CHAPTER 3:

DEMONSTRATE KNOWLEDGE IN MEDICAL PHYSIOLOGY

3.1 Introduction of the Unit of Learning / Unit of Competency

This unit specifies the competencies required to demonstrate the knowledge of medical physiology. It involves demonstrating the knowledge of physiologic principles, demonstrating the knowledge of human body systems, integumentary system.

3.2 Performance Standard

By the end of this unit of learning/competency, the trainee should demonstrate understanding in the structure and functions of the cell based on resource materials, the functioning of human body and its relation to nutrition, health and diseases as per the cellular inclusions and workplace procedures.

3.3 Learning Outcomes

3.3.1 List of the Learning Outcomes

1. Demonstrate the knowledge of physiologic principles
2. Demonstrate the knowledge of the human body systems

3.3.2 Learning Outcome 1: Demonstrate the knowledge of physiologic principles

3.3.2.1 Learning Activities

Learning activity	Special instructions
Analyse the structure of the normal cell	Draw a normal cell showing all the organelles
Identify functions of ***cellular organelles*** as per the structure	
Describe types of cell division	Differentiate between Mitosis & Meiosis
Identify types of mammalian cells	Use of a light microscope
Identify the organization, size and composition of body fluids	Differentiate between intracellular and extracellular fluids
Identify Units of measurement of the physiochemical constituent in cells identified	
Identify forces producing movement of substances between body fluid com-partments	Illustrate knowledge of passive and active processes
Analyse maintenance and variations in cell membrane potential	
Outline the buffering system of the body	

3.3.2.2 Information Sheet

Structure of the Normal Cell

Types of cells

Cells are the smallest living structure

Cell = functional unit of the body

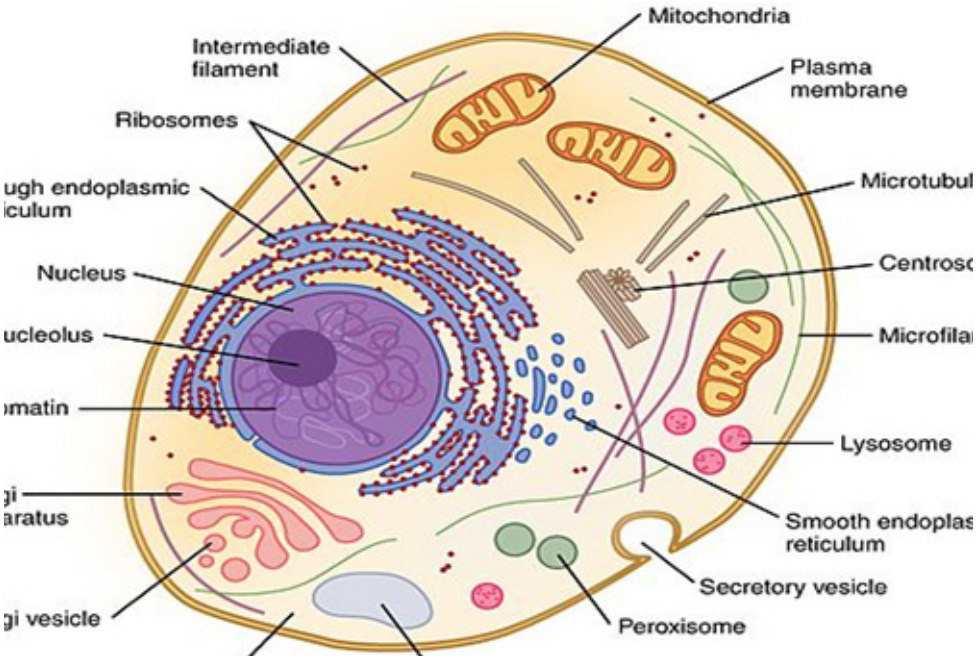
Cytology = The Study of Cells

Ultrastructural Cytology = Cytology at the Electron Microscopic level

Histology = the study of tissues

The basic organizational structure of the human body is the cell. There are 50-100 trillion cells in the human body. Differentiation is when cells specialize. As a result of differentiation, cells vary in size and shape due to their unique function.

The cell structure



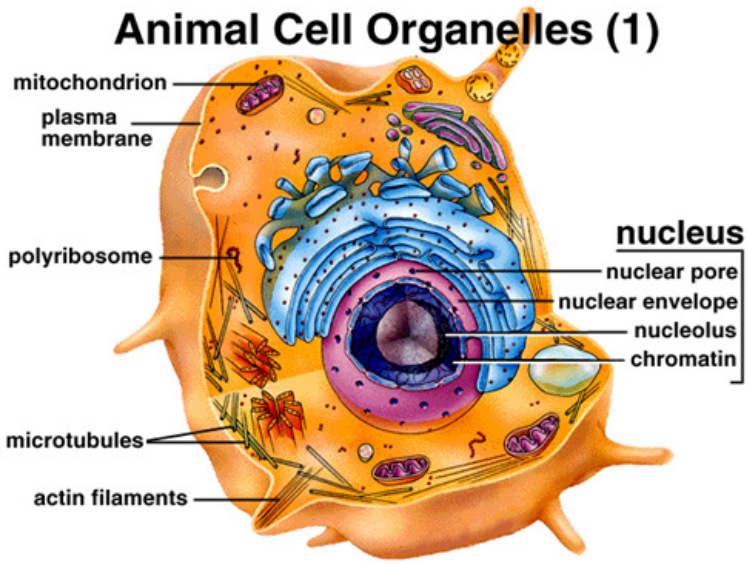
To learn more about the cell structure and the nucleus, follow the link below:

https://www.youtube.com/watch?v=URUJD5NEXC8

Also called a 'typical' cell. Major parts include:

- Nucleus--contains DNA
- Cytoplasm--cellular contents between plasma membrane & nucleus
- Cell membrane---selective barrier

Functions of Cellular Organelles



The composition of cytoplasm

Cytoplasm is the Cellular content between plasma membrane & nucleus Cytoplasm=cytosol + organelles

Cytosol = watery fluid

Organelles = solids small organs; highly specialized functions

Roles and functions of cell components

Organelles

Structures INSIDE a cell that have specific functions.

Membranous

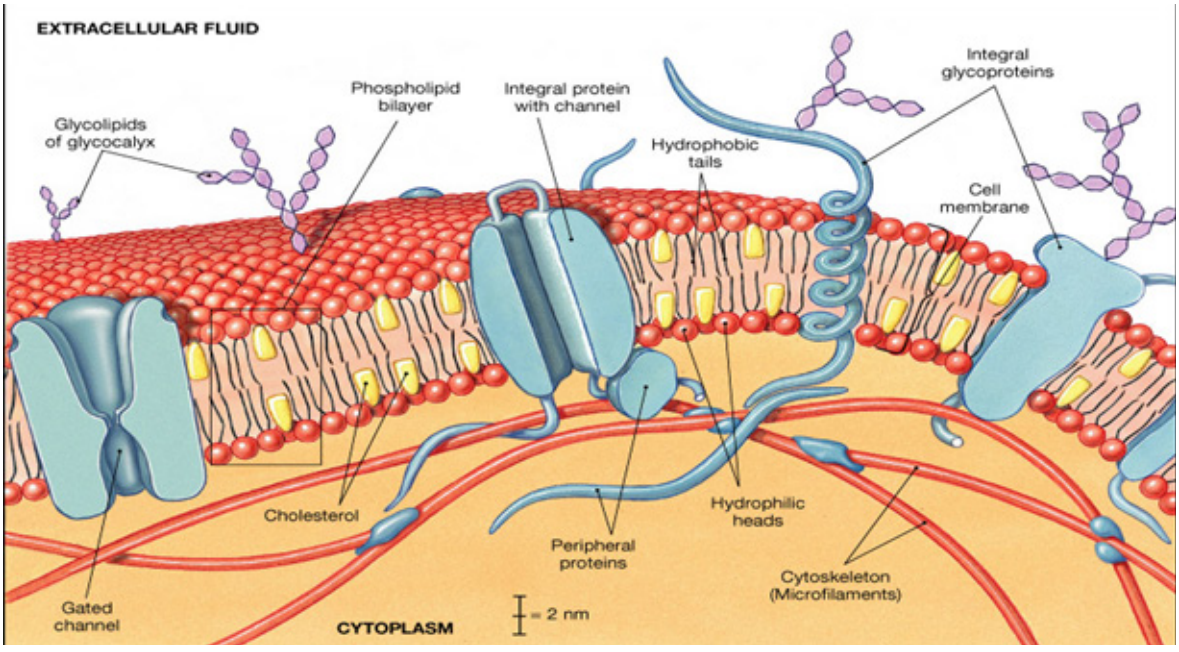
- Nucleus
- Endoplasmic reticulum
- Vesicles and lysosomes
- Golgi apparatus
- Mitochondria

Non-membranous

- Ribosomes
- Actin/Myosin in muscle cells
- Microtubules (cytoskeleton)

Cell membrane

- It consists of a lipid bilayer with embedded proteins.
- Outer limit of the cell
- Controls what moves in and out of the cell.



Follow this link to learn more on the cell membrane and its functions:
https://www.youtube.com/watch?v=UxvFdW9aO0s

Endoplasmic Reticulum (ER)

- Connected, membrane-bound sacs, canals, and vesicles
- Transport system
- Rough ER--Studded with ribosomes (protein synthesis)
- Smooth ER--Lipid synthesis

Ribosomes

- Free floating or connected to ER
- Protein synthesis

Golgi apparatus

- Stack of flattened, membranous sacs
- Modifies, packages and delivers proteins

Vesicles

- Membranous sacs
- Store substances

Mitochondria

- Membranous sacs with inner partitions
- Generate energy

Lysosomes

- Enzyme-containing sacs
- Digest worn out cell parts or unwanted substances

Centrosome

- Directs organisation of microtubules
- Two rod-like centrioles (cell division.)
- Used to produce cilia and flagella
- Distributes chromosomes during cell division

Peroxisomes

- Enzyme-containing sacs
- Break down organic molecules

Cilia

- Short hair-like projections
- Propel substances on cell surface

Flagellum

- Long tail-like projection
- Provides motility to sperm

Microfilaments and microtubules

- Thin rods and tubules
- Support cytoplasm
- Allows for movement of Organelles

Cell nucleus

- It is found in the center of the cell. It contains the genetic material that is DNA and RNA
- It controls all the activities of the cell.

Process of cell division

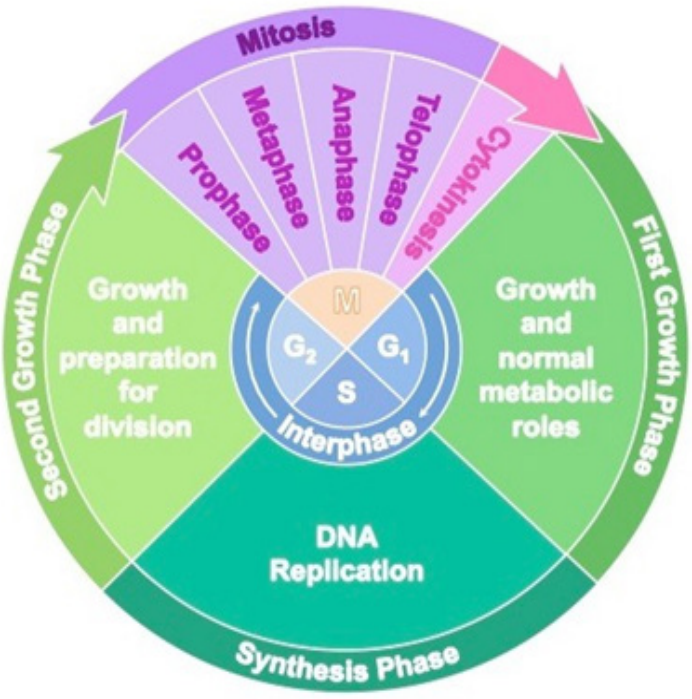
- Division by mitosis-produces two new genetically identical daughter cells.
- Gametes (sex cells); division takes place by meiosis-produces four haploid cells.
- Interphase: period between cell division
- At the end of interphase the chromatin replicates and becomes tightly coiled forming a double chromosome i.e. chromatids for cell division.
- Chromatids are joined at the center by a centromere.
- Chromatid is one copy of a newly copied chromosome which is still joined to the original chromosome by a single centromere.

The Cell Cycle

Series of changes a cell undergoes from the time it forms until the time it divide

Stages:

- Interphase
- Mitosis
- Cytokinesis



Interphase

- Very active period
- Cell grows
- Cell maintains routine functions
- Cell replicates genetic material to prepare for nuclear division
- Cell synthesizes new organelles to prepare for cytoplasmic division

Phases:

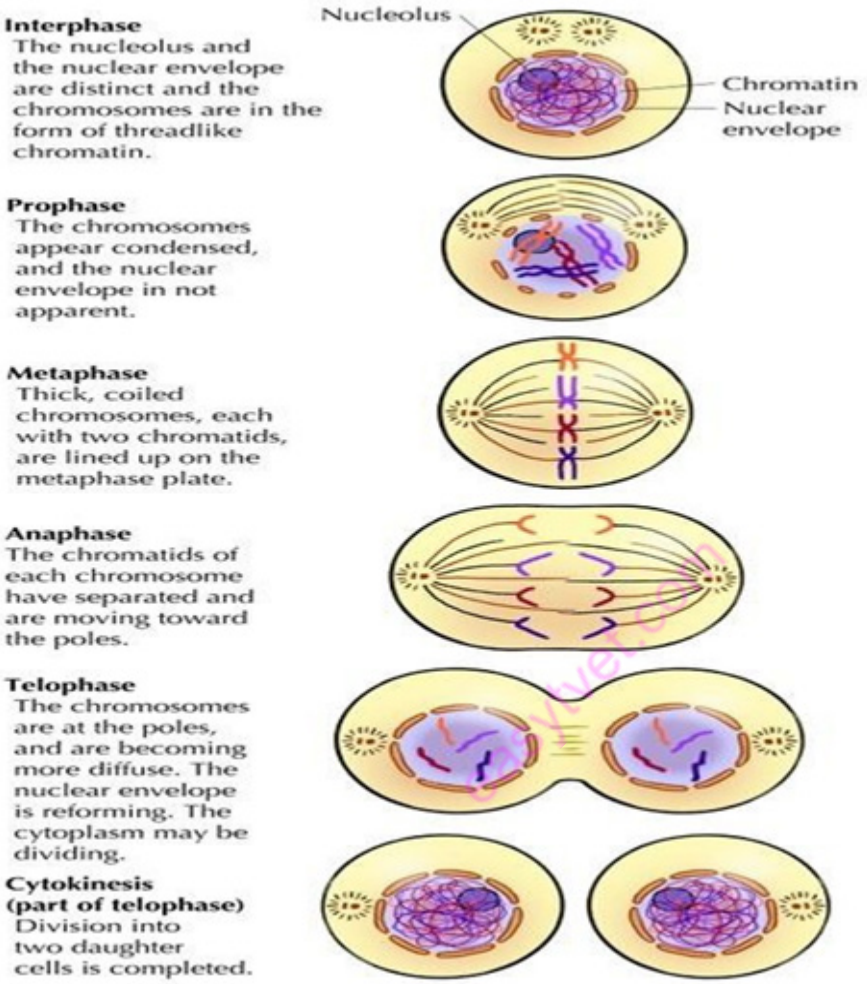
- G phases – cell grows and synthesizes structures other than DNA
- S phase – cell replicates DNA

Mitosis

- Produces two identical daughter cells from an original somatic cell.
- Nucleus divides – karyokinesis
- Cytoplasm divides – cytokinesis

Phases of Nuclear Division:

- Prophase – chromosomes form; nuclear envelope disappears
- Metaphase – chromosomes align midway between centrioles
- Anaphase – chromosomes separate and move to the opposite poles of the cell.
- Telophase – chromatin forms; nuclear envelope forms



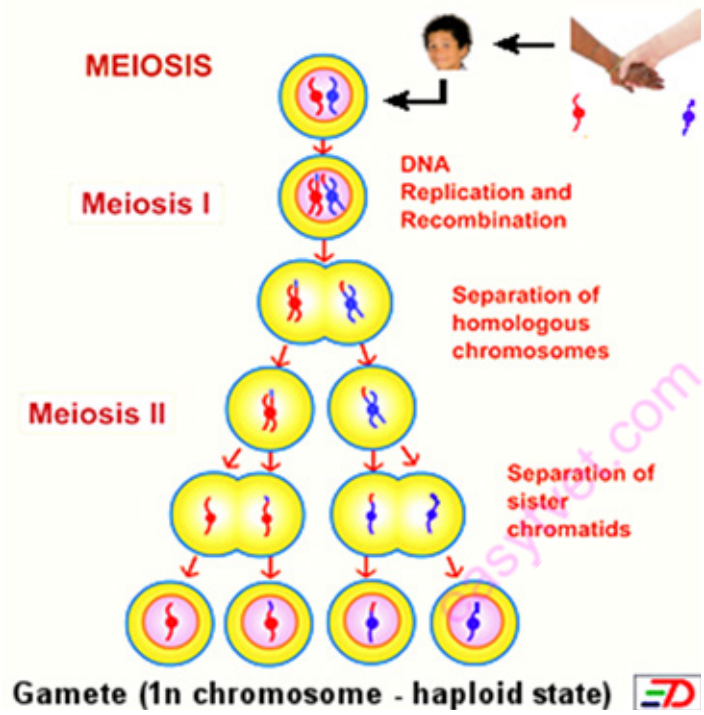
Follow this link to learn more on the process of mitosis:
https://www.youtube.com/watch?v=xsrH050wnIA

Cytoplasmic Division

- Also known as ***cytokinesis***
- Begins during anaphase
- Continues through telophase
- Contractile ring pinches cytoplasm in half.

Meiosis

- Is a specialized type of cell division that reduces the chromosome number by half, creating four haploid cells, each genetically distinct from the parent cell that gave rise to them.
- This type of cell division is only used to form gametes cells i.e. sperm and ovum.
- In meiosis, the chromosomes duplicate (during interphase) and homologous chromosomes exchange genetic information (chromosomal crossover) during the first division, called meiosis I. The daughter cells divide again in meiosis II, splitting up sister chromatids to form haploid gametes.
- Two gametes fuse during fertilization, creating a diploid cell with a complete set of paired chromosomes.



Follow this link to learn more on the process of meiosis:
https://www.youtube.com/watch?v=c5hA0WCv1lg

Differences Between Mitosis and Meiosis	
Mitosis	**Meiosis**
This type of division takes place in somatic cells	This type of division takes place in gamete cells
Two daughter cells are formed	Four daughter cells are formed
Number of chromosomes remains diploid in daughter cells	Number of chromosomes becomes haploid in daughter cells
Mitosis is necessary for growth and repair	Meiosis is necessary for sexual reproduction
Crossing over does not take place	Crossing overtakes place

Control of Cell Division

- Cell division capacities vary greatly among cell types
    - Skin and blood cells divide often and continually
    - Neuron cells divide a specific number of times then cease
- Cells divide to provide a more favorable surface area to volume relationship
- Growth factors and hormones stimulate cell division
    - Hormones stimulate mitosis of smooth muscle cells in uterus
    - Epidermal growth factor stimulates growth of new skin
- Tumors are the consequence of a loss of cell cycle control

Tumors

Two types of tumors:

- **Benign** – usually remains localized
- **Malignant** – invasive and can metastasize; cancerous

Two major types of genes cause cancer:

- Oncogenes – activate other genes that increase cell division
- Tumor suppressor genes – normally regulate mitosis; if inactivated they are unable to regulate mitosis

Cells are now known as "immortal".

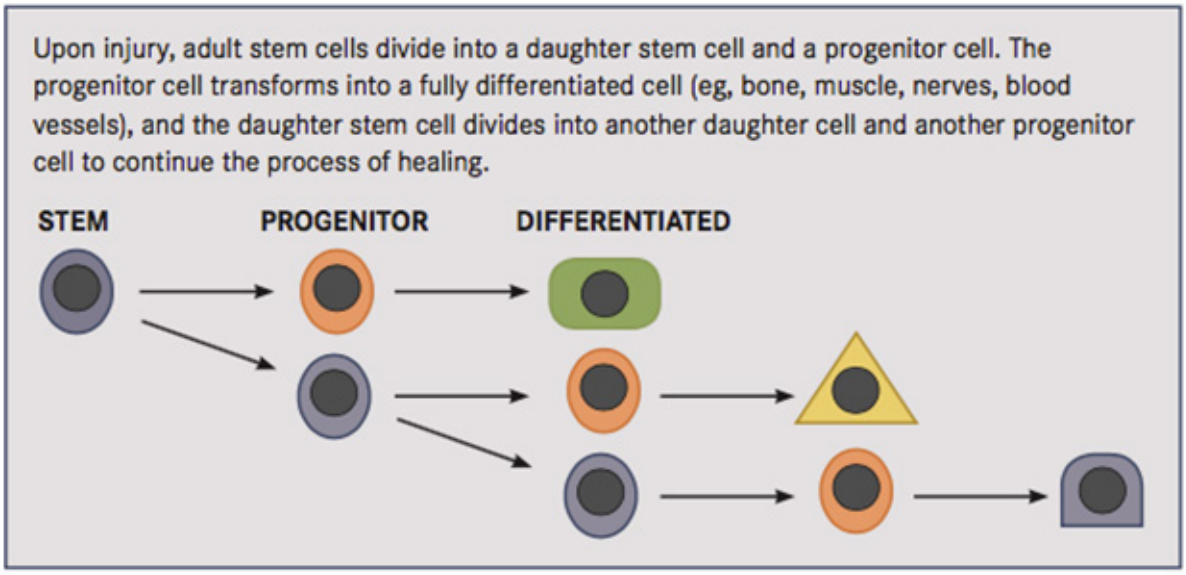
Stem and Progenitor Cells

Stem cell: An undifferentiated cell of a multicellular organism which is capable of giving rise to indefinitely more cells of the same type, and from which certain other kinds of cell arise by differentiation.

- Can divide to form two new stem cells
- Self-renewal
- Can divide to form a stem cell and a progenitor cell
- Totipotent – can give rise to every cell type
- Pluripotent – can give rise to a restricted number of cell types.

Progenitor cell:

- Committed cell that can divide into restricted specific cells.
- Can divide to become any of a restricted number of cells
- Pluripotent



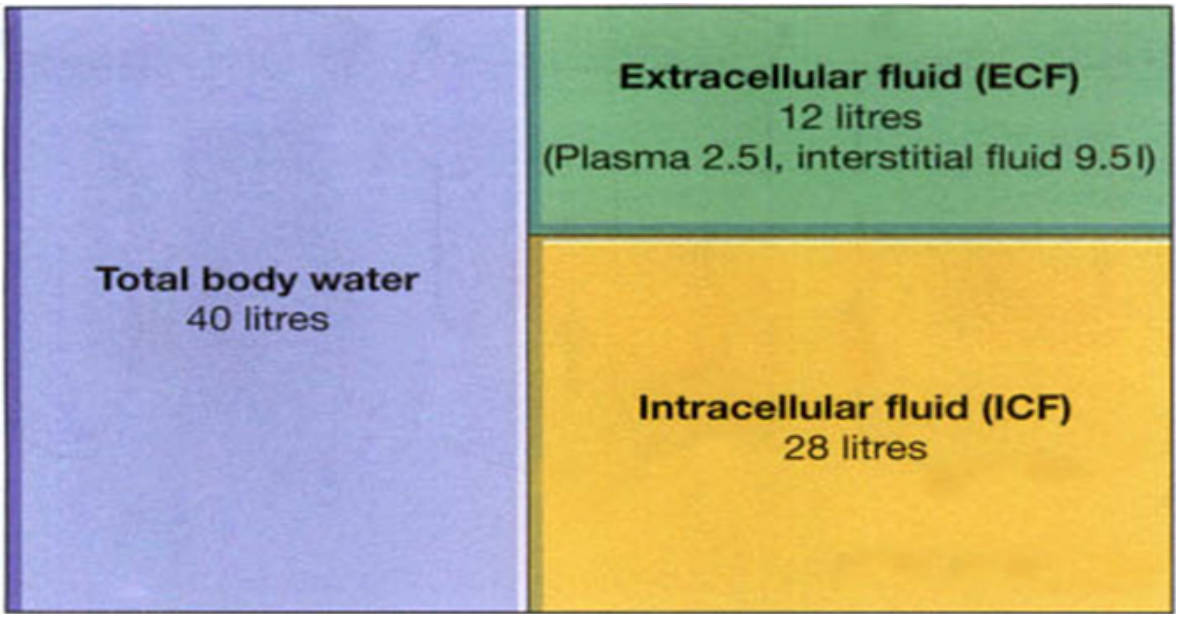
Cell Death

Apoptosis:

- Programmed cell death
- Acts as a protective mechanism
- Is a continuous process

Body Fluids Composition

- Total body water in adults is about 60% of body weight.
  - Extracellular water…..about 22% of body weight
  - Intracellular water……about 38% of body weight
- Proportion is higher in
  - Young people and adults below average weight.
- It is lower in:
  - The elderly
  - Obesity



Distribution of body water in a 70 kg person

Importance of Water

- It makes up part of all body fluids
- It protects cells from outside pressure
- It helps in the regulation of body temperature
- It maintains intracellular pressure
- It is involved in chemical reactions
- It washes out wastes and is, therefore, a medium of excretion

Extracellular Fluid (ECF)

- Consists of
    - blood,
    - plasma,
    - lymph,
    - cerebrospinal fluid
    - fluid in the interstitial spaces of the body.
    - Others (synovial fluid, pericardial fluid, pleural fluid)
- Interstitial or intercellular fluid (tissue fluid) bathes all the cells of the body except the outer layers of skin.
- It is the medium through which substances pass from blood to the body cells, and from the cells to blood.

INTRACELLULAR FLUID (ICF)

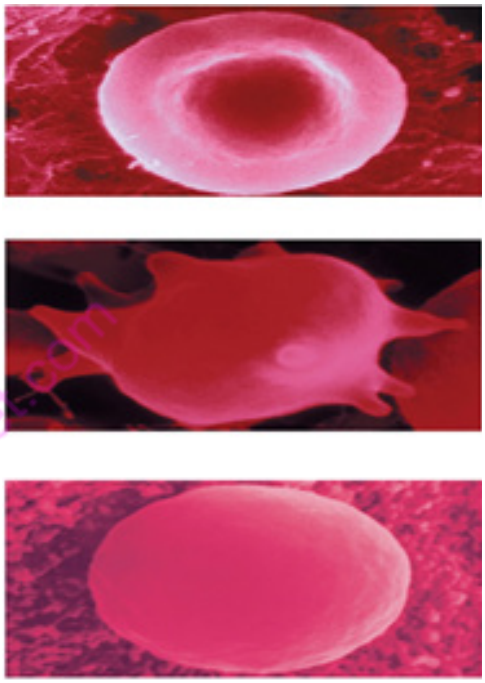
- Its composition is largely controlled by the cell itself, because there are selective uptakes and discharge mechanisms present in the cell membrane.
- Thus, sodium levels are nearly ten times higher in the ECF than in the ICF.
- This concentration difference occurs because although sodium diffuses into the cell down its concentration gradient there is a pump in the membrane which selectively pumps it back out again.

Units of measurement of the physiochemical constituent in cells identified as per the concentration

Isotonic – same osmotic pressure

Hypertonic – is one where the concentration of solutes is greater outside the cell than inside it.

Hypotonic – is one where the concentration of solutes is lower outside the cell than inside it.



Forces Producing Movement of Substances between Body Fluid Compartments

Movements Into and Out of the Cell

Passive (Physical) Processes

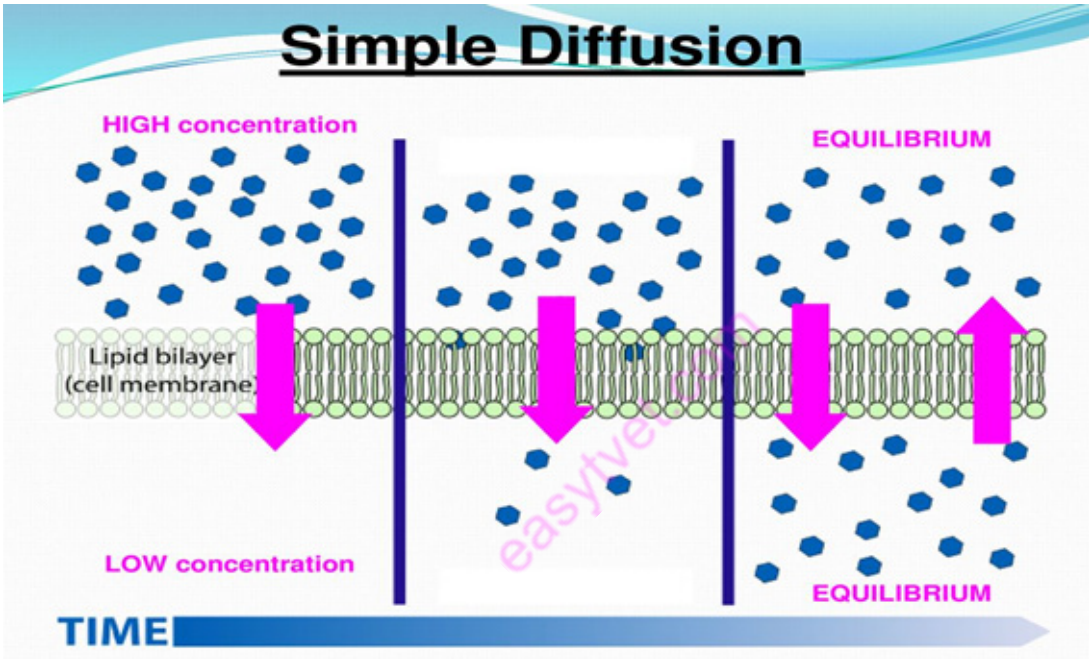
- Substances cross the semipermeable membrane down the concentration gradient.
- Require no cellular energy and include:
    - o Simple diffusion
    - o Facilitated diffusion
    - o Osmosis
    - o Filtration

Active (Physiological) Processes

- Require cellular energy and include:
  - o Active transport
  - o Endocytosis
  - o Exocytosis
  - o Transcytosis

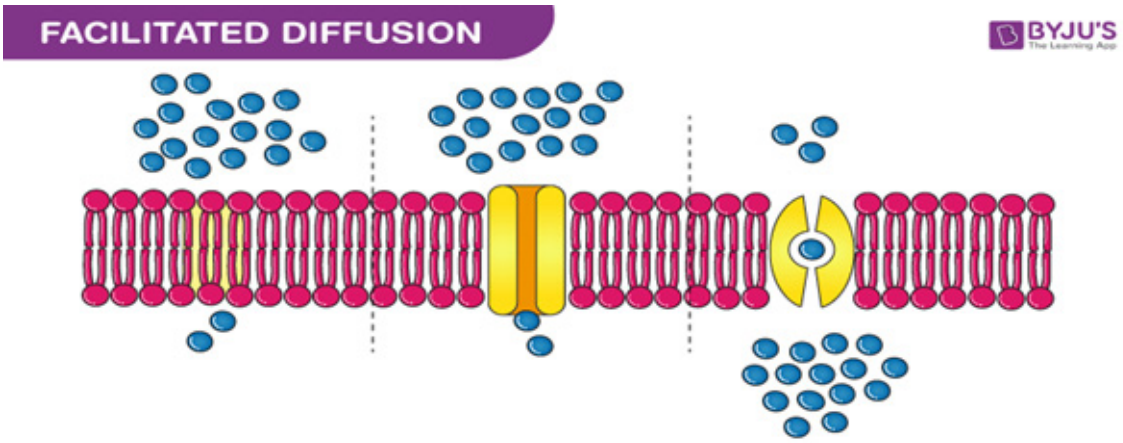
Simple Diffusion

- Movement of substances from regions of higher concentration to regions of lower concentration.
- Oxygen, carbon dioxide and lipid-soluble substances.



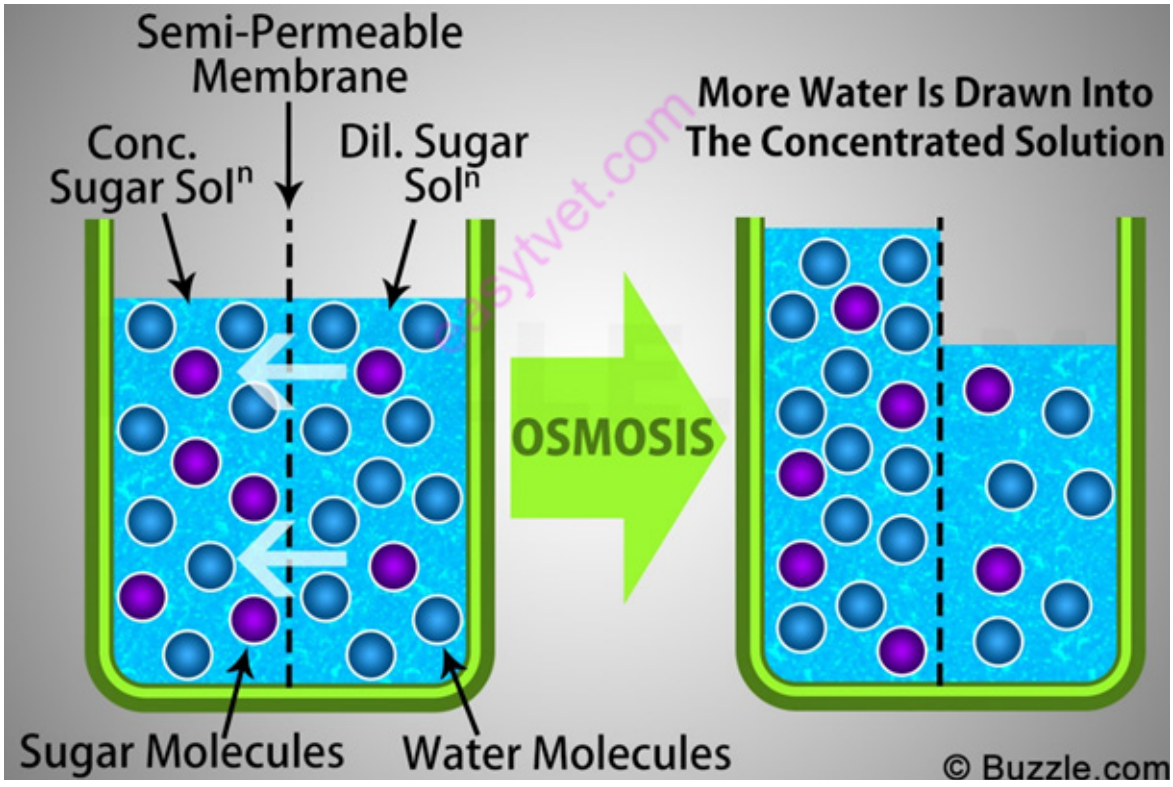
Facilitated Diffusion Facilitated Diffusion

- Diffusion across a membrane with the help of a channel or carrier molecule.
- Carrier molecule are site specific, limited in number therefore transports a limited amount of substances at any time.-transport maximum.
- Glucose and amino acids.



Osmosis

Movement of water, from a region of lower solute concentration to a region of higher solute concentration through a semi permeable membrane. Water moves toward a higher concentration of solutes.



Osmosis and Osmotic Pressure

Osmotic Pressure – ability of osmosis to generate enough pressure to move a volume of water

Osmotic pressure increases as the concentration of solutes increases.

Isotonic – same osmotic pressure

Hypertonic – is one where the concentration of solutes is greater outside the cell than inside it.

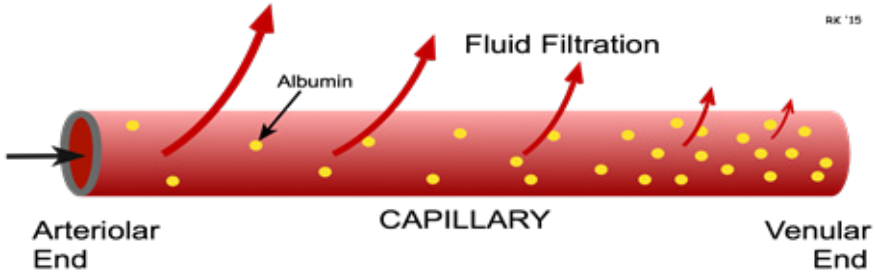
Hypotonic – is one where the concentration of solutes is lower outside the cell than inside it.

Filtration

Smaller molecules are forced through porous membranes

Hydrostatic pressure important in the body

Molecules leaving blood capillaries

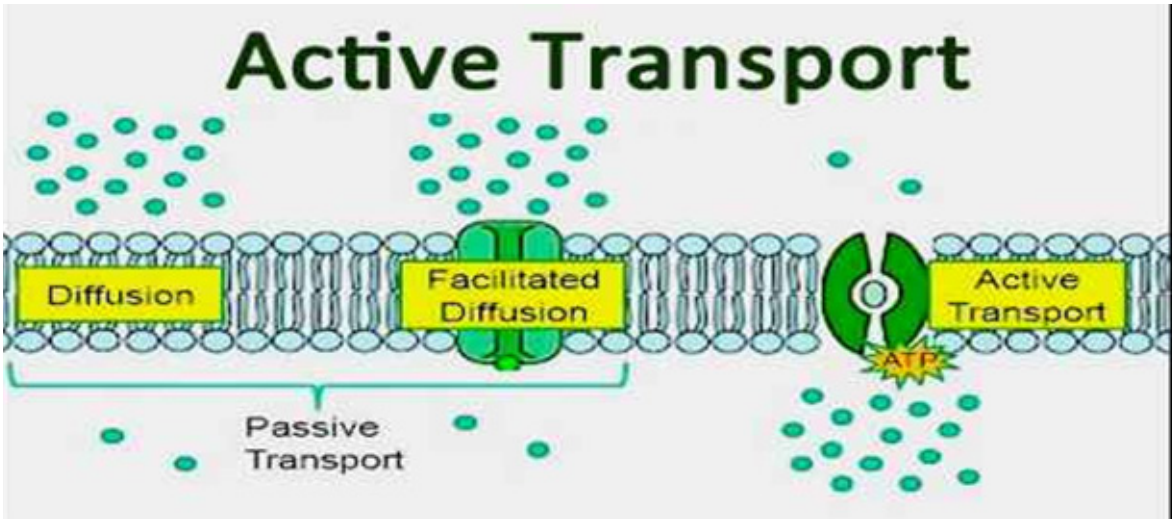


Active Transport

Carrier molecules transport substances across a membrane from regions of lower concentration to regions of higher concentration

Primary Active Transport—It uses energy in form of ATP to move molecules from a region of lower concentration to region of higher concentration.

Sugars, amino acids, sodium ions, potassium ions, etc. uses ATP Moves in both directions Site specificity.



Active Transport: Sodium-Potassium Pump

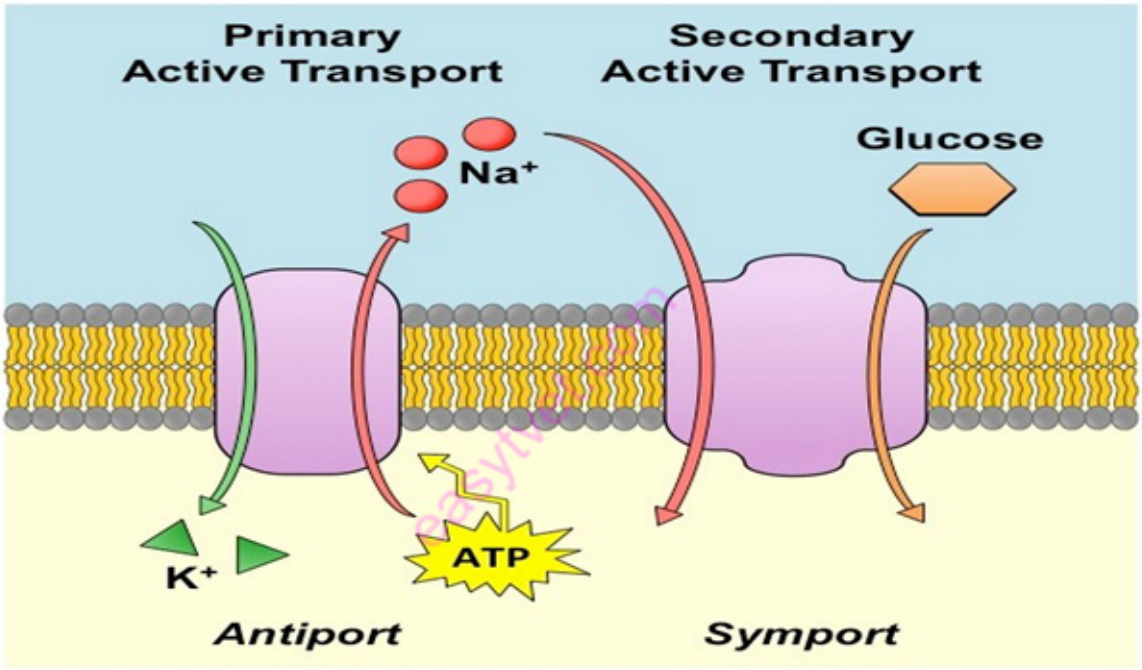
Active transport mechanism

Creates balance by "pumping" three (3) sodium (Na+) OUT and two (2) potassium (K+) INTO the cell 3:2 ratio K+ is intracellular and Na + extracellular and they diffuse down the concentration gradient. Na+ constantly pumped out of the cell in exchange for K +

Secondary Active Transport

Also called **co-transport**. Uses the energy stored in a concentration gradient. The gradient is established through active transport.

Symporters move substances in the same direction while **Antiporters** move substances in opposite directions.

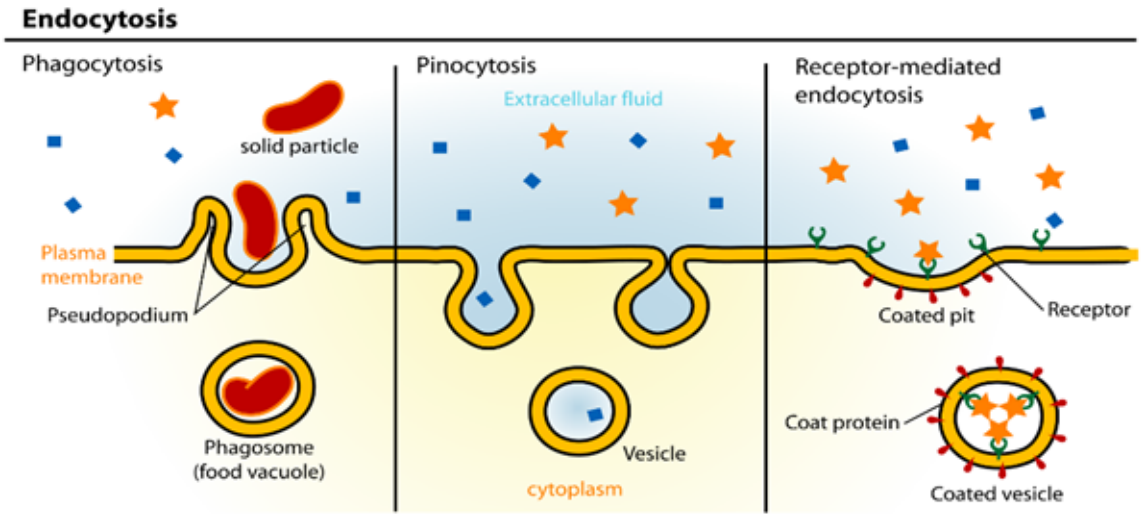


Endocytosis

Cell engulfs a substance by forming a vesicle around the substance

Three types:

- Pinocytosis – substance is mostly water
- Phagocytosis – substance is a solid
- Receptor-mediated endocytosis – requires the substance to bind to a membrane-bound receptor.



Exocytosis

Reverse of endocytosis

- Substances in a vesicle fuse with cell membrane
- Contents released outside the cell
- Release of neurotransmitters from nerve cells

Transcytosis

Endocytosis is followed by exocytosis

- Transports a substance rapidly through a cell
- HIV crossing a cell layer.

Maintenance and Variations in Membrane Potentials

Action Potential Definition of Terms

Action potential is a change in electrical potential associated with the passage of an impulse along the membrane of a muscle cell or a nerve cell.

Excitable membrane cell membrane that regulates the movement of ions so that an electrical signal can be generated.

An **action potential** is generated by the rapid influx of Na+ ions followed by a slightly slower efflux of K+ ions.

Membrane potential distribution of charge across the cell membrane, based on the charges of ions.

Resting membrane potential the difference in voltage measured across a cell membrane under steady-state conditions, it is typically -70 mV.

Depolarization change in a cell membrane potential from rest toward zero. Also defined as a change within a cell, during which the cell undergoes a shift in electric charge distribution, resulting in less negative charge inside the cell.

Repolarization is the return of the membrane potential to its normally negative voltage at the end of the action potential.

Refractory period time after the initiation of an action potential when another action potential cannot be generated

Hyperpolarization is a change in a cell's membrane potential that makes it more negative.

Relative refractory period time during the refractory period when a new action potential can only be initiated by a stronger stimulus than the current action potential because voltage-gated K+ channels are not closed.

Absolute refractory period time during an action period when another action potential cannot be generated because the voltage-gated Na+ channel is inactivated.

Electrochemical exclusion principle of selectively allowing ions through a channel on the basis of their charge.

Size exclusion principle of selectively allowing ions through a channel on the basis of their relative size

Gated property of a channel that determines how it opens under specific conditions, such as voltage change or physical deformation.

Inactivation gate part of a voltage-gated Na+ channel that closes when the membrane potential reaches +30 mV

Leakage channel ion channel that opens randomly and is not gated to a specific event, also known as a non-gated channel.

Ligand-gated channels another name for an ionotropic receptor for which a neurotransmitter is the ligand.

Voltage-gated channel—is an ion channel that opens because of a change in the charge distributed across the membrane where it is located

Mechanically gated channel ion channel that opens when a physical event directly affects the structure of the protein.

Ionotropic receptor neurotransmitter receptor that acts as an ion channel gate, and opens by the binding of the neurotransmitter.

Nonspecific channel a channel that is not specific to one ion over another, such as a nonspecific cation channel that allows any positively charged ion across the membrane.

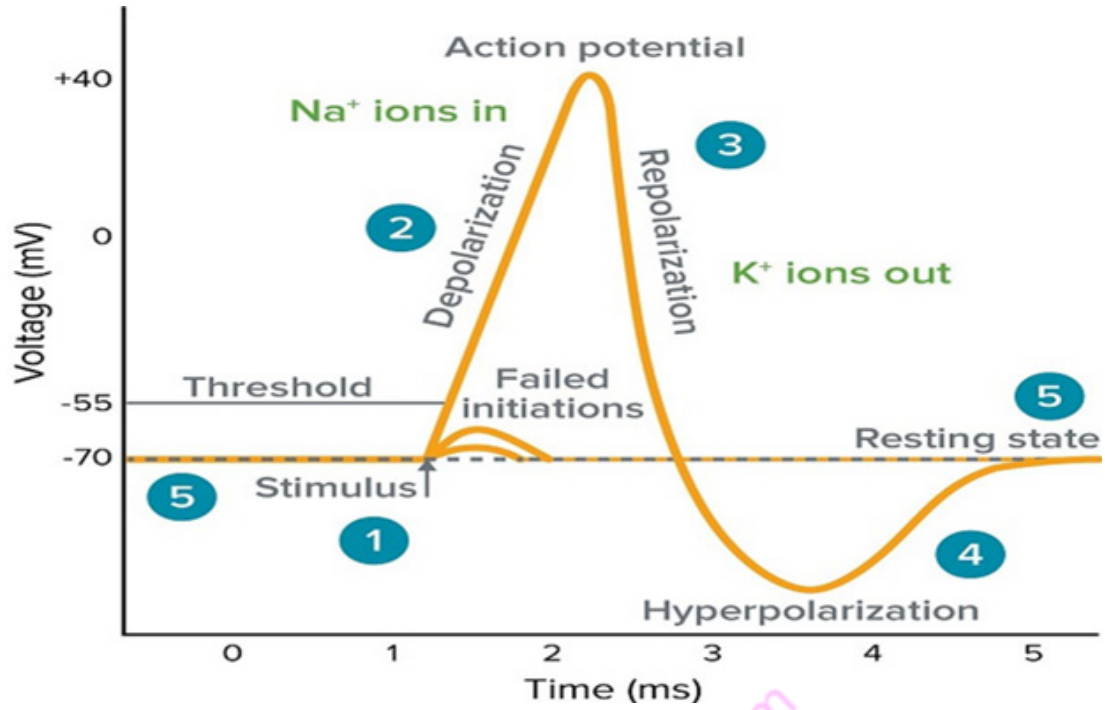
Inactivation gate part of a voltage-gated Na+ channel that closes when the membrane potential reaches +30 mV

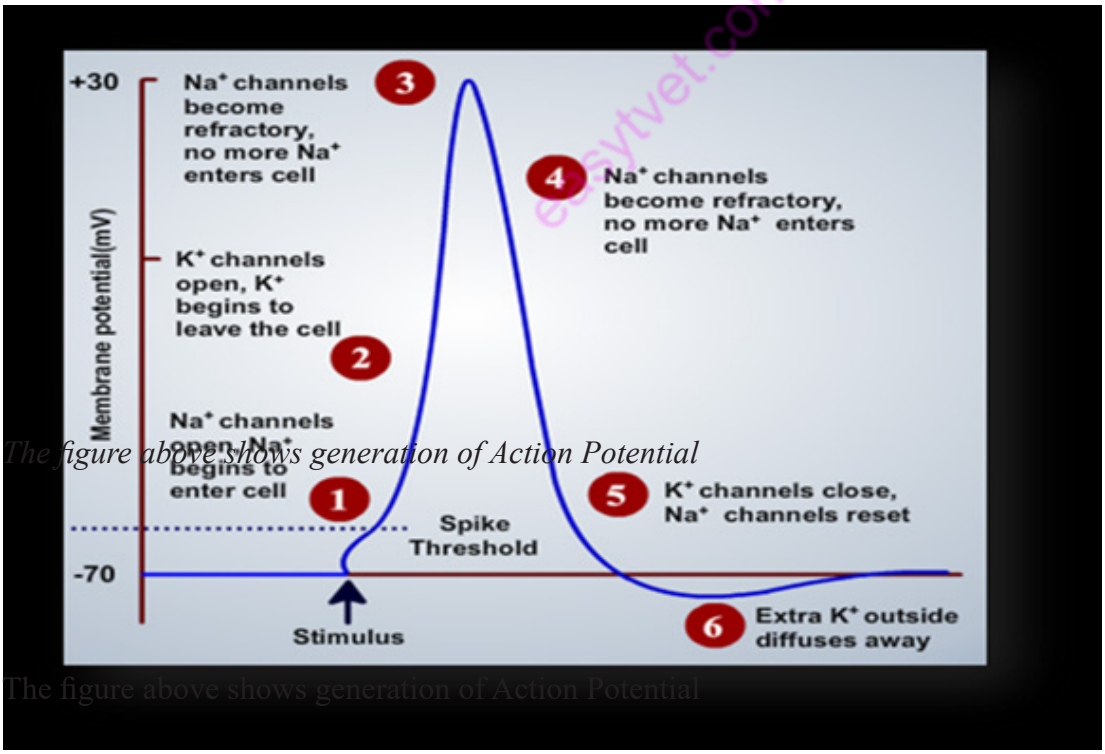
Continuous conduction slow propagation of an action potential along an unmyelinated axon owing to voltage-gated Na+ channels located along the entire length of the cell membrane.

Saltatory conduction quick propagation of the action potential along a myelinated axon owing to voltage-gated Na+ channels being present only at the nodes of Ranvier.

Resistance property of an axon that relates to the ability of particles to diffuse through the cytoplasm; this is inversely proportional to the fiber diameter

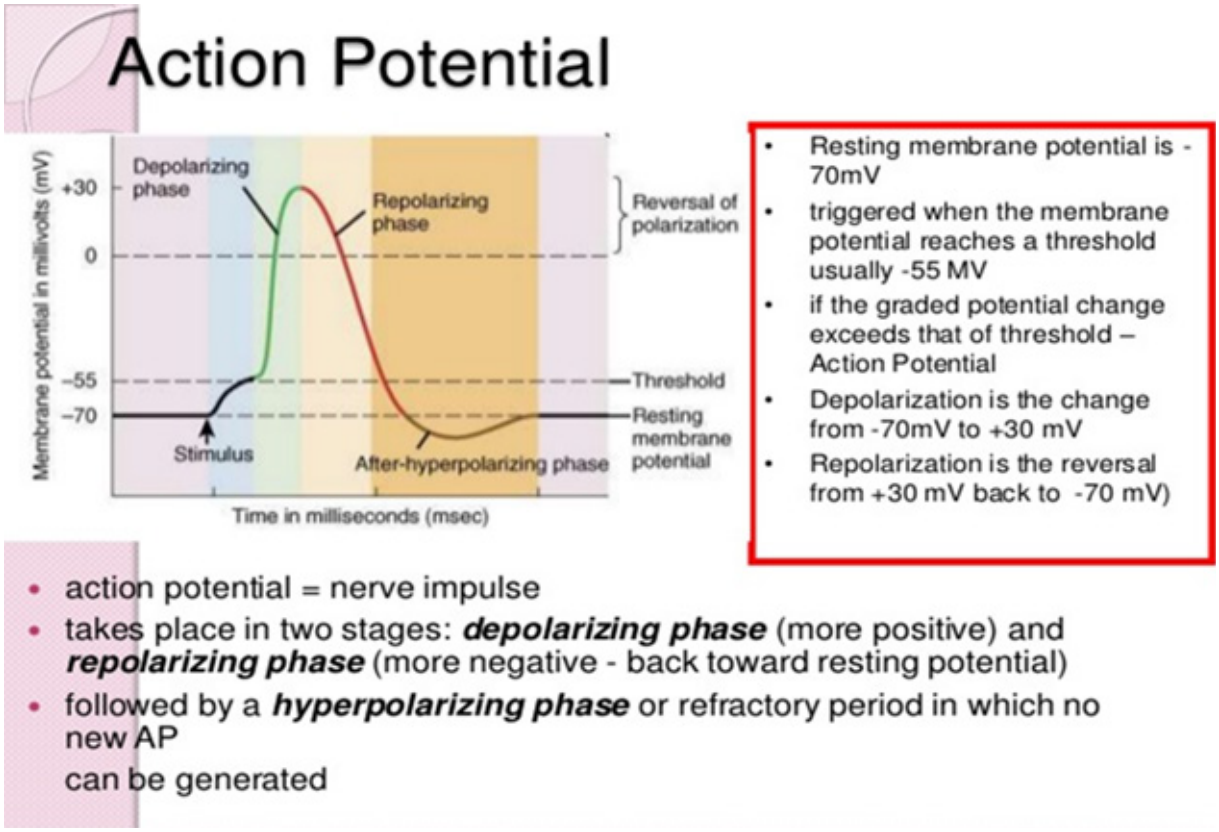
Action Potential





The figure above shows generation of Action Potential

The figure above shows generation of Action Potential



The Buffering System of the Body

Acids, Alkalis and pH

An acid: a substance that produces hydrogen ions when dissolved. Acids act as electrolytes in water. They neutralize bases to produce salt and water. Common acids are hydrochloric acid and carbonic acid.

A base: a substance that reacts with acid to form salt and water by acepting hydrogen ions and oftenly releasing hydroxyl (OH-) ions.

Common bases are magnesium hydroxide and aluminium hydroxide.

The balance between acids and bases must be maintained for the various processes in the body to take place optimally.

Number of H+ present in a solution is a measure of the acidity of the solution.

Maintenance of the normal H+ concentration within the body is an important factor in maintaining homeostasis.

The pH scale

Def: A standard scale for the measurement of the hydrogen ion concentration in solution.

Not all acids ionize completely when dissolved in water. The hydrogen ion concentration is a measure, therefore, of the amount of dissociated acid (ionized acid) rather than of the total amount of acid present. Strong acids dissociate more freely than weak acids, e.g. hydrochloric

acid dissociates freely into H+ and Cl~, while carbonic acid dissociates much less freely into H+ and HCO3-.

Alkalinity of a solution depends on the number of hydroxyl ions (OH-). Water is a neutral solution because every molecule contains one hydrogen ion and one hydroxyl radical.

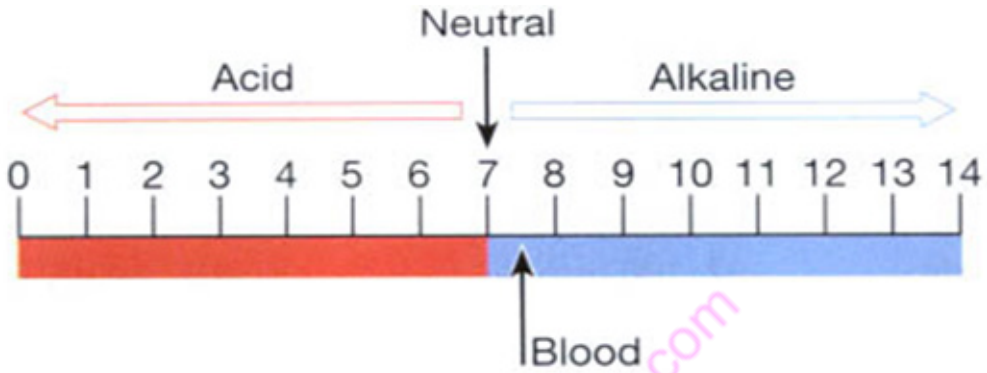
pH scale was developed taking water as the standard.

In a neutral solution such as water, where the number of hydrogen ions is balanced by the same number of hydroxyl ions, the pH = 7.

A pH reading below 7 indicates an acid solution, while readings above 7 indicate alkalinity.

A change of one whole number on the pH scale indicates a tenfold change in [H+]. Therefore, a solution of pH 5 contains ten times as many hydrogen ions as a solution of pH 6.

Ordinary litmus paper colors blue for alkalinity and red for acidity.



PH Values of Body Fluids

Vary.

pH value in an organ is produced by its secretion of acids or alkalis which establishes the optimum level.

Body fluid	pH
Blood	7.35 to 7.45
Saliva	5.4 to 7.5
Gastric juice	1.5 to 3.5
Bile	6 to 8.5
Crossing over does not take place	4.5 to 8.0

Buffering Systems in the Body

Buffering mechanisms temporarily neutralize fluctuations in pH thus keeping it stable within its normal limits.

The lungs and the kidney are the most active organs in buffering.

Lungs regulate CO2 levels in the body by either ⬆ or ⬇ breathing.

Kidneys regulate pH by either ⬆ or ⬇ excretion of hydrogen and bicarbonate ions as required.

Other buffer systems include **body proteins** and **phosphate**.

Buffer substances/systems help maintain the Acid-Base balance so that the pH remains within normal, but narrow, limits

Acidosis and Alkalosis

When the pH is below 7.35, and all the reserves of alkaline buffer are used up, the condition of **acidosis exists** (**Acidosis** is an increased acidity in the blood and other body tissue).

When the reverse situation persists and the pH is above 7.45, and the increased alkali uses up all the acid reserve, the state of **alkalosis exists** (**Alkalosis** refers to a condition reducing hydrogen ion concentration of arterial blood plasma)

3.3.2.3 Self-Assessment

1. Differentiate between a stem cell and a progenitor cell.
2. State four buffering mechanisms in the body.
3. The following bases take part in buffering human body. Which one is not?

   A. Magnesium hydroxide B. Aluminum hydroxide.

   C. Sodium hydroxide D. Potassium hydroxide

4. Briefly explain four physical processes that are used to move substances in and out of the cell.
5. Define the following terms; action potential, depolarization, repolarization and refractory period.

3.3.2.4 Tools, Equipment, Supplies and Materials

Slides, anatomy textbooks, white board, mark pen, skills laboratory demonstration.

3.3.2.5 References

Waugh A. & Grant A. (2016) Ross and Wilson Anatomy & Physiology 12th Edition; Churchill Livingstone

Bartholomew E.F. & Martini F.H. (2019) Essentials of Anatomy and Physiology; 8th Edition

Elaine N. & Katja H., 2016: Humana Anatomy and Physiology, 5th Edition

Barrett K.E., Barman S.M., Yuan J. & Brooks H.L. (2019) Ganong's Review of Medical Physiology, Twenty sixth Edition 26th Edition; McGraw-Hill Education

3.3.3 Learning outcome 3: Demonstrate the knowledge of the human body systems

3.3.3.1 Learning Activities

Learning activity	Special instructions
Identify the components of the human body systems as per the workplace procedures	The components of the human body systems • Describe the structure of a neuron • Demonstrate knowledge of the central nervous system • Illustrate knowledge of the functions of the brain • Demonstrate knowledge of the functions of the spinal cord • Describe the peripheral nervous system • Describe the somatic and autonomic nervous system
Identify relevant principles of the body systems to performance of therapy	Demonstrate understanding of relevant principles of the body systems to performance of therapy treatment
Apply relevant principles of the body systems to performance of therapy treatment as per the workplace procedures	Relevant functions of the body systems • The nervous system • The cardiovascular system • The respiratory system • The renal system • Musculoskeletal system • Reproductive system • Skin • Gastrointestinal system • Endocrine system • Special senses

3.3.3.1 Information sheet

Relevant Functions of the Body's Systems

The Nervous System

Introduction

Nervous system detects and responds to changes inside and outside the body. Consists of the brain, the spinal cord and peripheral nerves. Nervous system is divided into two main areas:

1. Central Nervous System (CNS); the brain and the spinal cord
2. Peripheral Nervous System (PNS); all the nerves outside the brain and spinal cord.

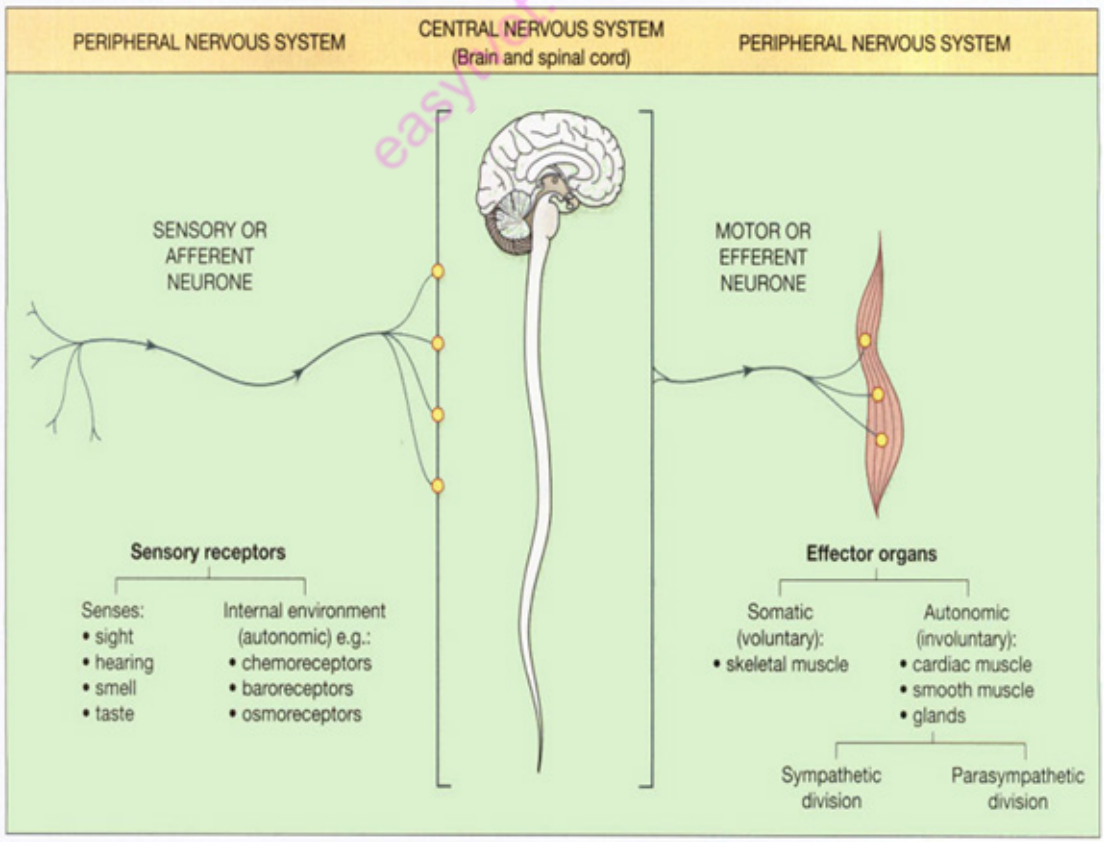
PNS has two functional parts:

1. The sensory division
2. The motor division

Motor division is involved in activities that are:

Voluntary —the **somatic nervous system** (movement of voluntary muscles)

Involuntary — the **autonomic nervous system (ANS)** (functioning of smooth and cardiac muscle and glands) which has 2 parts: ***sympathetic and parasympathetic***



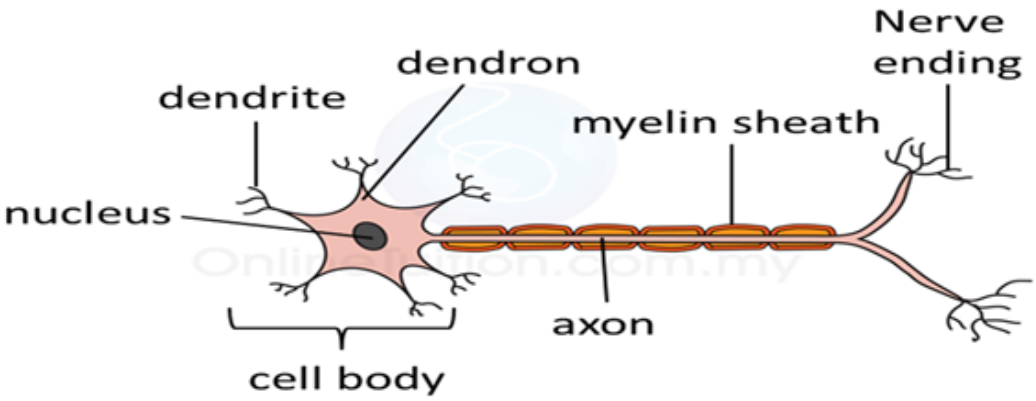
Functional components of the nervous system.

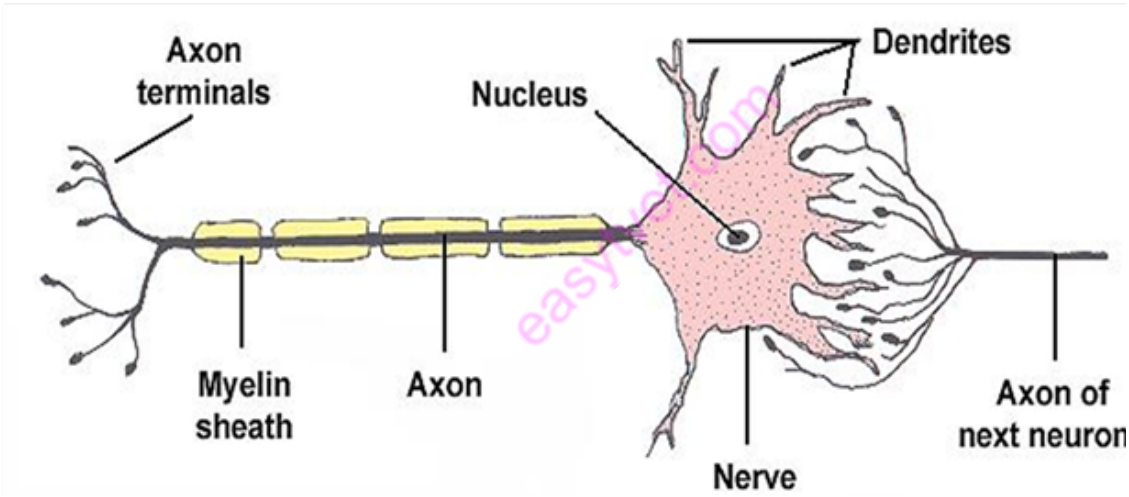
Cells and Tissues of the Nervous System

NEURONES

Neurones are nerve cells. Each neurone consists of a cell body and its processes, one axon and many dendrites.

Nerves: group/bundle of axons and/or dendrites of many neurons bound together.





Properties of Neurons

Have the characteristics of irritability and conductivity.

Irritability: ability to initiate nerve impulses in response to stimuli from: outside the body, e.g. touch, light waves Inside the body, e.g. a change in the CO2 concentration in the blood alters respiration.

Conductivity: ability to transmit an impulse.

