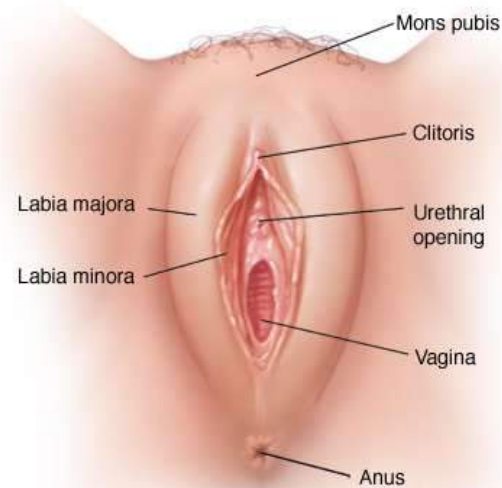
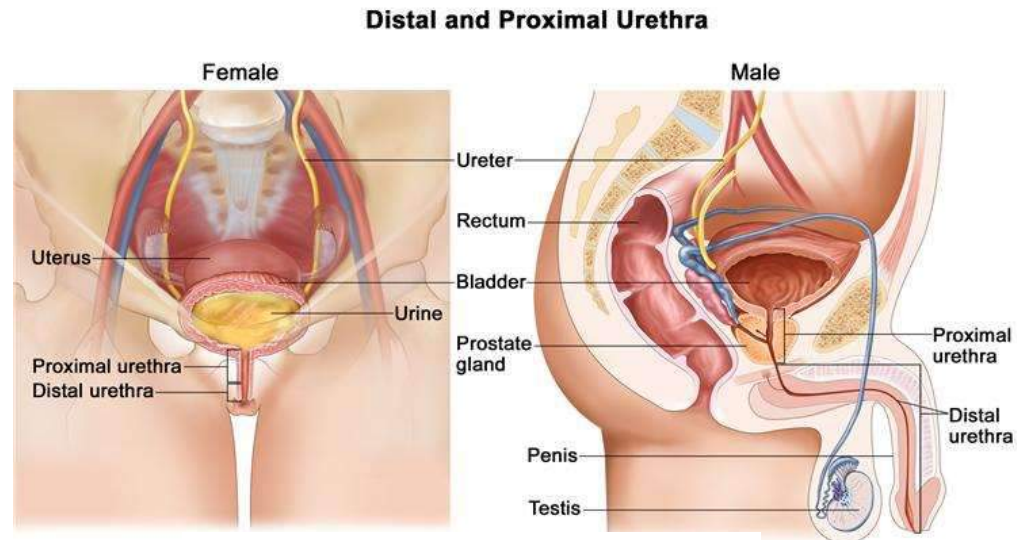


- The Internal urethral sphincter is involuntary. The ureters enter the bladder diagonally through its dorsolateral floor in an area called the trigone.
- The trigone is a triangular shaped area on the postero- inferior wall of the bladder. The urethra exits at the lowest point of the triangle of the trigone



Urethra:

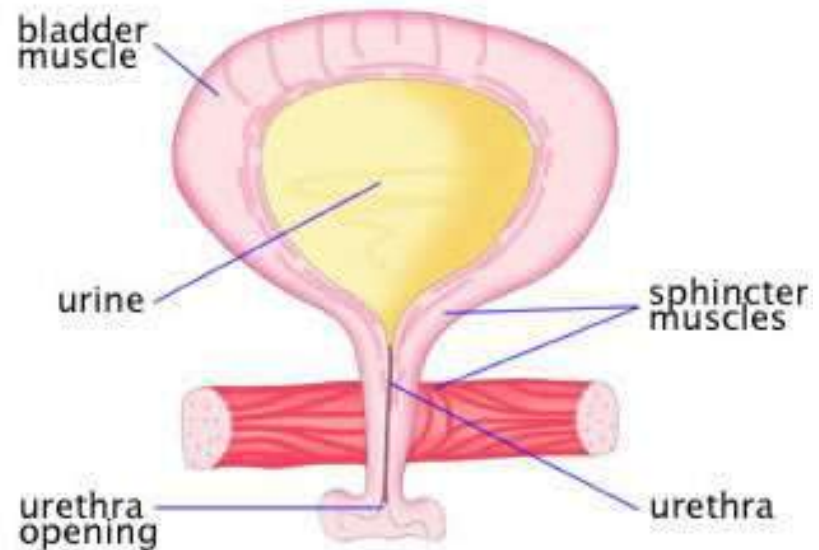
- The **urethra** is a muscular tube that connects the bladder with the outside of the body.
- **The function of the urethra is to remove urine from the body,** it measures about (3.8 cm) in the human female and opens in the vulva between the clitoris and the vaginal opening.
- In the human male, the urethra is about (20 cm) long and opens at the end of the penis.
- Because the Urethra is so much shorter in a woman it makes it much easier for a woman to get harmful bacteria in her bladder this is commonly called a bladder infection or a UTI.



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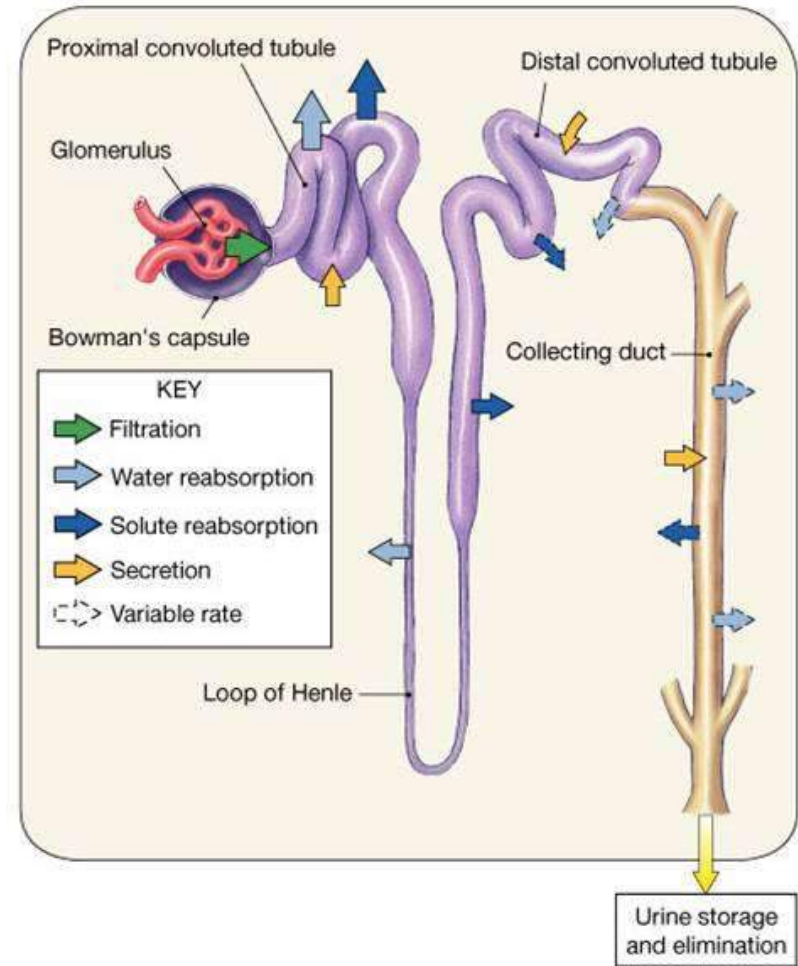
The urethral sphincter

- is a collective name for the muscles used to control the flow of urine from the urinary bladder; these muscles surround the urethra, so that when they contract, the urethra is closed.
- **There are two distinct areas of muscle:**
 1. The internal sphincter, at the bladder neck
 2. The external, or distal, sphincter
- Human males have much stronger sphincter muscles than females, meaning that they can retain a large amount of urine

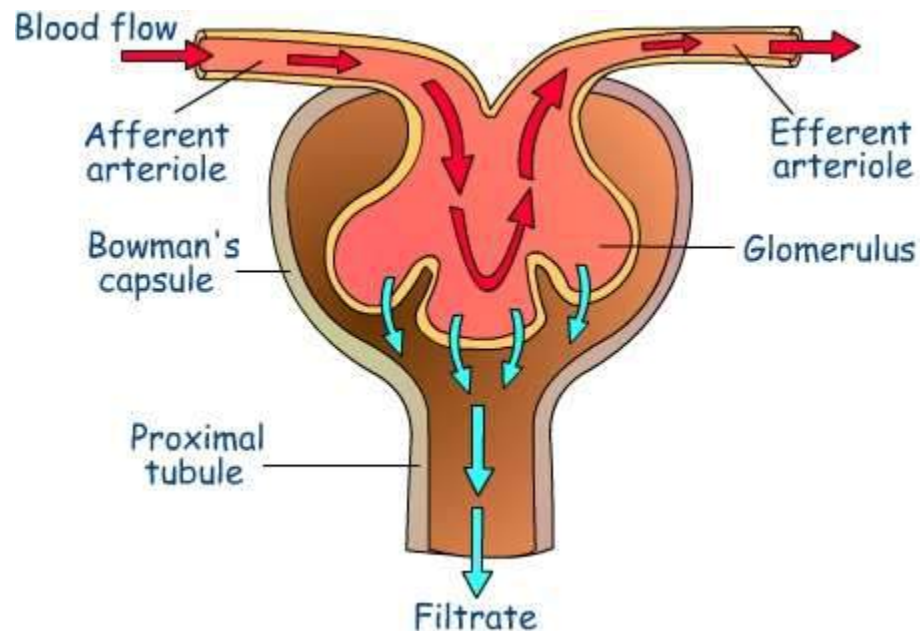


Formation of Urine:-

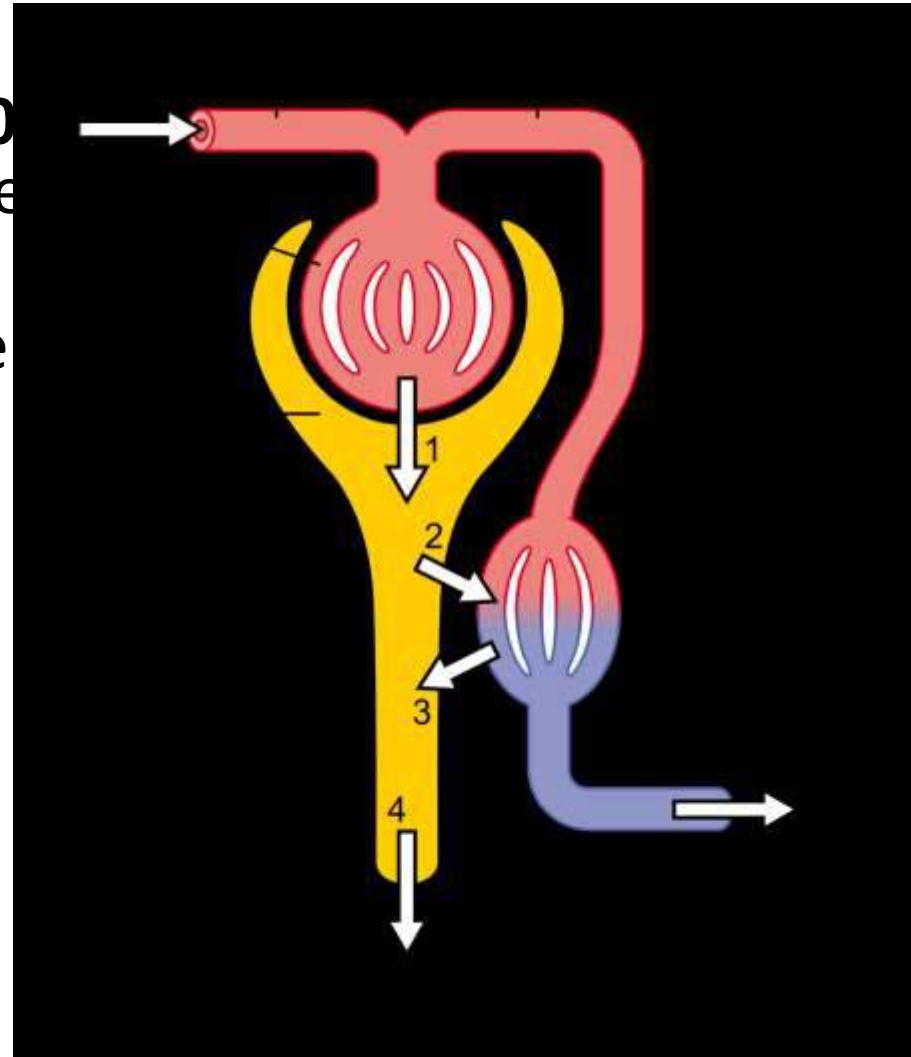
- **The formation of urine involves three major processes:**
 - 1. The first** is glomerular filtration, which takes place in the renal corpuscles.
 - 2. The second** and third are tubular reabsorption and tubular secretion, which take place in the renal tubules.



- **Filtration** is the process in which blood pressure forces plasma and dissolved material out of capillaries.
- In **glomerular filtration**, blood pressure forces plasma, dissolved substances, and small proteins out of the glomeruli and into Bowman's capsules, this fluid is no longer plasma but is called **renal filtrate**.
- The blood cells and larger proteins are too large to be forced out of the glomeruli, so they remain in the blood.

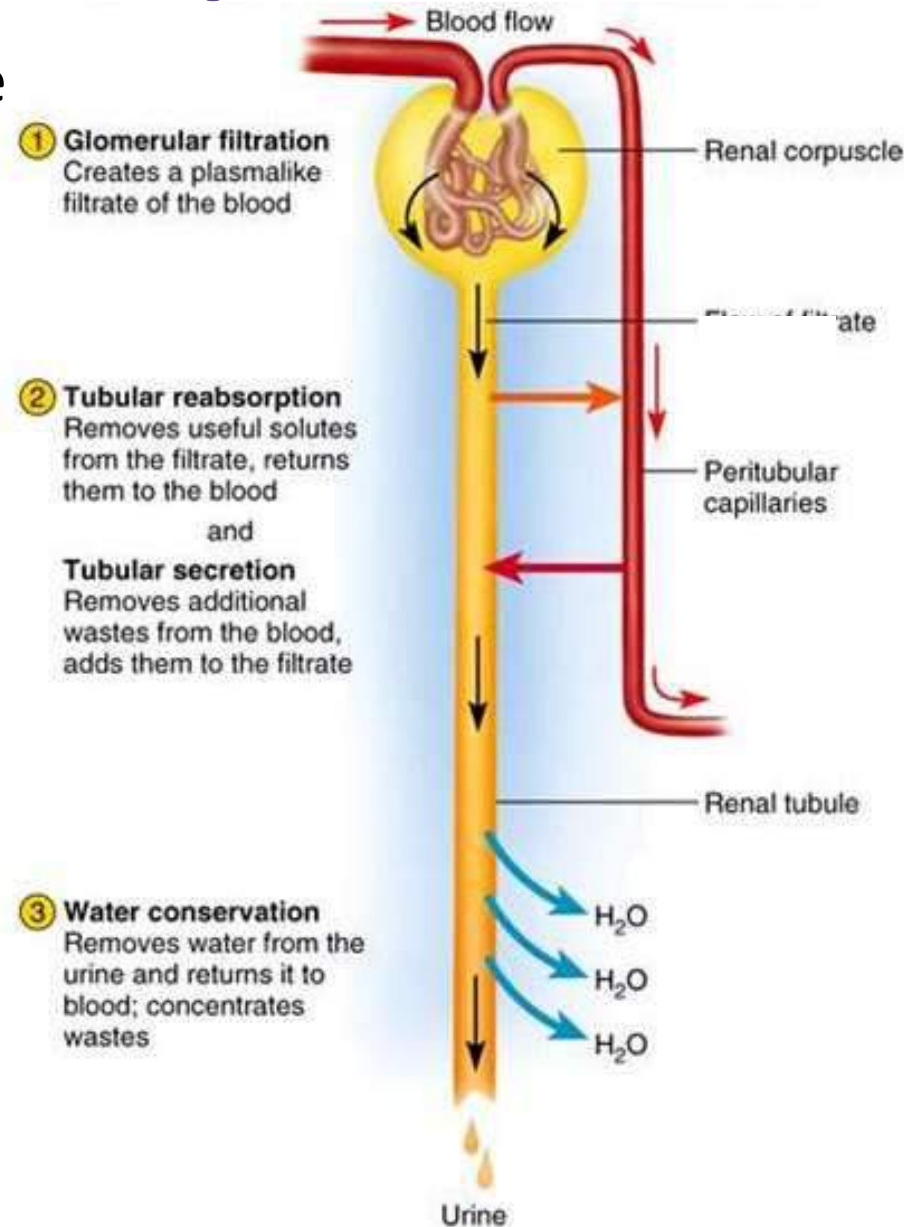


- The glomerular filtration rate (GFR) is the amount of renal filtrate formed by the kidneys in **1 minute**, and averages **100 to 125 ml per minute** (removes about **19%** of blood plasma).
- GFR may be altered if the rate of blood flows through the kidney changes.
 - ❖ If blood flow increases, **the GFR increases**, and more filtrate is formed.
 - ❖ If blood flow decreases (as may happen following a severe hemorrhage), **the GFR decreases**, less filtrate is formed, and urinary output decreases.



Tubular Reabsorption:

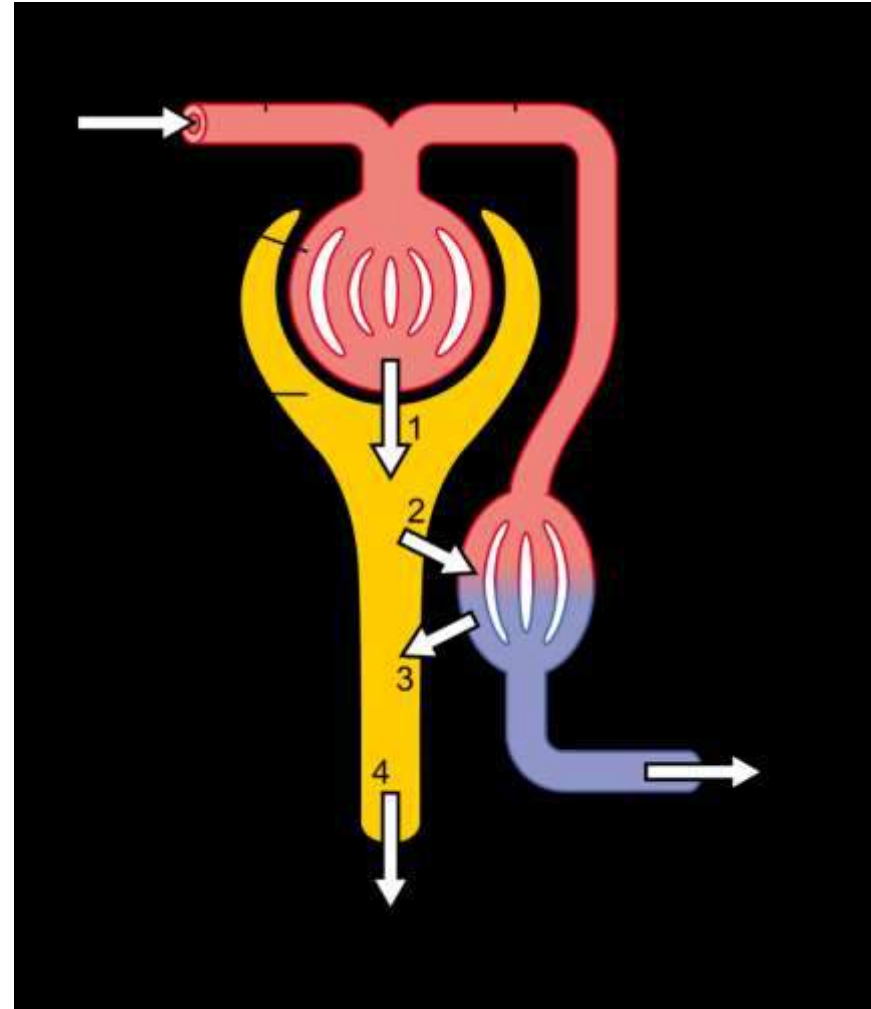
- **Tubular reabsorption** takes place from the renal tubules into the peritubular capillaries (the blood pressure in the peritubular capillaries is **15 mmHg**).
- In a **24-hour** period, the kidneys form **150 to 180 liters** of filtrate, and normal urinary output in that time is **1 to 2 liters**. Therefore, it becomes apparent that most of the renal filtrate does not become urine.
- Approximately **99%** of the filtrate is reabsorbed back into the blood in the peritubular capillaries. Only about **1%** of the filtrate will enter the renal pelvis as urine.



- Glomerular filtrate has now been separated into two forms:
reabsorbed filtrate and non-reabsorbed filtrate.

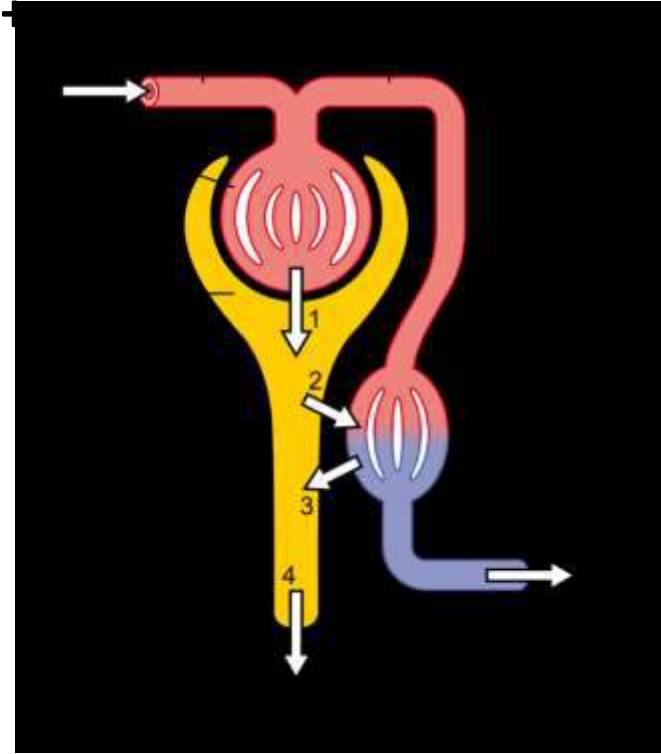
1. Non-reabsorbed filtrate is now known as tubular fluid as it passes through the collecting duct to be processed into urine.

- Most reabsorption and secretion (about 65%) take place in the **proximal convoluted tubules** whose cells have **microvilli** that greatly increase their surface area. **Water, Na⁺, Cl⁻, K⁺, glucose,** amino acid are reabsorbed in proximal convoluted tubules while other does not reabsorb like **inulin, creatinine** .



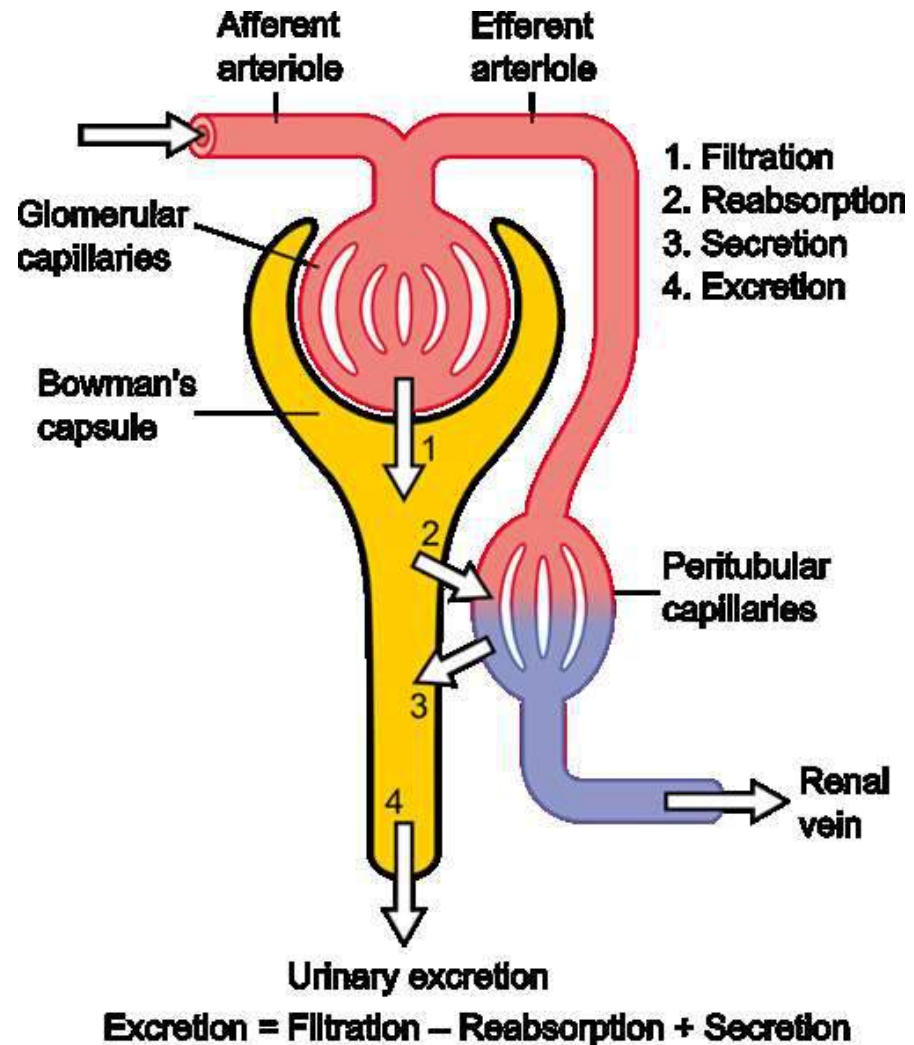
1. About **20%** of filtered **Na⁺** and **Cl⁻**, **15%** of filtered water and cations such as **K⁺**, **Ca²⁺** and **Mg²⁺** are reabsorbed in the loop of Henle.

2. In thin **descending limb of loop of Henle** water absorption occurs passively (because of hypertonic interstitial fluid) in this part of loop of Henle. It is accompanied by diffusion of sodium ions from interstitial fluid into tubular lumen.

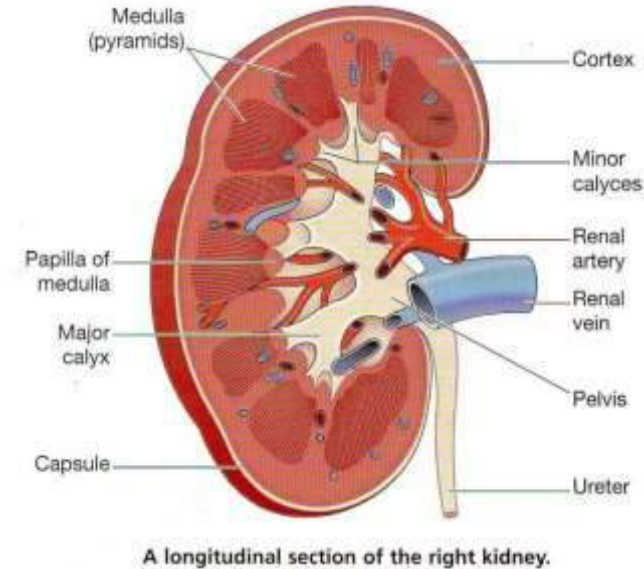


4. The thick ascending limb of loop of Henle is impermeable to water but is involved, in the reabsorption of **20 % of the filtered Na^+ , and Cl^- and other cations.**

5. The distal convoluted tubules and collecting tubules are also important sites for the reabsorption, approximately **7% of the filtered NaCl and about 8-17% of water** is reabsorbed.



- Early distal tubule (initial segment of distal tubule) reabsorbs Na^+ , Cl^- and Ca^{2+} , and is impermeable to water.
- Late distal tubule and collecting duct have two cell types (principal cells and intercalated cells) which perform both reabsorption and secretory functions.
- Sodium chloride reabsorbed into the system
 - Increases the osmolality of blood in comparison to the glomerular filtrate.
 - Allows water (H_2O) to pass from the glomerular filtrate back into the circulatory system.



Glucose and various amino acids also are reabsorbed



(Towards the end of the proximal convoluted tubules)



Into the circulatory system,



Nutrients have carrier molecules that claim the glomerular molecule



Release it back into the circulatory system.

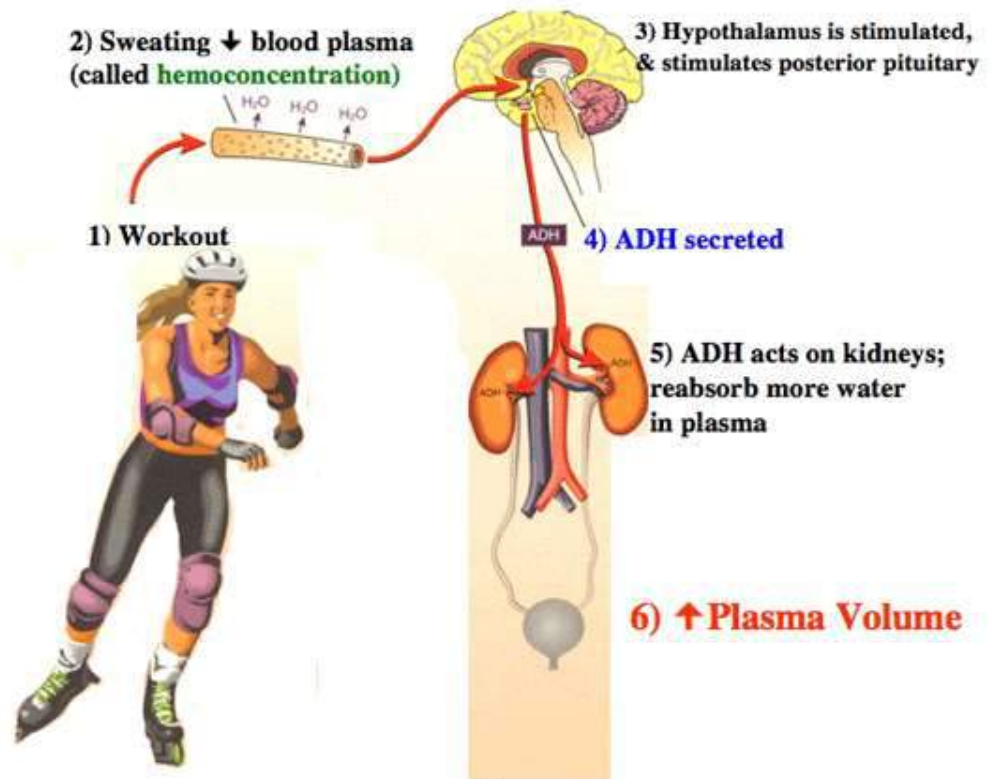
- **If all of the carrier molecules are used up, excess glucose or amino acids are set free into the urine.**

Reabsorption of Water and Salt:

- **Direct control of water excretion in the kidneys is exercised by the anti-diuretic hormone (ADH).**
 - Posterior lobe of the pituitary gland
 - ↓
 - Anti-diuretic hormone (ADH)
 - ↓
 - Causes the insertion of water channels into the membranes of cells lining the collecting ducts,
 - ↓
 - Allowing water reabsorption to occur.
- **Without ADH, little water is reabsorbed in the collecting ducts and dilute urine is excreted.**

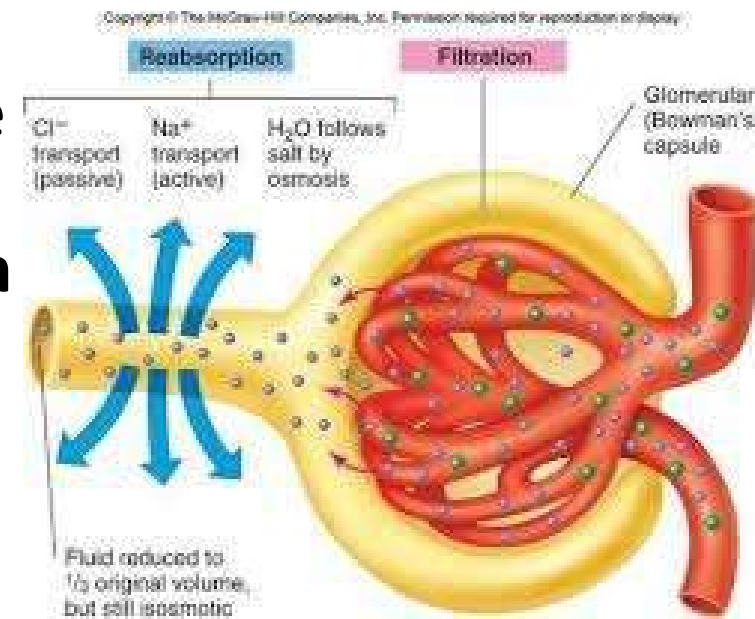
There are several factors that influence the secretion of ADH.

- The first of these happen
 - When the blood plasma gets too concentrated
- ↓
- Special receptors in the hypothalamus release ADH.
- ↓
- When blood pressure falls
- ↓
- Stretch receptors in the aorta and carotid arteries
- ↓
- Stimulate ADH secretion to increase volume of the blood.

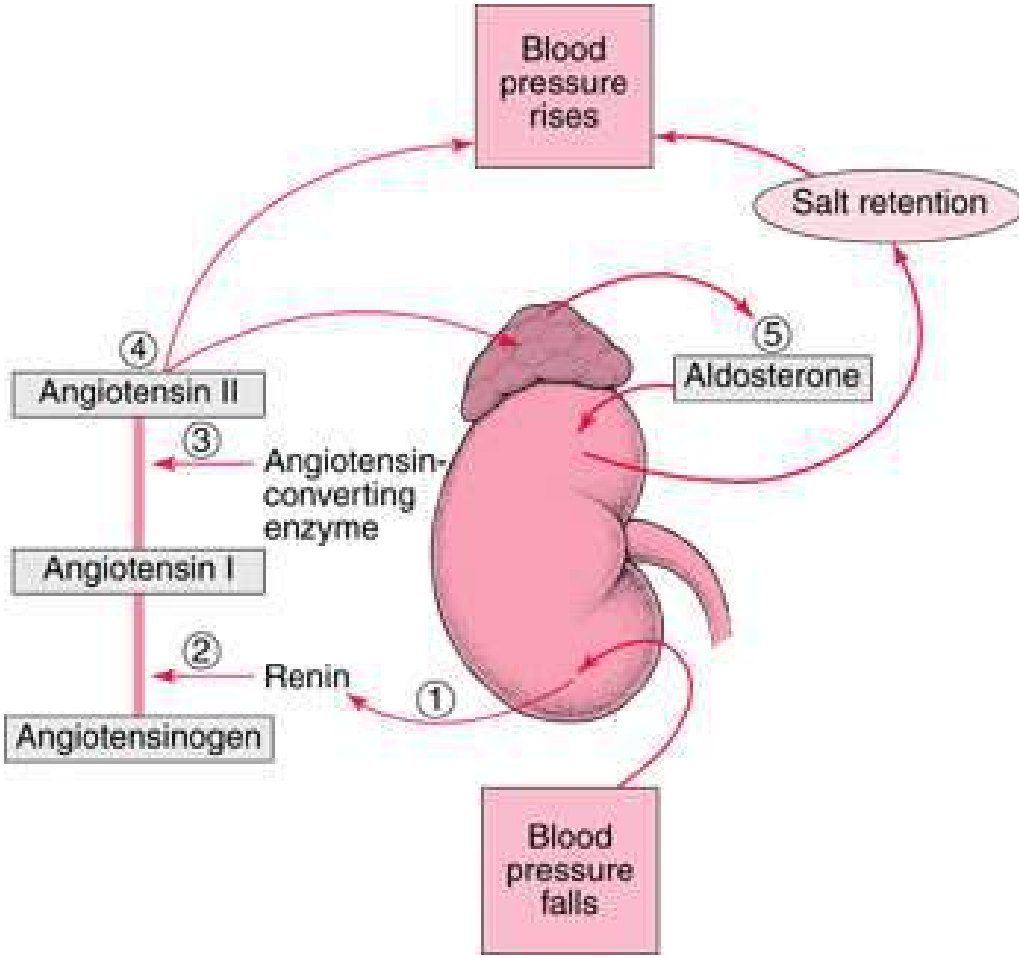


How helps maintain normal blood volume and blood pressure?

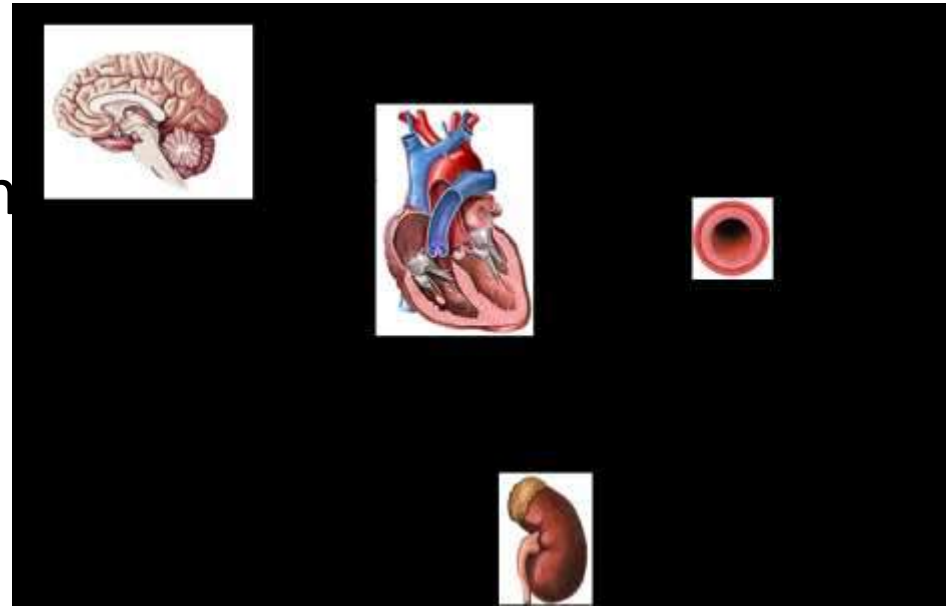
- **Aldosterone** is secreted by the adrenal cortex in response to a high blood potassium level, to a low blood sodium level, or to a decrease in blood pressure.
- Aldosterone promotes **the excretion of potassium ions and the reabsorption of sodium ions**, when aldosterone stimulates the reabsorption of Na⁺ ions, water follows from the filtrate back to the blood.



- The release of Aldosterone is initiated by the secretion of renin the enzyme that converts **angiotensinogen** (a large plasma protein produced by the liver) into **Angiotensin I** and eventually into **Angiotensin II** which stimulates the adrenal cortex to produce aldosterone.

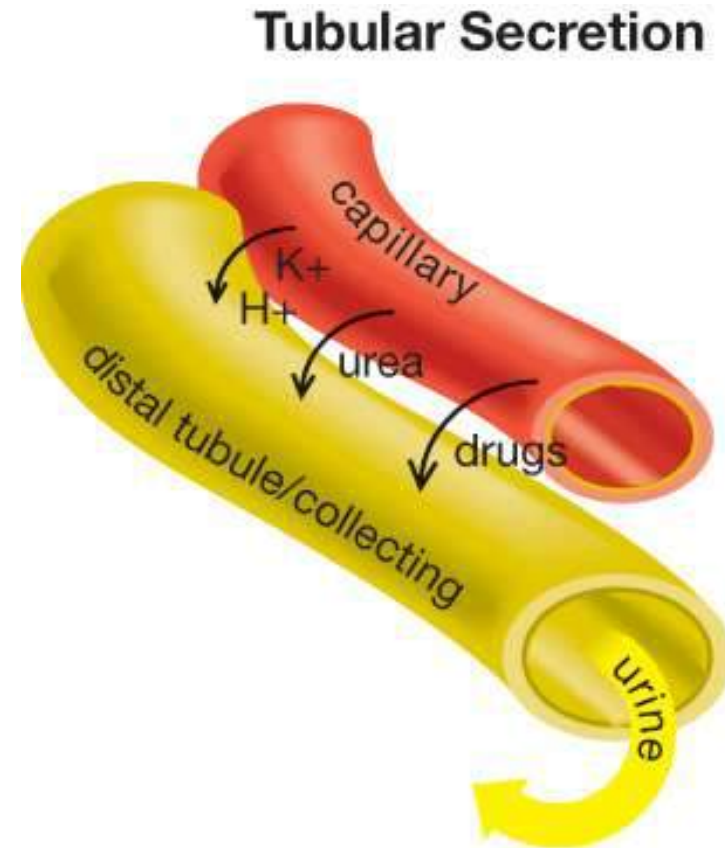


- The antagonist to aldosterone is **atrial natriuretic peptide (ANP)**, which is secreted by the atria of the heart when the atrial walls are stretched by high blood pressure or greater blood volume. ANP inhibits the secretion of renin by the **juxtaglomerular apparatus** and the secretion of the aldosterone by the adrenal cortex.
- This promotes the excretion of sodium. When sodium is excreted so is water. This causes blood pressure and volume to decrease.



Tubular Secretion:

- Some substances are removed from blood through the **peritubular capillary network into the distal convoluted tubule or collecting duct** and **K^+ and H^+** are secreted in these segments. This mechanism also changes the composition of urine.
- In tubular secretion, substances are actively secreted from the blood in the peritubular capillaries into the filtrate in the renal tubules. Waste products, such as **ammonia and some creatinine**, and **the metabolic products of medications** may be secreted into the filtrate to be eliminated in urine.