Neuron Anatomy

Cell body

- Nucleus
- Large nucleolus

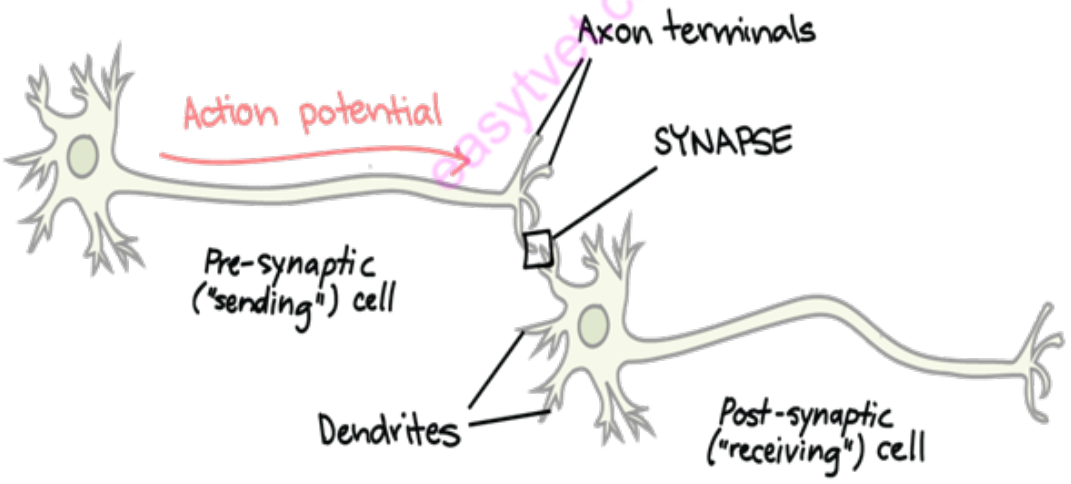
Extensions outside the cell body

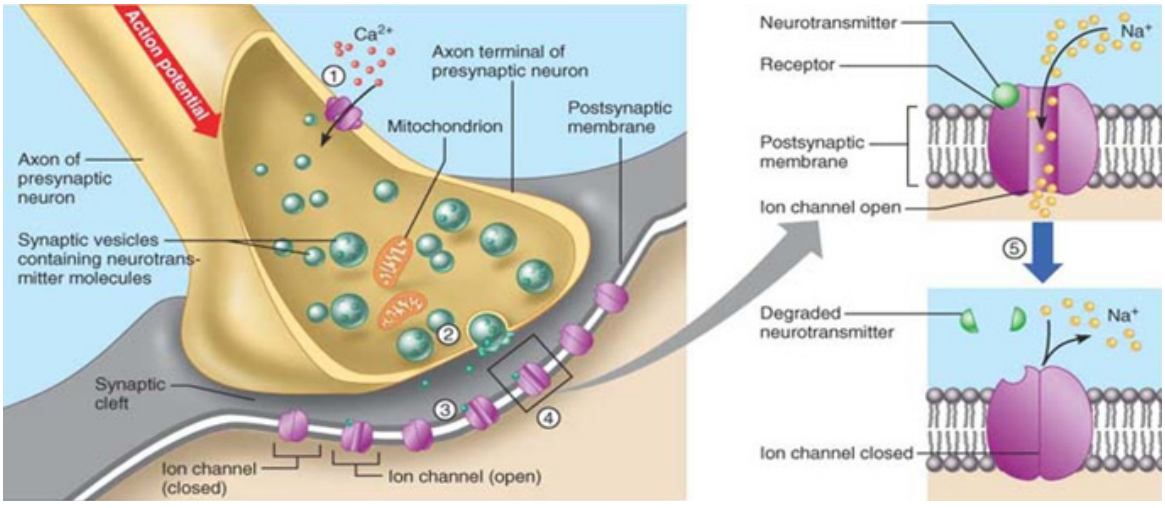
Dendrites – conduct impulses toward the cell body

Axons – conduct impulses away from the cell body

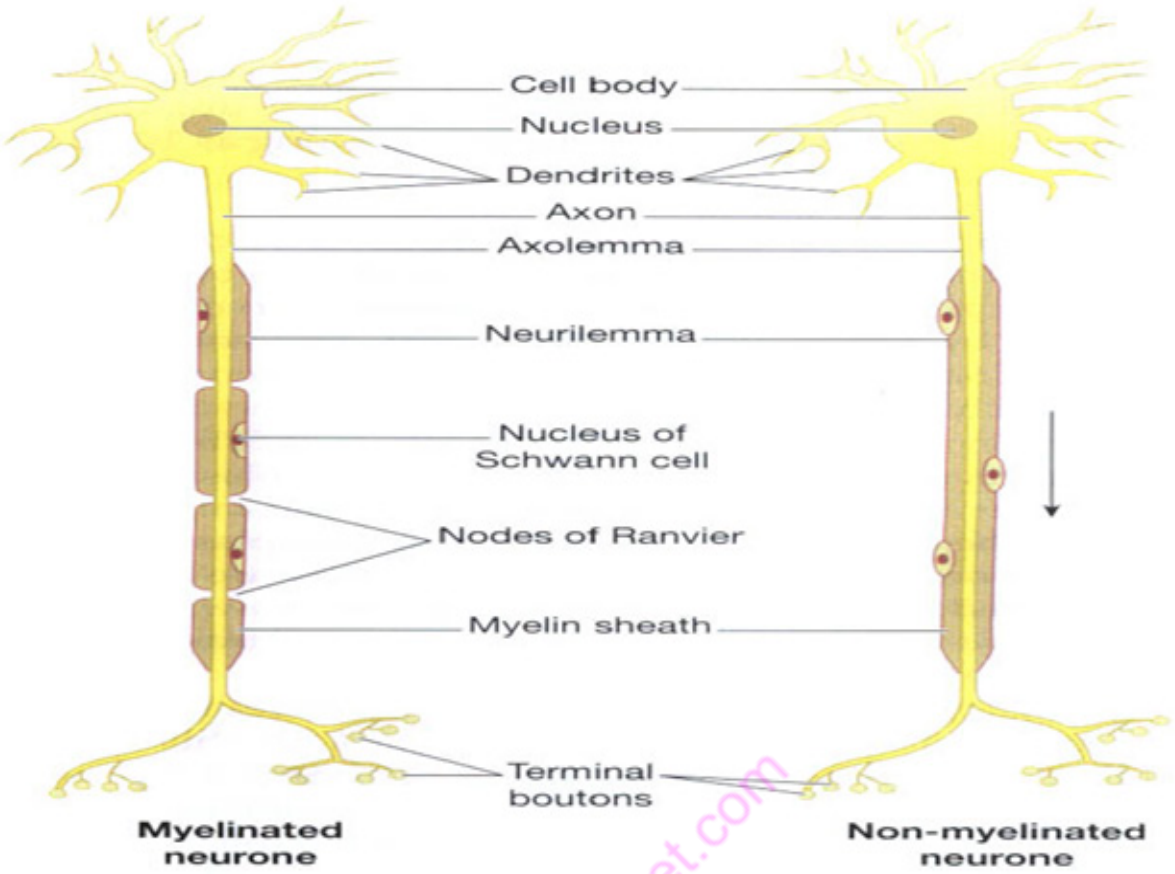
- Usually neurons have only one axon but may have many dendrites
- Axons end in axonal terminals
- Axonal terminals contain tiny vesicles or sacs which store neurotransmitters
- Axonal terminals are separated from the next neuron by a tiny gap called
- **Synaptic cleft** – gap between adjacent neurons
- **Synapse** – junction between nerves

Diagram Showing a Synapse and synaptic cleft

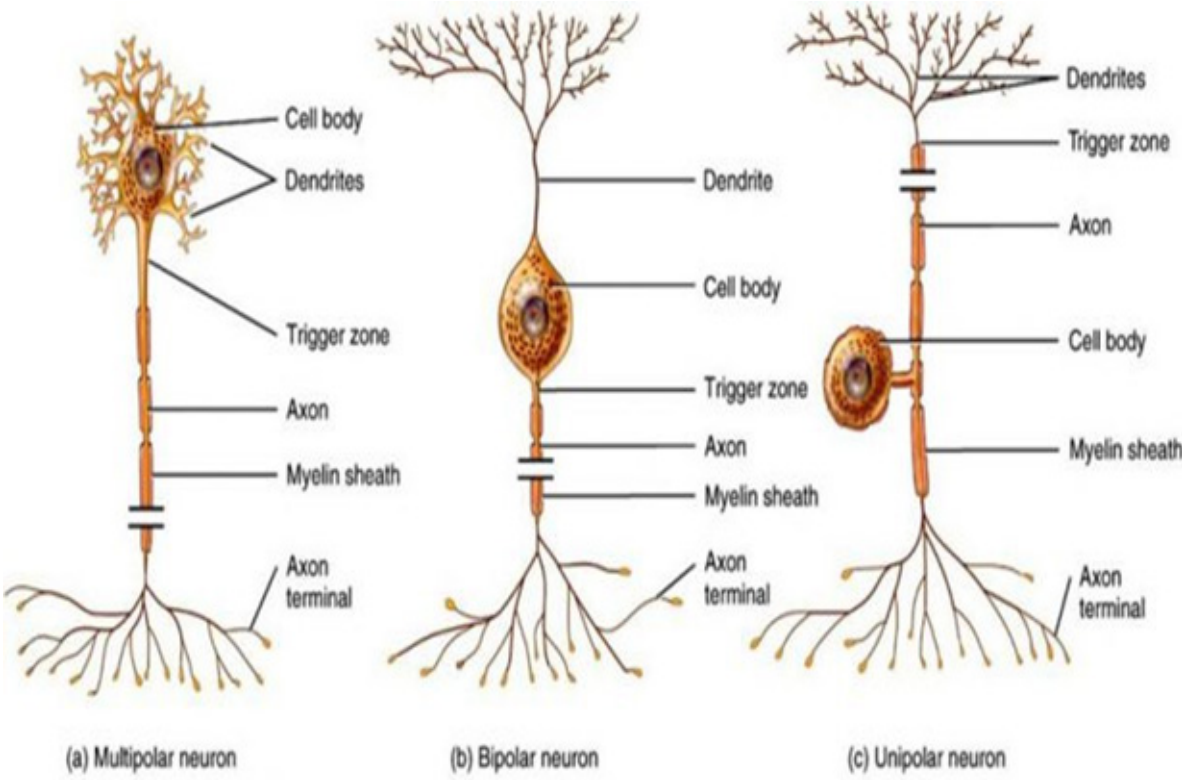




Most long **nerve fibers** (axon) are covered with a whitish fatty material **(myelin). Myelin** protects and insulates the fibers and increase the rate of transmission of the nerve impulses.



Neuron Classification by Shape



Nervous System Communication

Communication between neurons takes place via **electrical impulses.**

Nerve impulse propagation occurs via **action potential.**

Action potential is a change in electrical potential associated with the passage of an impulse along the membrane of a muscle cell or a nerve cell.

Excitable membrane cell membrane that regulates the movement of ions so that an electrical signal can be generated.

Neurotransmitters include:

- Noradrenaline,
- Acetylcholine,
- Serotonin (5-hydroxytryptamine),
- Endorphins
- Gamma ammo- butyric acid (gaba),
- Dopamine,
- Enkephalins,
- Substance p.

Nerves

A nerve consists of numerous neurons collected into bundles

Types of Neurons

a) Sensory or Afferent Nerves

Transmit action potentials (information) generated by sensory receptors on the body to the spinal cord which is then carried to the brain.

Sensory receptors are specialized nerve endings that respond to different stimuli (changes). Various types to include:

- *Somatic, cutaneous or common senses:* Originate in the skin. They are: pain, touch, heat and cold.
- *Proprioceptor senses.* Originate in muscles and joints and contribute to the maintenance of balance and posture.
- *Special senses.* Sight, hearing, smell, touch and taste.
- *Autonomic afferent nerves.* Originate in internal organs, glands and tissues, e.g. baroreceptors, chemoreceptors, and are associated with reflex regulation of involuntary activity and visceral pain.

b) Motor or Efferent Nerves

Originate in the brain, spinal cord and autonomic ganglia and transmit impulses to the effector organs: muscles and glands. 2 types:

- *Somatic nerves:* involved in voluntary movement and reflexes
- *Autonomic nerves:* involved in cardiac and smooth muscle contraction and glandular secretion

c) Mixed Nerves

Occur outside the spinal cord, when sensory and motor nerves are enclosed within the same sheath of connective tissue e.g. sciatic nerve.

Neuroglia

Neurones of the CNS are supported by 4 types of non-excitable glial cells that make up a quarter to a half of the volume of brain tissue.

Unlike nerve cells these continue to replicate throughout life.

They are :

- Astrocytes,
- Microglia
- Oligodendrocytes,
- Ependymal cells.

Name	Function
Astrocytes	Support neurons, help maintain K+ level, contribute to the blood-brain barrier (BBB)
Oligodendrocytes	Produce the myelin sheath to electrically insulate neurons of the CNS, provide support
Microglia	Capable of movement and phagocytosis of pathogens and damaged tissue
Ependymal cells	Line the ventricles of the brain; many of the cells have cilia; involved in circulation of CSF

Central Nervous System

The Meninges

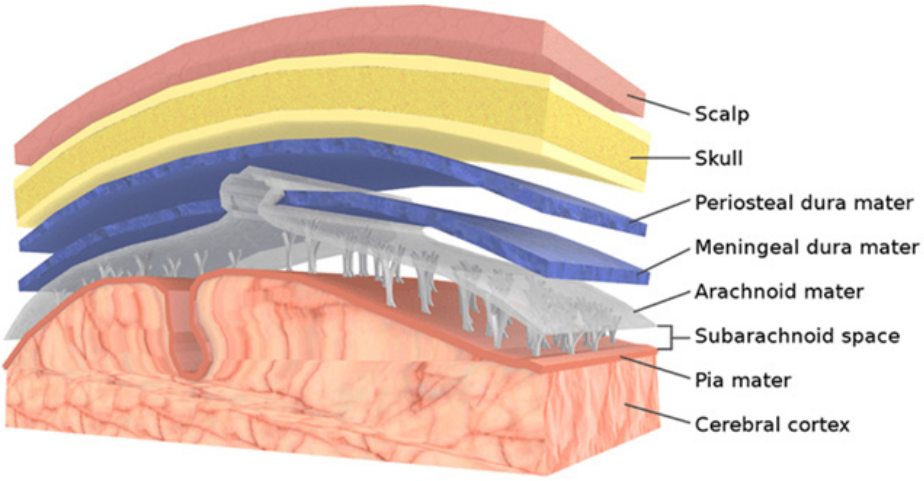
These are tissue membranes that cover the brain and spinal cord.

Has 3 layers of tissue named from outside inwards; they are:

- Dura mater
- Arachnoid mater
- Pia mater

Dura and **arachnoid** maters are separated by a potential space, the **subdural space.**

Arachnoid and **pia** maters are separated by the **subarachnoid** space, containing **cerebrospinal fluid.**



Ventricles of the Brain and the Cerebrospinal Fluid

The brain contains 4 irregular-shaped cavities called Ventricles containing **cerebrospinal fluid (CSF).**

They are:

- Right lateral ventricle
- Left lateral ventricle
- Third ventricle
- Fourth ventricle.

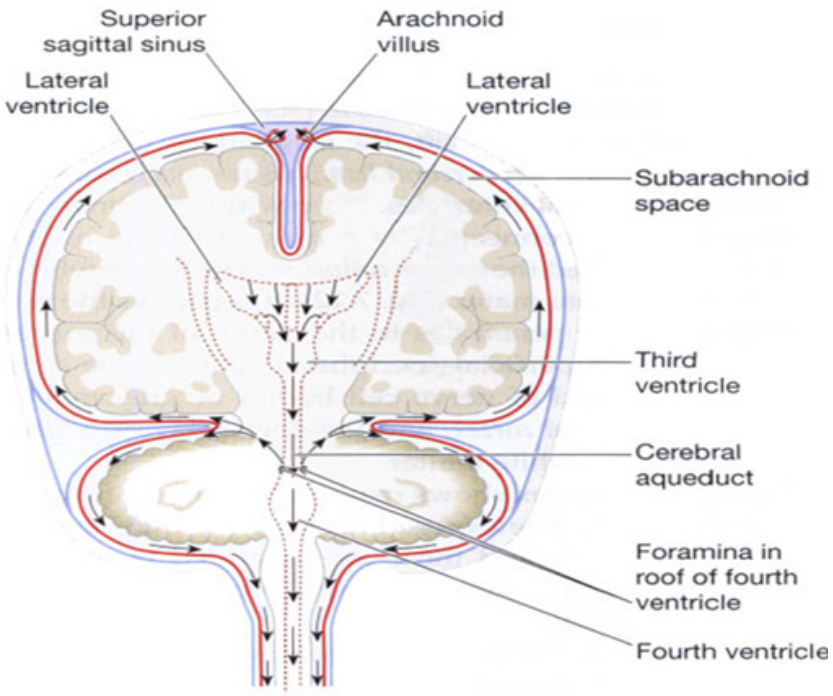
Cerebrospinal Fluid

CSF is secreted into each ventricle of the brain by **choroid plexuses**; a capillary of network that forms cerebrospinal fluid from blood plasma.

CSF passes back into the blood through tiny diverticula of arachnoid mater, called **arachnoid villi.**

CSF is a clear, slightly alkaline fluid found in the brain and spinal cord, consisting of:

- Water
- Mineral salts
- Glucose
- Plasma proteins: small amounts of albumin and globulin
- Creatinine (small amounts)
- Urea (small amounts)
- A few leukocytes.



Functions of CSF

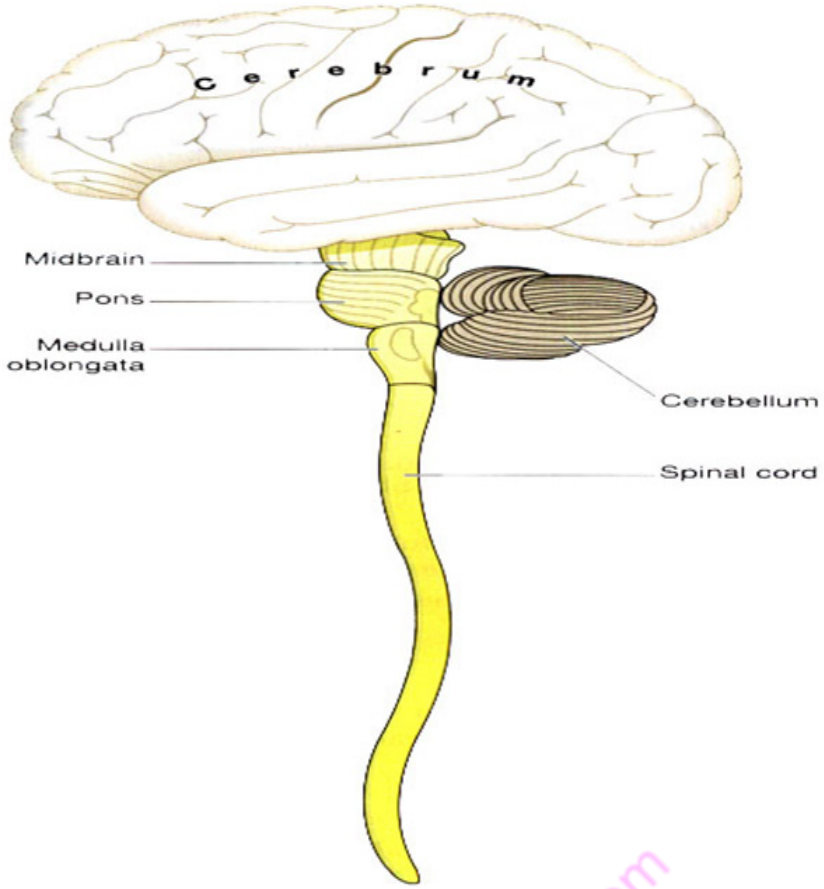
- It is involved in the exchange of substances, for example, nutrients between the CSF and the nerve cells.
- It keeps the brain and spinal cord moist.
- It is a shock absorber for the brain, spinal cord and nerves.
- It supports the brain and spinal cord and protects them by maintaining pressure around the delicate structures in a uniform manner.

The Brain

Constitutes about one-fiftieth of the body weight and lies within the cranial cavity.

The parts are

- Cerebrum
- Hypothalamus
- Pons
- Cerebellum
- Thalamus
- Midbrain
- Medulla oblongata



Cerebrum

It is the largest part of the brain & occupies the anterior and middle cranial fossae.

Cerebral cortex shows many infoldings of varying depth.

Exposed areas of the folds are the gyri or convolutions and these are separated by **sulci** or **fissures.**

Convolutions greatly increase the surface area of the cerebrum.

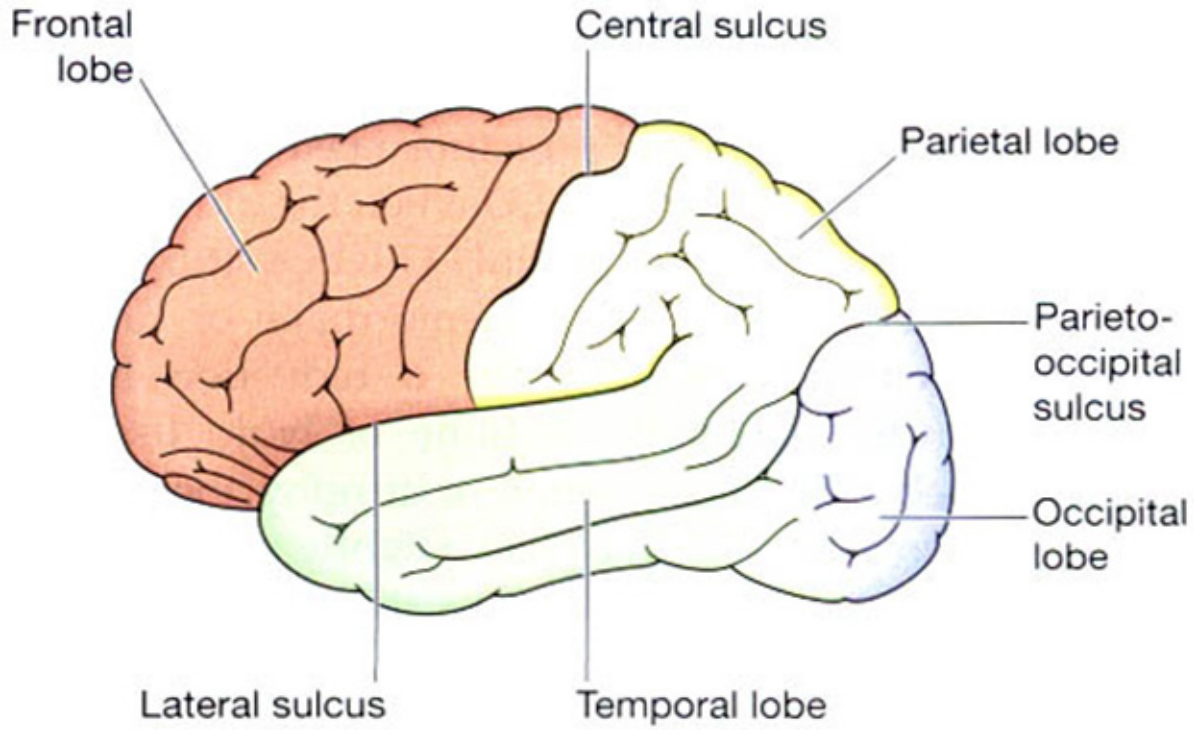
Cerebral cortex is divided into **lobes** that have the same names as the cranial bones under which they lie:

The lobes include:

- Frontal lobe
- Parietal lobe
- Temporal lobe
- Occipital lobe

Boundaries of the lobes are marked by deep sulci (fissures). They include:

- Central sulci
- Lateral sulci
- Parieto-occipital sulci



The lobes and sulci of the cerebrum

Functions of the Cerebral Cortex

- Mental activities involved in memory, intelligence, sense of responsibility, thinking, reasoning, moral sense and learning.
- Sensory perception, including the perception of pain, temperature, touch, sight, hearing, taste and smell
- Initiation and control of skeletal (voluntary) muscle contraction.

Functional Areas of the Cerebrum

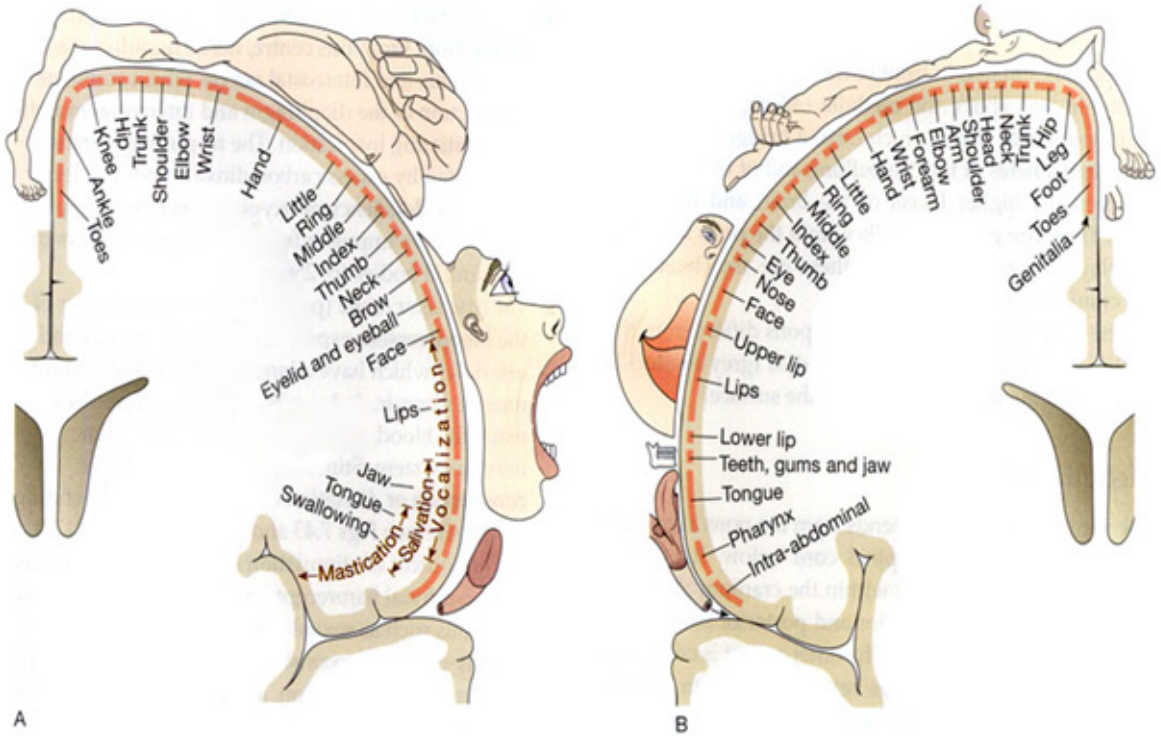
A) Motor Areas of the Cerebrum

1. The primary motor area.

Lies in the frontal lobe immediately anterior to the central sulcus. Its cell bodies control **skeletal muscle activity.**

2. The Motor Speech (Broca's area)

Lies in the frontal lobe just above the lateral sulcus and it controls the movements of muscles necessary for speech.



The motor homunculus showing body representation in the motor area of the cerebrum (A) & sensory area (B) of the cerebrum

B) Sensory Areas of the Cerebrum

1. The Somatosensory Area.

Lies behind the central sulcus.

Perceives sensations of pain, temperature, pressure and touch, knowledge of muscular movement and the position of joints (proprioception).

2. The Auditory (hearing) Area.

Lies immediately below the lateral sulcus within the temporal lobe. It is involved in hearing.

3. The Olfactory (Smell) Area

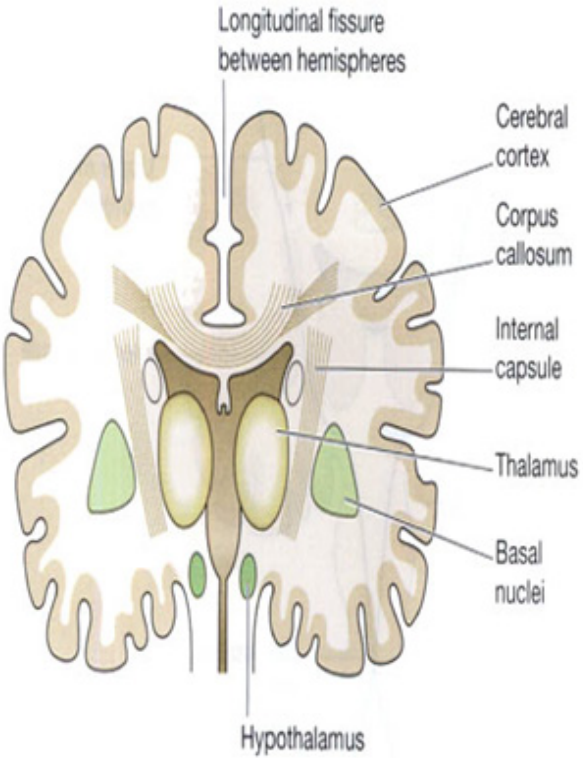
Lies deep within the temporal lobe and is involved with smell.

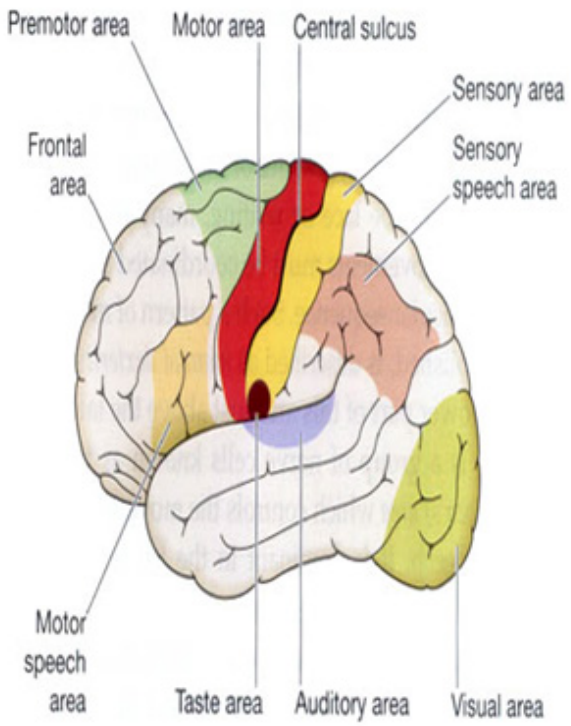
4. The Taste Area

Lies just above the lateral sulcus in the deep layers of the sensory area. Involved with taste.

5. The Visual Area

Lies behind the parieto-occipital sulcus and includes the greater part of the occipital lobe. Involved with vision.





C) Association Areas

These are areas that connected to other functional areas of the cortex and their main function is to receive, coordinate and interpret impulses from the sensory and motor areas thus permitting higher cognitive/thinking abilities.

1. The Prefrontal Area

Lies in the frontal lobe immediately anterior to the motor area. The cells exert a controlling influence over the motor area, ensuring an orderly series of movements.

2. The Frontal Area

It forms the rest of the frontal lobe. It is responsible for:

- The behavior,
- Character
- Emotional state of the individual.

3. The Sensory Speech (Wernicke's) Area

Situated in the lower part of the parietal lobe and extends into the temporal lobe. **Spoken words** are perceived here.

Diencephalon

Deep within the cerebral hemispheres there are groups of cell bodies called nuclei which act as relay stations where impulses are passed from one neurone to the next in a chain.

Important masses of grey matter include:

- Thalamus
- Hypothalamus.

Thalamus: Situated below corpus callosum. Sensory input from the skin, viscera and special sense organs is transmitted to the thalamus before redistribution to the cerebrum.

Hypothalamus: Situated below and in front of the thalamus, immediately above the ***pituitary gland.*** It controls **output of hormones** from the **pituitary gland**

- Hypothalamus also Controls:
- The autonomic nervous system
- Appetite and satiety
- Thirst and water balance
- Body temperature
- Emotional reactions, e.g. pleasure, fear, rage
- Sexual behaviour including mating and child rearing
- Biological clocks or circadian rhythms, e.g. sleeping and waking cycles, body temperature and secretion of some hormones.

Brain Stem

a) Midbrain

Situated around the cerebral aqueduct between the cerebrum above and the pons below.

Consists of nuclei and nerve fibres (tracts) which connect the cerebrum with lower parts of the brain and with the spinal cord.

The nuclei act as relay stations for the ascending and descending nerve fibres.

b) Pons

Situated in front of the cerebellum, below the midbrain and above the medulla oblongata.

Consists mainly of nerve fibres which form a bridge between the two hemispheres of the cerebellum, and of fibres passing between the higher levels of the brain and the spinal cord.

c) Medulla Oblongata

Extends from the pons above and is continuous with the spinal cord below.

Some cells constitute relay stations for sensory nerves passing from the spinal cord to the cerebrum.

The **Vital Centers**, consisting of nuclei associated with autonomic reflex activity, lie in its deeper structure. These are the:

- Cardiac center
- Respiratory center
- Vasomotor center
- Reflex center of vomiting, coughing, sneezing and swallowing.

d) Reticular Formation

A collection of neurones in the core of the brain stem.

Functions

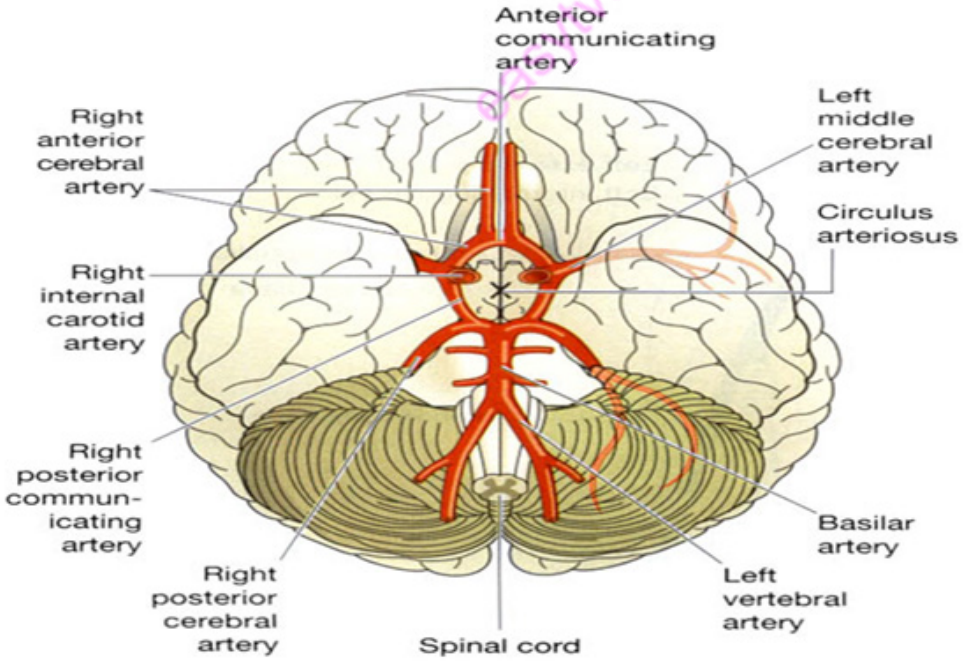
Coordination of skeletal muscle activity associated with voluntary motor movement and the maintenance of balance.

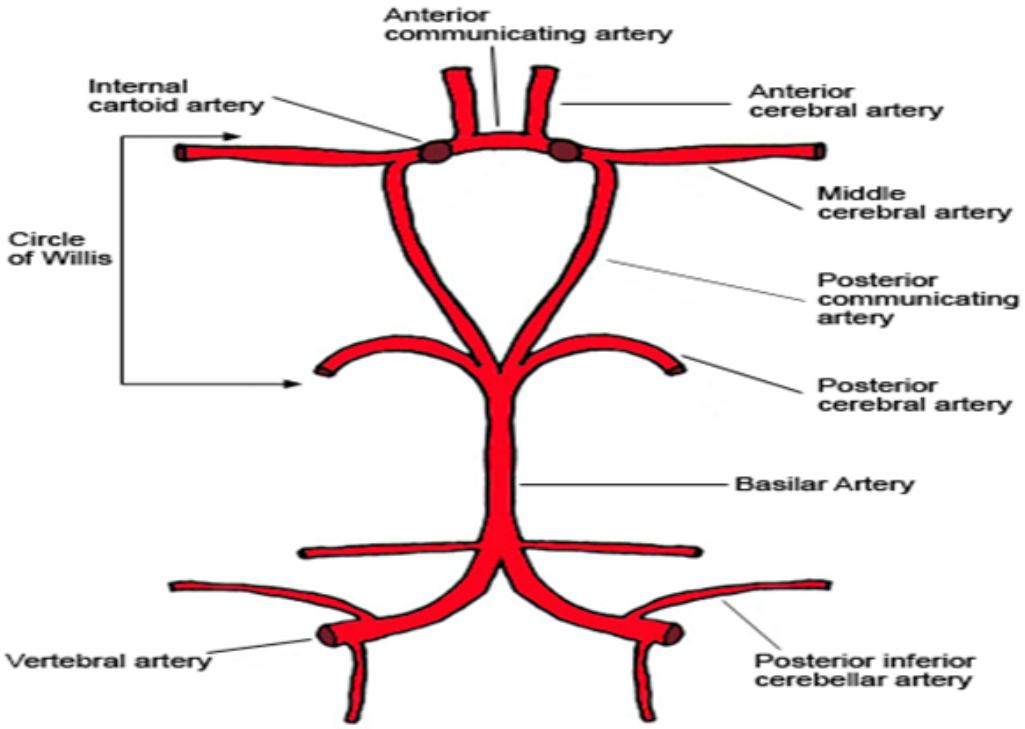
Coordination of activity controlled by the autonomic nervous system, e.g. CVS, Respiration and GIT activity.

Blood Supply to the Brain

By Circle of Willis (Circulus Arteriosus)

Receives about 15% of the cardiac output, approximately 750 ml of blood per minute.



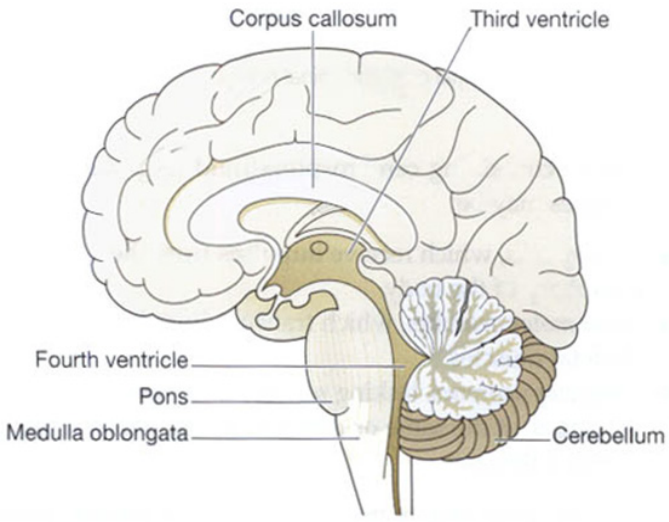


Cerebellum

Situated behind the pons and immediately below the posterior portion of the cerebrum occupying the posterior cranial fossa.

Functions

- Maintenance of balance and posture
- Coordination of voluntary movements
- Motor learning
- Cognitive functions especially language



Cerebellum and associated structures

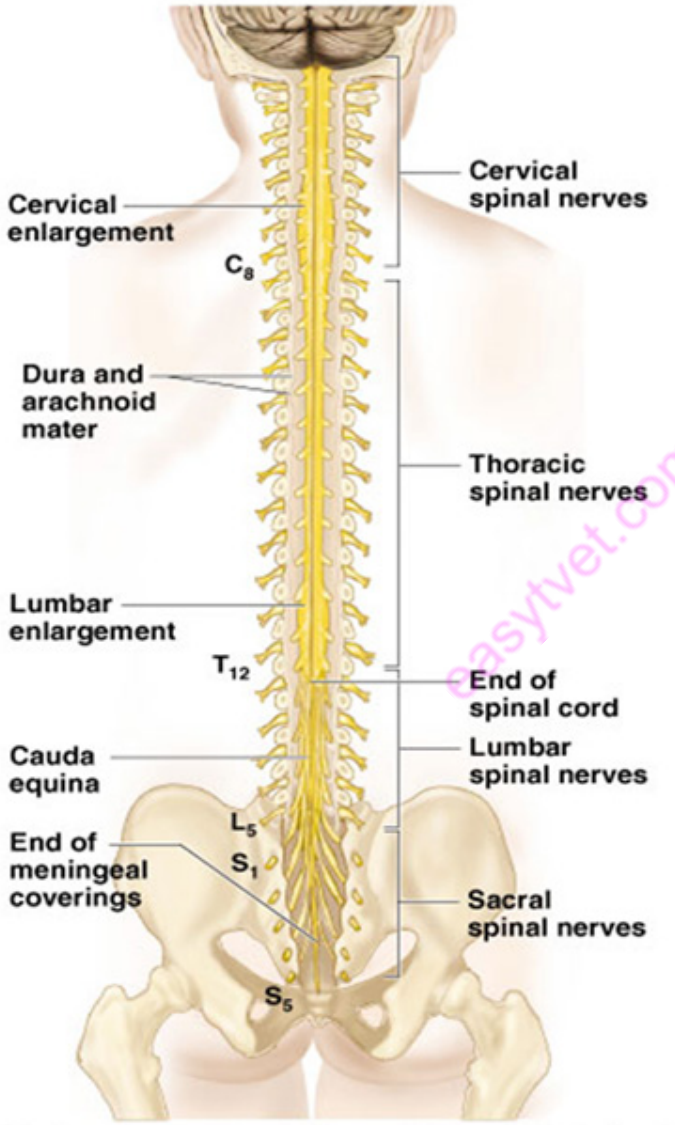
Spinal Cord

A cylindrical cord which is approximately 45cm long. It provides a two ways conduction pathways to and from the brain. It is a major reflex center, and extends from the medulla oblongata (foramen magnum) to the region of T12 or L1.

In humans 31 pairs of spinal nerves arise from it.

Enlargements occur in the cervical and lumbar regions.

Below T12 is the **cauda equina** (a collection of spinal nerves)-horses tail.



Clinical Implication

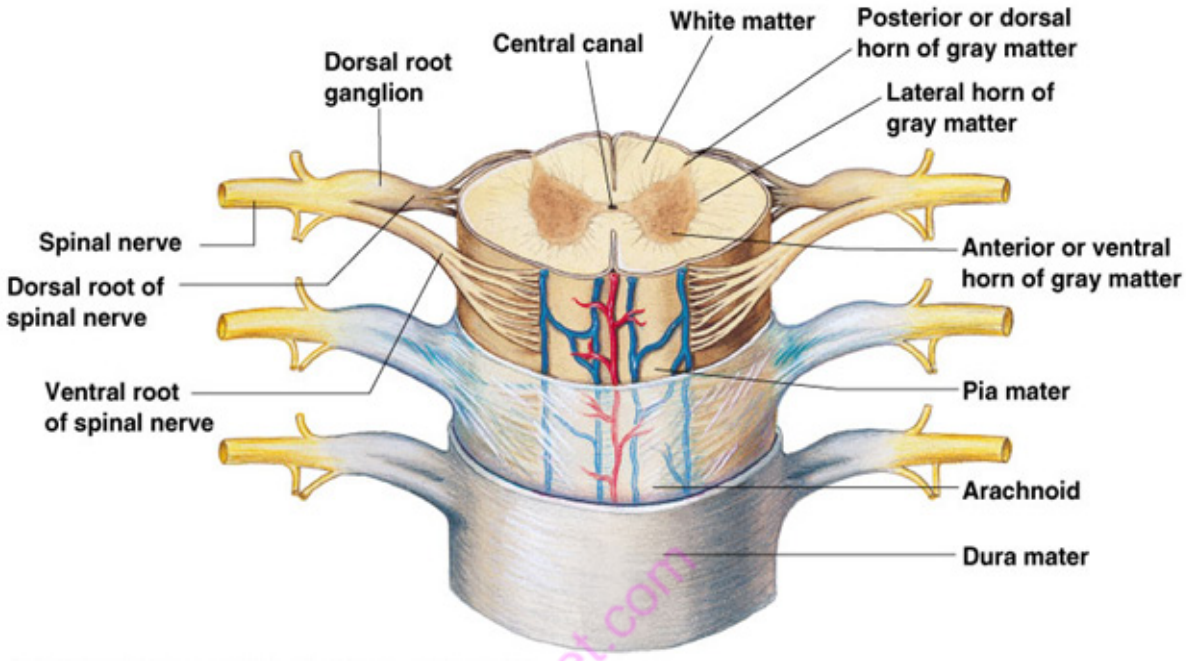
L1-L2 lumbar puncture

For clinical examination of CSF or administration of anesthetics.

Spinal Cord Anatomy

Internal gray matter - mostly cell bodies

- Dorsal (posterior) horns
- Anterior (ventral) horns
- Central canal filled with **cerebrospinal fluid**



Exterior white mater – conduction tracts

Gray matter

Arranged to resemble letter **H**.

The nerve cell bodies may be:

- Sensory neuron---receives impulses from the rest of the body
- Lower motor neurons: transmit impulses to skeletal muscles
- Connector neurons; links sensory and motor neurons to form **spinal reflex arcs.**

White matter

Anterior, lateral and posterior columns or tracts, and are formed by **motor, sensory and connector** fibers.

Tracts are named according to their points of origin and destination. e.g. spinothalamic, corticospinal.

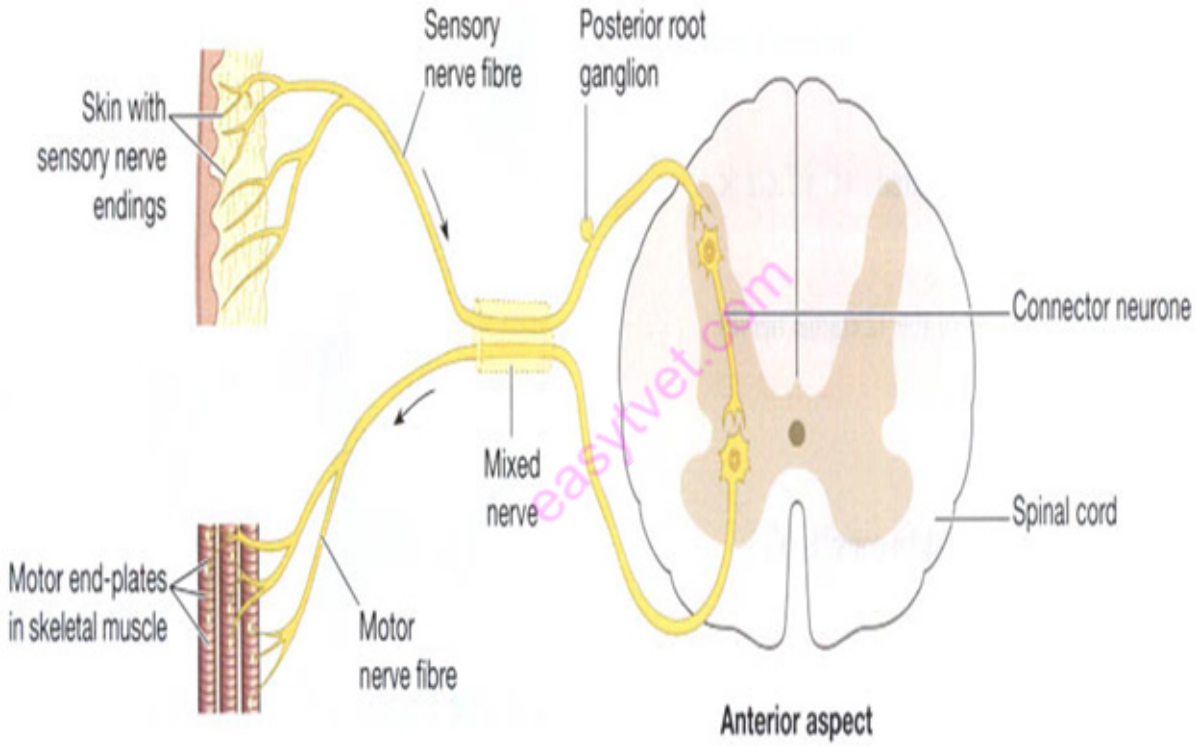
A Reflex Arc

Reflex arc – rapid, predictable, and involuntary responses to stimuli.

Reflex arc – direct route from a sensory neuron, to an interneuron, to an effector

It has 5 Essential Parts:

1. **Receptors** – detect a change (the stimulus) & generate impulses.
2. **Sensory neurons** – transmit impulses from receptors to the CNS.
3. **Central nervous system** – contains one or more synapses.
4. **Motor neurons** – transmit impulses from the CNS to the effector.
5. **Effector** – performs its characteristic action E.g. muscle contraction.



A simple reflex arc

Peripheral Nervous System

Consists of:
- 31 pairs of spinal nerves
- 12 pairs of cranial nerves
- Autonomic nervous system.

Most of PNS nerves are mixed nerves.

Spinal Nerves

Named and grouped according to the vertebrae with which they are associated.

- 8 cervical
- 12 thoracic
- 5 lumbar
- 5 sacral
- 1 coccygeal

Cranial Nerves

Def: 12 pairs of nerves originating from nuclei in the inferior surface of the brain, some sensory, some motor and some mixed. They are:

I. Olfactory
II. Optic
III. Oculomotor
IV. Trochlear
V. Trigeminal
VI. Abducent
VII. Facial
VIII. Vestibulocochlear (auditory)
IX. Glossopharyngeal
X. Vagus
XL. Accessory
XII. Hypoglossal

Name	Function	
Motor Cranial nerves	Sensory cranial nerves	Mixed cranial nerves
III -Oculomotor IV -Trochlear VI -Abducent XI -Accessory XII -Hypoglossal	I --Olfactory II --Optic VIII --Auditory	V -Trigeminal VII -Facial IX -Glossopharyngeal X -Vagus

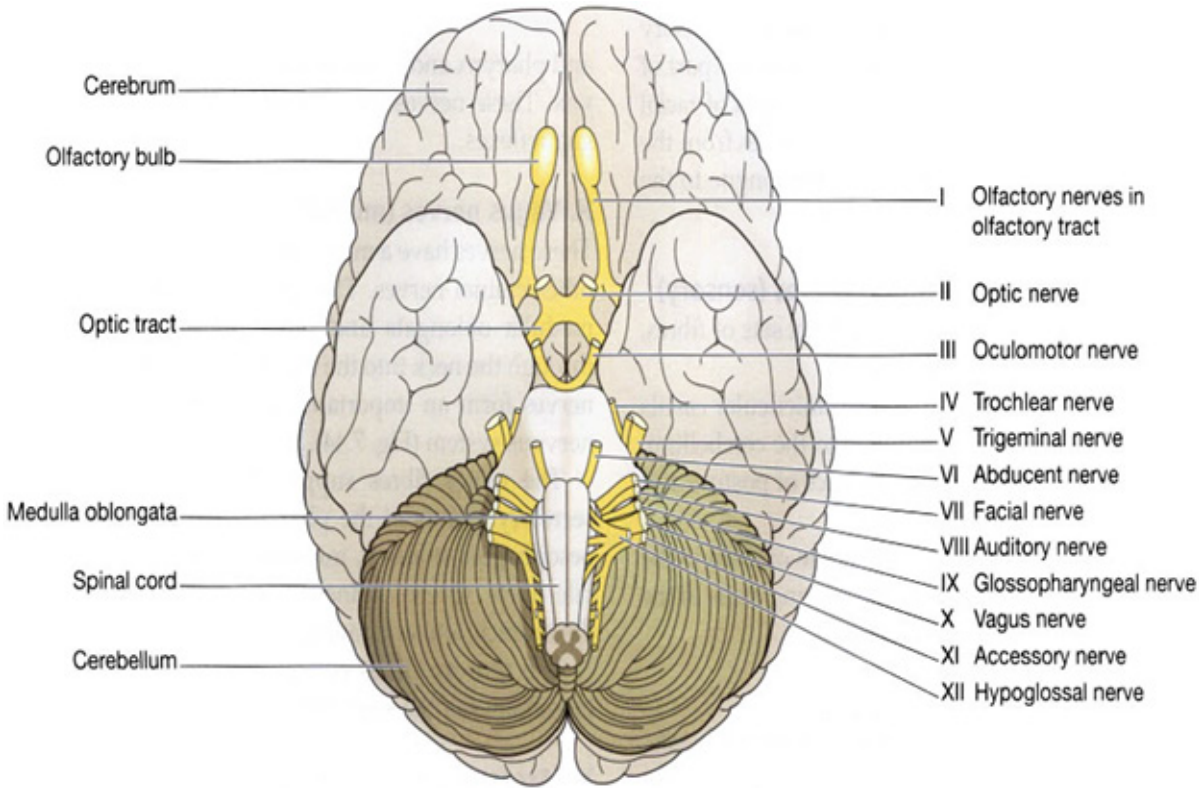
Functional Types

Cranial Nerves and Associated structures

Autonomic Nervous System

This is the involuntary branch of the nervous system. It consists of only motor nerves, and is divided into two divisions

- Sympathetic division
- Parasympathetic division



Anatomy of the Sympathetic Division

Originates from T1 through L2.

Norepinephrine and epinephrine are neurotransmitters to the effector organs

Anatomy of the Parasympathetic Division.

Cranial Nerves and Associated structures

Autonomic Nervous System

This is the **involuntary branch** of the nervous system, and consists of only **motor nerves**. It is divided into two divisions:

- Sympathetic division
- Parasympathetic division

Anatomy of the Sympathetic Division

Originates from T_1 through L^2

Norepinephrine and epinephrine are neurotransmitters to the effector organs

Anatomy of the Parasympathetic Division

Originates from the brain stem and S_1 through S_4

Always uses **acetylcholine** as a neurotransmitter.

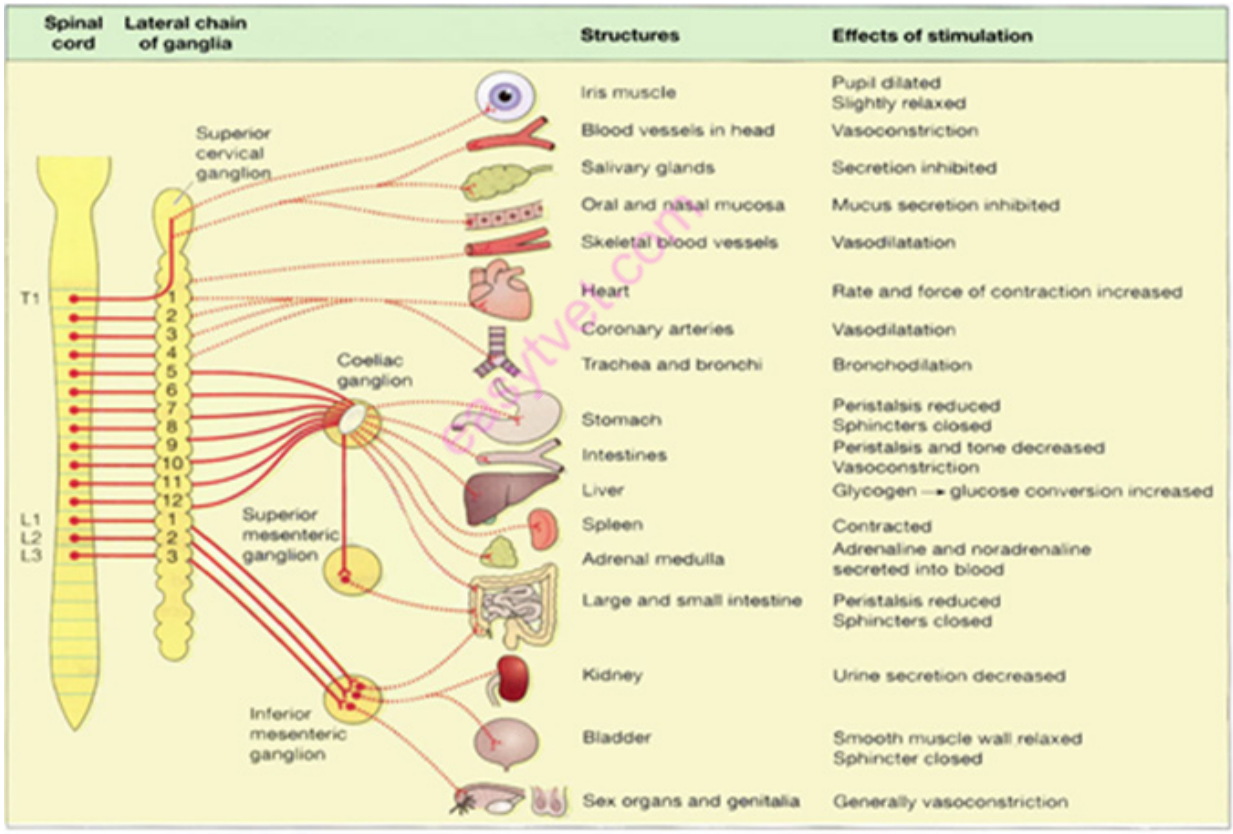
Autonomic Functioning

Sympathetic – "fight-or-flight"

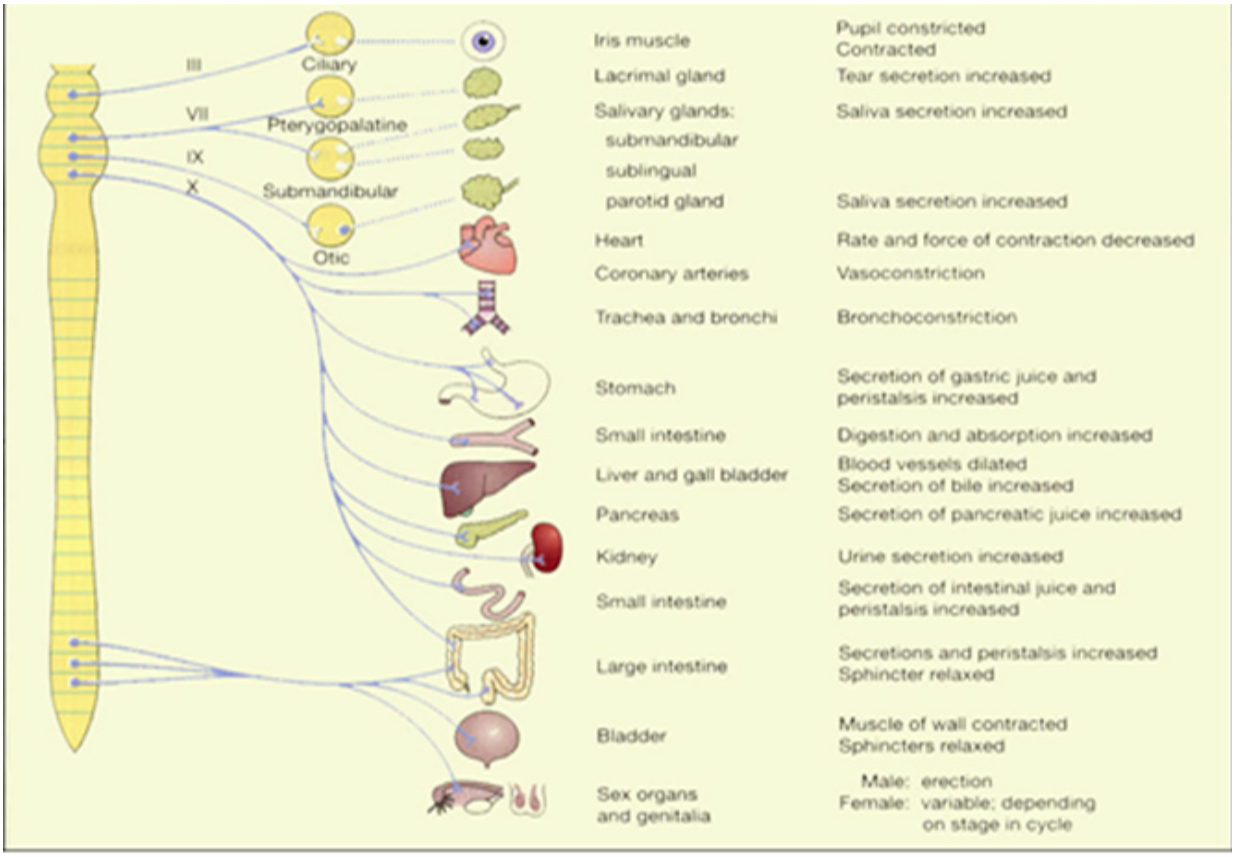
- Response to unusual stimulus
- Takes over to increase activities
- Remembered as the "E" division = exercise, excitement, emergency, and embarrassment

Parasympathetic – housekeeping activities

- Conserves energy
- Maintains daily necessary body functions
- Remembered as the "**D**" division - digestion, defecation, and diuresis



Sympathetic outflow; Solid red lines - preganglionic fibres; broken lines - postganglionic fibres.



Parasympathetic outflow; Solid blue lines-preganglionic fibres;broken lines-postganglionic fibres 93

THE CARDIOVASCULAR SYSTEM

Functions of the Circulatory System

- Brings blood containing oxygen, nutrients, and hormones to cells
- Transports CO2 and other wastes away from cells
- Fights infection
- Regulates body temperature
- Helps stabilize pH and ionic concentration of body fluids.

Components

- Heart
- Blood
- Vessels - Arteries | Veins | Capillaries

Paths of Circulation

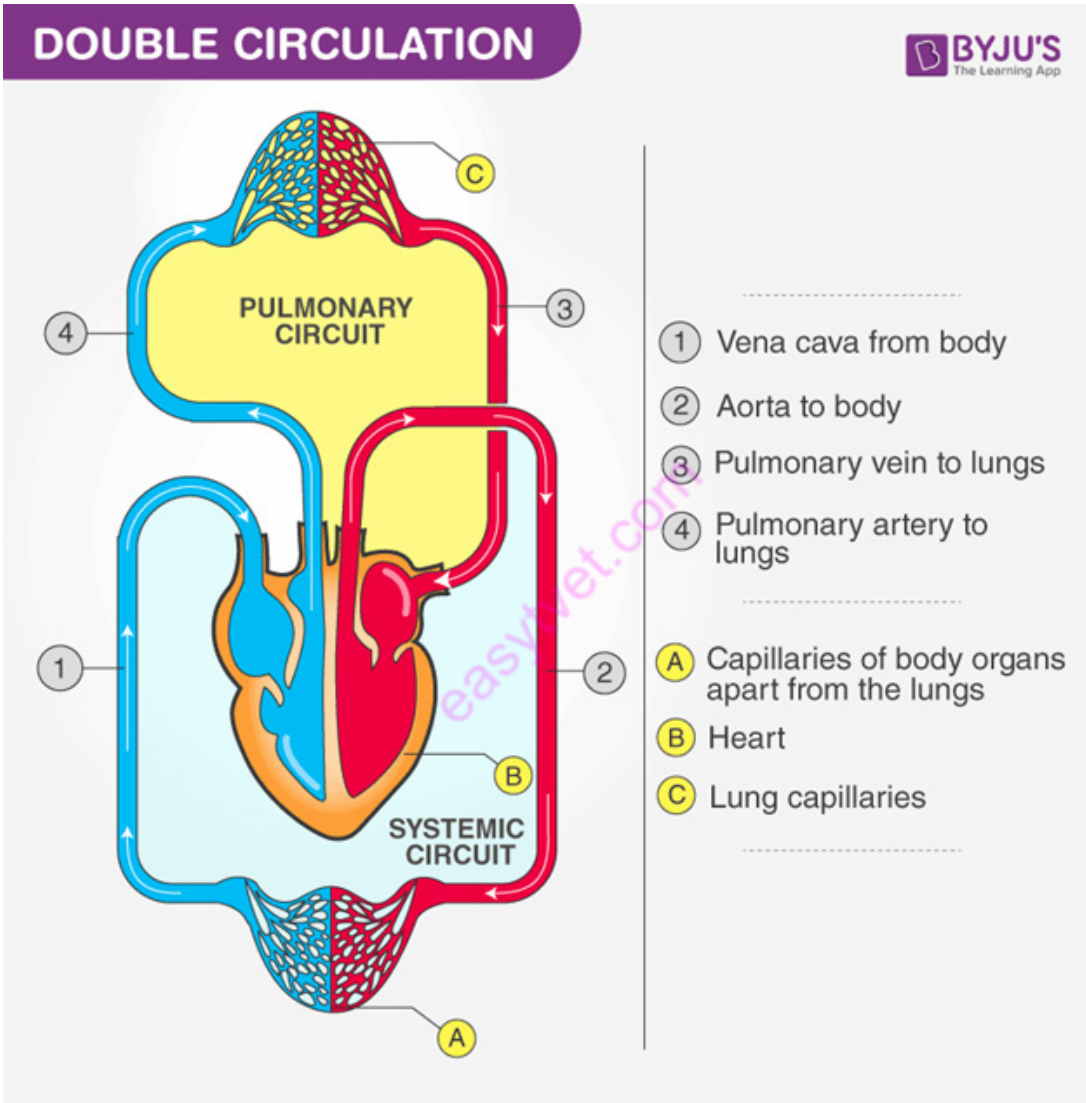
The body's blood vessels can be divided into a pulmonary circuit, including vessels carrying blood to the lungs and back, and a systemic circuit made up of vessels carrying blood from the heart to the rest of the body and back.

1. Pulmonary Circuit

The pulmonary circuit is made up of vessels that convey blood from the right ventricle to the pulmonary arteries to the lungs, alveolar capillaries, and pulmonary veins leading from the lungs to the left atrium.

2. Systemic Circuit

The systemic circuit includes the aorta and its branches leading to all body tissues as well as the system of veins returning blood to the right atrium.



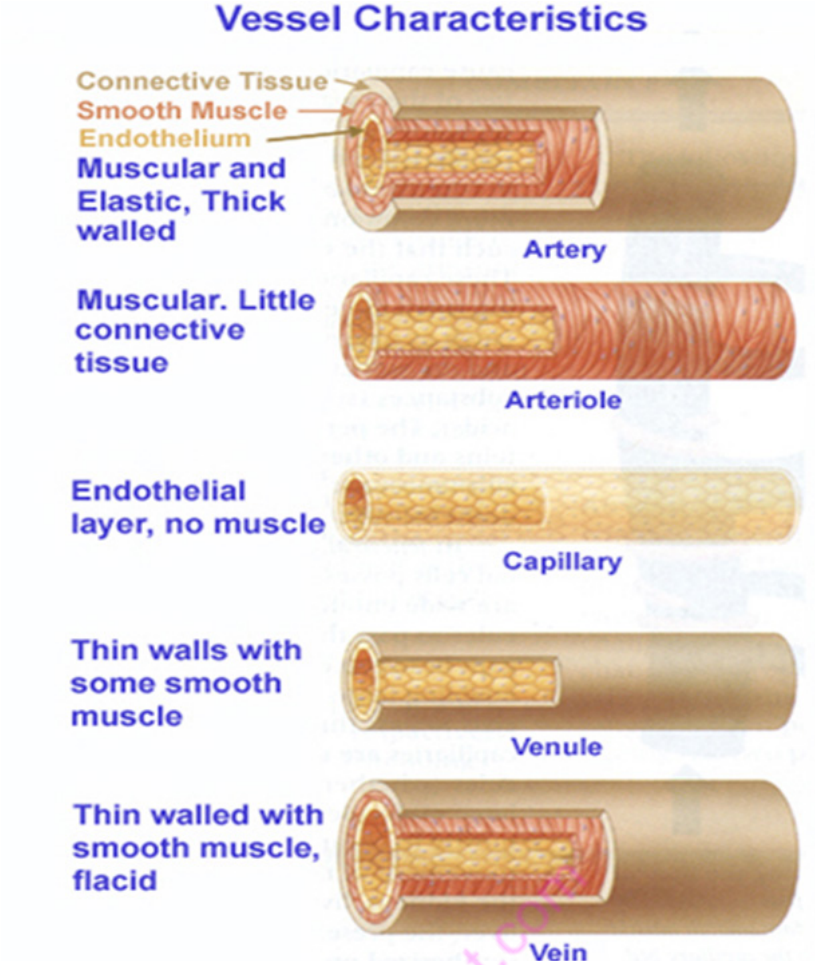
Blood Vessels

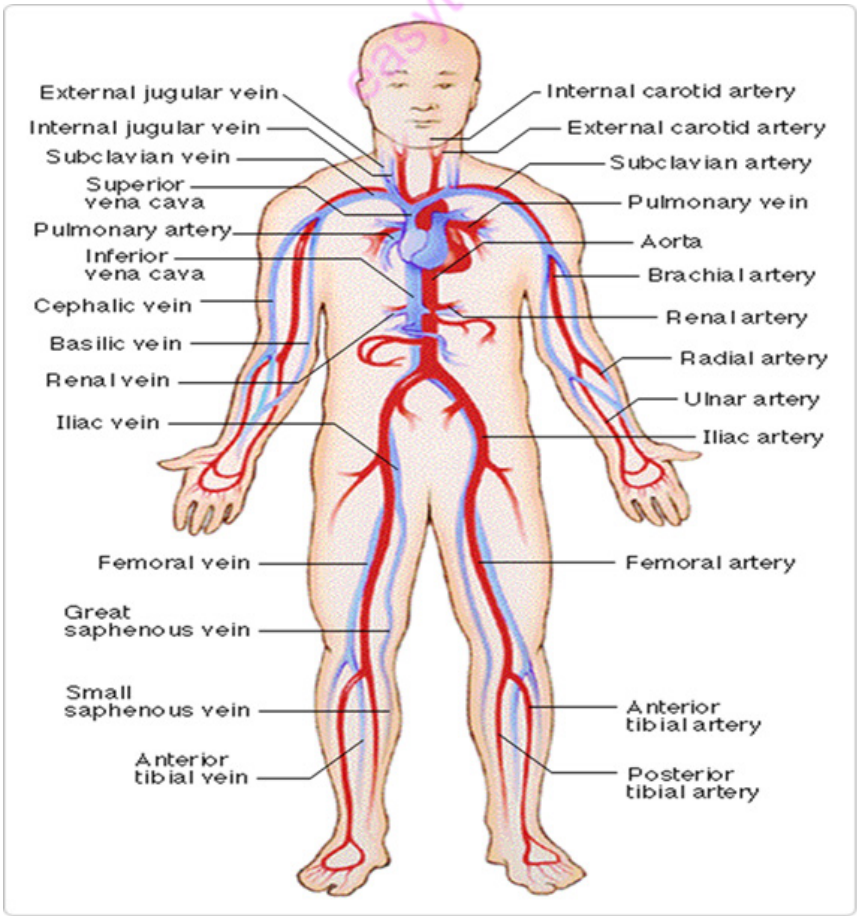
Form a closed circuit of tubes that carry blood throughout the body.

Laid end to end, the blood vessels in an average human body will stretch approximately 62,000 miles, 2.5 times around the earth

They have characteristic features:

Are distinguished by size, tissue layers and direction of blood flow.





Arteries

- Receive blood from ventricles
- Usually carry oxygenated blood
- Withstand greater blood pressure
- Connect to capillaries
- Take blood away from the heart
- Thickest vessel walls
- Are very elastic
- Aorta is the largest artery

They have 3 basic layers or tunics.

The **tunica interna** is a.k.a. the tunica intima. It lines the lumen and consists primarily of a simple squamous epithelium underlain by loose connective tissue. This helps provide a smooth surface ideal for fluid flow.

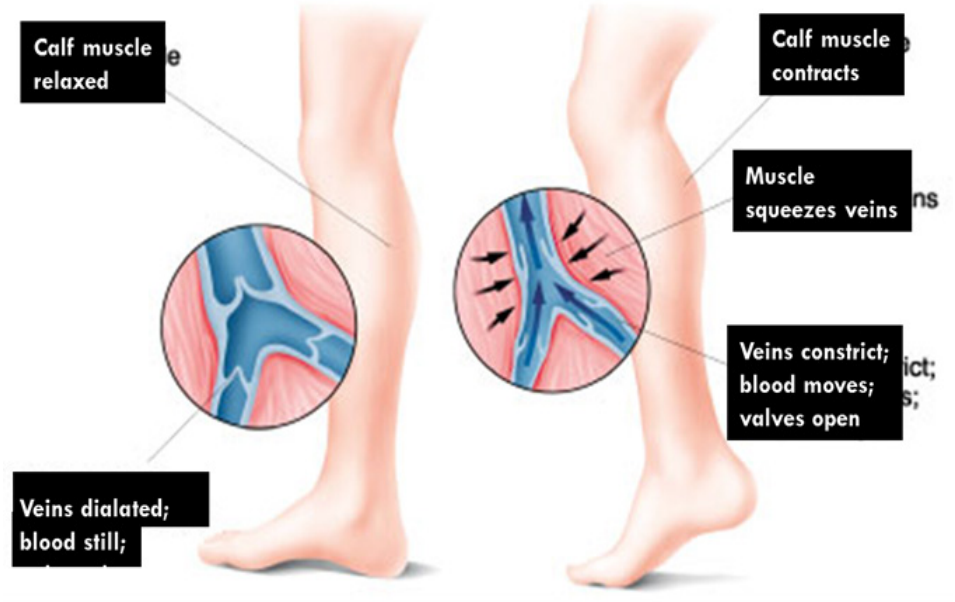
The **tunica media** consists of circularly arranged smooth muscle cells and sheets of the protein elastin.