- **Hydrogen ions (H^+)** may be secreted by the tubule cells to help maintain the normal pH of blood.
- Hypernatremia:**
- **Hypernatremia** is an increase in plasma sodium levels above normal.

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HYPERNATREMIA

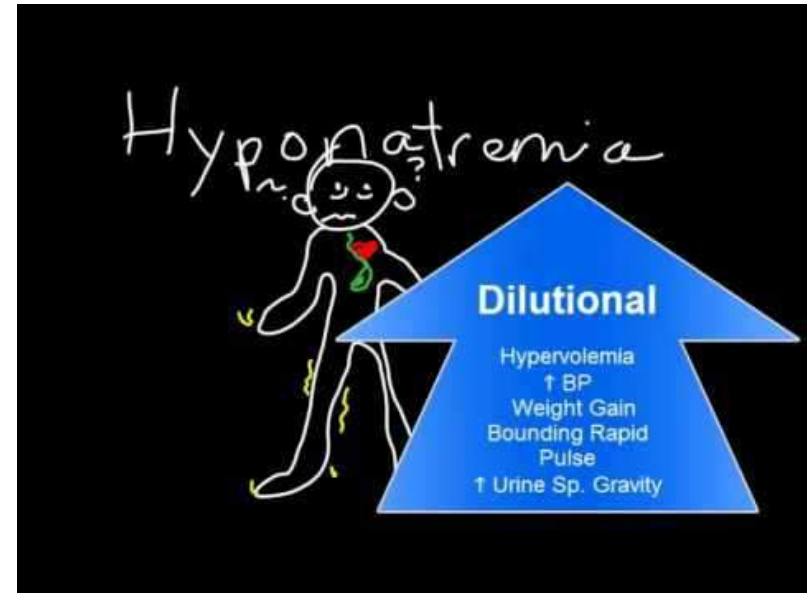
"THE MODEL"
(Causes of \uparrow serum sodium)



- M** Medications, meals (too much sodium intake)
- O** Osmotic diuretics
- D** Diabetes insipidus
- E** Excessive H_2O loss
- L** Low H_2O intake

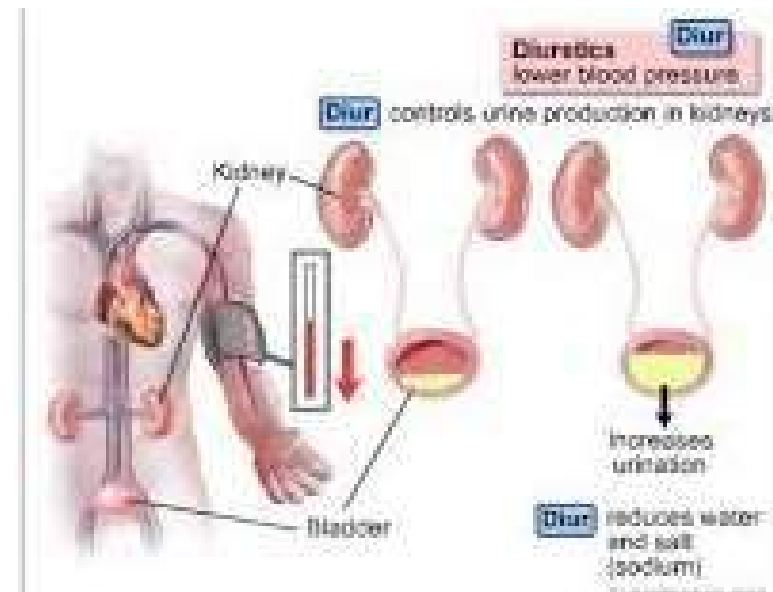
What is importance of sodium?

1. Sodium is the primary solute in the extracellular fluid.
 2. Sodium levels have a major role in osmolality regulation.
 3. For excitable cells the electrochemical gradient for sodium across the plasma membrane is critical for life.
 4. Water retention and an increased blood pressure usually are signs of hyponatremia.
- If plasma sodium levels are below normal it is called hyponatremia: Signs of this are low plasma the volume and hypotension

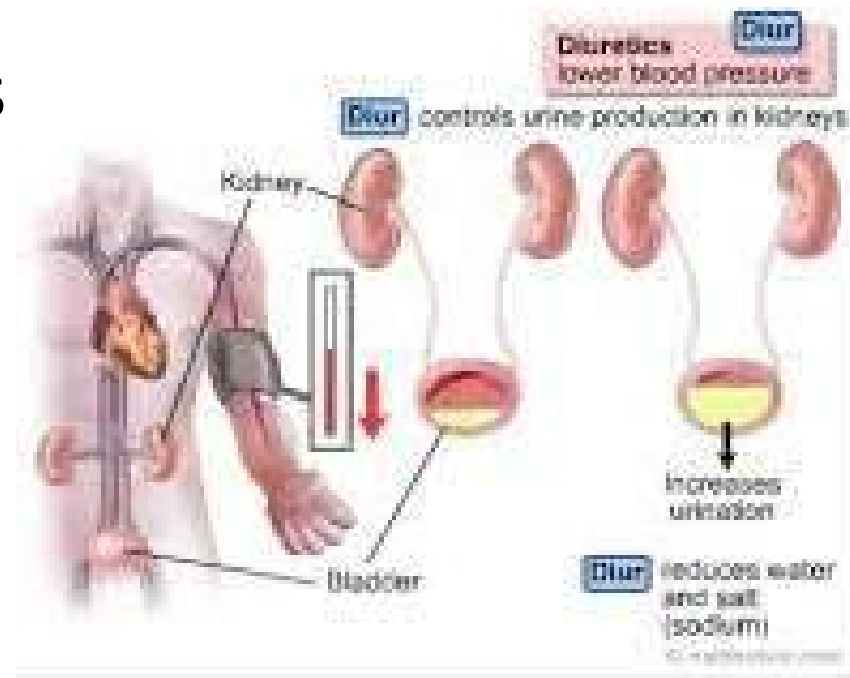


Diuretics:

1. A diuretic is any drug that elevates the rate of bodily urine excretion (diuresis),
2. Diuretics also decrease the extracellular fluid (ECF) volume, and are primarily used to produce a negative extracellular fluid balance.
3. Caffeine, cranberry juice and alcohol are all weak diuretics.
4. In medicine, diuretics are used to treat heart failure, liver cirrhosis, hypertension and certain kidney diseases.
5. Diuretics alleviate the symptoms of these diseases by causing Na^+ and water loss through the urine.



- Chemically, diuretics are a diverse group of compounds that either stimulate or inhibit various hormones that naturally occur in the body to regulate urine production by the kidneys.
- Alcohol produces diuresis through modulation of the vasopressin system.

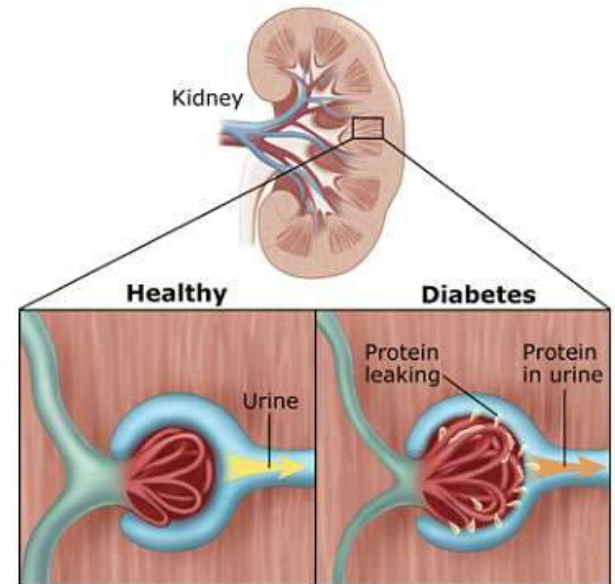


Diseases of the Kidney:-

1. **Diabetic nephropathy**; Is a progressive kidney disease caused by angiopathy of capillaries in the kidney glomeruli. It is characterized by nodular glomerulosclerosis. It is due to longstanding diabetes mellitus.

- In medicine **hematuria** (or "haematuria") is the presence of blood in the urine. It is a sign of a large number of diseases of the kidneys and the urinary tract, ranging from trivial to lethal.

Diabetes Affects the Kidney



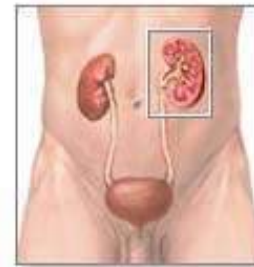
Gross hematuria means blood can be seen in the urine.



Microscopic hematuria means blood can be seen only with a microscope.

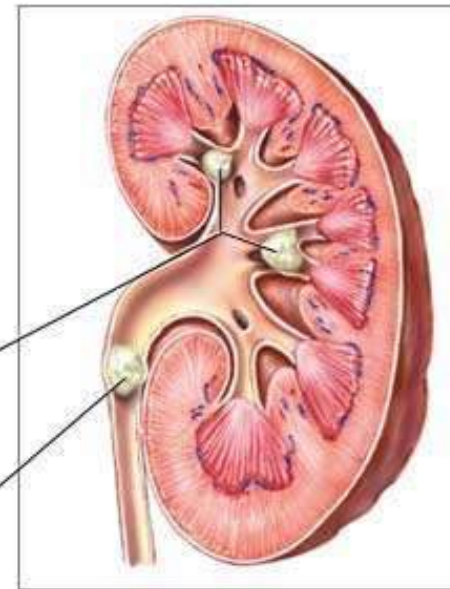
2. Kidney stones:

- Also known as nephrolithiases, urolithiases or renal calculi, are solid accretions (crystals) of dissolved minerals in urine found inside the kidneys or ureters.
- They vary in size from as small as a grain of sand to as large as a golf ball. Kidney stones typically leave the body in the urine stream;
- If they grow relatively large before passing (on the order of millimeters), obstruction of a ureter and distention with urine can cause severe pain most commonly felt in the flank, lower abdomen and groin.
- Kidney stones are unrelated to gallstones.



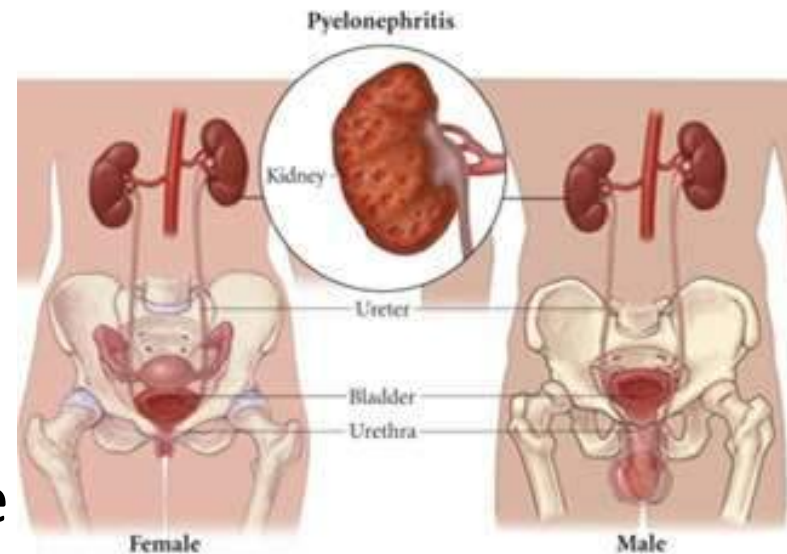
Kidney stones in the minor and major calyces of the kidney

Kidney stone in the ureter



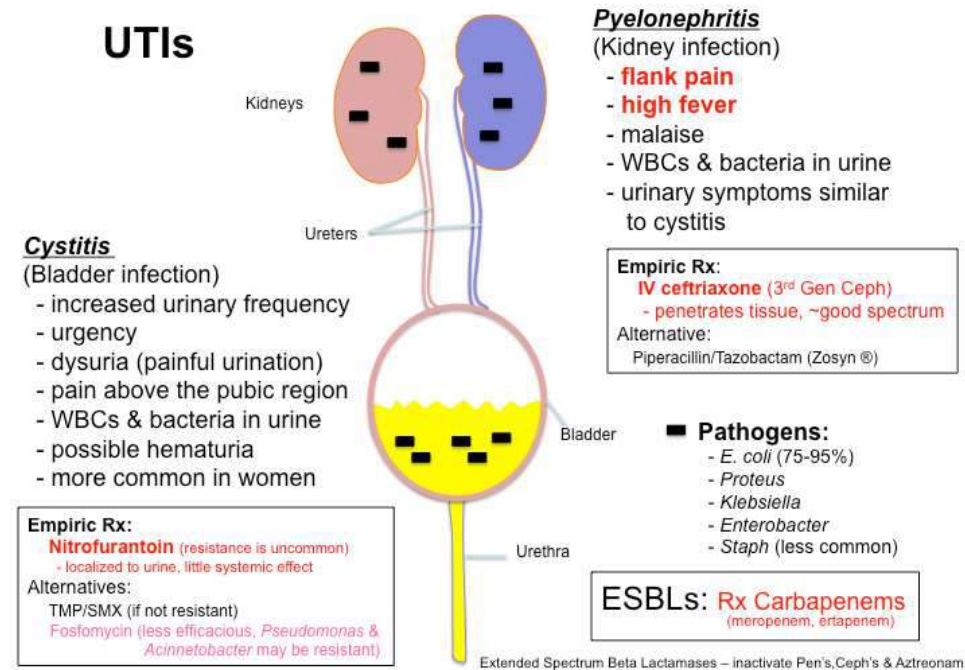
3. Pyelonephritis:

- When an infection of the renal pelvis and calices, called **pyelitis**, spreads to involve the rest of the kidney as well, the result is pyelonephritis.
- It usually results from the spread of fecal bacterium *Escherichia coli* from the anal region superiorly through the urinary tract. In severe cases, the kidney swells and scars, abscesses form, and the renal pelvis fill with pus.
- Left untreated, the infected kidney may be severely damaged, but administration of antibiotics usually achieves a total cure.



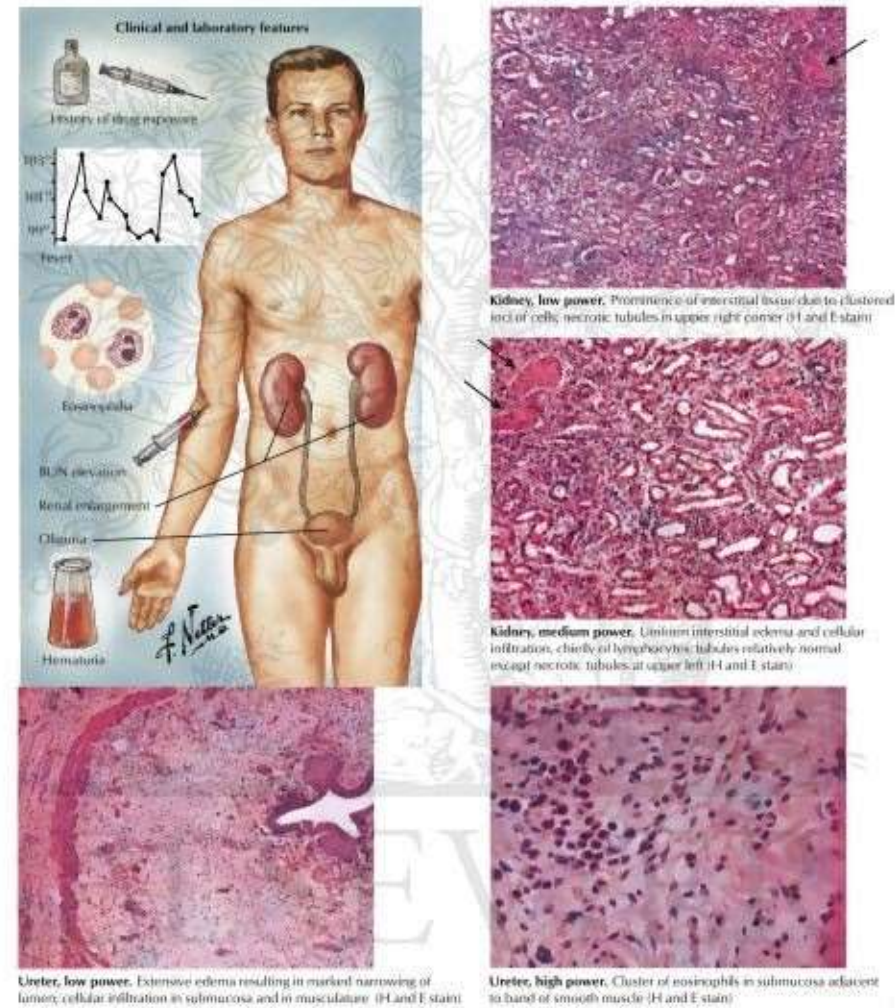
4. Urinary tract infections (UTI's):

- The second most common type of bacterial infections is UTI's. In the hospital indwelling catheters and straight Catheterizing predispose the opportunity for urinary tract infections.
- In females there are three stages in life that predispose urinary tract infections that is menarche, manipulation between intercourse, and menopause.



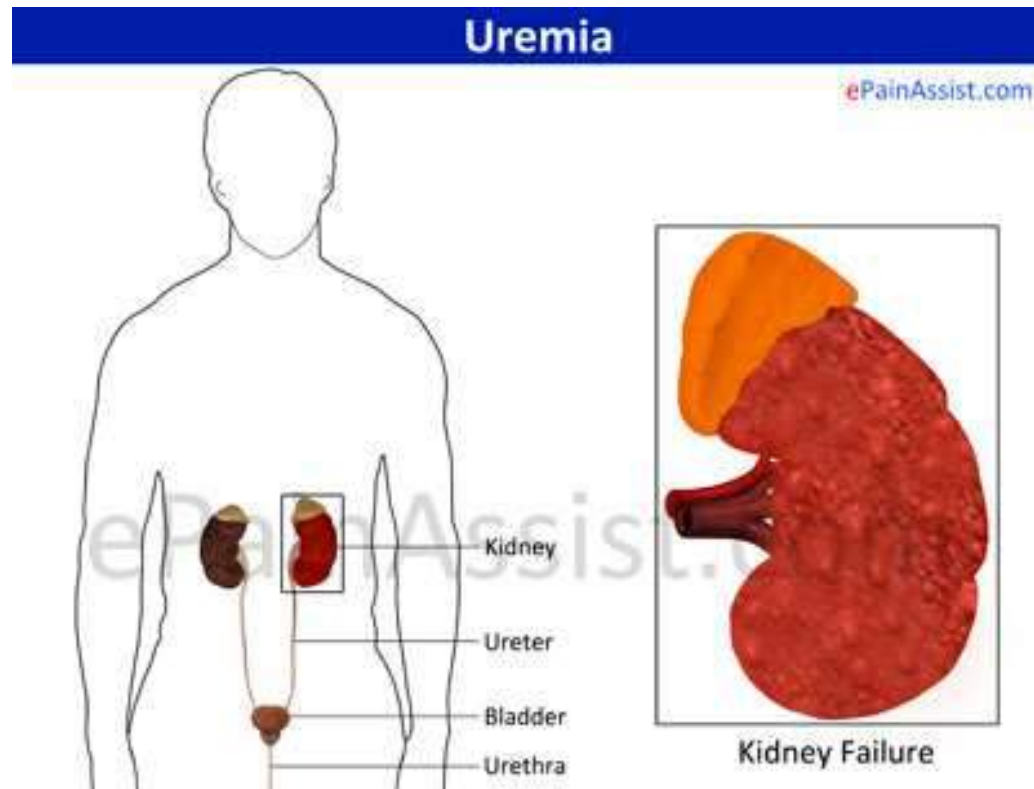
5. Glomerulonephritis:

- Inflammation of the glomerular can be caused by immunologic abnormalities, drugs or toxins, vascular disorders, and systemic diseases. Glomerulonephritis can be acute, chronic or progressive.
- Two major changes in the urine are distinctive of glomerulonephritis:
- **hematuria and proteinuria** with albumin as the major protein. There is also a decrease in urine as there is a decrease in GFR (glomerular filtration rate).



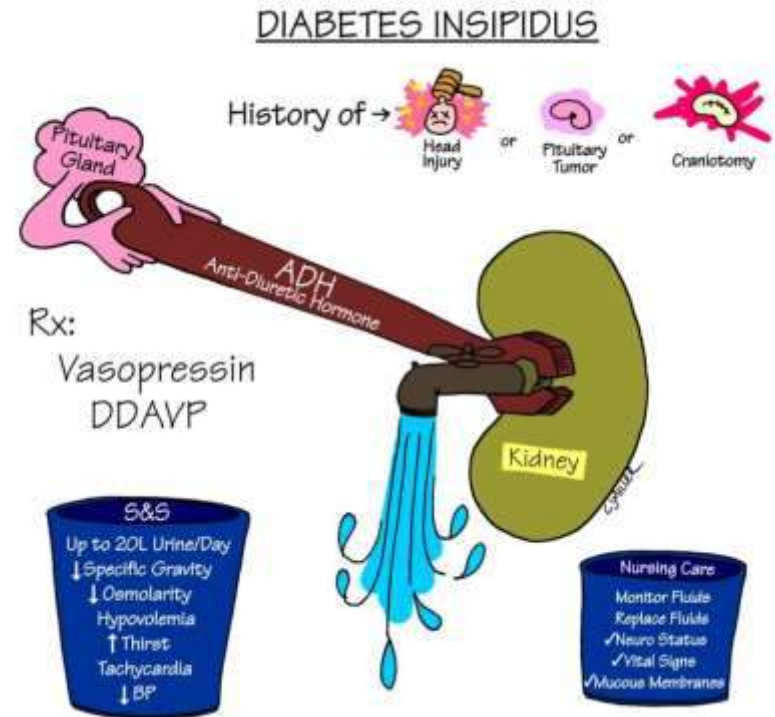
6. Renal Failure:

- **Uremia** is a syndrome of renal failure and includes elevated blood urea and creatinine levels. Acute renal failure can be reversed if diagnosed early.
- Acute renal failure can be caused by severe hypotension or severe glomerular disease.



Diabetes Insipidus (DI):

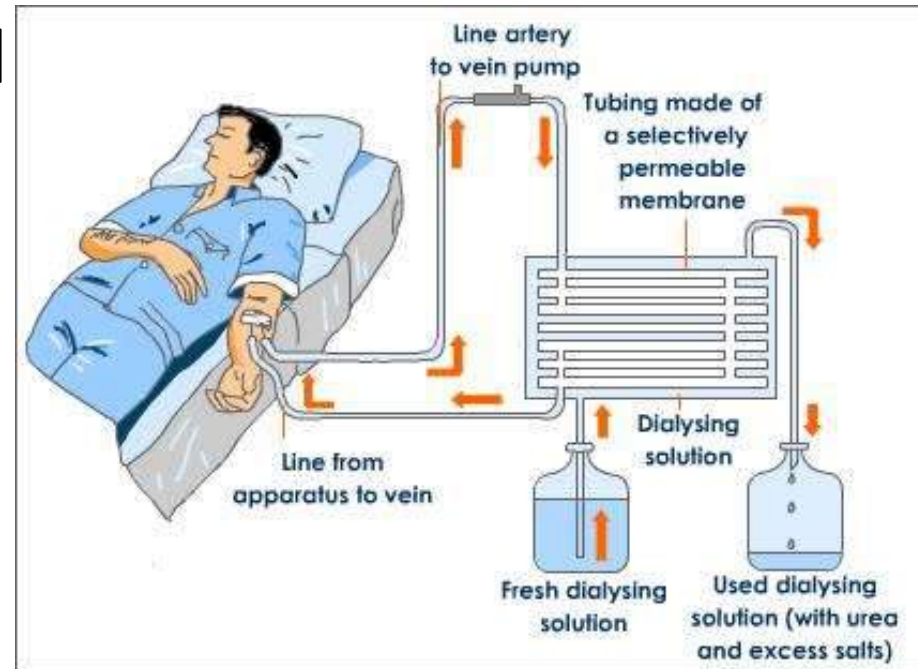
- This is caused by the deficiency of or decrease of ADH. The person with (DI) has the inability to concentrate their urine in water restriction, in turn they will void up' **3 to 20 liters/day**.
- **There are two forms of (DI):**
 1. Neurogenic: it is usually caused by head injury near the hypophysial tract.
 2. Nephrogenic, In nephrogenic (DI) the kidneys do not respond to ADH.
- **Usually the nephrogenic (DI) is characterized by:** The impairment of the urine concentrating capability of the kidney along with concentration of water. The cause may be a **genetic trait, electrolyte disorder, or side effect of drugs**.



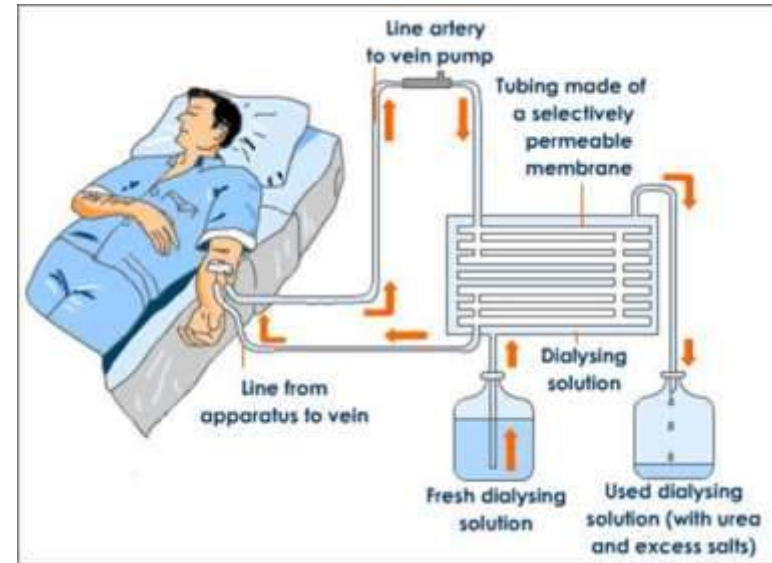
Dialysis and Kidney Transplant:-

- Generally, humans can live normally with just one kidney. **Dialysis** is a medical procedure, performed in various different forms, where the blood is filtered outside of the body. There are **two types of kidney transplants**:

- Living donor transplant
- Cadaveric (dead donor) transplant.

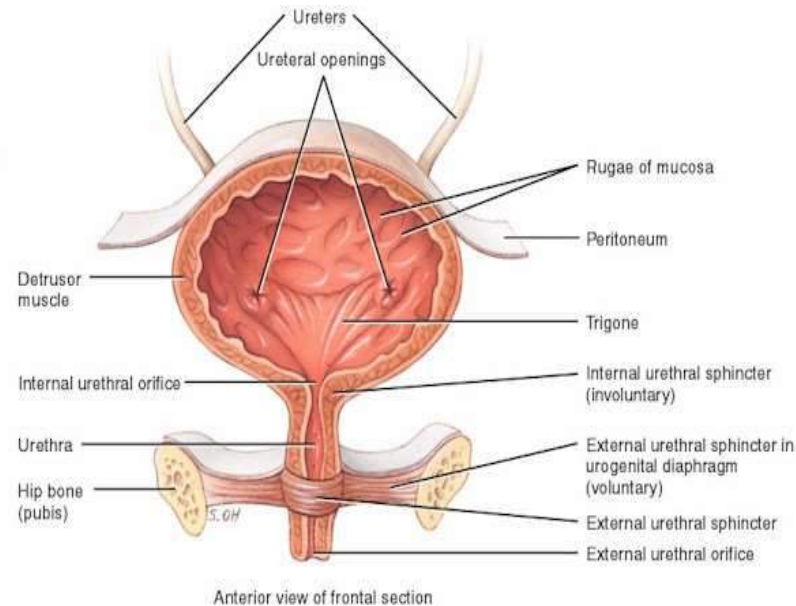
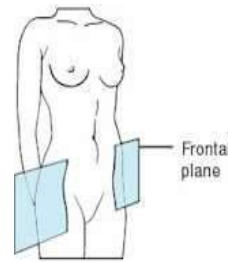


- When a kidney from a living donor, usually a blood relative, is transplanted into the patient's body, the donor's blood group and tissue type must be judged compatible with the patient's.
- In both cases, the recipient of the new organ needs to take drugs to suppress their immune system to help prevent their body from rejecting the new kidney.

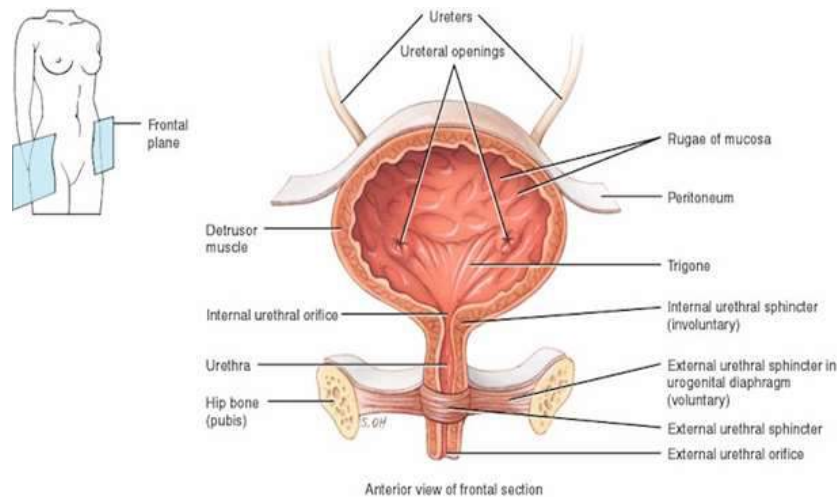


The Urination Reflex:

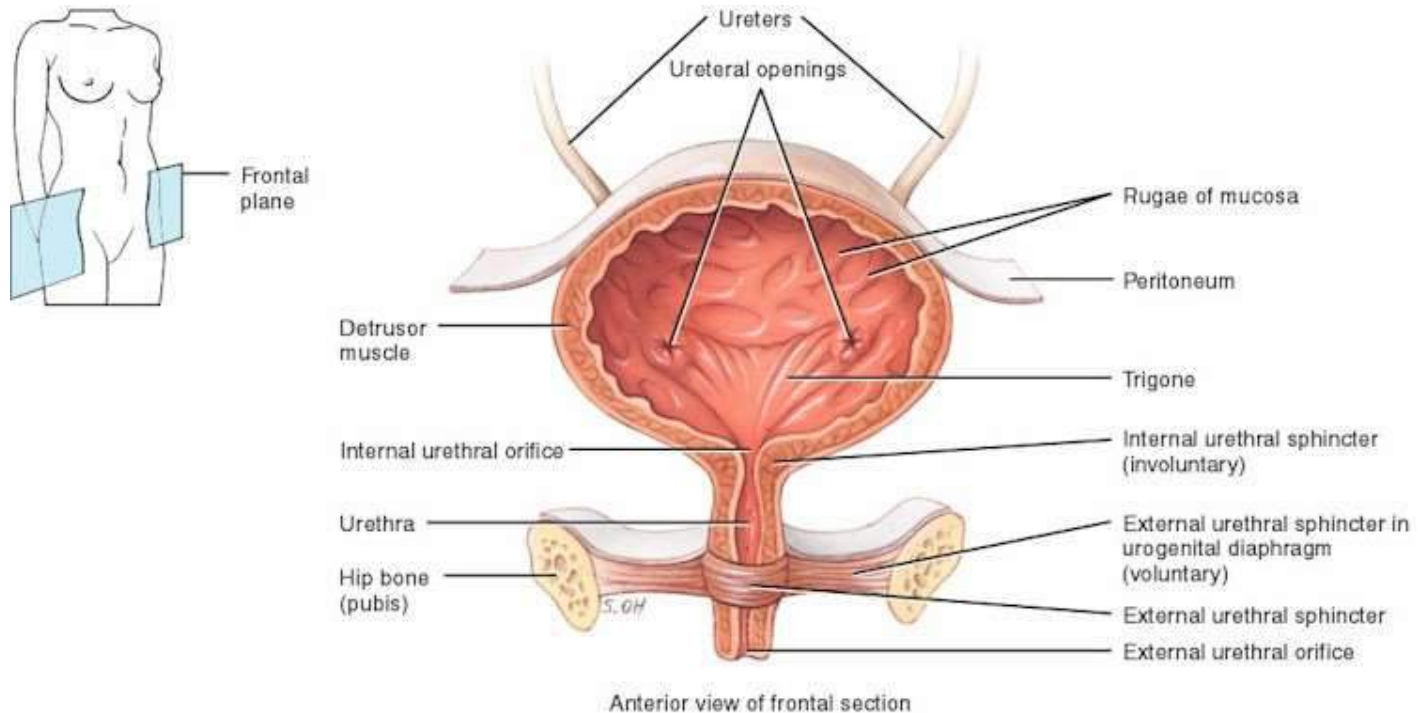
- Urination may also be called micturition or voiding. This reflex is a spinal cord reflex over which voluntary control may be exerted.
- The stimulus for the reflex is stretching of the detrusor muscle of the bladder.



- The bladder can hold as much as **800 mL** of urine, or even more, but the reflex is activated long before the maximum is reached. When urine volume reaches **200 to 400 ml**, the stretching is sufficient to generate sensory impulses that travel to the sacral spinal cord.
- Motor impulses return along parasympathetic nerves to the detrusor muscle, causing contraction.



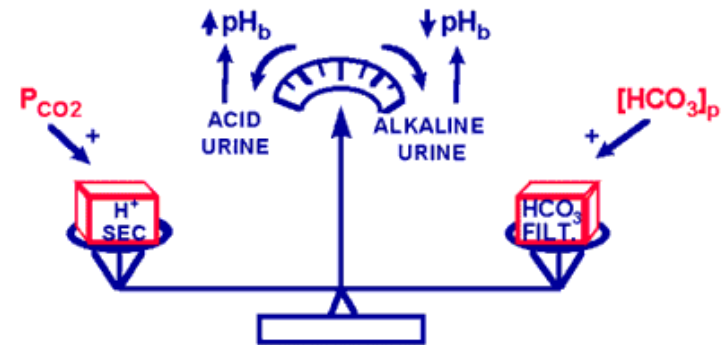
- At the same time, the internal urethral sphincter relaxes. If the external urethral sphincter is voluntarily relaxed, urine flows into the urethra, and the bladder is emptied. Urination can be prevented by voluntary contraction of the external urethral sphincter. However, if the bladder continues to fill and be stretched, voluntary control is eventually no longer possible.



The Kidneys and Acid- Base Balance:-

- The kidneys are the organs most responsible for maintaining the pH of blood (**normal 7.35 - 7.45**) and tissue fluid within normal ranges.
- They have the greatest ability to compensate for the pH changes that are a normal part of body metabolism or the result of disease, and to make the necessary corrections.
- Acid- base balance is controlled by renal regulation of **HCO₃⁻** and **H⁺** ions and by pulmonary excretion of **CO₂**.

ACID-BASE BALANCING BY THE KIDNEY

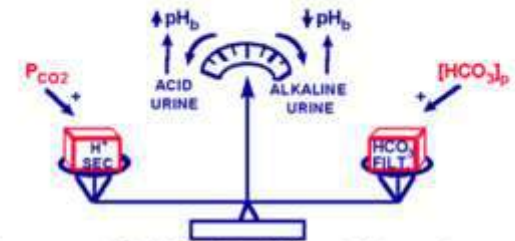


- The response of the kidney to acid-base imbalances is governed by the relative magnitudes of **proton secretion** and **HCO₃ filtration** because these two factors affect the rates of acid and alkali excretion.
- If **P_{CO₂}** rises, proton secretion becomes dominant and the kidney excretes acid, raising blood pH.
- If **[HCO₃]_p** rises, HCO₃ filtration increases and the kidney excretes alkali, reducing blood pH.

❖ If body fluids are becoming **too acidic**, the kidneys will secrete **more H^+ ions** into the renal filtrate and will **return more HCO_3^- ions to the blood**. This will help raise the pH of the blood back to normal.

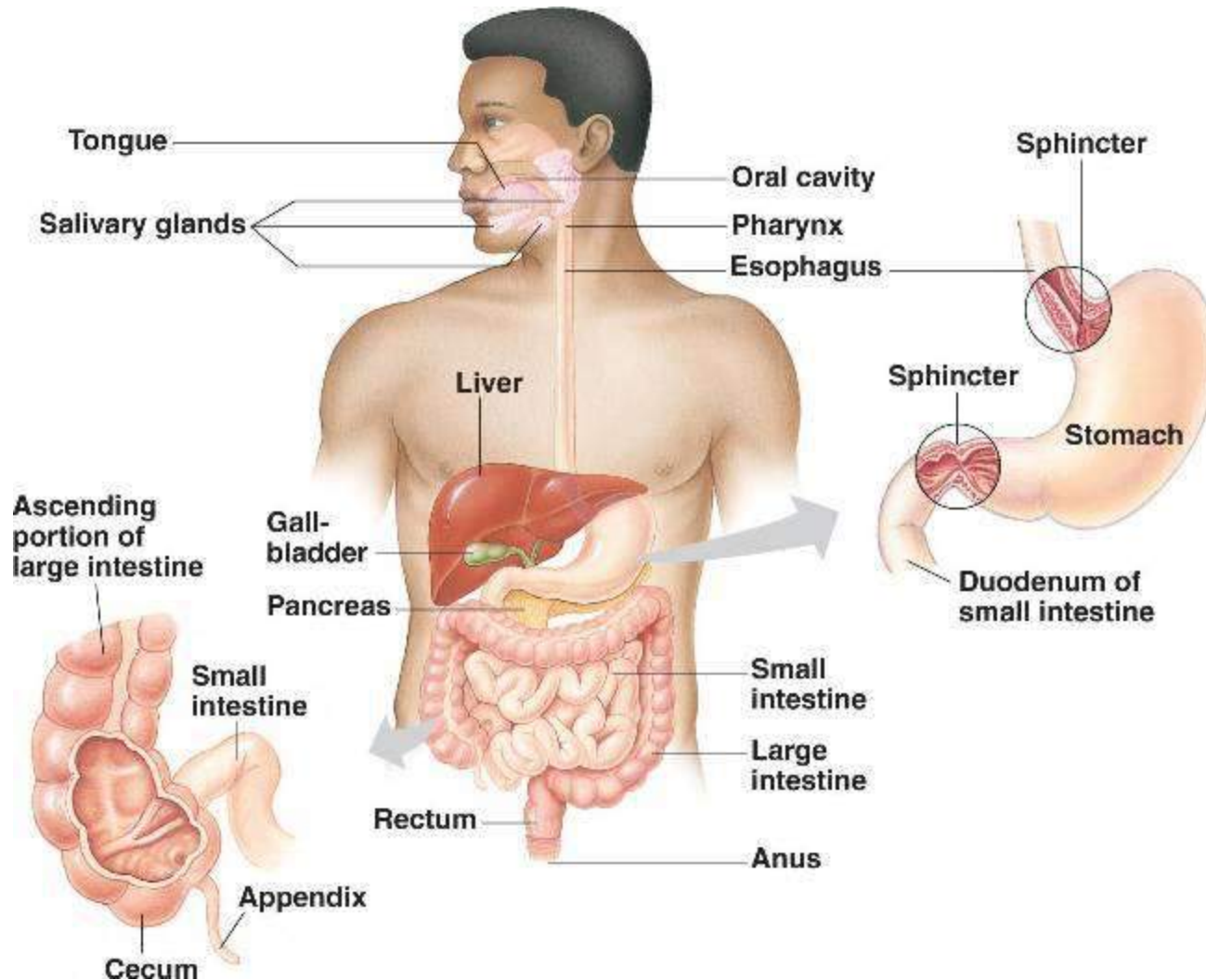
❖ If body fluids are becoming **too alkaline**, the kidneys will **return H^+ ions to the blood** and **excrete HCO_3^- ions in urine**. This will help lower the pH of the blood back to normal.

ACID-BASE BALANCING BY THE KIDNEY



- The response of the kidney to acid-base imbalances is governed by the relative magnitudes of **proton secretion** and **HCO_3^- filtration** because these two factors affect the rates of acid and alkali excretion.
- If P_{CO_2} rises, proton secretion becomes dominant and the kidney excretes acid, raising blood pH.
- If $[HCO_3^-]_p$ rises, HCO_3^- filtration increases and the kidney excretes alkali, reducing blood pH.