Tunica externa is a.k.a. **tunica adventitia**. It consists of mostly collagen fibers that protect, reinforce, and support the vessel. It is the most prominent layer in veins.

Veins

- Transport blood away from capillaries
- Take blood to atria
- Thinner vessel walls with less smooth muscles than arteries
- Have larger diameters
- Vena cava is the largest vein
- Carry blood toward heart
- Have valves
- Can stretch a great deal
- Usually carry de-oxygenated blood

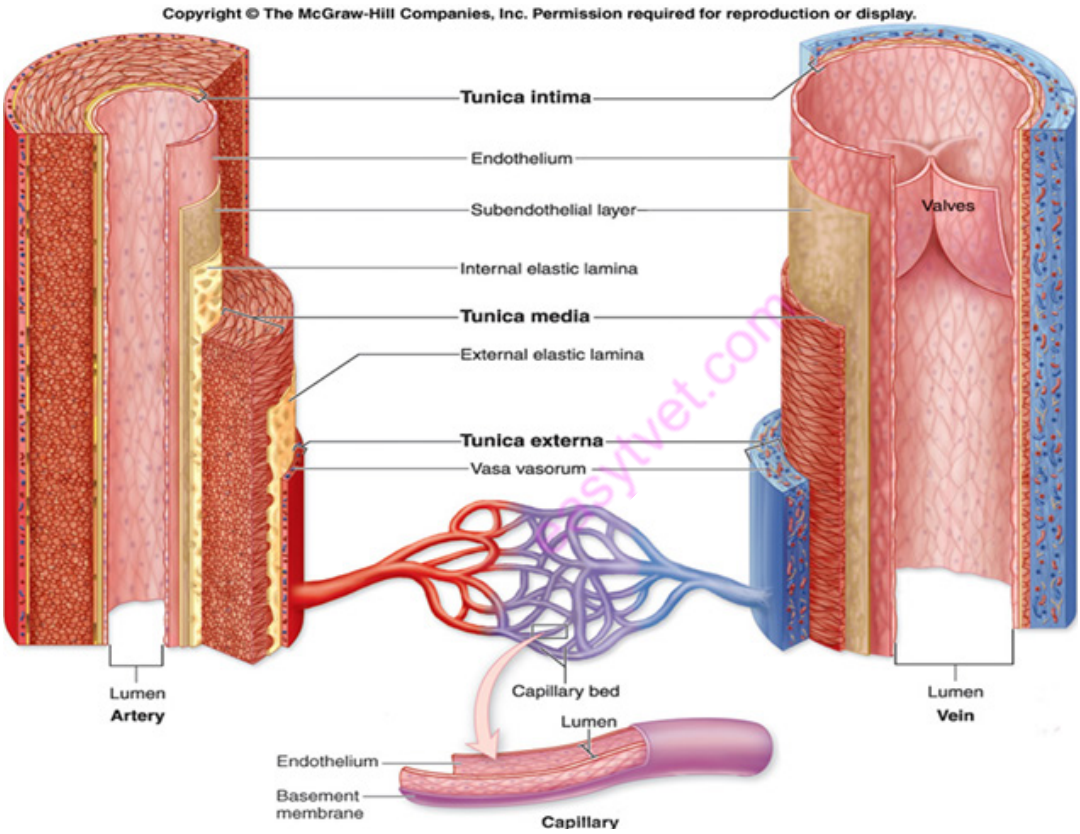
The contraction of muscles compressing veins helps push blood up through the leg veins back to the heart. The valves allow the blood to flow towards the heart only.



The walls of veins are thin and their lumens are large. They have very low resistance and are extremely compliant.

Capillaries

- Smallest of blood vessels
- Only one cell thick (epithelial cell)
- Connect arteries to veins
- Bring oxygen and nutrients to cells
- Removes CO2, urea, and other wastes from cells where blood is under low pressure and moving slowly.



Comparison of blood vessels

Control of Blood Vessel Diameter

Supplied by the ANS except the capillaries. They arise from the vasomotor centre in the medulla.

Alters the size of the lumen of the blood vessel, especially the small arteries & arterioles.

Vasodilatation and Vasoconstriction

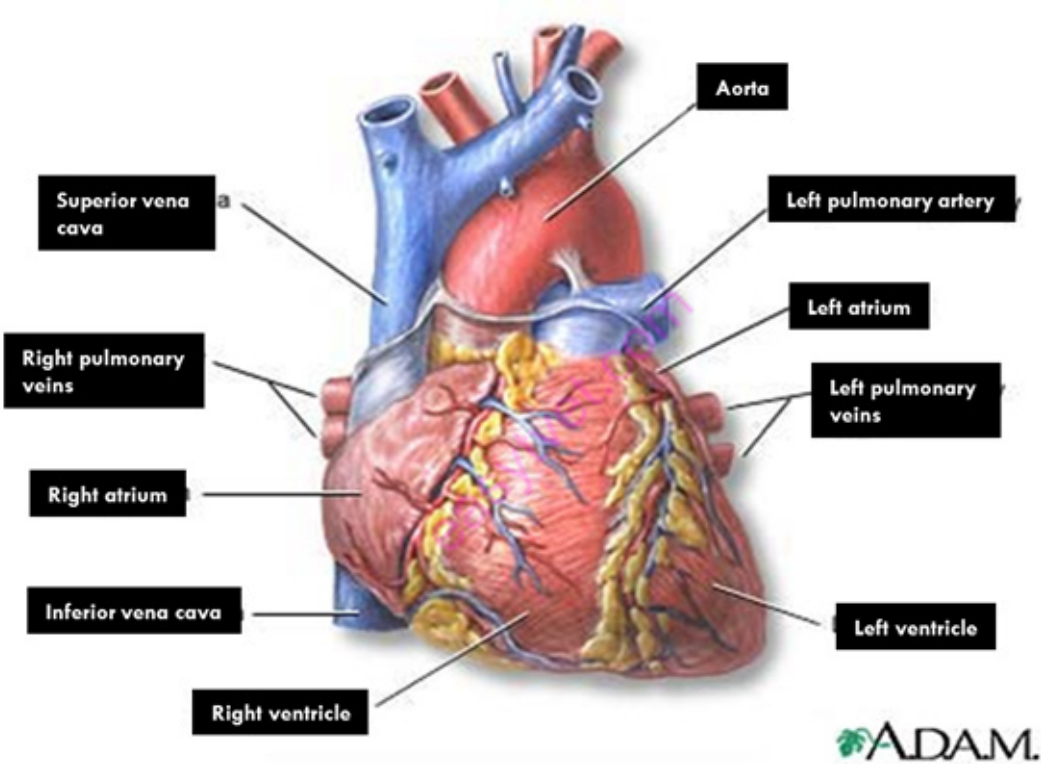
SNS supply the smooth muscles in the tunica media. ↓ in nerve stimulation relaxes the muscles enlarging the lumen i.e. vasodilatation with increased blood flow.

↑ nervous stimulation contracts the smooth muscles & decrease the lumen size thus Vasoconstriction and reduced blood flow.

These two aspects will determine peripheral resistance and systemic blood pressure.

The Heart

- A muscular pump, that moves blood through the body.
- It is suspended in the pericardial sac
- Cone shaped hollow muscular organ.
- 10cm long, the size of a fist
- About 225g in women.



The heart is located within the mediastinum, the medial cavity of the thorax.

Its apex rests on the superior surface of the diaphragm and points toward the left hip. Its base points toward the right shoulder.

The heart is medial to the lungs, anterior to the esophagus and vertebra column, and posterior to the sternum.

Relations:

Inferioly: apex rests on the central tendon of the diaphragm

Superiorly: the great blood vessels; aorta, sup.venacava, pul.artery & pul.vein.

Posterioly: esophagus, trachea, L & R bronchus, desc. Aorta, inf. venacava, thoracic vertebrae.

Laterally: the lungs; the left lung overlaps the left side of the heart

Anteriorly: sternum, ribs & intercostal muscles

Heart: Structure

1. Pericardium

A double-walled sac. The most superficial layer is the **fibrous pericardium** – a collagenous structure that protects and anchors the heart and prevents it from over distending.

Deeper is the **serous pericardium**, a 2 layered serous membrane. The **parietal pericardium** is the outer of the 2 and borders the fibrous pericardium.

The visceral pericardium is the inner of the 2 and is the external covering of the heart. It is also known as the epicardium.

The pericardial cavity is the space between the parietal and visceral layers. It contains serous fluid, which reduces friction between them when the heart beats.

2. Myocardium

It is the middle, and the muscle layer of the heart. It is strong and thick, and is composed of spontaneously contracting cardiac muscle fibers.

It can conduct electric impulses like nerves. It's blood supply comes from the coronary arteries.

The muscle fibers has cross stripes as skeletal muscles. Each fiber has a nucleus and one or more branches.

The ends of the cells or branches are in close contact with the adjacent cells with joints (intercalated discs) seen microscopically as thicker, darker lines than ordinary cross stripes thus appears as a sheet of muscle.

Because of this arrangement an impulse generated spreads from cell to cell via branches and intercalated discs over the whole muscle causing contraction.

Is thickest at the apex because of the pumping action of the ventricles.

The atrio-venticular septum separates the atria and ventricles

Electrical activity is conducted through a series of conducting system from the atria to the ventricles.

3. Endocardium

Consists of endothelium (simple squamous epithelium) resting on a layer of thin connective tissue. It lines the heart chambers and its folds create the heart valves.

Interior of the Heart

Chambers

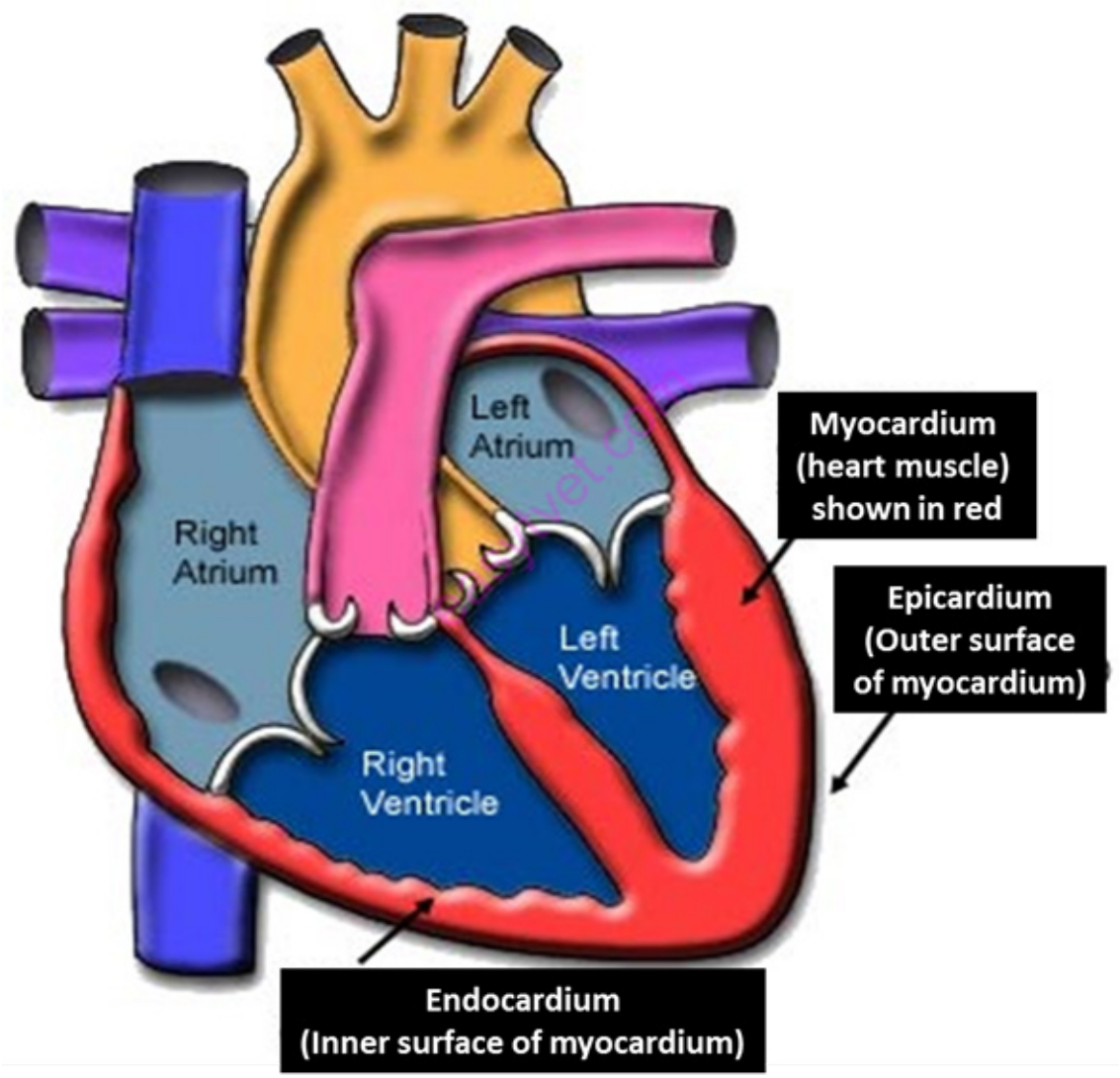
Atria- (2) upper chambers

- Thin walled
- Receive blood from veins
- Send blood to ventricles

Ventricles - (2) lower chambers

- Thick walled
- Receive blood from atria
- Pump blood out through arteries

Septum-Wall that divides heart into right and left halves.



Ventricles

These are large, muscular chambers. Thick musculature is necessary because they are the actual pumps.

They contain muscular ridges known as trabeculae carneae as well as muscular bulges known as papillary muscles.

The right ventricle discharges blood into the pulmonary trunk, the first vessel of the pulmonary circuit. The pulmonary semilunar valve separates the right ventricle and the pulmonary trunk.

The left ventricle discharges blood into the aorta, the first vessel of the systemic circuit. The aortic semilunar valve separates the LV and aortic trunk.

The left ventricle is larger (more muscular) than the right. More muscle is necessary because the left ventricle pumps blood a farther distance and against greater pressure (note – the right and left ventricle pump the same volume of blood per beat).

Atria

They are the heart's receiving chambers. They are small and thinly muscled.

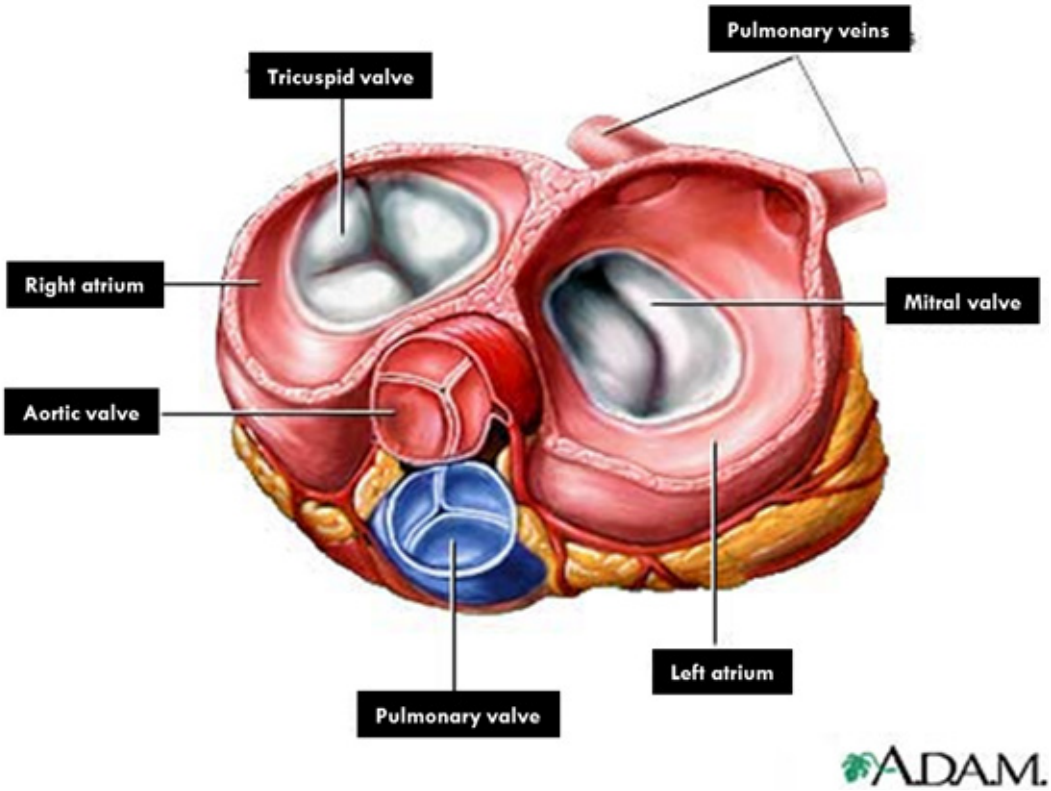
The right atrium receives blood from the systemic circuit via 3 vessels: (1) Superior vena cava carries low O_2/high CO_2 blood from arms, head, and upper torso; (2) Inferior vena cava carries low O_2/high CO_2 blood from the legs, abdomen, and pelvis; (3) Coronary sinus carries low O_2/high CO_2 blood from the coronary circulation – which nourishes the heart wall.

The right atrium passes blood to the right ventricle thru the tricuspid orifice, which is associated with the **tricuspid valve.**

Left atrium receives high O_2/low CO_2 blood from the pulmonary circuit via the 4 pulmonary veins. It passes blood to the left ventricle via the mitral (or bicuspid) orifice, which is associated with the **mitral (or bicuspid) valve.**

Valves

They prevent backflow of blood, and keep blood moving in one direction. They are situated between the chambers, at junctions of artery and chamber.



Heart Valves

Atrioventricular valves - between atria and ventricles (flaps = cusps)

Tricuspid valve: right side, 3 cusps

Bicuspid/Mitral valve: left side, 2 cusps

Cusps attached to chordae tendineae from papillary muscles on ventricle wall -contraction of papillary muscles prevent cusps opening backward during ventricle contraction.

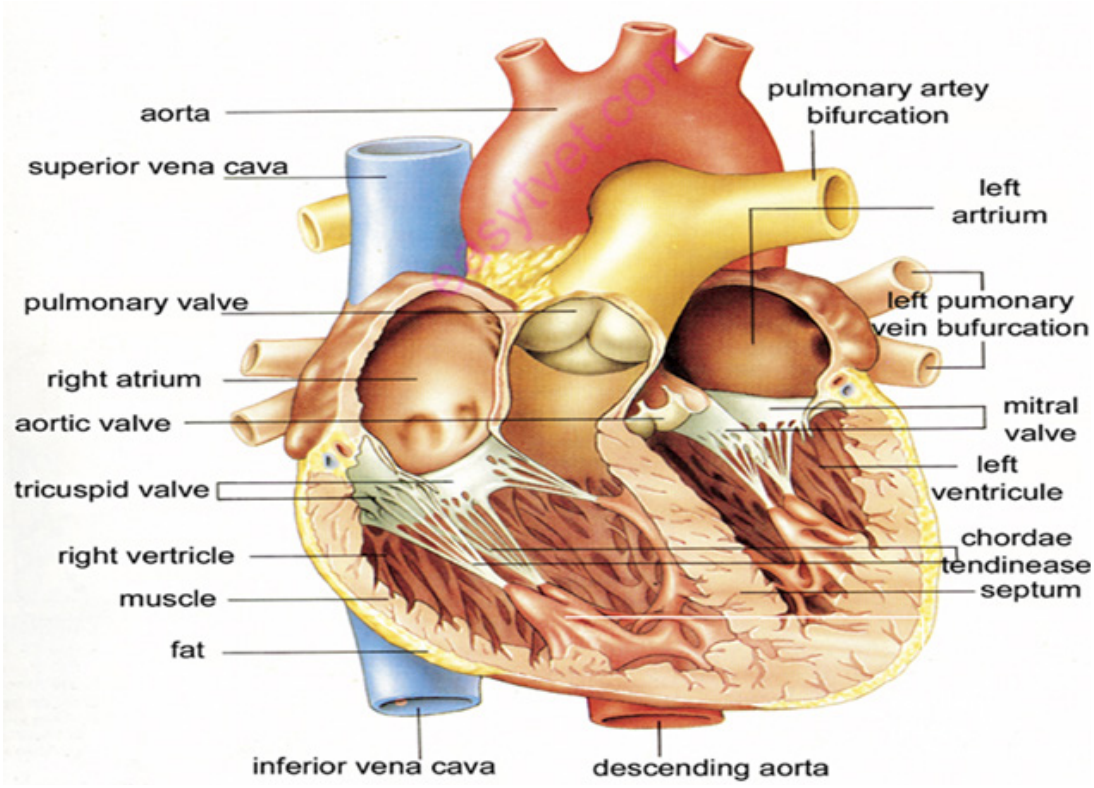
Cusps hang loose when ventricles not contracting, allow ventricles to fill with blood.

Structure of the Heart

Chordae tendineae

- Also known as "Heart strings"
- Cord-like tendons that connect papillary muscles to tricuspid and mitral valves
- Prevent inversion of valve

Papillary muscles – Small muscles that anchor the cords



Flow of blood through the heart

- Blood low in oxygen returns to the right atrium via the venae cavae and coronary sinus.
- The right atrium contracts, forcing blood through the tricuspid valve into the right ventricle.

- The right ventricle contracts, closing the tricuspid valve, and forcing blood through the pulmonary valve into the pulmonary trunk and arteries
- The pulmonary arteries carry blood to the lungs where it can rid itself of excess carbon dioxide and pick up a new supply of oxygen.
- Freshly oxygenated blood is returned to the left atrium of the heart through the pulmonary veins.
- The left atrium contracts, forcing blood through the left bicuspid valve into the left ventricle.
- The left ventricle contracts, closing the bicuspid valve and forcing open the aortic valve as blood enters the aorta for distribution to the body.

Blood Supply to the Heart

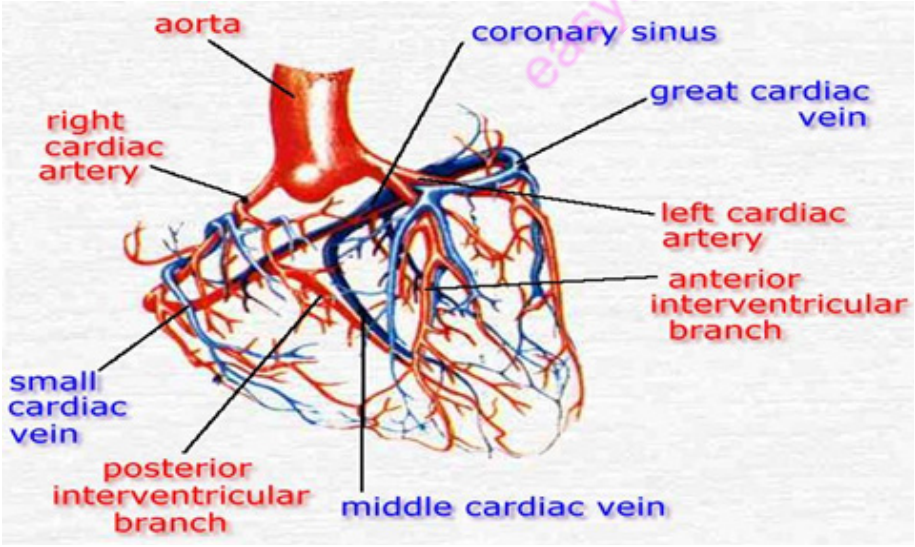
The first branches off the aorta, which carry freshly oxygenated blood, are the right and left coronary arteries that feed the heart muscle itself.

Branches of the coronary arteries feed many capillaries of the myocardium.

The heart muscle requires a continuous supply of freshly oxygenated blood, so smaller branches of arteries often have anastomoses as alternate pathways for blood, should one pathway become blocked.

Cardiac veins drain blood from the heart muscle and carry it to the coronary sinus, which empties into the right atrium.

Coronary Circulation

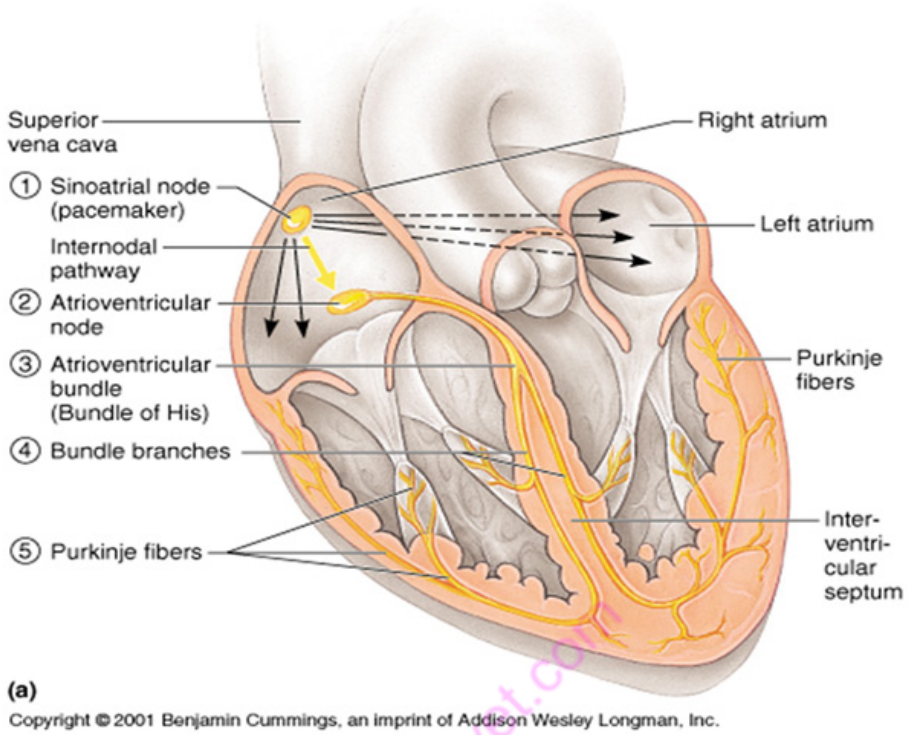


Cardiac Conduction System

Intrinsic control of the heart rate is the province of the auto-rhythmic cells (which have the ability to spontaneously and rhythmically contract without external stimulation). However this system can also be stimulated or depressed by nerve signals, hormones, and other blood-born substances).

There are 4 main groups of autorhythmic cells: Includes:

- SA node
- AV node
- Bundle of His
- Purkinje fibers



Sinoatrial Node (SA node)

It is located high on the right atrium near the opening of the sup venacava. It is the pacemaker of the heart because it initiates impulses rapidly than other neuromuscular cells.

It causes the wave of contractions in the atria, sending blood into the ventricles

1. Atrioventricular Node (AV node)

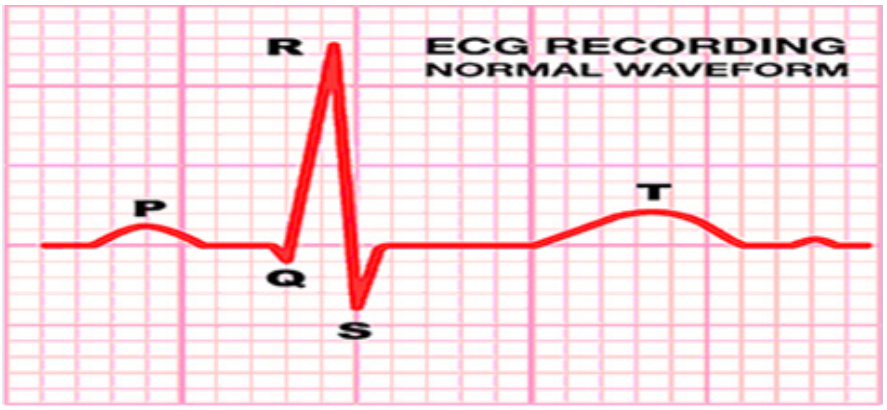
- Located in the interatrial septum close to the tricuspid valve
- Carries the electrical impulse from the SA node to fiber bundles in the ventricles.
- The electrical signal delays for 0.1s before passing through into the ventricles to allow the atria to finish contracting.
- It also acts as a secondary pacemaker as it takes over the role if there is a problem with the SA node though at a slower firing rate.

2. Atrioventricular bundle (AV bundle or Bundle of HIS)

- Originates from the AV node crosses the fibrous ring separating the atria from ventricle
- Divides at the upper end of ventricular septum into right and left bundle branches.
- The branches breaks up into fine fibres called purkinje fibres within the myocardium.

- These three fibres convey electrical impulse to the apex of the heart where ventricular contraction begins spreading upwards and outwards pumping blood to the pulmonary artery & aorta.

ECG DEFLECTION WAVES



An ECG is a recording of the deflection waves caused by depolarization of the heart.

The P wave indicates depolarization of the atria.

The QRS complex is caused by depolarization of the ventricles.

The T wave represents repolarization of the ventricles.

Nerve Supply to the Heart

ANS (SNS and PNS) originating from the cardiovascular centre in the medulla.

The vagus nerve (PNS) supply the AV and SA nodes and atrial muscles. Stimulation reduces the impulse generation rate↓ the rate & force of heart beat

The SNS supplies the SA and AV nodes and the myocardium of the ventricles. Stimulation ↑ the rate & force of the heart beat.

Cardiac cycle

Refers to all of the events from the beginning of one heart beat to the beginning of the next heart beat.

When cardiac muscle contracts it does so as a single unit, creating a heart beat.

- One heartbeat - a cardiac cycle - consists of two parts called systole and diastole
- Diastole is the period of time when the heart relaxes after contraction
- Oxygenated blood from the lungs fills the left atrium
- Deoxygenated blood from other parts of the body fills the right atrium.
- At the end of the diastole, the atria contract, starting the Systole
- Atrial systole is the contraction of the heart muscle of the left and right atria. Both atria contract at the same time, sending blood into the corresponding ventricle
- Ventricular systole is the contraction of the muscles of the left and right ventricles, which contract at the same time.
- During systole the ventricles contract, forcing the blood into the pulmonary artery to be re-oxygenated in the lungs, and into the aorta for systemic distribution of oxygenated blood.

Heart Sounds

Two normal heart sounds with each heart beat described as:

S1--"Lub"- sound- due to closure of the atrioventricular valves (mitral and tricuspid)

S2---"Dub"- sound- due to closure of the aortic valve and pulmonary valve

S3 and S4 are abnormal heart sounds.

Cardiac Output

Cardiac output is the amount of blood pumped by each ventricle in one minute. Cardiac output can be expressed mathematically as the product of heart rate and stroke volume: CO (mL/min) = HR(beats/min) x SV(mL/beat).

In an adult, SV is approx.70ml and HR 72b/m.

CO is therefore approx. 5l/min. this can be increased during exercise to about 25-30 l/min from the cardiac reserve.

Stroke volume

The amount of blood ejected when ventricles contract is known as the stroke volume.

It is determined by the volume of the blood in the ventricles before they contract. (VEDV) i.e. preload. Preload depends on the venous return.

Increased VEDV leads to stronger myocardial contraction & more blood expelled thus ↑ SV & CO

Stroke volume depends on 3 main variables: preload, contractility, and afterload.

Preload refers to the degree of ventricular stretch during filling. The more heart muscle is stretched (up to a point), the more forceful its contraction.

Contractility is the strength of the heart's contraction independent of its degree of stretch. Factors that increase contractility include: increased cardio acceleratory activity; and hormones such as epinephrine and thyroxine.

Afterload refers to the pressure that must be overcome to open the semilunar valve and eject blood. Afterload is equivalent to arterial blood pressure.

It is determined by distensibility/ elasticity of the large arteries & peripheral resistance of arterioles.

Venous Return

Blood flow through the venous system is only partially the result of heart action and instead also depends on skeletal muscle contraction, breathing movements, and vasoconstriction of veins.

Contractions of skeletal muscle squeeze blood back up veins one valve and a time especially the lower limbs (skeletal muscle pump).

Differences in thoracic and abdominal pressures draw blood back up the veins especially during inspiration.

Body position--gravity assists venous return from the head & neck and offers less resistance to venous return when lying flat.

Heart Rate (HR)

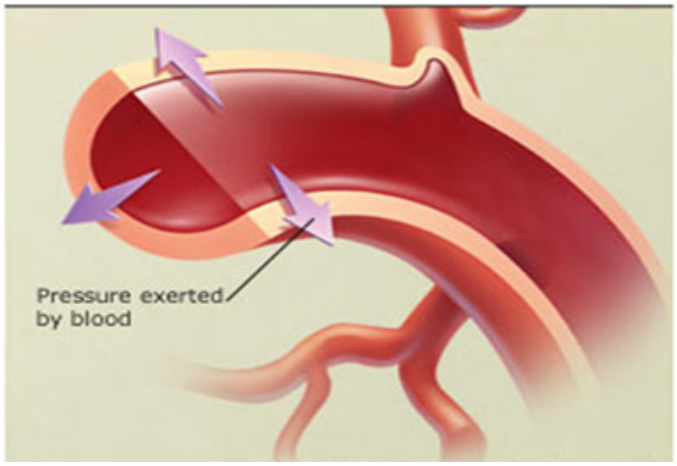
HR is affected by:

- Autonomic nervous input
    1. sympathetic = ↑ HR
    2. parasympathetic = ↓HR
- Hormones: adrenaline & noradrenaline, thyroxine
- Venous return
- More blood return = ↑ HR (stretch receptors activate sympathetic)
- Other factors (ions, drugs), hypoxia ↑, hypercalcemia
- Position: upright position, HR ↑
- Exercise: active exercise ↑ HR
- Emotional states: fear, excitement, anxiety increase HR
- Gender: faster in women
- Age; rapid in babies and small children
- Temperature: rises and falls with temp
- Baroreceptor reflex

Blood Pressure

Blood pressure refers to the force exerted by circulating blood on the walls of blood vessels

The pressure of the circulating blood decreases as blood moves through arteries, arterioles, capillaries, venules, and veins.



Blood pressure is most commonly measured via sphygmomanometer (blood pressure cuff). It uses the height of a column of mercury to reflect the circulating pressure.

Average blood pressure for an adult is 120/80 mmHg

Blood pressure readings = S/D

Pulse

Is a wave of distension and elongation felt in the artery wall due to contraction of the left ventricle. The waves travel along the walls of the arteries and can be felt on any superficial artery pressing against a bone. Is equivalent to the number of beats/min and on average about 60 to 80 at rest.

The pulse gives;

- The heart rate
- Regularity of the heartbeat
- Volume or strength of the beat
- Tension: soft and pliant
- The pulse may be different from the heartbeat because of; narrowing or blockage of an artery; a diseased or failing heart.

Common Pulse Areas

- Carotid – at the neck

- Femoral – groin
- Radial – wrist
- Brachial – arm
- Popliteal – behind the knee
- Posterior tibial artery – ankle joint
- Dorsalis pedis artery – foot

NB: During shock, the most prominent pulse is carotid followed by femoral followed by radial pulse.

Common Disorders Related to Cardiovascular System

- Hypertension
- Heart attack
- Shock
- Varicose veins
- Congenital heart diseases
- Cardiac arrhythmias
- Heart failure
- Stroke
- Coronary artery disease
- Aneurysm
- Myocarditis and pericarditis

THE BLOOD

Blood is a connective tissue. It provides means of communication between the cells of different parts of the body.

Functions of Blood:

It carries:

- Oxygen from the lungs to the tissues and carbon dioxide from the tissues to the lungs for excretion
- Nutrients from the alimentary tract to the tissues and cell wastes to the excretory organs, principally the kidneys
- Hormones secreted by endocrine glands to their target glands and tissues
- Heat produced in active tissues to other less active tissues
- Protective substances, e.g. antibodies, to areas of infection
- Clotting factors that coagulate blood, minimising its loss from ruptured blood vessels.

Blood makes up about 7% of body weight (about 5.6 litres in a 70 kg man). Proportion is less in women & greater in children, gradually decreasing until the adult level is reached.

Blood in the blood vessels is in continual flow to maintain a fairly constant environment for the body cells. Blood volume and the concentration of its many constituents are kept within narrow limits by homeostatic mechanisms.

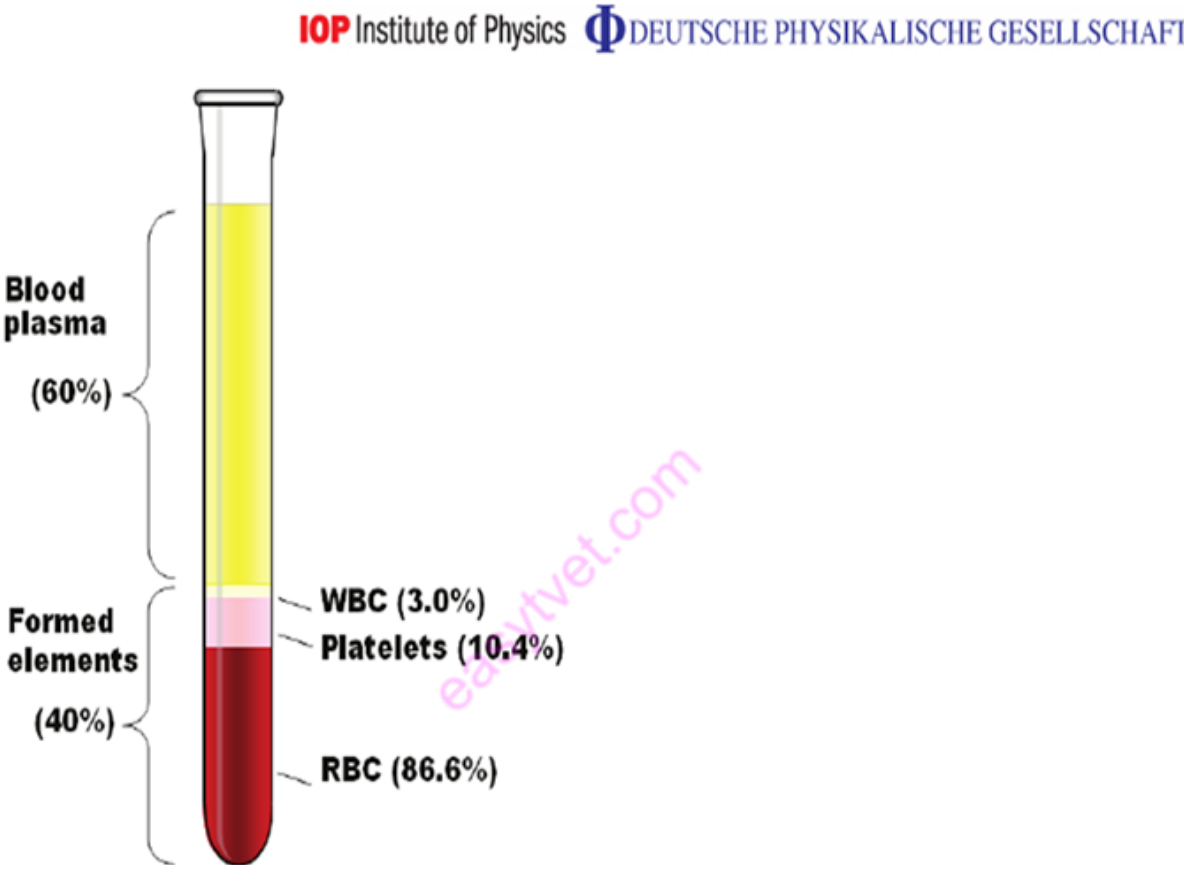
Composition of Blood

Blood makes up about 7% of body weight (about 5.6 litres in a 70 kg man).

Composed of a straw-colored (pale-yellow) transparent fluid, plasma, in which different types of cells are suspended.

Composition

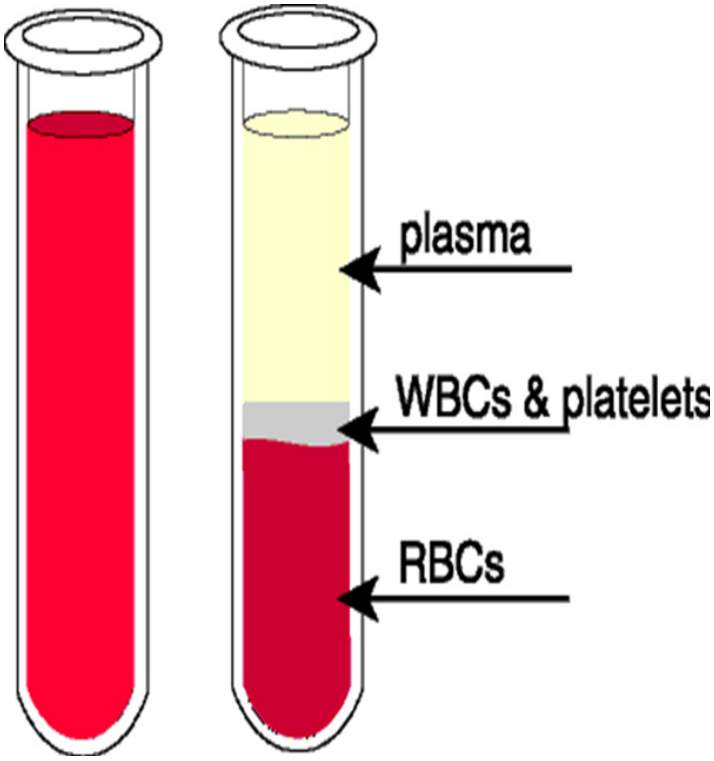
- Plasma constitutes about 55%
- Cells about 45% of blood volume



PLASMA

Constituents is water (90 to 92%) and dissolved substances, including:

- Plasma proteins: albumins, globulins (including antibodies), fibrinogen, clotting factors
- Inorganic salts (mineral salts): sodium chloride, sodium bicarbonate, potassium, magnesium, phosphate, iron, calcium, copper, iodine, cobalt
- Nutrients, principally from digested foods, e.g. Glucose, amino acids, fatty acids, glycerol and vitamins
- Waste materials, e.g. Urea, uric acid, creatinine
- Hormones
- Enzymes, e.g. Certain clotting factors
- Gases, e.g. oxygen, carbon dioxide, nitrogen.



Plasma Proteins

They make up about 7% of plasma, and are normally retained within the blood, because they are too big to escape through the capillary pores into the tissues.

Largely responsible for creating the osmotic pressure of blood which keeps plasma fluid within the circulation.

Examples:

- Albumins,
- Globulins (including antibodies),
- Fibrinogen,
- Clotting factors

Cellular Content of Blood

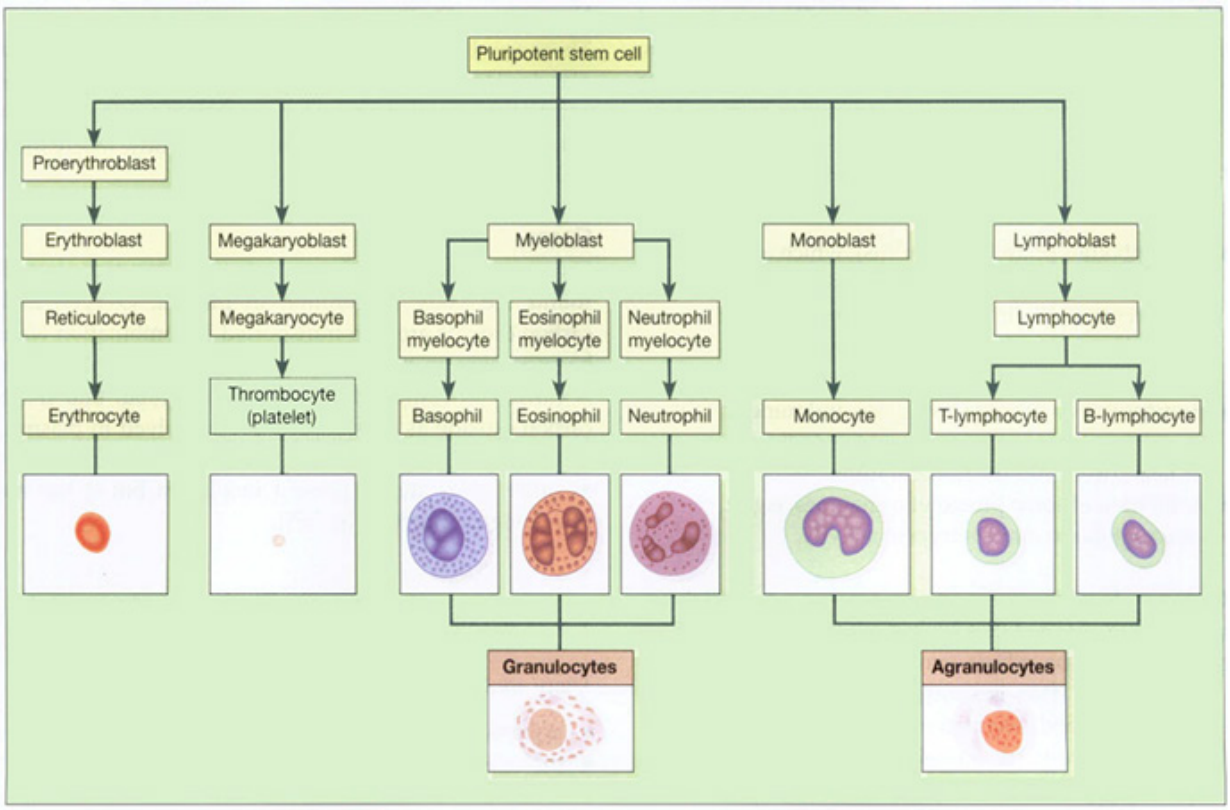
Three types of blood cells.

1. Erythrocytes or red cells
2. Thrombocytes or platelets
3. Leukocytes or white cells.

All blood cells originate from **pluripotent stem cells** and go through several developmental stages before entering the blood.

Haemopoiesis: process of blood cell formation; takes place within red bone marrow.

Haemopoiesis



ERYTHROCYTES (Red Blood Cells)

Circular biconcave non-nucleated discs with a diameter of about 7 micrometers whose main function is transport of gases.

Characteristics (Adaptations) of the R.B.C

- They are biconcave – to ↑ S.A for gaseous exchange
- They have a thin central portion – to allow fast entry and exit of gases
- They are flexible – so that they can squeeze thru narrow capillaries
- Contain no organelles – thus creating more room for heamoglobin.
- They contain hemoglobin for O2 transport

R.B.C Counts

Erythrocyte count: number of erythrocytes per litre (1) or per cubic millimetre (mm3) of blood.

Packed cell volume (PCV)or haematocrit: volume of red cells in 1 litre or 1 mm3 of whole blood.

Mean cell volume(MCV): average volume of cells, measured in femtolitres (fl = 101-15 litre).

Haemoglobin: weight of haemoglobin in whole blood, measured in grams per 100 ml.

Mean cell haemoglobin (MCH): average amount of haemoglobin in each cell, measured in picograms (pg = 101^{-12} gram).

Mean cell haemoglobin concentration (MCHC): amount of haemoglobin in 100 ml of red cells.

Development and Lifespan of the Erythrocytes

Formed in red bone marrow, which is present in the ends of long bones and in flat and irregular bones.

Life span in the circulation is about 120 days. Process of development of red blood cells from pluripotent stem cells takes about 7 days and is called **erythropoiesis.**

It is characterised by two main features:

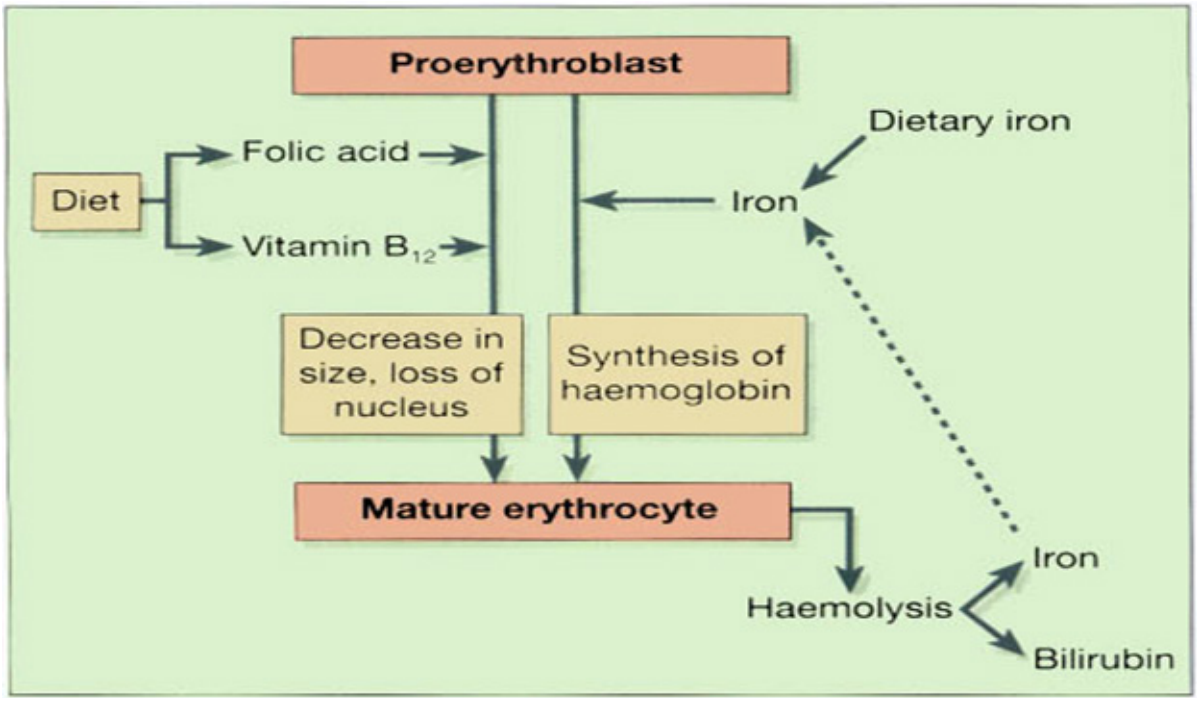
1. Maturation of the cell
2. Formation of haemoglobin inside the cell.

Maturation of the Cell

During this process the cell decreases in size and loses its nucleus.

These changes depend on the presence of vitamin B12 and folic acid. These are present in sufficient quantity in a normal diet containing dairy products, meat and green vegetables; excess is stored in the liver.

Maturation of the erythrocyte



Formation of Haemoglobin

Haemoglobin (Hb) is a complex protein, consisting of globin and an iron-containing substance called haem, and is synthesised inside developing erythrocytes in red bone marrow.

Hb in mature erythrocytes combines with oxygen to form oxyhaemoglobin, giving arterial blood its characteristic red colour.

Control of Erythropoiesis

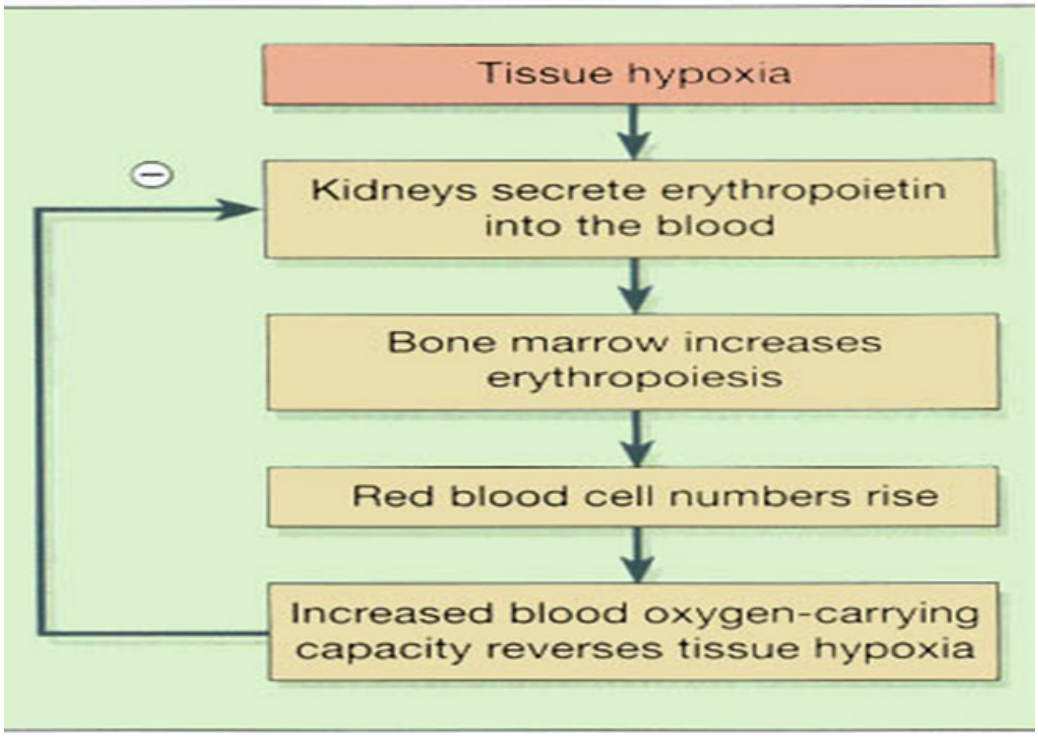
Through homeostatic negative feedback mechanism; the bone marrow produces erythrocytes at the rate at which they are destroyed.

Primary stimulus to increased erythropoiesis is hypoxia which occurs when:

- Oxygen-carrying power of blood is reduced by e.g. haemorrhage or excessive erythrocyte breakdown (haemolysis) due to disease
- Oxygen tension/concentration in the air is reduced, as at high altitudes.
- Hypoxia increases erythrocyte formation by stimulating the production of the hormone erythropoietin, mainly by the kidneys.

Effects of Erythropoietin

- Increases production of proerythrocytes
- Speeds up reticulocyte maturation
- And this ↑ oxygen carrying capacity of blood and thus hypoxia.
- When erythropoietin levels are low, red cell formation does not take place even in the presence of hypoxia, and anaemia develops.



Cotrol of Erythropoiesis

Destruction of Erythrocytes

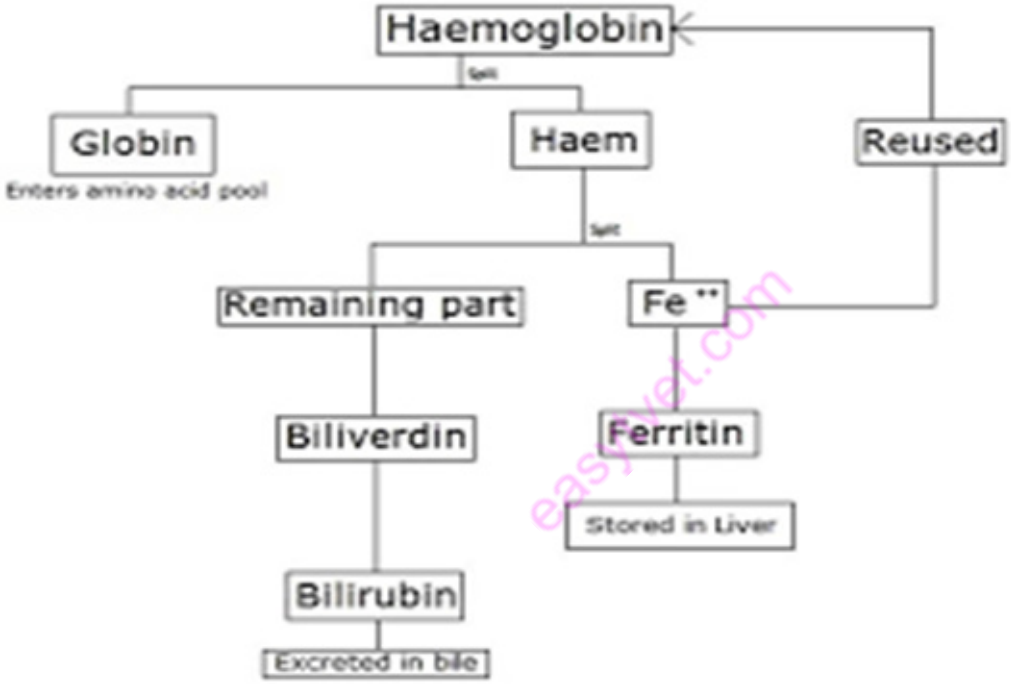
Life span of erythrocytes is about 120 days. Their breakdown/haemolysis, is by phagocytic reticuloendothelial cells found mainly in the spleen, bone marrow and liver.

As erythrocytes age, changes in their cell membranes make them more susceptible to haemolysis (membranes become fragile).

Iron released by haemolysis is retained in the body and reused in the bone marrow to form haemoglobin.

Biliverdin (green pigment) is formed from the breakdown of heme part of the hemoglobin.

It is then reduced to the yellow pigment bilirubin, before it is bound to plasma globulin and transported to the liver. In the liver it is changed from a fat-soluble to a water-soluble form before it is excreted as a constituent of bile.



Blood Groups

Antigens, found on the surfaces of individual's RBCs, which are inherited, determine the individual's blood group.

In addition, individuals make antibodies to these antigens, but not to their own type of antigen, since if they did the antigens and antibodies would react causing a transfusion reaction.

These antibodies circulate in the bloodstream and the ability to make them is genetically determined and not associated with acquired immunity.

If individuals are transfused with blood of the same group, i.e. possessing the same antigens on the surface of the cells, their immune system will not recognize them as foreign and will not reject them.

However, if they are given blood from an individual of a different blood type, i.e. with a different type of antigen on the red cells, their immune system will mount an attack upon them and destroy the transfused cells.

This is the basis of the transfusion reaction; the two blood types, the donor and the recipient, are incompatible.

There are two important systems of blood grouping:

1. ABO system
2. Rhesus system

The ABO System

About 55% of the population has either A-type antigens (blood group A), B-type antigens (blood group B) or both (blood group AB) on their red cell surface.

The remaining 45% have neither A nor B type antigens (blood group O).

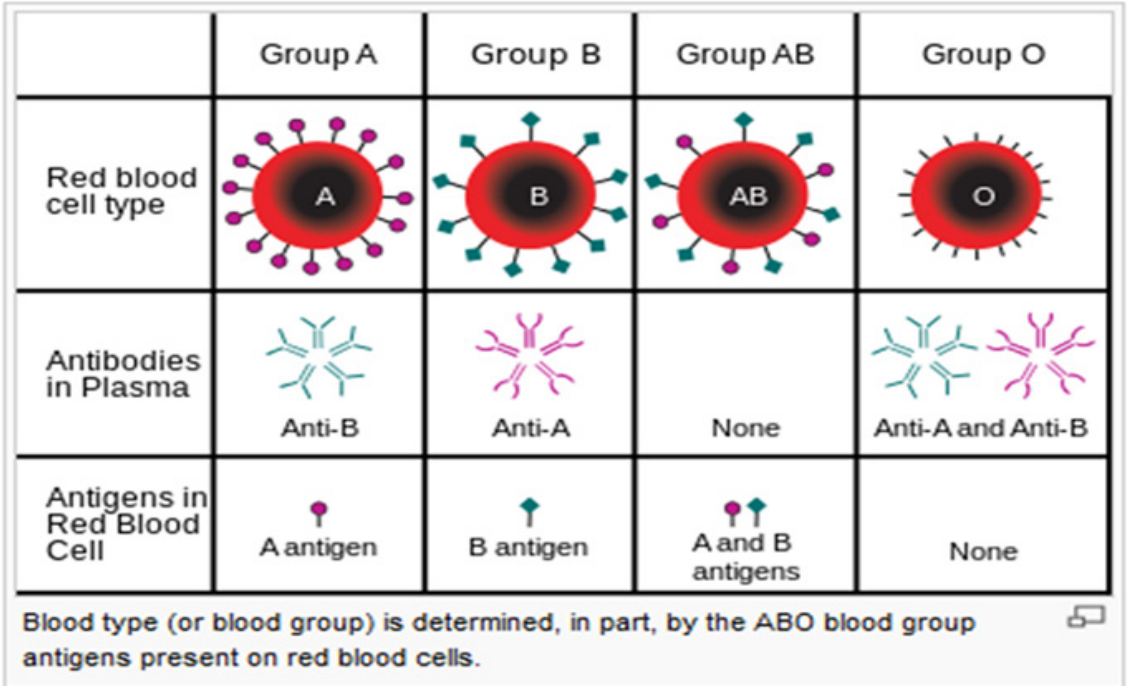
The corresponding antibodies are called anti-A and anti- B.

Blood group A individuals cannot make anti-A (and therefore do not have these antibodies in their plasma), since otherwise a reaction to their own cells would occur; they do, however, make anti-B.

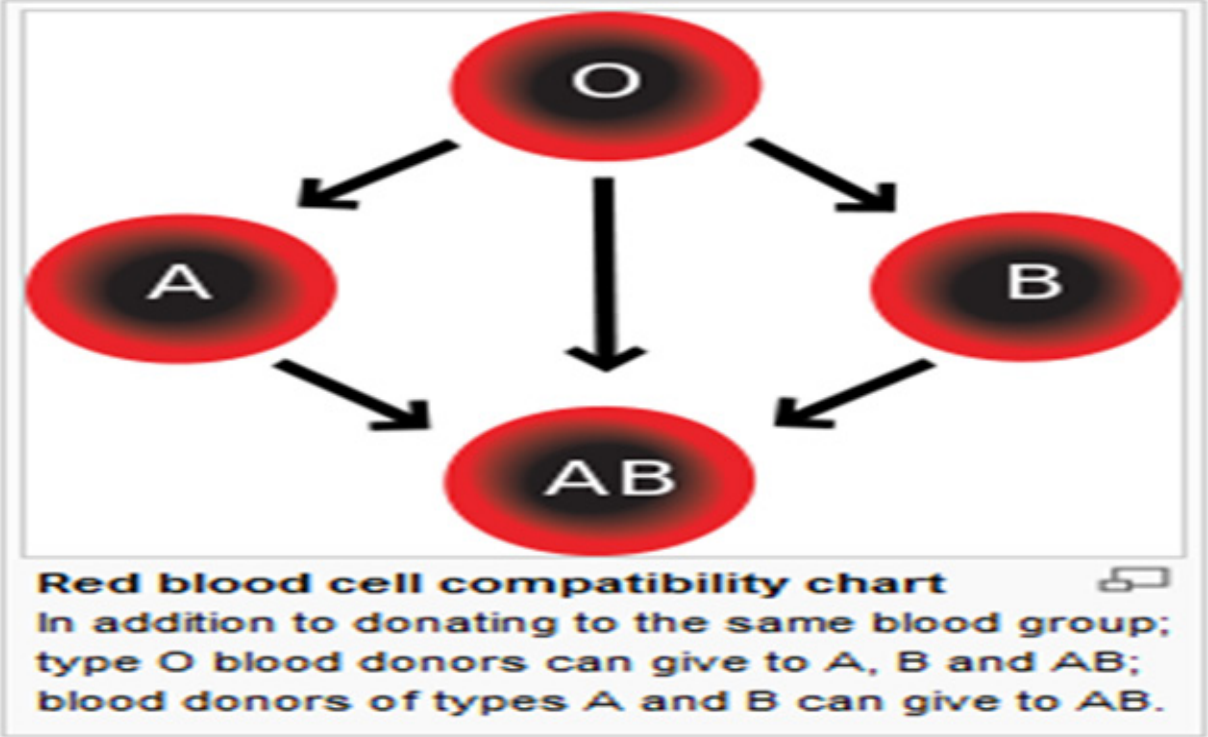
Blood group B individuals, for the same reasons, make only anti-A. Blood group AB make neither, and blood group O make both anti-A and anti-B .

Because blood group AB people make neither anti-A nor anti-B antibodies, they are known as universal recipients: transfusion of either type A or type B blood into these individuals is safe, since there are no antibodies to react with them.

Conversely, group O people have neither A nor B antigens on their red cell membranes, and their blood may be safely transfused into A, B, AB or O types; group O is known as the universal donor.



Blood type (or blood group) is determined, in part, by the ABO blood group antigens present on red blood cells.



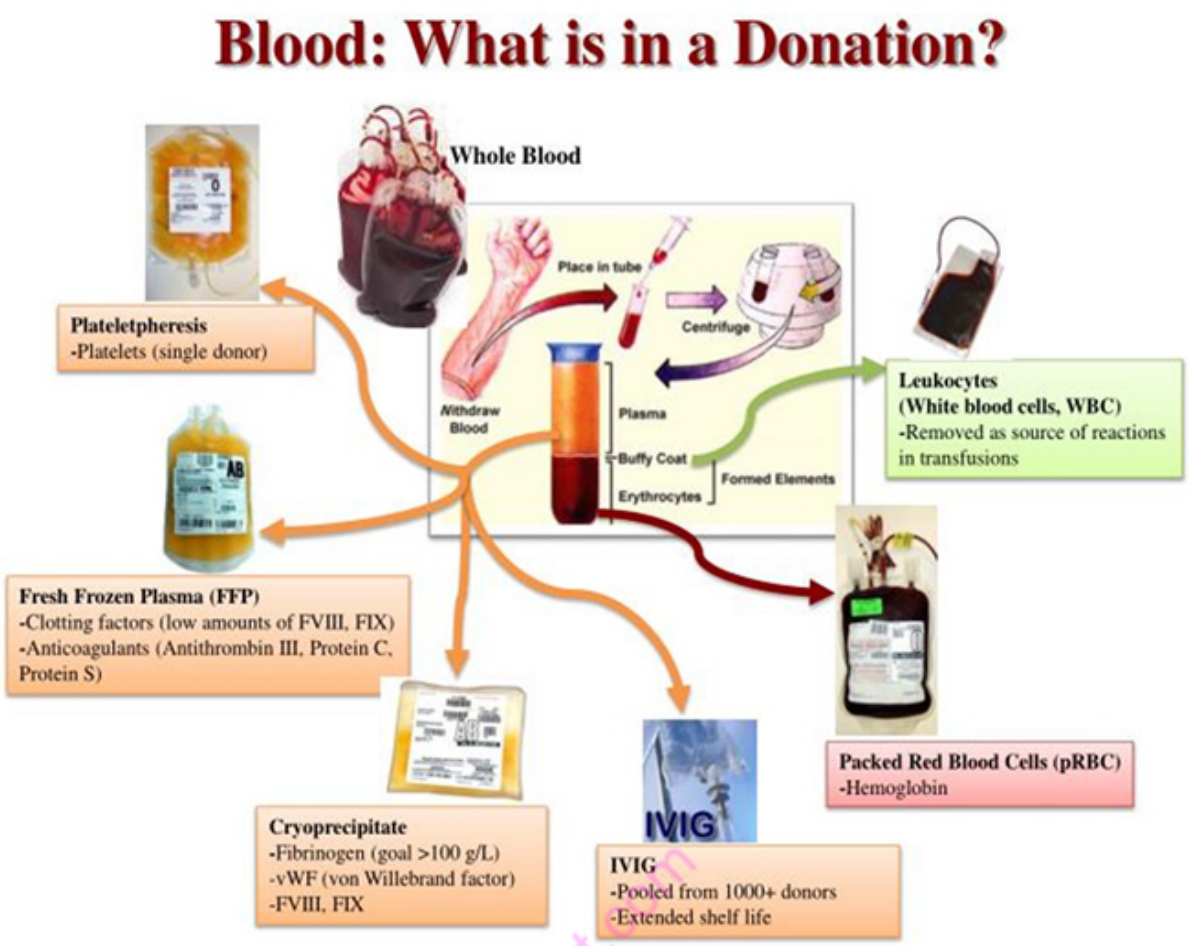
Universal Donor vs Recipient

Blood Transfusions

Blood Type of Donor	Blood Type of Recipient			
	A	B	AB	O
A	✓	X	✓	X
B	X	✓	✓	X
AB	X	X	✓	X
O	✓	✓	✓	✓

X = Unsuccessful transfusion ✓ = Successful transfusion

Red Blood Cell Compatibility Table



Explanation why Blood Group O is a Universal Donor

Why then is O still the universal donor and they have both anti-A and anti-B antibodies?

First, the blood plasma containing the antibodies is (virtually) removed after centrifugation. Hence, it can be donated to everyone, as far as that the rhesus factor matches.

Secondly, even if plasma is transfused, antibodies in the donor's plasma are a minor problem, because of the small amount of antibody present in the donated plasma, which is further diluted on transfusion into the recipient's circulation (Dean, 2005).

NB: For blood compatibility, we only check the antigen for donors and antibodies for recipients

Plasma Compatibility Table

Plasma contains anti-A and anti-B antibodies depending upon the blood group. Plasma lack antigens because they are found on the surface of red blood cell membrane. Our body also has antibodies to A and/or B antigens according to our blood group. Patients should only receive plasma that does not contain an antibody which could attack the antigens present on their own red cells.

Group A recipients have A antigen on their red cells, so they can't receive group O or group B plasma as the anti-A will attack their red cells. Group B recipients have B antigen on their red cells, so they can't receive group O or group A plasma as the anti-B will attack their red cells.

Group AB recipients can only receive group AB plasma. Group O recipients do not have either A or B antigen, so can safely receive plasma of any blood group type.

NB: Plasma compatibility table is opposite of red blood cell compatibility table. Blood group O become the universal recipient while AB become the universal donor.

Plasma compatibility table[25]

Recipient	Donor[1]			
	O	A	B	AB
O	✓	✓	✓	✓
A	✗	✓	✗	✓
B	✗	✗	✓	✓
AB	✗	✗	✗	✓

Blood group	Antigen + antibody(ies) present	As donor, is	As recipient, is
A	 Antigen A — Makes anti-B	Compatible with: A and AB Incompatible with: B and O, because both make anti-A antibodies that will react with A antigens	Compatible with: A and O Incompatible with: B and AB, because type A makes anti-B antibodies that will react with B antigens
B	 Antigen B — Makes anti-A	Compatible with: B and AB Incompatible with: A and O, because both make anti-B antibodies that will react with B antigens	Compatible with: B and O Incompatible with: A and AB, because type B makes anti-A antibodies that will react with A antigens
AB	 Antigens A and B — Makes neither anti-A nor anti-B	Compatible with: AB only Incompatible with: A, B and O, because all three make antibodies that will react with AB antigens	Compatible with all groups **UNIVERSAL RECIPIENT** AB makes no antibodies and therefore will not react with any type of donated blood
O	 Neither A nor B antigen — Makes both anti-A and anti-B	Compatible with all groups **UNIVERSAL DONOR** O red cells have no antigens, and will therefore not stimulate anti-A or anti-B antibodies	Compatible with: O only Incompatible with: A, AB and B, because type O makes anti-A and anti-B antibodies

The ABO system of blood grouping: antigens, antibodies and compatibility.

The Rhesus System

Rhesus factor; it's a red blood cell membrane antigen.

About 85% of people have this antigen; they are said to be Rhesus positive (Rh+) and do not therefore make anti-Rhesus antibodies.

The remaining 15% have no Rhesus antigen (they are Rhesus negative, or Rh -).