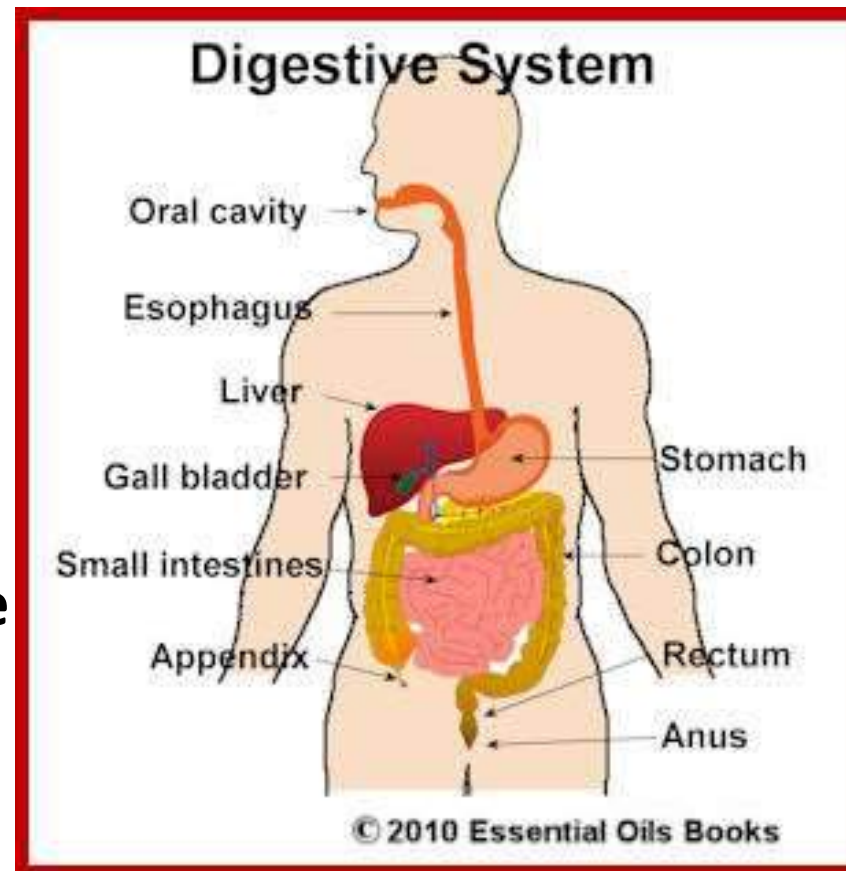
Digestive system



Lec.Dr.Ruwaidah F. Khaleel

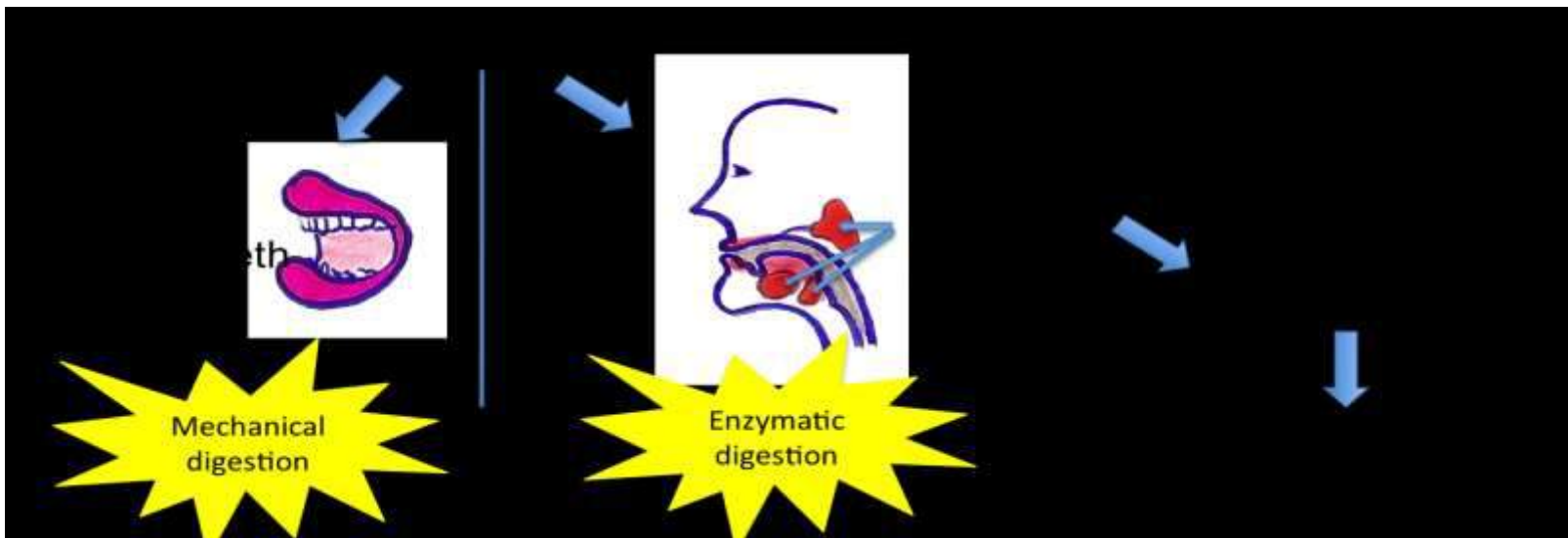
Digestive system

- **The digestive system:** It is referred to as the **gastrointestinal (GI)**, can be divided into the
 1. **Tubular gastrointestinal (GI) tract**
 2. **Accessory digestive organs**
- The GI tract is approximately **9 m long** and extends from the mouth to the anus.
- The organs of the GI tract include the **mouth, pharynx, esophagus, stomach, small intestine, and large intestine.**
- The accessory digestive organs are not part of the tract but secrete substances into it via connecting ducts, they include **the salivary glands, liver, gallbladder, and pancreas.**



Functions of the GI system

- The functions of the GI system can be described in terms of the following four processes:
 1. **Digestion:** this refers to the breakdown of food molecules into their smaller subunits, which can be absorbed. During digestion, two main processes occur at the same time.
 - A. **Mechanical digestion:** larger pieces of food get broken down into smaller piece while being prepared for chemical digestion. Mechanical digestion starts in the **mouth** and continues into the **stomach**.
 - B. **Chemical digestion:** several different enzymes breakdown macromolecules into smaller molecule that can be absorbed. Chemical digestion starts in the **mouth** and continues into the **intestines**.

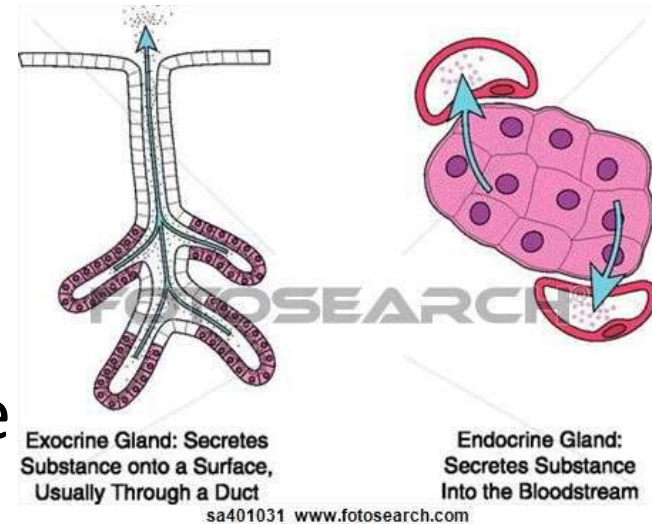


2. Secretion: this include both exocrine and endocrine secretion

A. Exocrine secretions: water, hydrochloric acid, bicarbonate, and many digestive enzymes are secreted into the lumen of the GI tract

B. Endocrine secretions: the stomach and small intestine secrete a number of hormones that help to regulate the digestive system

3. Absorption: this refers to the passage of digested and products from the lumen of the GI tract across a layer of epithelial cells into the blood or lymph



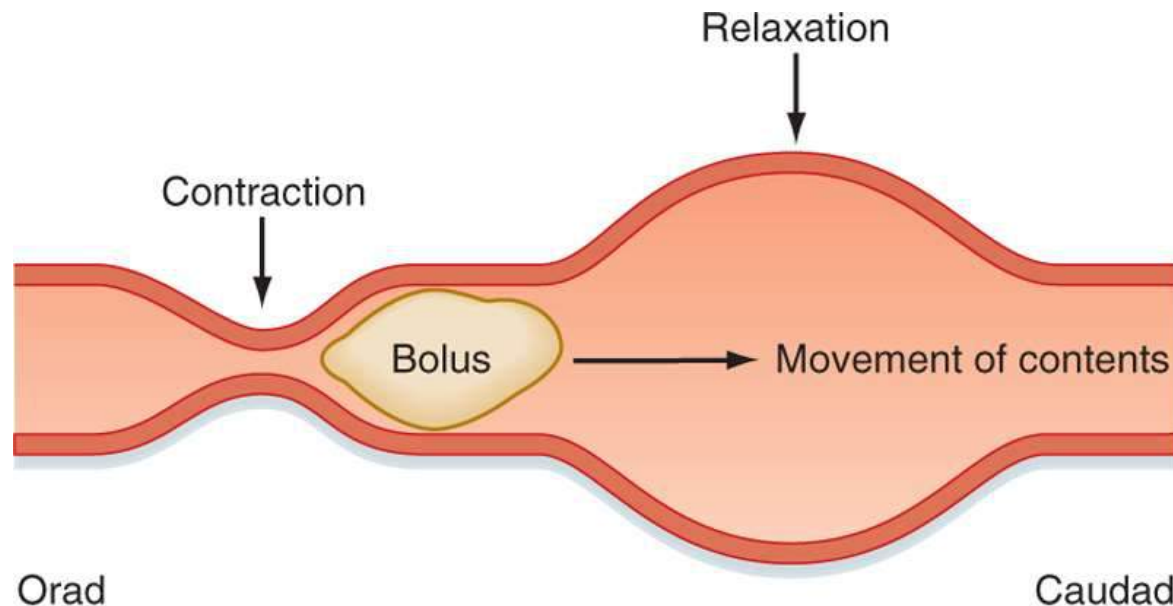
4. Motility: this refers to the movement of food through the digestive tract through the processes of :

A. Ingestion: taking food into the mouth

B. Mastication: ^{مضغ} chewing the food and mixing it with saliva.

C. Deglutition: ^{بلع} swallowing food

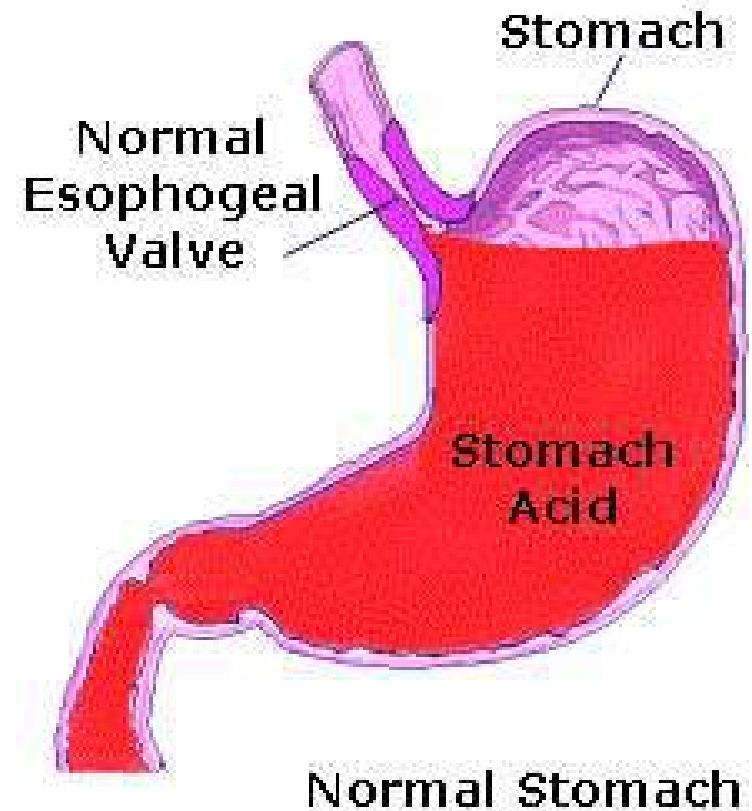
D. Peristalsis: Rhythmic, wavelike contractions that move food through the GI tract.



لتحقيق

To achieve these different functions the following mechanisms are involved:

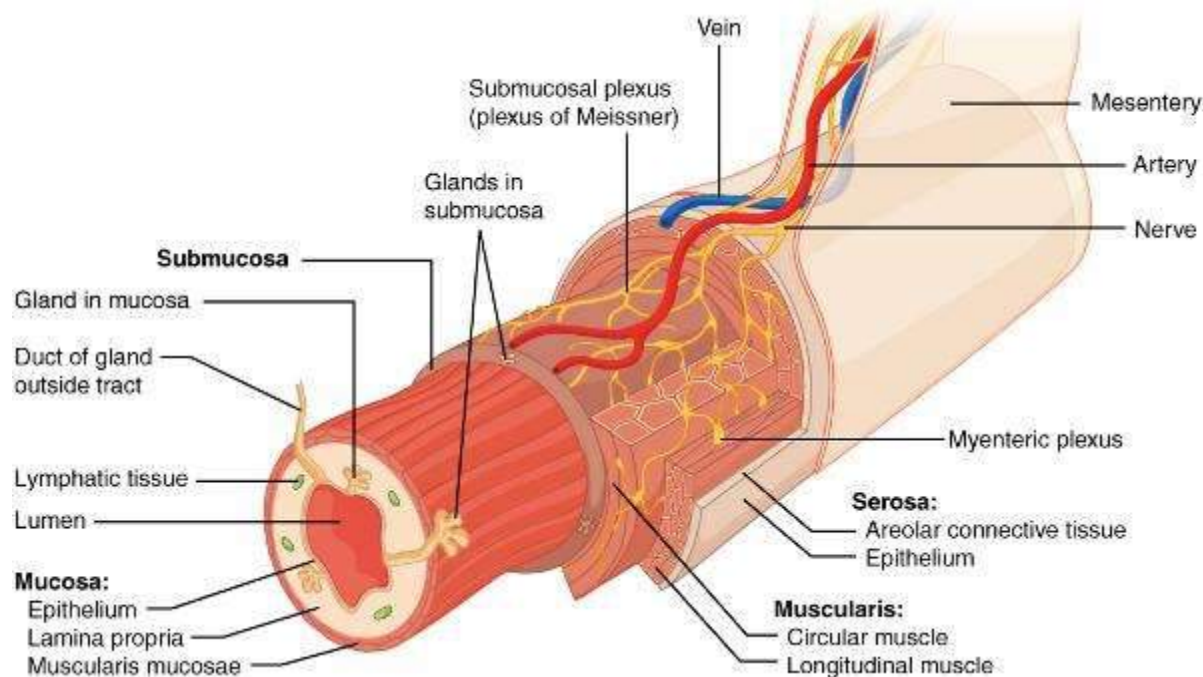
1. Section of digestive juices such as saliva, gastric HCl, enzymes and bile.
2. GI tract motility for mixing with digestive juices and passage the GI tract
3. Secretion of GI tract hormones.



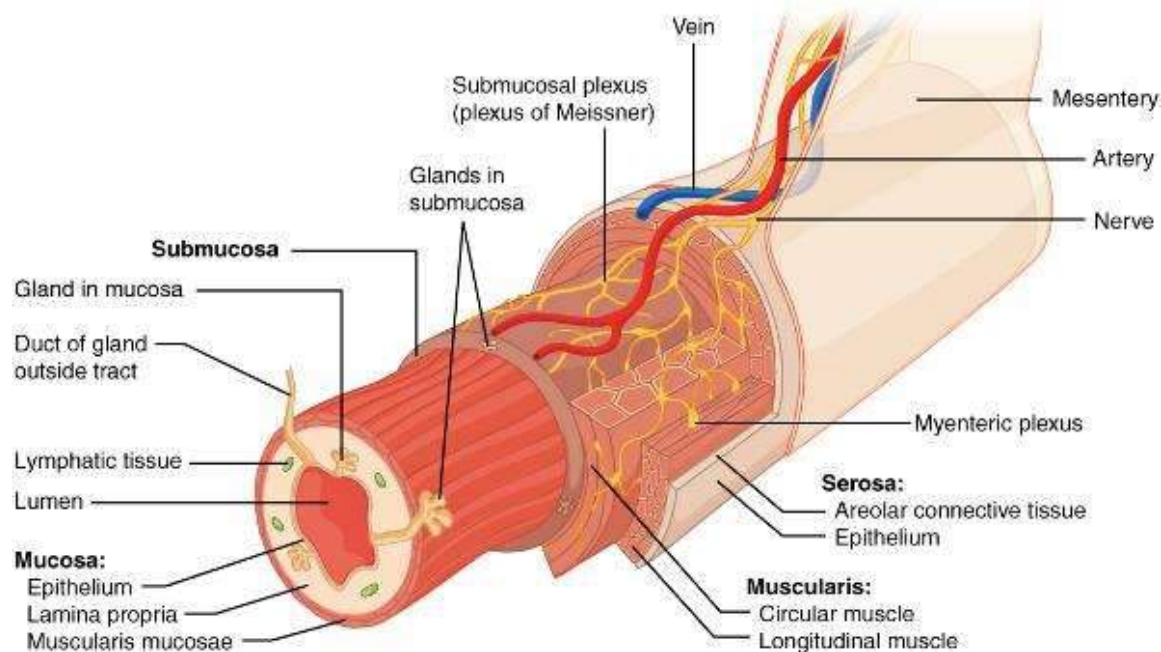
Layers of the GI tract

- The GI tract composed of **four layers**, each layer has different tissues and functions. From the inside out they are:

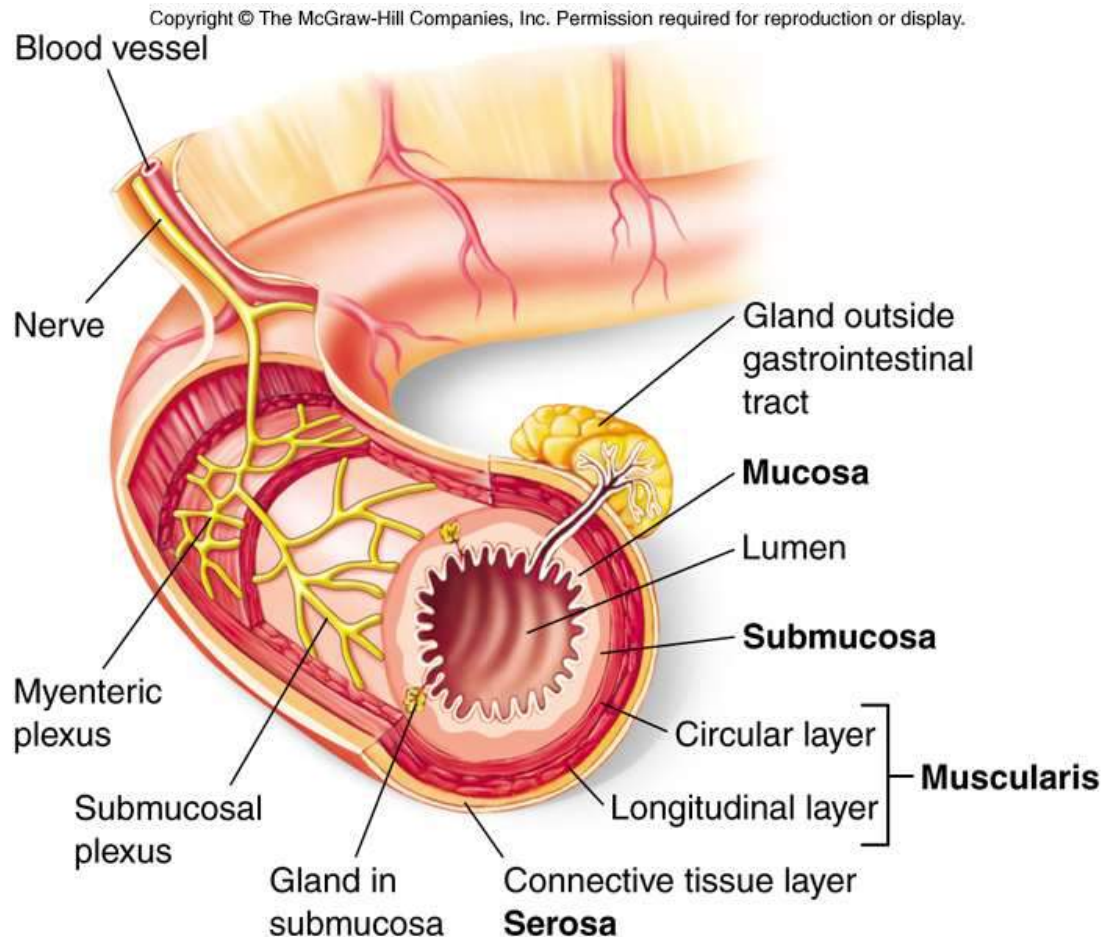
- Mucosa:** is the inner layer of the GI tract that surrounding the lumen. It is composed of **simple epithelium cells and a thin connective tissue**. This layer comes in direct contact with the food and is **responsible for absorption and secretion**



2. **Submucosa:** consists of a dense irregular layer of connective tissue with large blood vessel, lymphatic and nerve branching into mucosa and muscularis.
 3. **Muscularis:** is composed of two layers of muscle an inner circular and outer longitudinal layer of smooth muscle. The circular muscle layer prevents the food from going backwards and the longitudinal layer shorten the tract (peristalsis).
- The muscularis is responsible for segmental contractions and peristaltic movement in GI tract.

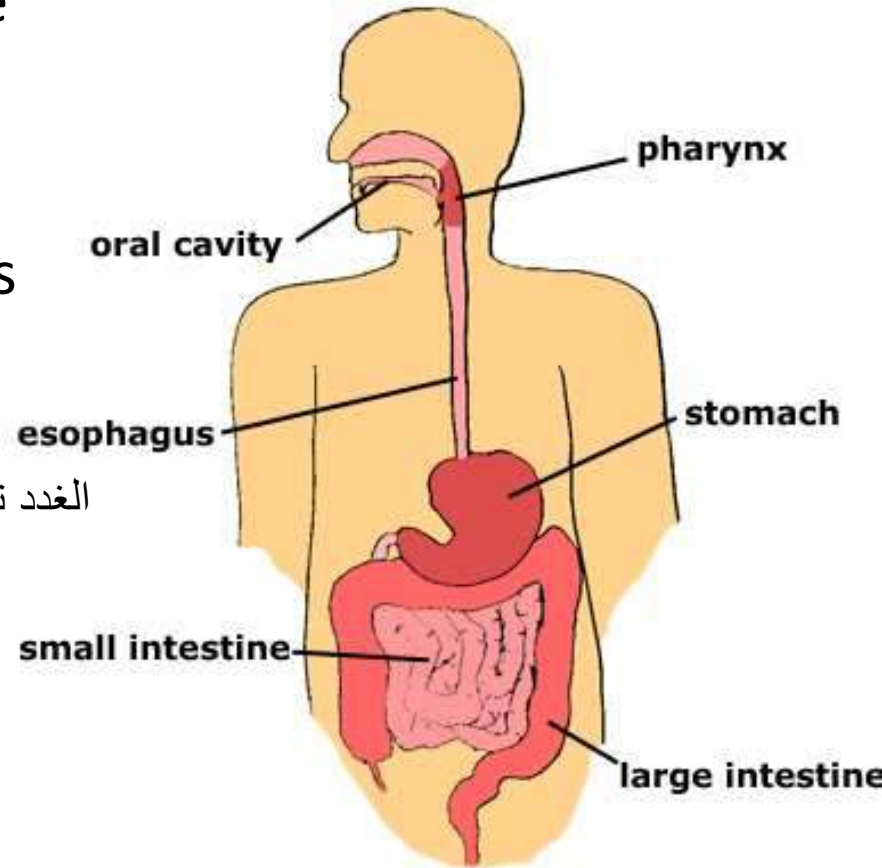


4. Serosa or adventitia: consists of several layers of connective tissue and simple squamous epithelium. This last layer is a protective layer, it secretes lubricating serous fluid.

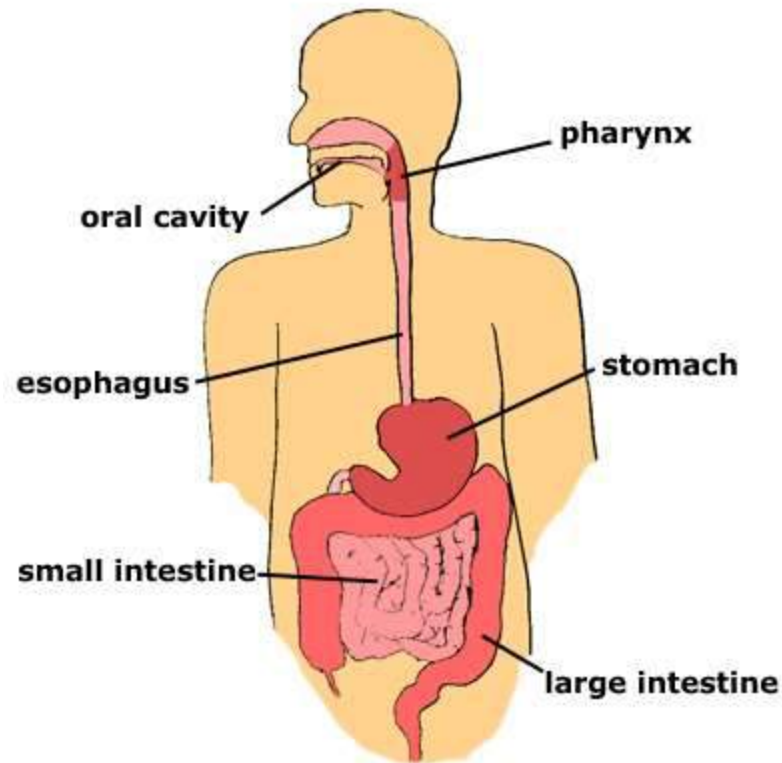


Phases of digestion:

- **Oral cavity and esophagus:**
- The GI tract begins with the **mouth**, and digestion starts there with chewing, which breaks up large pieces of food into smaller particles that can be swallowed.
- **Saliva** was secreted by three pairs of **salivary glands**, they are:
 1. **parotid glands** الغدد النكفية
 2. **submandibular glands** الغدد تحت الفك السفلي
 3. **sublingual glands**. الغدد تحت اللسان.
- Saliva, which contains mucus, moistens and lubricates the food particles before swallowing. يرطب ويزيت
- It also contains the enzyme **amylase**, which partially digests polysaccharides

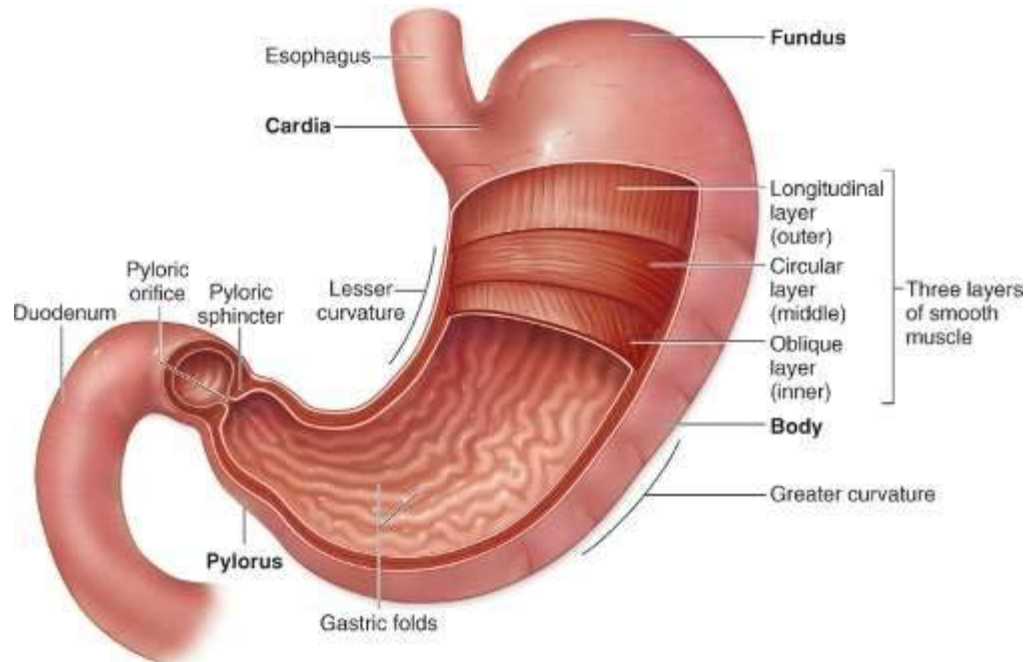


- The next segments of the GI tract, the **pharynx** and **esophagus**, contribute nothing to digestion but provide the pathway by which ingested materials reach the stomach. The muscles in the walls of these segments control swallowing.



Stomach

- **The stomach** is a saclike organ, located between the esophagus and the small intestine, it is the most distensible part of the GI tract. جزء قابل للنفخ
- **The stomach is divided into four sections:**
 1. Cardiac region is where the contents of the esophagus empty into the stomach
 2. Fundus is formed by the upper curvature of the organ انحناء العلوي
 3. Body is the main central region القاع
 4. Pylorus is the lower section of the organ that facilitates emptying the contents into the small intestine البوابة

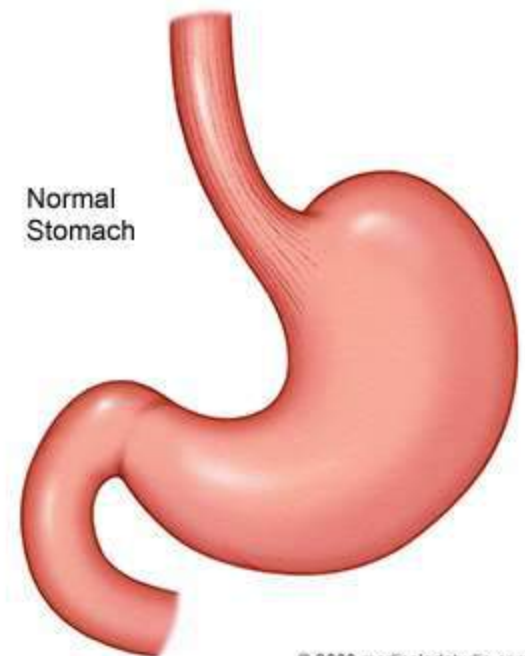
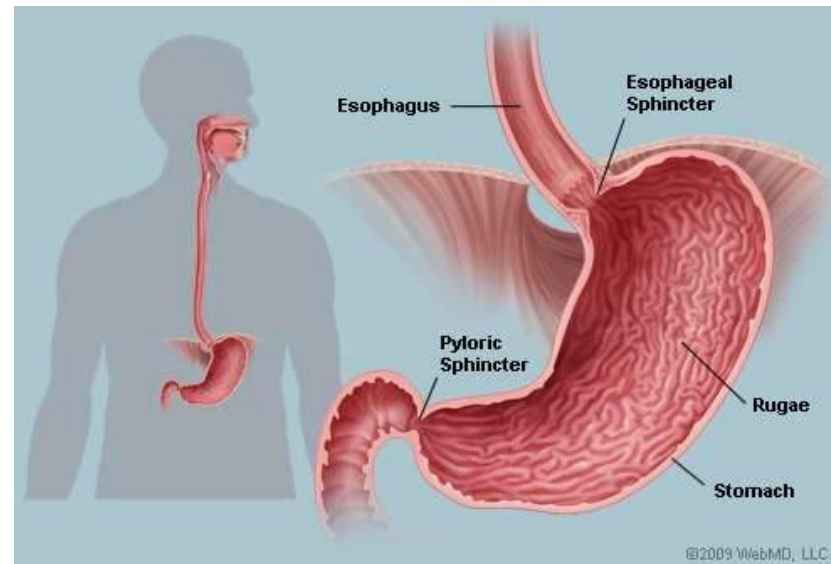


❖ **There are two sphincters keep the contents of the stomach:**

1. Cardiac or esophageal sphincter dividing the tract above
2. Pyloric sphincter dividing the stomach from the small intestine.

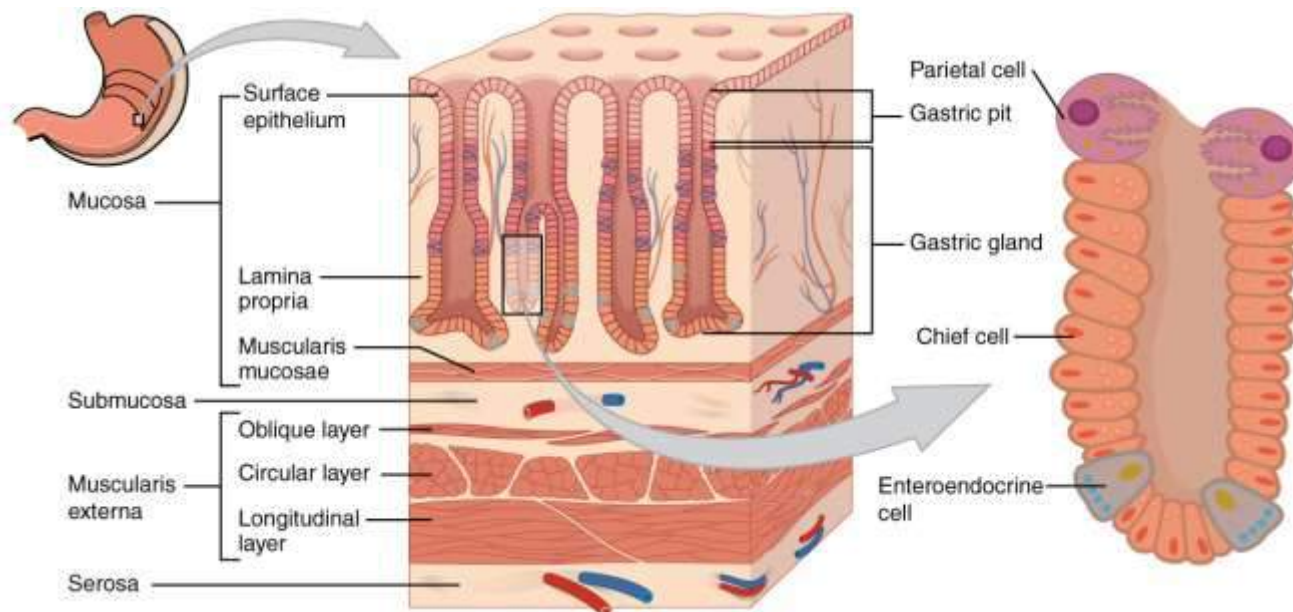
❖ **The functions of the stomach are :**

1. To store food
2. To initiate the digestion of proteins,
3. To kill bacteria with the strong acidity of gastric juice
4. To move the food into the small intestine as a pasty material called **chyme**, which contains molecular fragment of proteins and polysaccharides, droplets of fat, and salt, water, and various other small molecules ingested in the food.



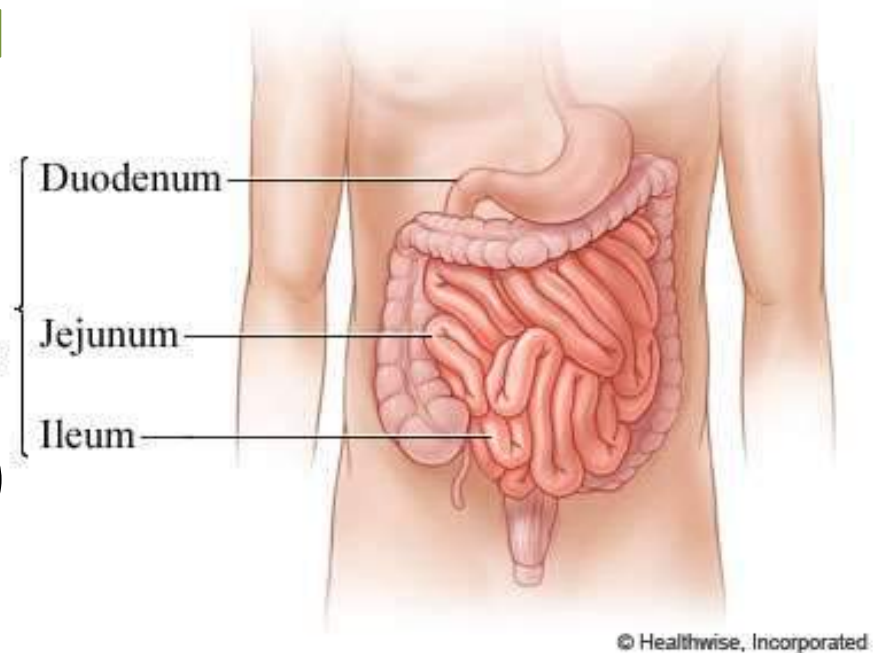
The glands lining the stomach wall are called gastric glands, these glands contain several types of cells that secrete different products:

1. Goblet cells secrete mucus
2. Parietal cells secrete hydrochloric acid (HCl)
3. Chief cells secrete pepsinogen, an inactive form of the protein-digesting enzyme pepsin.

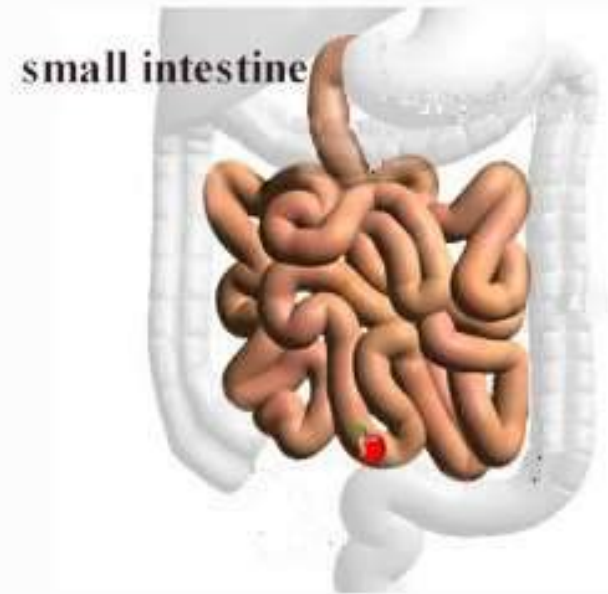


Small intestine

- The small intestine is divided into three segments:
 1. short segment (**the duodenum**) المعى الاثنا عشري
 2. jejunum الصائم
 3. longest segment (**the ileum**) اللفائفي
- Normally, most of the chyme entering from the stomach is digested and absorbed in the first quarter of the small intestine, in the **duodenum and jejunum**



- Digestions final stage and most absorption occur in the **small intestine**.
- Here molecules of intact or partially digested **carbohydrates, fats, and proteins** are broken down by **hydrolytic enzymes** are on the luminal surface of the intestinal lining cells, while others are secreted by the pancreas and enter the intestinal lumen



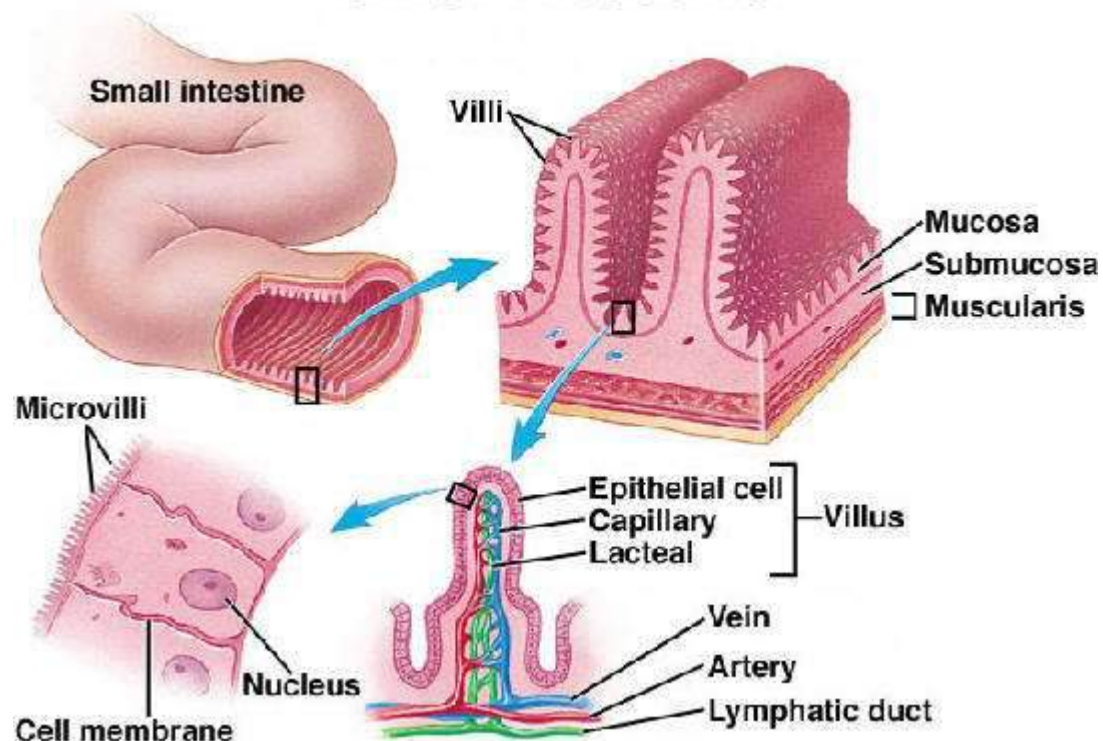
Digestive enzymes

| Reaction | Enzymes | Produced by | Site of Occurrence |
|--|--|----------------------------------|----------------------------------|
| Starch + H ₂ O → maltose | a. Salivary amylase b. Pancreatic amylase | a. Salivary gland b. Pancreas | a. Mouth b. Small intestine |
| Maltose + H ₂ O → glucose | Maltase | Intestinal cells | Small intestine |
| Protein + H ₂ O → peptides | a. Pepsin b. Trypsin | a. Gastric glands b. Pancreas | a. Stomach b. Small intestine |
| Peptides + H ₂ O → amino acids | Peptidase | Intestinal cells | Small intestine |
| Fats + H ₂ O → glycerol + fatty acids | Lipase | Pancreas | Small intestine |

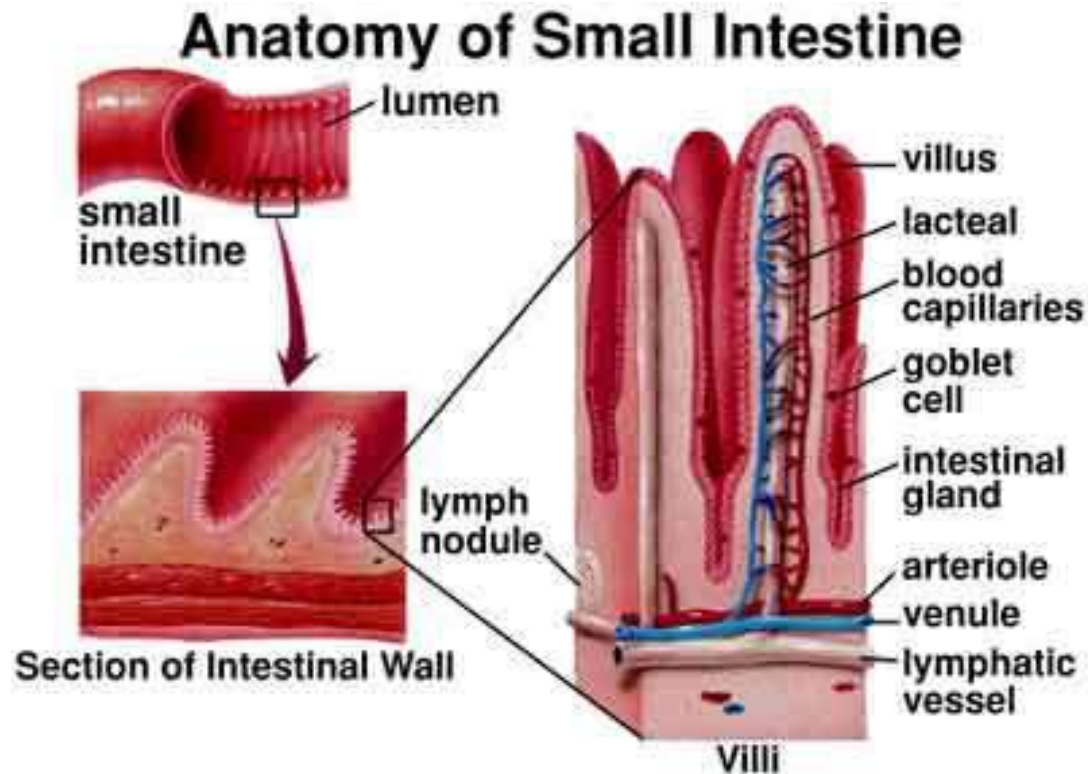
- The mucosa of the small intestine contain many folds that are covered with tiny fingerlike projections called **villi**.
- In turn, the villi are covered with microscopic projections called **microvilli**.
- These structures create a vast surface area through which nutrients can be absorbed. The products of digestion are absorbed across the epithelial cells and enter the blood and/or lymph.