Rh - individuals are capable of making anti-Rhesus antibodies, but are stimulated to do so only in certain circumstances, e.g. in pregnancy, or as the result of an incompatible blood transfusion.

Summary

Red blood cell compatibility table[24][25]

Recipient[1]	Donor[1]							
	O−	O+	A−	A+	B−	B+	AB−	AB+
O−	✓	✗	✗	✗	✗	✗	✗	✗
O+	✓	✓	✗	✗	✗	✗	✗	✗
A−	✓	✗	✓	✗	✗	✗	✗	✗
A+	✓	✓	✓	✓	✗	✗	✗	✗
B−	✓	✗	✗	✗	✓	✗	✗	✗
B+	✓	✓	✗	✗	✓	✓	✗	✗
AB−	✓	✗	✓	✗	✓	✗	✓	✗
AB+	✓	✓	✓	✓	✓	✓	✓	✓

LEUKOCYTES (White Blood Cells)

Main function: Defending the body against microbes and other foreign materials.

They are the largest blood cells, and account for about 1% of the blood volume. They contain nuclei and some have granules in their cytoplasm.

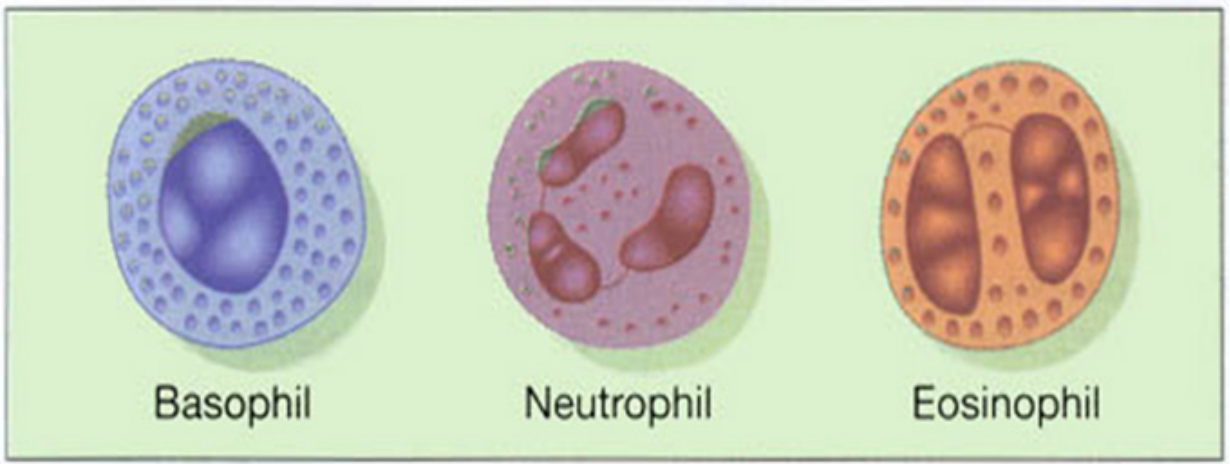
Two main types:

- Granulocytes (polymorphonuclear leukocytes) neutrophils, eosinophils and basophils
- Agranulocytes monocytes and lymphocytes.

Granulocytes (polymorphonuclear leukocytes)

They have multilobed nuclei in their cytoplasm. Their names represent the dyes they take up when stained in the laboratory.

- Eosinophils; red acid dye, eosin;
- Basophils; alkaline methylene blue;
- Neutrophils (purple); take up both dyes.



Types of Leukocytes

Granulocytes

i. Neutrophil

- Non-specific defense
- Phagocytic
- 50-70% of WBCs
- Granules contain enzymes and defensins
- Very mobile: first at injury
- Life span less than 10h.

Functions:

- Kill phagocytosed things
- Degranulation: release defensins, lyse bacteria
- Prostaglandins: induce inflammation to stop spread of injury
- Leukotrienes: attract phagocytes.

ii. Eosinophil

- Non-specific defense
- Phagocytic
- 2-4% of WBCs
- Granules contain toxins

- Life span 9 days

Functions:

- Phagocytosis of antibody covered objects
- Defense against parasites:
- Exocytose toxins on large pathogens
- Reduce inflammation: anti-inflammatory
- Chemicals/enzymes

iii. Basophil

- In tissues are called mast cell
- Non-specific defense
- Not phagocytic
- Less than 1% of WBCs
- Granules contain Histamine: dilate blood vessels
- Heparin: prevents clotting
- Life span 9 days

Functions:

- Inflammation
- Allergic response (via histamine)

iv. Agranulocytes

- Have a large nucleus
- Have no granules in their cytoplasm
  - Make up 25% to 50% of all leukocytes
  - Includes:
    1. Monocytes and
    2. Lymphocytes

1. Monocytes

Are large mononuclear cells that originate in red bone marrow.

Some circulate in the blood and are actively motile and phagocytic while others migrate into the tissues where they develop into macrophages.

Macrophages have important functions in inflammation and immunity, and are actively phagocytic.

The monocyte-macrophage system/ Reticuloendothelial system

Consists of the body's complement of monocytes and macrophages.

Some macrophages are mobile whereas others are fixed.

Cells of this system include:

- Histiocytes in connective tissues
- Microglia in the brain
- Kupffer cells in the liver
- Alveolar macrophages in the lungs
- Sinus-lining macrophages (reticular cells) in the spleen, lymph nodes and thymus gland
- Mesangial cells in the glomerulus of nephrons in the kidney
- Osteoclasts in bone.
- Langerhans cells in the skin
- Synovial cells in the joints.

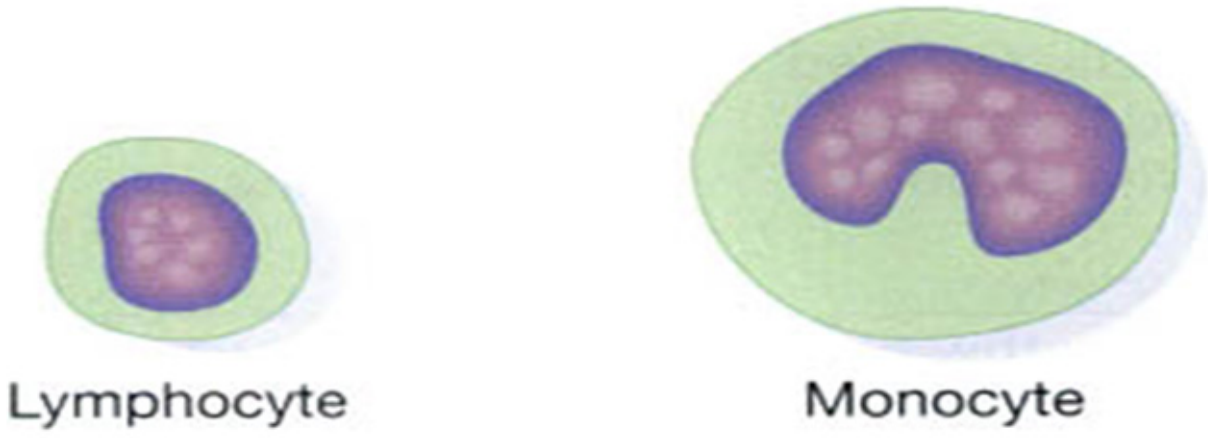
2. Lymphocytes

Smaller than monocytes and have large nuclei.

Circulate in the blood and are present in great numbers in lymphatic tissue such as lymph nodes and the spleen.

Lymphocytes are usually activated in the lymphatic tissue (especially the Thymus) to produce two distinct types: T-lymphocytes and B-lymphocytes which have different functions.

T-lymphocytes are responsible for cell mediated immunity while B-lymphocytes are responsible for antibody production against certain antigens.



THROMBOCYTES (Platelets)

Very small non-nucleated discs derived from the cytoplasm of megakaryocytes in red bone marrow.

Contain a variety of substances that promote blood clotting, which causes haemostasis (cessation of bleeding).

Control of production is a fall in platelet count (stimulus) and thrombopoietin (effector) a hormone produced by the liver and the kidney.

Life span is between 8 and 11 days.

Haemostasis

Cessation of bleeding is achieved through the following processes:

1. Vasoconstriction. When platelets come in contact with a damaged blood vessel, their surface becomes sticky and they adhere to the damaged wall.

They then release serotonin which constricts the vessel, reducing blood flow through it. Thromboxanes; released by the damaged vessel itself also cause vasoconstriction.

2. Platelet plug formation. Adherent platelets clump to each other and release adenosine diphosphate (ADP), which attract more platelets to the site.

Passing platelets stick to those already at the damaged vessel and they too release their chemicals.

Many platelets rapidly arrive at the site of vascular damage and quickly form a temporary seal — the platelet plug (within 6 minutes).

3.Coagulation (blood clotting). Results in the formation of an insoluble thread-like mesh of fibrin which traps blood cells and is much stronger than the rapidly formed platelet plug. In the final stages of this process prothrombin activator acts on the plasma protein prothrombin converting it to thrombin.

Thrombin then acts on fibrinogen converting it to fibrin.

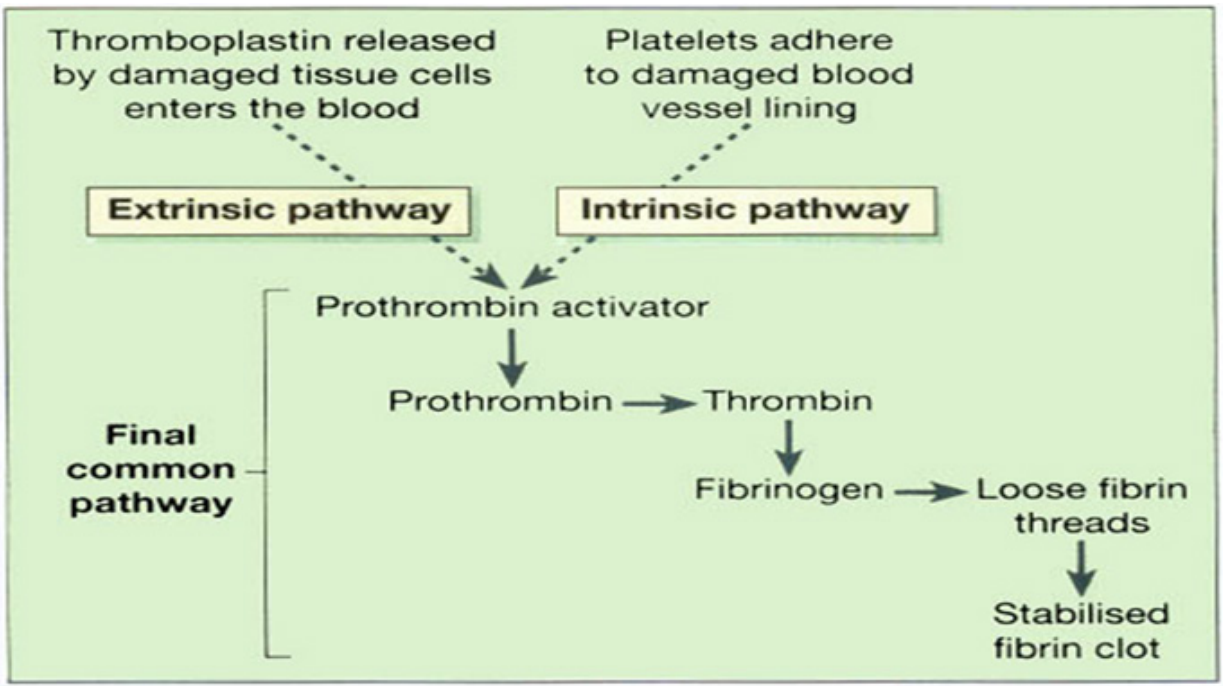
Prothrombin activator can be formed by two processes which often occur together: the extrinsic and intrinsic pathways.

Extrinsic pathway occurs rapidly (within seconds) when there is tissue damage outside the circulation. Damaged tissue releases a complex of chemicals called thromboplastin or tissue factor, which initiates coagulation.

Intrinsic pathway is slower (3-6 minutes) and is confined to the circulation. It is triggered by damage to a blood vessel lining (endothelium) and the effects of platelets adhering to it.

After a time the clot shrinks, squeezing out serum.

Stages of Blood Clotting



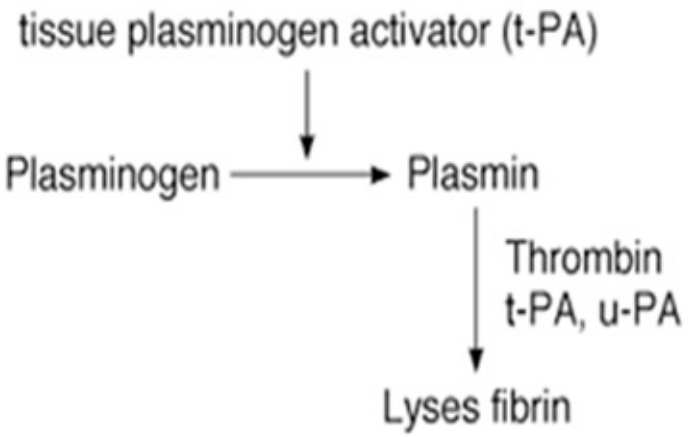
4. Fibrinolysis--after the clot has formed the process of removing it and healing the damaged blood vessel begins.

An inactive substance called plasminogen is present in the clot and is converted to the enzyme plasmin by activators released from the damaged endothelial cells.

Plasmin initiates the breakdown of fibrin to soluble products; removed by phagocytosis.

As the clot is removed, the healing process restores the integrity of the blood vessel wall.

Fibrinolysis Process



Common Blood Disorders

- Anemia
- Sickle Cell Disease
- Hemolytic Disease of the Newborn
- Rhesus disease
- Bleeding disorders like hemophilia, von Willebrand Disease
- Blood cancers such as leukemia, lymphoma, and myeloma.

THE RESPIRATORY SYSTEM

Introduction

The respiratory system consists of passages that filter incoming air and transport it into the lungs and to the many microscopic air sacs where gases are exchanged

Respiration is the process of exchanging gases between the atmosphere and body cells

It consists of the following events:

- Ventilation
- Transport of gases
- Cellular respiration
- External respiration
- Internal respiration

Respiration is associated with 4 processes:

- Pulmonary ventilation is the movement of air into/out of the lungs
- External respiration is the movement of O_2 from the lungs to the blood and CO_2 from the blood to the lungs.
- Gas transport refers to the mechanisms by which O_2 and CO_2 are moved thru the blood.
- Internal respiration is the movement of O_2 from the blood to the cell interior and CO_2 from the cell interior to the blood.

Main functions of the Respiratory System

- Exchange of O_2 and CO_2.
- Voice production.
- Regulation of plasma PH
- Olfaction (sensation of smell)
- Infection (pathogen invasion) prevention.

Organs of the Respiratory System

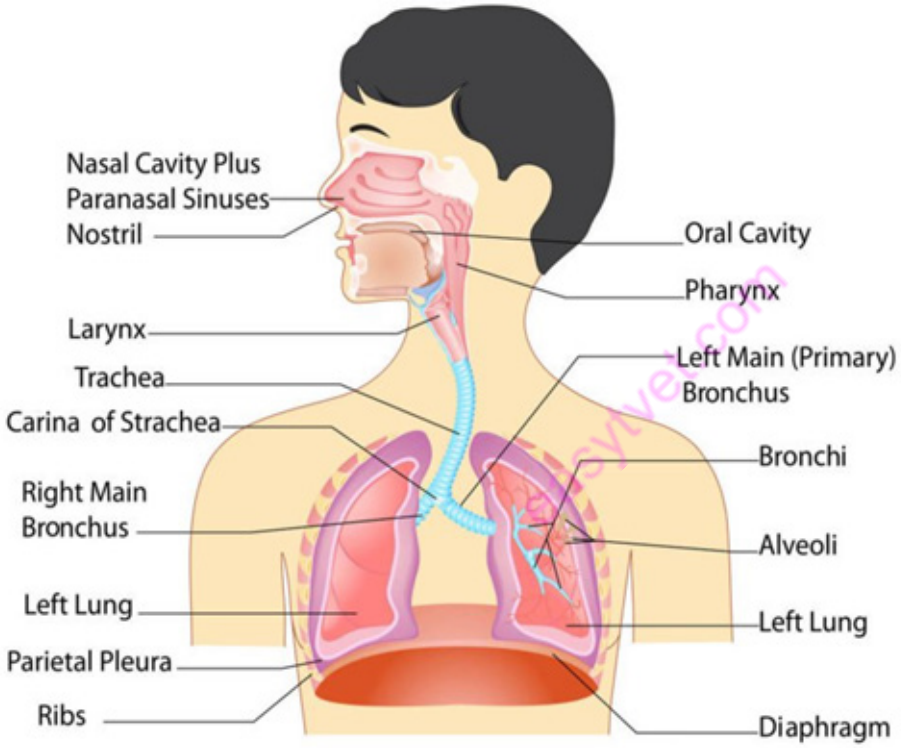
The organs of the respiratory system can be divided into two tracts:

Upper respiratory tract

- The nose
- Nasal cavity
- Sinuses
- Pharynx

Lower respiratory tract

- Larynx
- Trachea
- Bronchial tree
- Lungs
- Muscles of breathing



Zones of the Respiratory System

1. Conducting zone

Respiratory passages that carry air to the site of gas exchange. Filters, humidifies and warms air.

2. Respiratory zone

Site of gas exchange, and is composed of:

Respiratory bronchioles

- Alveolar ducts
- Alveolar sacs

The Nose

- Provides airway
- Moistens and warms air
- Filters air
- Resonating chamber for speech
- Olfactory receptors

Nasal Cavity

- Air passes through nares (nostrils)
- Nasal septum divides nasal cavity in midline (to right & left halves)
- Perpendicular plate of ethmoid bone, vomer and septal cartilage
- Connects with pharynx posteriorly through choanae (posterior nasal apertures*)
- Floor is formed by palate (roof of the mouth)
- Anterior hard palate and posterior soft palate.

Nose & Nasal Cavity

Relations

Roof: cribriform plate of the ethmoid bone and the sphenoid bone, frontal bone & nasal bones

Floor: hard and soft palate (maxilla and palatine bones & involuntary muscles)

Medial wall: nasal septum

Lateral wall: maxilla, ethmoid bone & inferior conchae

Posterior wall: post. Wall of pharynx

Lining of the Nose

The majority of the nasal cavity is lined by respiratory epithelium. Respiratory epithelium is pseudostratified columnar epithelium with goblet cells.

The mucus secreted by goblet cells, as well as by mucous glands, helps filter and trap inspired particulate matter. The moist mucus (as well as the watery solution secreted by serous glands) contributes to the humidification of inspired air.

Cilia help sweep mucus to the pharynx where it is swallowed.

Respiratory epithelium is underlain by a dense vasculature. The blood helps warm inspired air. Mucus also contains lysozyme as well as immunoglobulins, which help prevent infection.

Respiratory Mucosa

Pseudostratified ciliated columnar epithelium

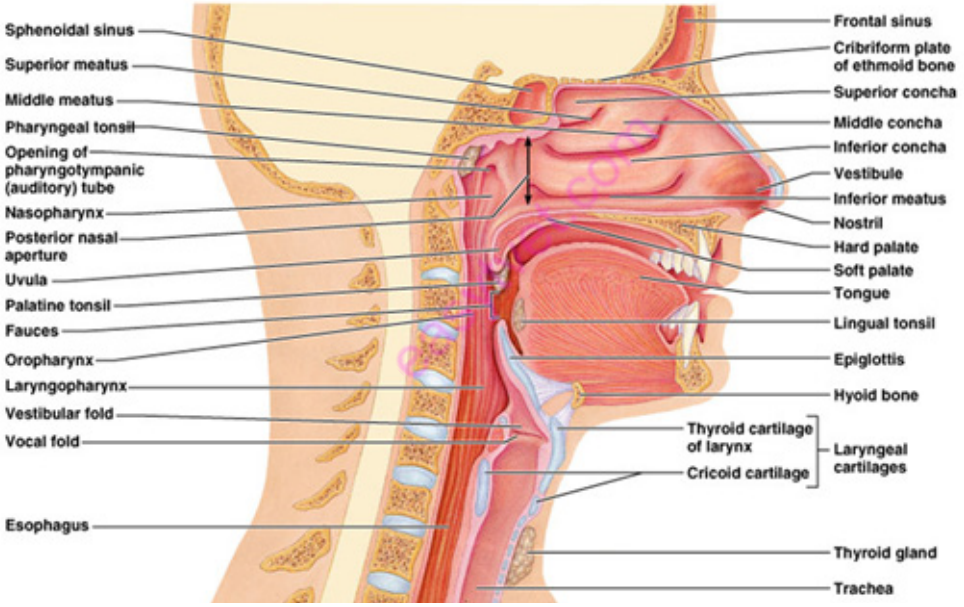
Scattered goblet cells

Underlying connective tissue lamina propria

- Mucous cells – secrete mucous
- Serous cells – secrete watery fluid with digestive enzymes, e.g. lysozyme

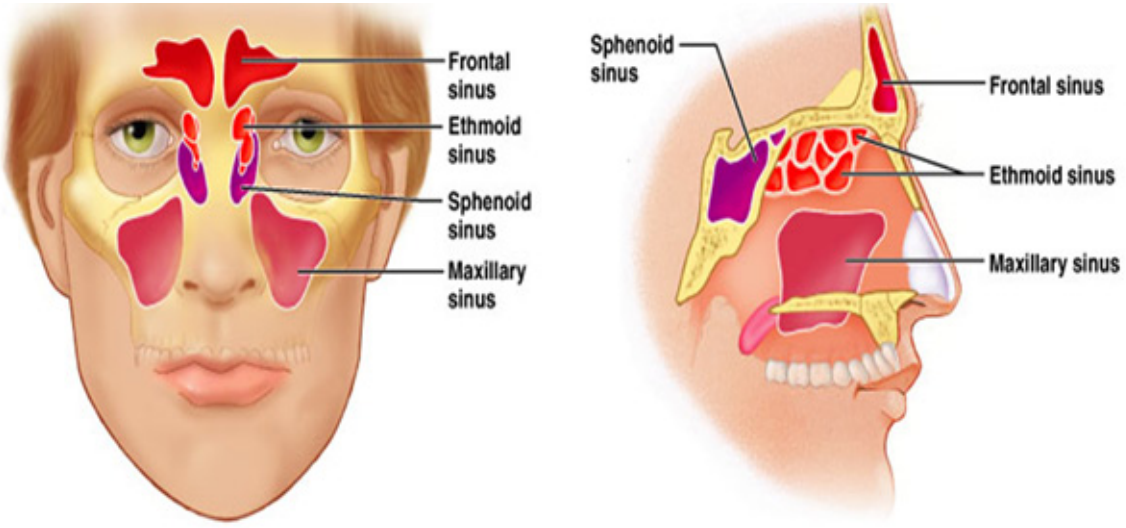
Nasal Conchae

- Inferior to each is a meatus*
- Increases turbulence of air
- 3 scroll-like structures
- Reclaims moisture on the way out



Paranasal Sinuses

- Frontal, sphenoid, ethmoid and maxillary bones
- Open into nasal cavity
- Lined by same mucosa as nasal cavity and perform same functions
- Also lighten the skull
- Can get infected: Sinusitis



Openings into the Nasal Cavity

Anterior nares: nostrils are openings from exterior to the nasal cavity. The initial space just beyond the open is the nasal vestibule and it contains vibrissae (hairs) which perform a filtration function.

Posterior nares: from the nasal cavity to the pharynx

Nasolacrimal ducts: from the lateral wall of the nose to the conjunctival sac.

Functions of the Nose

Respiratory Functions

- Warming: highly vascularised
- Filtering & cleaning: hair, mucus, cilia
- Humidification: moist mucosa

Pharynx

The pharynx is posterior to the oral cavity and between the nasal cavity and the larynx.

It conducts air to larynx and food to esophagus, and is divided into 3 sections: nasopharynx, oropharynx, & laryngopharynx.

1. Nasopharynx

Is lined by respiratory epithelium. The posterior-most portion that hangs down is the uvula. The soft palate and uvula flip up during swallowing and help prevent food/drink from entering the nasopharynx.

On the lateral walls of the nasopharynx are the openings to the auditory tubes (Eustachian tubes). Each auditory tube connects the pharynx to a middle ear cavity. They ensure that air pressure within the middle ear cavities is equal to atmospheric pressure.

The nasopharynx also contains the pharyngeal tonsil. (lymphoid tissue) prominent up to to 7yrs of age then atrophy.

2. Oropharynx

Is inferior to the uvula and superior to the epiglottis .

It's posterior to the oral cavity.

Two sets of tonsils (palatine and lingual) are located right nearby.

It's lined by nonkeratinized stratified squamous epithelium.

This provides the necessary protection since this region is a common pathway for food and air.

3. Laryngopharynx

The is inferior to the epiglottis and superior to the split between the larynx and the esophagus

It's lined by nonkeratinized stratified squamous epithelium because it is also a common pathway for food and air.

It's continuous with the larynx inferiorly.

Pharynx: Structure

Mucus membrane: at the nasopharynx is ciliated columnar epithelium, oropharynx & laryngopharynx, stratified squamous epithelium like esophagus & mouth to protect it from abrasive action of foodstuffs passing.

Smooth muscle; involuntary constrictor muscles for swallowing

Pharynx: Functions

- Passage for airway and food
- Taste
- Protection from infections
- Warming and humidifying air
- Hearing
- Speech (voice resonator)

The Larynx (Voice box)

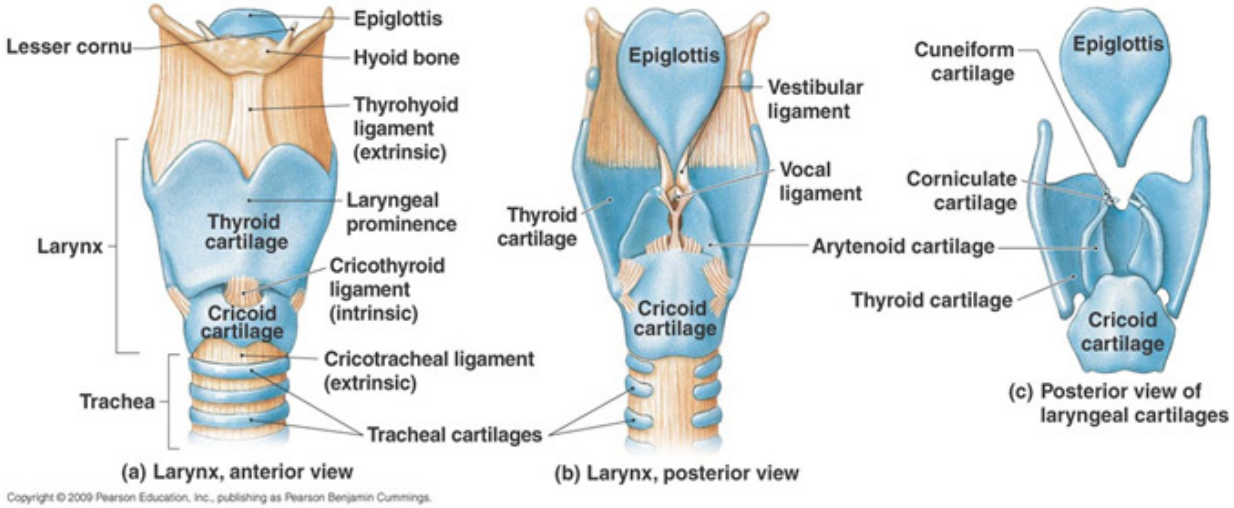
Rigid structure between laryngopharynx and trachea, that contain vocal cords, which produce voice on vibration

Rigidity is maintained by muscles, ligaments and 9 cartilages.

Three functions:

- Produces vocalizations (speech)
- Provides an open airway (breathing)
- Switching mechanism to route air and food into proper channels.

Closed during swallowing, Open during breathing



Epiglottis* (the 9th Cartilage)

Elastic cartilage covered by mucosa (stratified sq.epi)

Epiglottis tips inferiorly to cover and seal laryngeal inlet

Keeps food out of lower respiratory tract

Larynx: Functions

- Sound production-
  - Pitch; depends on the length & tightness of the cord
  - Volume; depends on the force of cord vibration during exhalation
  - Resonance; depends on the shape of the mouth, tongue position, lips position, facial muscles & air and paranasal sinuses
- Speech: occurs during expiration when sounds produced by vocal cords are manipulated by the tongue, cheeks & lips.
- Protection of lower respiratory tract during swallowing
- Passage for air
- Humidifying, filtering & warming air.

Trachea

The trachea (windpipe) is a flexible cylindrical tube about 2.5 centimeters in diameter and 12.5 centimeters in length.

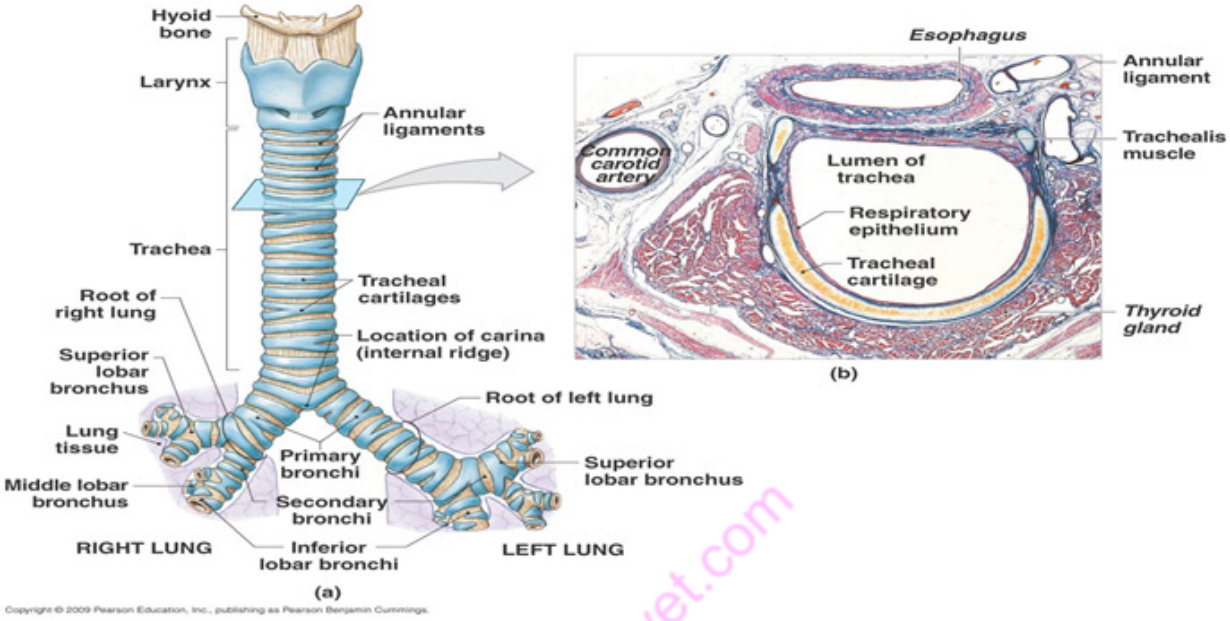
As it extends downward anterior to the esophagus and into the thoracic cavity, it splits into the right and left primary bronchi.

Trachea: Structure

16-20 C-shaped rings of hyaline cartilage joined by fibro-elastic connective tissue posteriorly intact with esophagus.

The trachea is associated with copious mucus secretion – due to its abundant seromucous glands

The lack of posterior cartilage is important because it provides the esophagus with room to expand when a large bolus of food is swallowed.



Trachea: Functions

Support and patency: cartilage arrangement and presence of supporting connective tissue posteriorly.

Mucocilliary escalator: beating of the cilia wafts adherent particles upwards and are either coughed or swallowed.

Cough reflex: irritation in the airway stimulates nerve endings which generates impulses through the vagus nerve to the respiration center which cause coughing.

Warming, humidifying and filtering the air

Lungs

The right and left lungs are soft, spongy, cone-shaped organs in the thoracic cavity. The right lung has three lobes and the left lung has two lobes

Relations

Apex: rounded, rises into the root of the neck, lies close to 1st rib, blood vessels & nerves in the root of the neck.

Base: concave & semilunar in shape, lies in the thoracic surface of the diaphragm

Costal surface: convex and lies against the costal cartilages, ribs & intercostal muscles

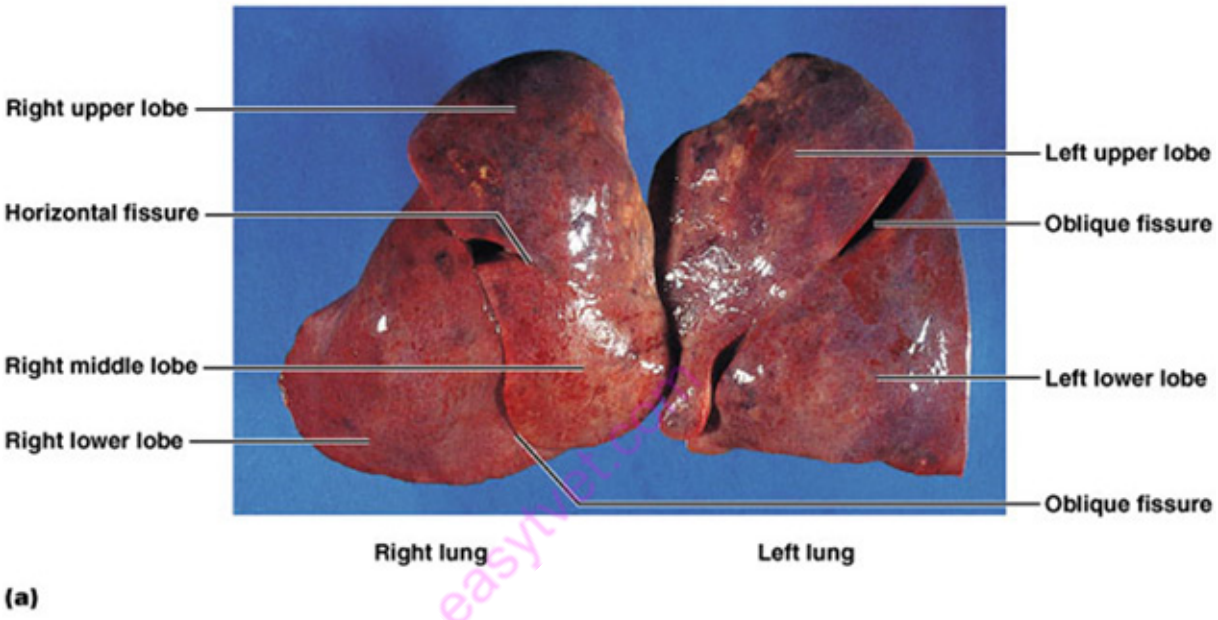
Medial surface: concave, has a roughly triangular shaped area; hilum.

Structures forming the root of the lungs enter and leave the lung through the hilum i.e. primary bronchus, pulmonary aa, pulmonary v., bronchial aa & v, lymphatic & nerve supply.

Lungs

Each is cone-shaped with anterior, lateral and posterior surfaces contacting ribs, Superior tip is apex, just deep to clavicle

Concave inferior surface resting on diaphragm is the base.



Hilus or (hilum)

- Indentation on mediastinal (medial) surface.
- Place where blood vessels, bronchi, lymph vessel, and nerves enter and exit the lung.
- Each lobe is made up of bronchopulmonary segments separated by dense connective tissue
- Each segment receives air from an individual segmental (tertiary) bronchus
- Approximately 10 bronchopulmonary segments in each lung
- Limit spread of infection
- Can be removed more easily because only small vessels span segments
- Smallest subdivision seen with the naked eye is the lobule
- Hexagonal on surface, size of pencil eraser
- Served by large bronchiole and its branches
- Black carbon is visible on connective tissue separating individual lobules in smokers and city dwellers.

Difference between the lungs

	Right lung	Left lung
length	Shorter.	Longer.
width	Wider.	Narrower.
lobes	3 (upper, middle and lower).	2 (upper and lower).
fissures	oblique,horizontal.	Oblique.
cardiac notch	absent.	present.
Lingula	absent.	present.

Lungs and Pleura

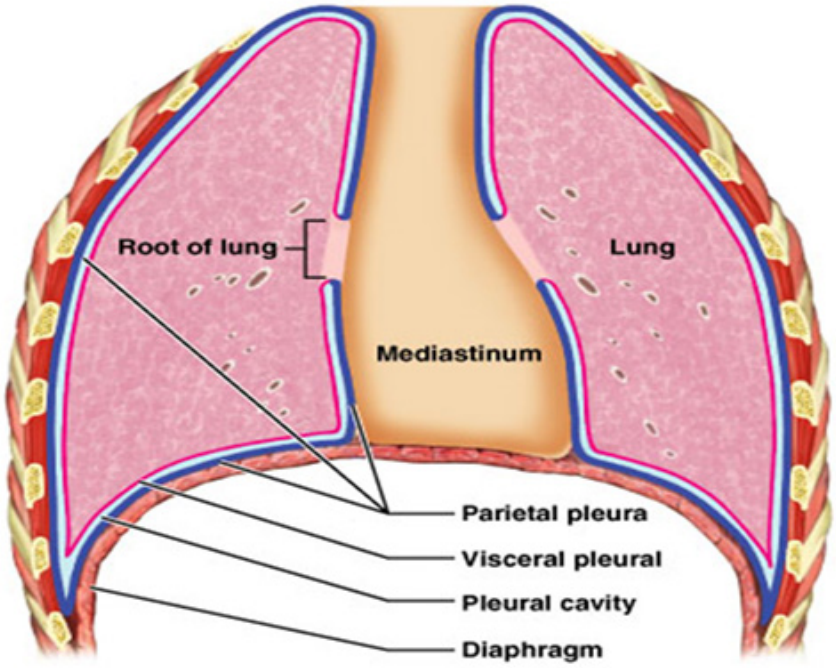
Around each lung is a flattened sac of serous membrane called pleura.

Parietal pleura – outer layer, adheres inside the chest wall, continuous with visceral pleura

Visceral pleura – directly on lung, passes all round the lungs

Pleural cavity – slit-like potential space filled with pleural fluid separating the 2 pleura layers.

Pleural fluid *reduces friction* during expansion and contraction of the lungs.



Interior of the lungs

Consists of bronchi, bronchioles, alveoli, CT, blood vessels, lymph vessels, nerves and embedded elastic connective tissue matrix .

Pulmonary blood supply: pulmonary trunk divides to R & L pulmonary artery which eventually divides to dense capillary network at the walls of the alveoli. (one cell thick) where exchange of gases takes place through this fine membrane (respiratory membrane)

Pulmonary capillaries join to form 2 pulmonary veins which leaves the lungs at the hilum with oxygenated blood to the left atrium.

Bronchial tree bifurcation

- Right main bronchus (more susceptible to aspiration)
- Left main bronchus

Each main or primary bronchus runs into hilus of lung posterior to pulmonary vessels

Branches of the Bronchial Tree

The successive divisions of the branches from the trachea to the alveoli are:

- Right and left primary bronchi
- Secondary or lobar bronchi
- Tertiary or segmental bronchi

- Intralobular bronchioles
- Terminal bronchioles
- Respiratory bronchioles
- Alveolar ducts
- Alveolar sacs
- Alveoli

Bronchial Tree

The bronchial tree consists of branched airways leading from the trachea to the microscopic air sacs in the lungs.

Bronchi

As the bronchial tree branches, its histology changes markedly:

Cartilage rings are replaced by cartilage plates, and within the bronchioles, cartilage is absent entirely.

Epithelium changes from pseudostratified columnar to simple columnar to simple cuboidal.

The number of cilia declines.

The number of goblet cells declines.

The relative amount of smooth muscle increases.

Bronchi: Functions

- Control of air entry: through contraction and relaxation of the muscles of the respiratory passage under ANS control.
- Warming and humidifying air
- Support and patency
- Removal of foreign body
- Cough reflex

Respiratory Zone

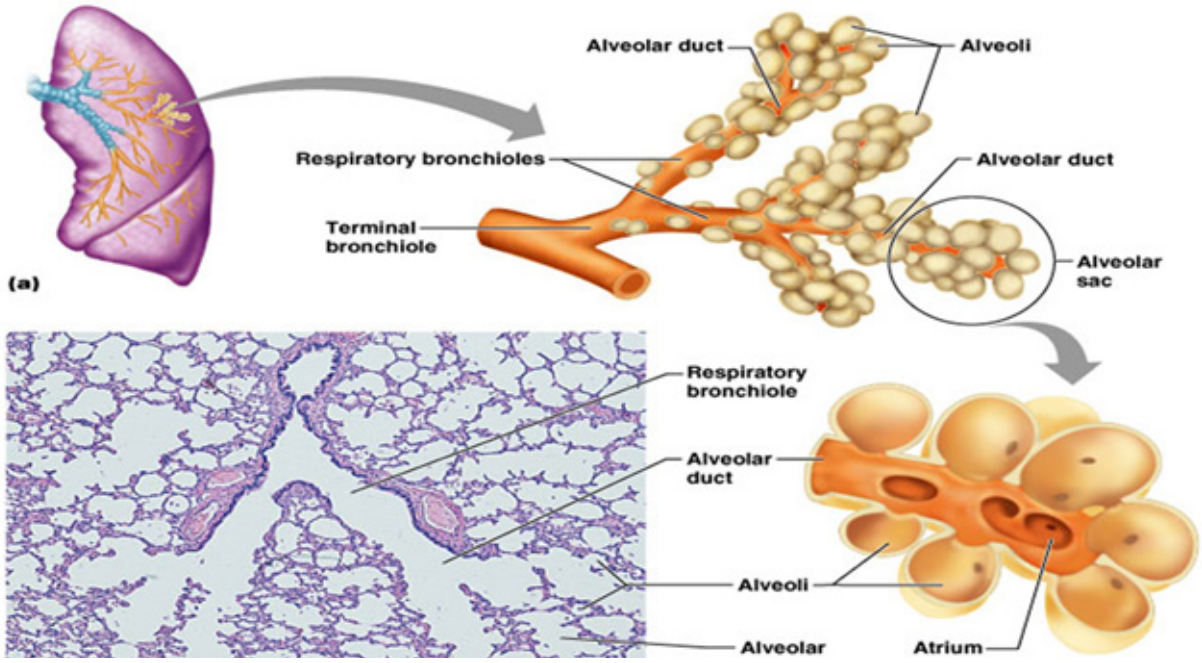
End-point of respiratory tree

Structures that contain air-exchange chambers are called alveoli

Respiratory bronchioles lead into alveolar ducts: walls consist of alveoli

Ducts lead into terminal clusters called alveolar sacs – are microscopic chambers

There are 3 million alveoli!



Respiratory Bronchioles and Alveoli lungs-lobules, supplied by terminal bronchioles which divides to respiratory bronchioles, alveolar ducts and finally alveoli.

About 150m alveoli in an adult.

The wall a single layer of simple squamous epithelial cell is found at the alveoli level supported by loose network of CT in which nerves, lymph vessel, blood vessels, and macrophages are found.

Alveoli is surrounded by dense capillary network where external respiration takes place through the respiration membrane. (fusion of alveolar wall and capillary wall)

Type II cuboidal epithelial cells lies between squamous cells and secrete surfactant.

Surfactant prevents the alveoli from drying out, reduces surface tension and prevents alveolar walls from collapsing.

Begins at 35th week fetal life, in newborn babies it facilitates lung expansion of the lungs and establishment of respiration.

Gas Exchange

- Air filled alveoli account for most of the lung volume
- Very great area for gas exchange (1500 sq ft)
- *Alveolar wall:* Single layer of squamous epithelial cells (type 1 cells) surrounded by basal lamina
- 0.5um (15 X thinner than tissue paper)
- External wall covered by cobweb of capillaries

- Respiratory membrane: fusion of the basal laminas of
  - Alveolar wall
  - Capillary wall

Respiratory Bronchioles

Functions

1. Defense against microbes: defense cells are present in the lungs; includes, macrophages, lymphocytes and plasma cells.
2. Warming and humidifying air.
3. Provides airway
4. Ventilation

   Breathing = "pulmonary ventilation"

Pulmonary means related to the lungs

Two phases

- Inspiration (inhalation) – air in | - Expiration (exhalation) – air out

Muscle of breathing

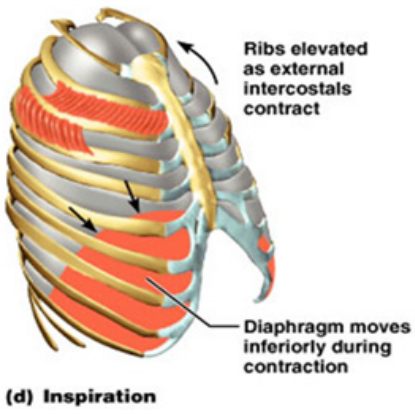
- Intercostal muscles
- Diaphragm

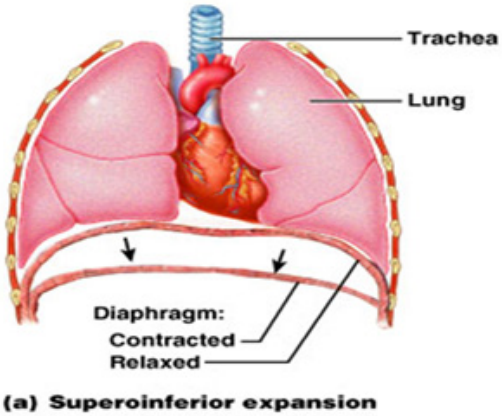
Diaphragm: Dome shaped, separates thoracic and abdominal cavities,

Contraction shortens the muscles enlarging the thoracic cavity while relaxation decreases the thoracic cavity pressure. Supplied by Phrenic n.

The Intercostal muscles: 11 pairs, occupy the space between the 12 ribs.

Internal intercostal muscles: extends downwards & backwards from the lower border off the ribs above to the upper border of the ribs.





During deep or forced inspiration, additional muscles are recruited:

Accessory Muscles of Respiration

Scalene muscles- a group of three pairs of muscles in the lateral neck

Sternocleidomastoid (some of these "accessory muscles" of ventilation are visible to an observer; it usually tells you that there is respiratory distress – working hard to breathe)

Atmospheric pressure due to the weight of the air is the force that moves air into the lungs

At sea level, atmospheric pressure is 760 millimeters of mercury (mm Hg)

Moving the plunger of a syringe causes air to move in or out

Air movements in and out of the lungs occur in much the same way

Intra-alveolar pressure decreases to about 758 mmHg as the thoracic cavity enlarges due to diaphragm downward movement caused by impulses carried by the phrenic nerves.

Atmospheric pressure then forces air into the airways

Major Events in Inspiration

1. Nerve impulses travel on phrenic nerves to muscle fibers in the diaphragm, contracting them
2. As the dome shaped diaphragm moves downward, the thoracic cavity expands
3. At the same time, the external intercostal muscles may contract, raising the ribs and expanding the thoracic cavity further
4. The intra-alveolar pressure decreases
5. Atmospheric pressure, greater on the outside, forces air into the respiratory tract through the air passages
6. The lungs fill with air.

Expiration

Quiet expiration in healthy people is chiefly passive.

Inspiratory muscles relax

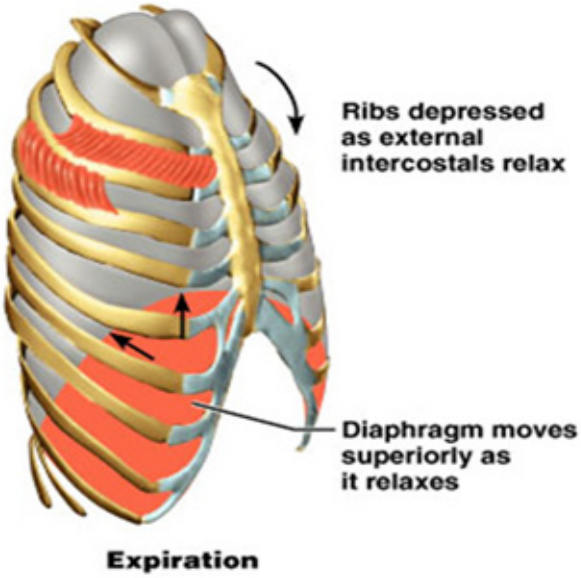
Rib cage drops under force of gravity

Relaxing diaphragm moves superiorly (up)

Elastic fibers in lung recoil

Volumes of thorax and lungs decrease simultaneously, increasing the intra thoracic pressure.

Air is forced out



The forces responsible for normal resting expiration come from elastic recoil of lung tissues and from surface tension.

These factors increase the intra-alveolar pressure about 1 mm Hg above atmospheric pressure forcing air out of the lungs

Major Events in Expiration

1. The diaphragm and external respiratory muscles relax
2. Elastic tissues of the lungs and the thoracic cage, stretched during inspirations, suddenly recoil, and the surface tension collapses the alveolar walls
3. Tissues recoiling around the lungs increases the inta-alveolar pressure
4. Air is squeezed out of the lungs

Physiological Variables Affecting Breathing

1. Airway resistance can sometimes affect airflow. It's normally insignificant due to the relatively large diameters of the air passages, low viscosity of air, and incredible amount of branching. However, during severe allergic reactions histamine causes contraction of bronchiolar smooth muscle. This decreases airway volume and increase airway resistance.
2. Compliance refers to the ability of the lungs to expand. The ease with which the lungs can expand facilitates efficient ventilation. Replacement of the elastic lung tissue with inelastic scar tissue as well as reduced surfactant production will decrease lung compliance.
3. Elasticity: refers to the ability of the lung to return to its normal shape after each breath. Loss of elasticity necessitates forced expiration & increased effort on inspiration.

Lung Capacities

Not all inspired air is exchanged b/c not all of it reach the alveoli. An example is the air that occupies the conducting zone. B/c that air cannot be exchanged, structures in the conducting zone are collectively referred to as the anatomical dead space.

Any alveoli not involved in exchange (due to collapse or obstruction) comprise the alveolar dead space. The combination of anatomical and alveolar dead spaces is known as the total dead space.

Alveolar Ventilation

The volume of new atmospheric air moved into alveoli per minute is Alveolar ventilation= (TV-anatomical dead space) X Respiratory rate

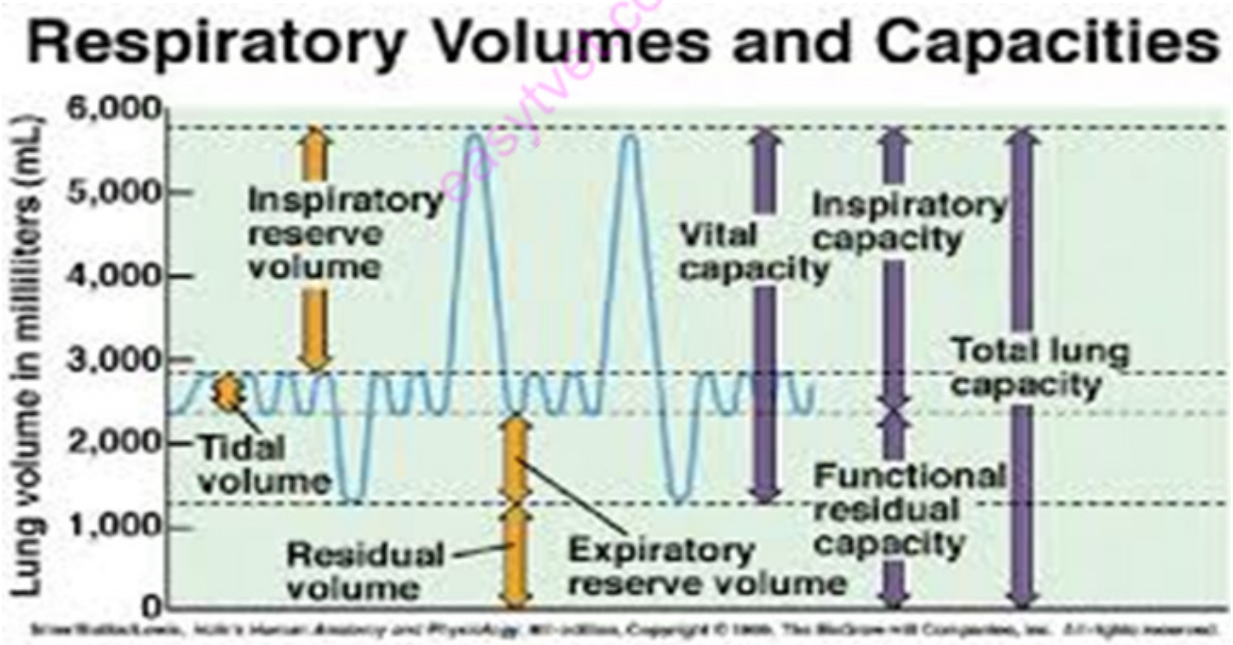
= (500 - 150) ml x 15 per minute

= 5.25 litres per minute

Respiratory Air Volumes and Capacities

Different degrees of effort in breathing move different volumes of air in and out of the lungs. A normal respiratory cycle is about 15 cycle per minute.

This measurement of volumes is called spirometry.



Lung Volumes and Capacities

The tidal volume (TV), about 500 mL, is the amount of air inspired during normal, relaxed breathing.

The inspiratory reserve volume (IRV), about 3,100 mL, is the additional air that can be forcibly inhaled after the inspiration of a normal tidal volume.

The expiratory reserve volume (ERV), about 1,200 mL, is the additional air that can be forcibly exhaled after the expiration of a normal tidal volume.

Residual volume (RV), about 1,200 mL, is the volume of air still remaining in the lungs after the expiratory reserve volume is exhaled.

Summing specific lung volumes produces the following lung capacities:

The total lung capacity (TLC), about 6,000 mL, is the maximum amount of air that can fill the lungs (TLC = TV + IRV + ERV + RV)..

The vital capacity (VC), about 4,800 mL, is the total amount of air that can be expired after fully inhaling (VC = TV + IRV + ERV = approximately 80 percent TLC). The value varies according to age and body size.

The inspiratory capacity (IC), about 3,600 mL, is the maximum amount of air that can be inspired (IC = TV + IRV).

The functional residual capacity (FRC), about 2,400 mL, is the amount of air remaining in the lungs after a normal expiration (FRC = RV + ERV).

Composition of air

Air is a mixture of gases: nitrogen, oxygen, CO_2, water vapour and some inert gases.

Each gas in a mixture of gases exerts a certain amount of pressure, which is known as the partial pressure for that gas. PO_2, PCO_2.

Composition of inspired and expired air		
	Inspired air &	Expired air &
Oxygen	21	16
Carbon dioxide	0.04	4
Nitrogen	78	78
Water vapor	variable	variable

Gas Transport

Blood transports O2 and CO2 between the lungs and the body cells.

As the gases enter the blood, they dissolve in the plasma or chemically combine with other atoms or molecules.

Oxygen Transport

Oxygen is carried by blood in 2 ways.

1.5% of the O_2 is simply dissolved in plasma.

The other 98.5% is bound to hemoglobin within red blood cells in the form of oxyhemoglobin.

Chemical bonds between O_2 and hemoglobin are relatively unstable.

Oxyhemoglobin releases O_2 into the body cells.

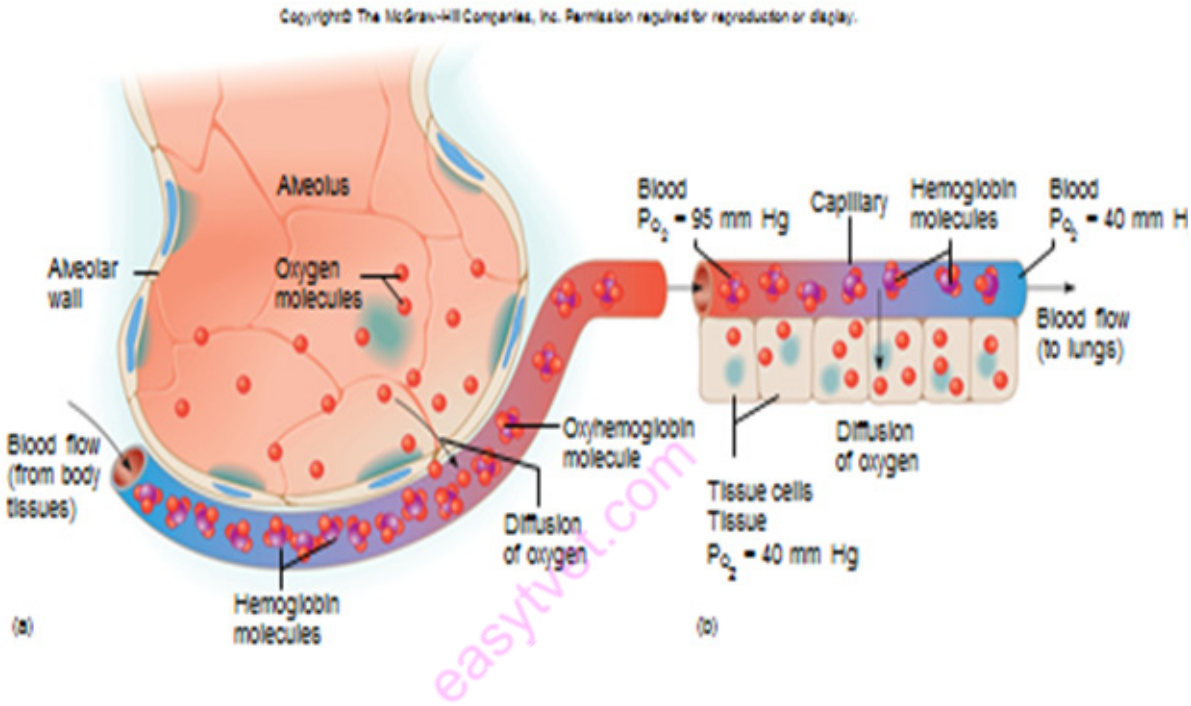
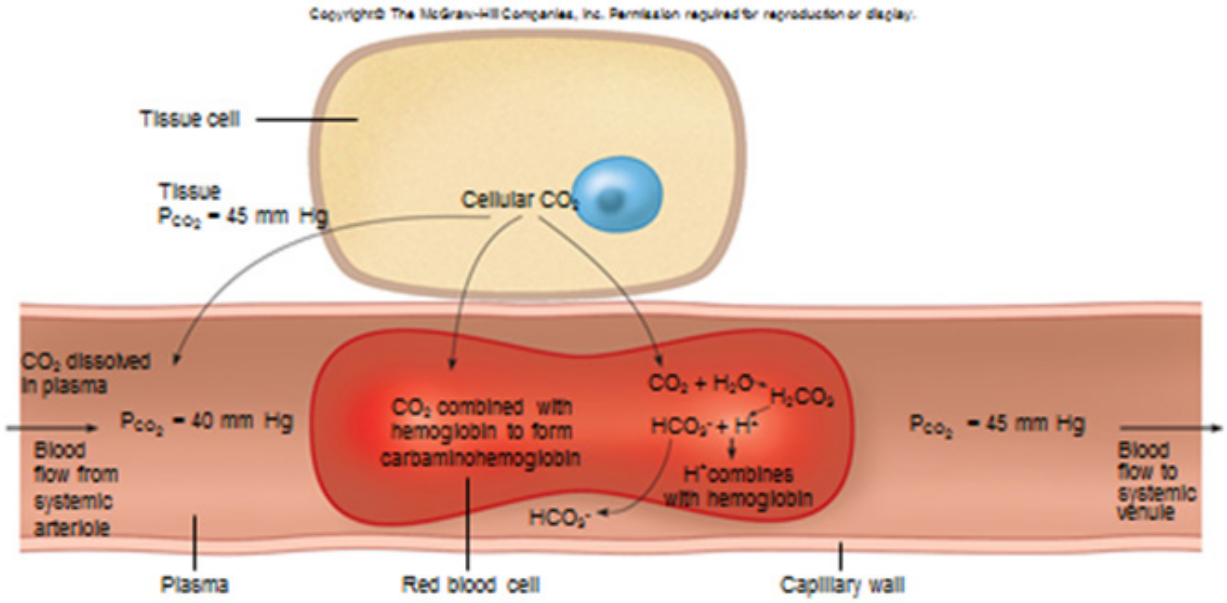


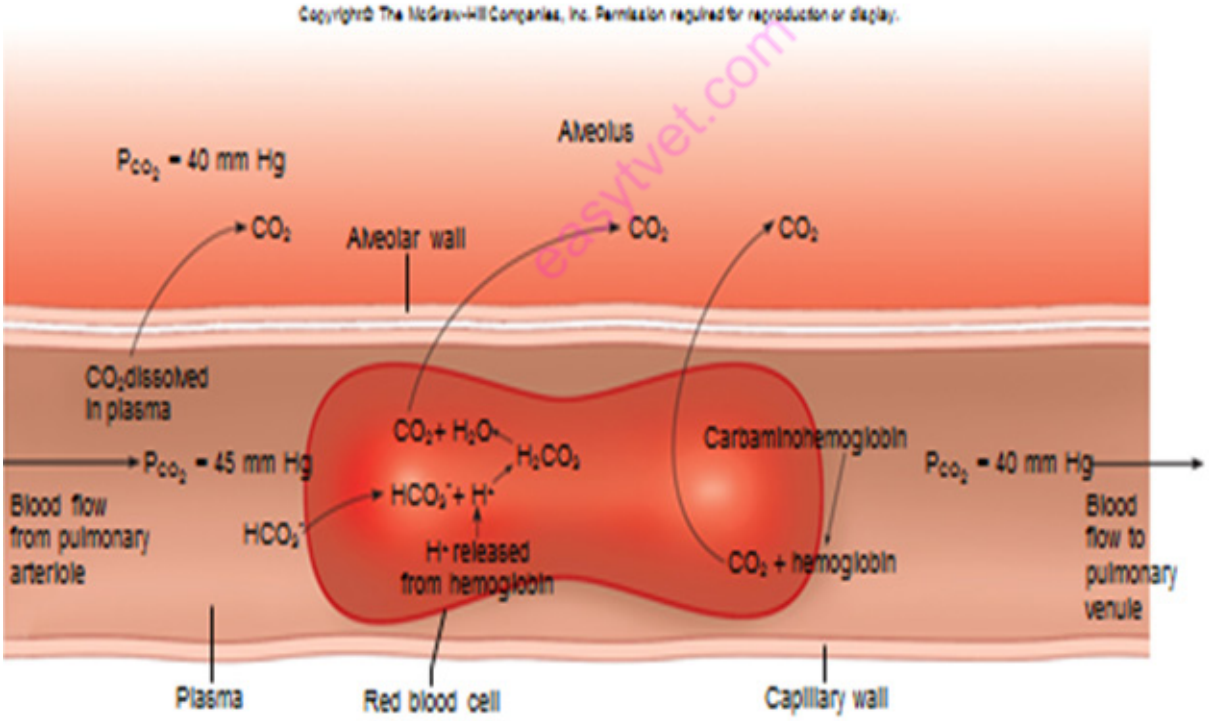
Figure shows the diffusion of oxygen gas at the alveoli and at the tissues

Carbon Dioxide Transport

- Blood flowing through capillaries gains CO_2 because the tissues have a high Pco_2.
- The CO_2 is transported to the lungs in one of three forms:
    - As CO_2 dissolved in plasma
    - As part of a compound with hemoglobin--carbaminohemoglobin
    - As part of a bicarbonate ion



The figure above shows the diffusion of carbon dioxide gas in the tissues



The figure above shows the diffusion of carbon dioxide gas at the alveoli.

Control of Breathing

Normal breathing is a rhythmic, involuntary act that continues when a person is unconscious

Respiratory muscles can be controlled as well voluntarily

Respiratory Areas

Groups of neurons in the brainstem comprise the respiratory areas that control breathing

Respiratory areas also adjust the rate and depth of breathing

The respiratory areas include:

- Respiratory center of the medulla
- Respiratory group of the pons.

Neural Control of Ventilation

Chemo-Receptors

Central in the medulla---When PCO_2 rises (Hypercapnia), they stimulate the respiratory centre, to increase lung respiration and lower arterial PCO_2.

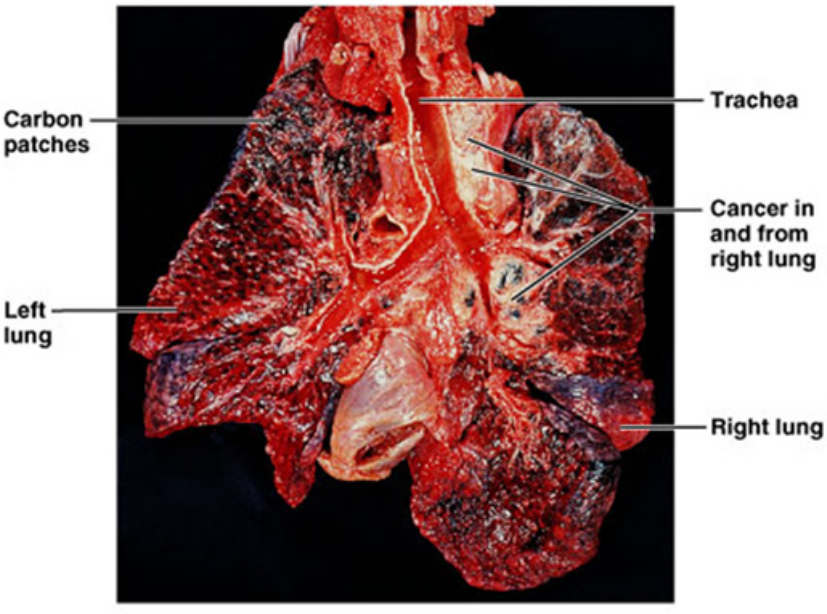
This sensitivity is important in controlling blood gas levels.

Factors Affecting Breathing

A number of factors affect breathing rate and depth including:

- Partial pressure of oxygen (Po_2)
- Emotional state
- Level of physical activity
- Partial pressure of carbon dioxide (Pco_2)
- Drugs e.g. sedatives
- Chemoreceptors

You might want to think twice about smoking….



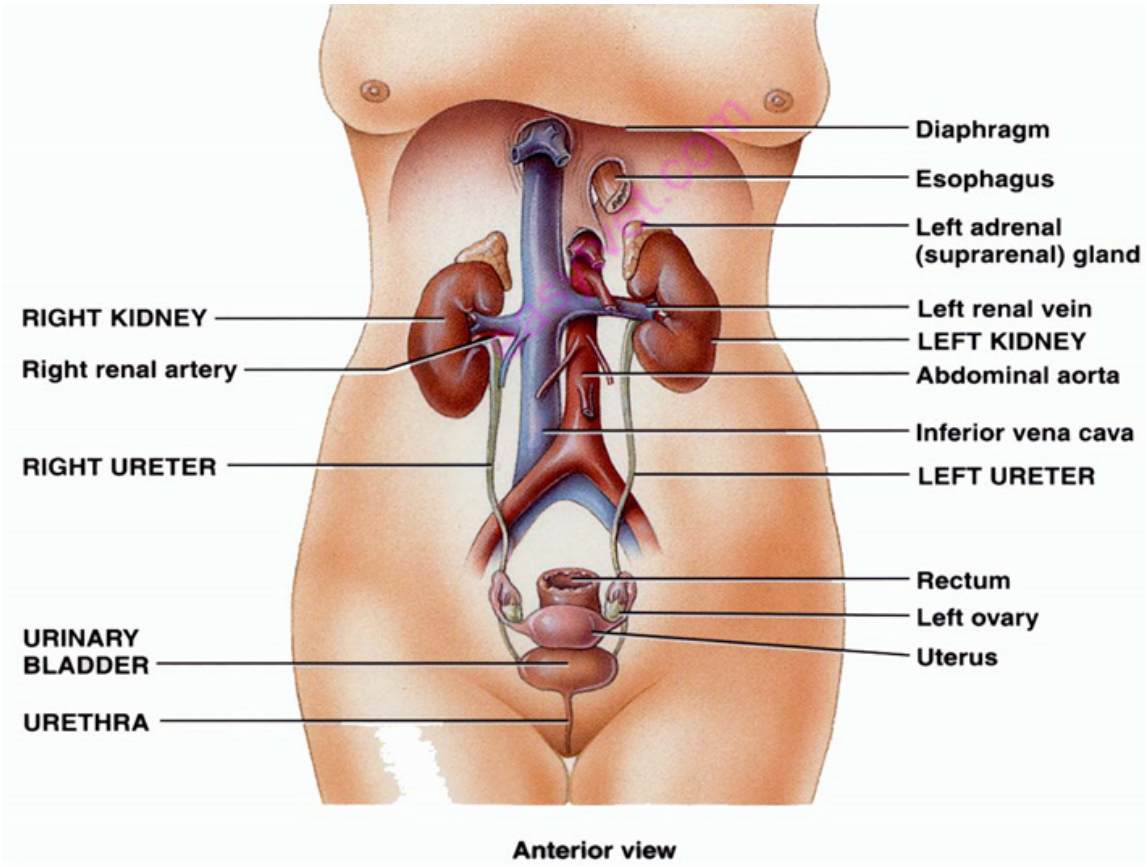
THE RENAL SYSTEM

GUT

- Genital urinary system/tract (GUT) is the main excretory organ.
- Excretion is process of eliminating wastes from the body.
- Kidney is primary excretory organ

Major Components

1. 2 kidneys – secretes urine
2. 2 ureters – conveys urine from the kidneys to the urinary bladder
3. 1 urinary bladder – collects and stores urine temporarily
4. 1 urethra – urine passes from the bladder to the exterior.



Functions of Kidneys

1. Excrete wastes in urine.
2. Regulate blood volume.
3. Regulate blood composition.
4. Regulate blood pressure.
5. Release erythropoietin.
6. Participate in vitamin D synthesis.
7. Secretion of Renin

Development of the GUT

Through by 2nd month of development

Defects includes

1. Displaced kidneys
2. Undersized
3. Cystic kidney-numerous sac-like structures containing water, pus or gas
4. One kidney
5. Horse shoe kidney- kidneys fuse together to form a horse shoe shape.

Kidneys

The paired kidneys are reddish, kidney-bean-shaped organs.

They are located above the waist between the peritoneum and the posterior wall of the abdomen.

The kidneys lie behind peritoneum on the posterior abdominal wall on either side of vertebral column. Extends from T12 to L3

They are retroperitoneal.

The right kidney is slightly lower than the left due to the presence of the liver.

External Anatomy Of The Kidneys

A typical kidney is 10-12 cm long, 5-7 cm wide and 3 cm thick. Weighs 150g

The concave medial border of the kidneys faces the vertebral column.

Embedded and held in position by a mass of fat.

Enclosed by a connective tissue-renal fascia.