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Small Intestine



- Each villus has a network of capillaries and fine lymphatic vessels called **lacteals** close its surface.
- The epithelial cells of the villi transport nutrients from the lumen of the intestine into these capillaries (amino acids and carbohydrates) and lacteals (lipids).
- The food that remains undigested and unabsorbed passes into the large intestine.

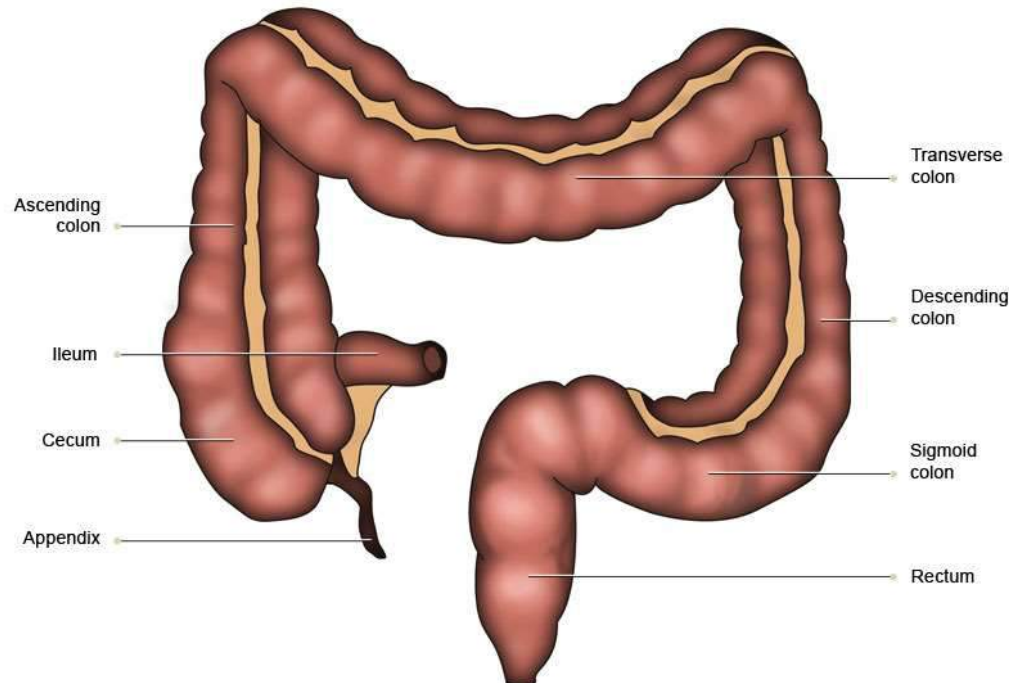


Large intestine

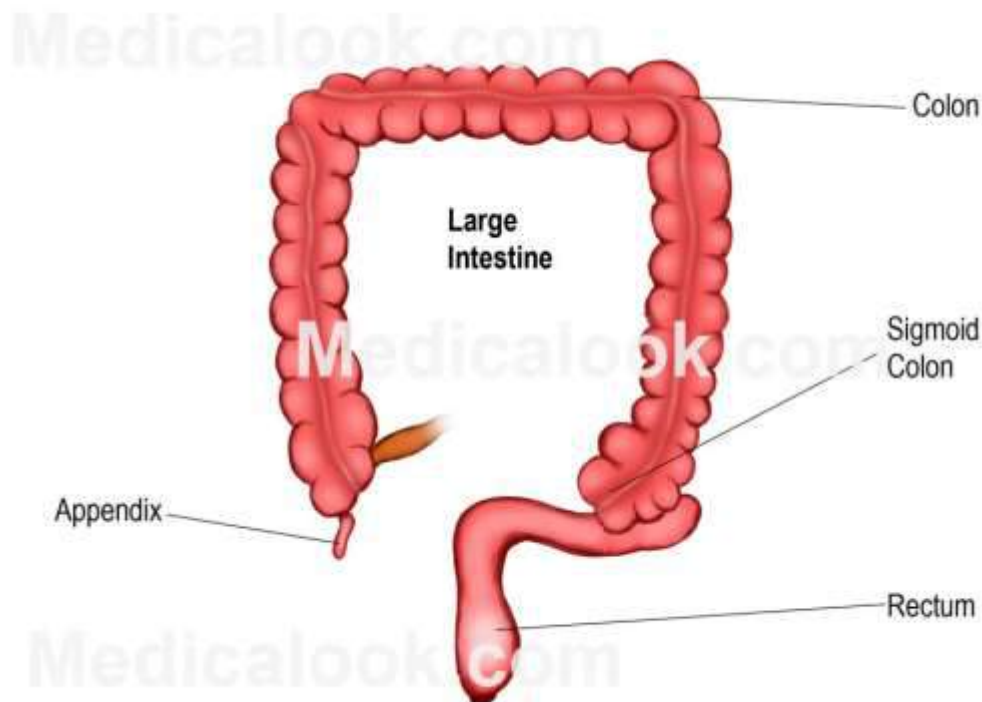
- The large intestine is divided into the:

1. Cecum الاعور
2. Colon القولون
3. Rectum المستقيم
4. Anal canal الشرج

- Chyme from the ileum passes into the cecum, which is a blind pouch containing appendix (open only at one end) at the beginning of the large intestine.

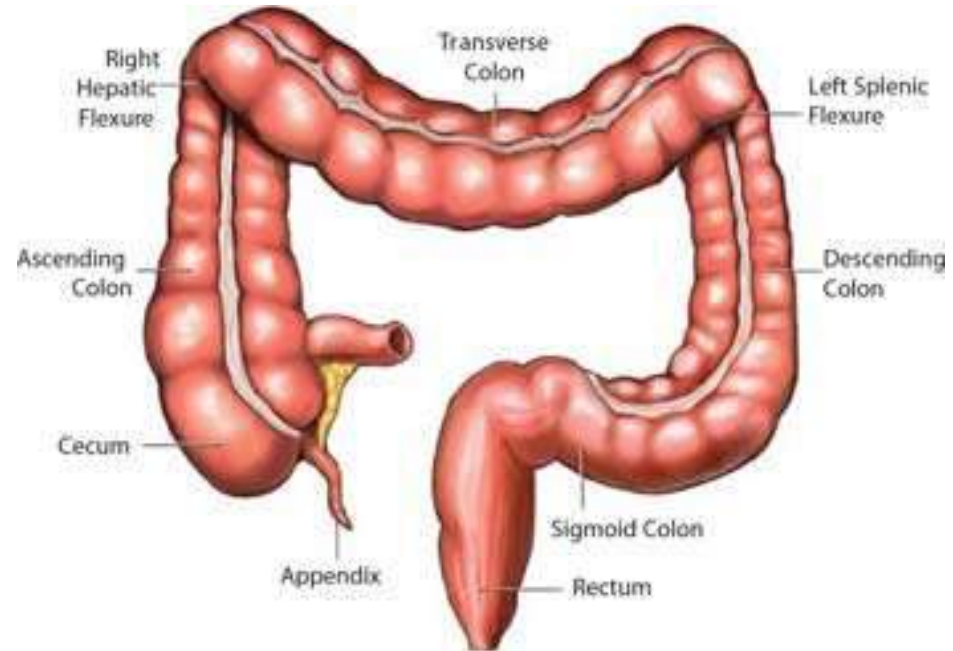


- The large intestine has little or no digestive function, but it does **absorb water and electrolyte from the remaining chyme.**
- Bacteria residing in the intestine, primarily the colon- collectively referred to as the [intestinal microflora](#), **they ferment undigested nutrient, make gas and produce significant amount of vitamin K and folic acid, which are absorbed in the large intestine.**



Waste material then passes in sequence through the:

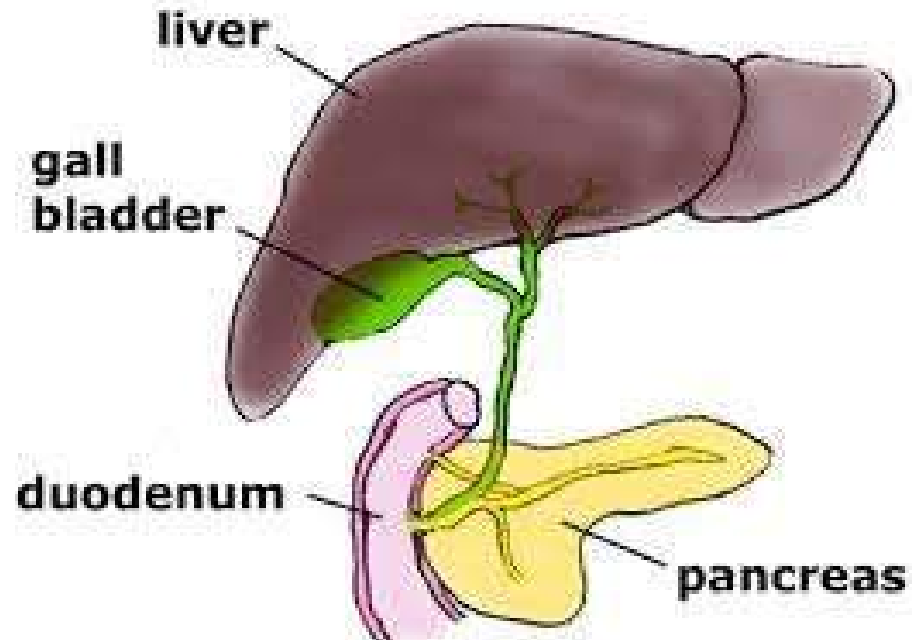
1. Ascending colon ^{القولون الصاعد}
2. Transverse colon ^{القولون المستعرض}
3. Descending colon ^{القولون النازل}
4. Sigmoid colon ^{القولون المقطع}
5. Rectum ^{المستقيم}
6. Anal canal ^{قناة المخرج}
7. Waste material (feces) is excreted through the anus, the external opening of the anal canal.



Anatomy of Large Intestine

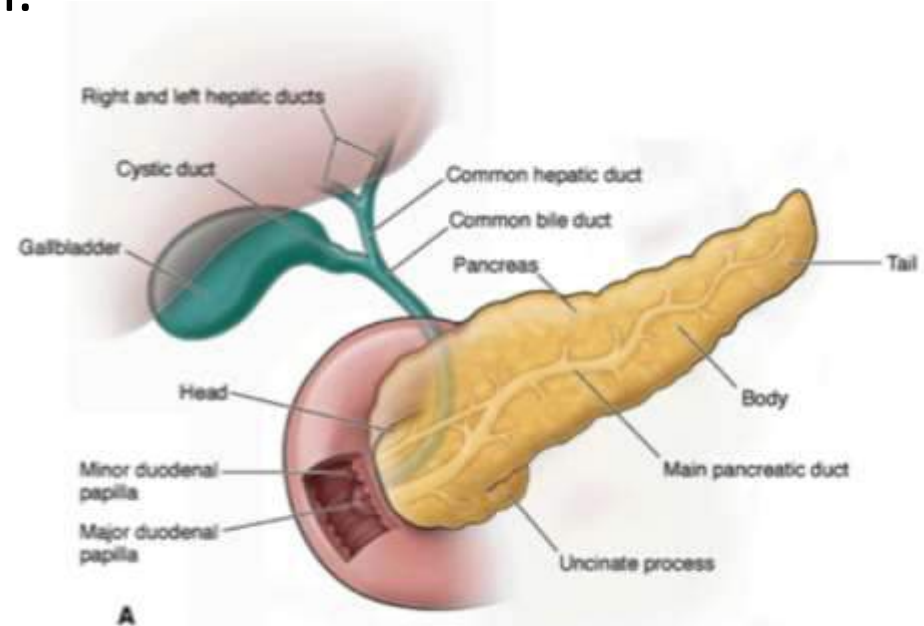
Pancreas, liver, and gallbladder

- The pancreas, liver, and gallbladder are essential for digestion.
- 1. **Pancreas** that help digest proteins, fat and carbohydrates.
- 2. **Liver** produces bile that helps the body absorb fat.
- 3. **Gallbladder** stores the bile until it is needed.
- The enzymes and bile travel through ducts and into the small intestine where they help break down the food.



Pancreas

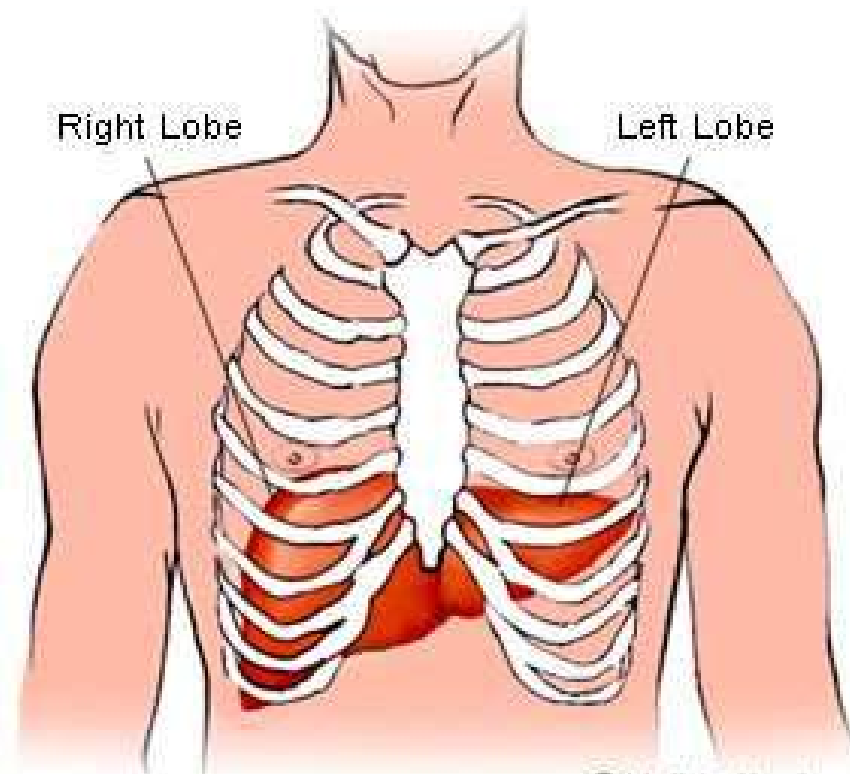
- **The pancreas:** is an elongated gland located behind the stomach and in close association with the duodenum.
- The pancreas has both endocrine and exocrine functions.
- The exocrine portion of the pancreas secretes digestive enzymes and a fluid rich in bicarbonate ions.
- The high acidity of chyme coming from the stomach would inactivate the pancreatic enzymes in the small intestine if the acid were not neutralized by the bicarbonate ions in the pancreatic fluid.



Liver

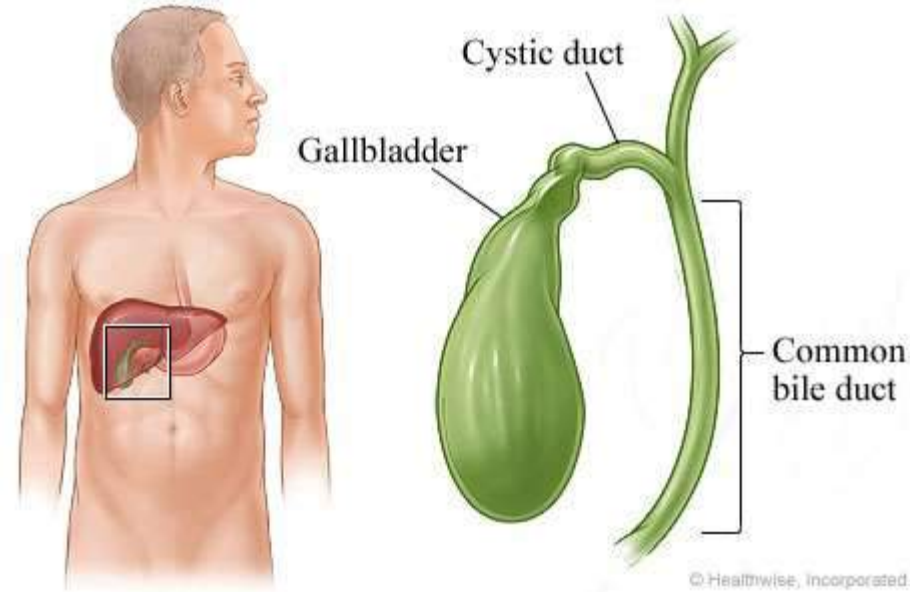
- **The liver** ^{الحجاب الحاجز} is located under the diaphragm on the right side of the upper abdomen; it lies on the right side of the stomach and makes a kind of bed for the gallbladder.
- The liver plays a major role in metabolism and has a number of functions.
- It also produces and excretes bile, which is important in digestion, it requires for dissolving fats.

The Liver



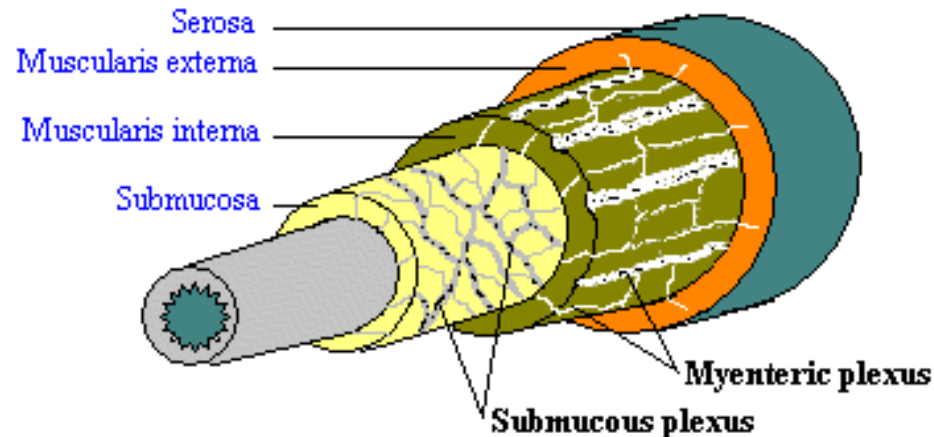
Gallbladder

- The gallbladder is a pear shaped organ that stores about **50ml** of bile until the body needs it for digestion, the gallbladder is dark green in appearance due to its contents (bile), not its tissue.
- Bile is stored between meals in the gallbladder. At mealtime, it is squeezed out of the gallbladder, through the bile ducts, and into the intestine to mix with the fat in food.

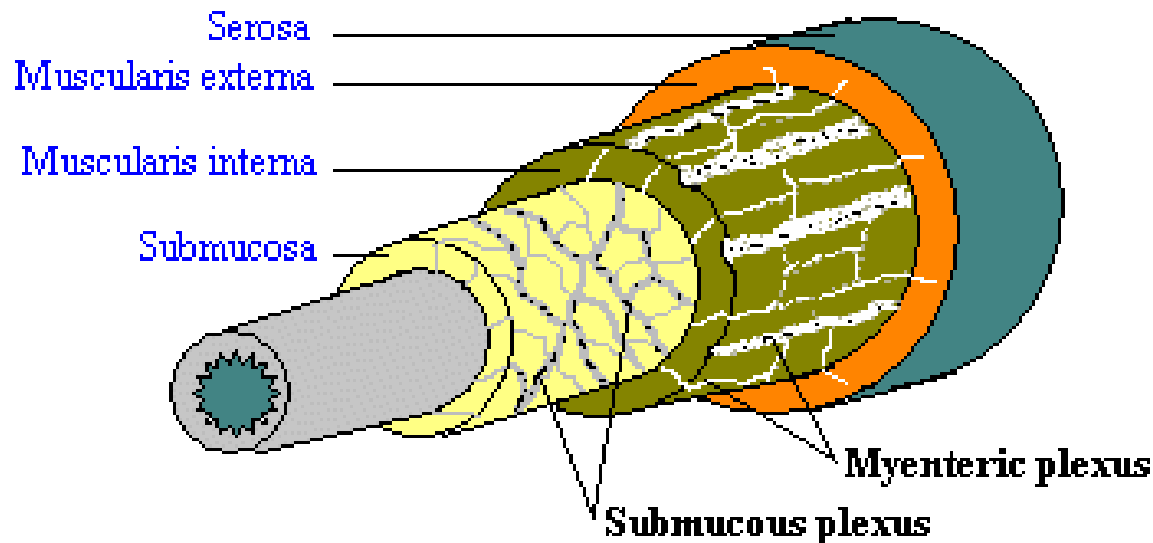


Neural and endocrine regulation of the digestive system

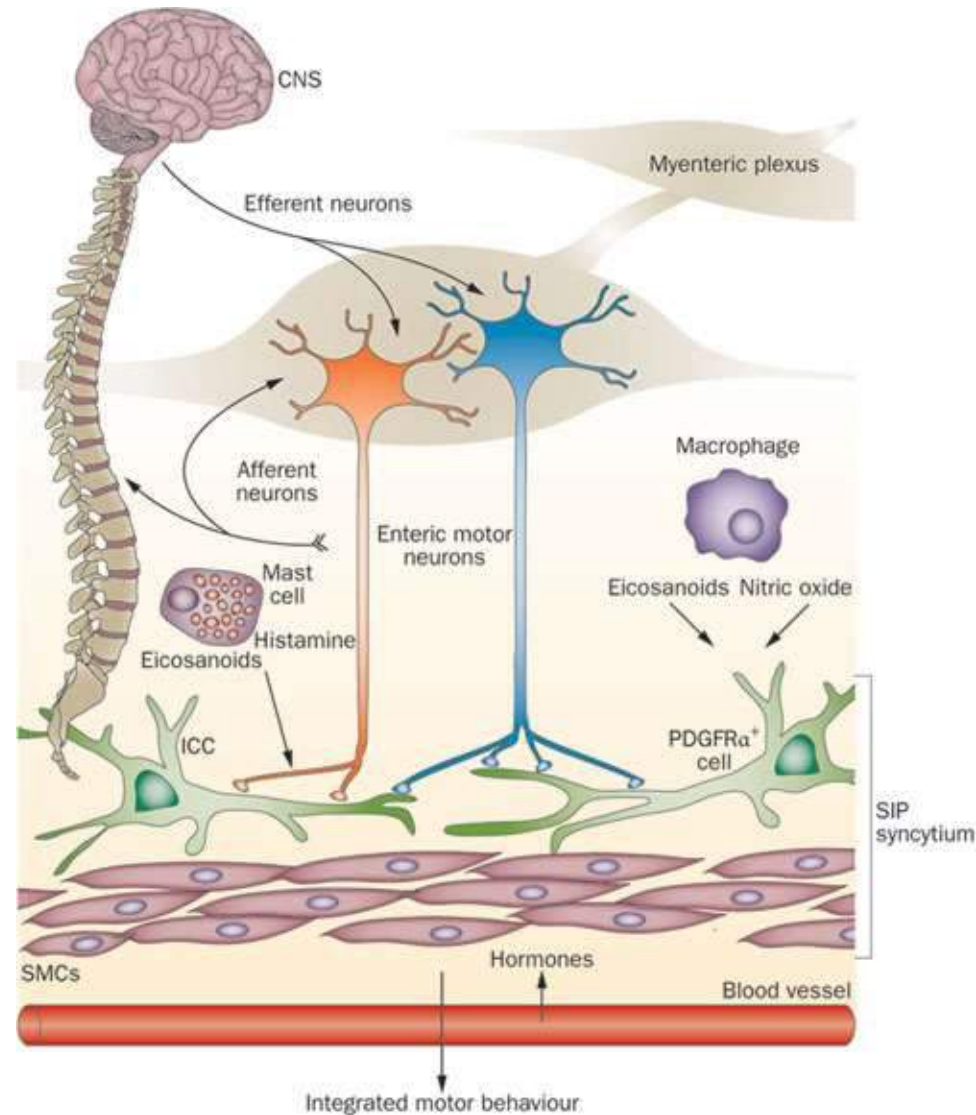
- Neural and endocrine control mechanisms modify the activity of the digestive system
- **Neural regulation**
- The GI tract has its own nervous system, known as the enteric nervous system, in the form of two nerve networks:
 1. **Myenteric plexus**, lies between longitudinal and circular muscle layers
 2. **Meissner's or submucous plexus**, lies in the submucosa.



- In addition, nerve fibers from both the sympathetic and parasympathetic branches of the autonomic nervous system enter the intestinal tract and synapse with neurons in both plexuses:
 1. **Parasympathetic nervous** stimulate motility and secretions of the gastrointestinal tract.
 2. **Sympathetic nerves** the effects to reduce peristalsis and secretory activity and stimulate the contraction of sphincter muscles along the GI tract

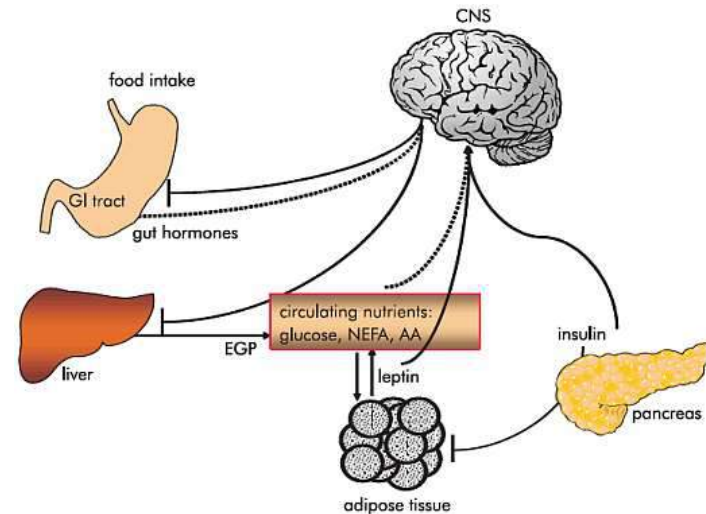


- It should be noted that not all neural reflexes are indicated by signals within the tract.
- The sight or smell of food and the emotional state of an individual can have significant effects on the GI tract, effects that are mediated by the CNS via autonomic neurons.



Hormonal regulation:

- The major hormones that control the functions of the GI system are produced by **endocrine cells in the mucosa of the stomach and small intestine.**
- One surface of each endocrine cell is exposed to the lumen of the GI tract.
- At this surface, various chemical substances in the chyme stimulate the cell to release its hormones from the opposite side of the cell into the blood.

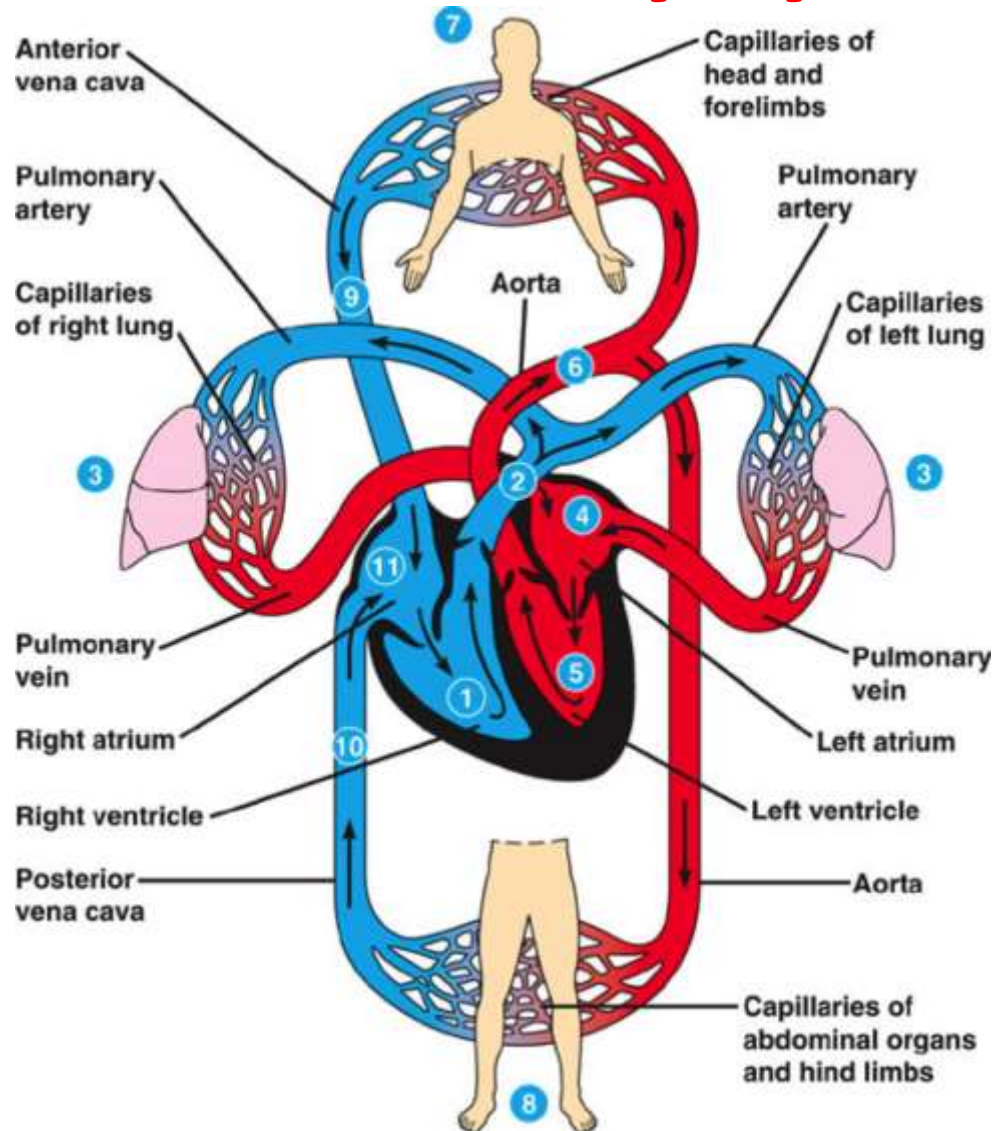


The main hormones that control digestion and their effects are summarized in the following table

Gastrointestinal Hormones

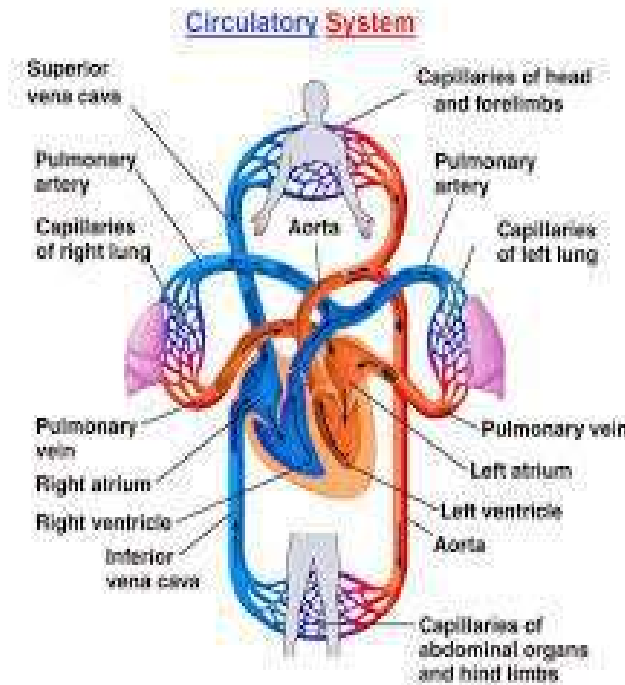
| Hormone | Secreted by | Stimuli for hormone release | Effects |
|---|-----------------|---|---|
| Gastrin | Stomach | Amino acids, peptides in stomach | Stimulates parietal cells to secrete HCl. Stimulates chief cells to secrete pepsinogen. |
| Secretin | Small intestine | Acid in small intestine | Stimulates secretion of bicarbonate by pancreas. |
| Cholecystokinin (CCK) | Small intestine | Amino acids, fatty acids in small intestine | Stimulates contraction of gallbladder. Stimulates secretion of pancreatic enzymes. Inhibits gastric motility and secretion. |
| Glucose-dependent insulintropic peptide (GIP) | Small intestine | Glucose, fat in small intestine | Stimulates secretion of insulin from pancreatic islets. Inhibits gastric motility and secretion. |

The Circulatory System



The Circulatory System

- **The circulatory system** consists of a muscular chambered **heart**, a network of closed branching **blood vessels** and **blood**, the fluid which is circulated. Together, the heart and blood vessels comprise the **cardiovascular system**.
- Humans have a **closed** circulatory system; this means that the blood is always contained in tubes and vessels.
- **The circulatory system has the following three main functions:**
 1. It transports gases, nutrients, waste materials, and chemical substances from one part of the body to the other.
 2. It regulates internal temperature by altering the blood flow through the skin..
 3. It protects against blood loss from injury and against disease-causing microbes or toxic substances.

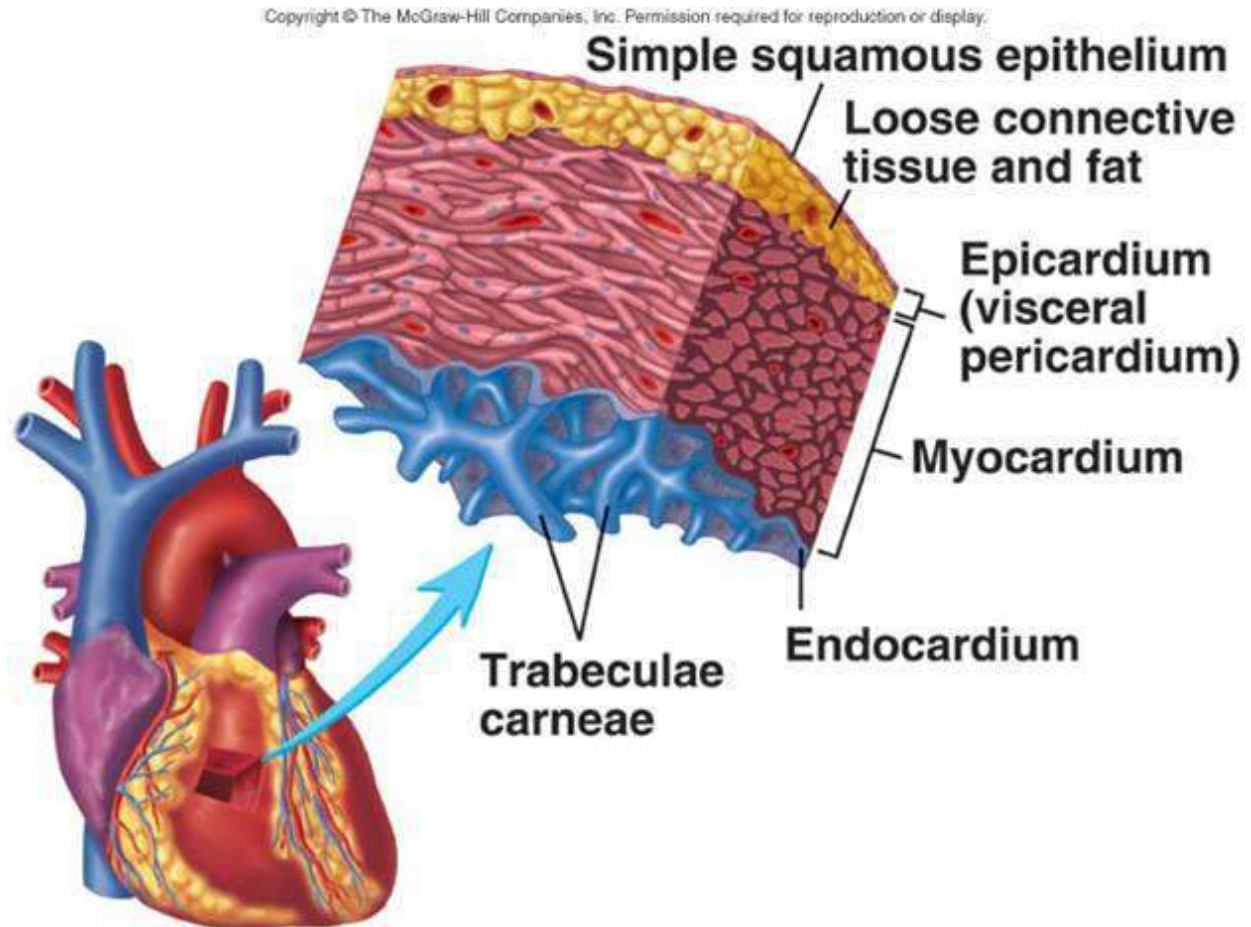


The Heart

- **The heart** is a muscular cone-shaped organ about the size of a closed fist^{قبضة اليد}; it is located in the center of the thorax between the lungs, slightly tilted to the left.

➤ The heart wall is composed of three layers of tissue:

1. The Epicardium
2. The Myocardium
3. The Endocardium.

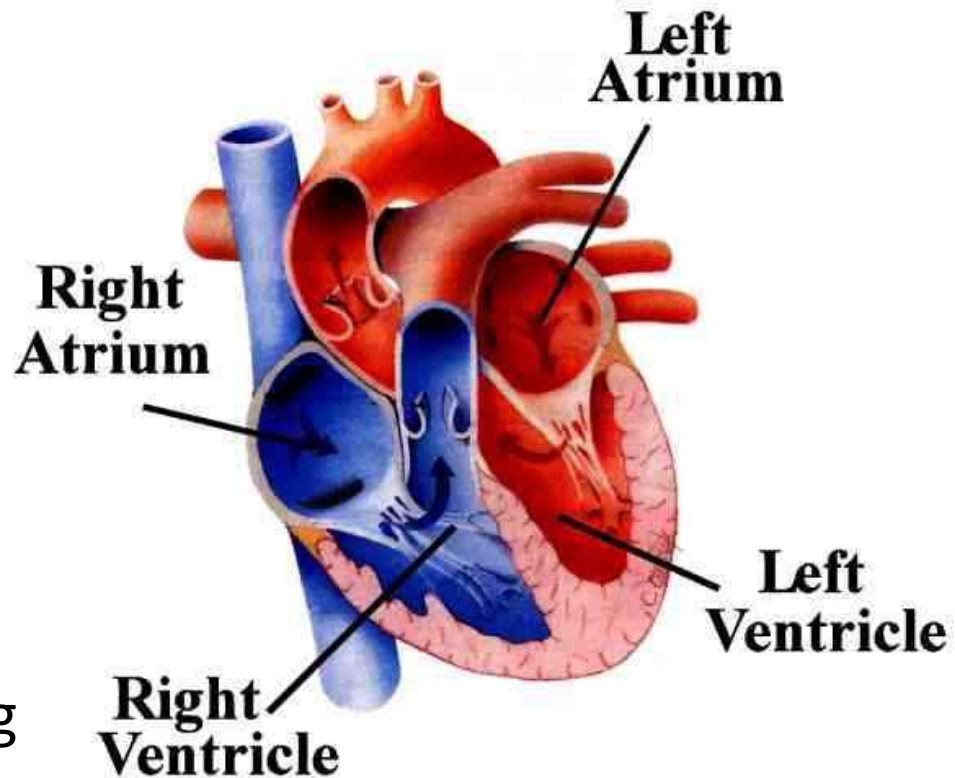


The heart has four chambers:

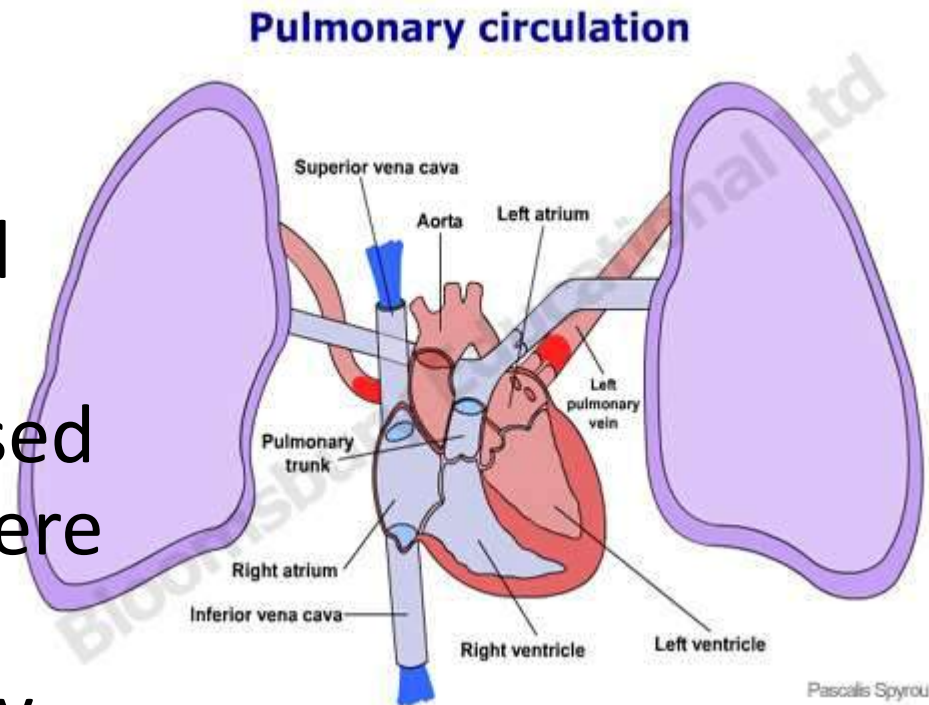
1. Two relatively small upper chambers called **atria**
2. Two larger lower chambers called **ventricles**.

من خلال مضخات

- The heart can be thought of as two pumps sitting side by side. Vertically dividing the two sides of the heart is a wall, known as the **septum**.
- The septum prevents the mixing of oxygenated (left side) and deoxygenated (right side) blood.



- The blood pumped by the right ventricle enters the pulmonary artery, whereas the left ventricle pumps blood into the aorta.
- The deoxygenated blood pumped into the pulmonary artery is passed on to the lungs from where the oxygenated blood is carried by the pulmonary veins into the left atrium. This pathway constitutes the **pulmonary circulation**.



- oxygenated blood entering the aorta is carried **by** a network of arteries, arterioles and capillaries to the tissues from where the deoxygenated blood is collected by a system of ^{الوريد الأجوف} venules, veins and vena cava and emptied into the right atrium. This is the **systemic circulation**.
- The heart itself is supplied by blood vessels that are in the heart muscle; the movement of blood through the heart tissues is called **cardiac circulation**.

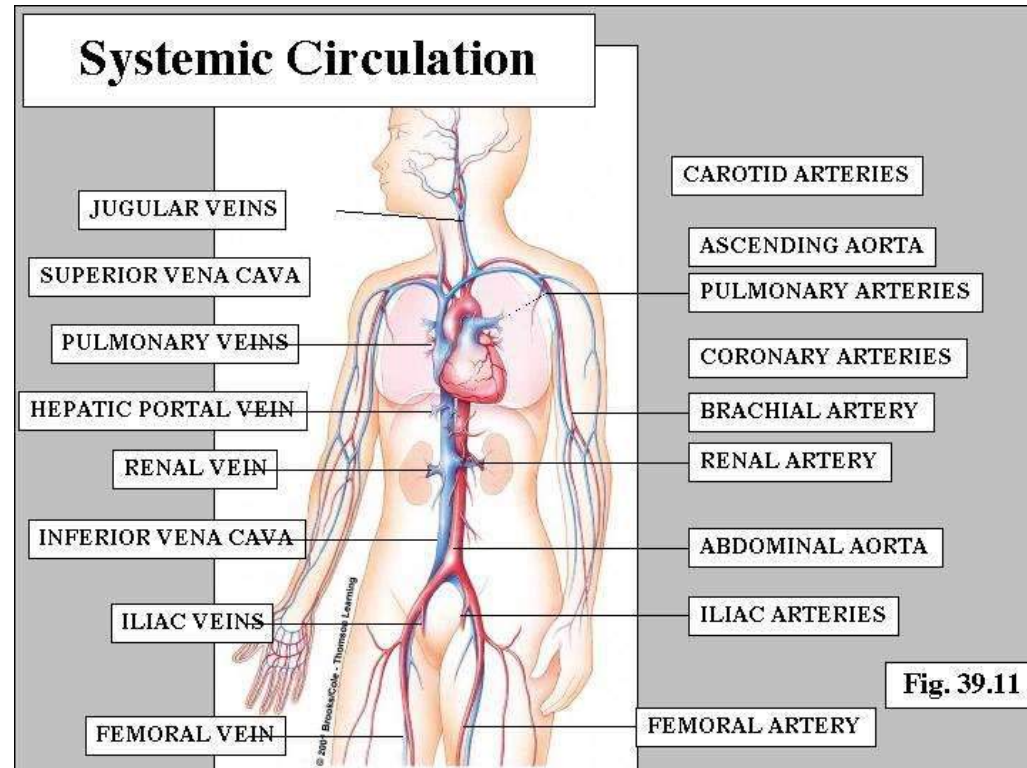
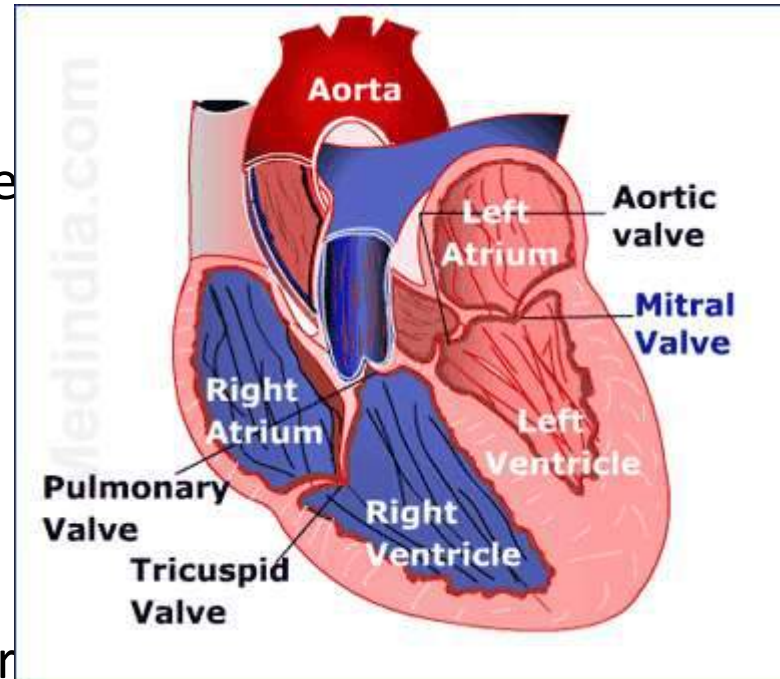


Fig. 39.11

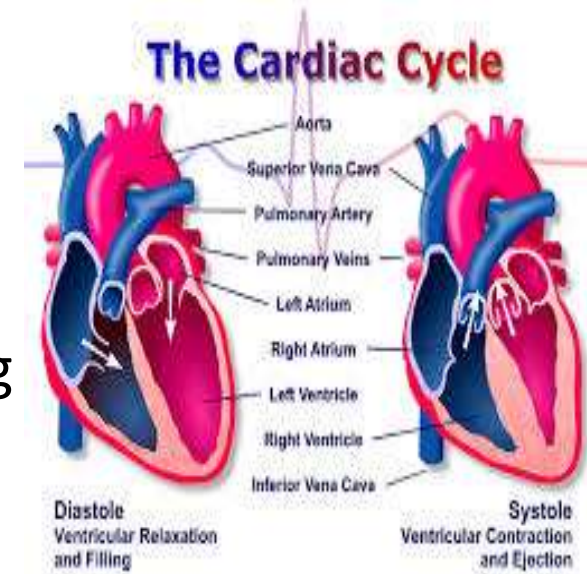
Heart-Valves

- The heart has four valves inside it. These valves ensure that blood flows in the correct direction.
- The atria and ventricles are separated from each other by two valves called **atrioventricular valves**.
 1. The atrioventricular valve on the right side is called the **tricuspid valve** because it is made up of three flaps.
 2. The atrioventricular valve on the left side is called the **bicuspid valve (or mitral valve)** because it has only two flaps.
- The aorta and pulmonary trunk possess **aortic** and **pulmonary semilunar valves**, respectively. They so called because of their half-moon shape. The valves in the heart allows the flow of blood only in one direction, i.e., from the atria to the ventricles and from the ventricles to the pulmonary artery or aorta. These valves prevent any backward flow.

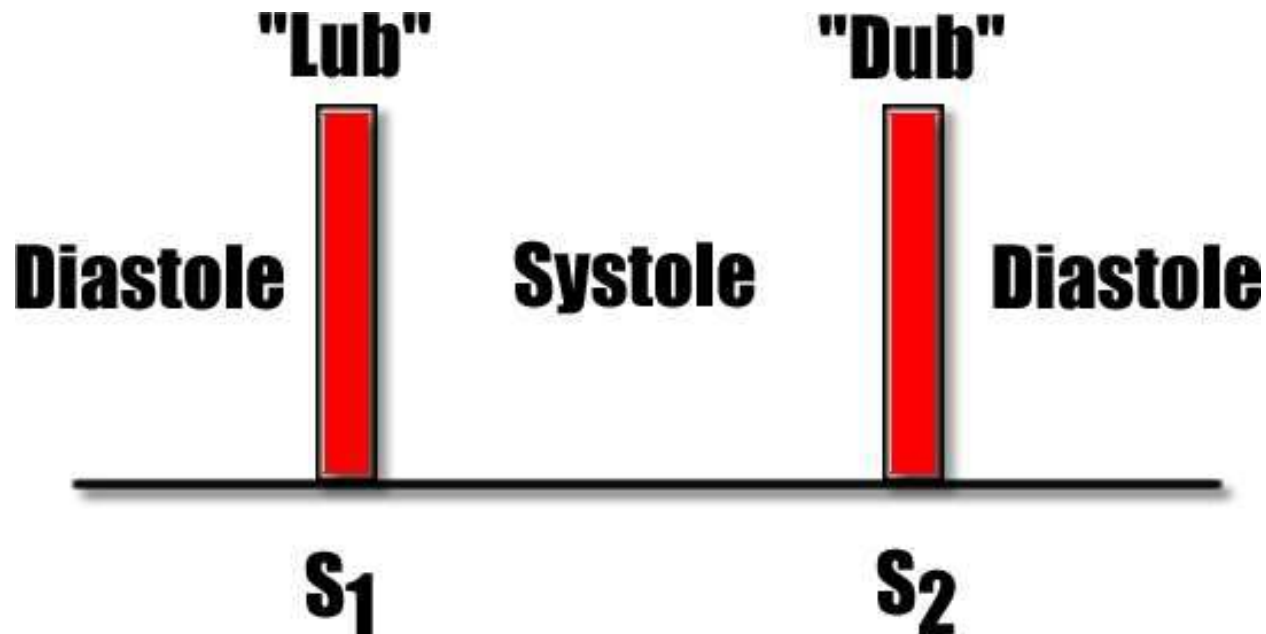


Cardiac Cycle

- **The cardiac cycle** is the sequence of events in one heartbeat. In its simplest form, the cardiac cycle is the simultaneous contraction of both atria, followed a fraction of a second later by the simultaneous contraction of both ventricles.
- **A heartbeat has two phases:**
- **Phase 1: Systole** is the term for contraction. This occurs when the ventricles contract, closing the atrioventricular valves and opening the semilunar valves to pump blood into the two major vessels leaving the heart.
- **Phase 2: Diastole** is the term for relaxation. This occurs when the ventricles relax, allowing the back pressure of the blood to close the semilunar valves and opening the atrioventricular valves.

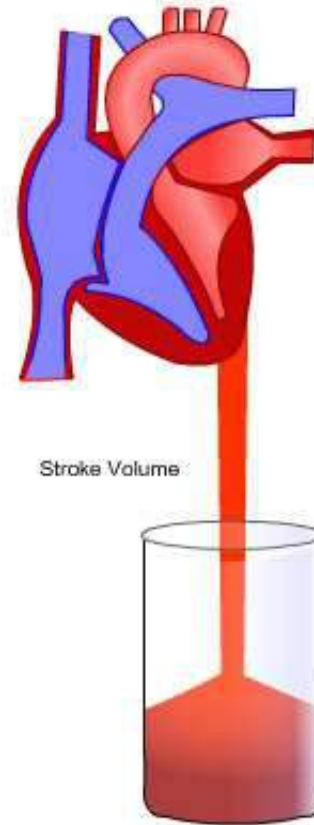


- During each cardiac cycle two prominent sounds are produced which can be easily heard through a stethoscope.
- **The first heart sound (lub)** is associated with the closure of the tricuspid and bicuspid valves
- **the second heart sound (dub)** is associated with the closure of the semilunar valves.
- These sounds are of clinical diagnostic significance. If any of the valves do not close properly, an extra sound called **heart murmur** may be heard.



Cardiac Output and Stroke Volume

- **cardiac output:** The amount of blood pumped by the heart is often and is measured in ml/min. Cardiac output is an indicator of the level of oxygen delivered to the body.
- **Two factors contribute to cardiac output:**
- **heart rate** is the number of heart beats per minute
- **stroke volume**. حدة الصوت is the amount of blood forced out of the heart with each heartbeat.



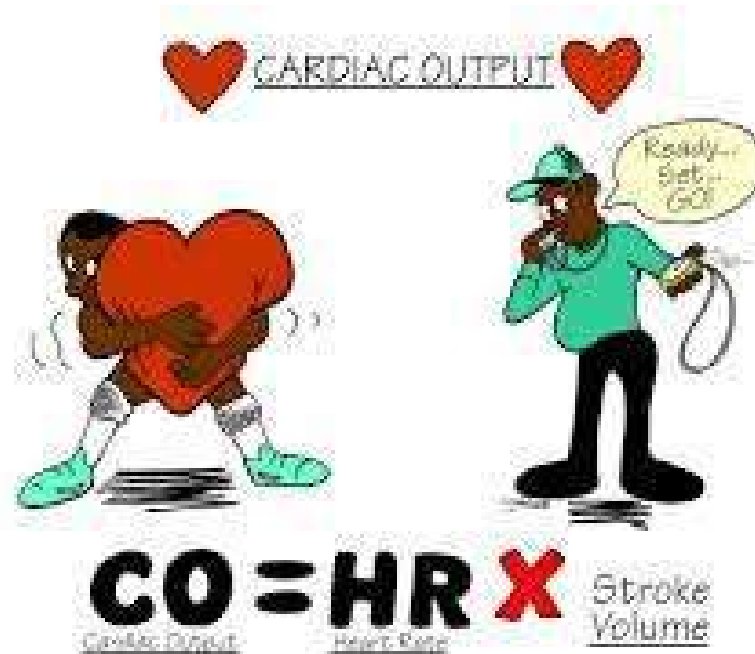
To increase cardiac output

Increase stroke volume
or

Increase heart rate
or

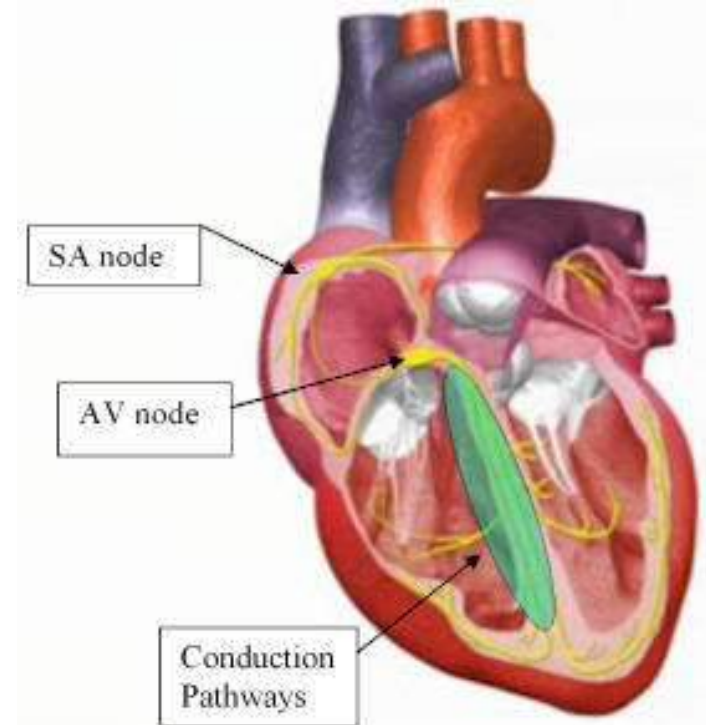
increase both

- ***Cardiac output = heart rate * stroke volume.***
- The average person has a **stroke volume** of about 70 ml and a **resting heart rate** of about 70 **beats per minute**.
- This means that the cardiac output for a typical adult at rest is **70 * 70**, or **4900 ml/minute**.
- Recall that the average adult human has about 5 L of blood in their circulatory system.



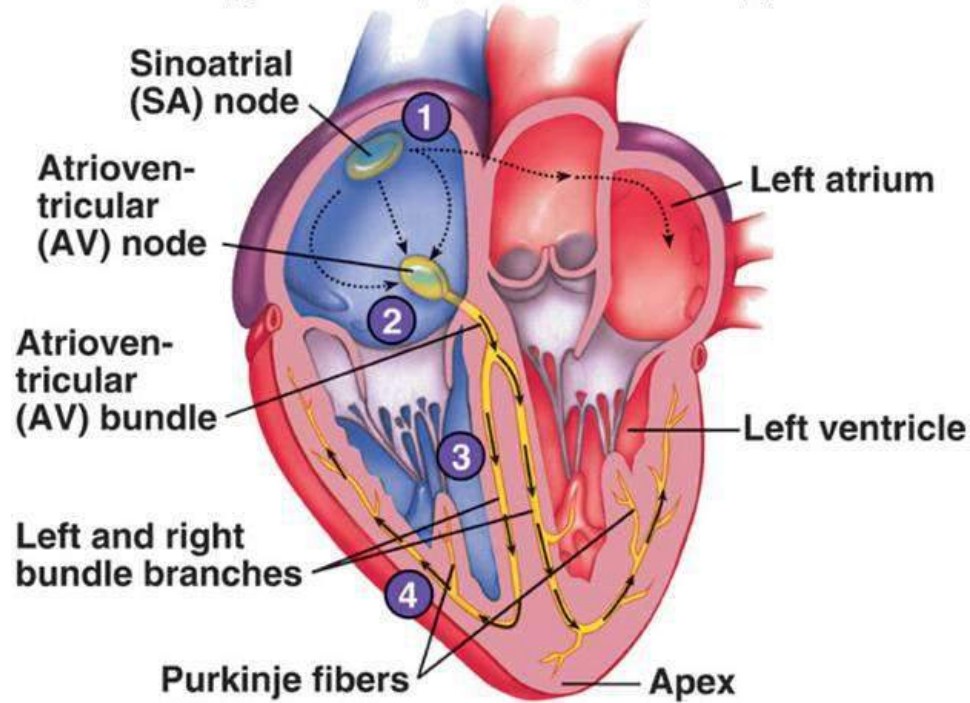
Contraction of the Heart

- Within the heart, a bundle of specialized muscle tissue, called the **sinoatrial (SA) node**, stimulates the muscle cells to contract and relax rhythmically.
- The SA node is also referred to as the **pacemaker**, because it sets the pace for cardiac activity.
- The SA node is in the wall of the right atrium, it generates an electrical signal that spreads over the two atria and makes them contract simultaneously.

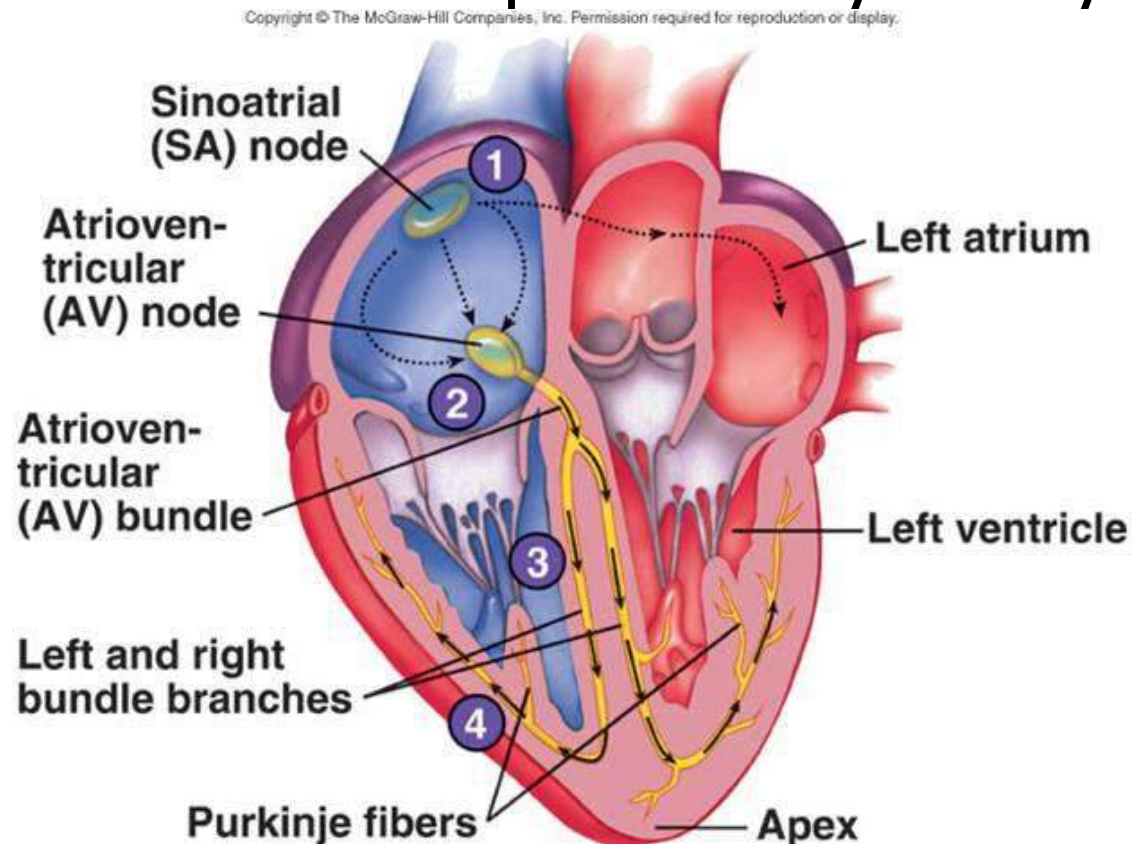


- As the atria contract, the signal reaches another node, called the **atrioventricular (AV) node**,
- The AV node transmits the electrical signal through a bundle of specialized fibers called the **bundle of His**.
- These fibers relay the signal through two branches of bundles that divide into fast conducting **Purkinje fibers**.
- The Purkinje fibers initiate the almost simultaneous contraction of all cells of the right and left ventricles.

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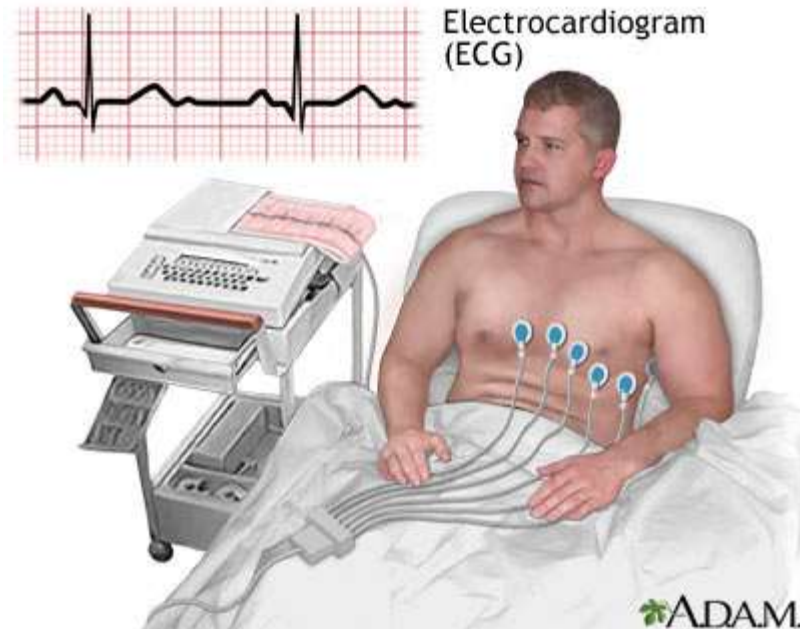


- A wave of contraction is initiated by the SA node, which forces blood from the atria into the ventricles.
- A subsequent wave of contraction begins at the apex of the heart causing the ventricles to forcibly expel blood into the pulmonary artery and the aorta.

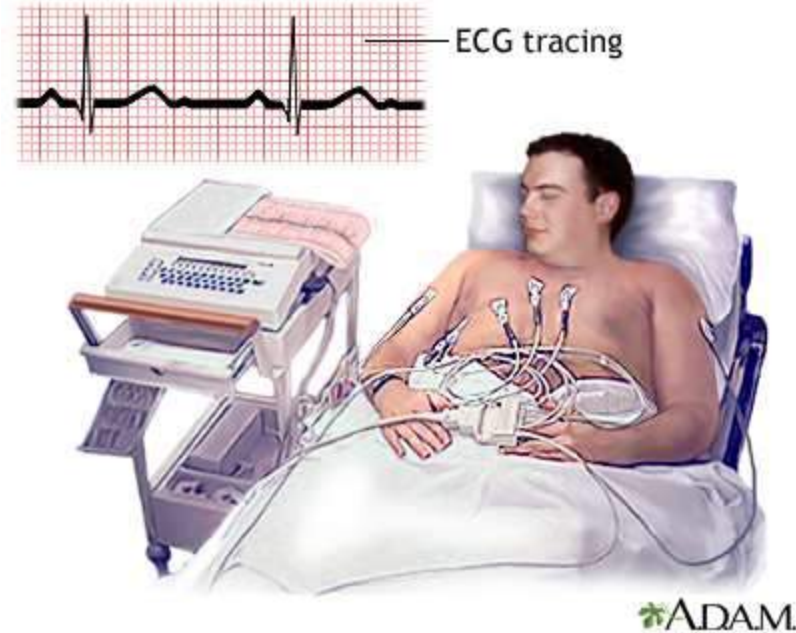


The Electrocardiogram (ECG)

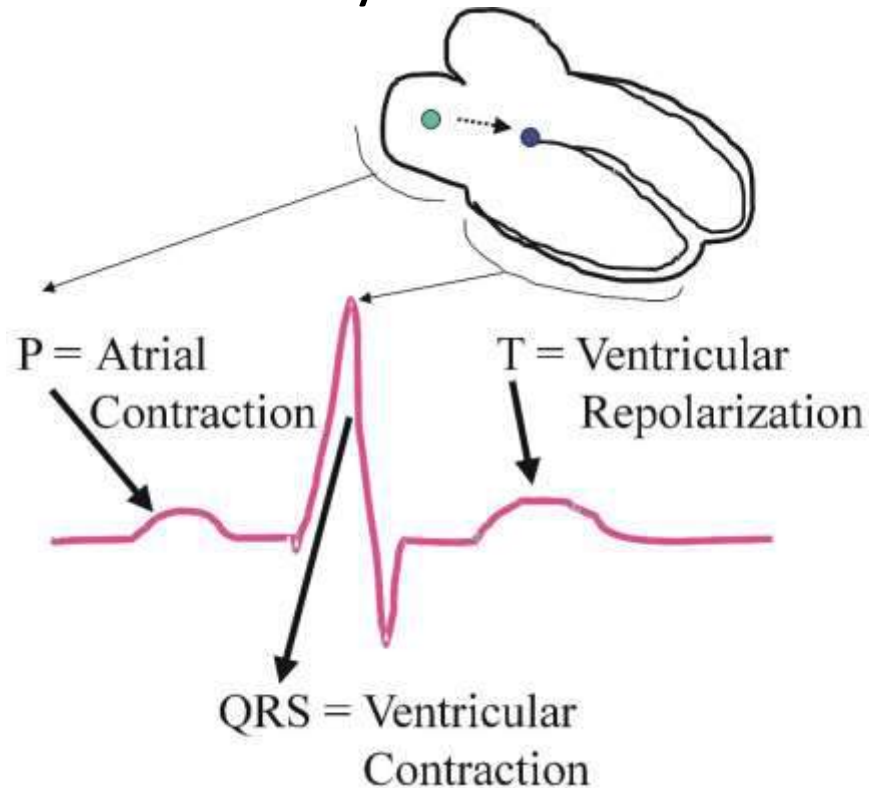
- The electrical pulses that cause the heart to beat create small voltage changes that can be measured by electrodes placed on the skin of the chest.
- These voltage measurements produce an **electrocardiogram (ECG)** that physicians use to diagnose the health of the heart.
- This type of machine (**electrocardiograph**) is used to obtain an electrocardiogram (ECG).
- ECG is a graphical representation of the electrical activity of the heart during a cardiac cycle.



- To obtain a standard ECG, a patient is connected to the machine fifth three electrical leads (one to each wrist and to the left ankle) that continuously monitor the heart activity.
- Each peak in the ECG is identified with a letter from P to T that corresponds to a specific electrical activity of the heart.

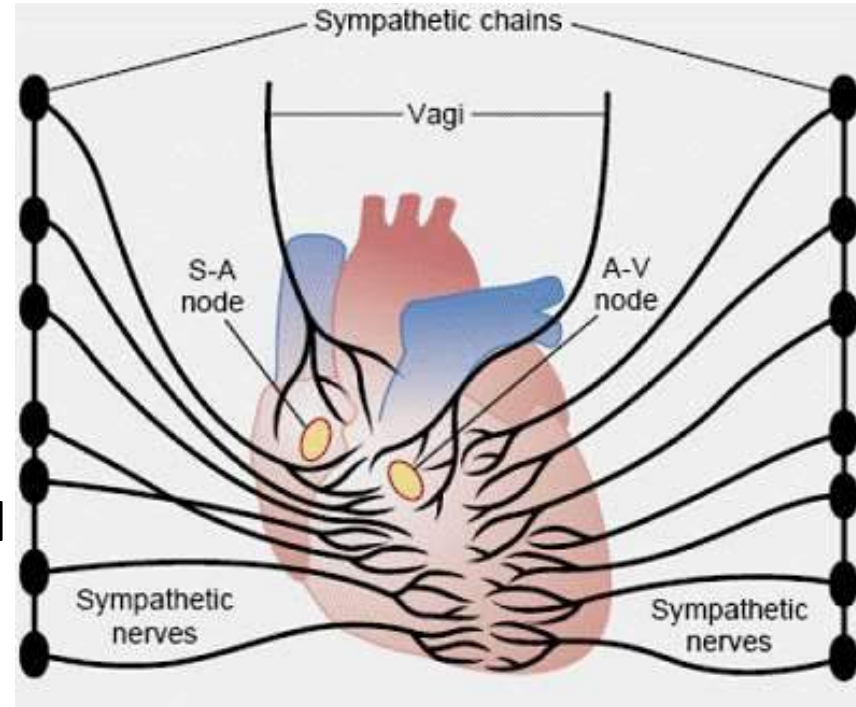


- **The P-wave:** represents the **depolarization of the atria**, which leads to the contraction of both the atria.
- **The QRS complex:** represents the **depolarization of the ventricles**, which initiates the ventricular contraction. The contraction starts shortly after Q and marks the beginning of the systole.
- **The T-wave:** represents the return of the ventricles from excited to normal state (**repolarization**). The end of the T-wave marks the end of systole.



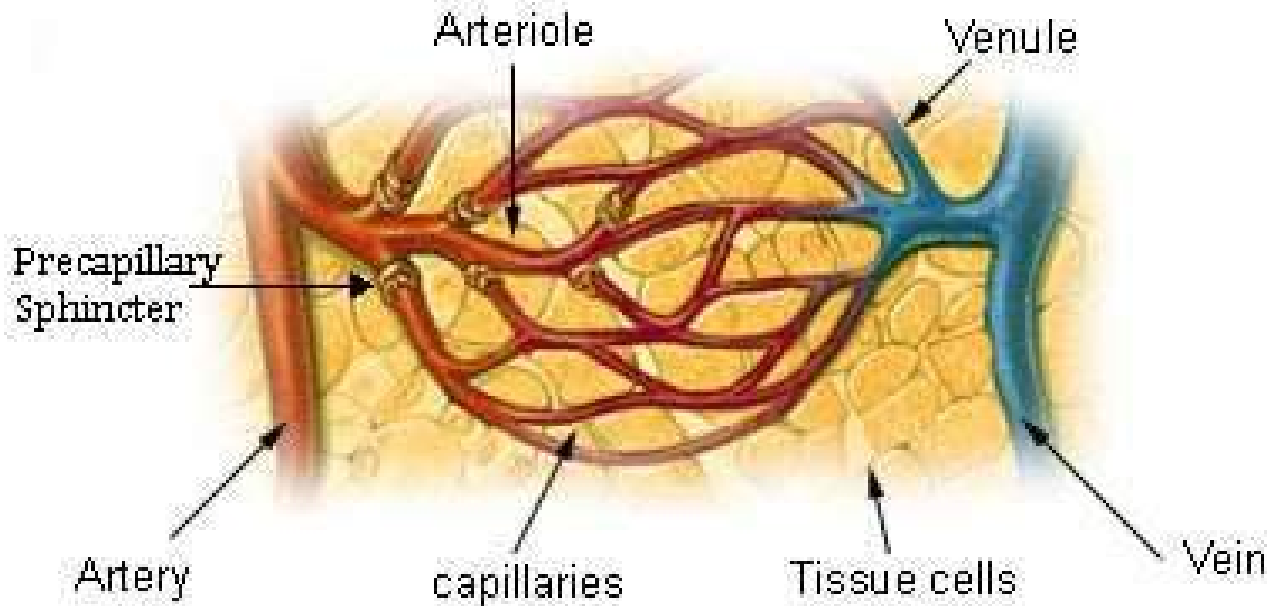
Regulation of Cardiac Activity

- Normal activities of the heart are regulated intrinsically, ie., auto regulated by specialized muscles (nodal tissue), hence the heart is called **myogenic**.
النخاع المستطيل
- A special neural center in the medulla oblongata can moderate the cardiac function through autonomic nervous system (ANS).
- **Neural signals through the:**
 1. **Sympathetic nerves** (part of ANS) can increase the rate of heart beat, the strength of ventricular contraction and thereby the cardiac output.
 2. **Parasympathetic neural signals** (another component of ANS) decrease the rate of heart beat, speed of conduction of action potential and thereby the cardiac output. Adrenal medullary hormones can also increase the cardiac output..



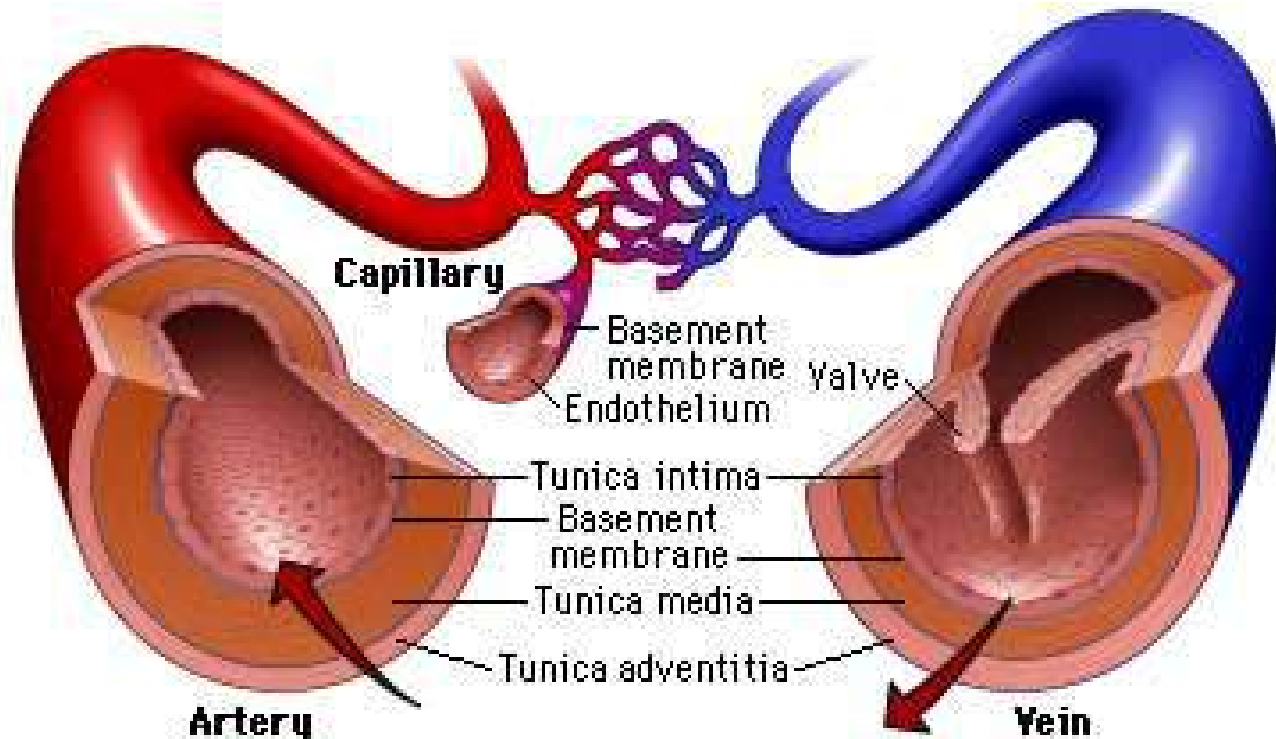
Blood vessels

- There are three main types of blood vessels in the human body.
 1. **Arteries** carry blood away from the heart
 2. **veins** carry blood toward the heart.
- Smaller-diameter arteries are called **arterioles**,
- smaller-diameter veins are called **venules**,
- 3. A network of **capillaries** joins the arteries and arterioles with venules and veins.
- The one-cell-thick capillaries are the sites where gases, nutrients, and other materials are transferred from blood to tissue cells and from tissue cells to blood



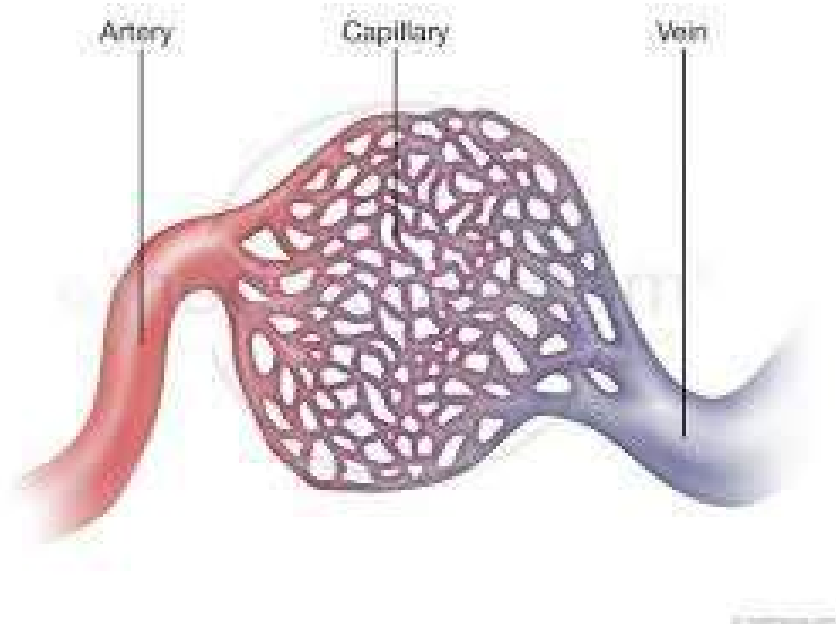
Artery versus Vein

- The wall of the artery is thicker.
- The lumen of the artery is much narrower.
- Arteries do not have valves along their length, veins do.
- Blood flows away from the heart in arteries; blood flows towards the heart in veins.
- Blood pressure in arteries is higher and so also the speed of blood flow.
- Pulsed flow in an artery, steady flow in a vein.