Relations

Right Kidney

Superiorly-rt adrenal gland

Anteriorly- rt lobe of the liver, duodenum, hepatic flexure of the colon

Posteriorly- diaphragm, muscles of the posterior abdominal wall

Left Kidney

Superiorly- left adrenal gland

Spleen, stomach, pancreas, jejunum and splenic flexure of the colon

Posteriorly- diaphragm, muscles of the posterior abdominal wall

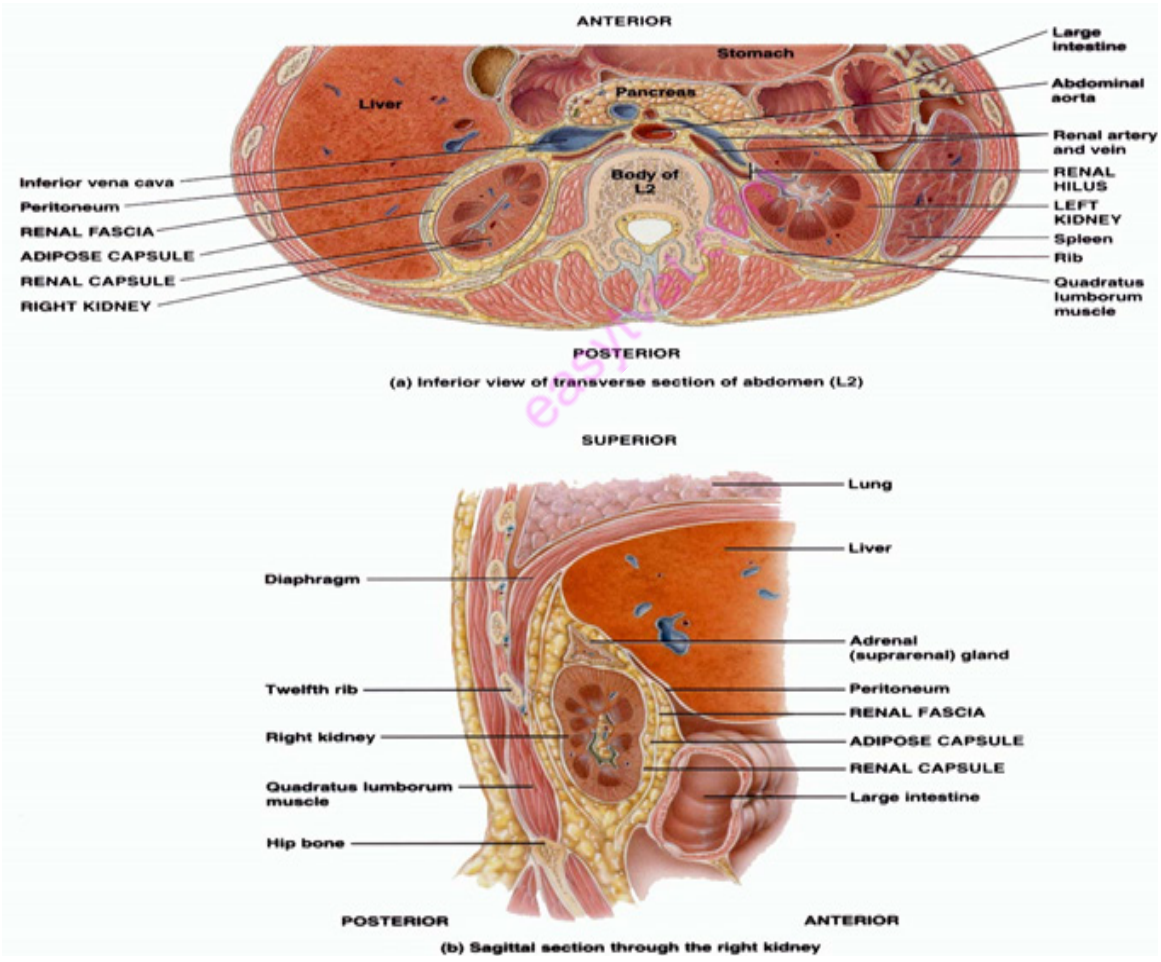
External Anatomy Of The Kidneys

Layers of tissue around the kidneys

Renal capsule – deep layer. Smooth transparent sheet of dense irregular connective tissue. Maintains the shape of the kidney.

Adipose capsule – mass of fatty tissue. Protects the kidney from trauma and holds it in place.

Renal fascia – superficial layer. Anchors the kidney to the surrounding structures and to the abdominal wall.



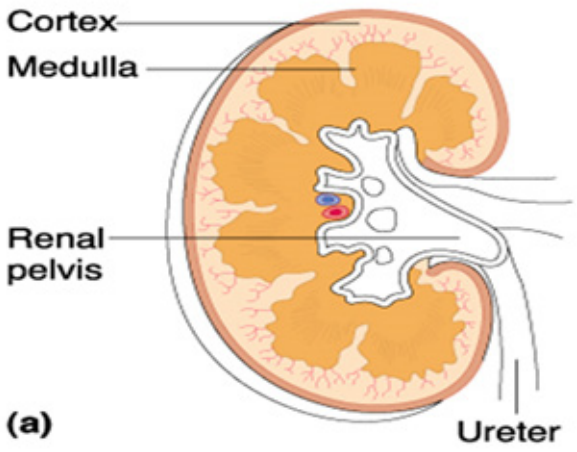
Internal Anatomy of the Kidney

A frontal section of a kidney reveals 3 regions:

Namely: 1. Renal Cortex

2. Renal Medulla

3. Renal Pelvis



Cortex has parts of nephron

Medulla most part of nephron found hear

Nephrons drain into collecting duct which form pyramids.

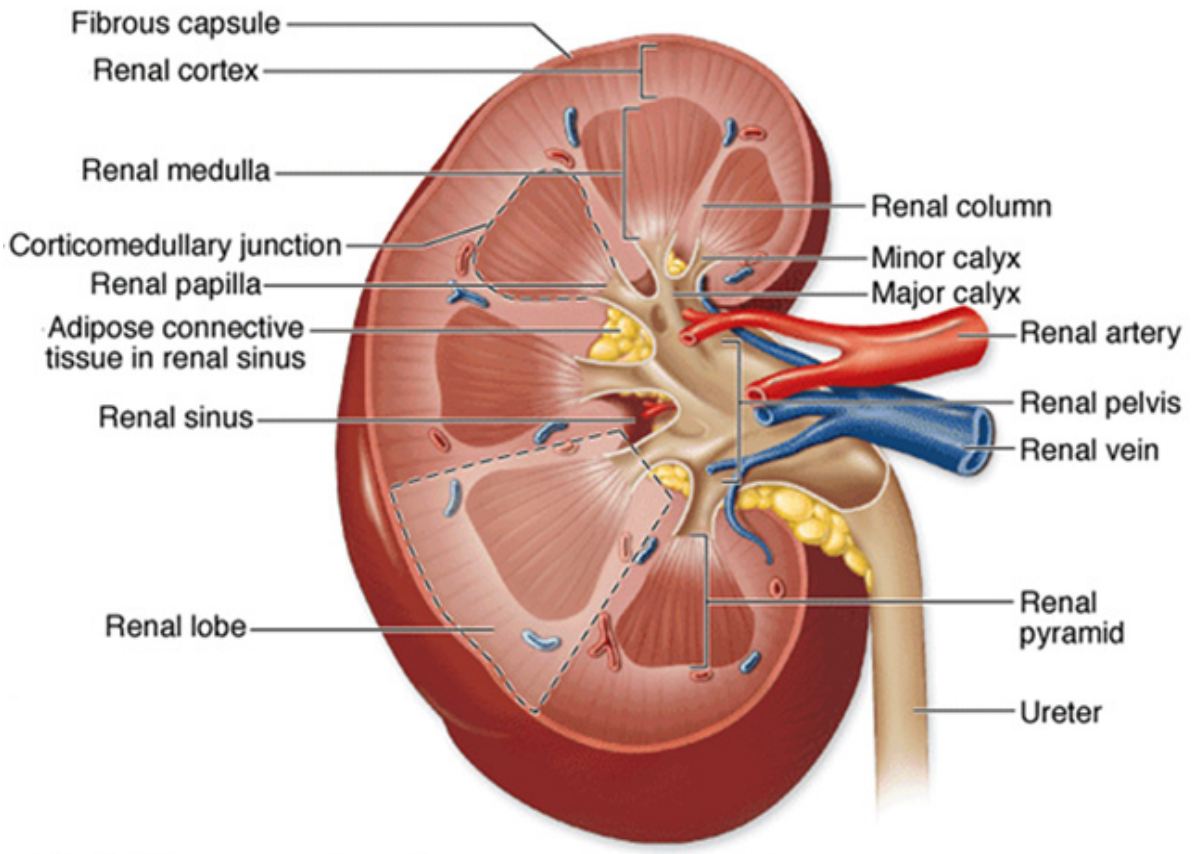
Pyramid end into papilla that drain into renal pelvis that drains into ureters.

Hilum: concave medial border of the kidneys where renal blood and lymph vessels, ureters and nerves enter.

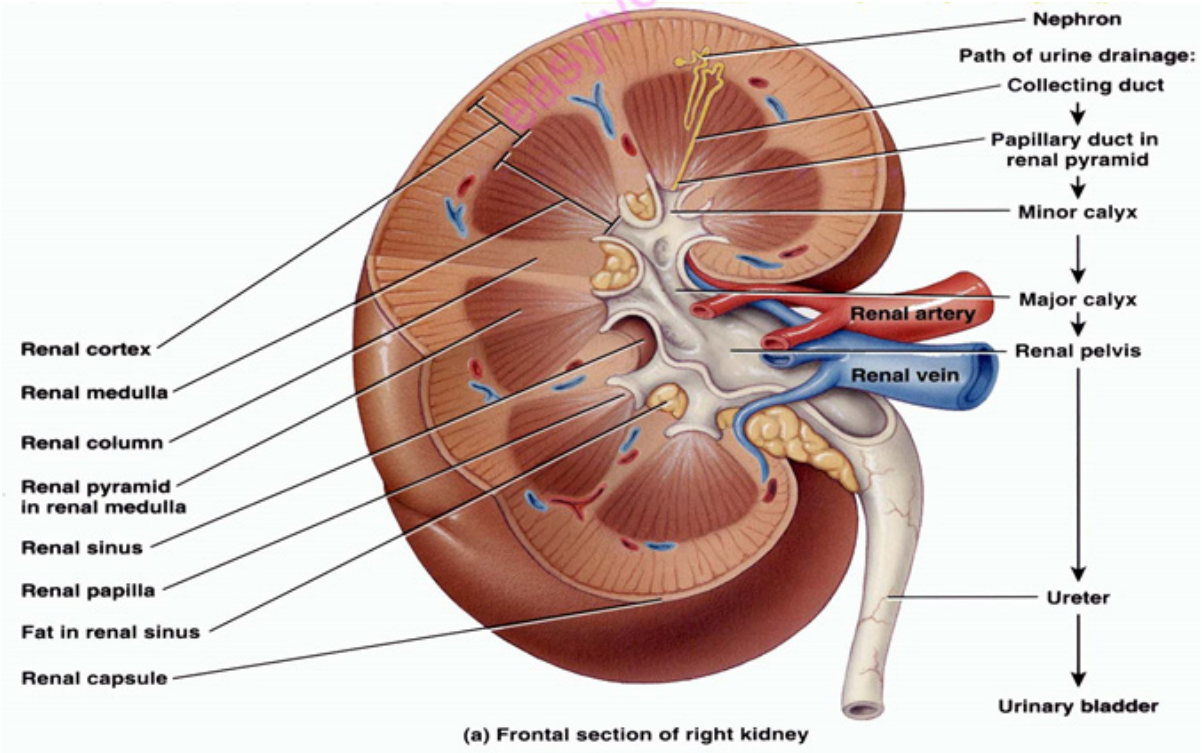
Renal pelvis: funnel shaped; it collects urine formed by the kidneys

The nephrons of the kidneys produces urine.

It flows from the renal papilla, to the minor calyx, to the major calyx, to the renal pelvis, and finally exits the kidney within the ureter.



Right kidney, coronal section



(a) Frontal section of right kidney

Blood Supply Of The Kidneys

The kidneys have abundant blood vessels.

The kidneys remove wastes from the blood and regulate its volume and ionic composition.

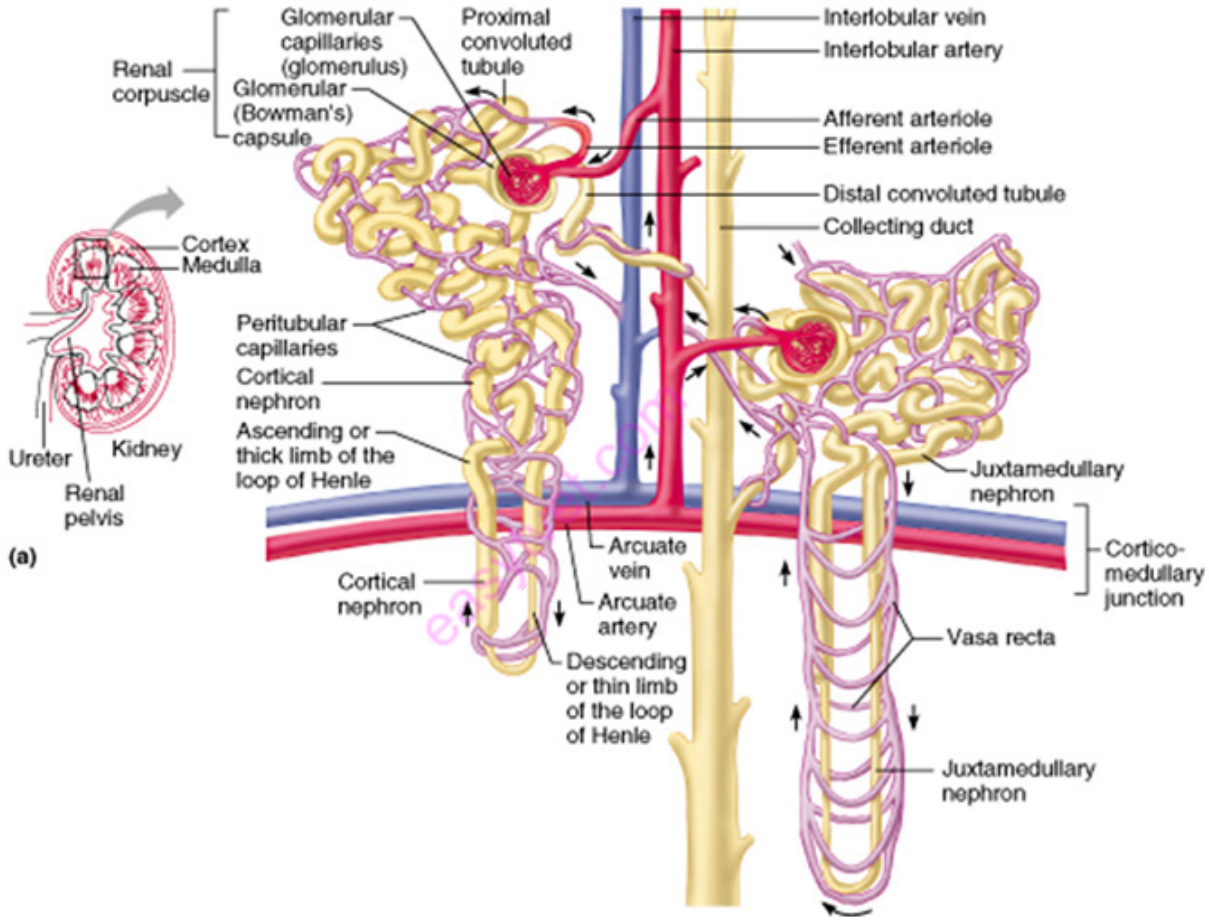
Right and left renal arteries supply the kidneys which divides to form the Afferent arterioles.

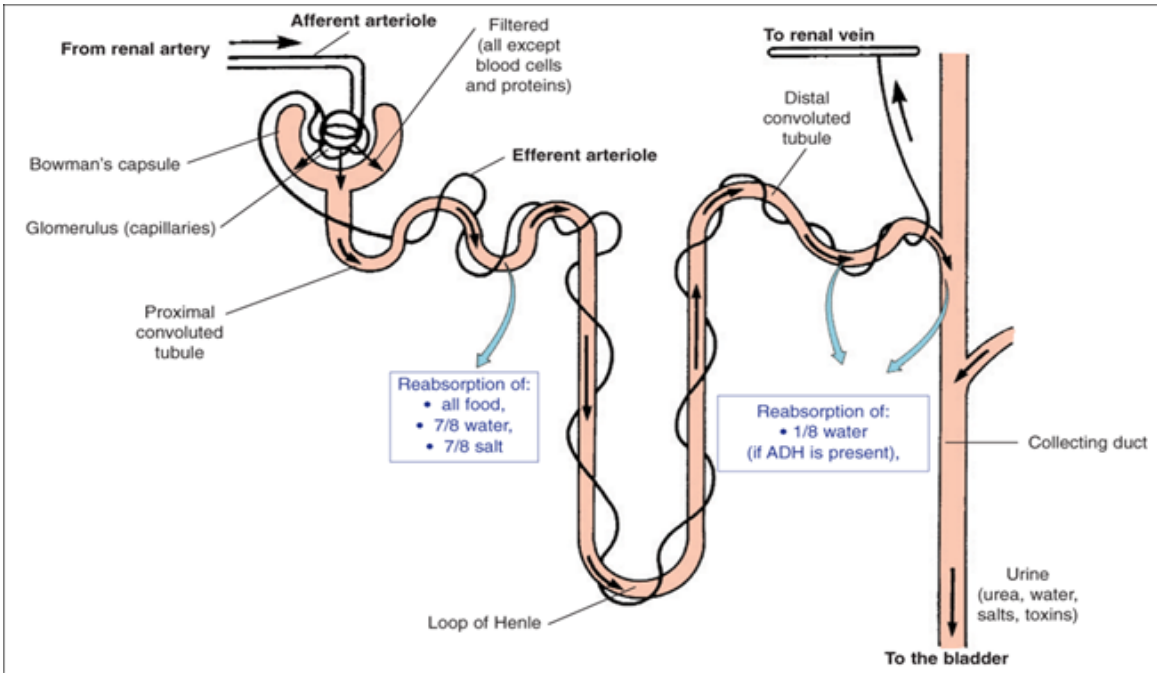
The afferent arteriole divides into a ball of capillaries called a glomerulus.

The glomerular capillaries reunite to form the efferent arteriole.

The efferent arteriole divides to form the peritubular capillaries.

These reunite to eventually form the renal vein.



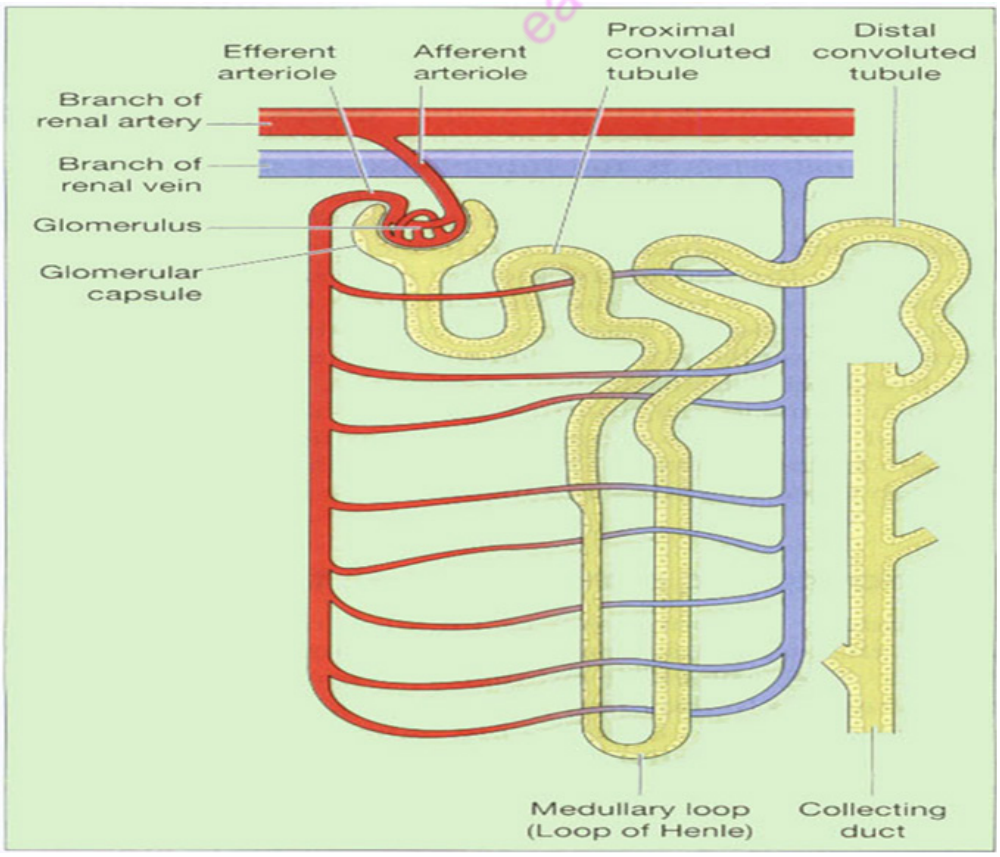


Nephron

Nephrons are the functional units of the kidneys.

Two main parts:

- **Renal corpuscle** – where blood plasma is filtered.
- **Renal tubule** – into which the filtered fluid passes.

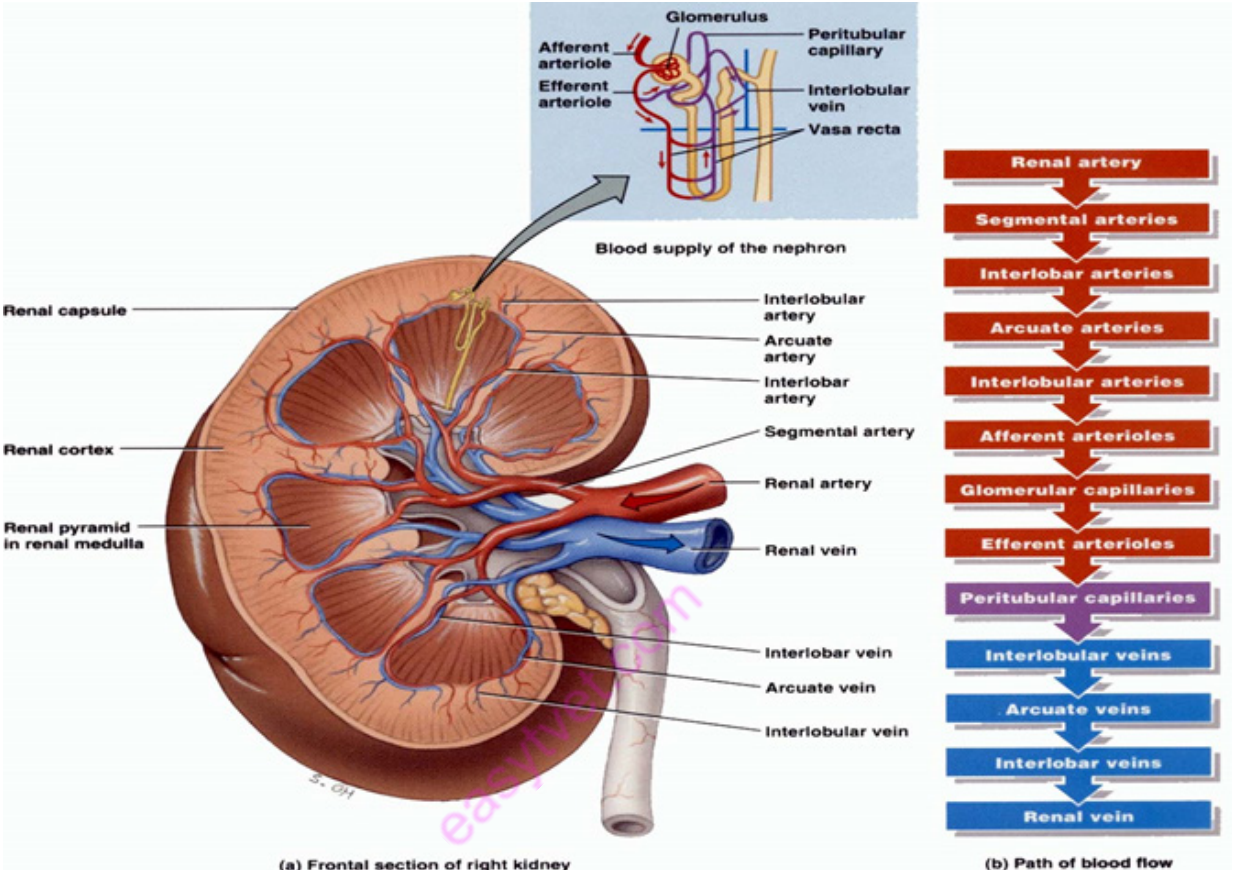


1. Renal Corpuscle

Two components:

Glomerulus – a capillary network.

Glomerular (bowman's) capsule – a double walled epithelial cup that surrounds the glomerular capillaries.



2. Renal Tubule

Three main sections:

- Proximal convoluted tubule.
- Loop of Henle (nephron loop).
- Distal convoluted tubule.

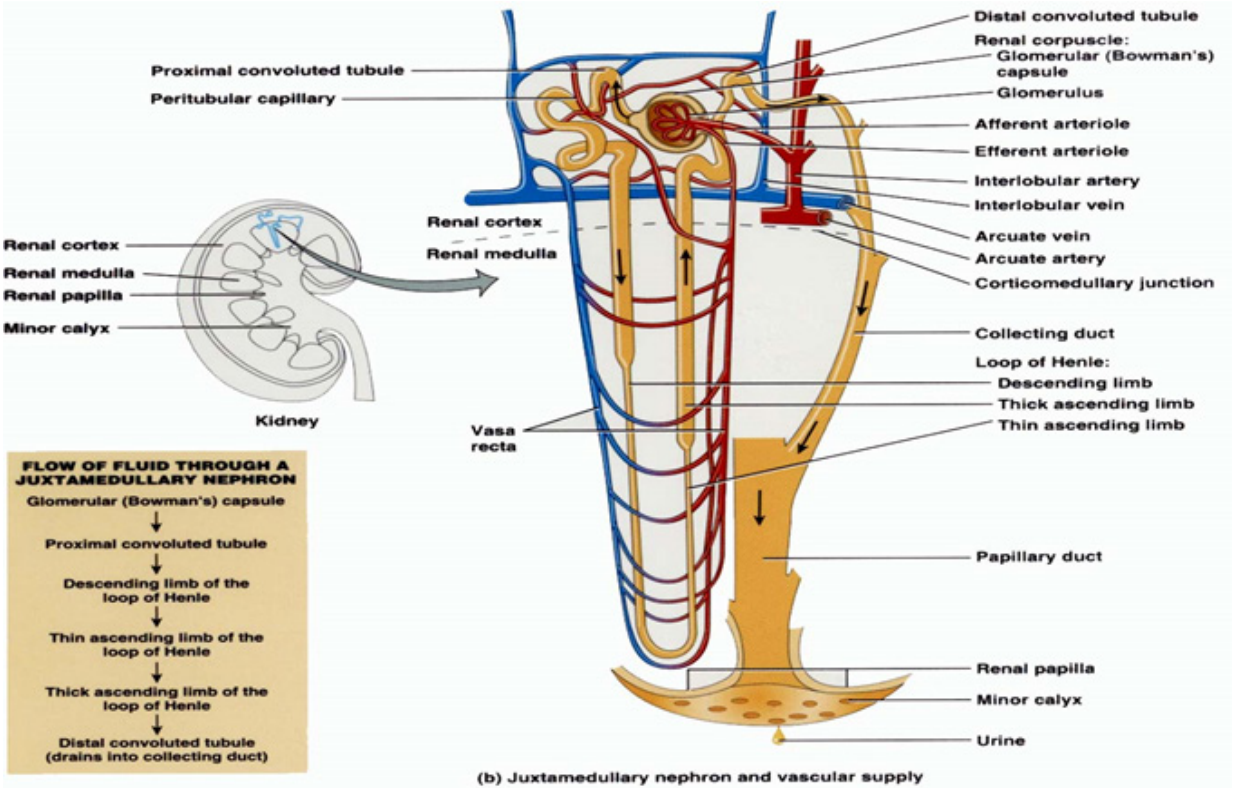
The distal convoluted tubules of several nephrons empty into a single collecting duct.

Collecting ducts then unite and converge into papillary ducts, which drain into minor calyces.

1 kidney has approximately 1 million nephrons.

Loop of Henle

The loop of Henle connects the proximal and distal convoluted tubules. It consists of a descending limb and an ascending limb.



Glomerular Capsule

The glomerular (bowman's) capsule consists of visceral and parietal layers with a capsular (bowman's) space in between.

Visceral layer – modified simple squamous epithelial cells called podocytes.

Parietal layer – simple squamous epithelium.

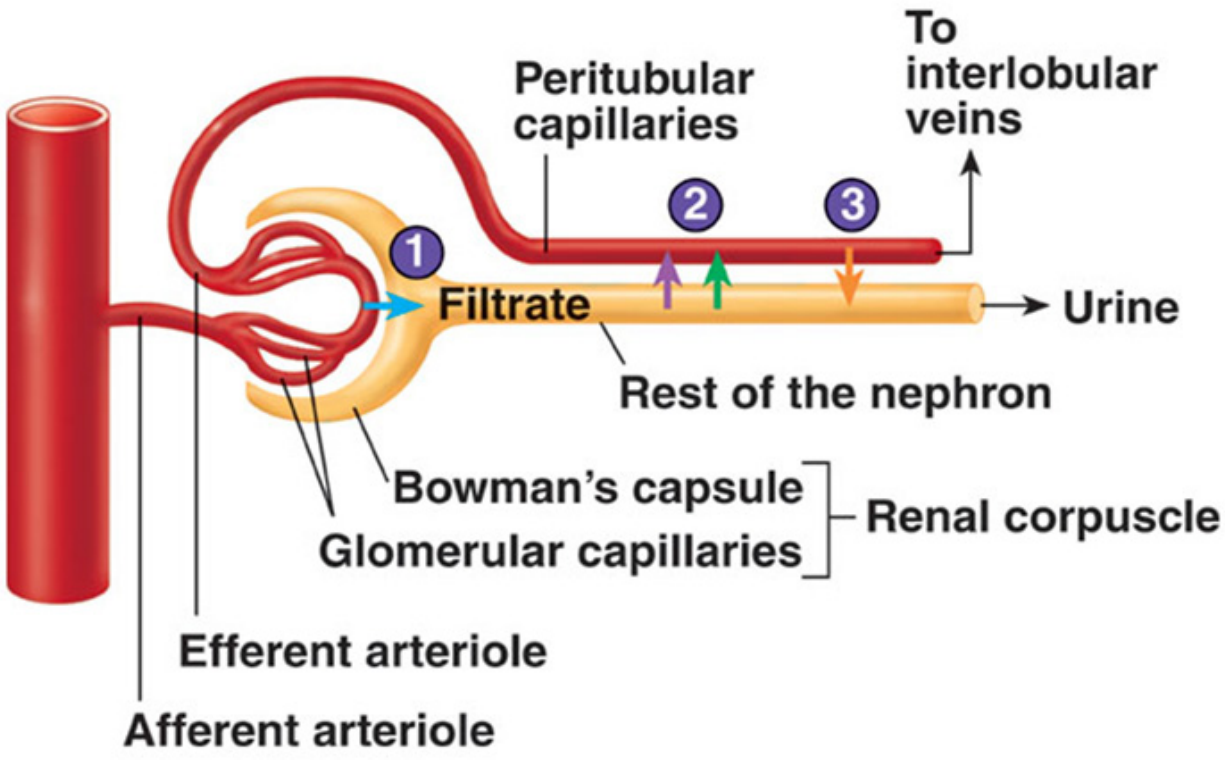
Fluid filtered from the glomerular capillaries enters the capsular space.

Kidney Physiology

- Urine formation and the simultaneous adjustment of blood composition involves

Three major processes:

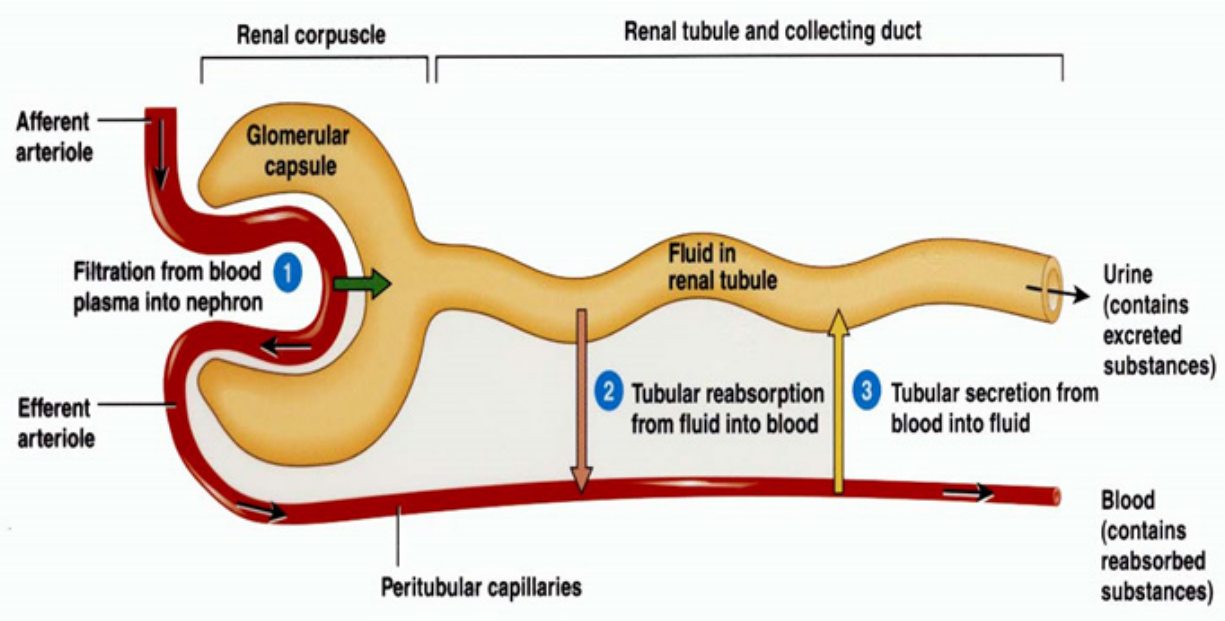
1. Glomerular filtration
2. Tubular reabsorption
3. Secretion



Filtration is the movement of substances from the glomerulus into the lumen of bowman's capsule. This forms filtrate.

Reabsorption is the movement of substances, solutes and water, across the walls of nephron tubule into the capillaries associated with the nephron.

Secretion is the transfer of materials from peritubular capillaries to the renal tubular lumen; it is the opposite process of reabsorption.



Glomerular Filtration

Glomerular filtrate – the fluid that enters the capsular space.

Filtration fraction – the fraction of blood plasma in the afferent arterioles of the kidneys that becomes filtrate (typically 16-20%).

Filtration Membrane

The endothelial cells of the glomerular capillaries and the podocytes, which encircle the capillaries, form a leaky barrier known as the filtration membrane.

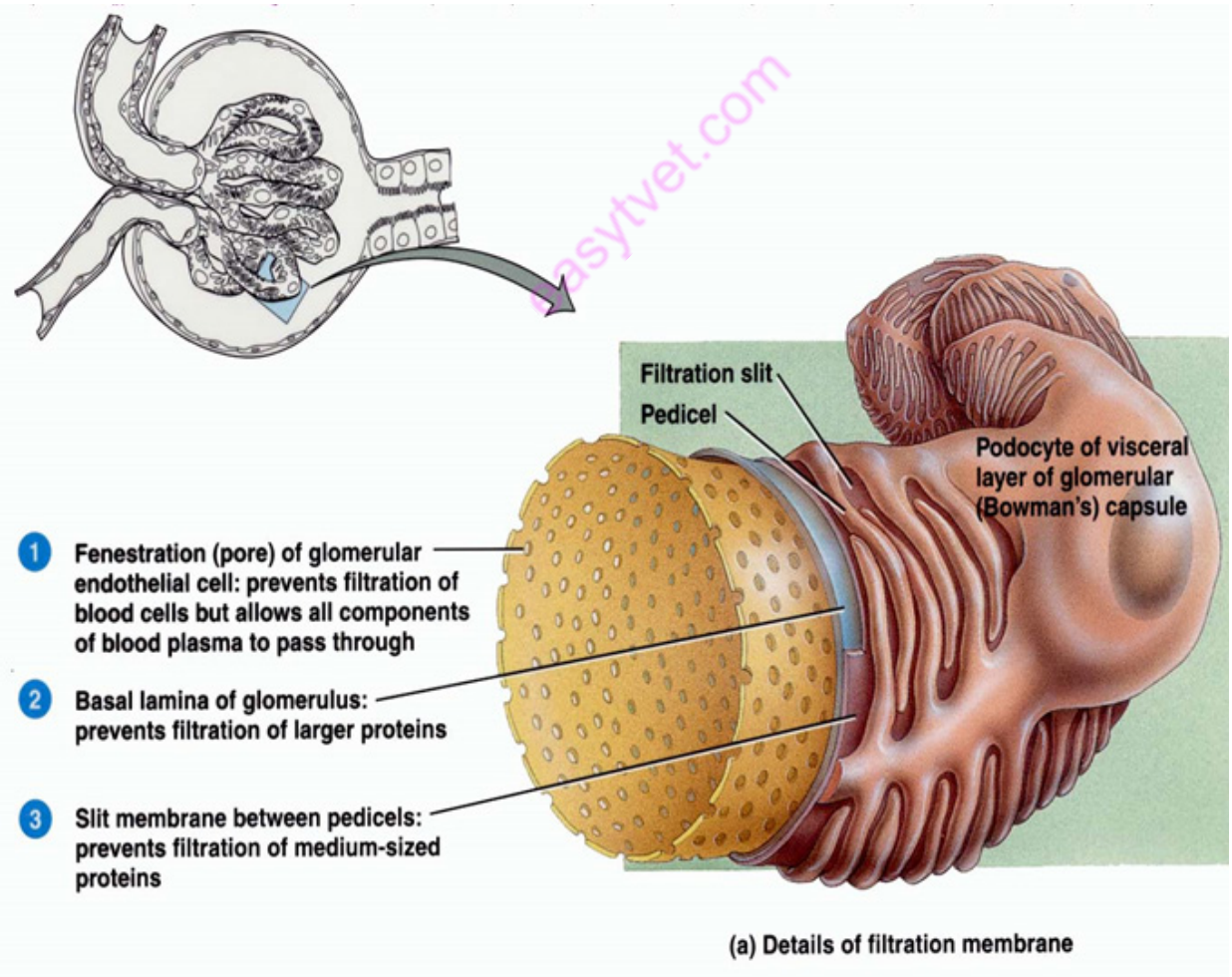
Fenestrations (pores) in the glomerular epithelial cells cause them to be quite leaky.

Filtration slits are spaces between the pedicels (footlike processes from the podocytes), which allow passage of molecules smaller than 6-7 nm.

Water, glucose, vitamins, amino acids, very small plasma proteins, ammonia, urea, and ions can pass through.

Albumin is too large to easily pass through the slits.

Filtration utilizes pressure to drive fluids and solutes through a membrane.



Factors That Affect Filtration

Glomerular capillaries present a large surface area for filtration because they are long and extensive.

The filtration membrane is thin and porous. Glomerular capillaries has fenestrations.

Glomerular capillary blood pressure is high due to a small diameter of the efferent arteriole resulting in backflow of blood.

Net Filtration Pressure

Three main pressures determine the level of glomerular filtration.

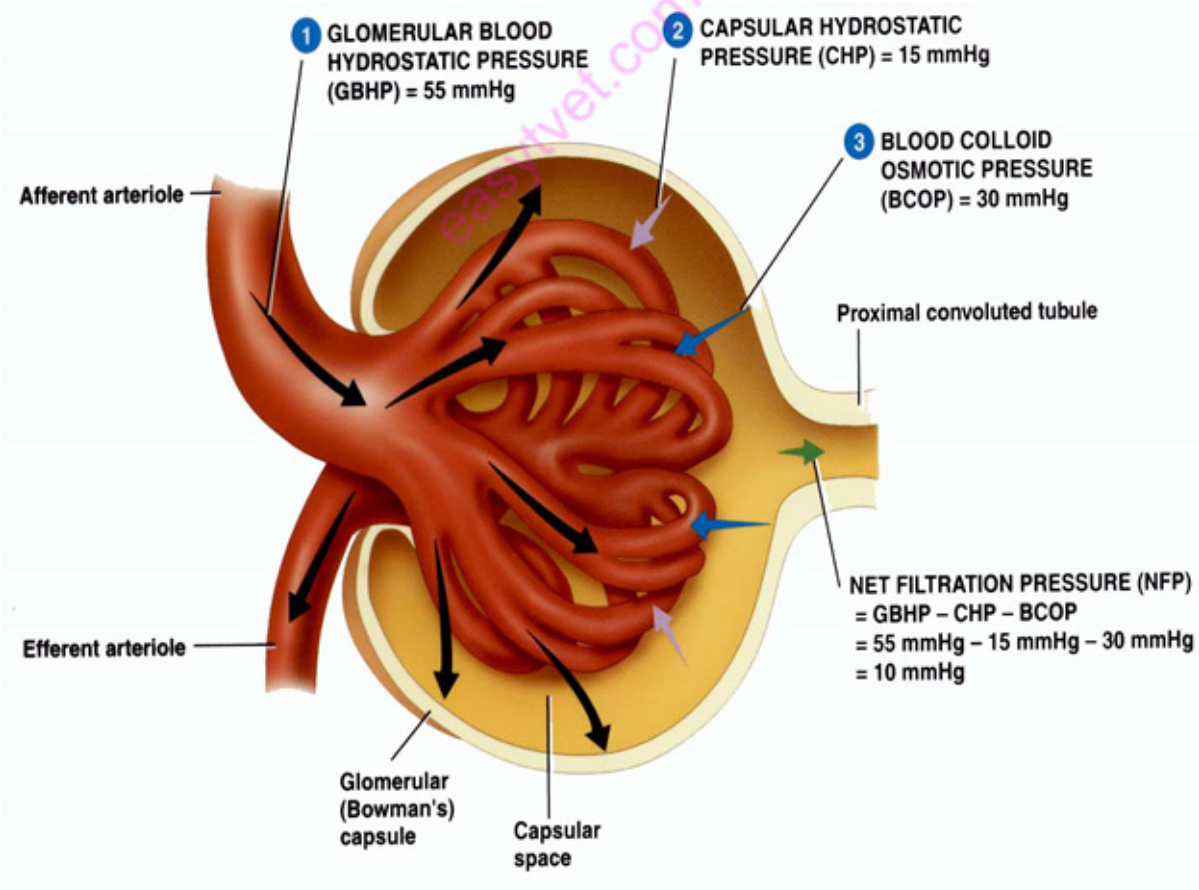
Capillary hydrostatic pressure (CHP) – promotes filtration. 55 mmHg.

Filtrate hydrostatic pressure (FHP) – opposes filtration. Hydrostatic pressure exerted by fluid already in the capsular space (back pressure). 15 mmHg.

Blood osmotic pressure (BOP) – opposes filtration. Plasma proteins (albumin, fibrinogen, globulins) draw fluid into capillaries. 30 mmHg.

Net filtration pressure (NFP) = CHP – FHP – BOP.

NFP = 55mmhg – 15mmhg – 30mmhg = 10mmhg.



Glomerular Filtration Rate

The amount of filtrate formed in all the renal corpuscles of both kidneys each minute is the glomerular filtration rate (GFR)---125ml/min

If the GFR is too high, substances may pass too quickly through the tubules that they are not reabsorbed.

If the GFR is too low, nearly all the filtrate may be reabsorbed resulting in inadequate excretion.

Renal autoregulation of gfr

To maintain a stable GFR, the kidney regulates the diameter of the afferent arteriole.

Therefore, when B.P. decreases the vessel dilates, and when B.P. increases the vessel constricts.

This results in a stable G.F.R.

Tubular reabsorption

The proximal convoluted tubules are the most active in tubular reabsorption.

All glucose, lactate, and amino acids are reabsorbed in this area.

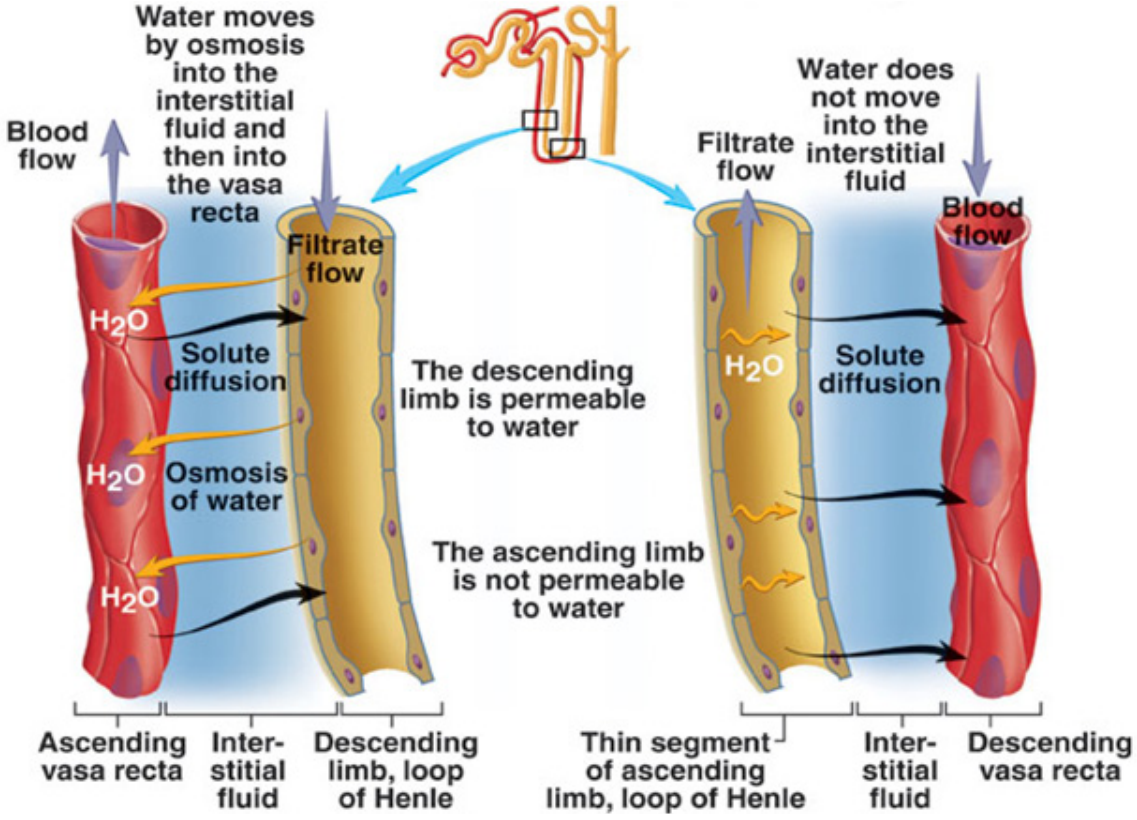
About 65% of sodium, 70% of water, are also reabsorbed.

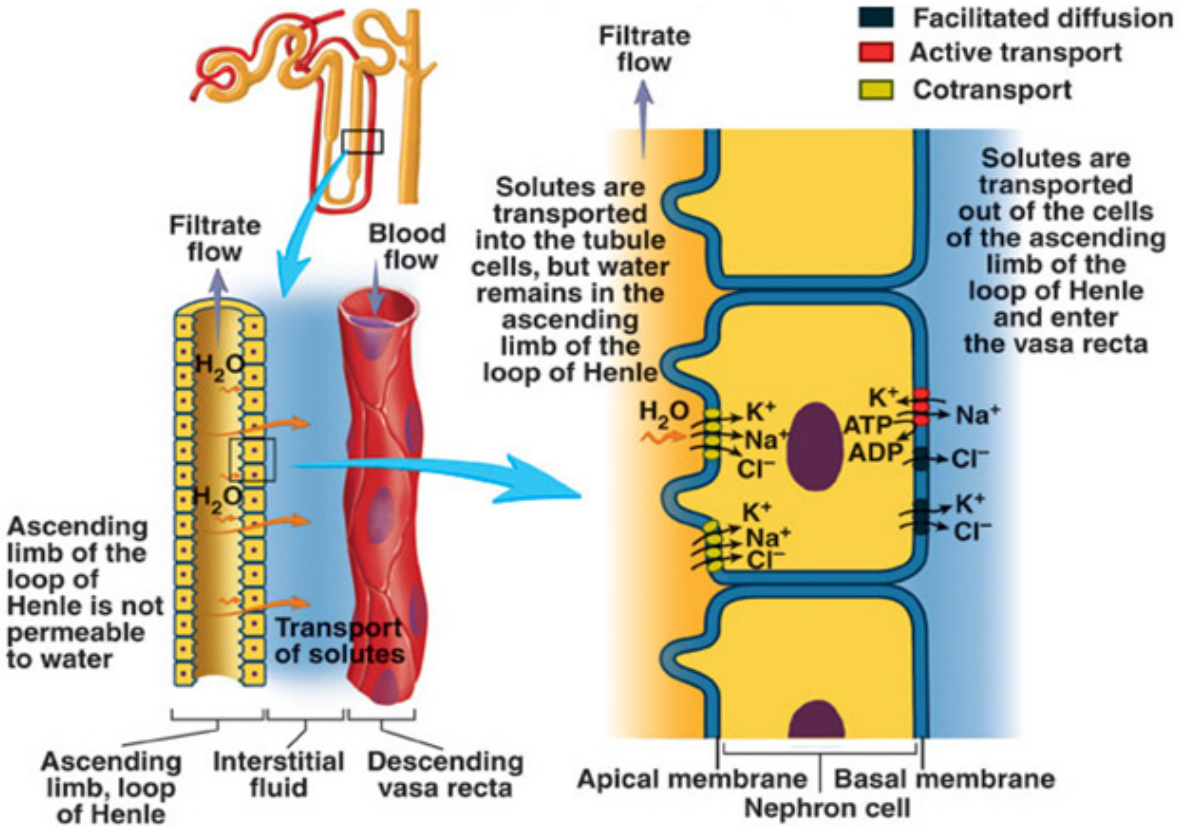
90% of bicarbonate ions, 50% of chloride ions, and 55% of potassium are reabsorbed in the proximal convoluted tubules.

This large amount of tubular reabsorption associated with the PCT, results in the GFR being reduced from 120 ml/min to about 40 ml/min.

Tubular reabsorption from the loop of Henle results in 10% of water being reabsorbed from the descending limb, 30% of potassium ions, 20% of sodium, and 35% of chloride from the ascending limb.

Reabsorption in loop of henle





Fluids enter the distal convoluted tubules at a rate of about 25 ml/min because about 80% of the water in the filtrate has been reabsorbed.

As fluid flows through the DCT, sodium and chloride are reabsorbed.

By the time fluids reaches the end of the DCT, about 90% of the filtered solutes and water has been returned to the blood.

Hormonal Regulation of Tubular Reabsorption & Secretion

1. Parathyroid hormone:

Parathyroid hormone is produced by the parathyroid gland in response to low levels of Ca2+ ions in the blood. EFFECTS OF PTH: Causes the break down of the inorganic matrix of bone, releasing Ca2+ ions, Increase absorption of Ca2+ ions from the intestines and Reabsorption of Ca2+ ions from the DCT thus increasing calcium concentration in the blood.

2. Calcitonin Hormone

Calcitonin is a hormone produced by the thyroid gland in response to high levels of Ca2+ ions in the blood. ITS EFFECTS: It increases Ca2+ ion deposition into bone and Inhibit osteoclasts that breaks down bone to produce Ca2+ thus lowering Calcium concentration in the blood.

3. Aldosterone

Produced from the adrenal cortex. Increases secretion of K+ and reabsorption of Na+, Cl-. This increases reabsorption of water and increases blood volume.

4.**Antidiuretic hormone (ADH) or vasopressin**

Increases facultative/situational reabsorption of water at the distal convoluted tubule and collecting ducts.

5.**Atrial natriuretic peptide (ANP)** – secreted by the atria of the heart in response to stretch of the arterial wall. Increases excretion of Na+ in urine (natriureses), increases urine output (diuresis) and decreases blood volume.

TUBULAR SECRETION

Tubular secretion is the movement of chemicals from the blood into the nephron.

This process can occur in the proximal or distal convoluted tubules.

This process is important for:

- Disposing of substances which were not filtered
- Removal of excess K+
- Controlling blood PH
- Eliminating substances which have been reabsorbed.
- Most secretion occurs within the PCT.
- Substances such as neurotransmitters, bile pigment, uric acid, penicillin, atropine, morphine, H+, and ammonia are secreted.

The DCT receives mainly K+ and H+ ions from the blood.

Evaluation of Kidney Function

The kidneys are evaluated by assessing the quantity of urine, the quality of urine, and the level of wastes in blood.

Urinalysis, blood urea nitrogen (BUN) test, plasma creatinine, and renal plasma clearance tests are utilized to assess kidney functioning.

Characteristics of Normal Urine

- *Volume* – 1 to 2 liters / 24 hours (varies).
- *Color* – yellow or amber, but varies with concentration and diet. Concentrated urine is darker. Diet (reddish color from beets), medications, and diseases may affect color. Kidney stones can produce blood in urine.
- *Turbidity* – transparent when freshly voided, but becomes turbid (cloudy) upon standing.
- *Odor* – mildly aromatic but becomes ammonia-like upon standing. Urine of diabetics has a fruity odor due to ketone bodies.
- *pH* – ranges between 4.6 and 8.0 (average 6.0). High protein diets increases acidity, vegetarian diets increase alkalinity.

- *Specific gravity (density)* – ranges from 1.020 to 1.030. Greater concentration of solutes yields greater specific gravity.

Water Balance and Urine Output

- Sources of body water: dietary food, & fluids; metabolic water
- Excreted through: urine, expired air, faeces and sweat
- Fluid intake and output is controlled by the kidneys
- The minimum volume of water required to excrete body waste is about 500ml per day.
- This is controlled by ADH though negative feedback mechanism.

Antiduretic Hormone (ADH)

Solute concentrations in the blood are monitored by osmoreceptors in the hypothalamus.

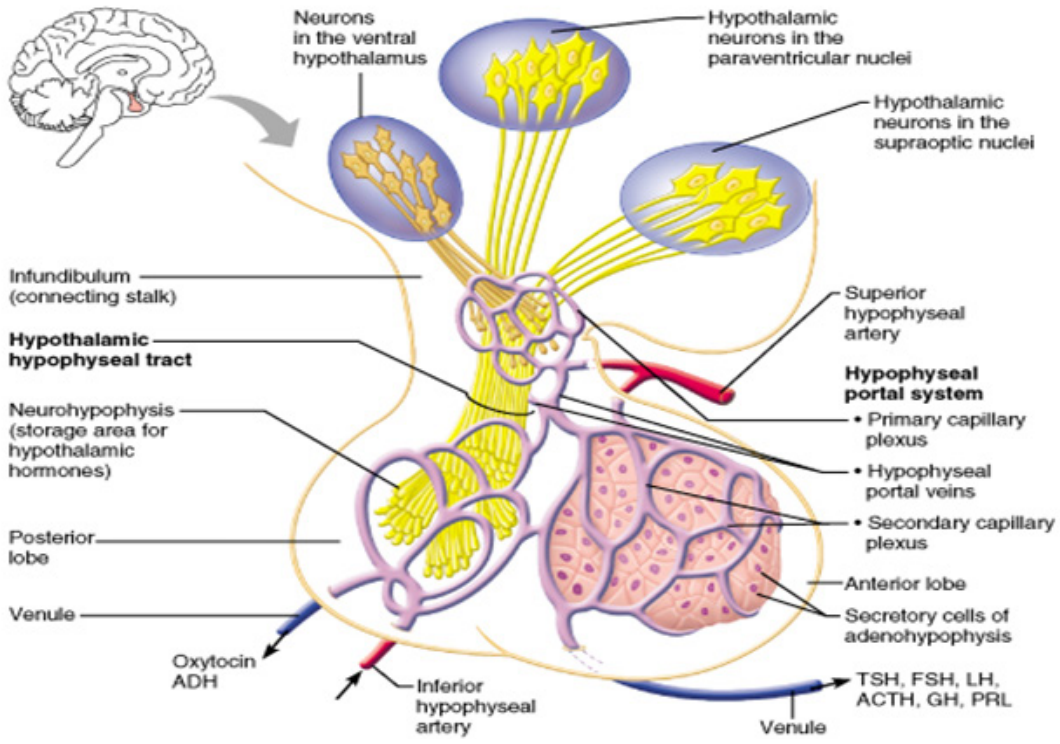
This is an example of humerol control. A humoral stimulus refers to the control of hormone release in response to changes in extracellular fluids, such as the ion concentration in the blood. For example, a rise in blood glucose levels triggers the pancreatic release of insulin.

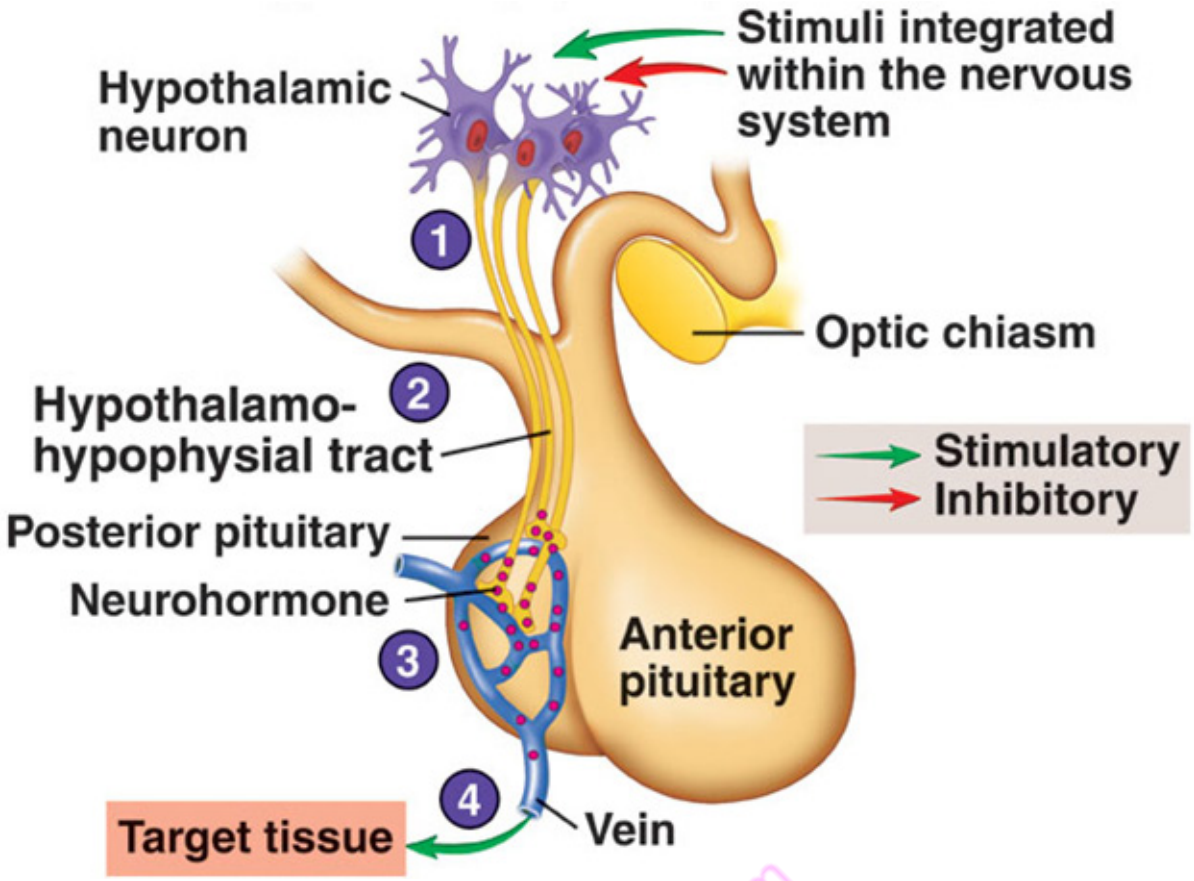
When solute concentrations increase, thereby, increasing osmotic pressure, the receptors are stimulated.

The osmoreceptors, in turn, stimulate hypothalamic neurons in the supraoptic nucleus, which synthesize ADH.

Nerve action potentials trigger the release of ADH from the axonal terminals in the posterior lobe of the pituitary.

ENDOCRINE SYSTEM



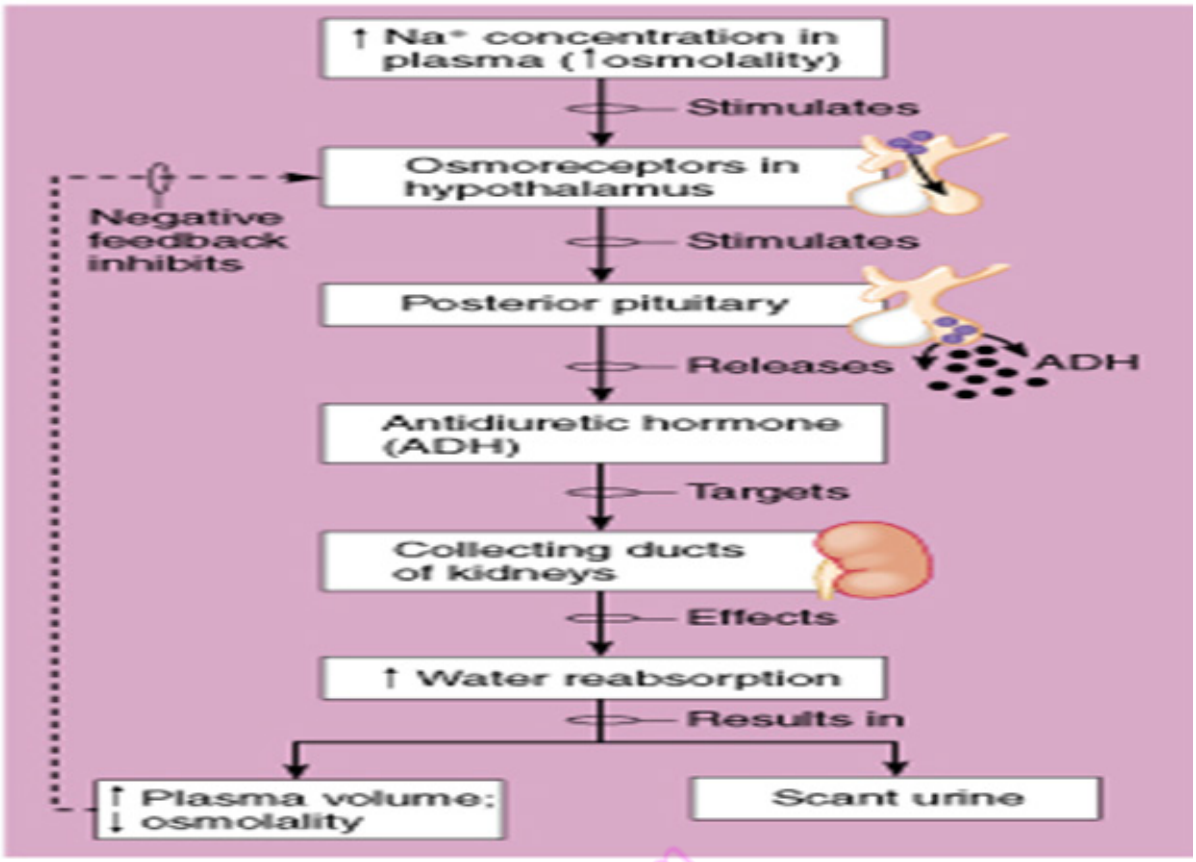


ADH travels through the systemic circulation to the distal convoluted tubules of the nephronand the collecting ducts.

ADH causes water to be reabsorbed from the D.C.T. and the collecting ducts into the capillaries which surround the nephron.

THE RESULTS OF ADH:

- A decrease in osmolality
- An increase in blood volume
- A decrease in urine output
- An increase in the concentration of the urine.



ADH is regulated by negative feedback; when solute concentrations are reduced to normal levels the amount of ADH is reduced.

The feedback mechanism is suppressed with excessive solute dissolved in blood.

In DM-diabetes mellitus when the blood glucose levels is beyond transport maximum, excess water is excreted with glucose (polyuria) which may lead to dehydration with acute thirst and water intake.

Atrial Natriuretic Peptide

Secreted by the atria of the heart in response to increased blood volume in the atria.

Reduces reabsorption of water in the PCT and CT.

This lowers blood volume and reduces atrial stretching

It also inhibits ADH and Aldosterone.

It's controlled via negative feedback.

Electrolyte Balance

Imbalance may occur due to changes in body water content or electrolyte level.

Sodium and Potassium Balance

Sodium-extracellular

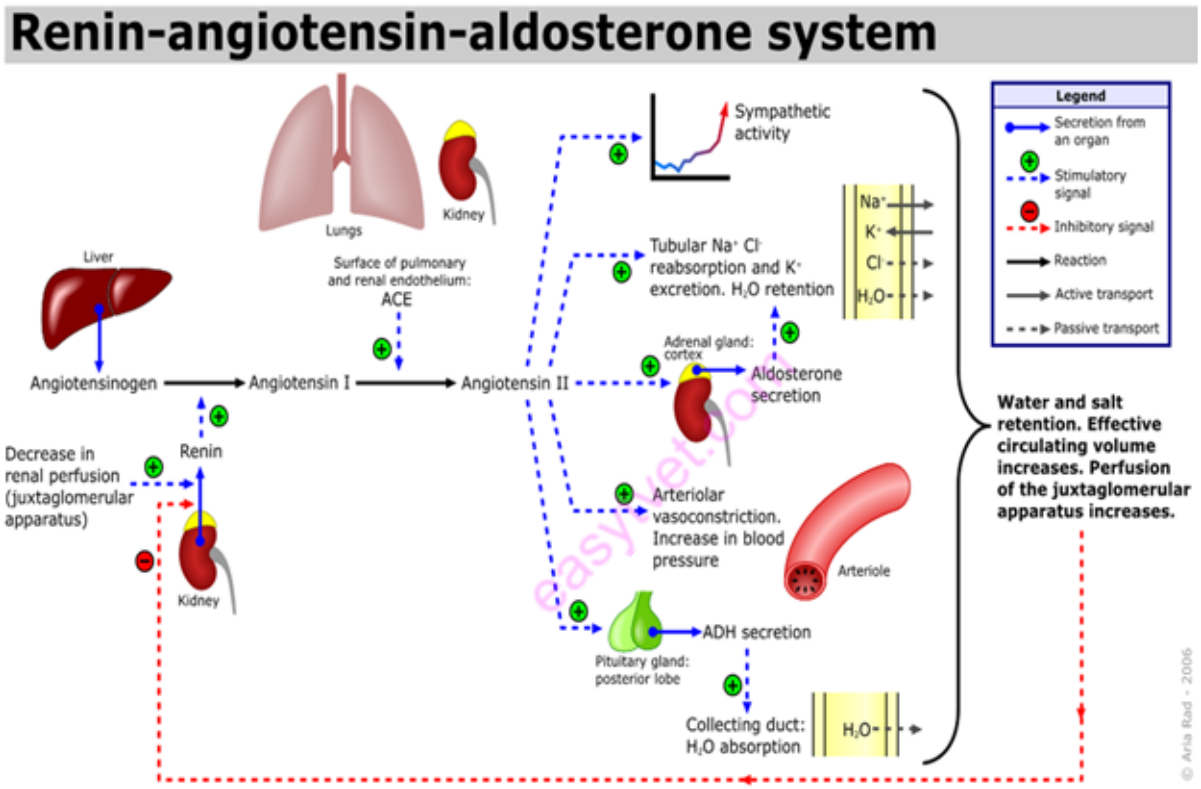
Potassium- intracellular

Intake of sodium is through food and is excreted through urine and sweat.

Excessive sodium losses may occur during high temp, fevers and sustained physical exercise.

In hot climate, acclimatisation (adjustment of an organism to the external envmt changes like temperature or altitude) occurs in 7 to 10 days and the amount of electrolytes lost in sweat is reduced.

Sodium is more in gastric juice while potassium in pancreatic and intestinal juice.

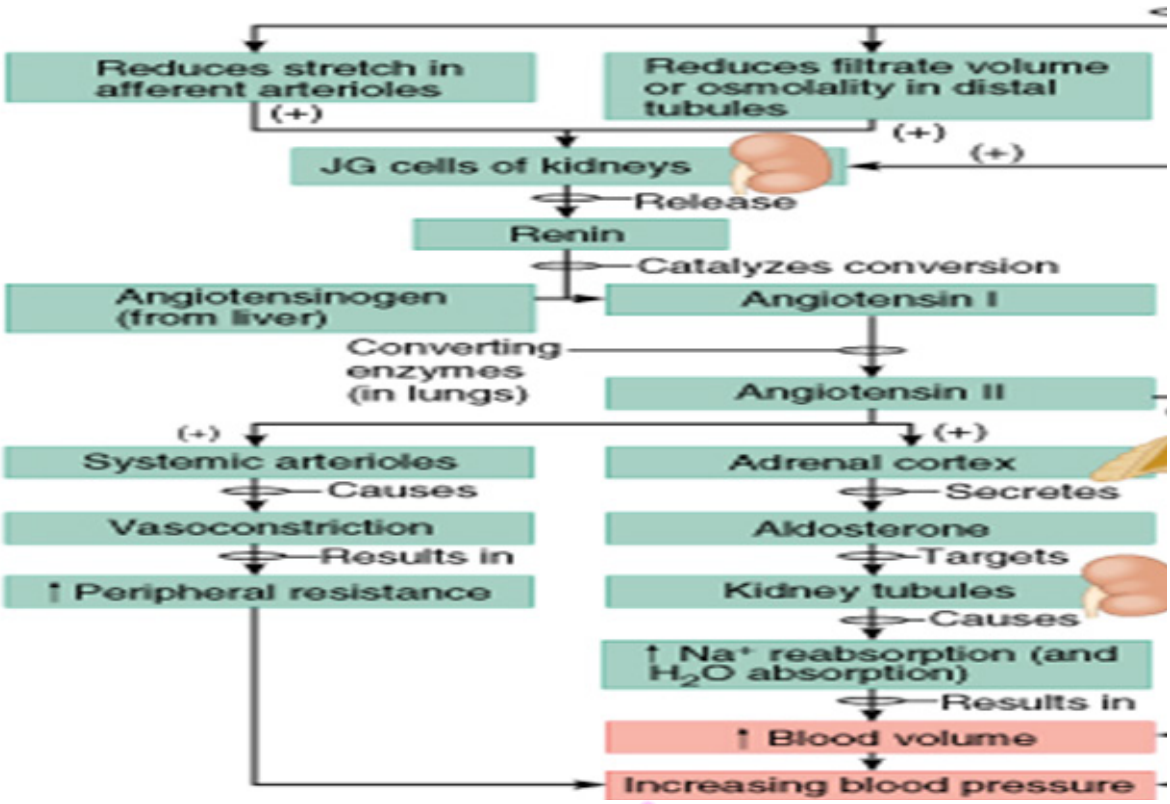


ALDOSTERONE

Aldosterone's function is to help maintain Na+ ion balance, and indirectly water balance and K+, within the fluid compartments of the body.

The chemical class of aldosterone is steroid

A decrease in blood pressure



Aldosterone targets the D.C.T. of the nephron.

EFFECTS OF ALDOSTERONE:

Reabsorption of Na+ ions.

Water is reabsorbed using the same transport mechanism.

K+ ions are secreted into the DCT from the capillaries.

Aldosterone secretion is controlled by negative Feedback.

PH Balance

H+ determines pH of urine.

The cells of the PCT secretes H+

Buffering system is present:

H+ + HCO-3 → H2CO3

H+ + NH3 → NH 4+

H+ + HPO2-3 → H2PO-3

CARBON DIOXIDE & pH

CO2 + H2O → H2CO3 → H+ + HCO3-

H+ is excreted in urine as ammonium salts and hydrogen phosphate.

Normal urine pH- 4.5 to 8 depending on diet and time of the day.

Ureters

These originate from the renal pelvis which in turn is formed by the union of the major calyces

They terminate in the wall of the urinary bladder

They pursue a retroperitoneal course over the posterior abdominal wall from the hilum of the kidneys at the level of L2 to the inferior portion of the urinary bladder (trigone)

The ureters enter the bladder wall obliquely and this arrangement prevent reflux of urine from a distended bladder except in congenital anomalies or in chronic obstruction

Microscopic Anatomy

The ureter is composed of three layers:

The inner mucosa is composed of transitional epithelium and these cells are specialised to withstand the toxic effects of urine

The middle muscularis consists of two layers; an inner longitudinal and outer circular layer

The adventitia is composed of dense connective tissue and serves to anchor the ureter on the posterior abdominal wall

The ureter is constricted in three portions; the pelviureteric junction, the pelvic brim and the ureterovesical junction

Ureters: Function

Propels urine from the kidneys into the urinary bladder by peristaltic contractions of the smooth muscle layer.

Peristalsis originates in a pacemaker in the minor calyces

Peristalsis sends little spurts of urine in the bladder

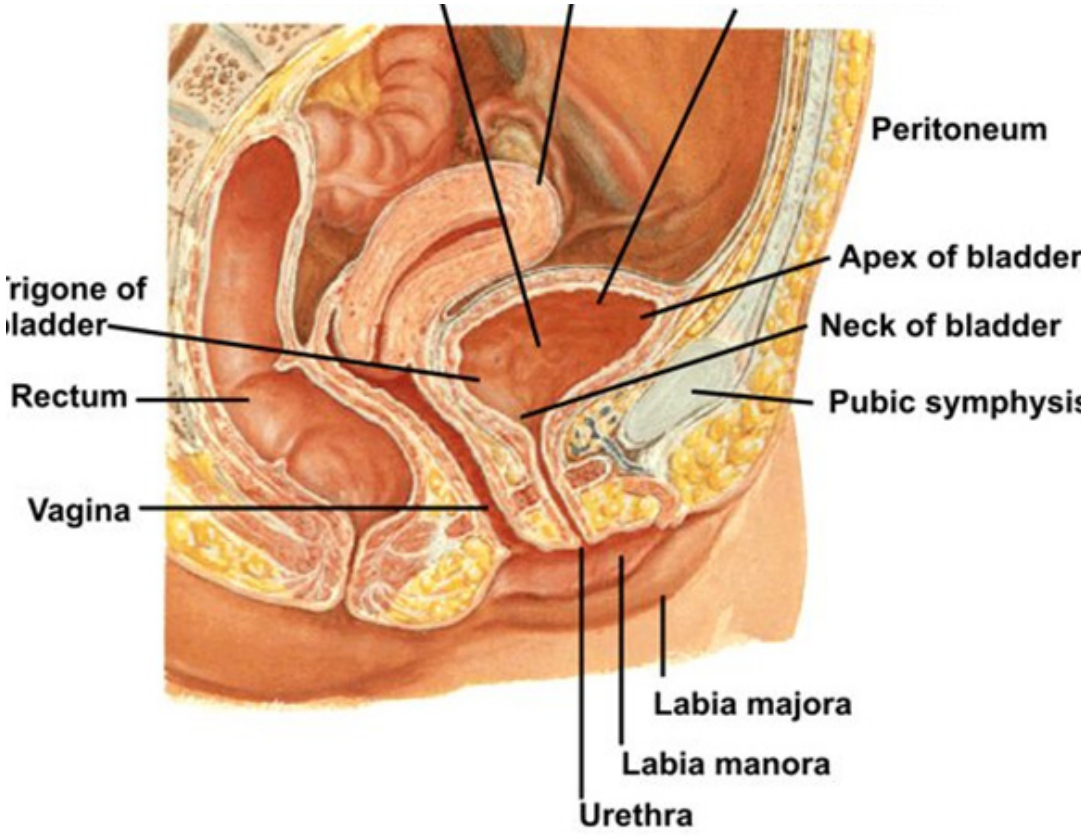
The Urinary Bladder

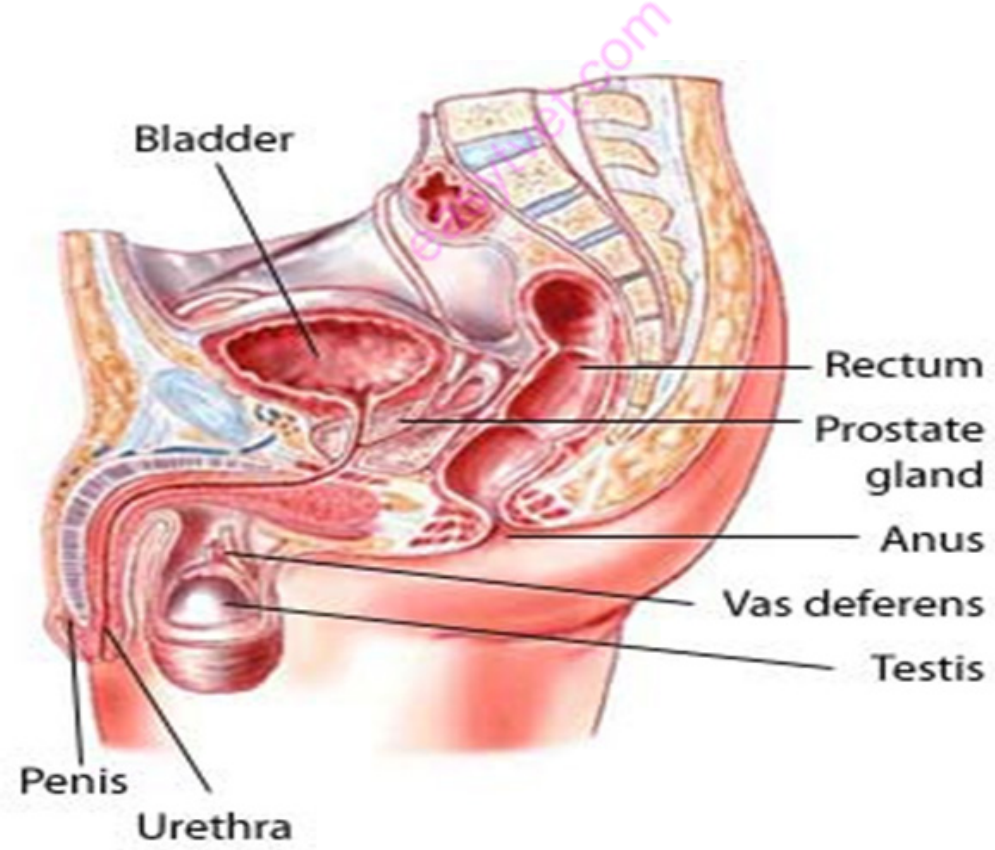
This is a fibro-muscular organ found mainly in the pelvis and stores urine. It lies posterior to the pubic symphysis.

In the male it is found anterior to the rectum and the prostate surrounds the outlet of the bladder

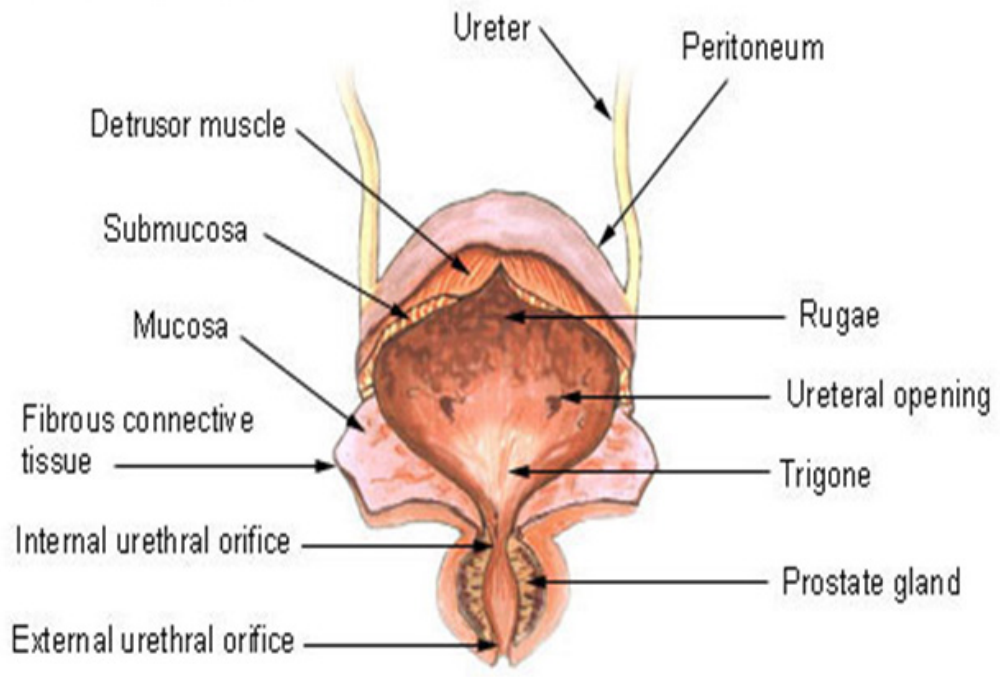
In the female it is found anterior to the vagina and uterus

Internally it has three openings; two for the ureters and one for the urethra. The triangular area where these openings are found is known as the trigone.


Peritoneum
Apex of bladder
rigone of
ladder
Neck of bladder
Rectum
Pubic symphysis
Vagina
Labia majora
Labia manora
Urethra


Bladder
Rectum
Prostate
gland
Anus
Vas deferens
Testis
Penis
Urethra

Urinary Bladder



Structure

- Pear shaped
- Oval when fills with urine
- Posterior surface is the base.
- It opens into the urethra at the neck.

Internal Structure

The urinary bladder wall is composed of three layers:

The inner mucosa consists of transitional epithelium

The middle muscularis contains the detrusor muscle which has outer and inner longitudinal and middle circular layers

The outer adventitia which on the superior surface is a serosa contains the lymphatic vessels and nerves.

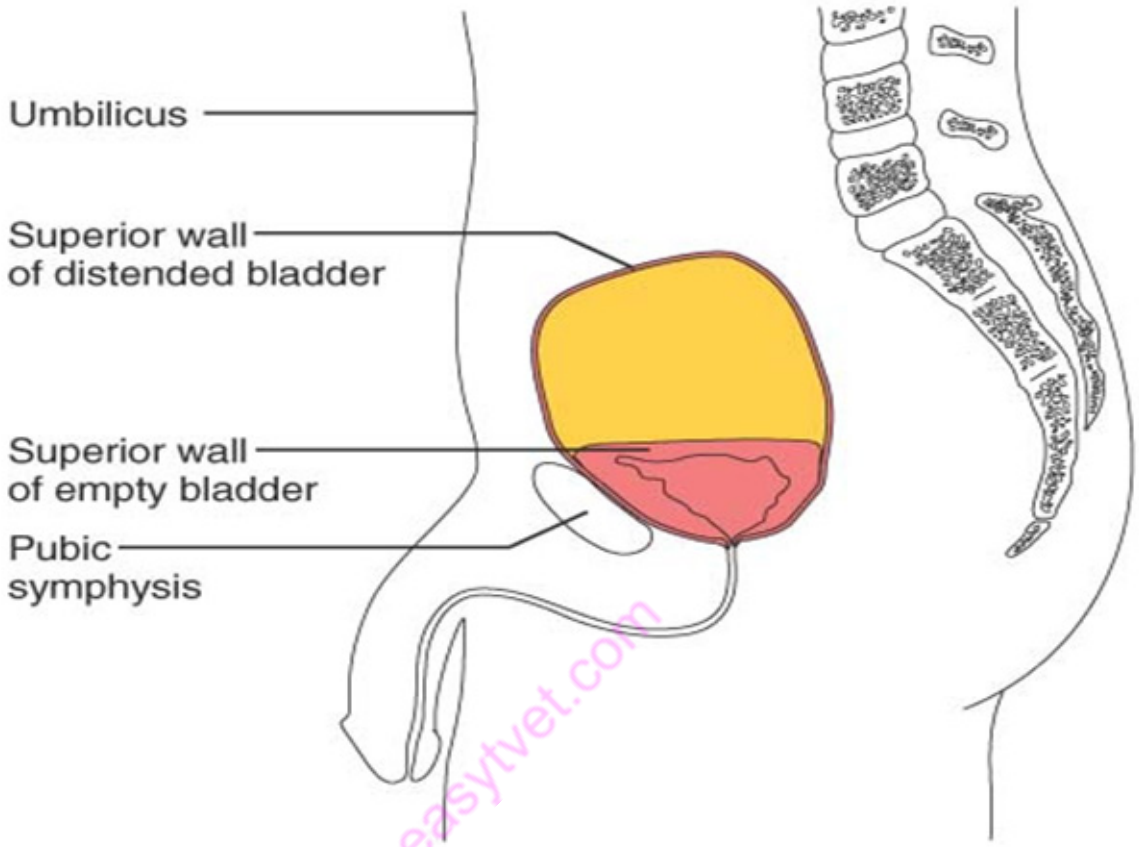
The bladder can expand to hold up to 1L of urine and expands superiorly into the abdominal cavity

The detrusor muscle is supplied by autonomic nerves from the sacral plexus.

The inner lining of an empty bladder is arranged in folds called rugae which disappears as the bladder fills.

The urinary bladder can distend to hold about 300-400 mls of urine. The total capacity is about 600mls.

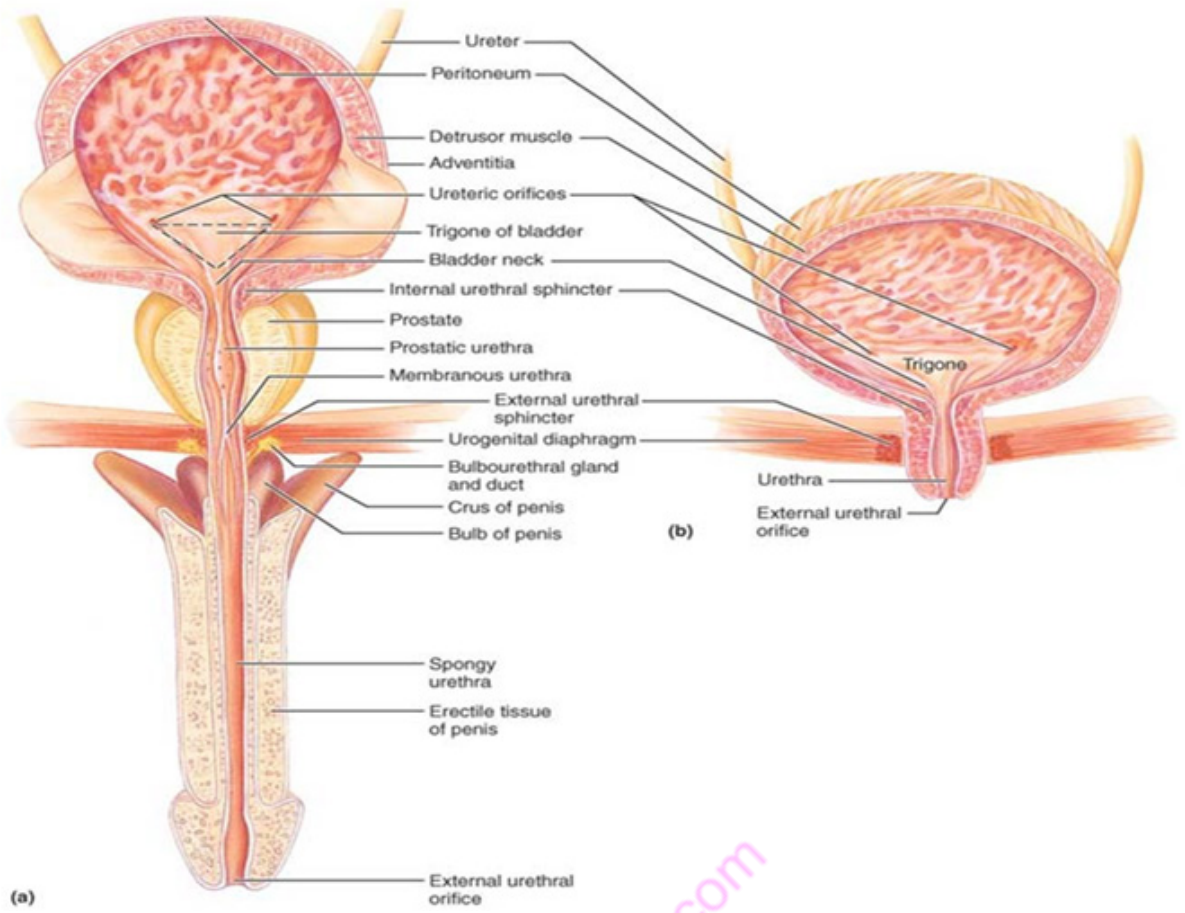
The three orifices (two ureters and the urethra) in the bladder wall have been arranged to form a trigone.



It is supplied by the superior and inferior vesical arteries from the internal iliac arteries and drains to the vesical plexus of veins which drain to the internal iliac vein

The inferior portion of the bladder at the beginning of the urethra is known as the bladder neck; the circular smooth muscle here is enlarged & thickened to form the involuntary internal urethra sphincter

More distal is found the voluntary external urethral sphincter.



The Urethra

This is a fibromuscular tube that conveys urine from the urinary bladder to the exterior.

It is lined by pseudostratified columnar epithelium that changes to transitional towards the urinary bladder and to stratified squamous towards the external urethral opening.

It is short in females measuring approx. 3-4 cm and tightly apposed to the anterior vaginal wall. It end in an external orifice that is found anterior to the vaginal opening and posterior to the clitoris in the vestibule.

Female Urethra

The wall is made up of the outer muscle layer: inner smooth muscle layer that is under involuntary control and an outer striated muscle layer that is under voluntary control

The mucosa is supported by loose connective tissue containing blood vessels and nerves.

Proximally it contains transitional epithelium and distally –stratified epithelium.

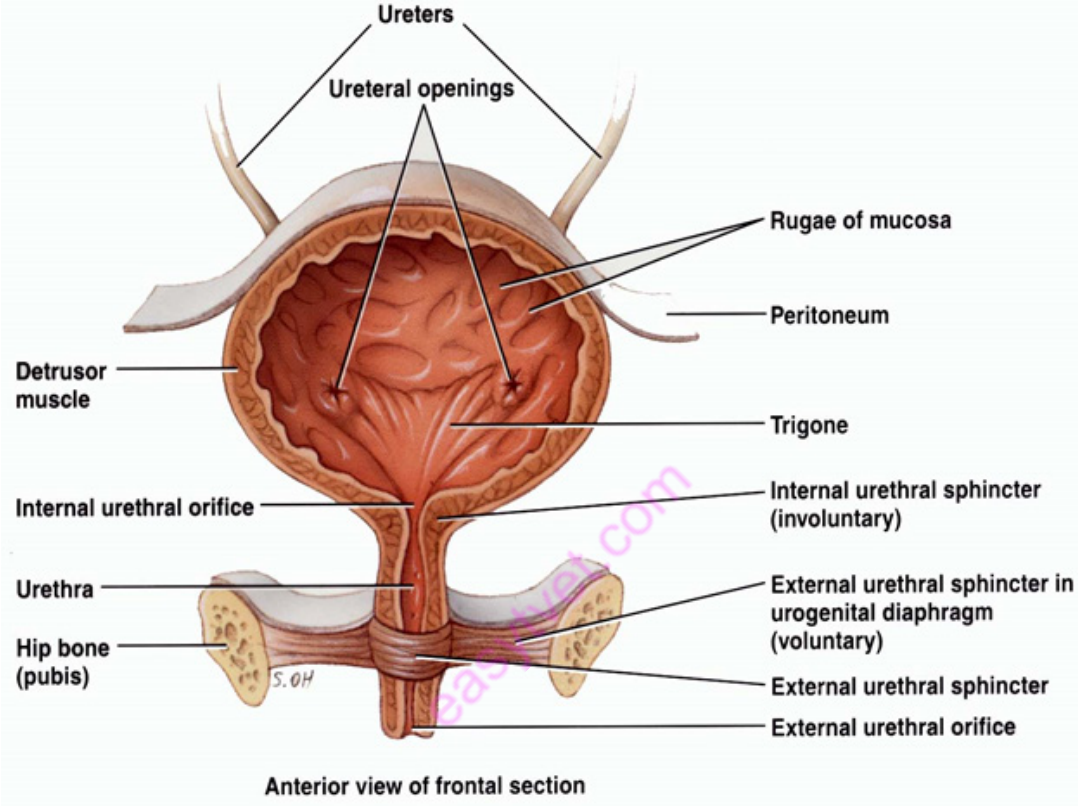
Male Urethra

In males it is approx. 20 cm long and is divided into three regions:

Prostatic 3 cm – surrounded by the prostate gland. The vas deferens opens into this portion of the urethra

Membranous 2cm – passes through the urogenital diaphragm

Spongy urethra 15cm – this is the rest of the urethra and is surrounded by the corpus spongiosum of the penis.



Micturition

Micturition is discharge of urine from the urinary bladder. It is also known as urination or voiding.

The micturition reflex occurs when volume within the bladder exceeds 200 – 400 mL and causes stretch of the bladder wall.

In infants: spinal reflex is initiated

PNS stimulates the bladder

Detrusor muscles contracts

Internal urethral sphincter relaxes

Urine is expelled from the bladder into the urethra before leaving the body.

For a fully developed nervous system, sensory impulses are sent to the brain for awareness of the need to pass urine.

For adults, the external urethral sphincter relaxes via voluntary control for micturation.

Micturition can also be assisted by increasing pressure in the pelvic cavity (lowering the diaphragm and abdominal muscles)- Valsalva's manoeuvre.

Over-distension of the bladder may cause involuntary relaxation of the external urethral sphincter allowing small amounts of urine to escape.

Urinary Incontinence

A lack of voluntary control over micturition is called urinary incontinence.

Types of Incontinence

Urge incontinence due to an overactive bladder

Stress incontinence due to poor closure of the bladder. Physical stresses that increase abdominal pressure such as coughing, sneezing, laughing, exercising, pregnancy, or walking can cause leakage of urine from the bladder.

Overflow incontinence due to either poor bladder contraction or blockage of the urethra

Functional incontinence due to medications or health problems making it difficult to reach the bathroom.

NB: Those who smoke have twice the risk or developing urinary incontinence.

Musculoskeletal System

Three (3) Types of Muscle Tissues

Skeletal Muscle

- Usually attached to bones
- Under conscious control
- Somatic nervous control
- Striated

Smooth Muscle

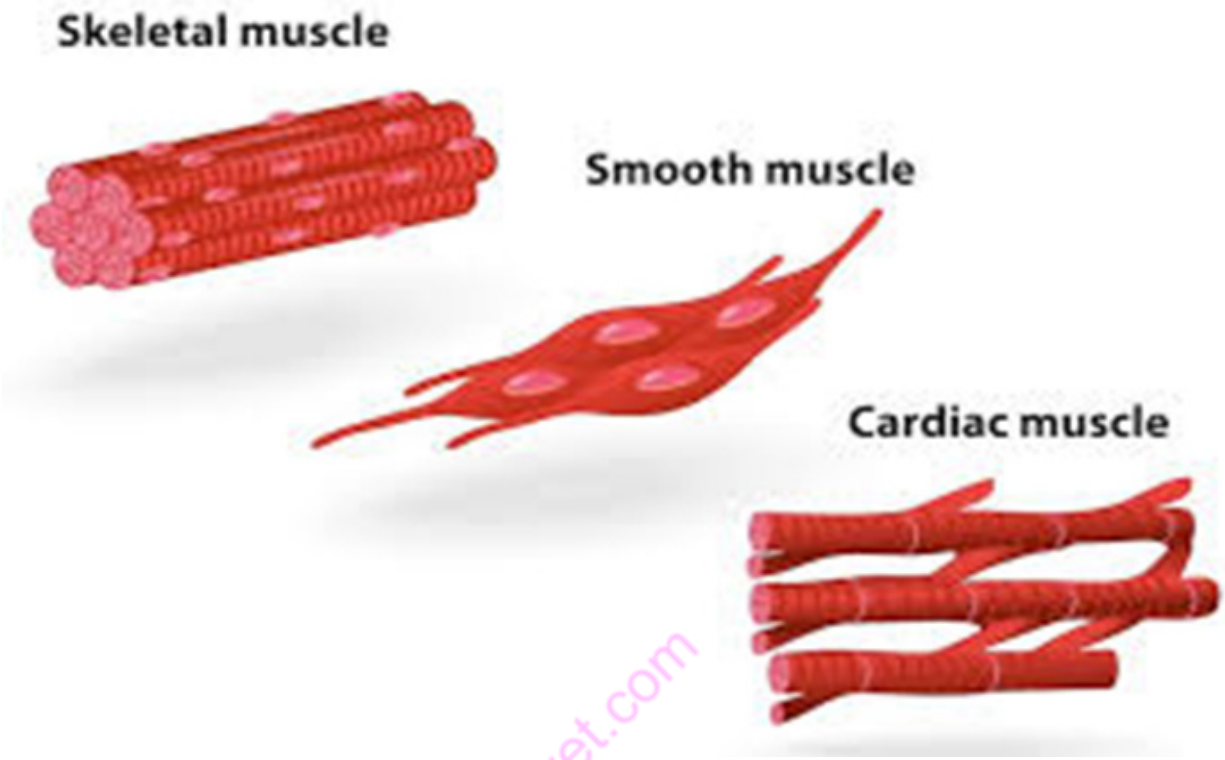
- Walls of most viscera, blood vessels and skin
- Not under conscious control
- Autonomic
- Not striated
- Spindle shaped

Cardiac Muscle

- Wall of heart
- Not under conscious control

- Autonomic nervous control
- Striated
- Have branches

Have intercalated discs



Structure of Skeletal Muscle

Skeletal Muscle

Organs of the muscular system

Skeletal muscle tissue

Nervous tissue

Blood

Connective tissues

Fascia-is a band or sheet of connective tissue, primarily collagen, beneath the skin that attaches, stabilizes, encloses, and separates muscles and other internal organs.

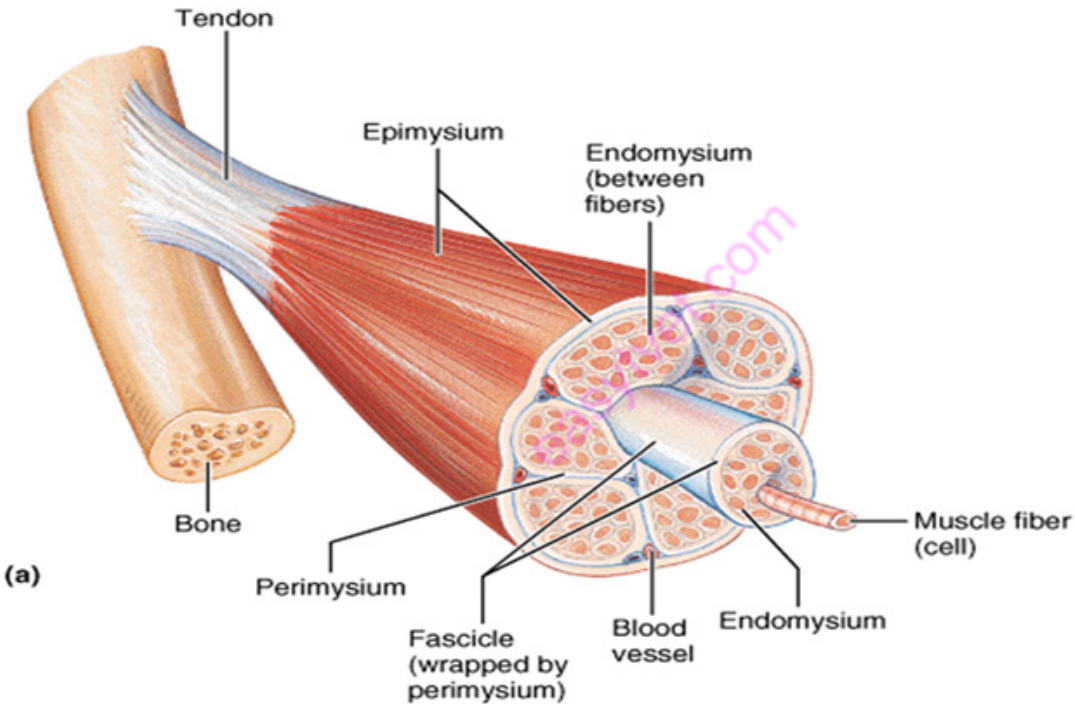
Tendons--- cord like end of muscle

Aponeuroses-a sheet of pearly white fibrous tissue which takes the place of a tendon in sheet-like muscles having a wide area of attachment.

Connective Tissue Coverings

Muscle Coverings:

- Epimysium-cover entire muscle
- Perimysium-cover muscle fascicle
- Endomysium-cover muscle fiber (muscle cell)
- Muscle organ
- Fascicles
- Muscle cells or fibers
- Myofibrils
- Thick and thin myofilaments
- Actin and myosin proteins



Skeletal Muscle Fibers

Sarcolemma—cell membrane of muscle cell or fiber

Sarcoplasm---the cytoplasm of striated muscle cells

Sarcoplasmic reticulum (SR)—is similar to endoplasmic reticulum in other cells and its function in muscle cell is to store calcium ions.

Transverse ('T') tubule– are extensions of the cell membrane that penetrate into the centre of skeletal and cardiac muscle cells.

Triad of skeletal muscle fiber

2 Cisternae of SR

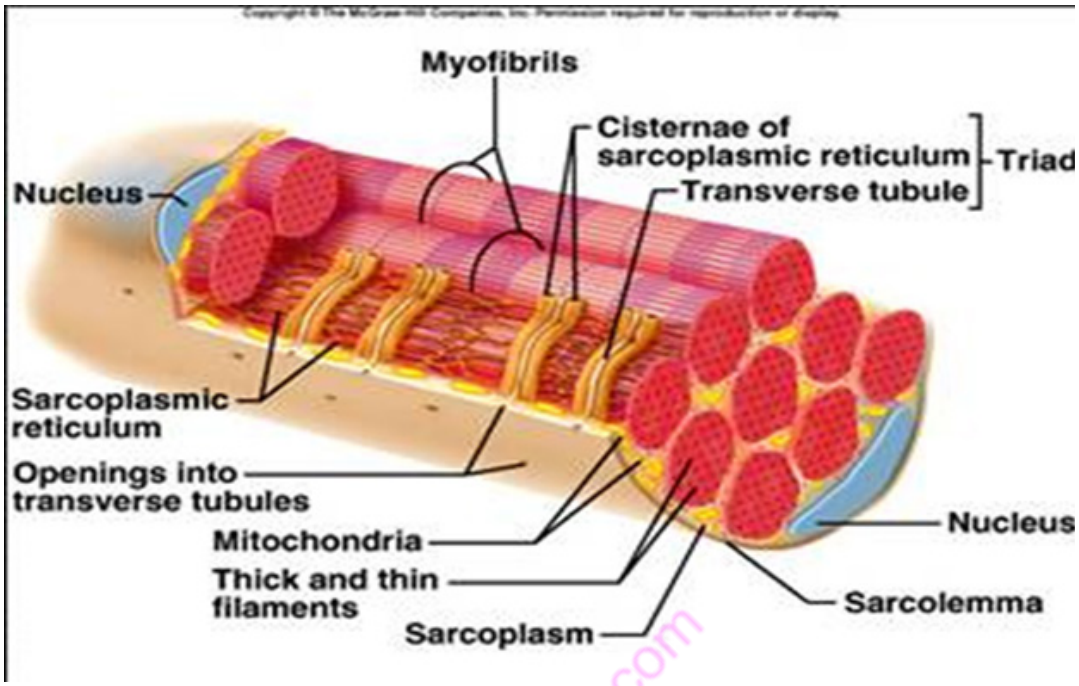
T tubule

Myofibril– any of the elongated contractile threads found in striated muscle cells

Actin myofilaments

Myosin myofilaments

Sarcomere—contractile unit of skeletal muscle



Skeletal Muscle Contraction

Movement within the myofilaments

I band (thin)

A band (thick and thin)

H zone (thick)

Z line (or disc)

M line- center of A band

Myofilaments

Thick myofilaments

Composed of myosin protein

Form the cross-bridges

Thin myofilaments

Composed of actin protein

Associated with troponin and tropomyosin proteins

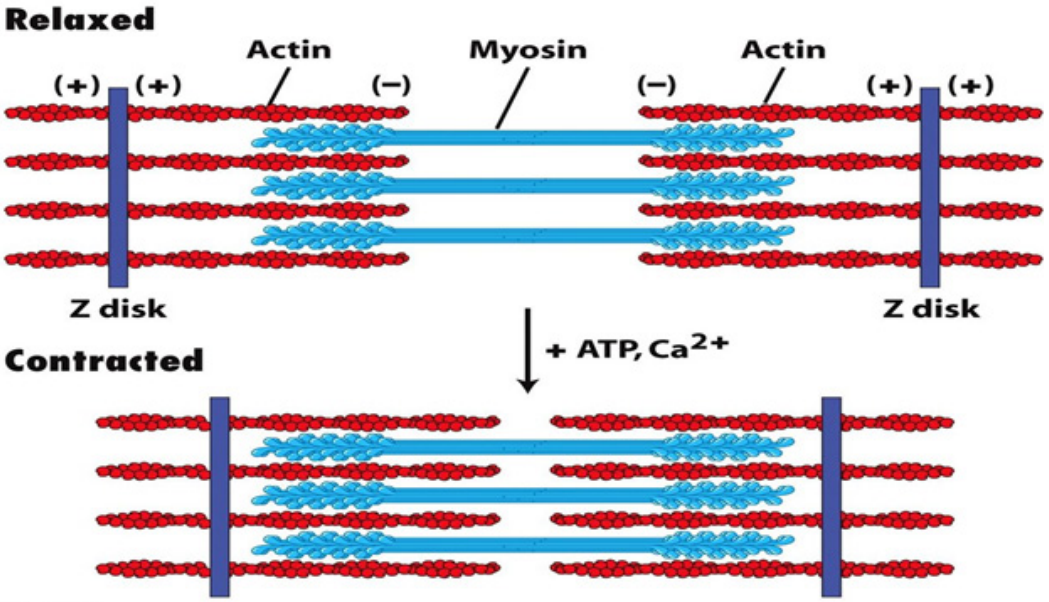


Figure 17-30
Molecular Cell Biology, Sixth Edition

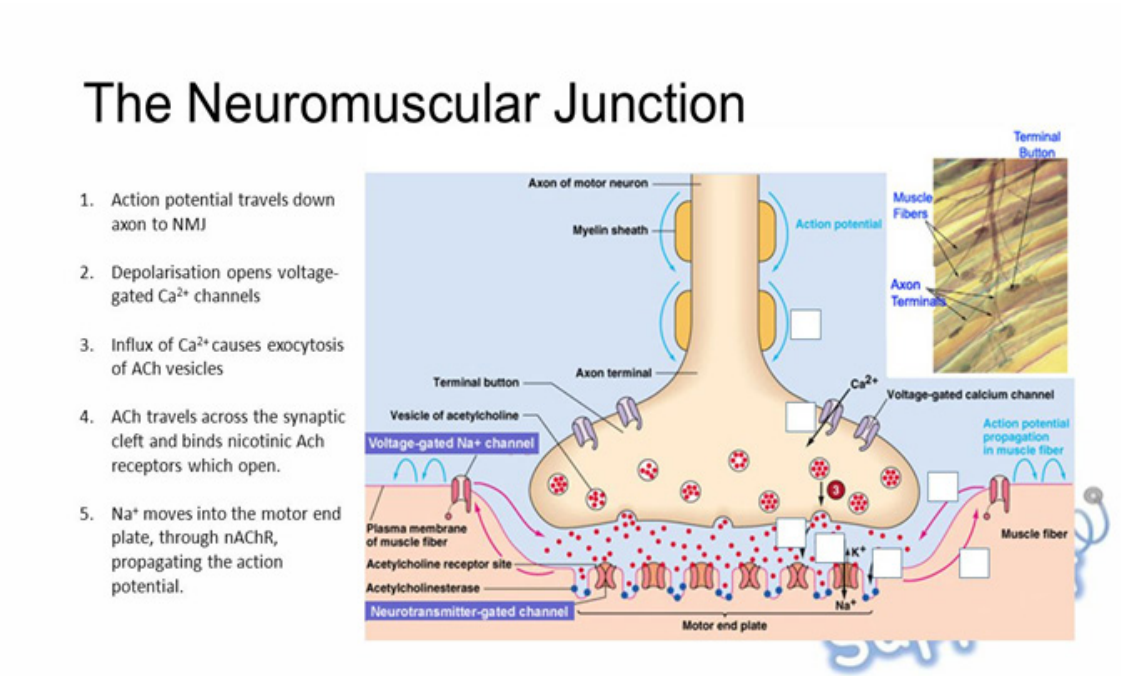
Neuromuscular Junction

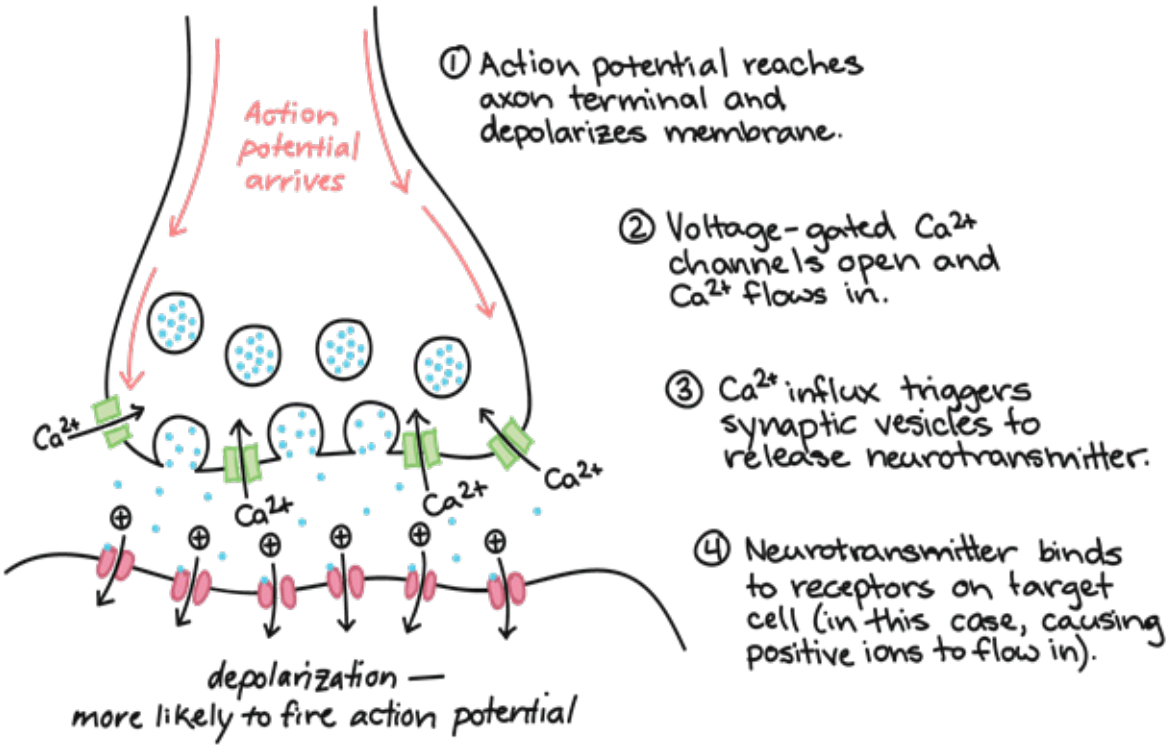
Also known as NMJ or myoneural junction.

Site where an axon and muscle fiber meet.

Parts to know:

- Motor neuron
- Synapse
- Synaptic vesicles
- Motor end plate
- Synaptic cleft
- Neurotransmitters





The Neuromuscular Junction Physiology

The action potential travels down the axon to the NMJ.

Arrival of the impulse causes depolarization of the pre-synaptic membrane causing opening of calcium gated channels resulting in the influx of calcium ions which causes the vesicles containing acetylcholine to fuse with the pre-synaptic membrane.

The vesicles then releases their content which is acetylcholine into the synaptic gap or cleft.

The neurotransmitter diffuses across the gap and attaches to the specific receptor protein on the post-synaptic membrane and opens them.

Sodium ions influx or enters into the post-synaptic membrane and it changes the membrane potential of the sarcolemma (the cell membrane of the muscle cell) generating an action potential.

The action potential moves through the T-tubules and sarcoplasmic reticulum which release calcium ions which cause contraction of the muscle fibers.

Motor Unit

Motor unit refers to all muscle fibers controlled by one motor neuron.

Single motor neuron

As few as four fibers

As many as 1000's of the muscle fibers

Stimulus for Contraction

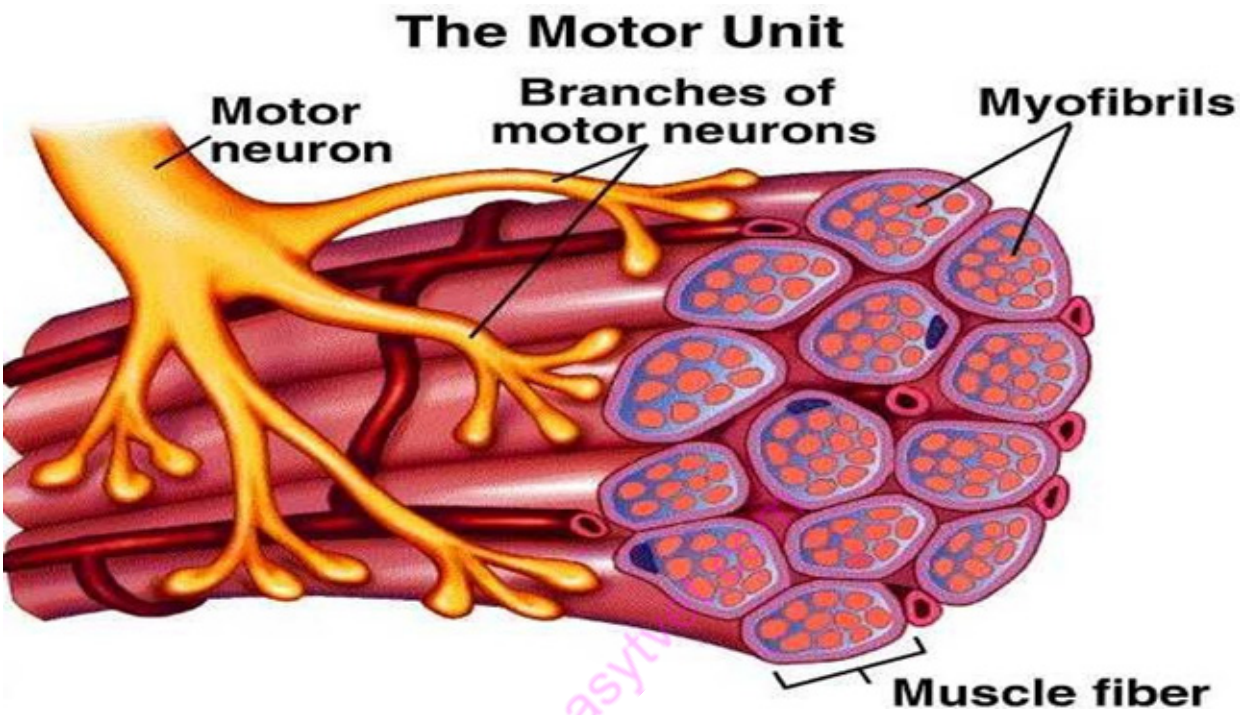
Acetylcholine (ACh)

Nerve impulse causes release of ACh from synaptic vesicles

ACh binds to ACh receptors on motor end plate.

Generates a muscle impulse

Muscle impulse eventually reaches the SR and the cisternae causing muscle contraction.



Excitation-Contraction Coupling

Muscle impulses cause SR to release calcium ions into cytosol

Calcium binds to troponin to change its shape.

The position of tropomyosin is altered.

Binding sites on actin are now exposed.

Actin and myosin molecules bind via myosin cross-bridges

Cross Bridge Cycling

The Four Steps of Cross Bridge Cycling

1. *The cross bridge formation*-the activated myosin head binds to actin forming a cross bridge. Inorganic phosphate is released from hydrolysis of ATP to ADP and the bond between myosin and actin become stronger.
2. *The power stroke*—ADP is released and the activated myosin head pivots sliding the thin myofilaments towards the center of the sarcomere.

3. *Cross bridge detachment*- when another ATP binds to the myosin head, the link between the myosin head and the actin weakens, and the myosin head detaches.
4. *Reactivation of myosin head*-ATP is hydrolyzed to ADP and inorganic phosphate. The energy released during hydrolysis reactivates the myosin head returning it to the cocked position.

The Sliding Filament Theory of Muscle Contraction

For a contraction to occur there must first be a stimulation of the muscle in the form of an impulse (action potential) from a motor neuron (nerve that connects to muscle).

Note that one motor neuron does not stimulate the entire muscle but only a number of muscle fibres within a muscle.

The individual motor neuron plus the muscle fibres it stimulates, is called a motor unit. The motor end plate (also known as the neuromuscular junction) is the junction of the motor neurons axon and the muscle fibres it stimulates.

When an impulse reaches the muscle fibres of a motor unit, it stimulates a reaction in each sarcomere between the actin and myosin filaments. This reaction results in the start of a contraction and the sliding filament theory.

The reaction, created from the arrival of an impulse stimulates the 'heads' on the myosin filament to reach forward, attach to the actin filament and pull actin towards the centre of the sarcomere.

This process occurs simultaneously in all sarcomeres, the end process of which is the shortening of all sarcomeres.

Troponin is a complex of three proteins that are integral to muscle contraction.

Troponin is attached to the protein tropomyosin within the actin filaments.

When the muscle is relaxed tropomyosin blocks the attachment sites for the myosin cross bridges (heads), thus preventing contraction.

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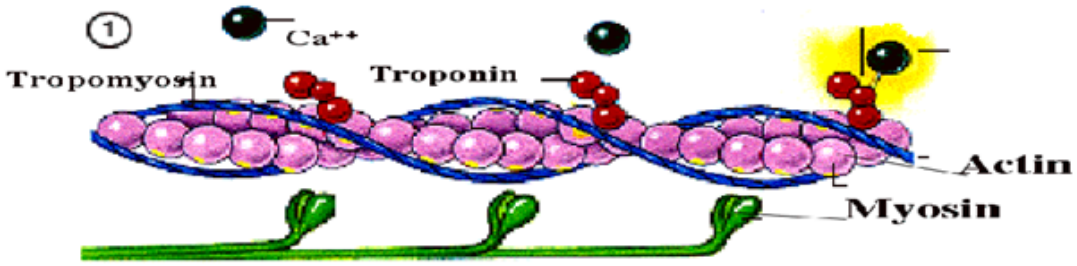
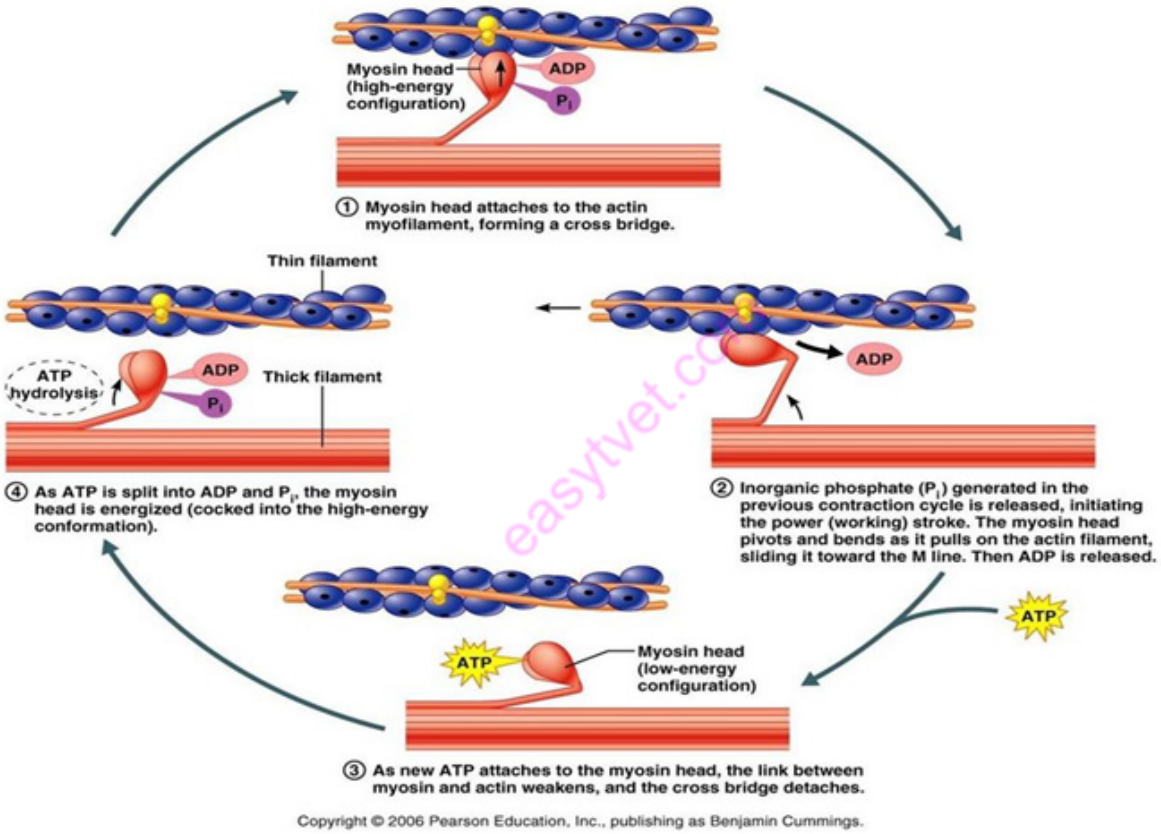




A Few Things Can Stop a Contraction;

Energy system fatigue: There is no more ATP left in the muscle cell so it can't keep contracting.

Nervous system fatigue: The nervous system is not able to create impulses sufficiently or quickly enough to maintain the stimulus and cause calcium to release.

Voluntary nervous system control: The nerve that tells the muscle to contract stops sending that signal because the brain tells it to, so no more calcium ions will enter the muscle cell and the contraction stops.

Sensory nervous system information: For example, a sensory neuron (nerves that detect stimuli like pain or how heavy something is) provides feedback to the brain indicating that a muscle is

injured while you are trying to lift a heavy weight and consequently the impulse to that muscle telling it to contract is stopped.

Relaxation

Acetylcholinesterase – rapidly decomposes Ach remaining in the synapse

Muscle impulse stops

Stimulus to sarcolemma and muscle fiber membrane ceases

Calcium moves back into sarcoplasmic reticulum (SR)

Myosin and actin binding prevented

Muscle fiber relaxes.

Energy Sources for Contraction

1) Creatine phosphate and 2) Cellular respiration

Creatine phosphate – stores energy that quickly converts ADP to ATP

Oxygen Supply and Cellular Respiration

Cellular respiration:

Anaerobic Phase

- Glycolysis
- Occurs in cytoplasm
- Produces little ATP

Aerobic Phase

- Citric acid cycle
- Electron transport system
- Occurs in the mitochondria
- Produces most ATP
- Myoglobin stores extra oxygen

Oxygen Debt

Oxygen debt – amount of oxygen needed by liver cells to use the accumulated lactic acid to produce glucose.

- Oxygen not available
- Glycolysis continues

- Pyruvic acid converted to lactic acid
- Liver converts lactic acid to glucose

Muscle Fatigue

Inability to contract muscle

- Commonly caused by:
- Decreased blood flow
- Ion imbalances across the sarcolemma
- Accumulation of lactic acid
- Cramp – sustained, involuntary muscle contraction

Heat Production

By-product of cellular respiration.

Muscle cells are major source of body heat. Blood transports heat throughout body core

Muscular Responses

Muscle contraction can be observed by removing a single skeletal muscle fiber and connecting it to a device that senses and records changes in the overall length of the muscle fiber.

Threshold Stimulus--Minimal strength required to cause contraction.

Recording of a Muscle Contraction

Recording a Muscle Contraction

- ***Twitch***-small muscle contractions
- Latent period
- Period of contraction
- Period of relaxation

Refractory period

All-or-none response-The principle that the strength by which a nerve or muscle fiber responds to a stimulus is not dependent on the strength of the stimulus. If the stimulus is any strength above threshold, the nerve or muscle fiber will either give a complete response or no response at all.

Recording of a Muscle Contraction

A **twitch** is a single contractile response to a stimulus

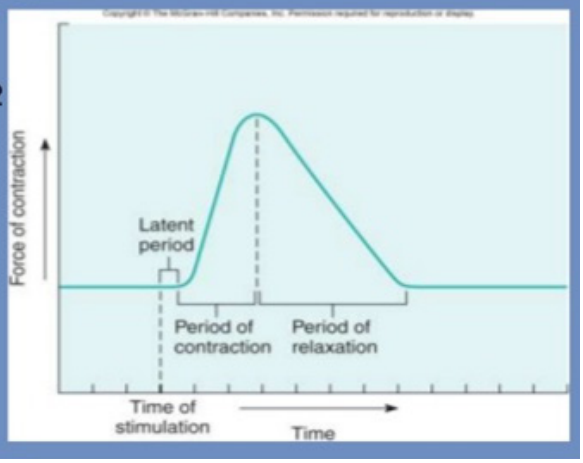
A **twitch** can be divided into three periods.

1. Latent period
   brief delay between the stimulus and the muscle contraction

   The latent period is less than 2 milliseconds in humans

2. Period of contraction

3. Period of relaxation



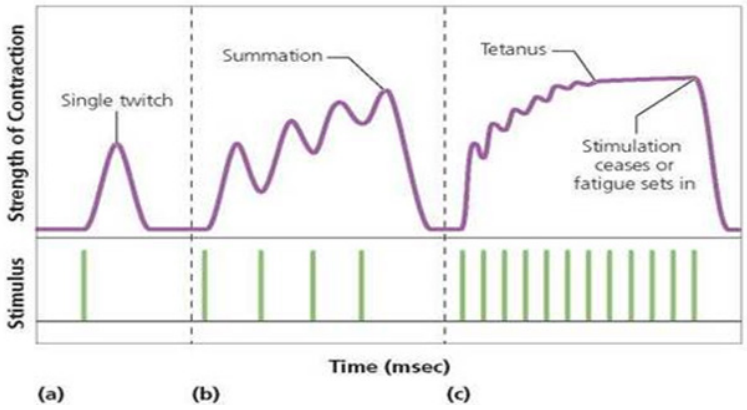
Summation

Process by which individual twitches combine.

Temporal Summation-the sum of all muscle tension produced by a single motor unit at different time.

Produces sustained contractions

Can lead to tetanic contractions



Recruitment of Motor Units

Recruitment - increase in the number of motor units activated

Muscle recruitment-the sum of all tensions produced by different motor units at the same time.

Whole muscle composed of many motor units

More precise movements are produced with fewer muscle fibers within a motor unit.

As intensity of stimulation increases, recruitment of motor units continues until all motor units are activated.

Sustained Contractions

Smaller motor units (smaller diameter axons) - recruited first

Larger motor units (larger diameter axons) - recruited later

Produce smooth movements

Muscle tone – continuous state of partial contraction

Types of Contractions

Isotonic – muscle contracts and changes length

Eccentric – lengthening contraction

Concentric – shortening contraction

Isometric – muscle contracts but does not change length

Fast Twitch and Slow Twitch Muscle Fibers

Slow-twitch fibers (Type I)

- Always oxidative
- Resistant to fatigue
- Red fibers
- Most myoglobin
- Good blood supply

Fast-twitch glycolytic fibers (Type IIa)

- White fibers (less myoglobin)
- Poorer blood supply
- Susceptible to fatigue

Fast-twitch fatigue-resistant fibers (Type IIb)

Intermediate fibers

Oxidative

Intermediate amount of myoglobin

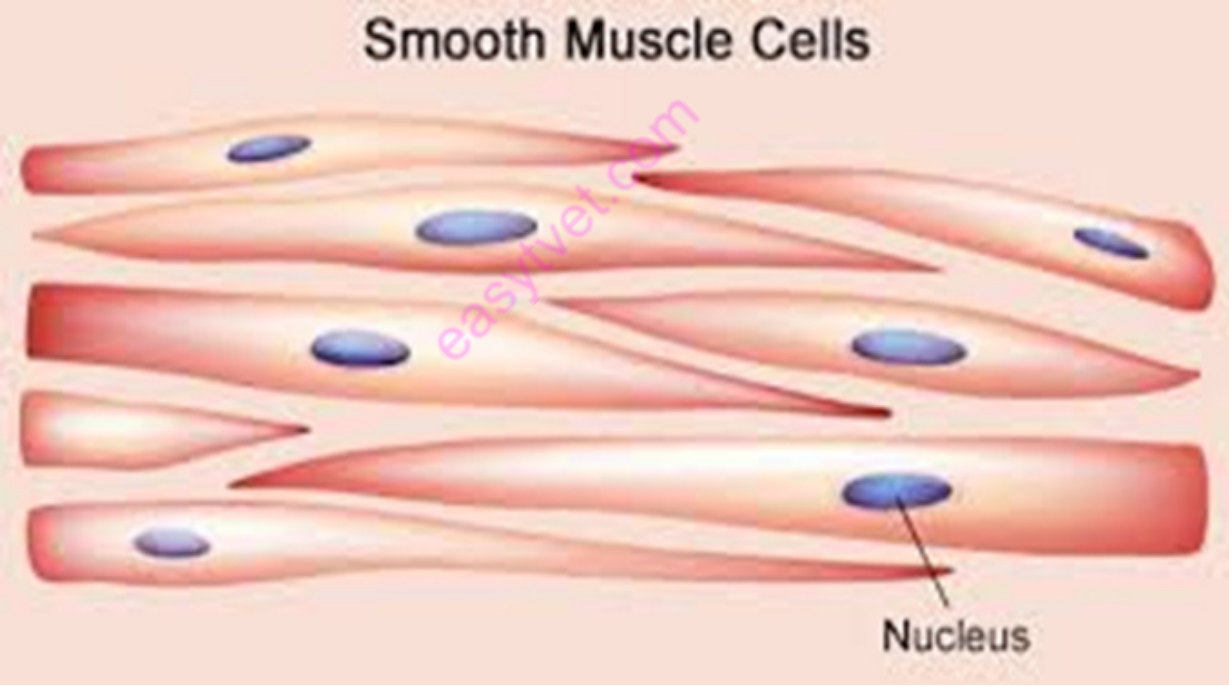
Pink to red in color

Resistant to fatigue

Smooth Muscles

Compared to skeletal muscle fibers, smooth muscle fibers are:

- Shorter
- Single, centrally located nucleus
- Elongated with tapering ends
- Myofilaments randomly organized
- Lack striations
- Lack transverse tubules
- Sarcoplasmic reticula (SR) not well developed.



Smooth Muscle Fibers

Visceral Smooth Muscle

- Single-unit smooth muscle
- Fibers held together by gap junctions
- Exhibit peristalsis
- Sheets of muscle fibers
- Exhibit rhythmicity
- Walls of most hollow organs

Multi-Unit Smooth Muscle

- Less organized
- Fibers function separately
- Walls of blood vessels
- Function as separate units
- Iris of eye

Smooth Muscle Contraction

Resembles skeletal muscle contraction in that:

- Interaction between actin and myosin
- Both use calcium and ATP
- Both are triggered by membrane impulses

Different from skeletal muscle contraction in that:

- Smooth muscle lacks troponin
- Smooth muscle uses calmodulin

Two neurotransmitters affect smooth muscle

  - Acetlycholine (Ach) and norepinephrine (NE)
- Hormones affect smooth muscle e.g. gastrin hormone
- Stretching can trigger smooth muscle contraction
- Smooth muscle slower to contract and relax
- Smooth muscle more resistant to fatigue
- Smooth muscle can change length without changing tautness

Cardiac Muscle

- Located only in the heart
- Muscle fibers joined together by intercalated discs
- Fibers branch
- Network of fibers contracts as a unit
- Self-exciting and rhythmic
- Longer refractory period than skeletal muscle

Skeletal Muscle Actions

Skeletal muscles generate a great variety of body movements.

The action of each muscle mostly depends upon the kind of joint it is associated with and the way the muscle is attached on either side of that joint.

Origin and Insertion

Origin – immovable end

Insertion – movable end

Interaction of Skeletal Muscles

Prime mover (agonist) – primarily responsible for movement

Synergists – assist prime mover

Antagonist – resist prime mover's action and cause movement in the opposite direction of the prime mover

Lifespan Changes

Myoglobin, ATP, and creatine phosphate decline

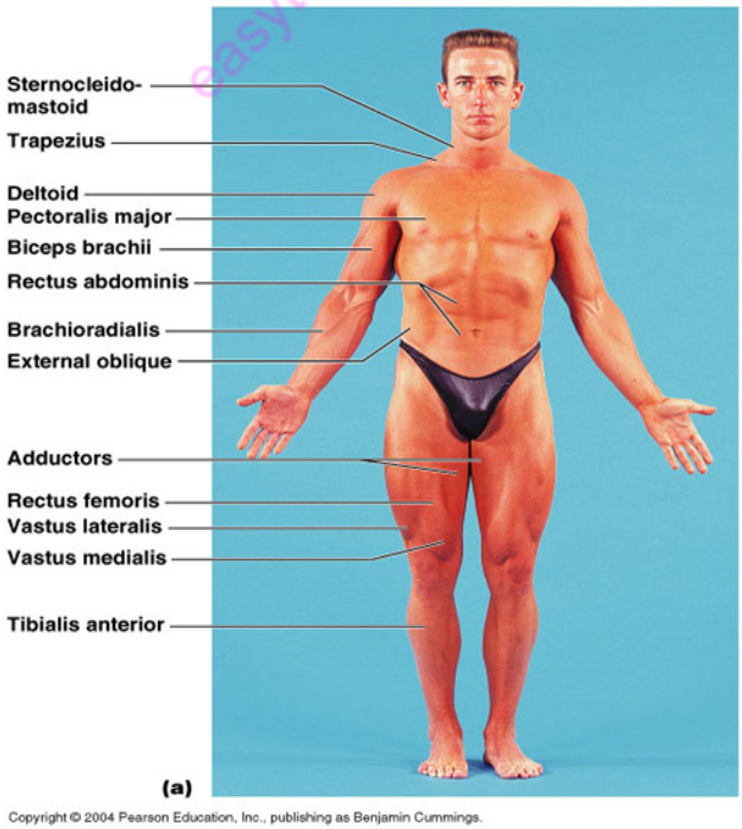
By age 80, half of muscle mass has atrophied

Adipose cells and connective tissues replace muscle tissue

Exercise helps to maintain muscle mass and function

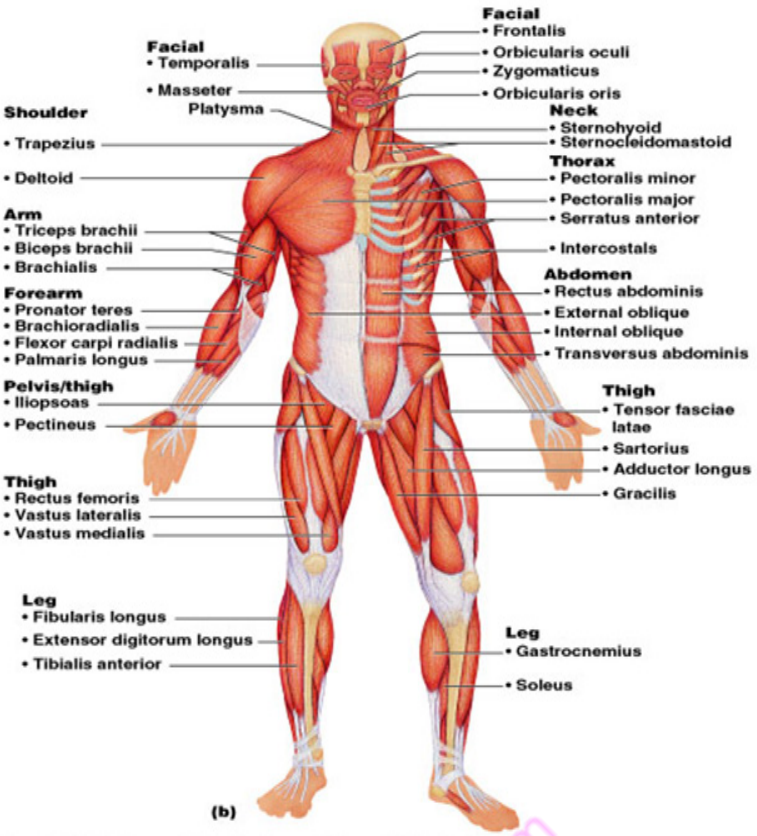
Skeletal Muscles

They are ver 600, Book only list approximately 125 pairs of them

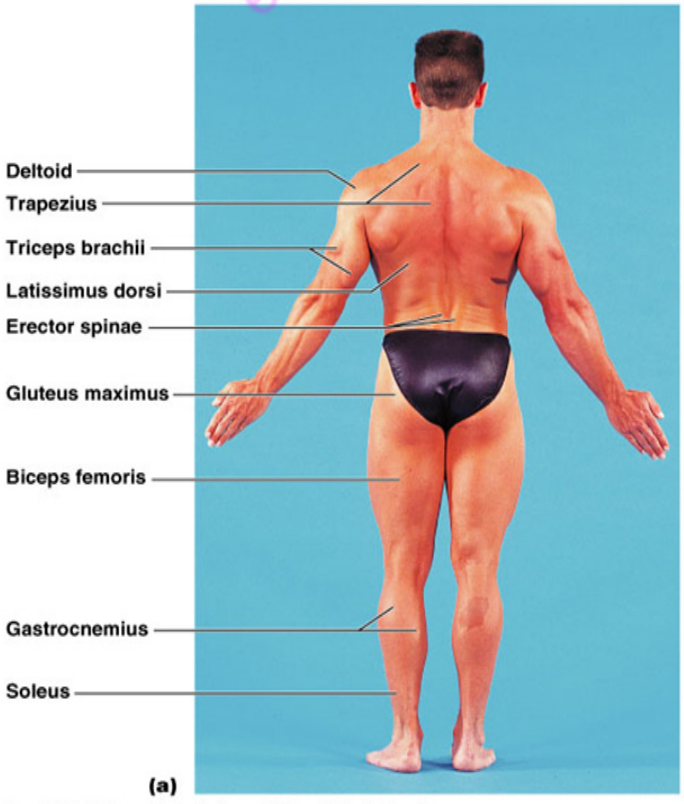


ANTERIOR SUPERFICIAL MUSCLES

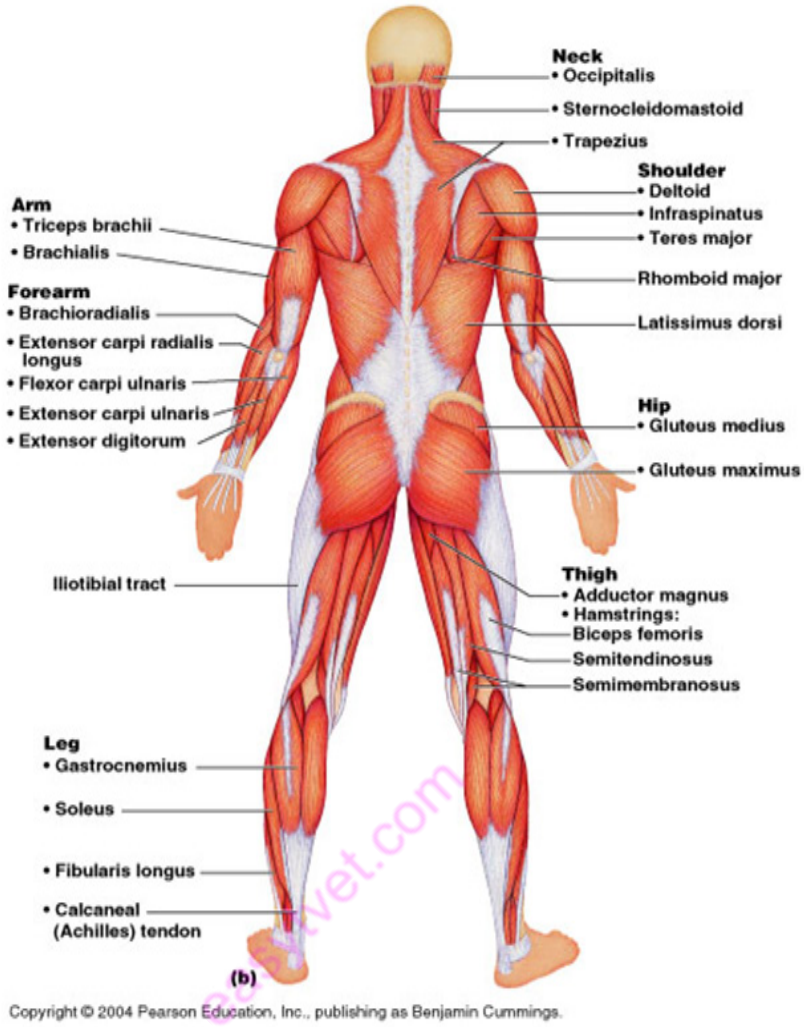
Diagrammatic view ofanterior muscles



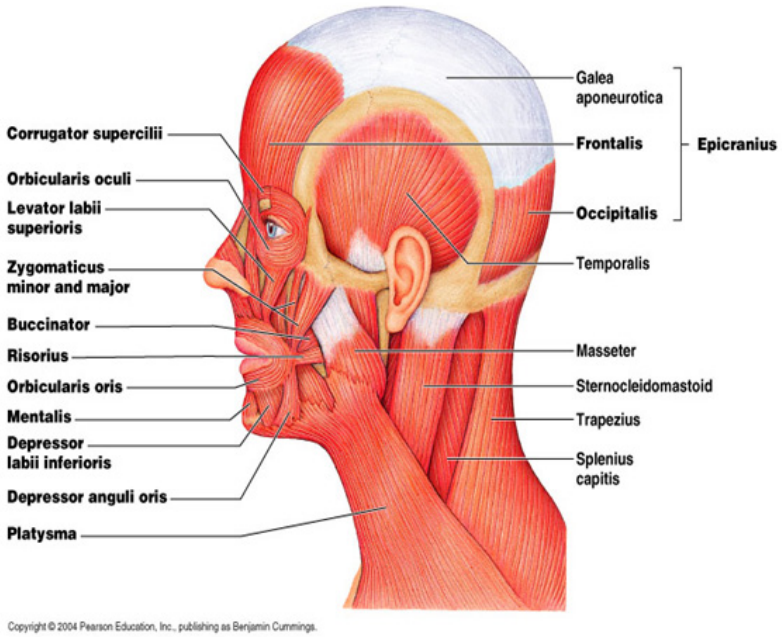
Posterior view of superficial muscles



Diagrammatic view of posterior muscles



Major skeletal muscles of the face



Frontalis: Cranial (facial nerve) VII

- Raises the eyebrows (as in surprise)
- Wrinkles forehead skin horizontally
- Cranial nerve VII

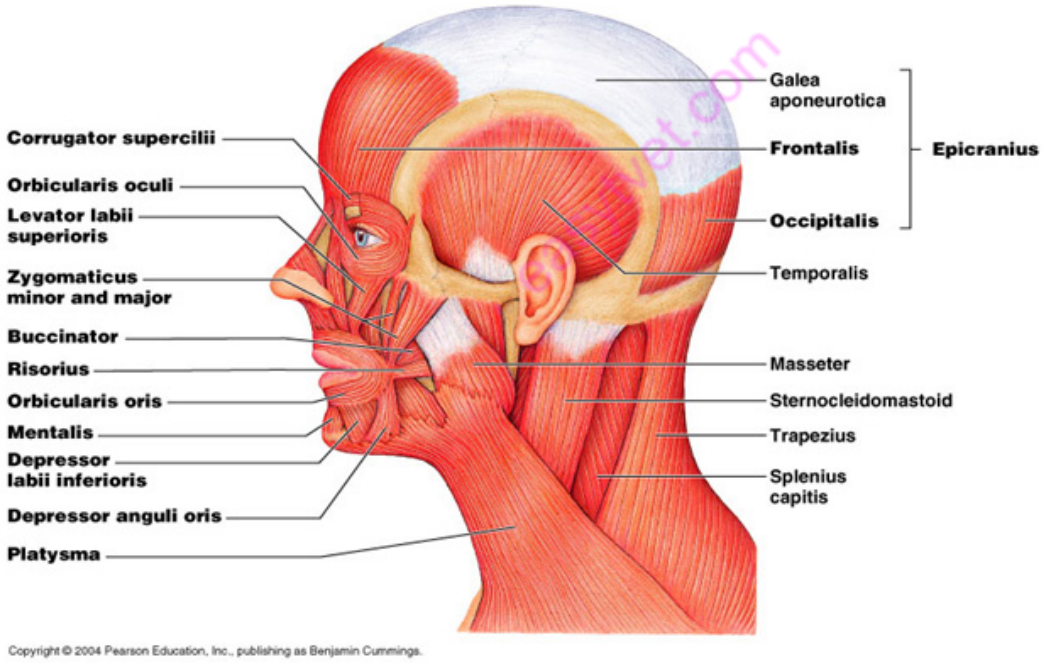
Orbicularis Oculi: Cranial (facial nerve) VII

- Protects eyes from intense light and injury
- Produces blinking, squinting
- Draws the eyebrows inferiorly

Orbicularis Oris: Cranial (facial nerve) VII

- Closes lips
- Purses (pucker) and protrudes (stick out) lips
- Kissing and whistling muscle

HEAD MUSCLES

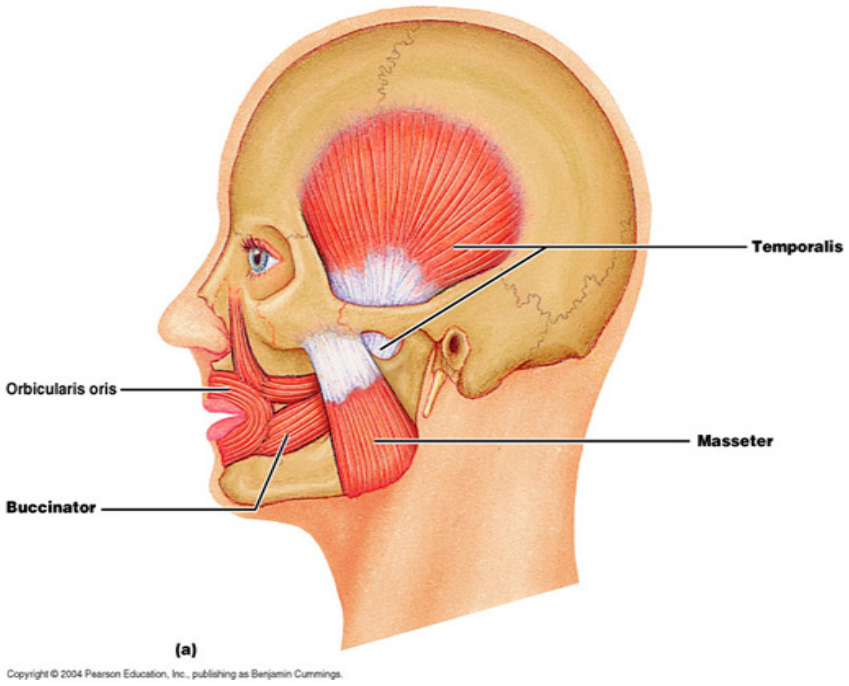


Mastication and Tongue Movement:

Muscles of mastication include the masseter, temporalis, medial pterygoid, lateral pterygoid, and the buccinator

Muscles promoting tongue movement are the genioglossus, hypoglossus, and the styloglossus.