Capillaries

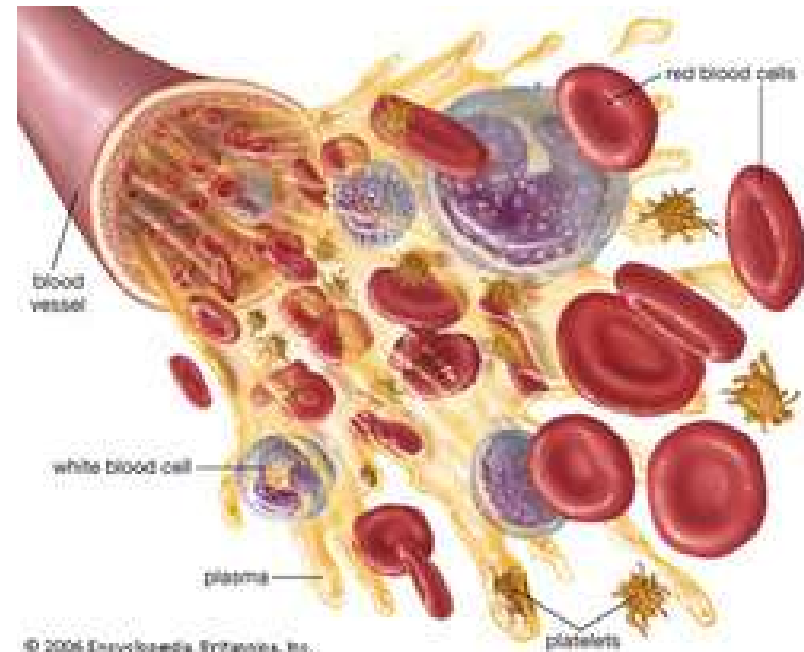
- **Capillaries** are the link between arteries and veins - where exchange with tissues occurs, the capillary wall is one cell thick and somewhat porous — ideal to allow materials to pass in and out.
- All tissue cells very close to capillary so exchange is very efficient.
- Exchange at the capillaries is by diffusion, mass flow and active transport.
- Blood flow in capillaries is slow giving enough time for effective exchange.



Blood and Its Components

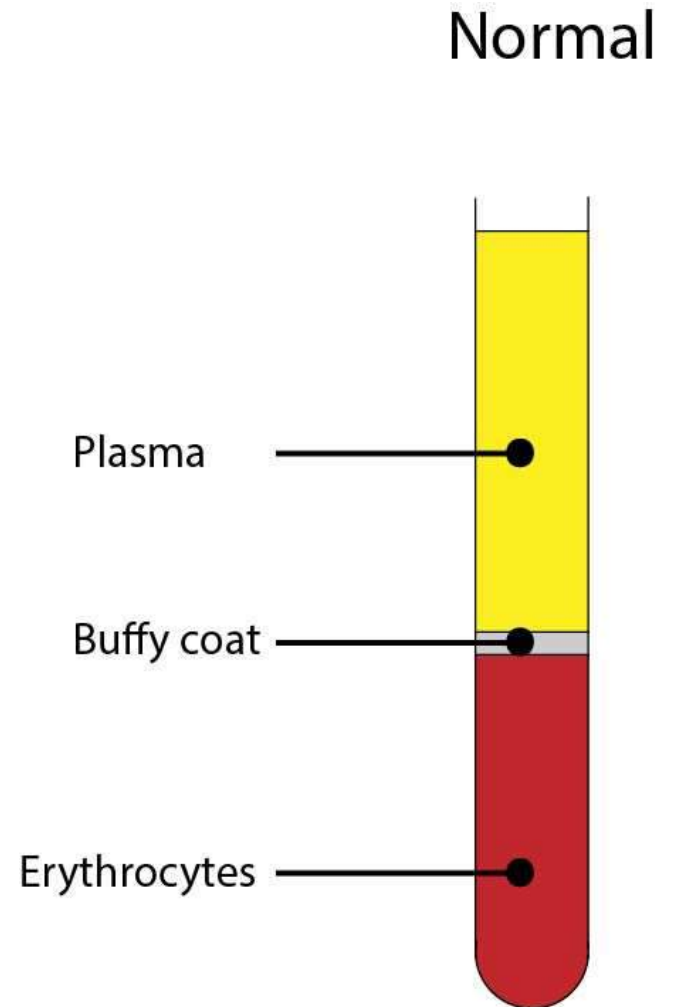
- An average adult human has about **5 liters** of blood moving continuously through the circulatory system. Blood consists of two distinct elements:

1. **The fluid portion**, called plasma, consists of water plus dissolved gases, proteins, sugars, vitamins, minerals, and waste products. Plasma makes up about 55% of the blood volume.
2. **The solid portion of the blood** consists of red blood cells, white blood cells, and platelets. These cells and platelets are produced in the bone marrow. The solid portion makes up the other 45% of the blood volume.



Plasma and Its Functions

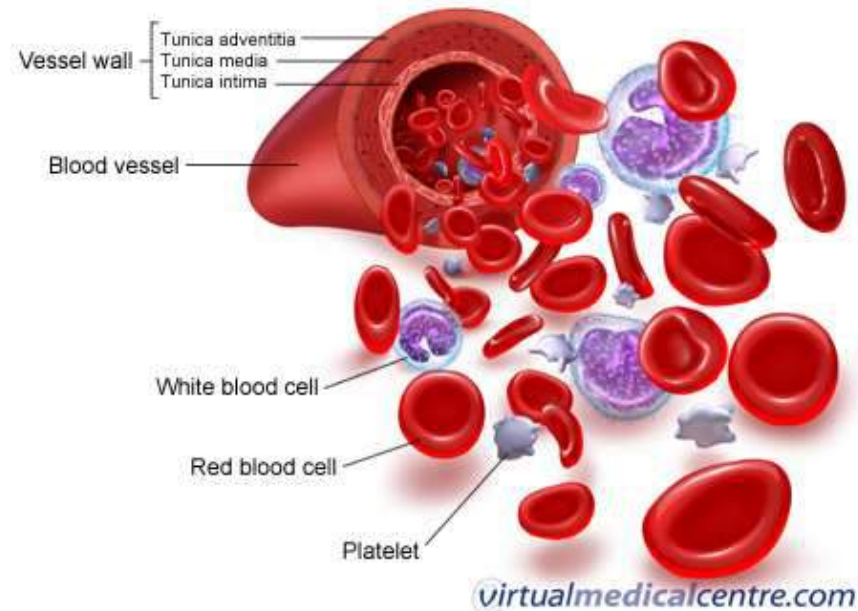
- Plasma is a clear, yellowish fluid composed of about 92% water and 7% dissolved blood proteins. The remaining 1% percent of plasma Consists of other organic substances and inorganic ions such as **sodium, potassium, chloride, and bicarbonate**.
- The main proteins in blood *are albumin, globulins, and fibrinogen*. Other substances transported by the blood include nutrients (**glucose, fatty acids, and vitamins**), respiratory gases (**O₂ and CO₂**), and the waste products of metabolism.



| | RBCs | WBCs |
|--------------------|--|--|
| Physical features | RBCs are bi-concave disc shaped, and have no nucleus. size is roughly approximately 6-8 μm | WBCs are irregular in shape, but have a nucleus and an outer buffer coat. |
| Life span | 120 days. | 4-30 days depending on body |
| Types | There is only one type of RBCs found in the blood. | There are various types of WBCs with distinct functions in the blood:neutrophils, T lymphocytes, B lymphocytes (plasma cell) monocytes (macrophage), eosinophils, basophils. |
| Circulatory system | Cardiovascular system | Cardiovascular and lymphatic systems. |
| Functions | Supplies oxygen to different parts of the body and carries carbon dioxide and other waste products. | Producing antibodies to develop immunity against infections. Some are phagocytic |
| Production | Produced in red bone marrow. | Produced in lymph nodes, spleen, etc. |
| Movement | they move in blood vessels eventually squeezing through capillaries giving O ₂ and nutrients to body cells. | they leave the blood vessels and move to the injury site. Capable of diapedesis-squeeze between cells of blood vessel walls to exit circulation. |
| Nuclei | RBC do not have nuclei in humans | WBC have nuclei in humans |

Platelets and Their Functions

- Platelets (also called **thrombocytes**) are the third major substance in the solid portion of the blood.
- Platelets are membrane-bound fragments of cells that form when larger cells in the bone marrow break apart.
- Platelets do not contain nuclei and they breakdown in the blood within **7 to 10 days** after they have formed.
- Platelets play a key role in clotting blood, which prevents excessive blood loss after an injury.



Blood Pressure

- As blood passes through the vessels in the body, it exerts pressure against the vessel walls. This, is called **blood pressure**.
- Changes in blood pressure correspond to the phases of the heartbeat. When the ventricles contract and force blood into the pulmonary arteries and the aorta, the pressure increases in these vessels.
- The maximum pressure during the Ventricular contraction is called **systolic pressure**. The phase during which this occurs is called ***systole***.
- The ventricles then relax and the pressure in the pulmonary arteries and the aorta drops.
- The lowest pressure before the ventricles contract is called the **diastolic pressure**. The phase during which this occurs is called ***diastole***.



- A blood pressure reading shows how much pressure the blood exerts against the vessel walls and indicates the condition of the heart and arteries.
- Blood pressure is usually measured at an artery in the arm, using a device called a **sphygmomanometer**.
- The systolic pressure is presented over the diastolic pressure in the form of a fraction. The blood pressure of an average healthy young person is below **120 mmHg over 80 mmHg**, or **120/80 (systolic/diastolic)**.



Blood pressure is affected by:

1. Genetics
2. Activity
3. Stress
4. Body temperature
5. Diet
6. Medications

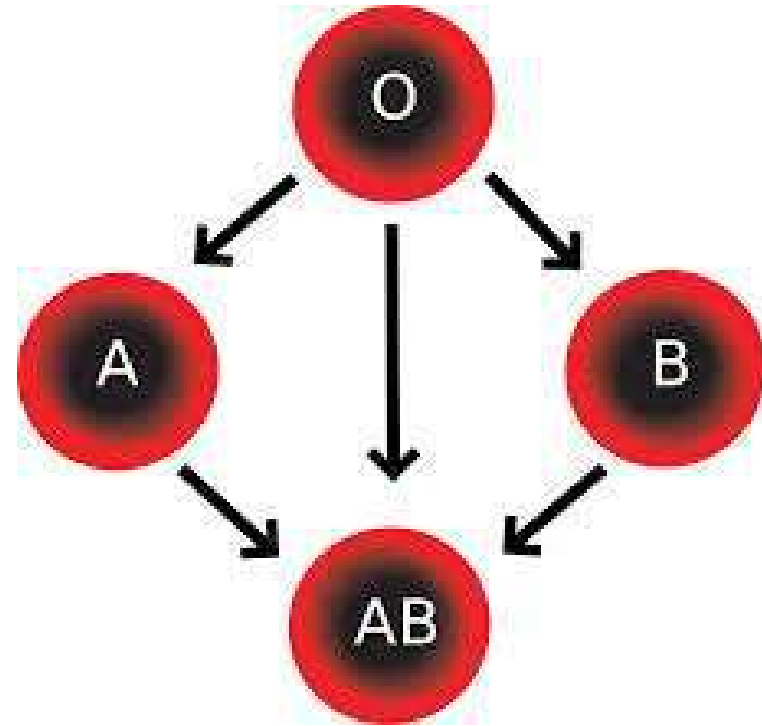


- However, continuous high blood pressure, also called ***hypertension***, causes the heart to work harder for extended periods of time. This can cause damage to arteries and increases the risk of **heart attack**, **stroke**, and **kidney failure**.

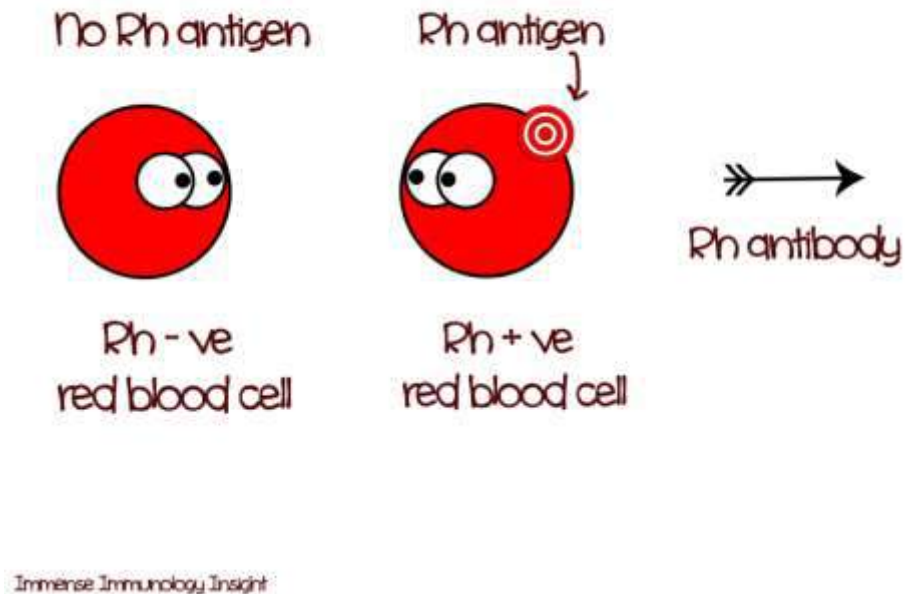
نوبة قلبية سكتة دماغية

Blood Group

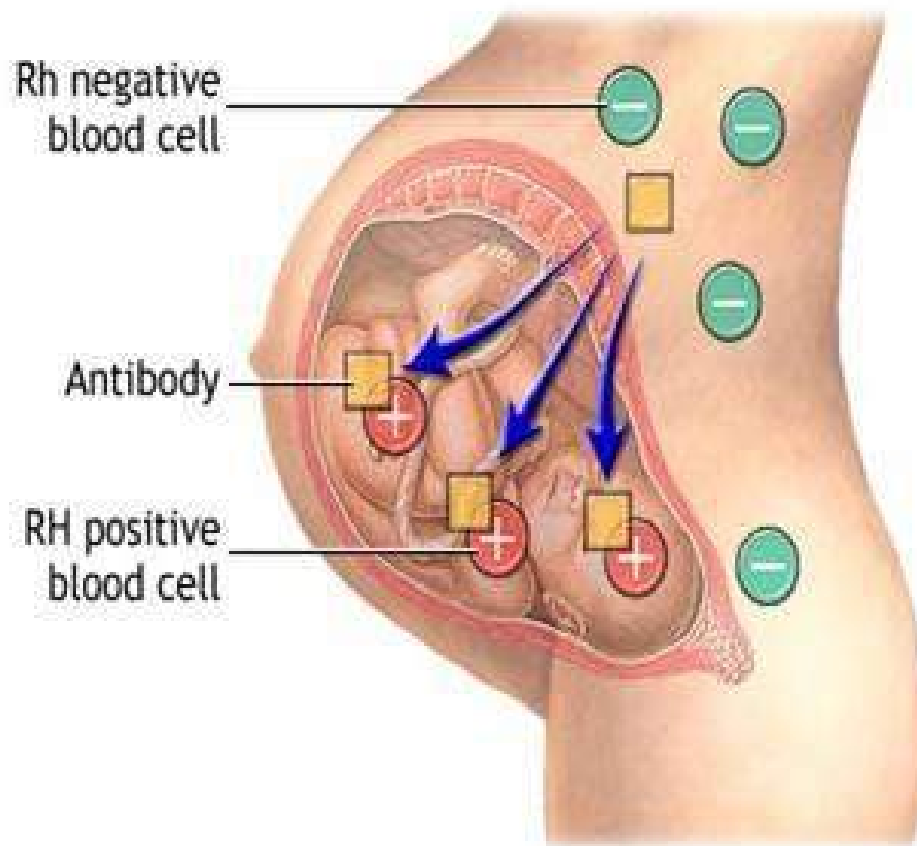
- Various types of grouping of blood have been done. Two such groupings, the **ABO** and **Rh**, are widely used all over the world.
- **ABO grouping** is based on the presence or absence of two surface antigens (chemicals that can induce immune response) on the RBCs namely A and B. Similarly, the plasma of different individuals contains two natural antibodies (proteins produced in response to antigens).
- During blood transfusion, any blood cannot be used; the blood of a donor has to be carefully matched with the blood of a recipient before any blood transfusion to **avoid severe problems of dumping (destruction of RBC)**.



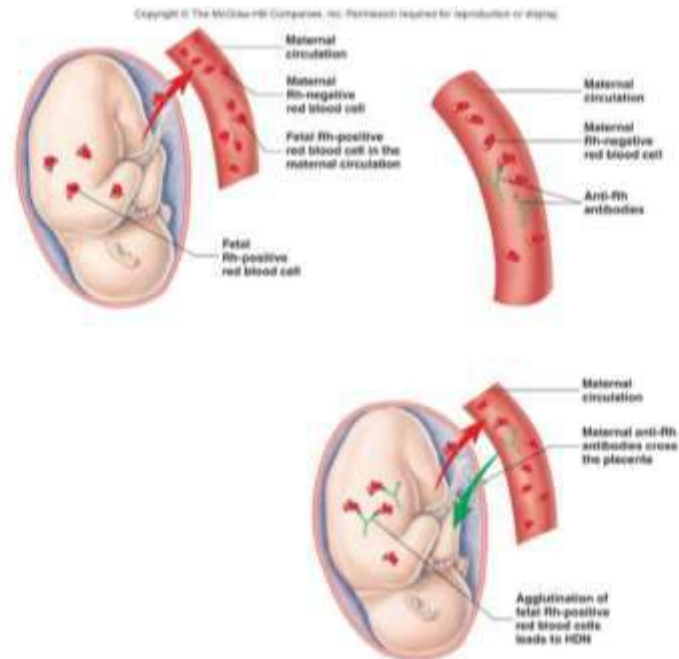
- **Rh grouping is based on the** another antigen, the Rh antigen similar to one present in Rhesus monkeys (hence Rh), is also observed on the surface of RBCs of majority (nearly 80 percent) of humans.
- Such individuals are called Rh positive (Rh+ve) and those in whom this antigen is absent are called Rh negative (Rh-ve).
- An Rh-ve person, if exposed to Rh+ve blood, will form specific antibodies against the Rh antigens. Therefore, Rh group should also be matched before transfusions.
- A special case of Rh incompatibility (**mismatching**) has been observed between the Rh-ve blood of a pregnant mother with Rh+ve blood of the fetus.



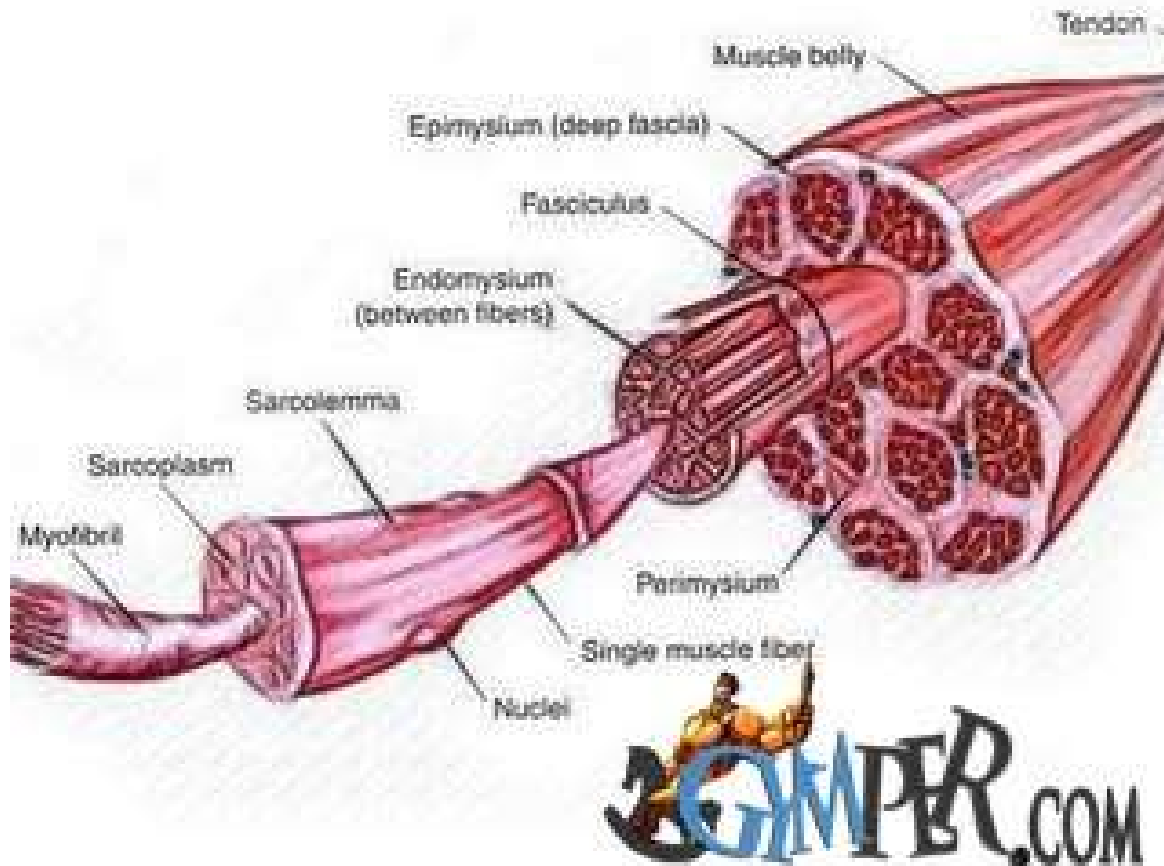
- Rh antigens of the fetus do not get exposed to the Rh-ve blood of the mother in the first pregnancy as the two bloods are well separated by the placenta. However, during the delivery of the first child, there is a possibility of exposure of the maternal blood to small amounts of the Rh+ve blood from the fetus, in such cases, the mother starts preparing antibodies against Rh antigen in her blood.



- In case of her subsequent pregnancies, the Rh antibodies from the mother (Rh-ve) can leak into the blood of the fetus (Rh+ve) and destroy the fetal RBCs. This could be fatal to the fetus or could cause severe anemia and jaundice to The baby. This condition is called **erythroblastosis fetalis**.
- This can be avoided by administering anti-Rh antibodies to the mother immediately after the delivery of the first child.



Muscle Physiology

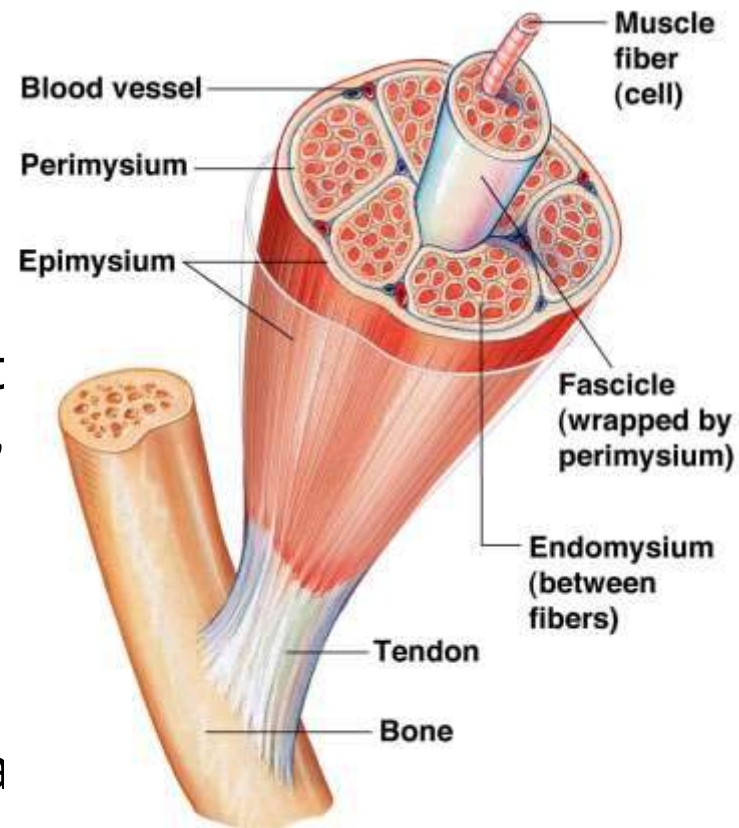


Lec.Dr.Ruwaidah F. Khaleel



Muscle tissue:

- Muscle tissue is composed of specialized cells (**fibers**) that respond to stimulation from the nervous system by undergoing internal changes that cause them to shorten.
- As muscle tissue shortens, it exerts physical forces on other tissues and organs to produce movement; these movements include **voluntary motion of body parts, blood circulation, respiratory activities, propulsion of materials along the digestive tract and waste elimination.**
- In muscle tissue, muscle cells or fibers usually are grouped into bundles, and have a rich network of blood capillaries to provide food and oxygen and to eliminate toxic waste products.



- The blood vessels are carried in fibroconnective tissue, which also serves to bind together the muscle fibers. The three histological types of muscle in the body are **skeletal** muscle, **cardiac** muscle, and **smooth** muscle.

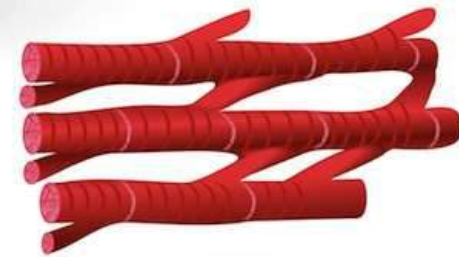
Skeletal muscle



Smooth muscle



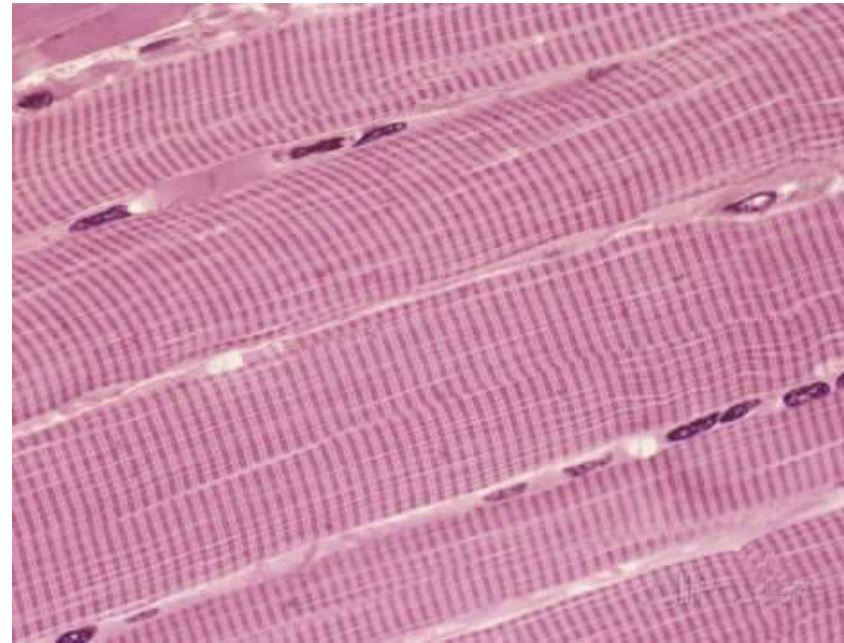
Cardiac muscle



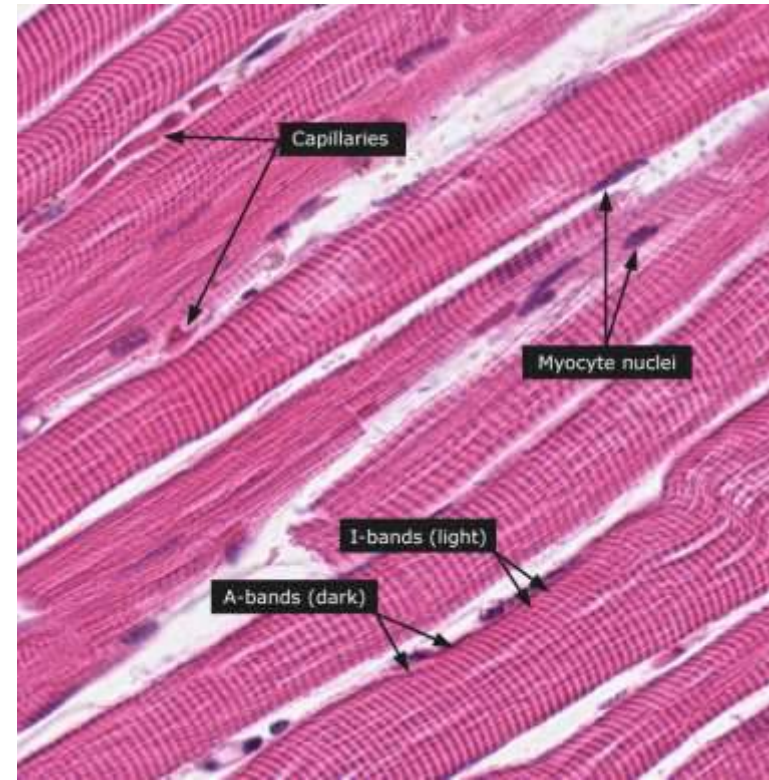
- **They vary in**
 - ❖ appearance.
 - ❖ Location.
 - ❖ Physiology.
 - ❖ Internal organization.
 - ❖ Means of control by the nervous system.
- Regular transverse bands along the length of the fibers are present in **striated** muscle and absent in **smooth** muscle. Functionally, muscle either is under the control of the will (**voluntary** muscle) or is not (**involuntary** muscle)

Skeletal muscle tissue:

- Is composed of long, cylindrical muscle cells, called muscle **fibers**,
- the individual skeletal muscle fibers or cells are striated in both longitudinal and transverse directions and vary from 1 to 40mm in length and 10 to 100 microns, in diameters,
- multinucleated; some contain hundreds of nuclei.
- The nuclei are ovoid, and located at the edge of the cell (called the periphery), adjacent to the sarcolemma.
- Skeletal muscle is described as striated and voluntary

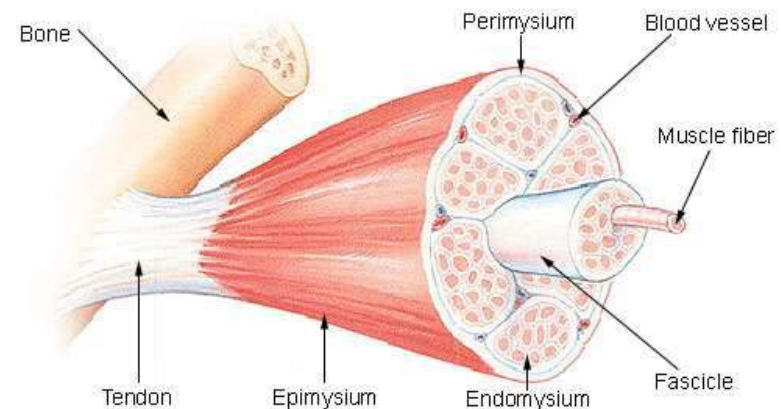


- Under the light microscope, the cells of skeletal muscle exhibit alternating light and dark bands, termed **striation**, that reflects the overlapping pattern of parallel thick and thin contractile protein filaments inside the cell.
- Additionally, skeletal muscle is considered **voluntary** because it usually does not contract unless stimulated by the somatic (voluntary) nervous system



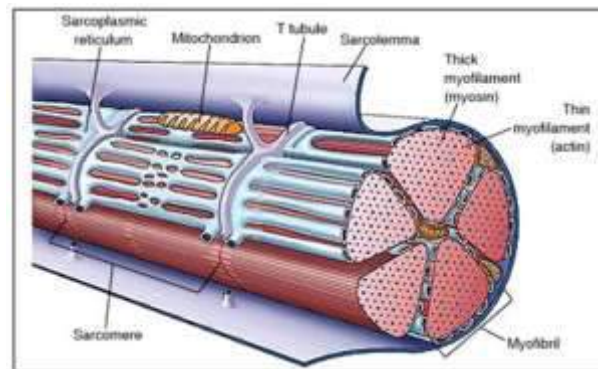
- The power of a muscle is dependent **not upon the length** of the component muscle fibers but **upon the total number of fibers** found present in the muscle.
- With exercise muscles increase in size is due to an increase in size of each individual fiber (**hypertrophy**) not to an increase in number of fibers (**hyperplasia**). Striated muscle contracts more rapidly than smooth

Structure of a Skeletal Muscle



Myofibrils and myofilaments

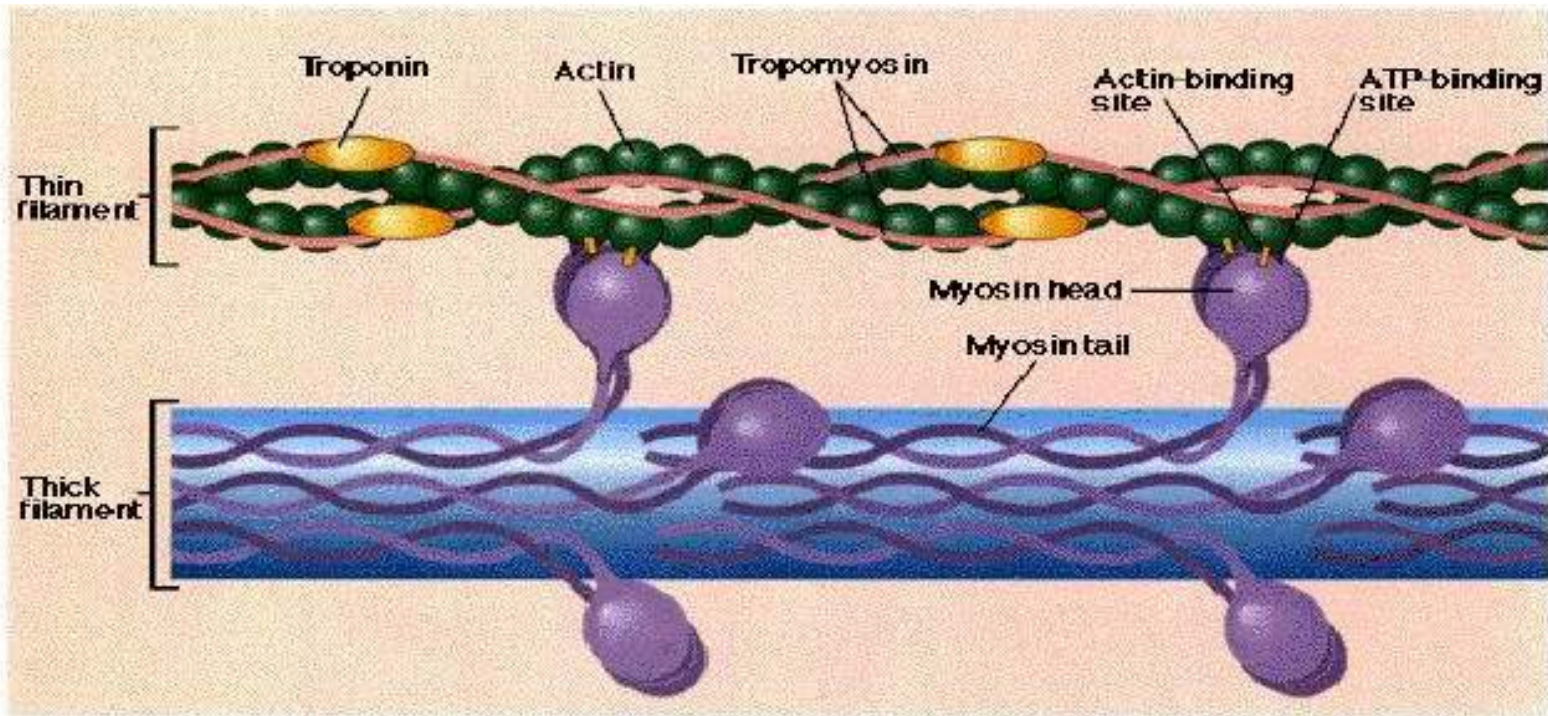
- The sarcoplasm of a skeletal fiber contains hundreds to thousands of long, cylindrical structures termed **myofibrils**. Each myofibril is about 1-2 micrometers in diameter and extends the length of the entire muscle fiber.
- During contraction, the myofibrils shorten as their component proteins change position. Because myofibrils are attached to the ends of the muscle fiber, the shortening of the myofibrils during a contraction causes the fiber to shorten.
- Myofibrils consist of bundles of short **myofilaments**.



Thin and thick filaments

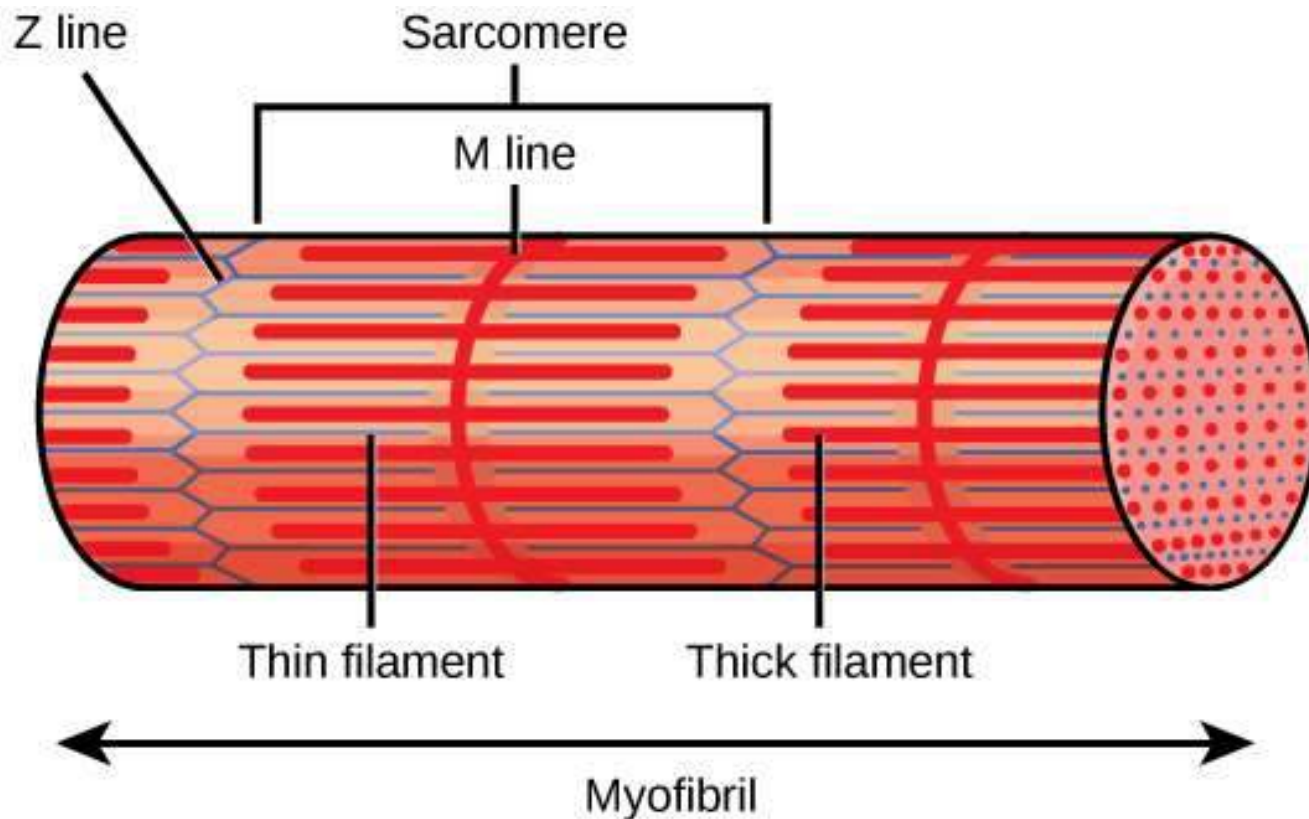
| Thin filament | Thick filament |
|--|--|
| About 5-6 nm | About 11 nm |
| Composed of 2 strand of protein actin twisted around each other form helical shape | Bundle of protein myocin consist of two strand : free globular head and attached elongated tail |
| In helical strand many small spherical molecules as long filament resembling string of beads | Myocin head are referred as crossbridges |
| Have tow regulatory protein tropomyosin resemble short thinner twisted filament cover small section of actin strand While troponin tow function, attaching actin to anchor the troponin in place and attach tropomyocin to hold it in place over the surface of the actin | Myocin head are referred to crossbridge because during contraction they bind thick filament to thin filament thus forming bridge between them |

- Myosin heads are also referred to as crossbridges because during a contraction they bind thick filaments to thin filaments, thus forming a "bridge" between them.