Mastication Muscles



Masseter: Temporalis: Cranial (trigeminal) nerve V

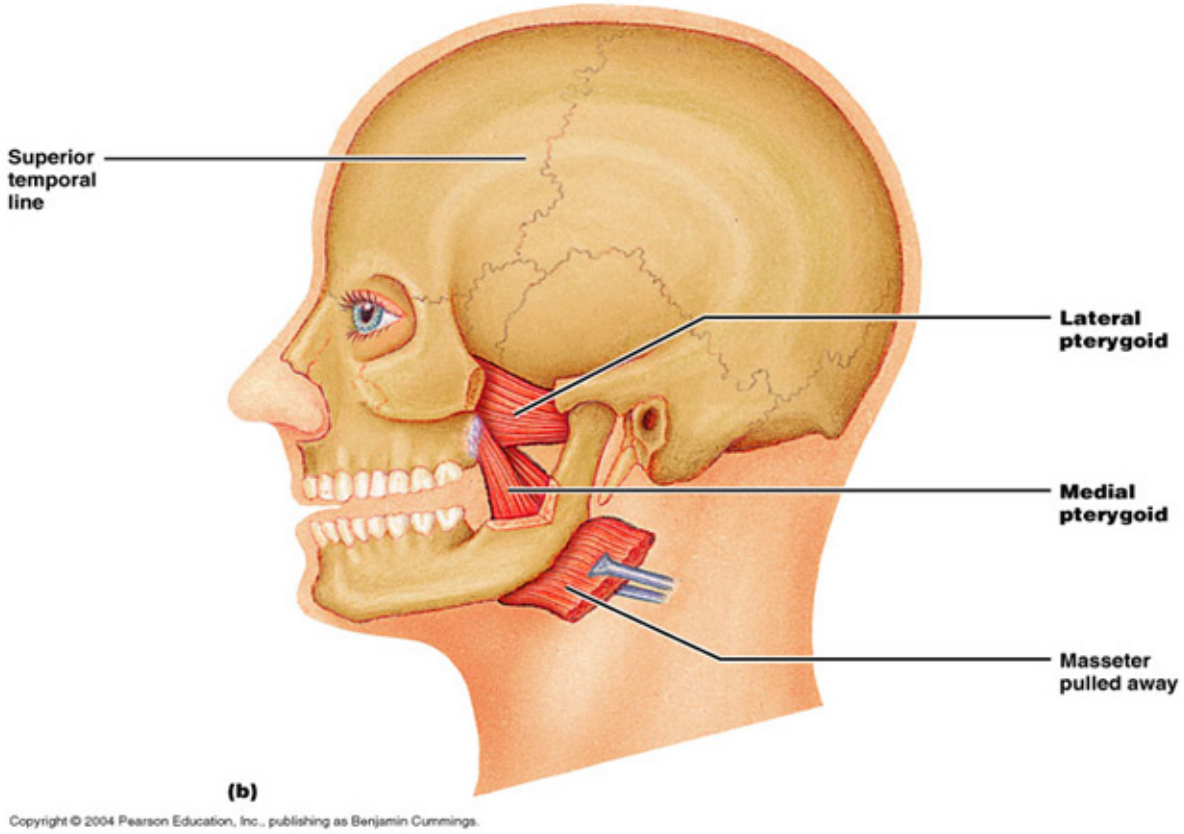
- Prime mover of jaw closure
- Elevates mandible

Temporalis: Cranial (trigeminal) nerve V

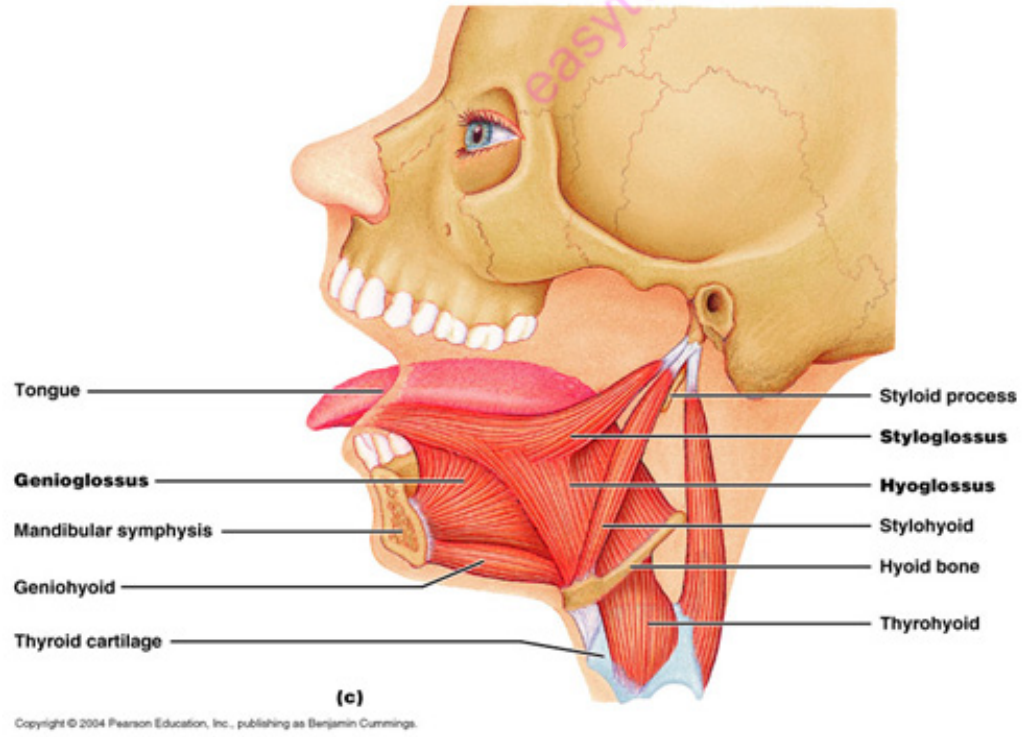
- Closes jaw
- Elevates and retracts mandible

Buccinator: Cranial (facial) nerve VII

- Trampoline-like action
- Keeps food between grinding surfaces of teeth during chewing



Tongue Muscles



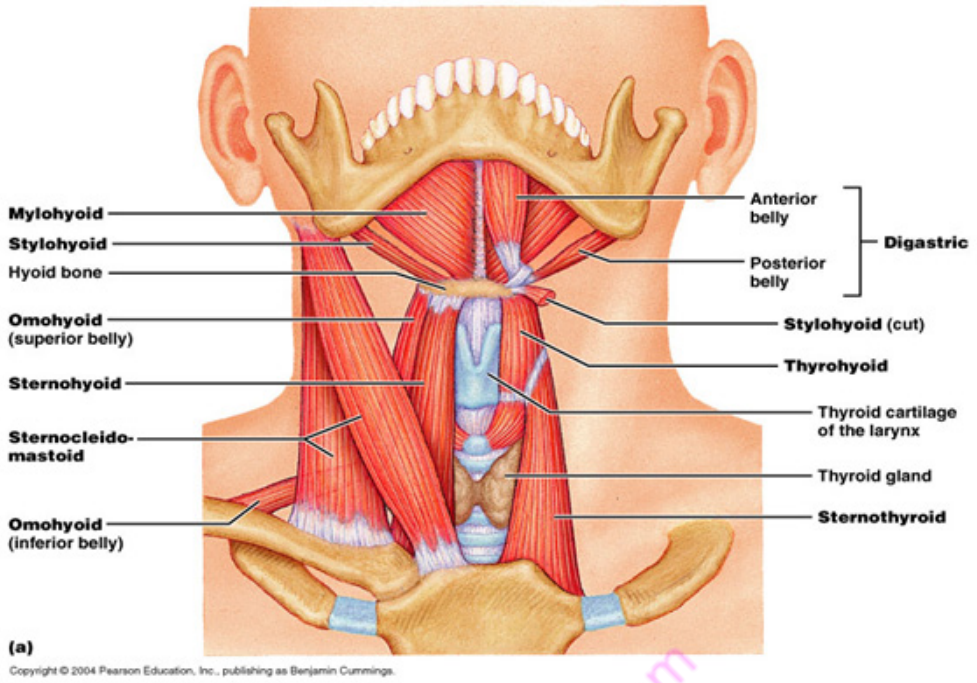
Genioglossus: Cranial (hypoglossal) nerve XII

Primarily protrudes tongue, but in concert with other extrinsic muscles to retract tongue.

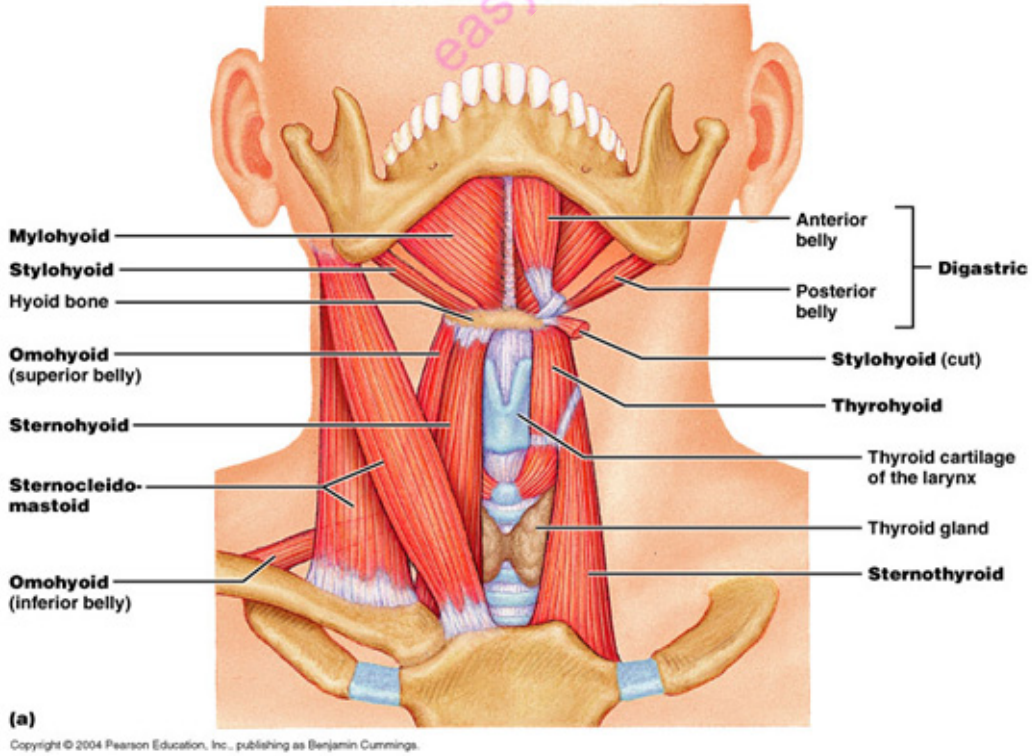
Muscles of the Anterior Neck and Throat: Swallowing

Suprahyoid muscles include digastric, stylohyoid, mylohyoid, and geniohyoid

Infrahyoid muscles include sternohyoid, sternothyroid, omohyoid, thyrohyoid, and the pharyngeal constrictor muscles (superior, middle, and inferior)



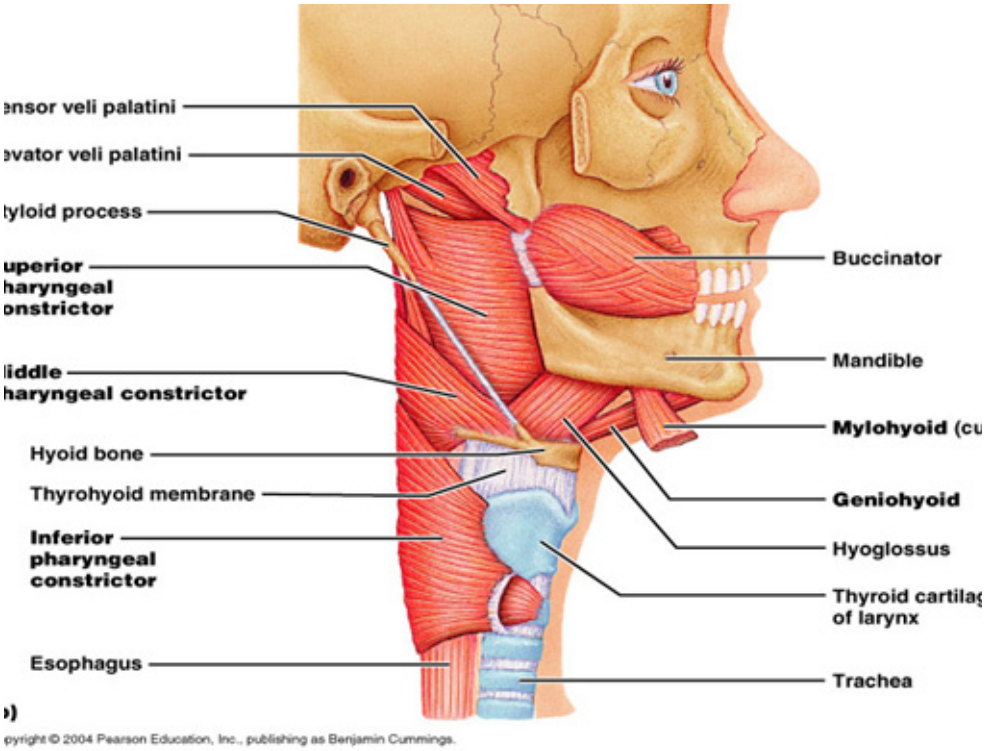
Neck and Throat Muscles



Mylohyoid:cranial (trigeminal) nerve V

Elevates hyoid bone and floor of mouth

Enables the tongue to exert backward and upward pressure that forces food bolus into pharynx.



Pharyngeal constrictor muscles (superior, middle, and inferior): Cranial (vagus) nerve X

Working as a group and in sequence, all constrict pharynx during swallowing

Propels food bolus to esophagus

Peristalsis

MAJOR SKELETAL MUSCLES OF THE BODY

Muscles of the Neck and Vertebral Column: Head and Trunk Movement.

Anterolateral neck muscles include the sternocleidomastoid, and scalenes (anterior, middle, and posterior)

Intrinsic muscles of the back include: splenius capitis, erector spinae or sacrospinalis, iliocostals, longissimus, spinalis, semispinalis, and the quadratus lumborum

Muscles of the Neck and Vertebral Column: Head and Trunk Movement.

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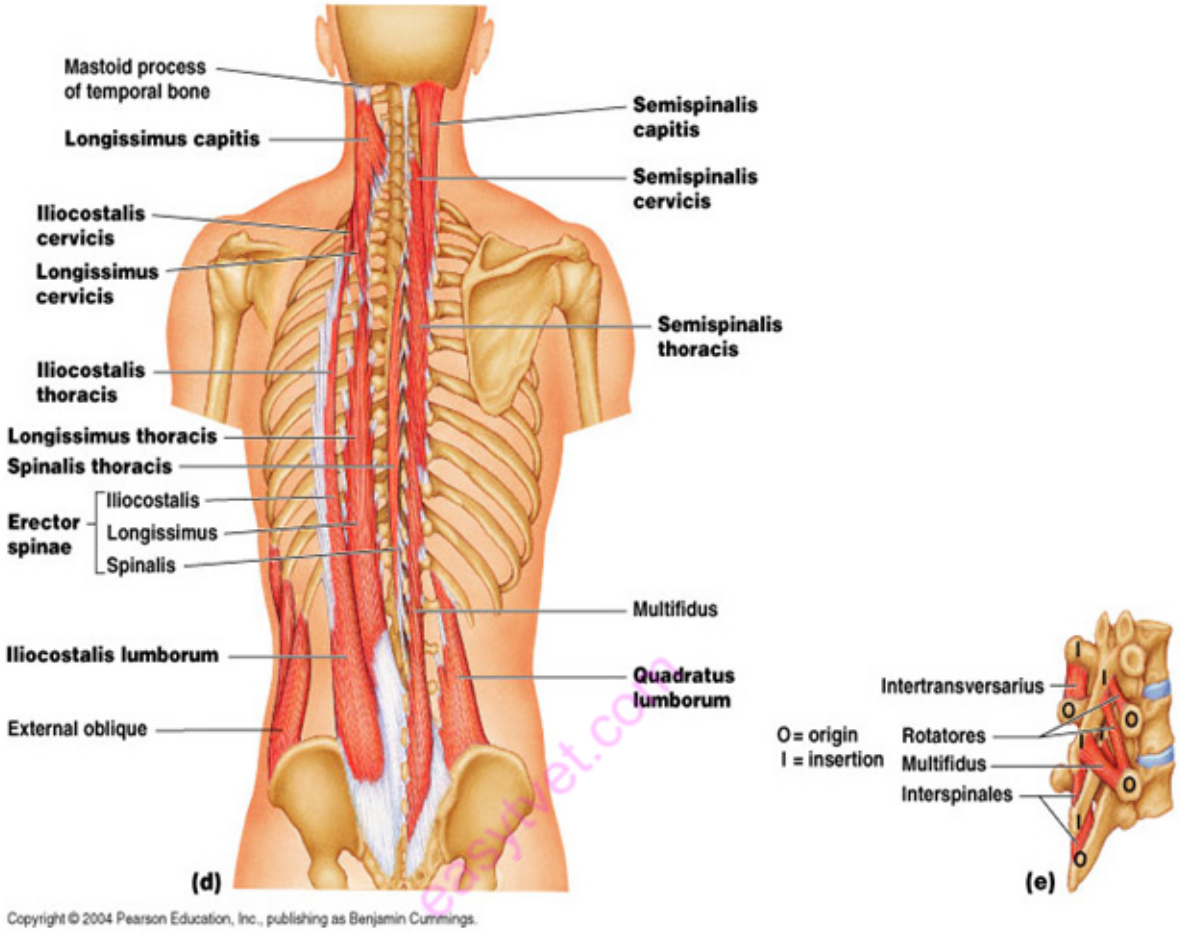
Sternocleidomastoid: cranial (accessory) nerve XI and branches of cervical nerves 2-4:

Prime mover of head flexion

Neck flexion

Head movement side-to-side



Longissimus: thoracis, cervicis, and capitis: spinal nerves:

Capitis: extends head and turns face side to side

Thoracis and cervicis: extend vertabral column side to side

Thorax and Abdominal Muscles

Muscles of the Thorax: Breathing

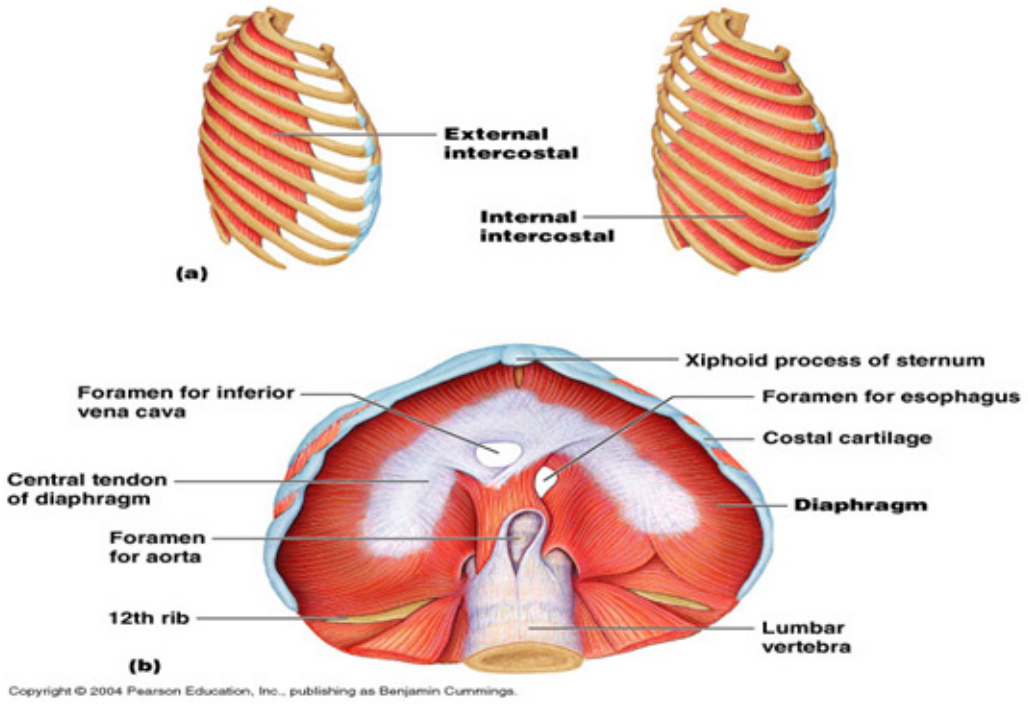
Muscles of the thorax include the external intercostals, internal intercostals, and the diaphragm

Muscles of the Abdominal Wall: Trunk Movement and Compression of Abdominal Viscera

Muscles of the anterolateral abdominal wall include the

- Rectus abdominis
- External oblique
- Transversus abdominis

Thorax Muscles



External intercostals: intercostal nerves:

Elevate rib cage | Aids in inspiration

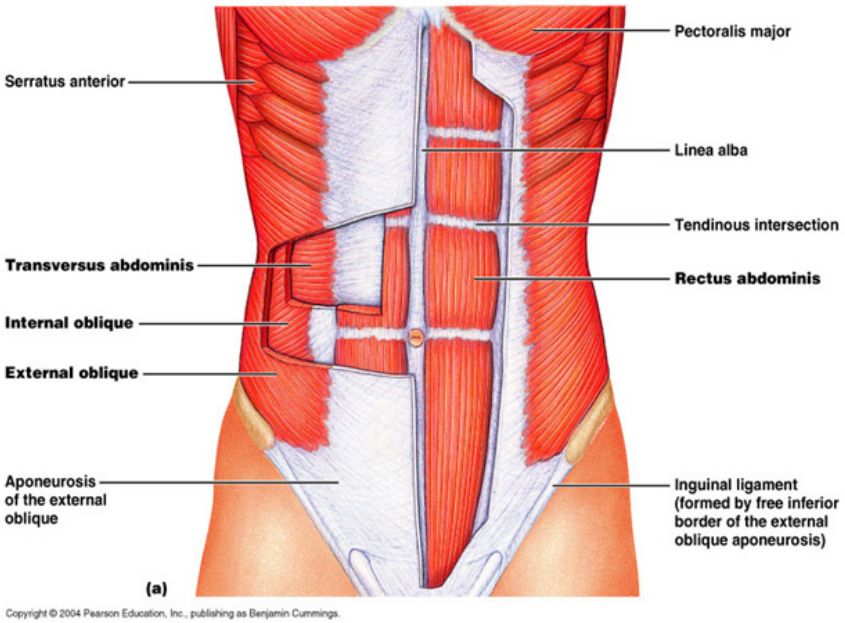
Internal intercostals: intercostal nerves:

Depress rib cage | Aids in expiration

Diaphragm:Cervical (phrenic) nerve (C_3-C_5)

Breathing

Abdominal Muscles



Rectus abdominis: Intercostal (thoracic) nerves:

Flex and rotate lumbar region

External oblique: Intercostal (thoracic) nerves:

Compression of abdominal wall

Transversus abdominis: Intercostal (thoracic) nerves:

Compression of abdominal wall

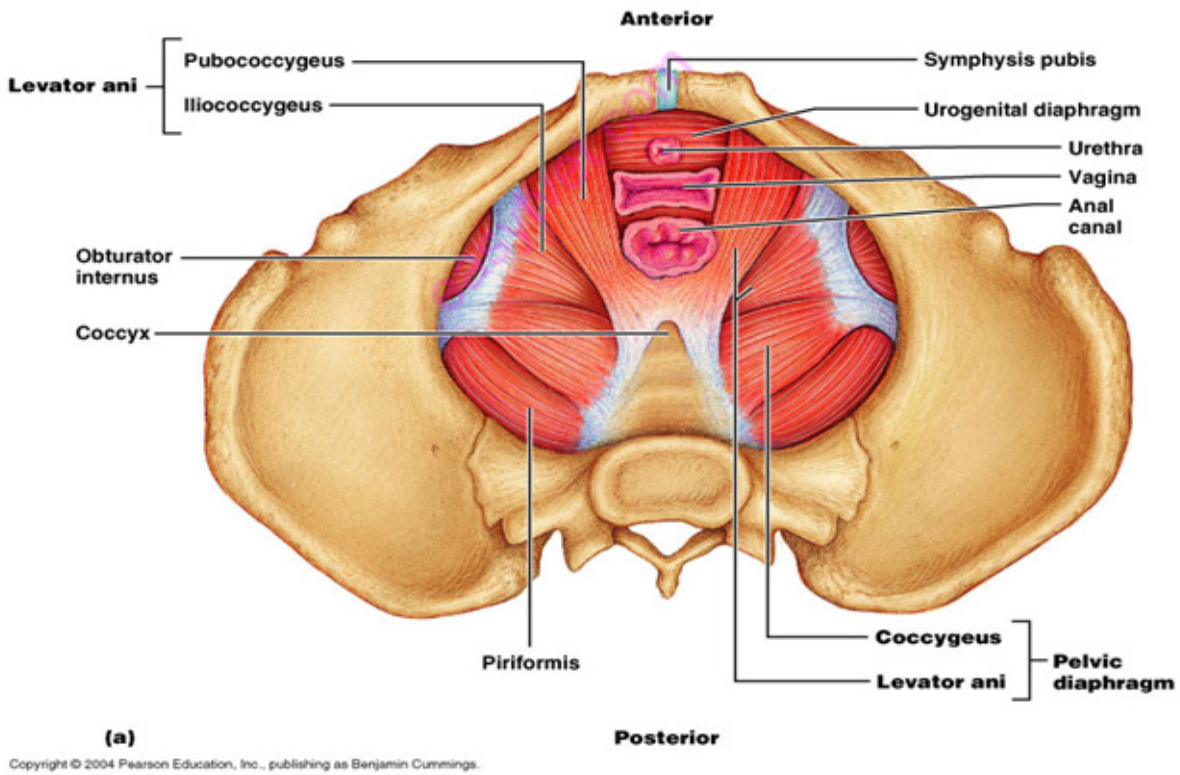
Muscles of the Pelvic Floor and Perineum

Muscles of the Pelvic Floor and Perineum: Support of Abdominopelvic Organs:

Muscles of the pelvic diaphragm include the levator ani and the coccygeus

Muscles of the urogenital diaphragm include the deep transverse perineus and the sphincter urethrae

Muscles of the superficial space include the ischiocavernosus, bulbospongiosus, and the superficial transverse perineus.



Pelvic Floor Muscles

Ischiocavernosus: pudendal (sacral) nerve:

Retards venous drainage and maintains erection of penis or clitoris

Bulbospongiosus: pudendal (sacral) nerve:

Empties male urethra

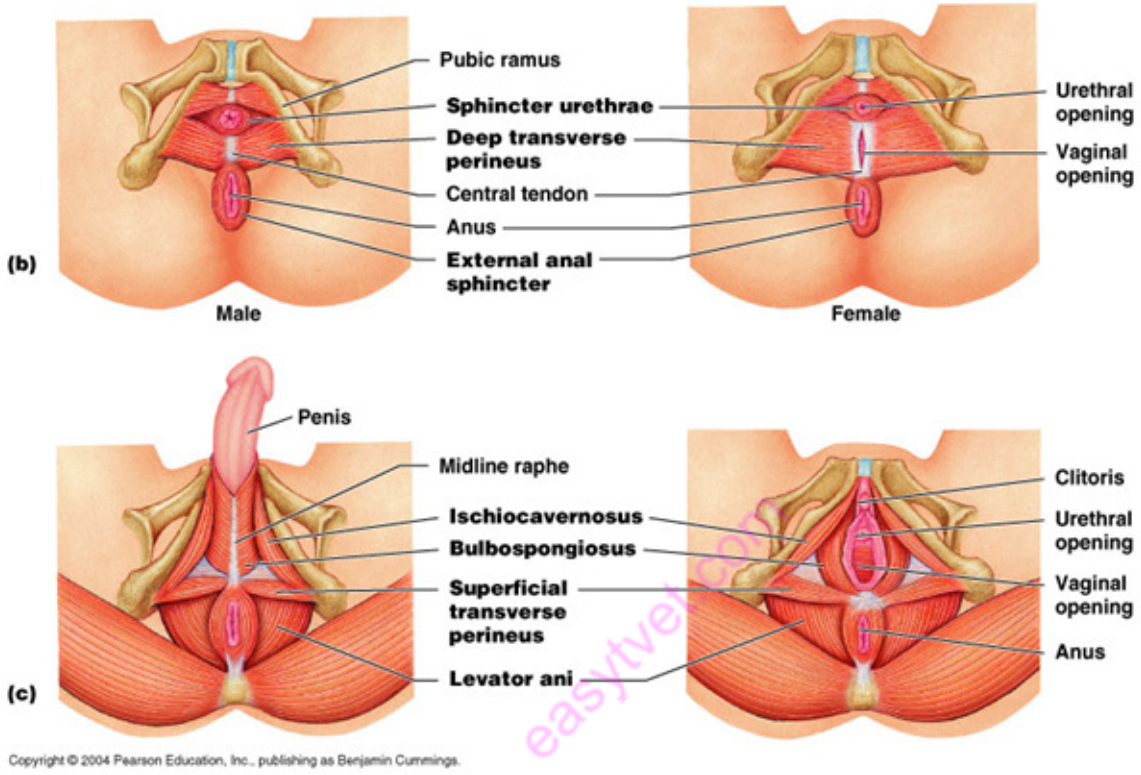
Assist in erection of penis in males and of clitoris in females

Superficial Muscles of the Anterior and Posterior Thorax

Superficial Muscles of the Anterior and Posterior Thorax: Movements of the Scapula

Muscles of the anterior thorax include the pectoralis minor, serratus anterior, and the subclavius

Muscles of the posterior thorax include the trapezius, levator scapulae, and the rhomboids (major and minor)

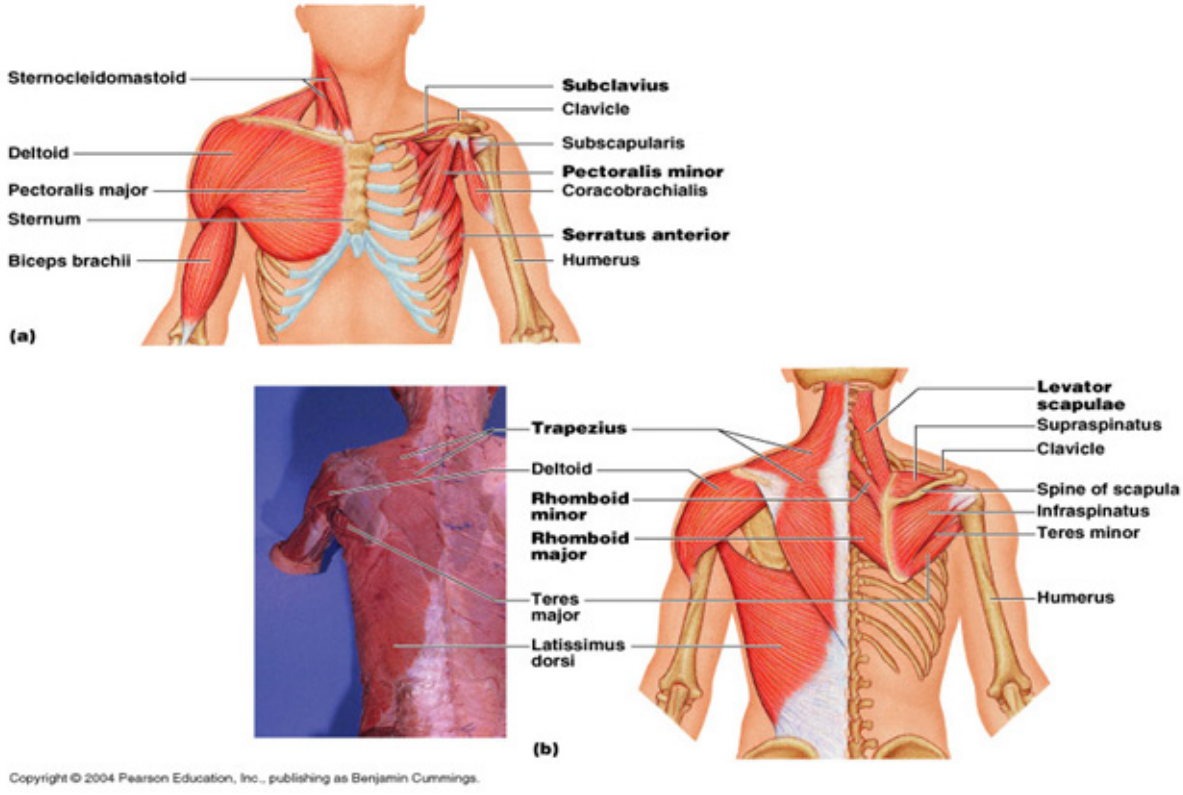


Muscles Crossing the Shoulder Joint

Muscles Crossing the Shoulder Joint: Movement of the Arm

Muscles moving the arm include the pectoralis major, latissimus dorsi, deltoid, subscapularis, supraspinatous, infraspinatous, teres minor, teres major, and the coracobrachialis

Thorax Muscles



Deltoid: cervical nerves:

Prime mover of arm abduction

Antagonists of pectoralis major and latissimus dorsi

Pectoralis major: cervical and thoracic nerves:

Prime mover of arm flexion

Adduction

Trapezius: cervical nerves:

Stabilizes, raises, retracts, and rotates scapula

Latissimus dorsi: cervical nerves

Prime mover of arm extension

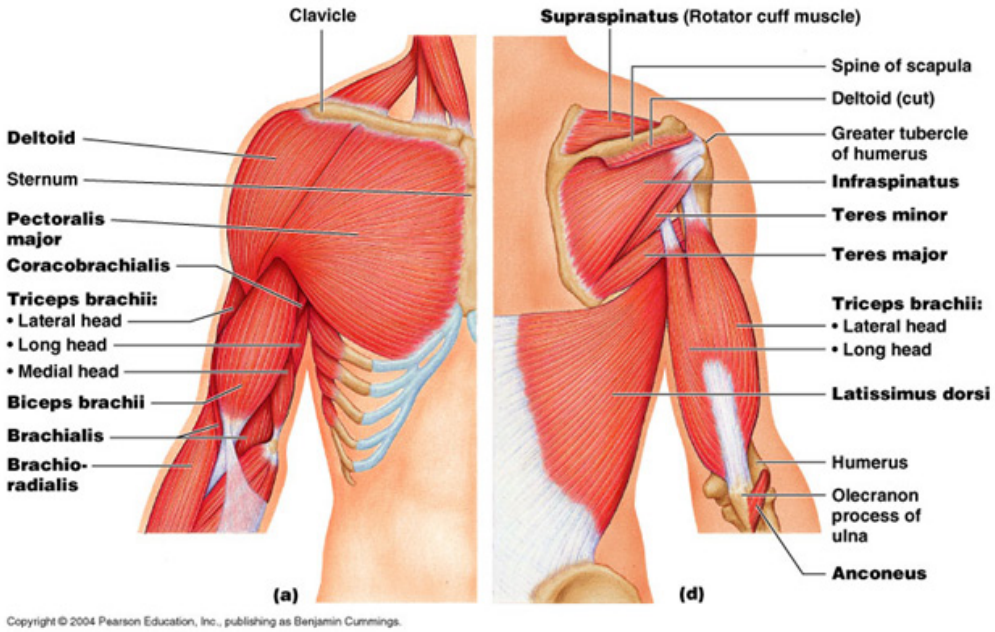
Powerful arm adductor

Striking a blow

Swimming

Rowing

SHOULDER MUSCLES



Muscles Crossing the Elbow Joint

Muscles crossing the Elbow Joint: Flexion and Extension of the Forearm

Posterior muscles include the triceps brachii, and the anconeus

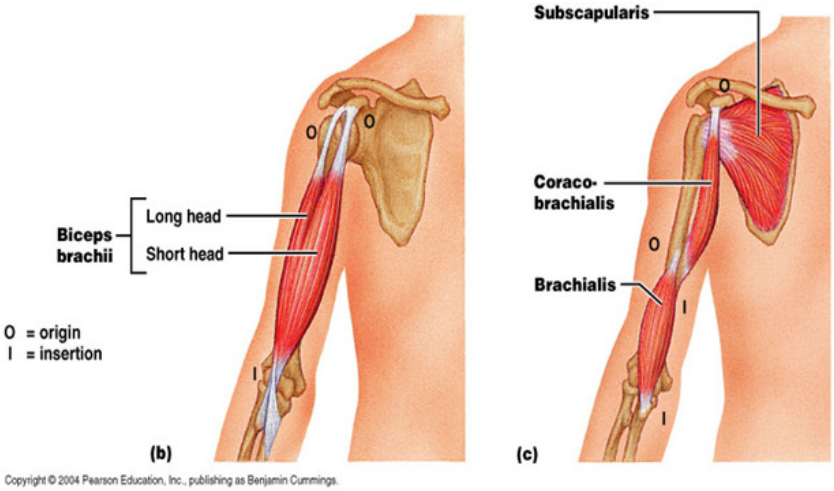
Anterior muscles include the biceps brachii, brachialis, and the brachioradialis

Triceps brachii: cervical nerves: Powerful forearm extensor

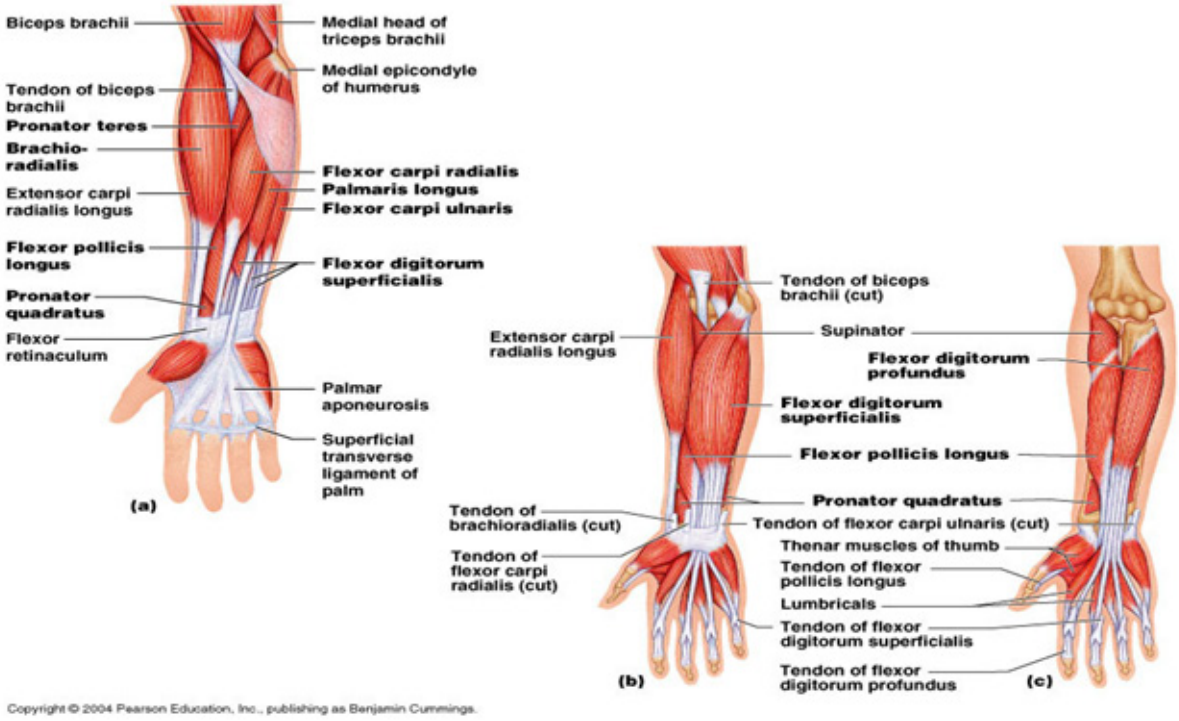
Biceps brachii: cervical nerves: Flexes elbow joint and supinates forearm

Brachialis: musculocutaneous nerve: Major forearm flexor. Lifts ulna as biceps lifts the radius

Brachioradialis: radial nerve: Synergist in forearm flexion



Forearm Muscles



Flexor carpi radialis: median nerve:

Powerful flexor of wrist

Flexor carpi radialis: median nerve:

Powerful flexor of wrist

Abducts hand

Flexor carpi ulnaris: ulnar nerve:

Powerful flexor of wrist

Adducts hand

Extensor carpi radialis brevis: radial nerve:

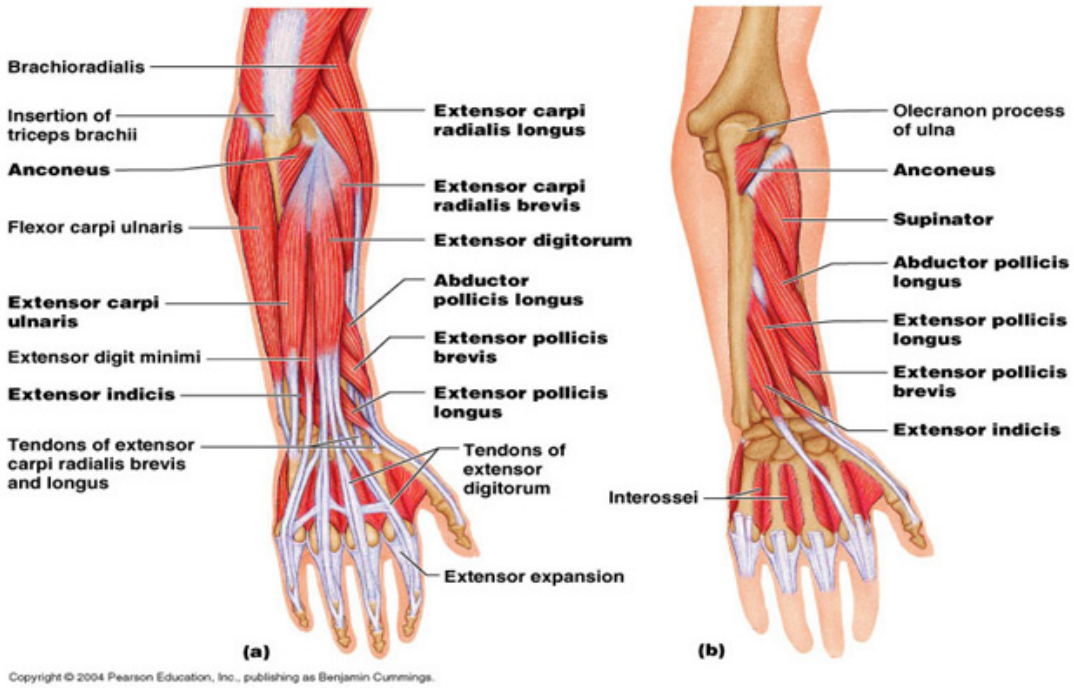
Extends and abducts wrist

Extensor digitorum: branch of radial nerve:

Prime mover of finger extension

Extends wrist

POSTERIOR ARM MUSCLES



MAJOR SKELETAL MUSCLES OF THE BODY

Muscles of the Forearm: Movements of the Wrist, Hand, and Fingers

Anterior superficial muscles include the pronator teres, flexor carpi radialis, palmaris longus, flexor carpi ulnaris, and the flexor digitorum superficialis

Anterior deep muscles include the flexor pollicis longus, flexor digitorum profundus, and the pronator quadratus

Posterior superficial muscles include the brachioradialis, extensor carpi radialis longus, extensor carpi radialis brevis, extensor digitorum, and the extensor carpi ulnaris

Posterior deep muscles include the supinator, abductor pollicis longus, extensor pollicis longus, and the extensor pollicis brevis

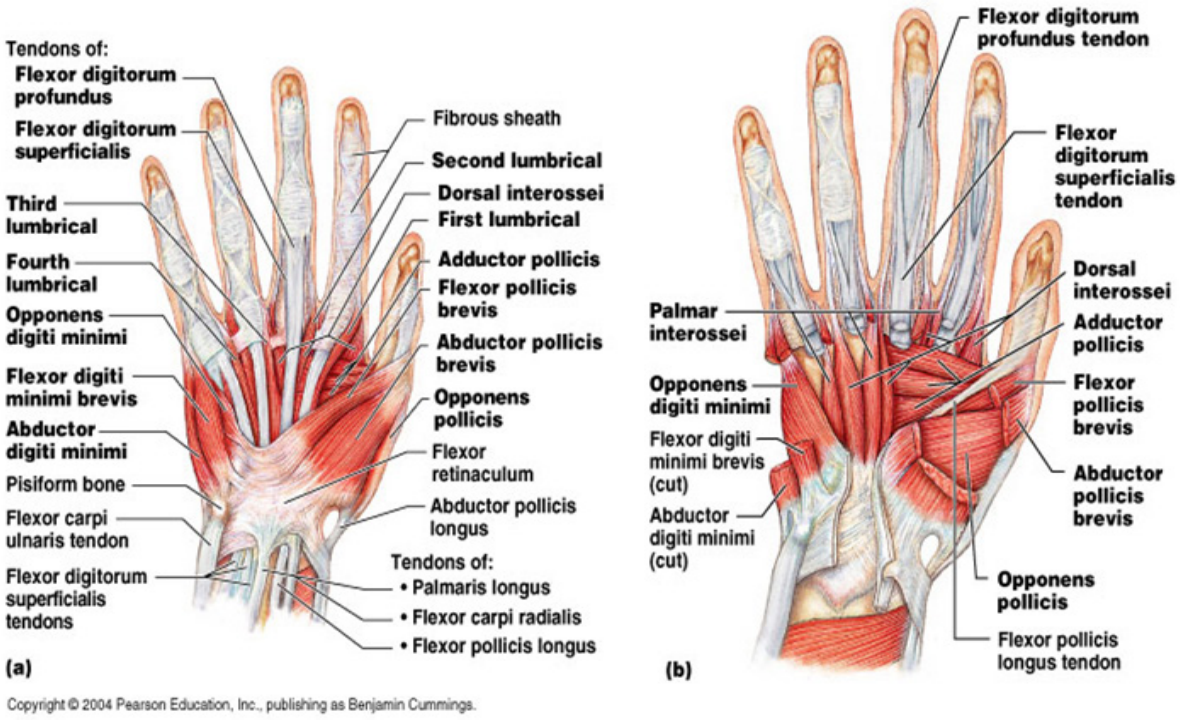
Intrinsic muscles of the Hand: Fine Movements of the Fingers

Thenar muscles in ball of thumb include the abductor pollicis brevis, flexor pollicis brevis, opponnens pollicis, and the adductor pollicis

Hypothenar muscles in ball of little finger include the abductor digiti minimi, flexor digiti minimi brevis, and the opponens digiti minimi

Midpalmar muscles include the lumbricals, palmar interossei, and the dorsal interossei

Hand Muscles



Abductor pollicis brevis: median nerve (cervical.thoracic)

Abducts thumb

Flexor digiti minimi brevis: ulnar nerve:

Flexes little finger

Muscles Crossing the Hip and Knee Joints: Movements of the Thigh and Leg

Anteromedial muscles include the iliopsoas, which is composed of the iliacus, the psoas major, and the sartorius

Muscles of the medial compartment of the thigh include the adductor group, which is made up of the adductor magnus, adductor longus and the adductor brevis, the pectineus, and the gracilis

Muscles of the anterior compartment of the thigh include the quadriceps femoris group, which is made up of the rectus femoris, vastus lateralis, vastus medialis and vastus intermedius, and the tensor fasciae latae

Posterior Muscles: gluteal muscles (origin on pelvis) include the gluteus maximus, gluteus medius, and the gluteus minimus

Lateral rotators include the piriformis, obturator externus, obturator internus, gemellus, and the quadratus femoris

Muscles of the posterior compartment of the thigh include the hamstring group, which consist of the biceps femoris, semitendinosus, and the semimembranosus.

NB: Highly examinable especially the quadriceps and hamstring group of muscles.

Thigh Muscles

Adductor longus: obturator nerve:

Adducts, flexes, and medially rotates thigh

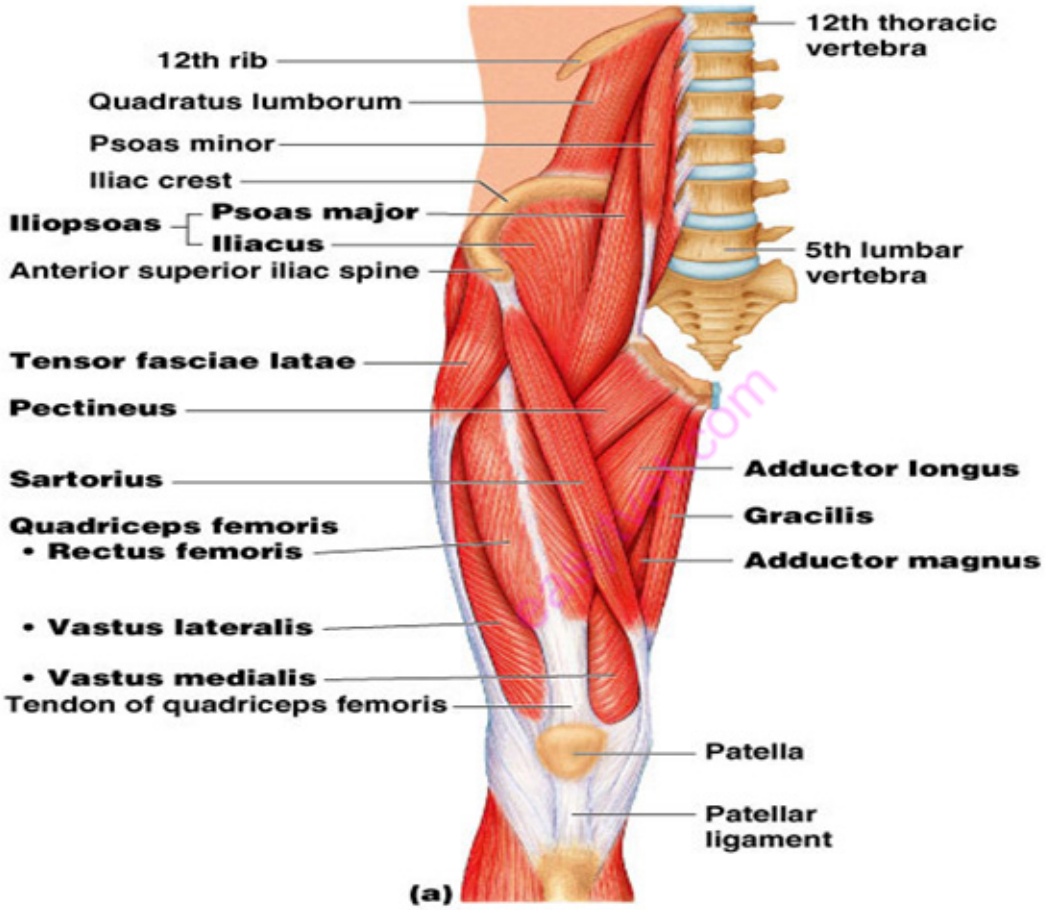
Gracilis: obturator nerve:

Adducts thigh, flexes, and medially rotates thigh, especially during walking

Quadriceps femoris:

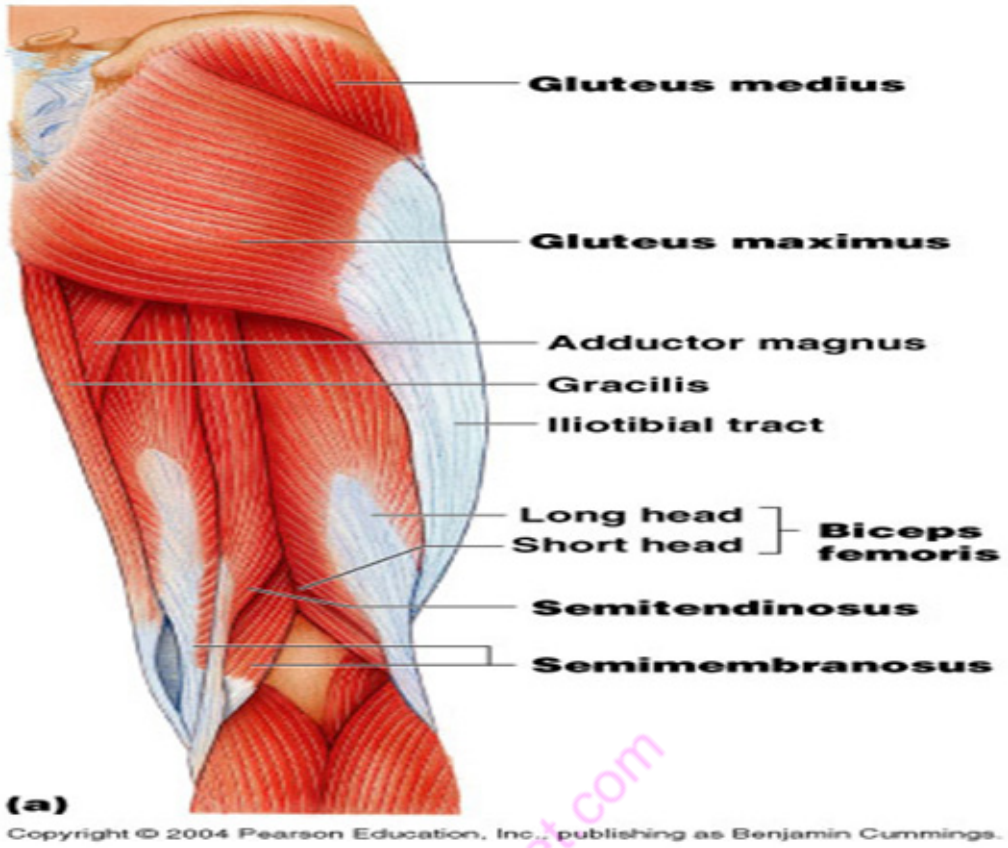
Rectus femoris: femoral nerve:

Extends knee and flexes thigh at hip.



ANTERIOR THIGH MUSCLES

Hip Muscles



Gluteus maximus: inferior gluteal nerve:

Major extensor of thigh

Complex, powerful, and most effective when thigh is flexed and force is necessary, as in rising from a forward flexed position and in thrusting the thigh posteriorly in climbing stairs and running

Inactive during standing

Muscles of the Leg: Movements of the Ankle and Toes

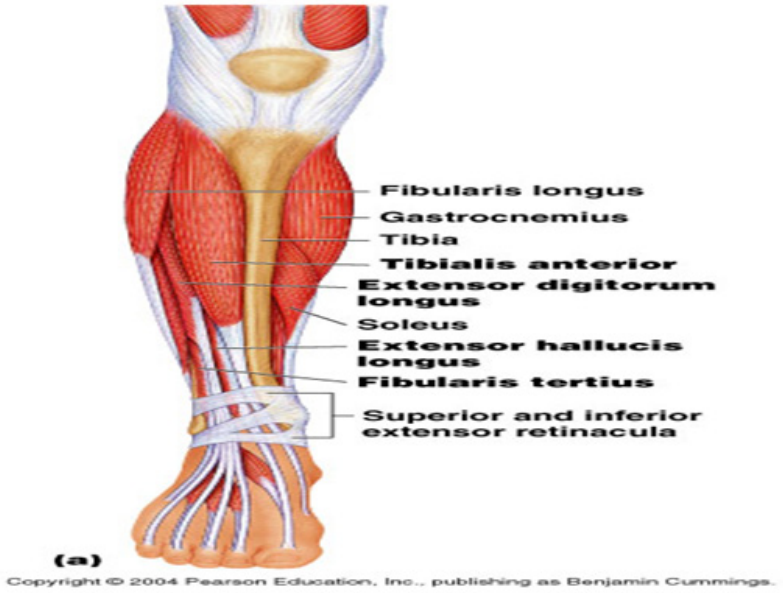
Muscles of the anterior compartment include the tibialis anterior, extensor digitorum longus, fibularis (peroneus) tertius, and the extensor hallucis longus

Muscles of the lateral compartment include the fibularis (peroneus) longus and the fibularis (peroneus) brevis

Superficial muscles of the posterior compartment include the triceps surae, which is composed of the gastrocnemius and the soleus, and the plantaris

Deep muscles of the posterior compartment include the popliteus, flexor digitorum longus, flexor hallucis longus, and the tibialis posterior

ANTERIOR LEG MUSCLES



Tibialis anterior: fibular nerve (lumbar):

Prime mover of dorsiflexion

Inverts foot

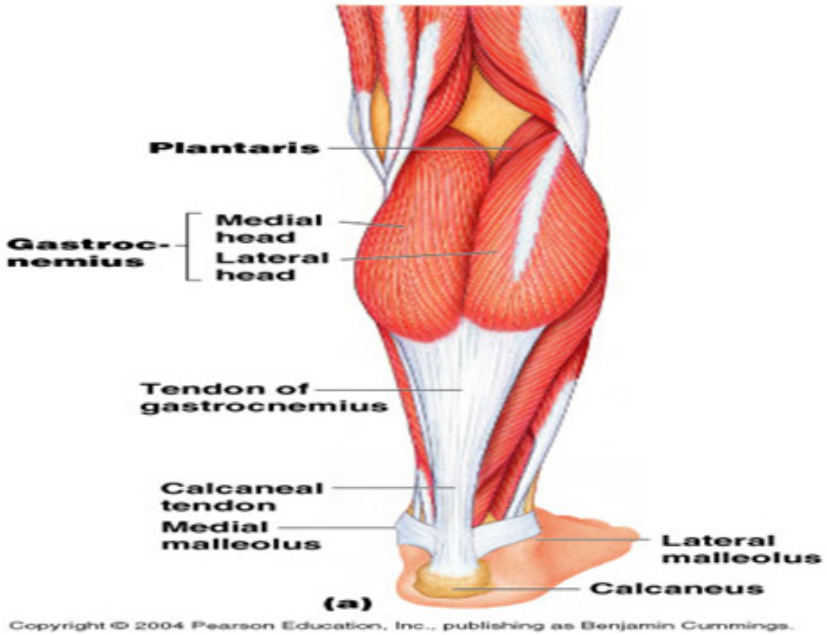
Assists in supporting medial longitudinal arch of foot

Fibularis longus: fibular nerve (lumbar):

Plantar flexes and everts foot

May help keep foot flat on ground

POSTERIOR LEG MUSCLES



Gastrocnemius: tibial nerve (sacral):

Plantar flexes foot when knee is extended

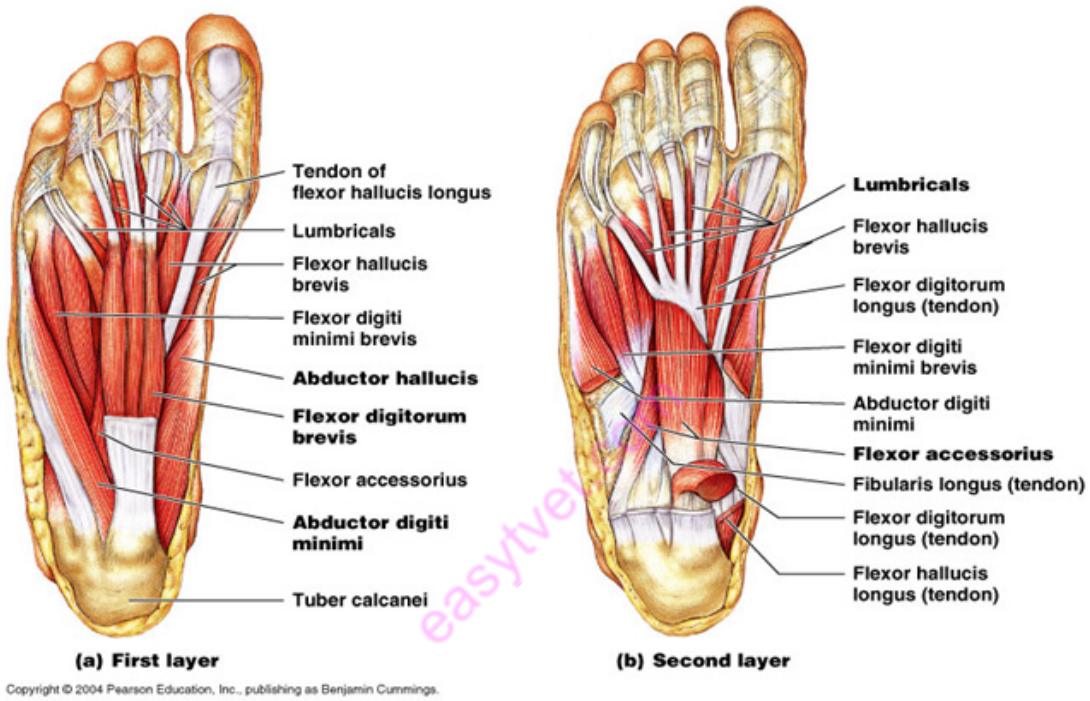
Since it also crosses knee joint, it can flex knee when foot is dorsiflexed

Soleus: tibial nerve (sacral):

Plantar flexes foot

Important locomotor and postural muscle during walking, running, and dancing

FOOT MUSCLES



THE SKELETON

The Bone

A strong and durable type of connective tissue.

Consists of:

- Water (25%)
- Organic constituents including osteoid (the carbon containing part of the matrix) and bone cells (25%)
- Inorganic constituents, mainly calcium phosphate (50%).

Functions of bones

- Provide the framework of the body
- Give attachment to muscles and tendons

- Permit movement of the body as a whole and of parts of the body, by forming joints that are moved by muscles
- Form the boundaries of the cranial, thoracic and pelvic cavities, protecting the organs they contain
- Contain red bone marrow in which blood cells develop; haematopoiesis
- Provide a reservoir of minerals, especially calcium phosphate.

Types of Bones

Bones are classified as long, short, irregular, flat and sesamoid.

Long bones consist of a shaft and two extremeties.Examples include the femur, tibia and fibula

Short, irregular, flat and sesamoid bones have no shafts or extremities and are diverse in shape and size e.g. short bones-carpals(wrist), irregular bones-vertebrae and some skull bones, flat bones-sternum, ribs and most skull bones, sesamoid bones-patella(knee cap)

1. Long Bones

Tubular shell with cavity in the middle.

Found in: Arms, legs, hands, etc. E.g. humerus & femur

Has the following layers:

- Periosteal layer for oppositional growth
- Compact layer for rigidity
- Cancellous/spongy layer for inner support
- Marrow support for blood forming cells

Growth takes place at the epiphyseal disc

Blood supply is from nutritional arteries, periosteal arteries supplying periosteum, epiphyseal arteries supplying epiphyses and around.

2. Short Bones

No marrow cavity; don't contain epiphysis. They are cuboidal than tubular in shape

Found in: Wrist & ankle E.g. carpals and tarsals.

3. Flat Bones

Flat and thin, (protection, broad surface for muscle attachment)

Found in: Cranium, pectoral & pelvic girdles e.g. parietal, scapula, ilium, sternum.

4. Irregular Bones

Specialized shape & function (support weight, dissipate loads, protect spinal cord)

Found in: Spinal column E.g. vertebral bodies.

5. Sesamoid Bones

Small bones embedded within a tendon or joint capsule (alters angle of insertion, reduces friction). Found in: Knee, hand, thumb & big toe E.g. patella & Pisiform

Bone Structure

General structure of a long bone

Have a diaphysis or shaft & two epiphyses or extremities.

Diaphysis; composed of compact bone with a central medullary canal, containing fatty yellow bone marrow.

Epiphyses; Consist of an outer covering of compact bone with cancellous bone inside.

Diaphysis & epiphyses are separated by epiphyseal cartilages, which ossify when growth is complete.

Thickening of a bone occurs by the deposition of new bone tissue under the periosteum.