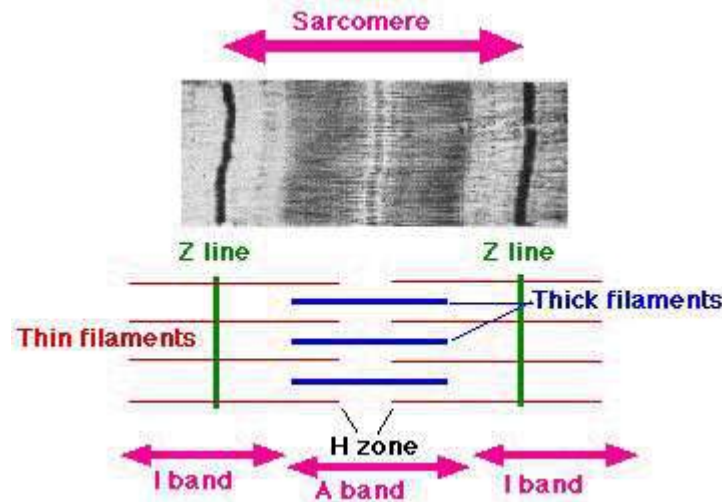


Myofibrils and striation:

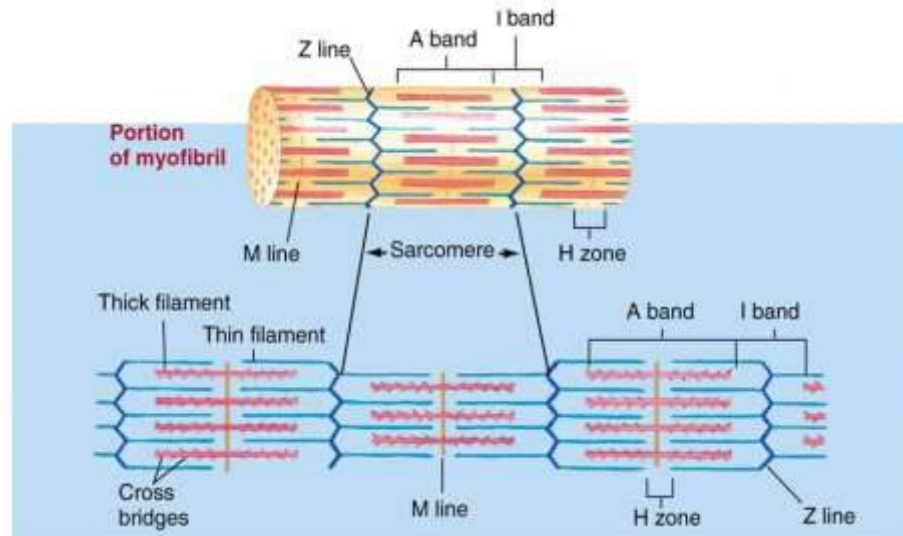
- As mentioned previously, skeletal muscle has striation. This striated appearance is due to size and density differences between thick and thin filaments. Under the light microscope, two differently shaded bands are observed.



- The dark bands, called **A bands**, and the light bands, called **I bands**, (the designation A band and I band are derived: from Anisotropic and Isotropic). **Anisotropic** means the area appears dark when viewed under polarized light, whereas **Isotropic** means the area appears light when viewed under polarized light.

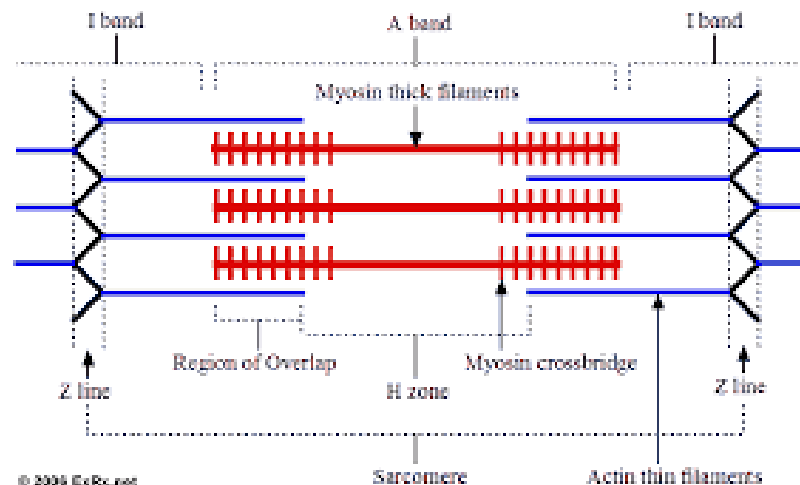


- The dark **A bands** contain the entire thick filament. At either end of a thick filament is a region where thin filaments extend into the **A band** between the stacked thick filaments. The light **I bands**, contain thin filaments only. An **I band** is lighter than an **A band** because only the thin filaments occupy this region.

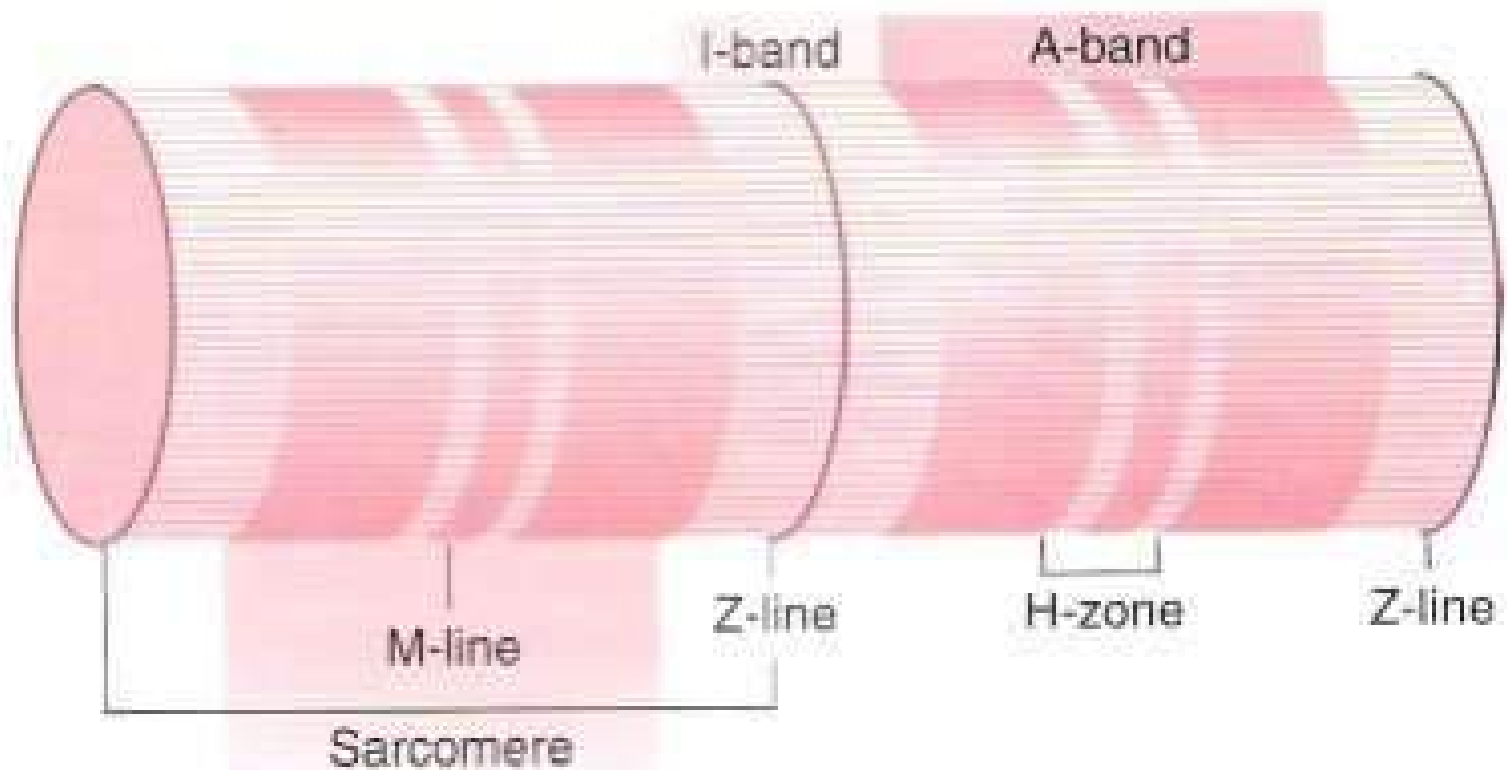


Within both the A bands and I bands, other important structures can be clearly observed using an electron microscope:

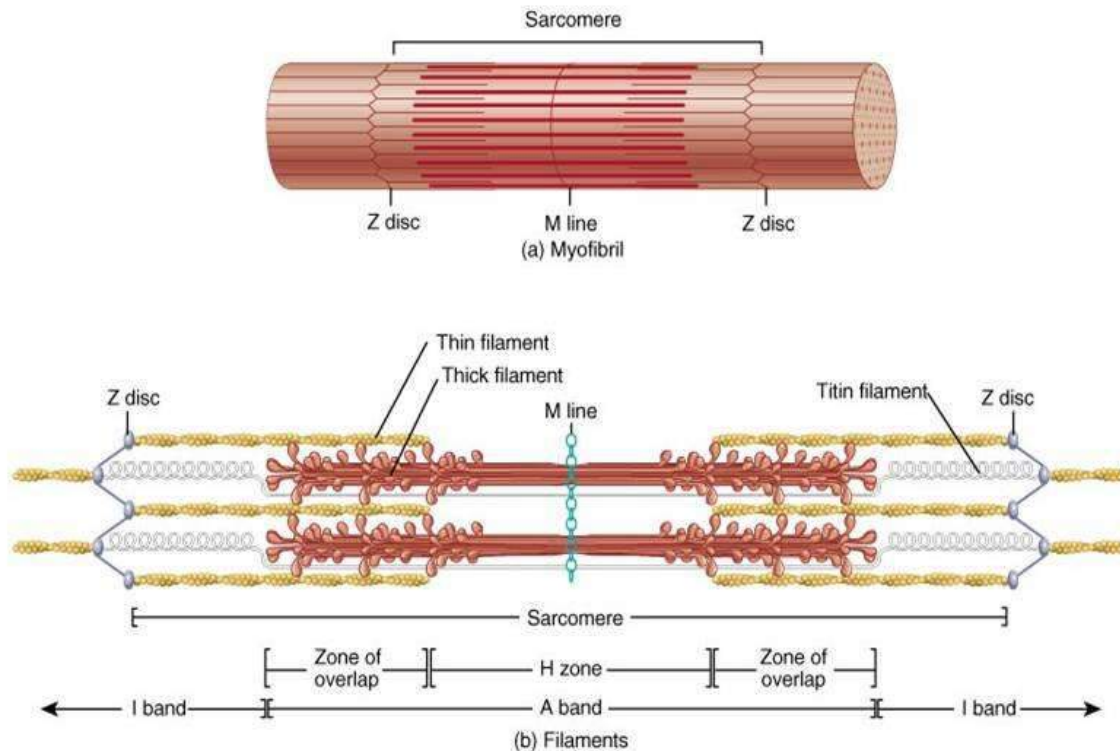
- The **H zone** is a light, central region in the **A band**. It is lighter shaded because only thick filaments are present; that is, there are no thin filaments in **H zone** in a relaxed muscle fiber. At maximal contraction, the thin filaments are pulled into this zone, and the **H Zone** disappears.



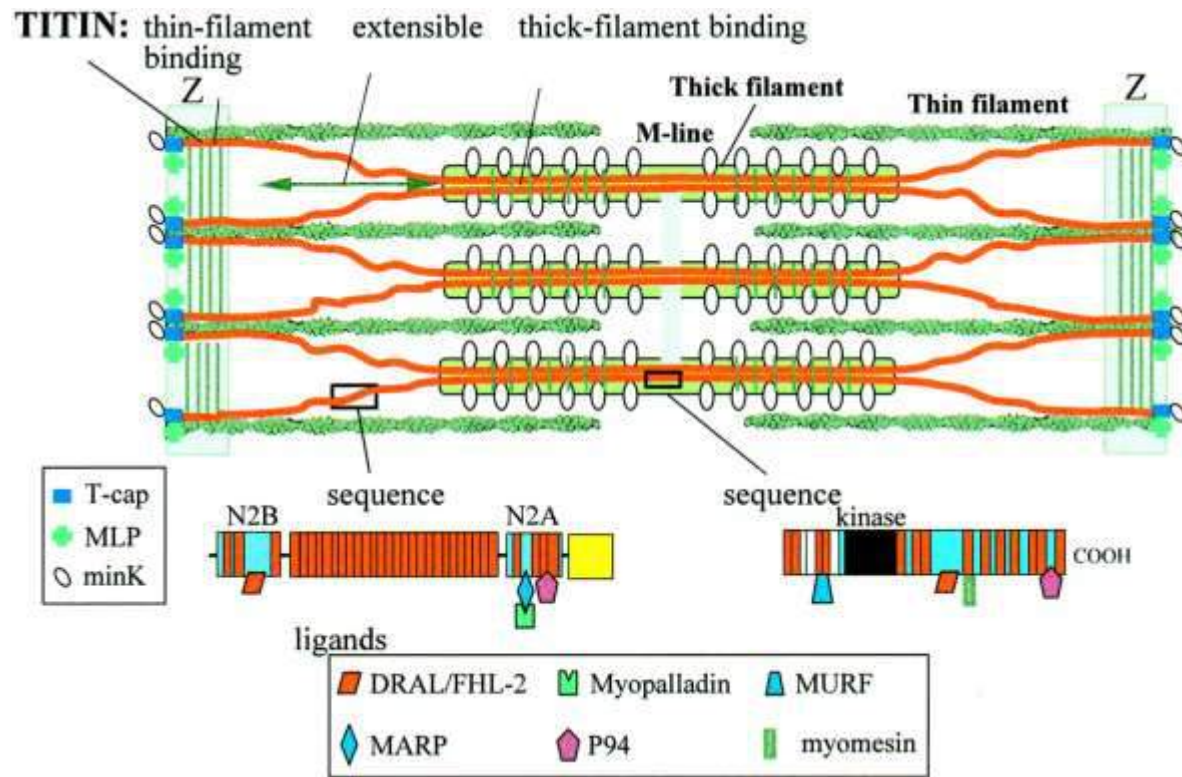
- **The M line** is a thin protein meshwork structure in the center of the H zone of a relaxed fiber. It serves as an attachment site for the thick filaments and keeps the thick filaments aligned during contraction and relaxation events.



- The **Z disc** (also called the **Z line**) is a thin protein structure in the center of **I band** that serves as an attachment site for thin filament ends. Although the **Z disc** is circular, when viewed "head-on", only the edge of the circle is visible, so it sometimes looks like a line.

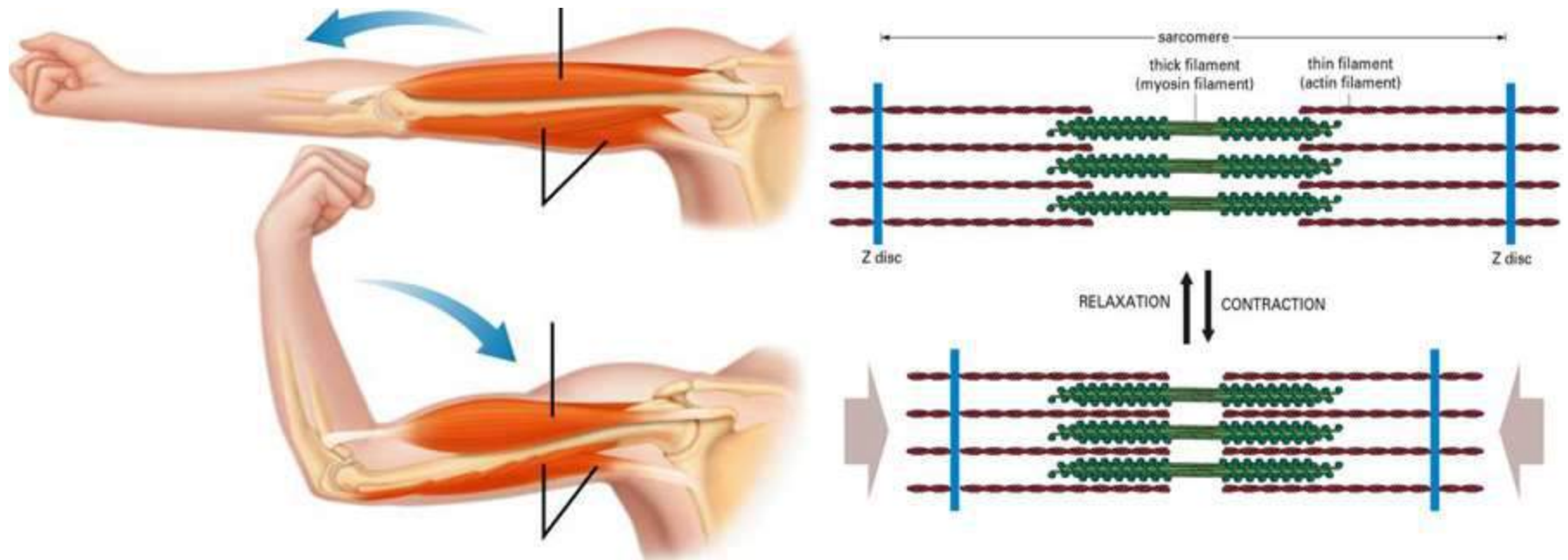


- **Connectins** are **Z disc** proteins that anchor and interconnect the thin filament ends at either end of a sarcomere. Additionally, elastic proteins called **titin** attach thin filaments, thick filaments, and **M line** proteins to the **Z disc** to maintain their organization and order.



Contraction of skeletal muscle fibers:

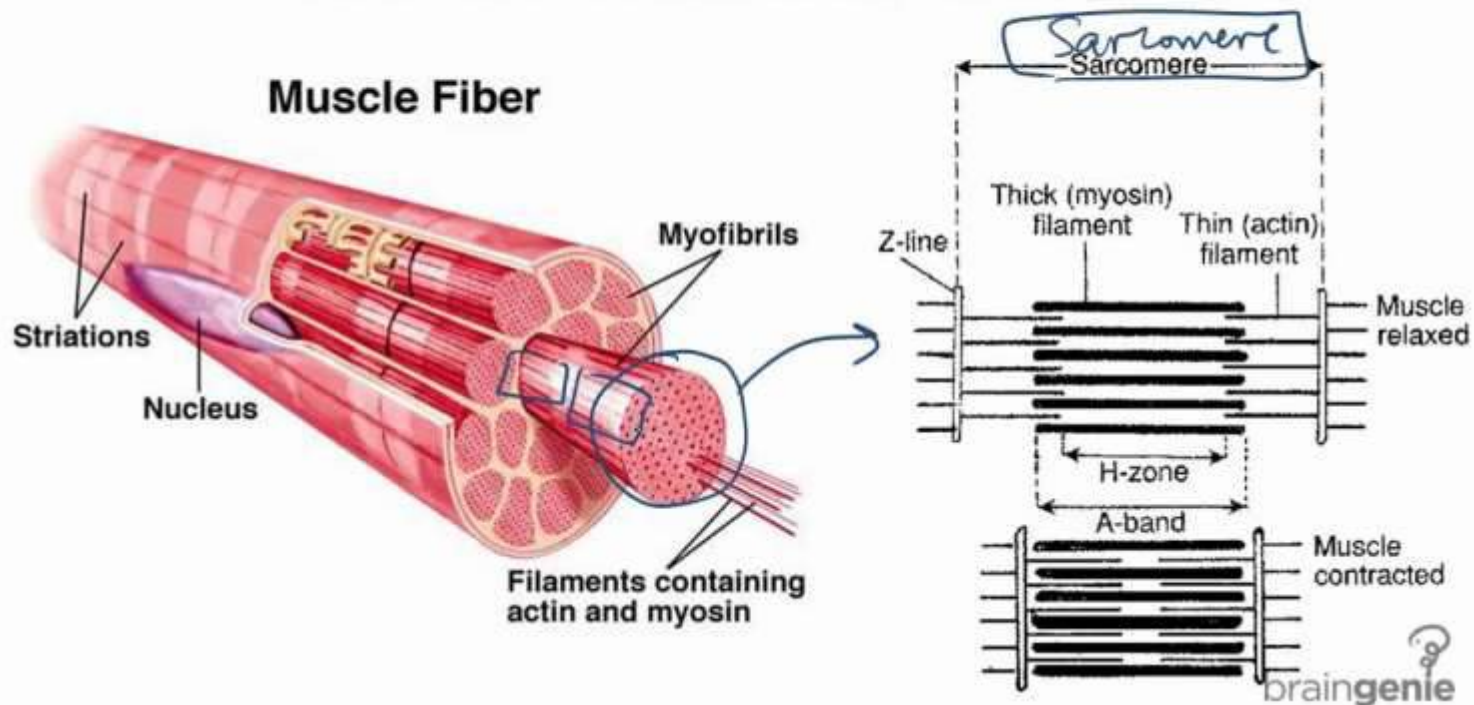
- A contracting muscle fiber typically shortens in length and exerts tension on the portion of the skeleton where it is attached. The thick and thin protein filaments in sarcomeres interact to cause muscle contraction. The mechanism for contraction is explained by the sliding filament theory.



The sliding filament theory:

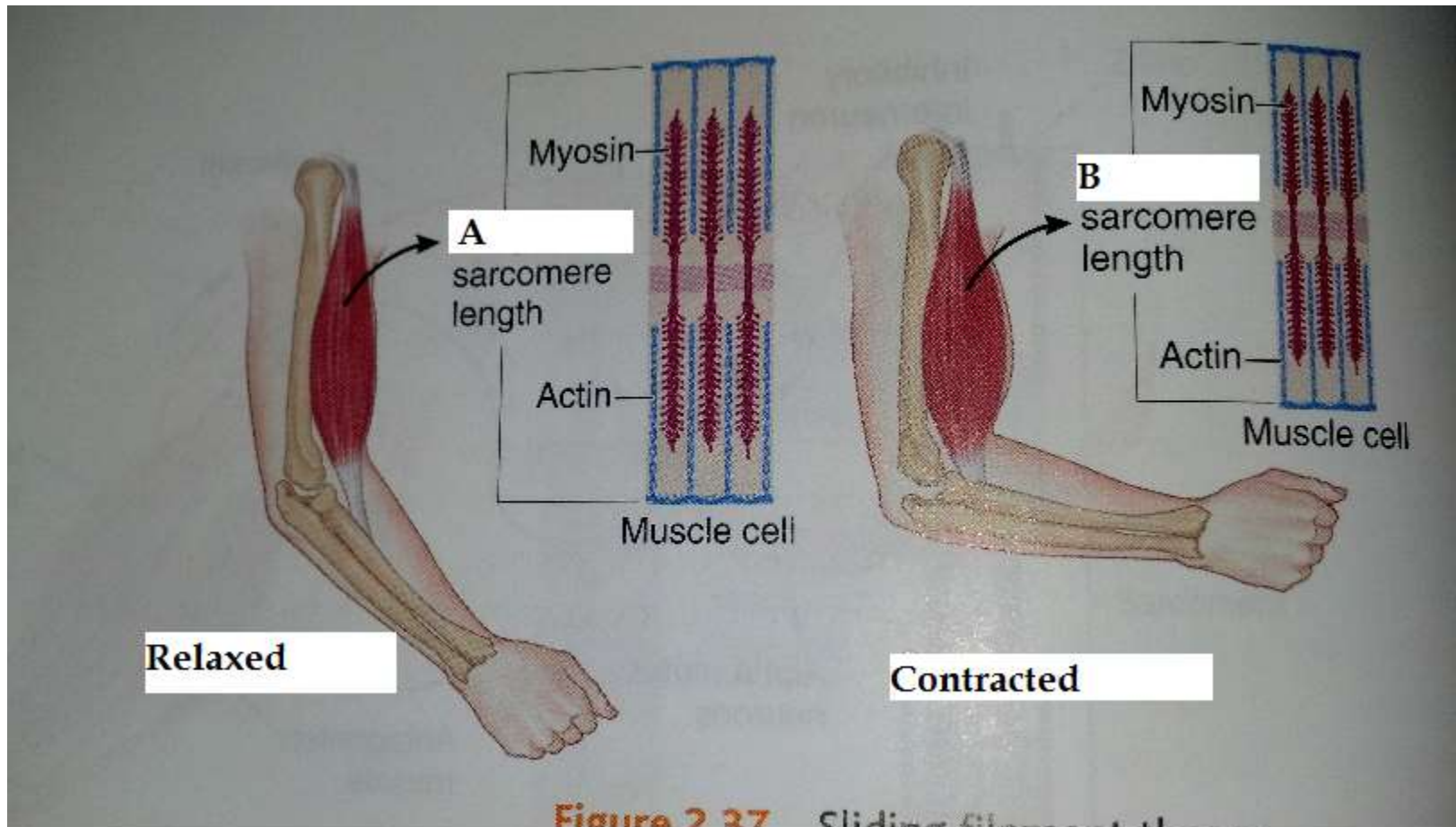
- According to the **sliding filament theory**, when a muscle contracts, thick and thin filaments slide past each other, and the sarcomere shortens

Sliding Filaments
How do muscles work?

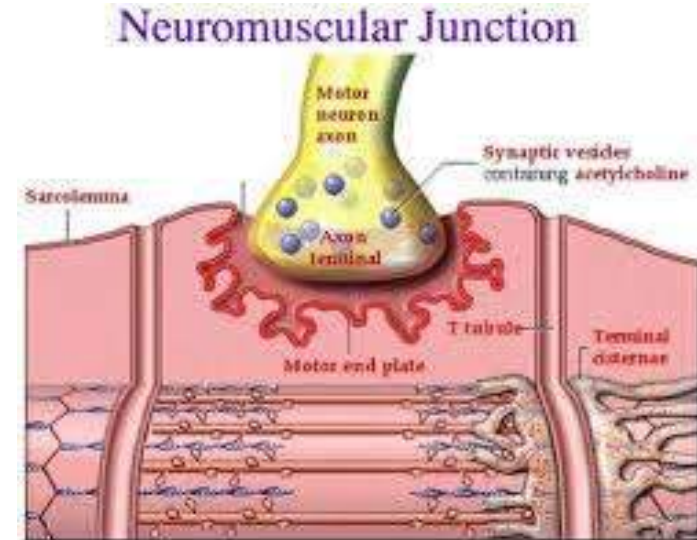


- The following changes occur within a sarcomere during contraction:
 1. The width of the **A band** remains constant, but the **H zone** disappears.
 2. The **Z discs** in one sarcomere move closer together.
 3. The sarcomere narrows.
 4. The **I bands** narrow.

- Thick and thin filaments maintain their same length, whether the muscle is relaxed or contracted. However, during muscle contraction, the relative position between the thick and thin filaments changed markedly.

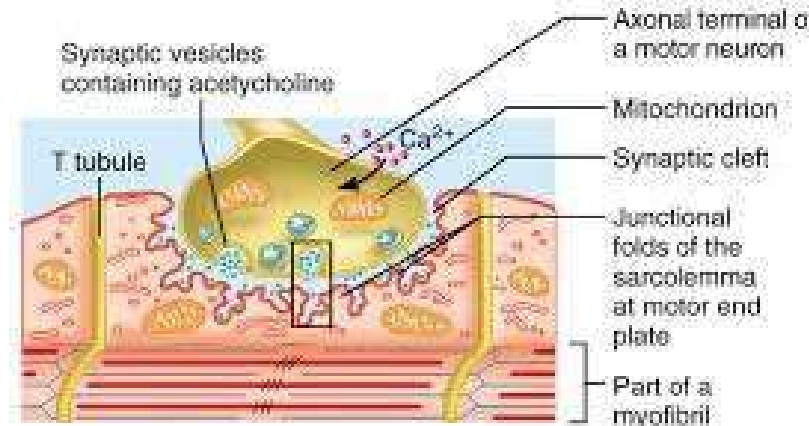


- Muscle contraction begins when a nerve impulse stimulates an impulse in a muscle fiber.
- Each muscle fiber is controlled by one motor neuron.
- The motor neuron transmits the effect of a nerve impulse to the muscle fiber at a **neuromuscular junction**, the point where a motor neuron meets a skeletal muscle fiber



The neuromuscular junction has the following components

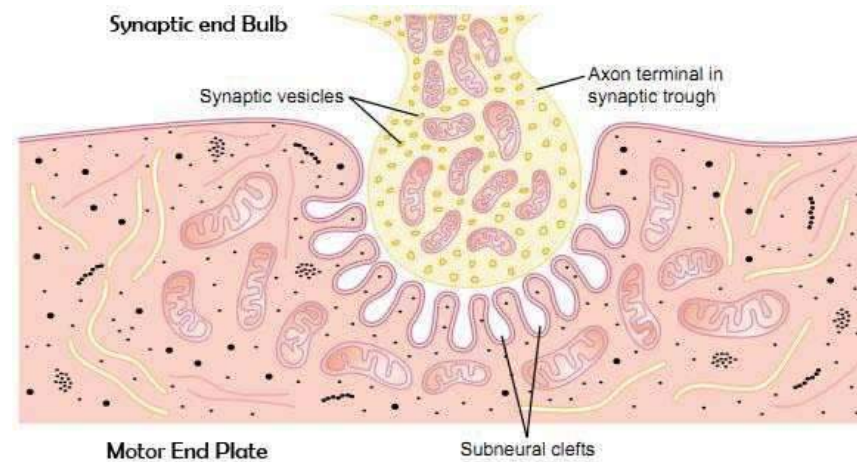
1. The **synaptic knob** of the neuron is an expanded tip of an axon. **A** nerve impulse travels through the axon to the synaptic knob.
2. The synaptic knob cytoplasm houses numerous **synaptic vesicles** (small membrane sacs) filled with molecules of the neurotransmitter **acetylcholine (ACh)**.



(b)

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3. The **motor end plate** is a specialized region of sarcolemma. It has folds and indentations to increase the membrane surface area covered by the synaptic knob.
4. The **synaptic cleft** is a narrow space separating the synaptic knob and the motor end plate.
5. **ACh receptors** in the motor end plate act like doors that normally are closed. **ACh** is the only "key" to open these receptor doors.
6. The enzyme **acetylcholinesterase (AChE)** resides in the synaptic cleft and breaks down molecules of **ACh**.



Physiology of muscle contraction:

- The arrival of a nerve impulse at the synaptic knob causes synaptic vesicles to release **ACh** into the synaptic cleft (figure 10.9).
- **ACh** attaches to receptors in the motor end plate. This causes the receptors to open, allowing sodium (Na^+) ions to enter the muscle fiber.

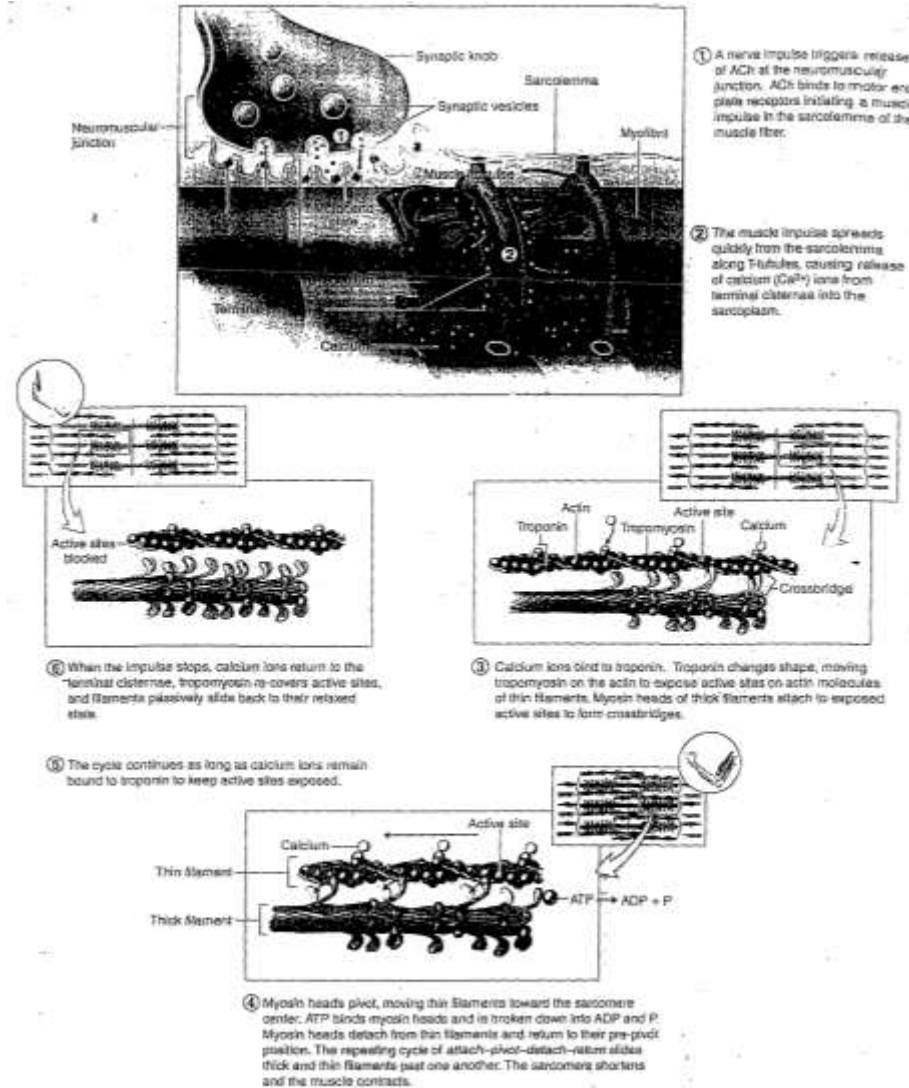
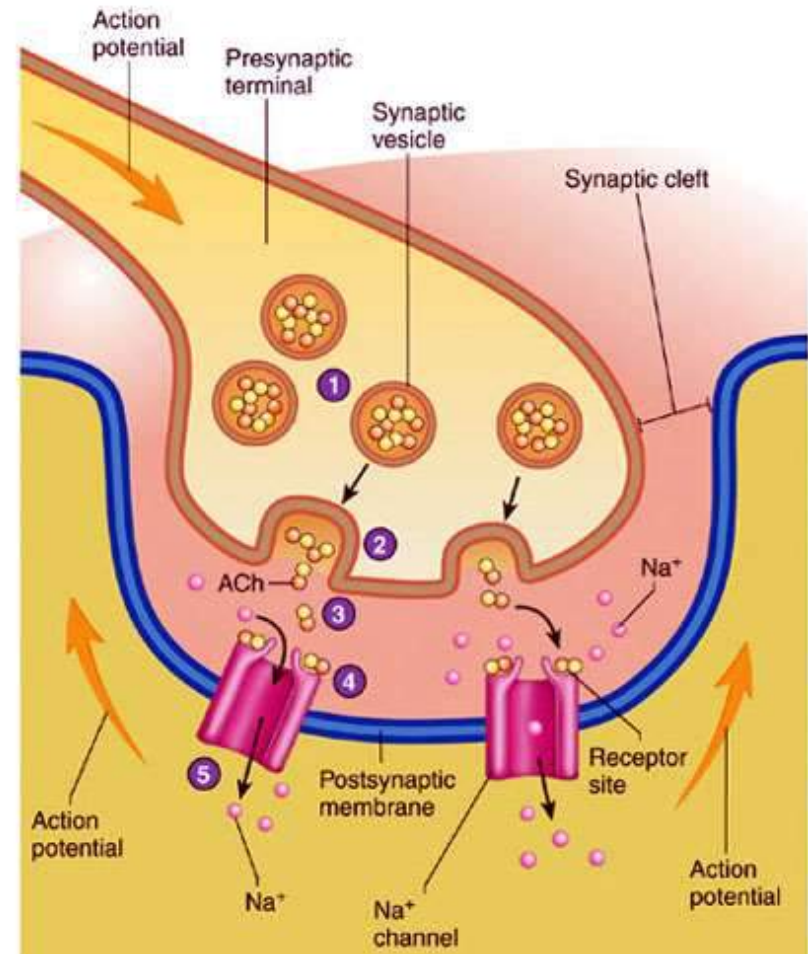
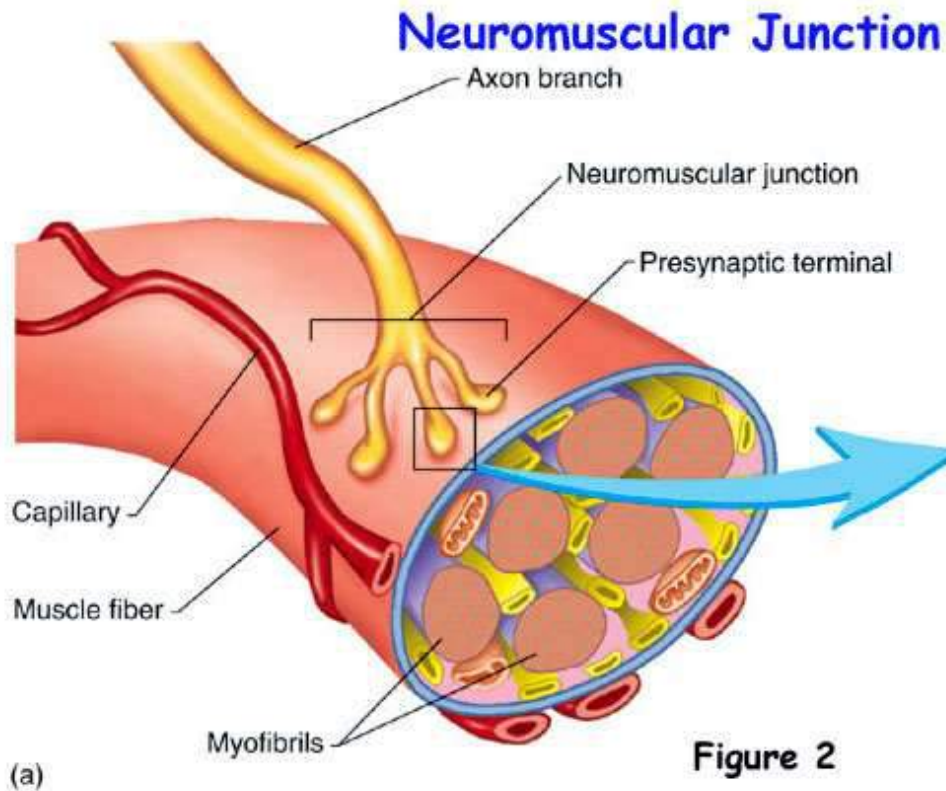


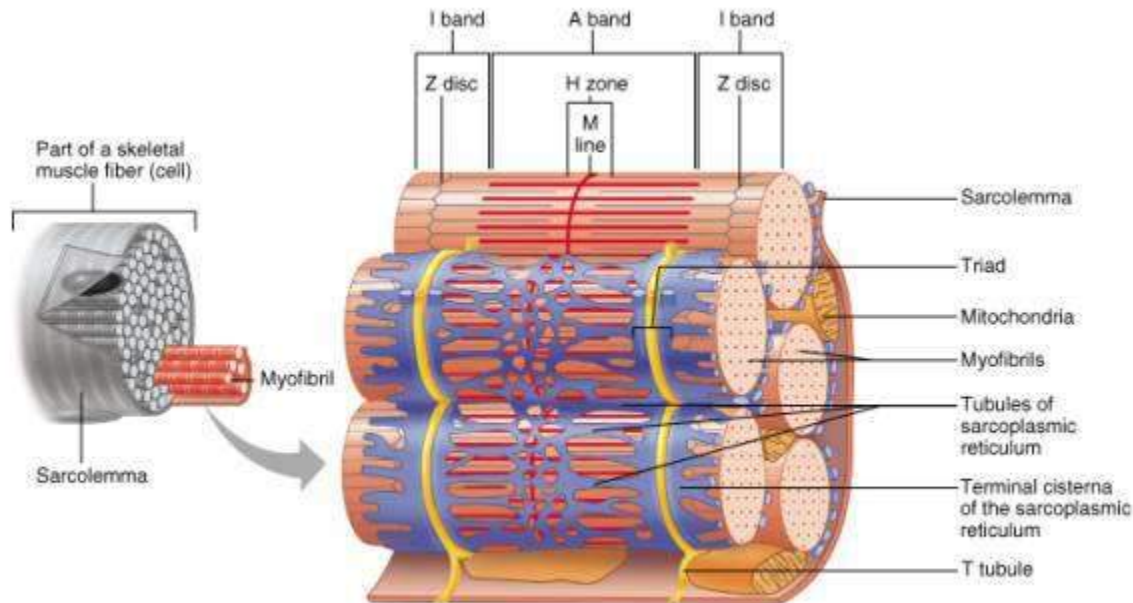
Figure 10.9
Events in Muscle Contraction.

- This ion movement changes the voltage (potential) across the sarcolemma, and a muscle impulse is initiated. The muscle impulse travels along the sarcolemma and into the muscle fiber by the T-tubules.
- The muscle impulse continues to spread throughout the muscle fiber as long as **ACh** keeps the receptors open. Usually **ACh** is quickly broken down and removed from the receptor by acetylcholinesterase.

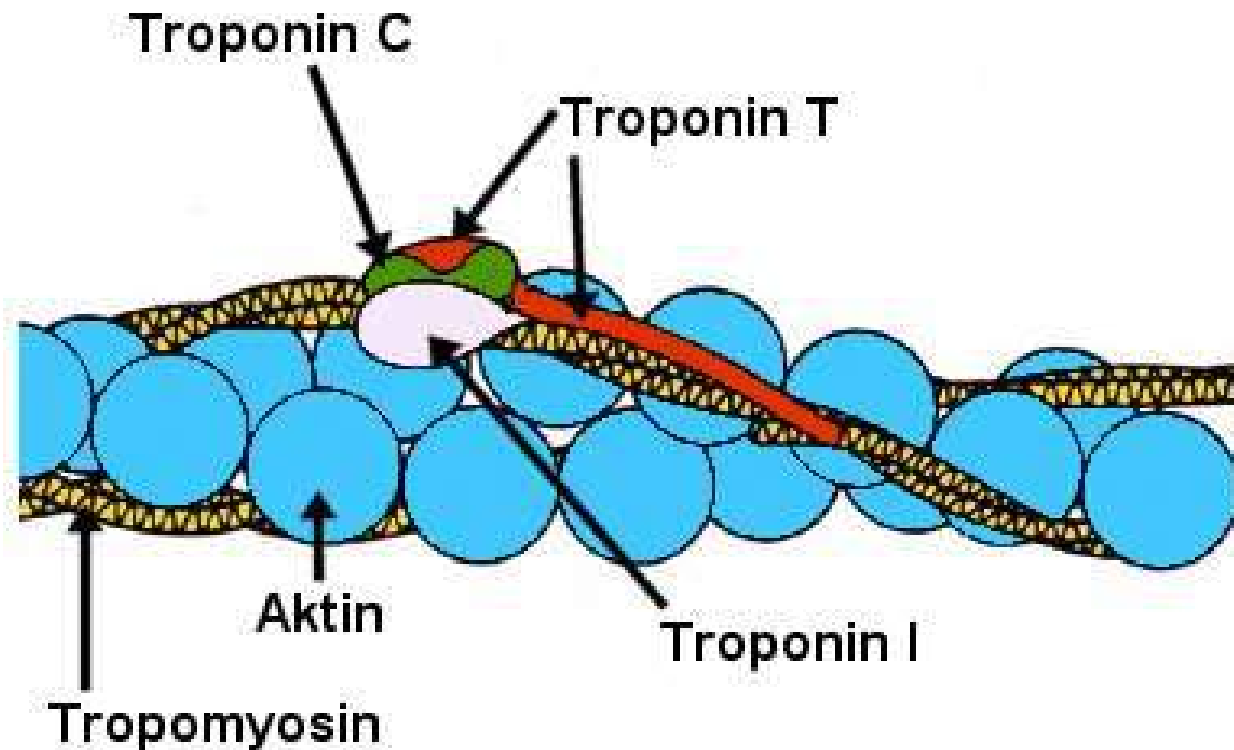


Interaction between the T-tubules and terminal cisternae:

- Recall that T-tubules distribute the muscle impulse through the inside of the muscle fiber, and they are sandwiched by terminal cisternae, which are reservoirs storing the calcium ions required for muscle contraction.

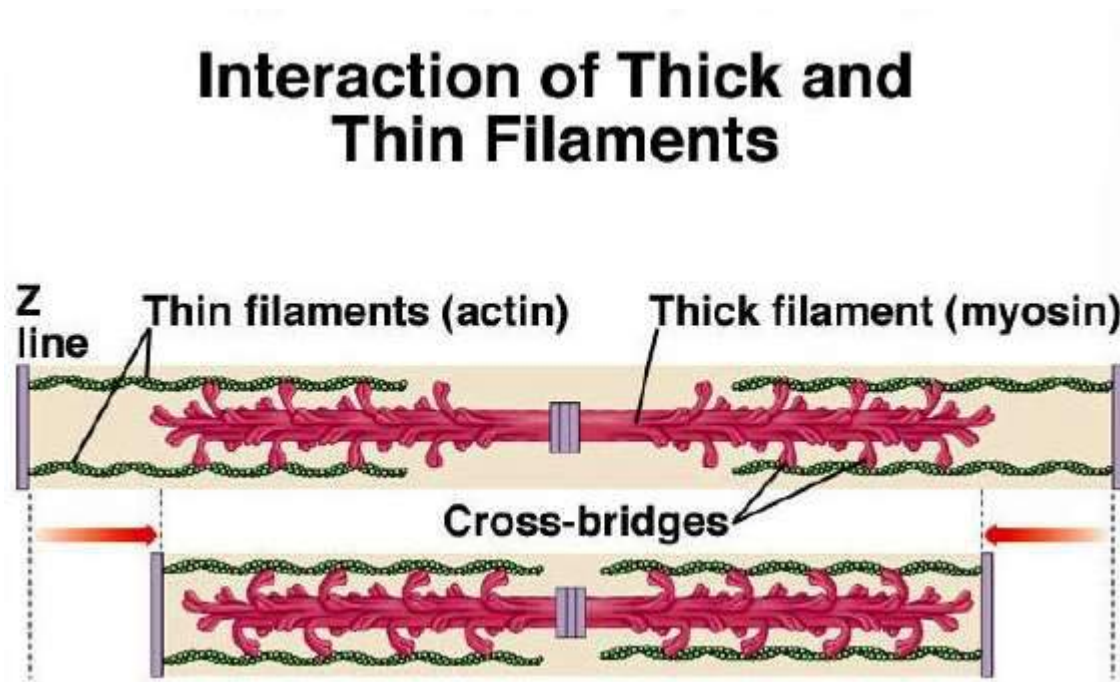


- Spread of a muscle impulse along the T-tubule membrane causes calcium ions to leak out of the terminal cisternae into the sarcoplasm of the muscle fiber. These calcium ions diffuse throughout the sarcoplasm and attach to the **troponin** in the thin filaments.

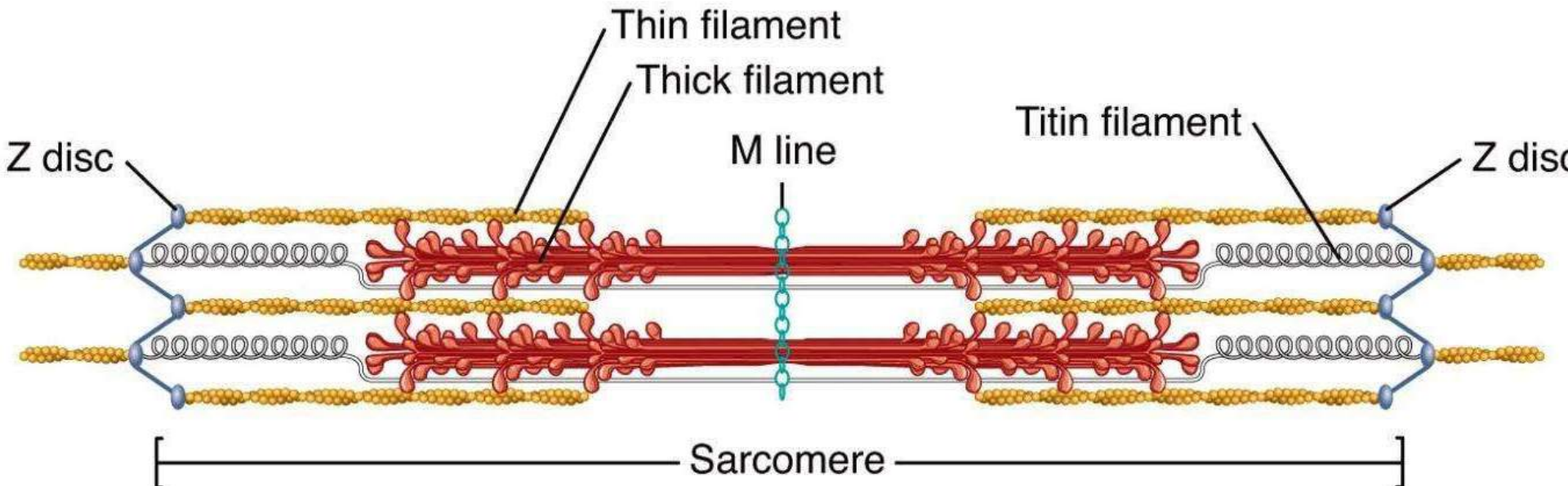


Interaction between thick and thin filaments:

- As the calcium ion concentration rises in the sarcoplasm, some calcium ions bind to one troponin molecules subunit, causing the troponin to change conformation.
- Recall that troponin molecules are attached to tropomyosin. When the fiber is at rest, the tropomyosin molecules block active sites for myosin on the actin. Thus, the thick filaments are unable to attach to thin filaments.



- So as troponin changes shape, the tropomyosin is moved away from the active sites on actin molecules.
- Contraction of muscle fiber requires that the myosin heads in the thick filament bind to active site on actin molecules within the thin filaments.



Mechanism of sliding

After Myocin heads **bind** to thin filaments myofilament sliding begins

Crossbridges
form



Myocin head **pivot** toward the
center of sarcomere



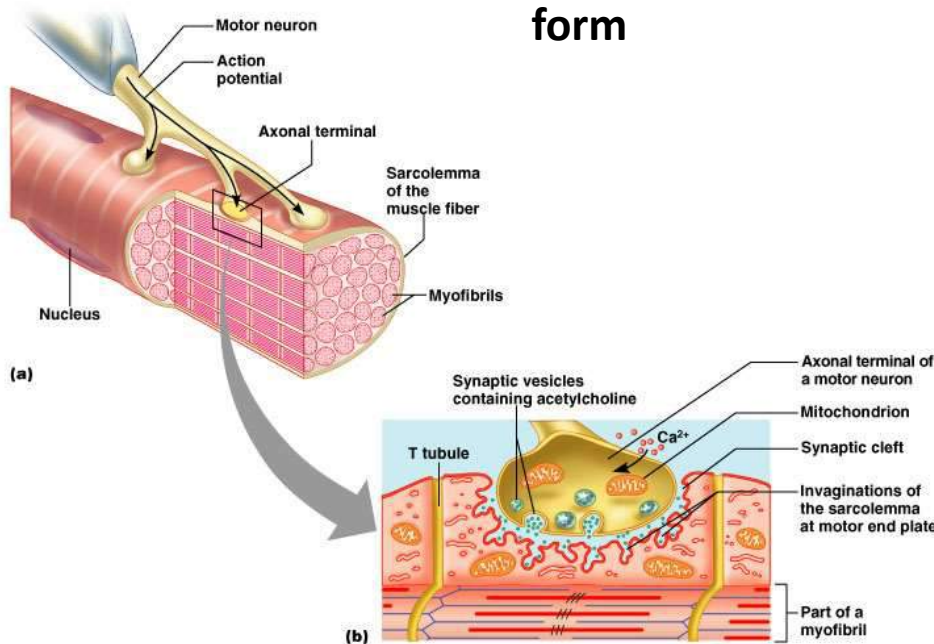
The actin pulls
thin filament
toward
sarcomere center



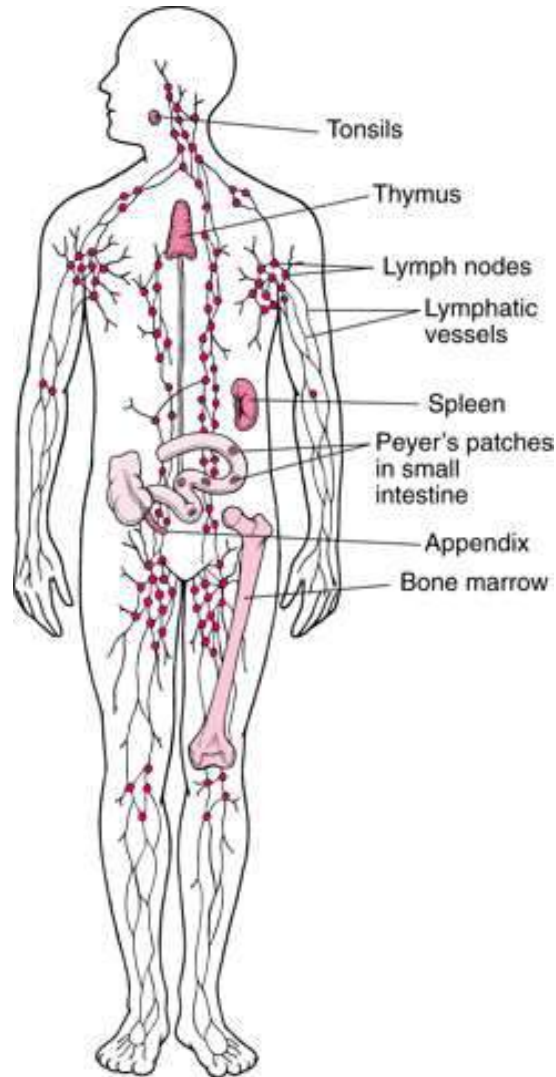
Z disk move closer
together



When myocin head complete pivoting the
crossbridge **detaches** and **returns** to its original
ready to repeat cycle



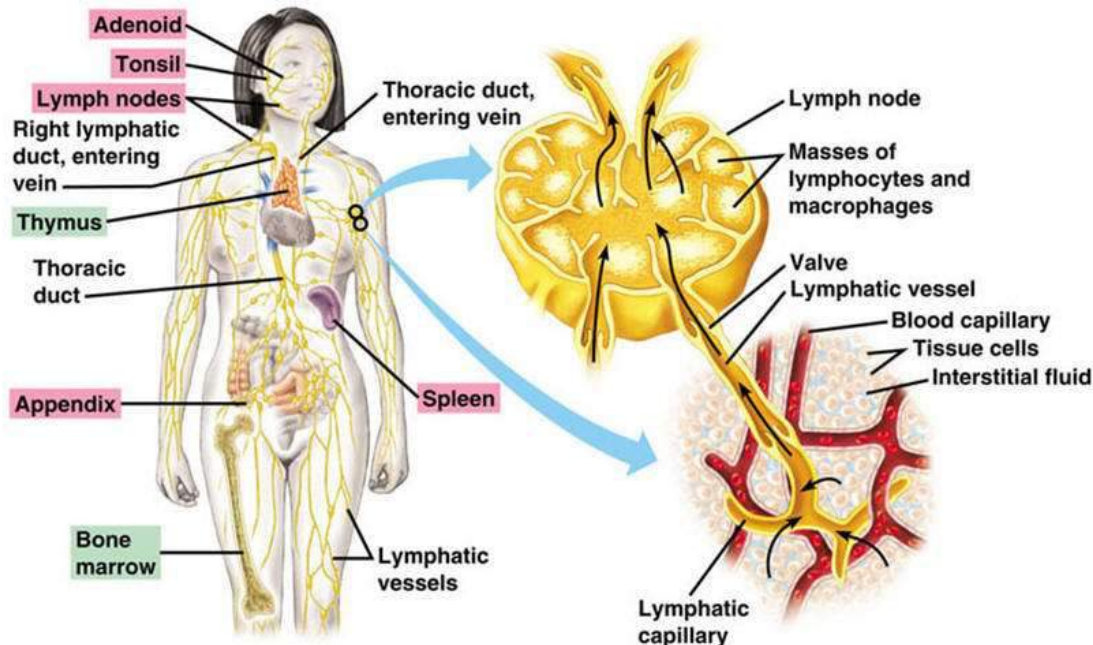
The Lymphatic System



Lec.Dr.Ruwaidah F. Khaleel

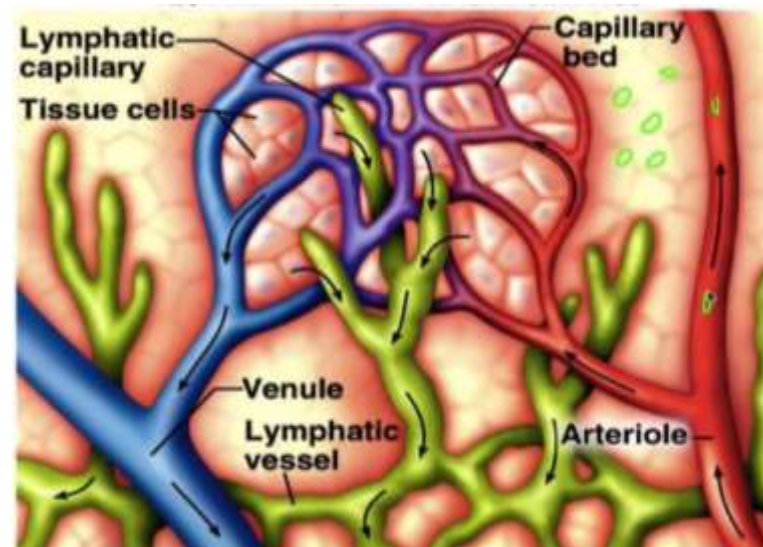
The Lymphatic System

- **Water and plasma** are forced from the capillaries into intracellular spaces; this interstitial fluid transports materials between the cells. Most of this fluid is collected in the capillaries of a secondary system which is called the **lymphatic system**.
- **The lymphatic system consists of:**
 1. Fluid (lymph).
 2. Lymphatic vessels that transport the lymph.
 3. Lymphatic organs.



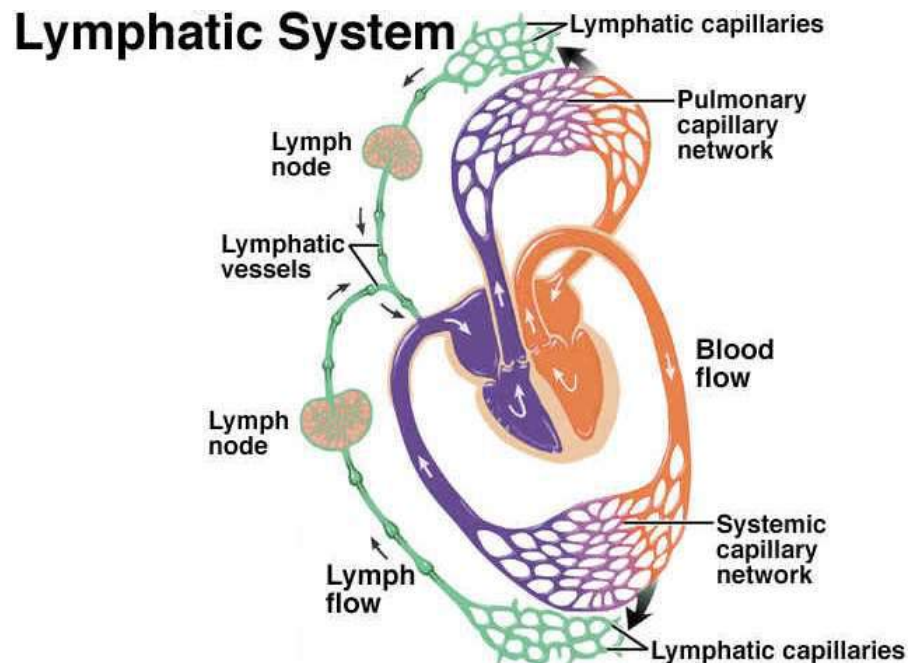
The lymphatic system has three basic functions:

1. Removal of excess fluids from body tissues and its return to the bloodstream.
2. Absorption of fatty acids and subsequent transport to the blood.
3. Formation of white blood cells, and initiation of immunity through the formation of antibodies.



Lymphatic Vessels and Ducts

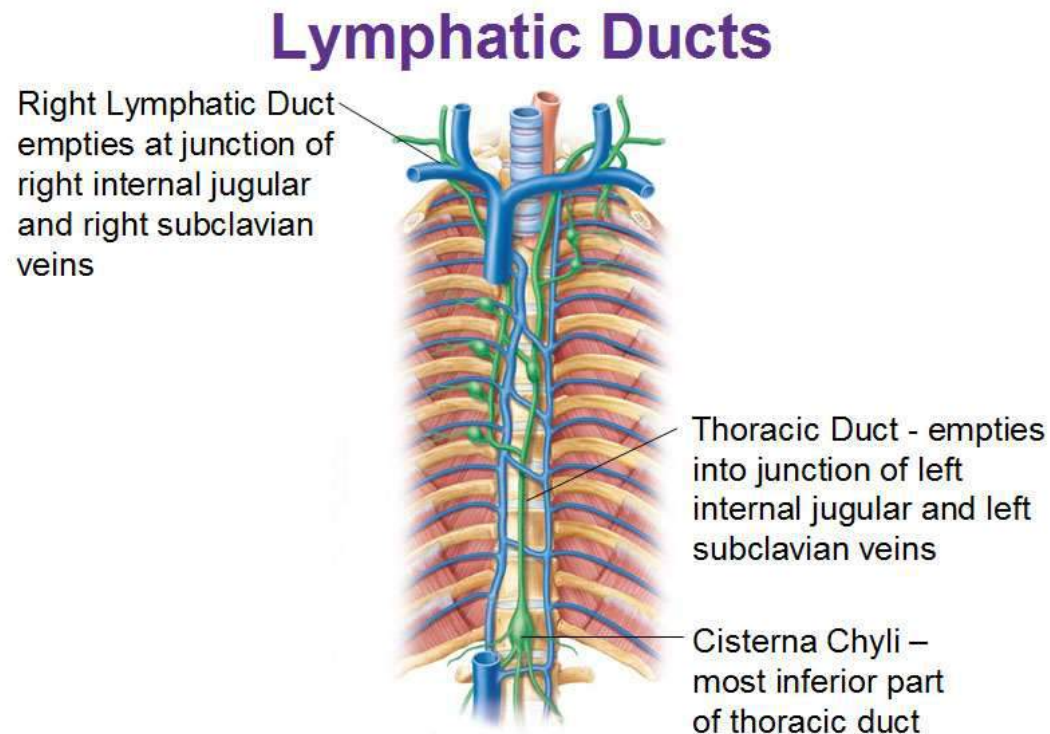
- The lymphatic vessels are similar in structure to the cardiovascular veins, meaning they also have **valves**.
- **They are dependent upon:**
 1. The contraction of skeletal muscle.
 2. Respiratory movements and valves that do not allow backward flow.



The vessels merge before entering one of two ducts:-

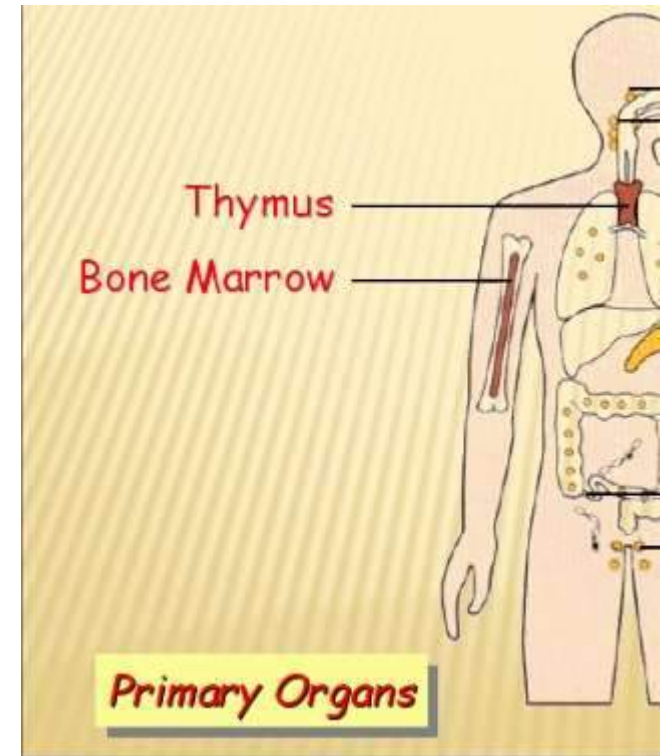
i. Thoracic duct: This duct serves the **abdomen, lower extremities and the left side of the upper body.**

ii. Right lymphatic duct: This duct serves all of the right side of the upper body and thoracic area.



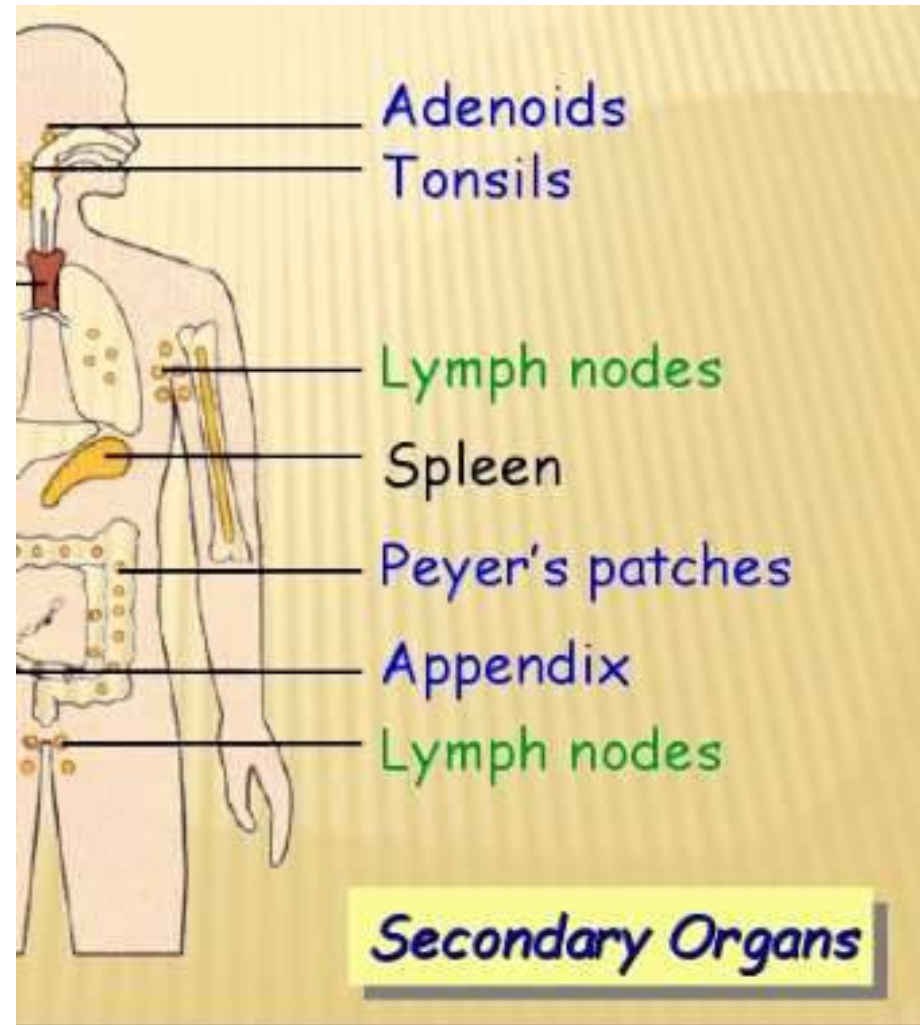
Lymphatic Organs

- Lymphatic organs are subdivided into:
- The primary lymphatic organs are the **red bone marrow and the thymus**.
- Function: They are the site of production and maturation of lymphocytes, the type of white blood cell that carries out the most important work of the immune system.



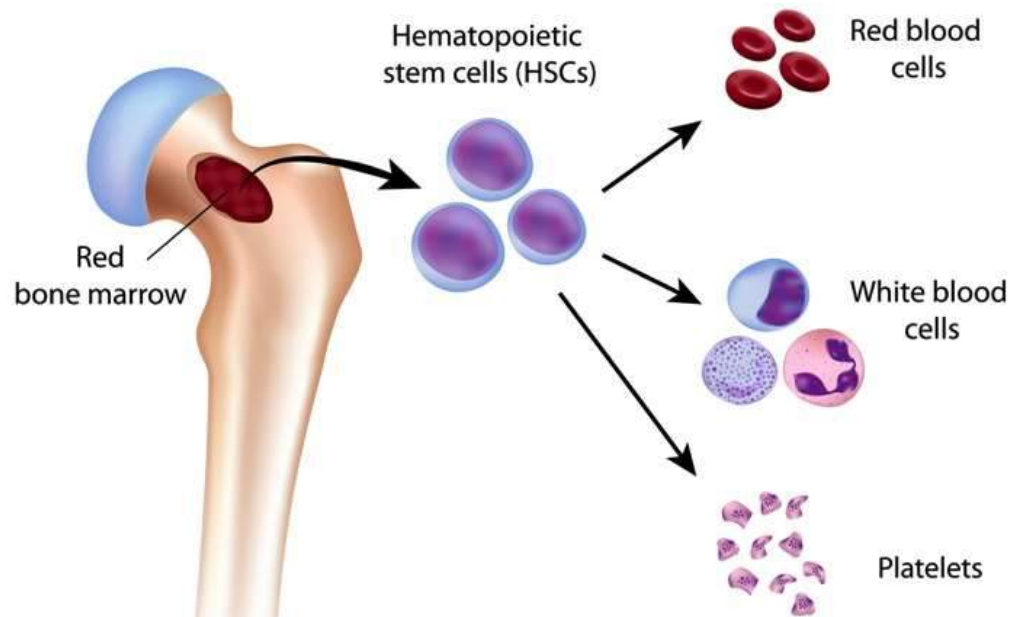
The secondary lymphatic organs

- Include the lymph nodes, spleen, tonsils, Peyer's patches, and the appendix.
- **Function:** They also play an important role in the immune system as they are places where lymphocytes find and bind with antigens.



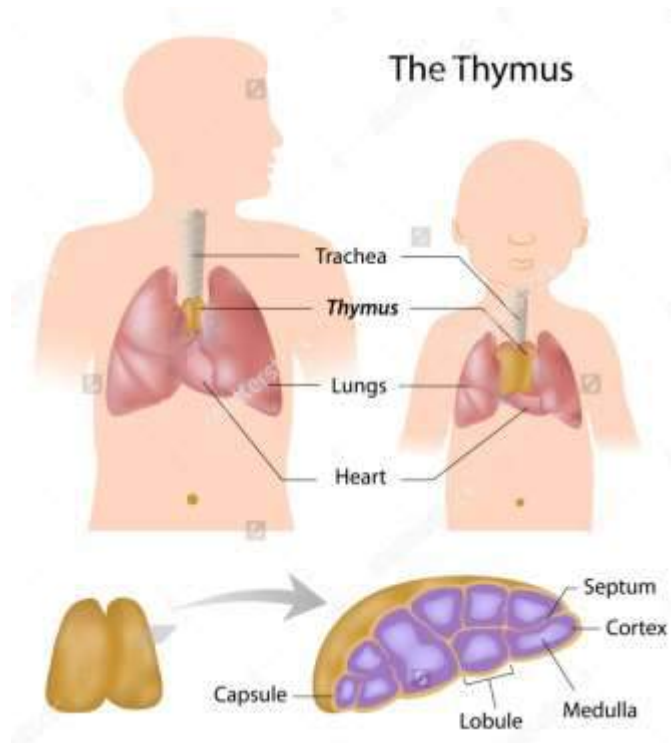
Red Bone Marrow

- It is soft, spongy, nutrient rich tissue in the cavities of certain long bones.
- Function:
 1. Is the organ that is the site of blood cell production.
 2. Is the site of maturation of B lymphocytes.



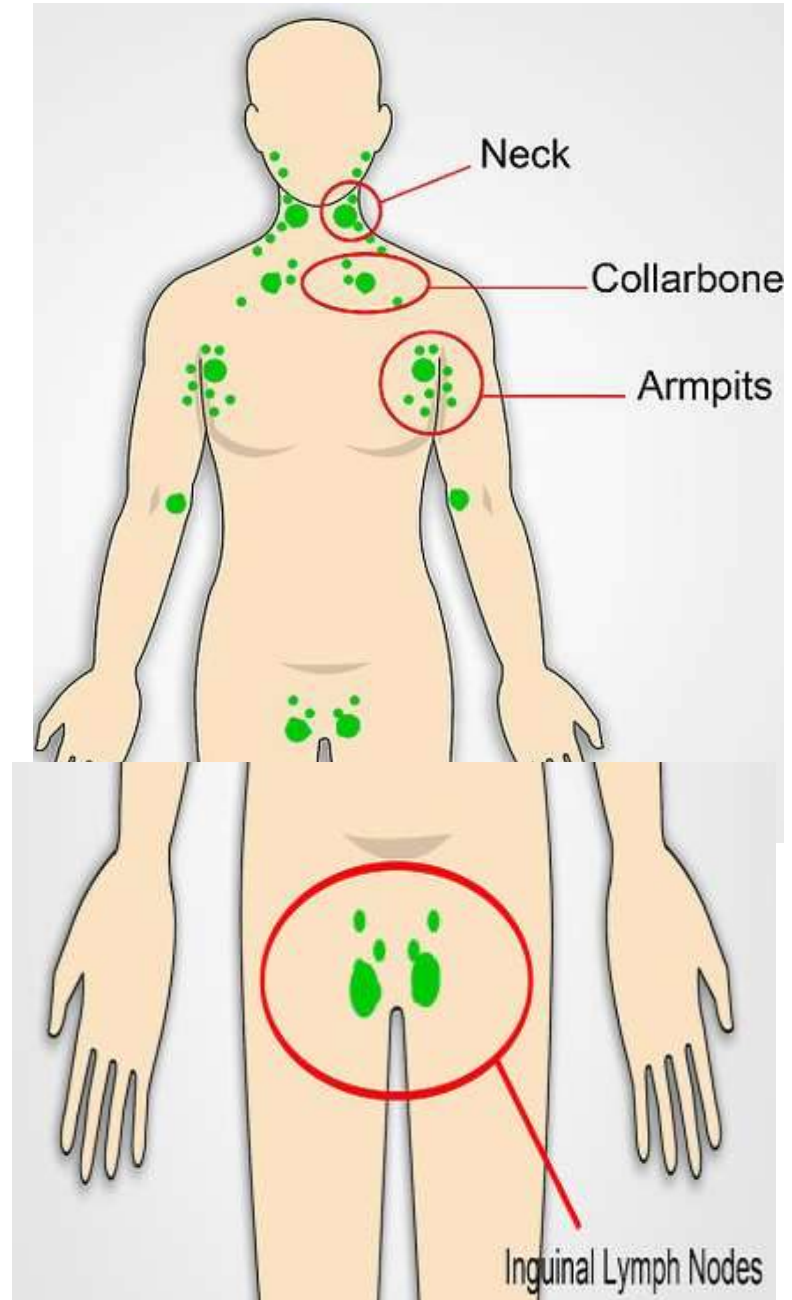
Thymus Gland

- It is a soft organ with two lobes that is located in the upper thoracic cavity posterior to the sternum.
- It is divided into: **an outer cortex and an inner medulla.**
- It is an organ that is more active in children, and shrinks as we get older.
- T- lymphocytes mature in the thymus.
- the thymus gland produces a hormone, **thymosin** which **thought to aid in the maturation of T- lymphocytes.**



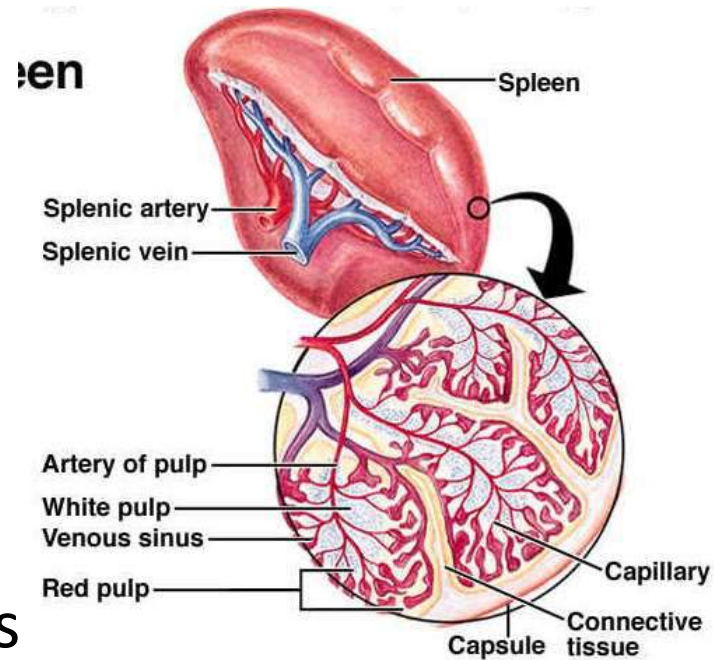
Lymph nodes

- The lymph nodes are small oval shaped structures located along the lymphatic vessels.
- **Function:** They act as filters, with an internal connective tissue filled with lymphocytes that collect and destroy bacteria and viruses.
- They concentrated in the neck, armpit, groin, and abdominal cavity.



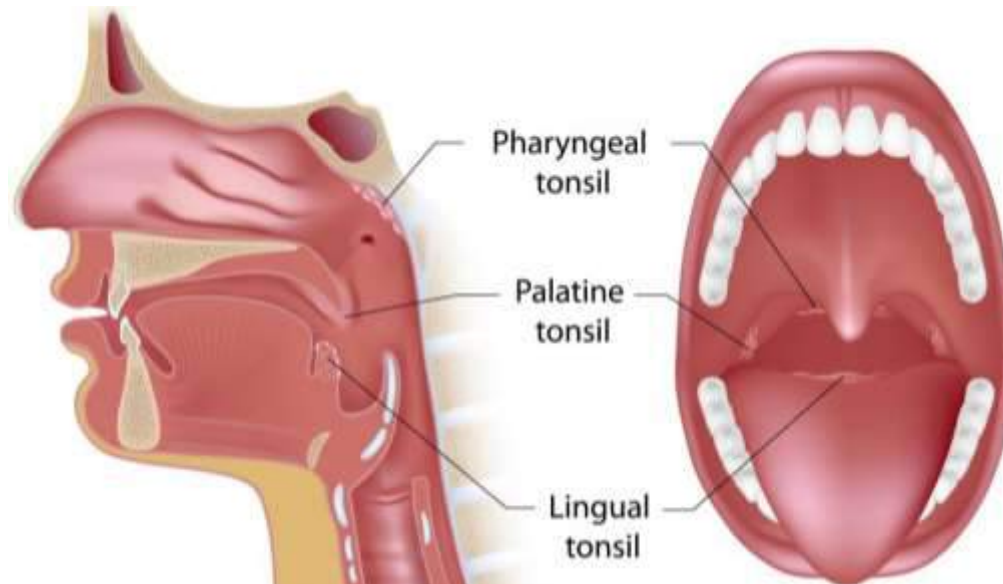
The spleen

- It is the largest of the lymphatic organs and lies in the left part of the abdominal cavity between the stomach and the diaphragm.
- It is divided into two partial compartments:
 1. **White pulp** contains lymphocytes.
 2. **Red pulp** contains venous sinuses.
- **Function**: When blood enters the spleen and flows through the sinuses for filtration, lymphocytes react to pathogens; macrophages engulf debris and remove old, worn out red blood cells.



Tonsils

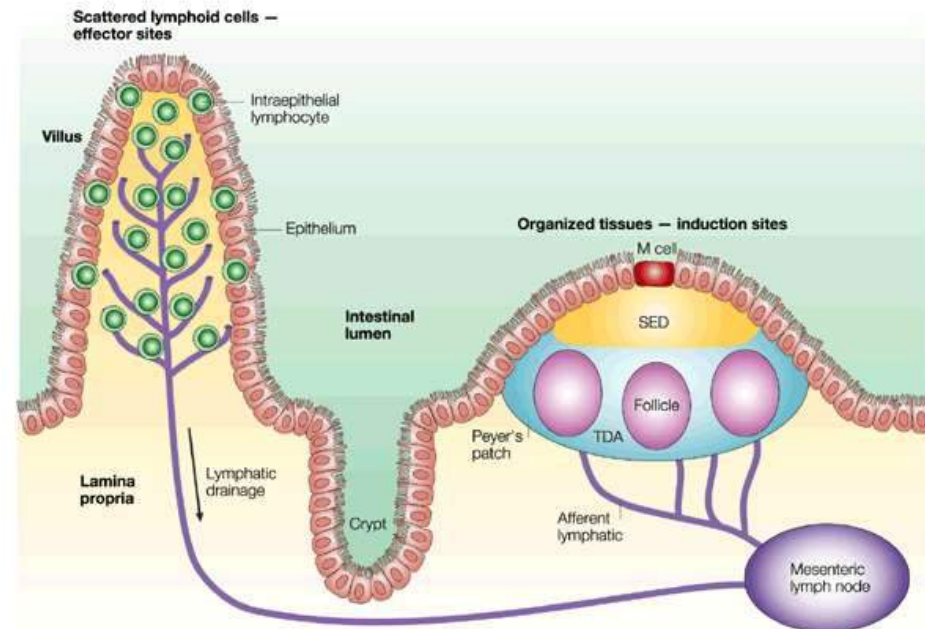
- Are a group of small rounded organs in the pharynx.
- They are filled with lymphocytes, macrophages, and macrophage-like cells.
- **Function:** Their lymphocytes respond to microbes that arrive by way of ingested food as well as inspired air.



Peyer's patches

- Are lymphoid tissues found in the wall of the small intestine, although they're more concentrated in the ileum.

Slide 57 Ileum



Appendix

- Its extends from the inferior end of the large intestine's cecum.
- The sub-mucosa of the appendix contains many masses of lymphoid tissue.
- The presence of lymphoid tissue suggests that the appendix **my play a role in immune system.**