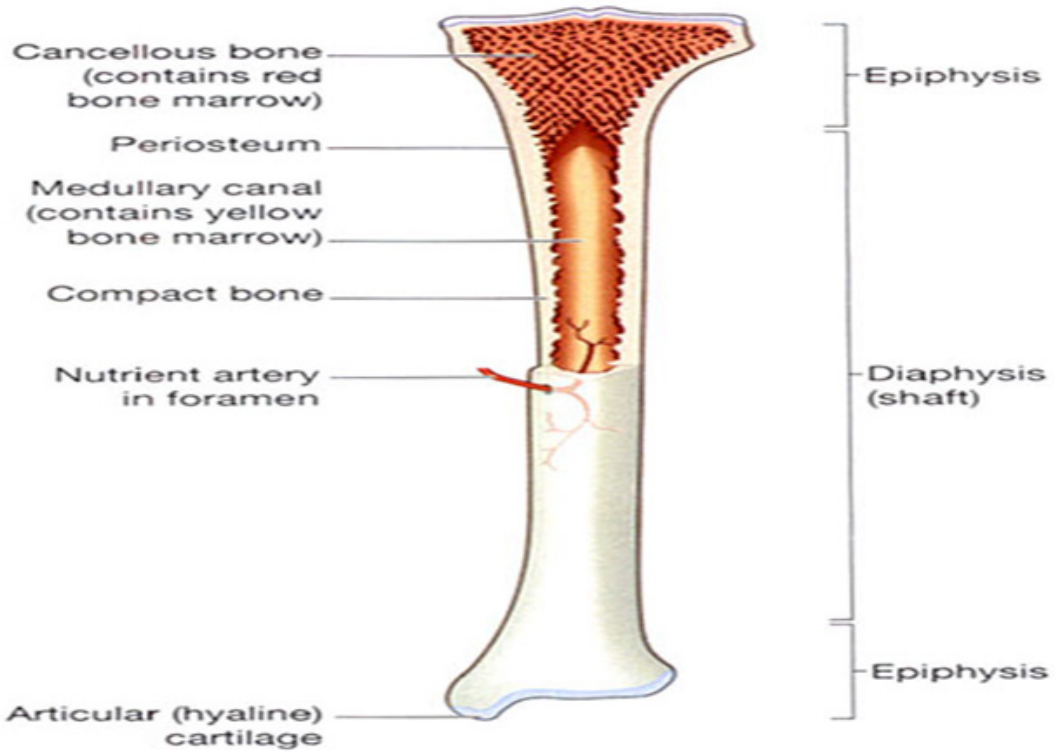
Long bones are almost completely coverd by, the periosteum.

Periosteum:

Has an outer layer, fibrous & the inner layer, osteogenic, containing osteoblasts & osteoclasts which are involved in maintenance & remodelling of bones; gives attachment to muscles & tendons, and protects bones from injury.

Hyaline cartilage replaces periosteum on the articular surfaces of bones forming synovial joints.

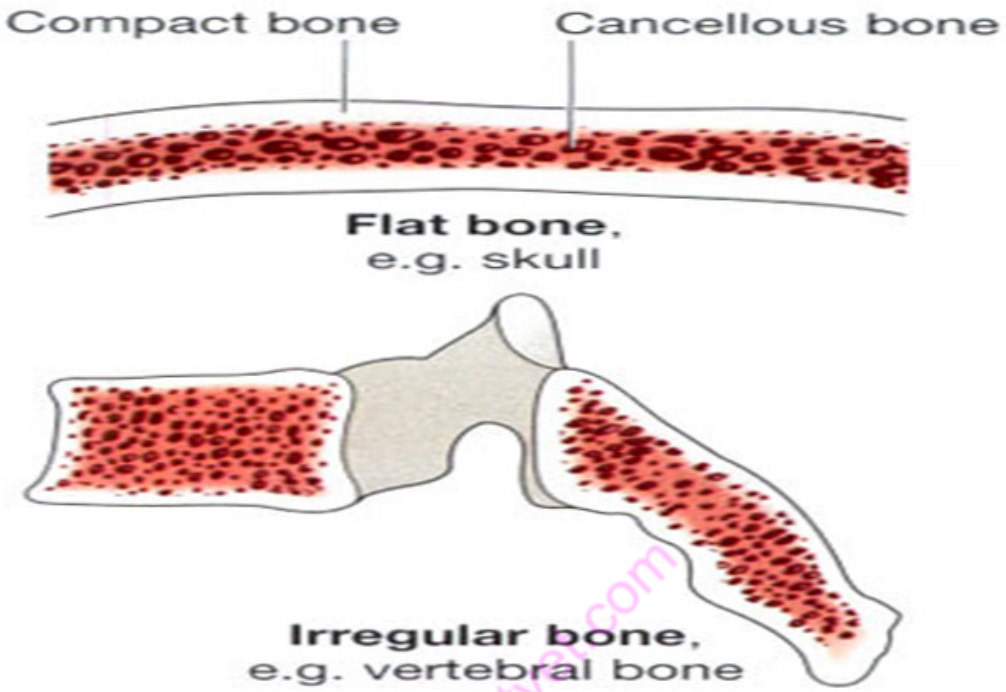
Structure of a mature long bone



Structure of short, irregular, flat & sesamoid bones

Relatively thin outer layer of compact bone with cancellous bone inside containing red bone marrow.

Enclosed by periosteum except the inner layer of the cranial bones where it is replaced by dura mater.



Flat & irregular bones

Microscopic structure of bone

a) Compact (cortical) bone

Large numbers of Haversian systems or osteons.

Consist of a central Haversian canal, containing blood & lymph vessels & nerves, surrounded by concentric rings or plates of bone (lamellae).

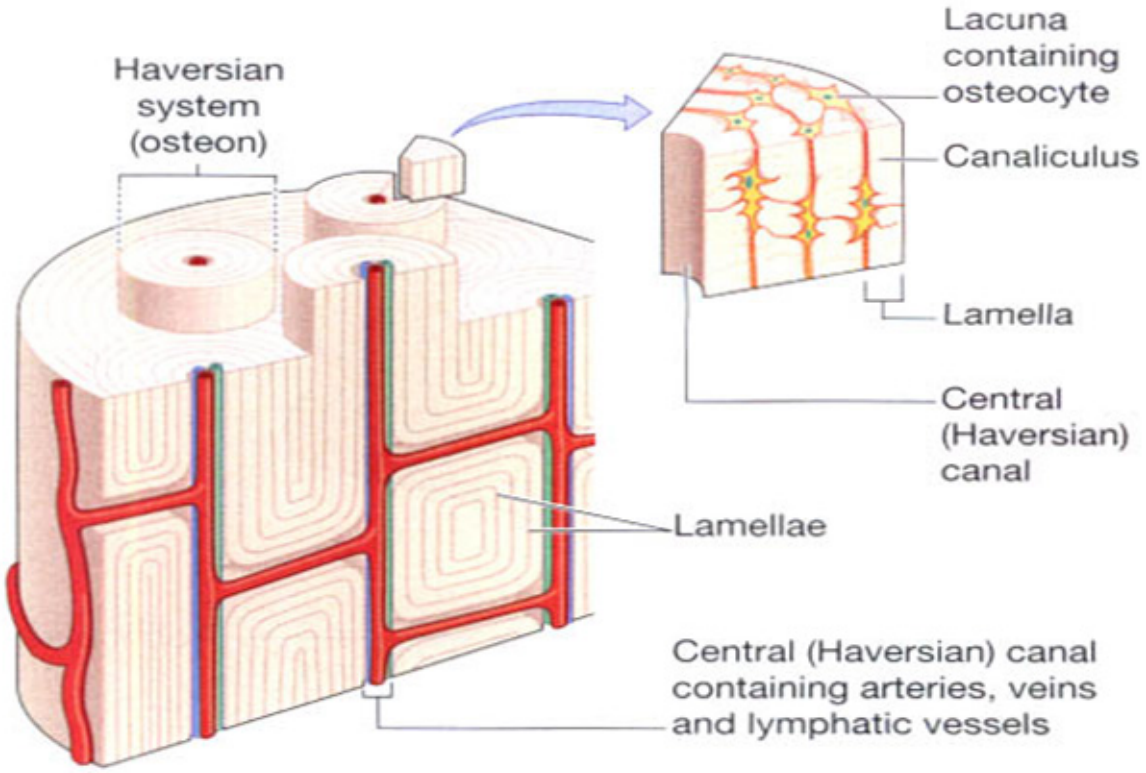
Between these are lacunae, tiny spaces, containing tissue fluid & spider-shaped osteocytes.

Canaliculi link the lacunae with each other and with the central Haversian canal.

Tissue fluid nourishes the bone cells.

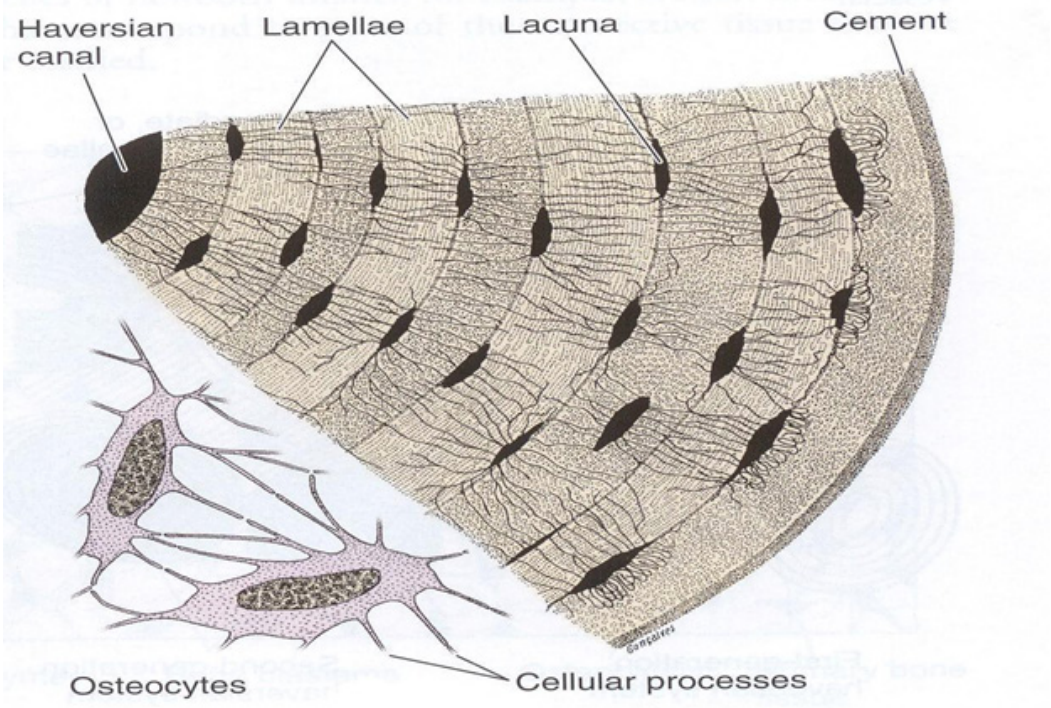
Areas between Haversian systems contain interstitial lamellae, remains of older systems partially broken down during remodelling or growth of bone.

The 'tubular' arrangement of lamellae gives bone greater strength than a solid structure of the same size.



Microscopic structure of compact bone

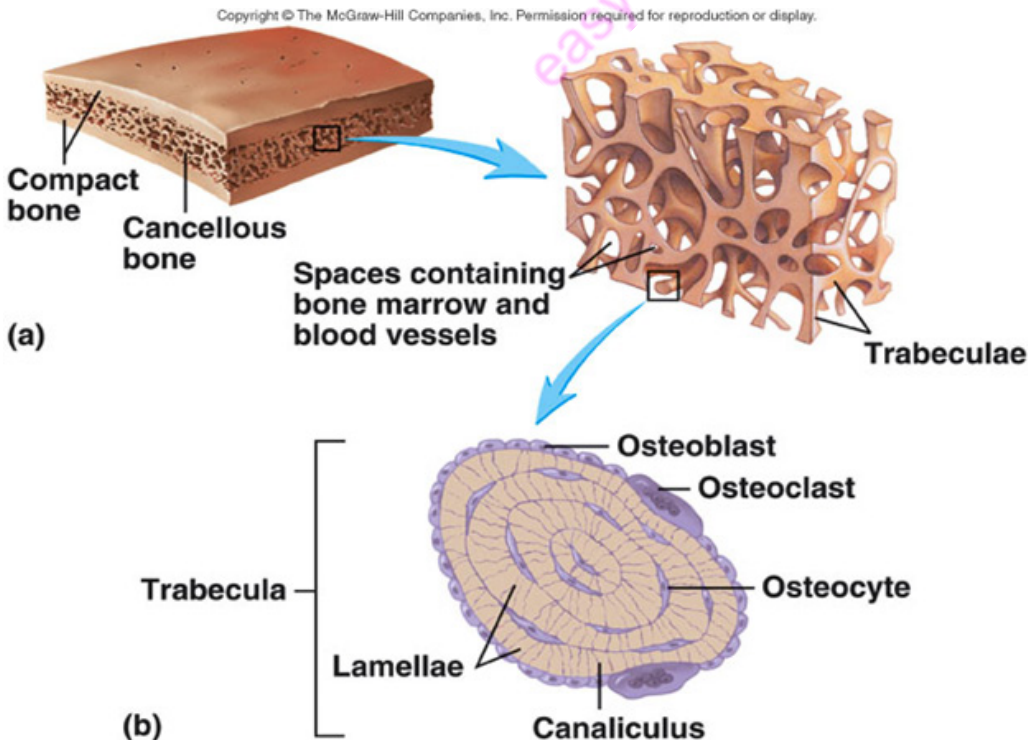
Compact Bone, Dried: An Osteon (transverse section). High magnification.



b) Cancellous (trabecular, spongy) bone

Has a framework formed from trabeculae (bony plates) which consist of a few lamellae & osteocytes interconnected by canaliculi.

Spaces between the trabeculae contain red bone marrow that nourishes the osteocytes.

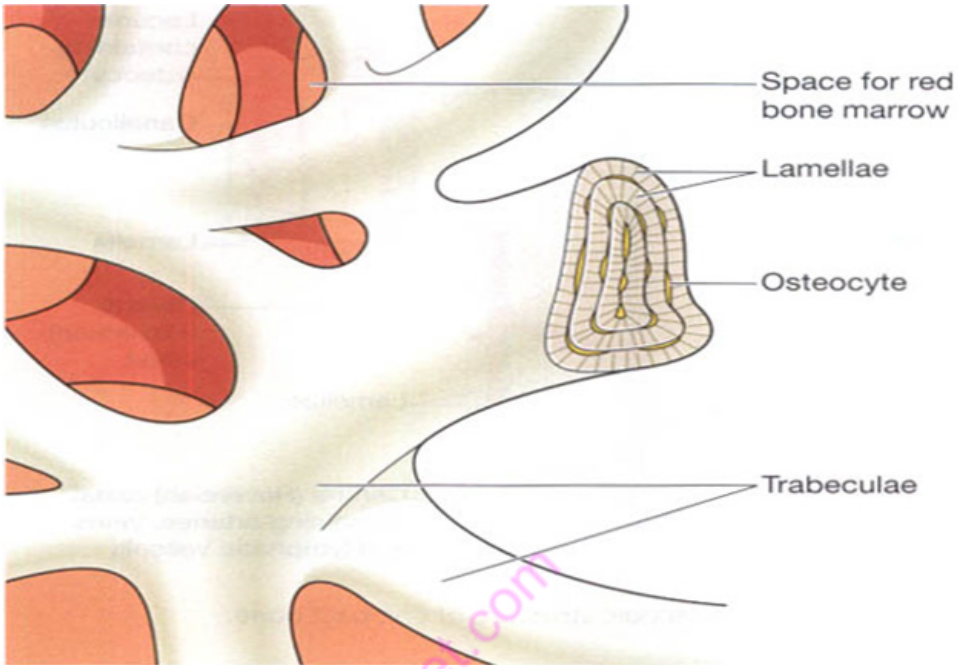


Bone Cells

Osteoblasts: cells responsible for bone formation (later mature into osteocytes).

Osteoblasts & chondrocytes (cartilage-forming cells) develop from the same parent fibrous tissue cells.

Differentiation into osteogenic cells, rather than chondroblasts, depends upon an adequate oxygen supply.



Microscopic structure of cancellous bone

1. Osteoblasts

Bone-forming cells that secrete collagen & other constituents of bone tissue.

Present:

- In the deeper layers of periosteum
- In the centres of ossification of immature bone
- At the ends of the diaphysis adjacent to the epiphyseal cartilages of long bones
- At the site of a fracture.

2. Osteocytes

As bone develops, osteoblasts become trapped and remain isolated in lacunae. They stop forming new bone at this stage and are called osteocytes.

Osteocytes are nourished by tissue fluid in the canaliculi that radiate from the Haversian canals.

3. Osteoclasts

Function: resorption of bone to maintain the optimum shape.

Takes place at bone surfaces:

under the periosteum, to maintain the shape of bones during growth and to remove excess callus formed during healing of fractures

round the walls of the medullary canal during growth and to canalise callus during healing.

A fine balance of osteoblast & osteoclast activity maintains normal bone structure and functions.

Development of Bone Tissue (Osteogenesis or Ossification)

Begins before birth & is not complete until about the 21st year of life.

Long, short & irregular bones develop from rods of cartilage, cartilage models.

Flat bones develop from membrane models and sesamoid bones from tendon models.

Bone development consists of 2 processes:

- Secretion by osteoblasts of osteoid, i.e. collagen fibres in a mucopolysaccharide matrix which gradually replaces the original cartilage and membrane models.
- Calcification of osteoid immediately after its deposition.

Two Types of Arrangement of Collagen in Osteoid

1. Woven (non-lamellar) bone--Collagen fibres are deposited in irregular bundles, then ossified.

Occurs during ossification of bones that originate as membrane models, e.g. skull bones.

In adults it is also present in bone tumors & healing fractures.

2. Lamellar bone--Collagen fibres are deposited as in woven bone, organized into characteristic lamellae found in compact and cancellous bone then ossified.

Occurs when cartilage models are replaced by bone and in healing of fractures.

Development of Long Bones

Ossification begins in small areas of osteogenic cells, or centres of ossification in the cartilage model.

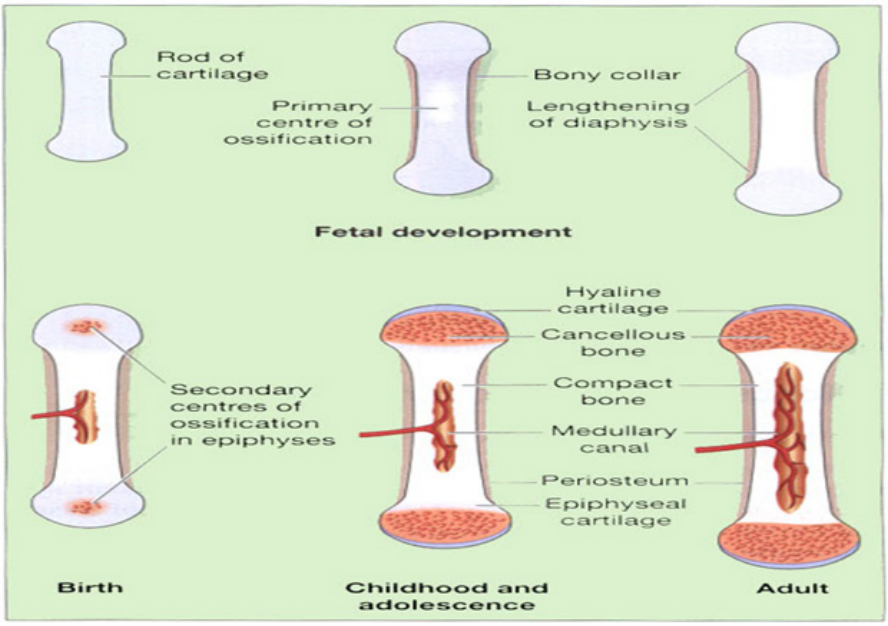
This is accompanied by development of a bone collar at about 8 weeks of gestation.

Later blood supply develops & bone tissue replaces cartilage as osteoblasts secrete osteoid components in the shaft.

Bone lengthens as ossification continues & spreads to the epiphyses.

Around birth, secondary centres of ossification develop in the epiphyses & the medullary canal forms when osteoclasts break down the central bone tissue in the middle of the shaft.

After birth, the bone grows in length by ossification of the diaphyseal surface of the epiphyseal cartilages and growth is complete when the cartilages become completely ossified.

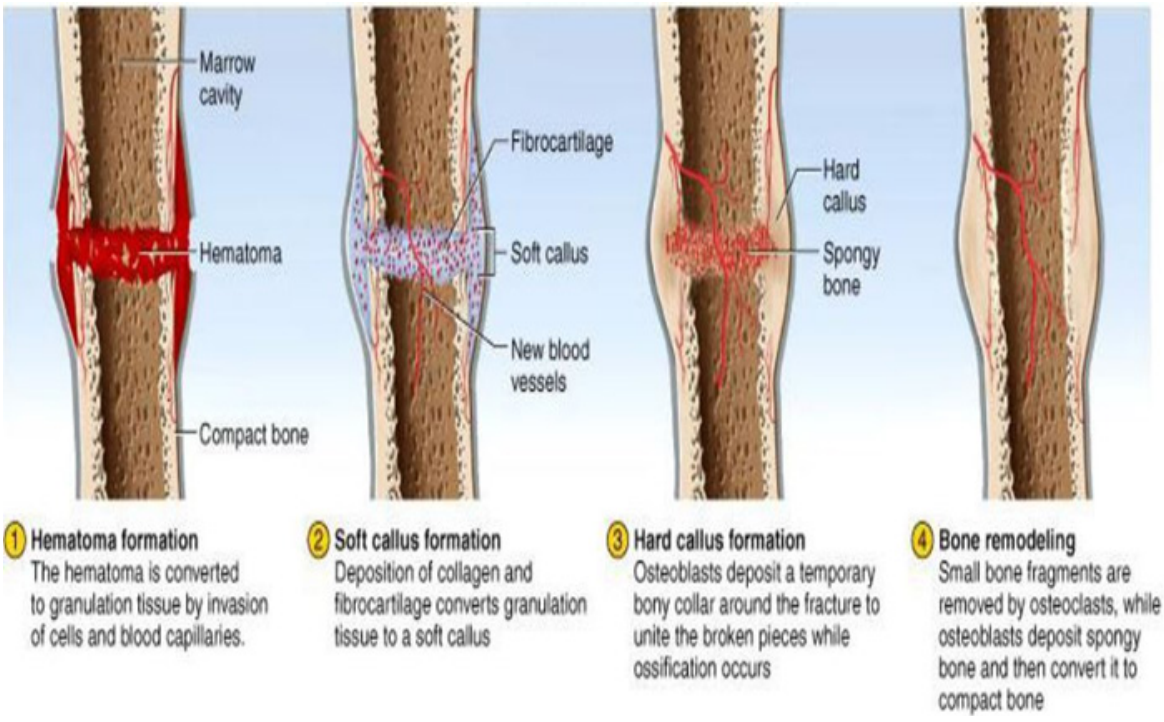


Stages in long bone development

Hormonal Regulation of Bone Growth

1. Growth hormone & thyroid hormones, are especially important during infancy & childhood.
2. Testosterone & oestrogens influence the physical changes that occur at puberty.
3. Calcitonin & Parathyroid hormone; homeostasis of blood & bone calcium levels required for bone development.

THE BONE HEALING PROCESS



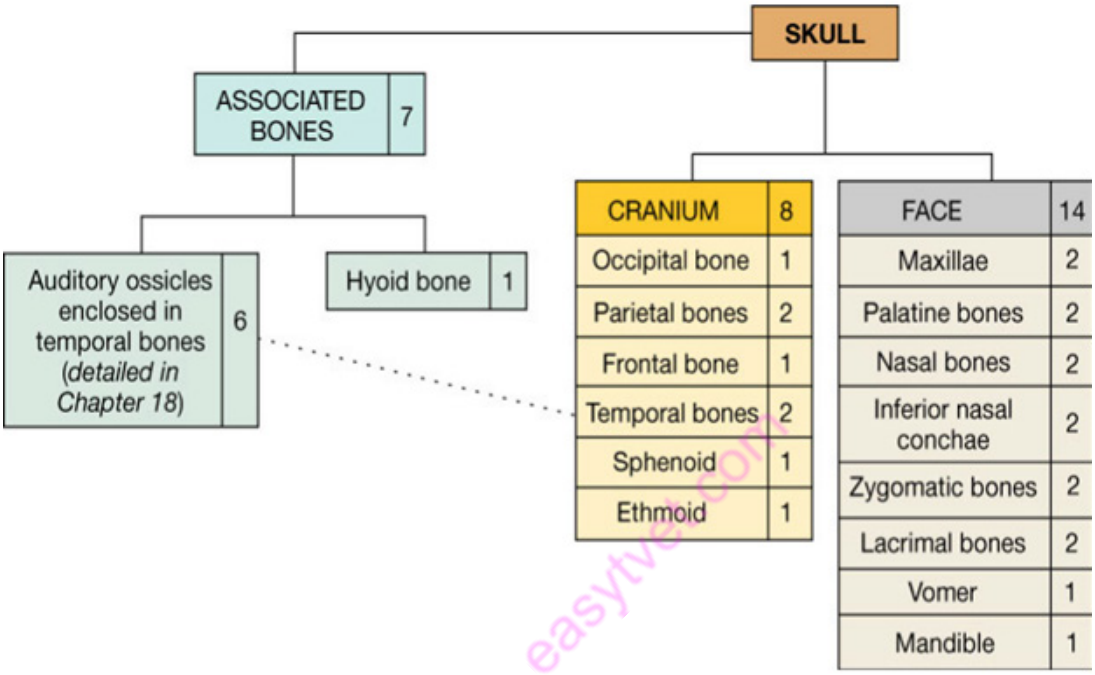
The Axial Skeleton (Part 1):

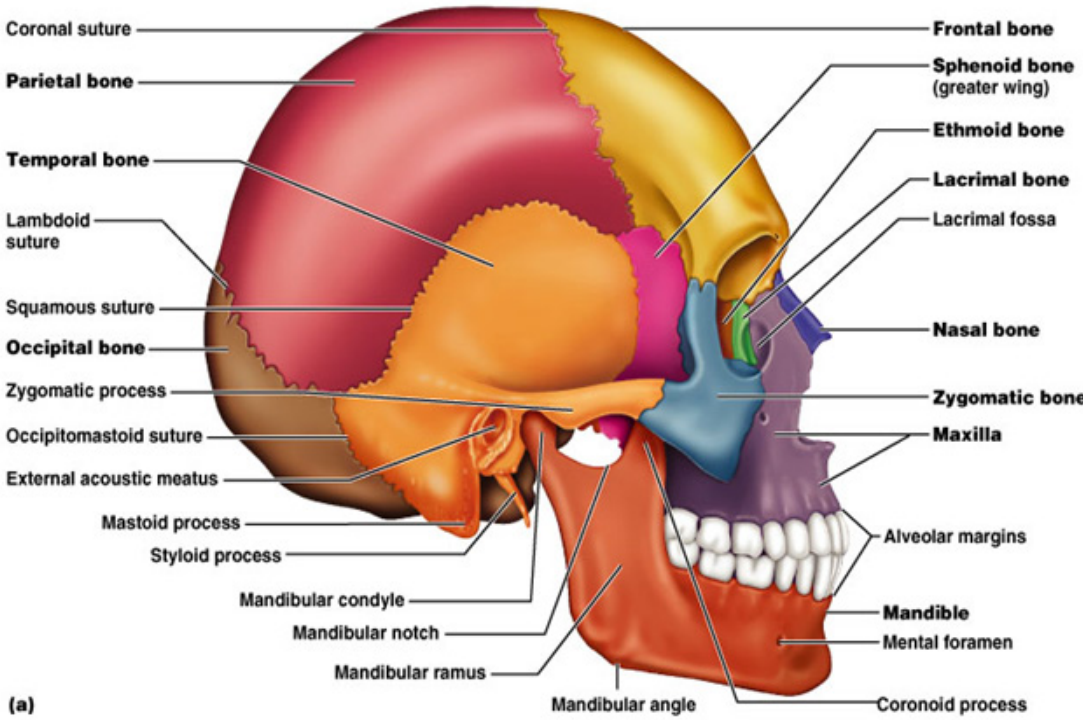
1. Skull
2. Spine
3. Sternum thorax
4. Ribs
5. Auditory ossicles—maleus, incus & stapes
6. Hyoid Bone

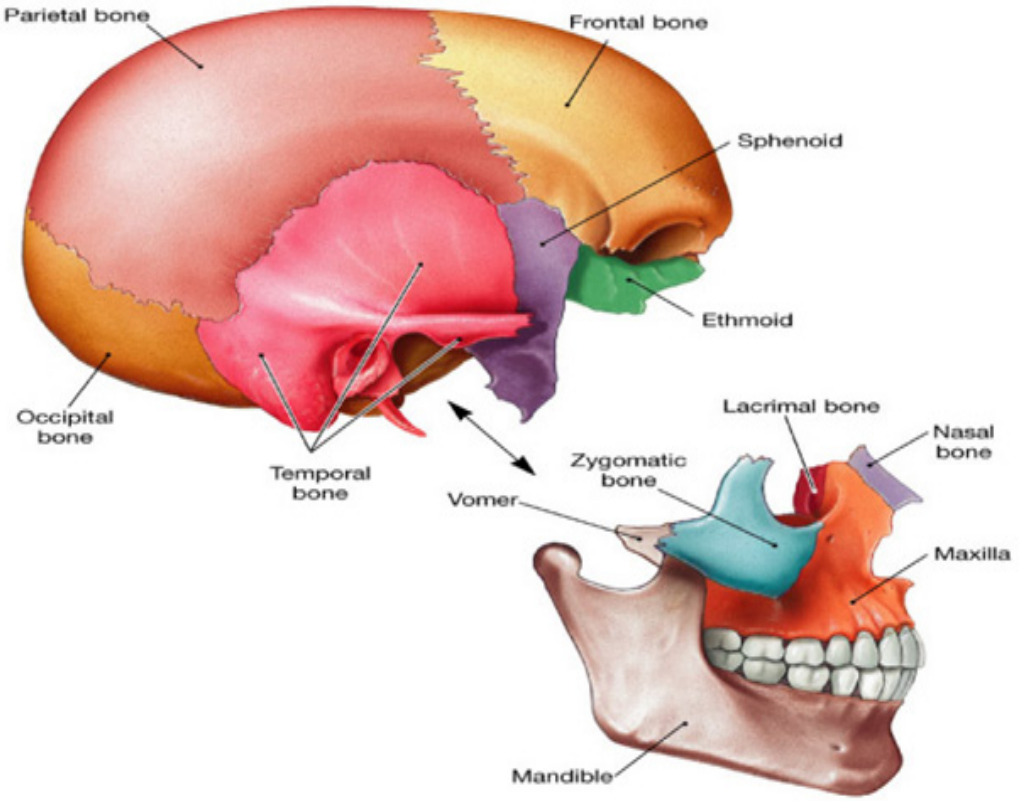
The Appendicular Skeleton (Part 2):

The appendages, i.e., everything else

Bones of the Skull.







Bones of the Calvarium

Frontal (forehead)

Anterior fossa of base of skull

Frontal Crests

More prominent in male

Frontal sinuses

Parietal (2)

Sutures

Occipital

Foramen Magnum

Occipital Condyles articulate with C1

Occipital Crest

Temporal (4 parts):

Squamous (very thin),

Mastoid (means breast-like) process

Small sinus

Petrous

Houses inner ear

Acoustic meatus

Jugular foramen

Zygomatic process

Styloid Process

Sphenoid

Sella turcica houses pituitary gland

Ethmoid (sieve)

Cribriform plate for olfactory nerve

Crista galli

Part of nasal septum

Frontal

Temporal

Petrous part

Occipital

Foramen magnum

Facial bones Maxilla (2)

Alveolar margin for teeth

Maxillary sinus

Anterior portion of hard palate

Palatine (2)

Posterior aspect of hard palate

Nasal (2)

Inferior Nasal conchae (2)

Will be covered in Respiratory System

Zygomatic (2) AKA cheek bones

Zygomatic process of temporal bone

Lacrimal (2)

Lacrimal sac

Vomer

Separate the right and left nasal cavities

Mandible

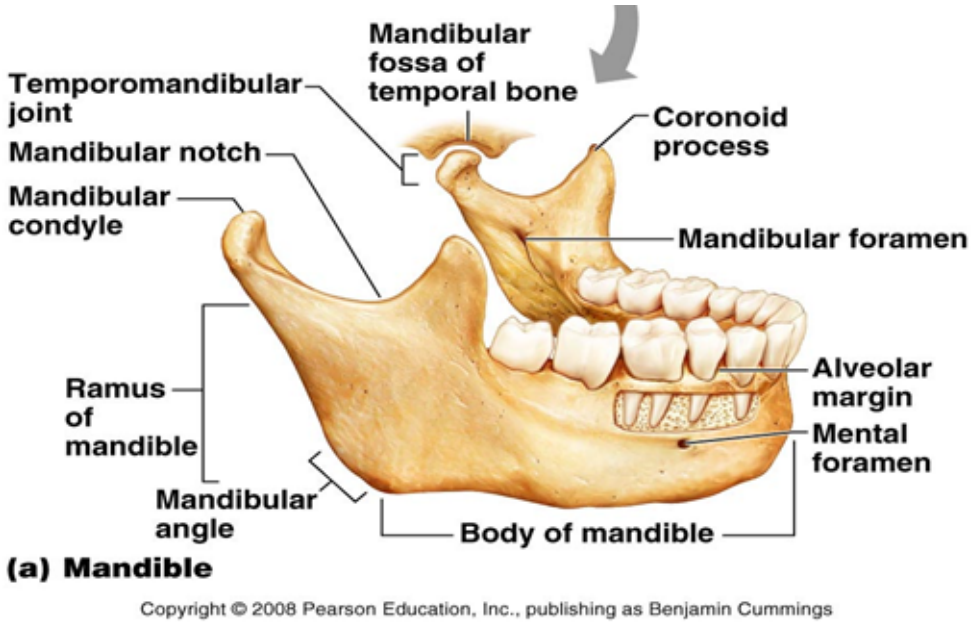
Mandibular condyles (TMJ)

Mandibular notch

Coronoid process

Ramus

Angle



Sutures and Fontanels

Sutures are fibrous Articulation, no movement, fused in adulthood

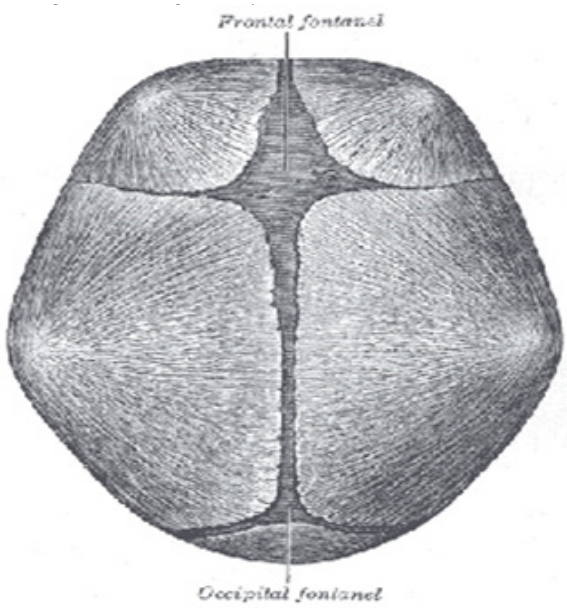
Lambdoidal—between occipital and parietal

Saggital --- between parietals

Coronal– between frontal and parietals

Squamous – between parietals and temporals

Anterior and Posterior Fontanels



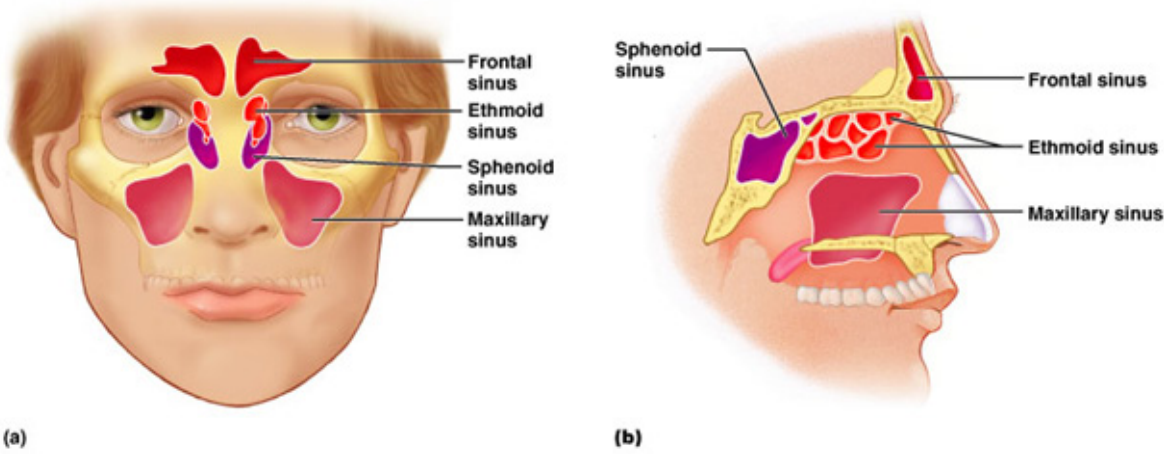
Paranasal Sinuses

Sinus—Is an air filled cavity inside the skull bones. It makes the skull lighter and also help to resonate sound.

Frontal Ethmoid

Sphenoid Maxillary

Narrow passageways from each sinus provide communication with nasal cavity



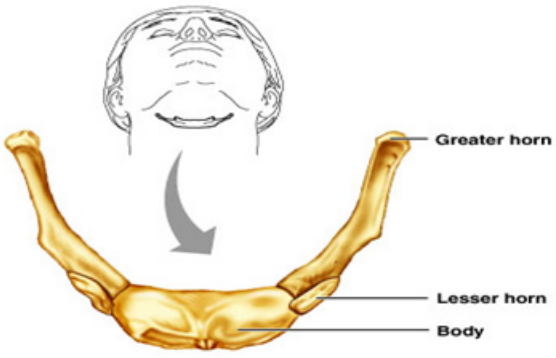
Sinusitis

-itis = inflammation

- Bacterial, viral, fungal, allergic
- Swelling causes poor drainage and pressure differentials
- Sinus headache
- Treatment might include decongestants, e.g., pseudephedrine

Hyoid Bone

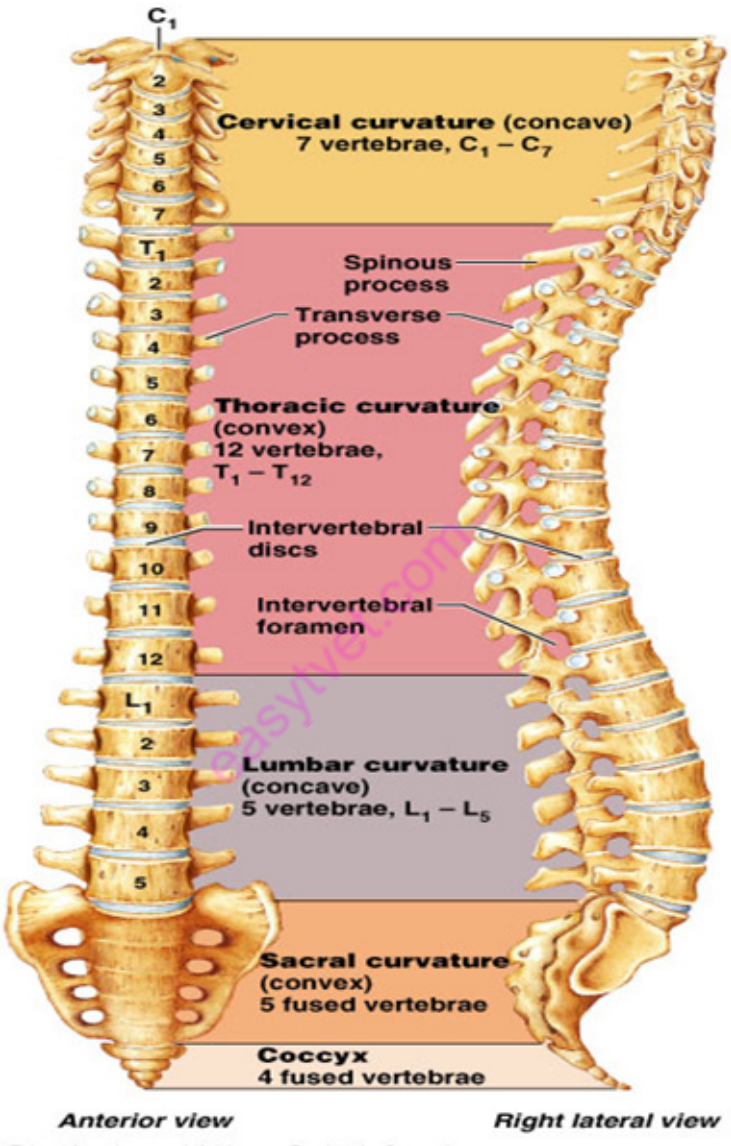
- Inferior to the mandible
- Supports many cervical muscles
- Superior to the larynx
- Supports the larynx.



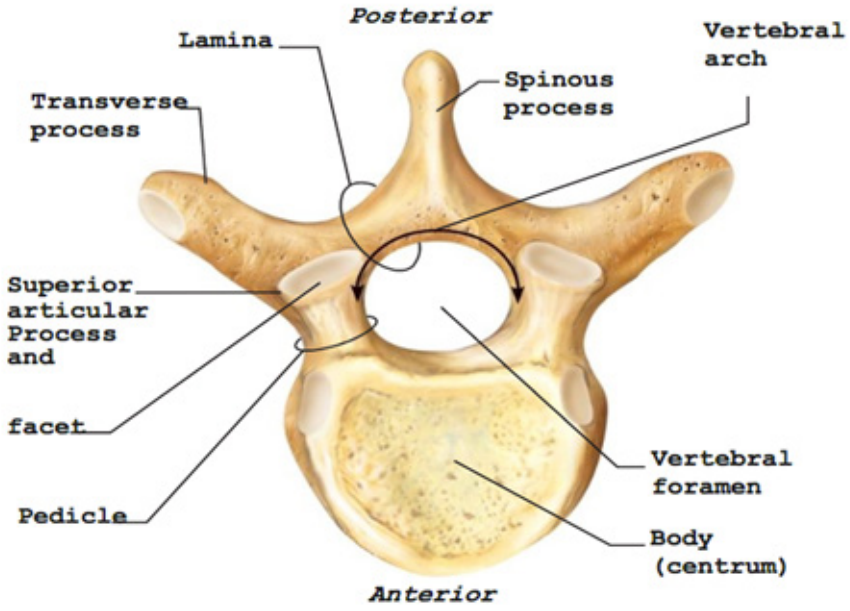
The Vertebral Column

7 Cervical	12 Thoracic
5 Lumbar	5 Sacral (fused)
4 Coccygeal (fused)	

Curvatures: Cervical, Thoracic, Lumbar, Sacral.



A "Typical" Vertebra



Body and intervertebral disks

Spinous Process

Intervertebral Foramina

Articular processes/facets

- Superior
- Inferior

Vertebral (neural) Arch

- Pedicles and Laminae

Vertebral Canal/foramen

Cervical Vertebrae (C1 – C 7)

C1 = Atlas (no body)

C1-C2 – site of rotation

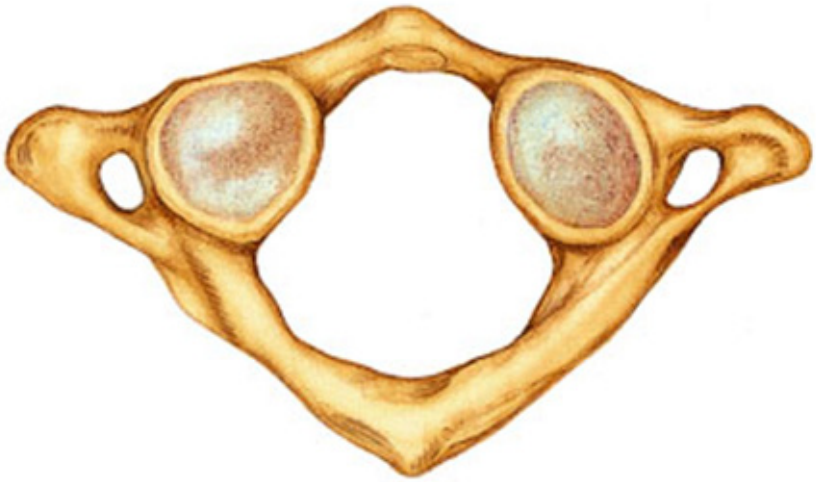
C2 = Axis

C3 - C6 are similar

Note the transverse foramina in each cervical vertebra

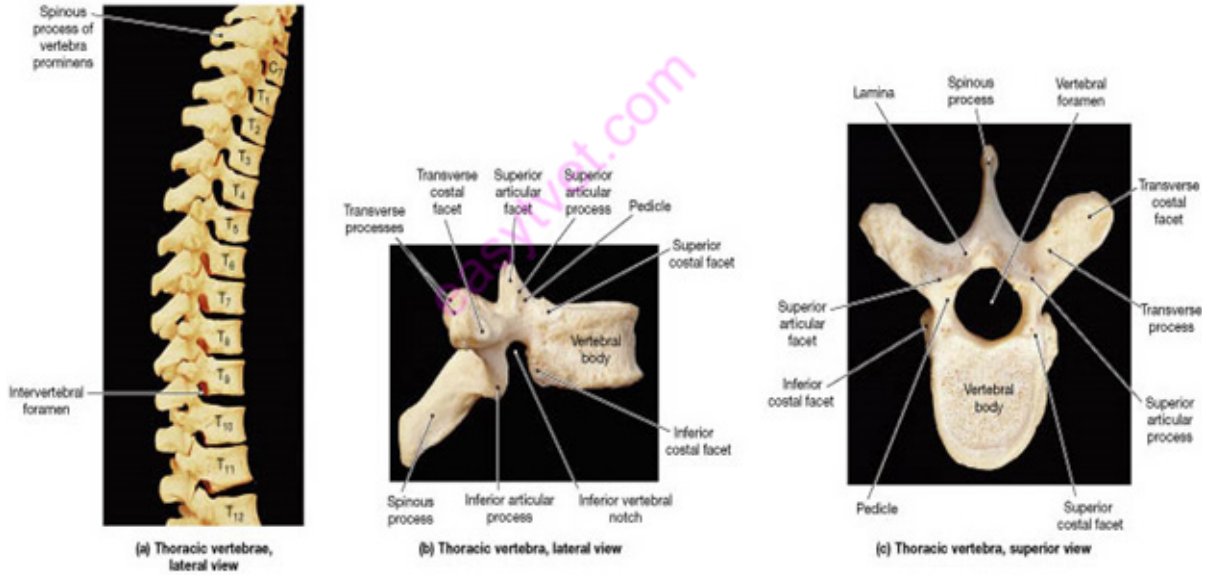
Vertebral Artery/Vein

C7 has the vertebra prominens– It has long spinous process which is palpable.



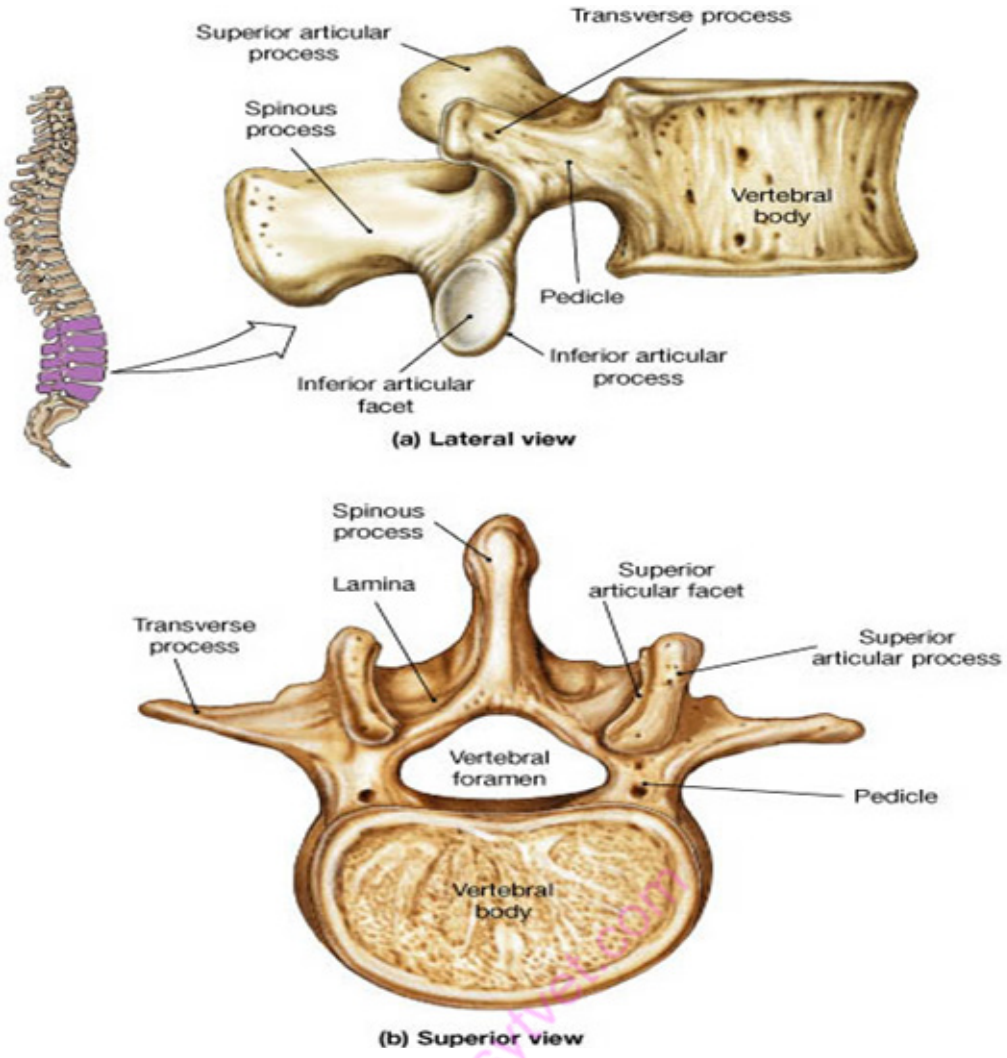
Thoracic Vertebrae (T1 - T12)

- Large Spinous Processes
- Articulations for ribs, both superior and inferior

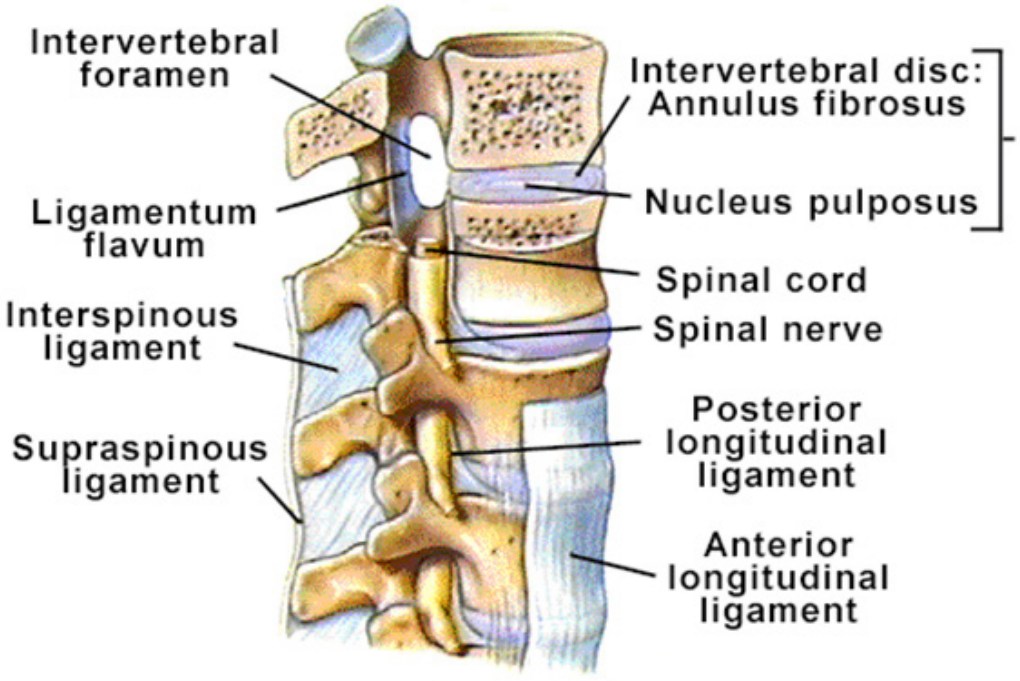


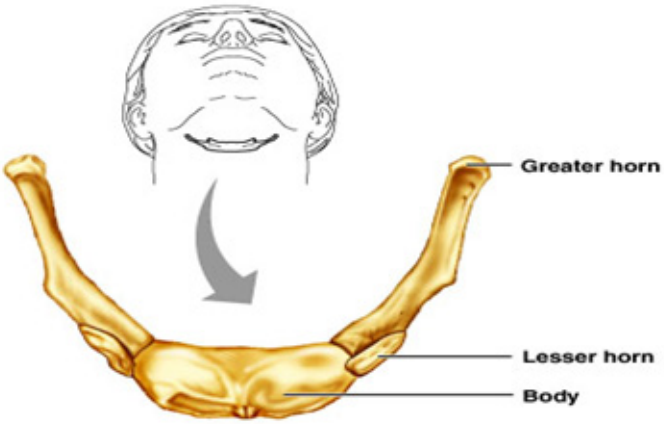
Lumbar Vertebrae (L1 - L5)

- Body
- Lamina
- Transverse Process
- Spinous Process
- Articular Facets
- Pedicle



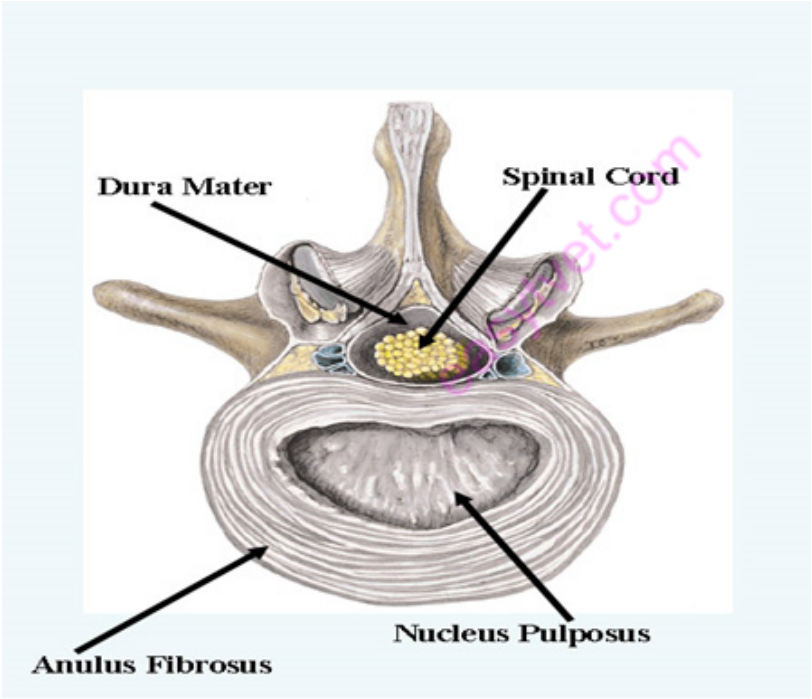
Intervertebral Articulation





Intervertebral Disk

Nucleus Pulposus | Annulus Fibrosus | Fibrocartilage



Disc Problems

Most common sites for disc problems:

C5 - C6

L4 - L5

L5 - S1

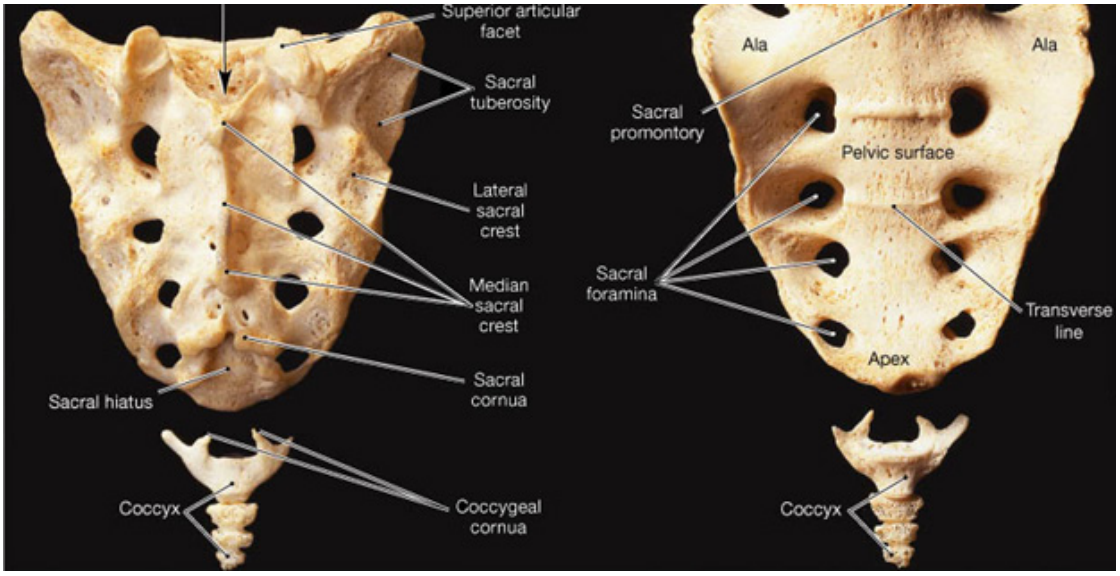
Laminectomy--(surgical removal of vertebral arch by shaving laminae to access disc)

Sacrum (5 fused)

Coccyx (3-5 fused)

Sacroiliac joint

Sacral Foramina



Thoracic (Rib) Cage

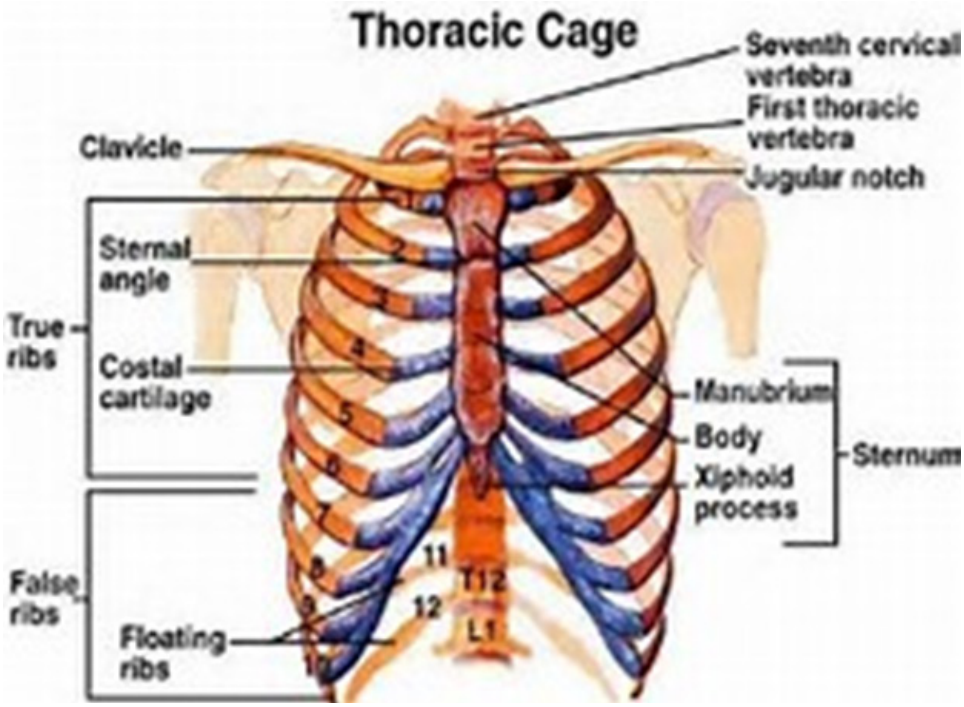
Protection and muscle attachments

Ribs – 12 pairs

1 - 7 are “true” ribs, with attachment to the sternum

8 - 12 attach indirectly to the sternum, or not at all

Costal Cartilages

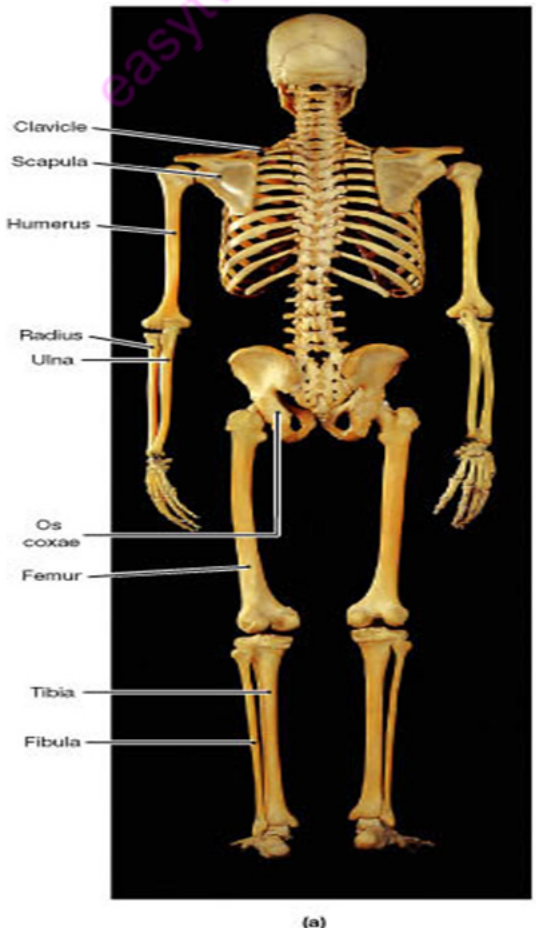


Sternum

Manubrium | Clavicular Notch | Body | Xiphoid

The Appendicular Skeleton

Appendicular Skeleton =Everything that is not in the Axial Skeleton, i.e., pelvis and limbs



The Girdles

Girdle mean--that which girds, encircles, or encloses.

Pectoral Girdle

Supports the Arms

Clavicle and Scapula

Pelvic Girdle

Supports the Legs

Pelvis

Ilium, ischium, pubic bone

Manubrium to Acromion

Scapula (shoulder blade)

Glenoid

Acromion

Inferior and Superior Angles

Coracoid Process

Clavicle (collarbone)

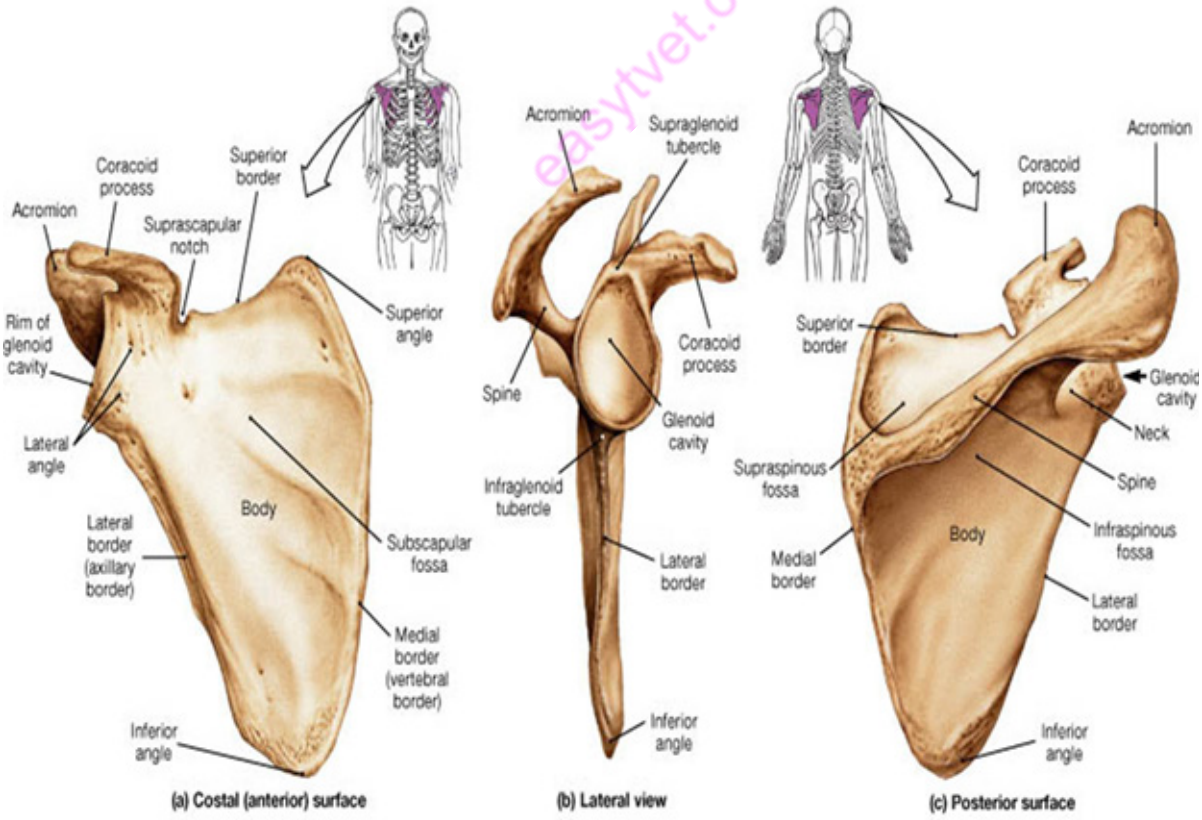
Frequently fractured

Spine

Acromioclavicular joint

Origin of biceps brachii muscle:

Supraglenoid tubercle

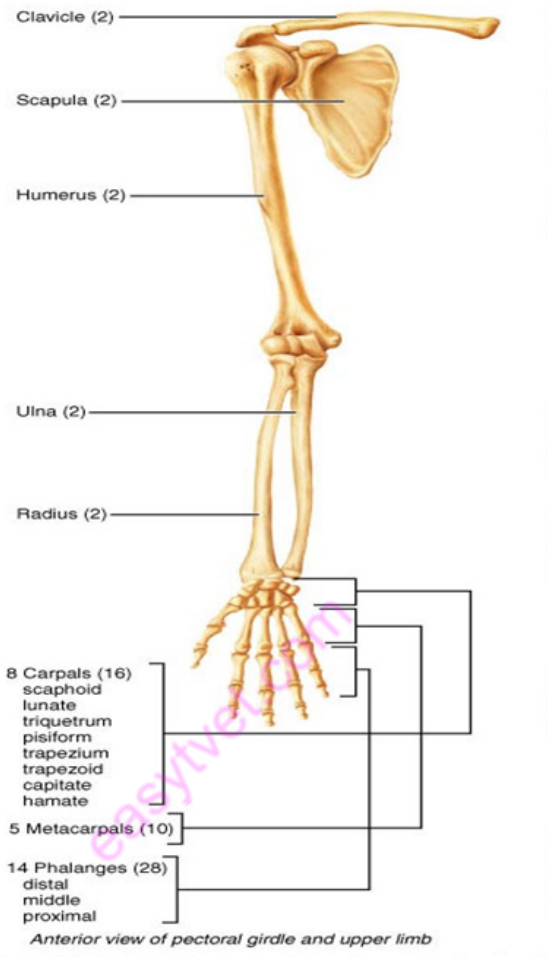


The Arm

Synonym: Upper limb

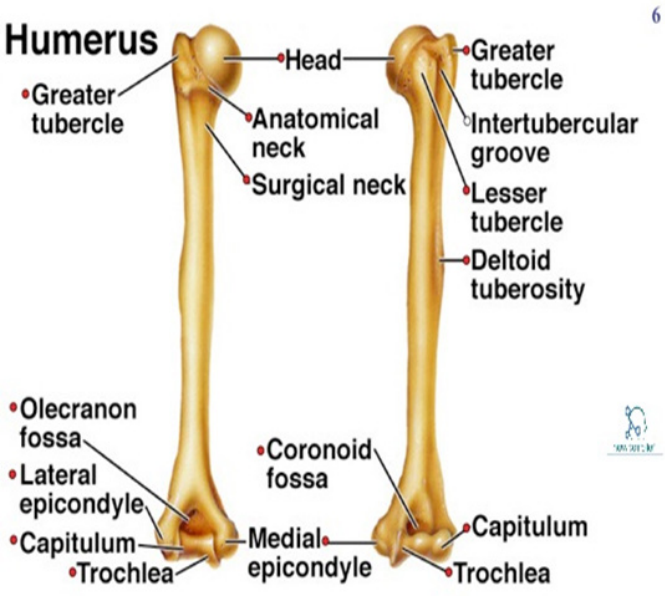
Upper Arm = Brachium | Forearm = Antebrachium

Humerus, Radius and Ulna | Carpus (wrist) | Hand (manus)



Anterior view of pectoral girdle and upper limb

Humerus



Head

Greater and Lesser Tubercles

Intertubercular Sulcus

Biceps tendon

Coronoid Fossa

Olecranon Fossa

Trochlea

Medial and Lateral Epicondyles

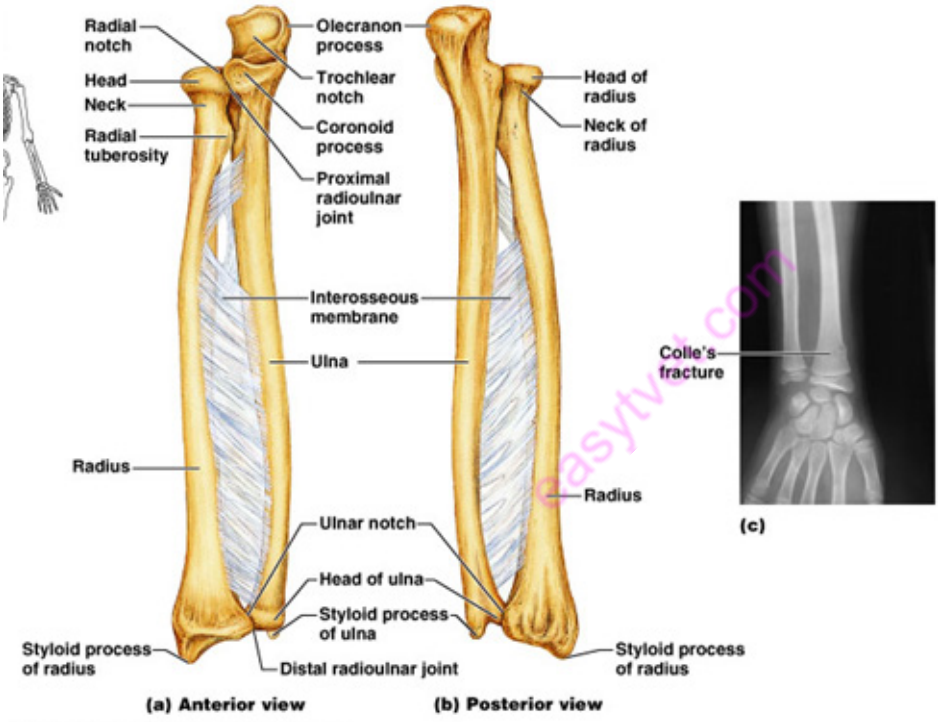
Radius

Head, neck, shaft

Insertion of biceps brachii:

Radial Tuberosity

Radial Styloid Process



Ulna

Olecranon

Trochlear notch

Coronoid Process

Ulnar Styloid Process

Interosseous Membrane (between radius and ulna)

Note how the two bones can cross \ "Funny bone"

Carpus = Wrist

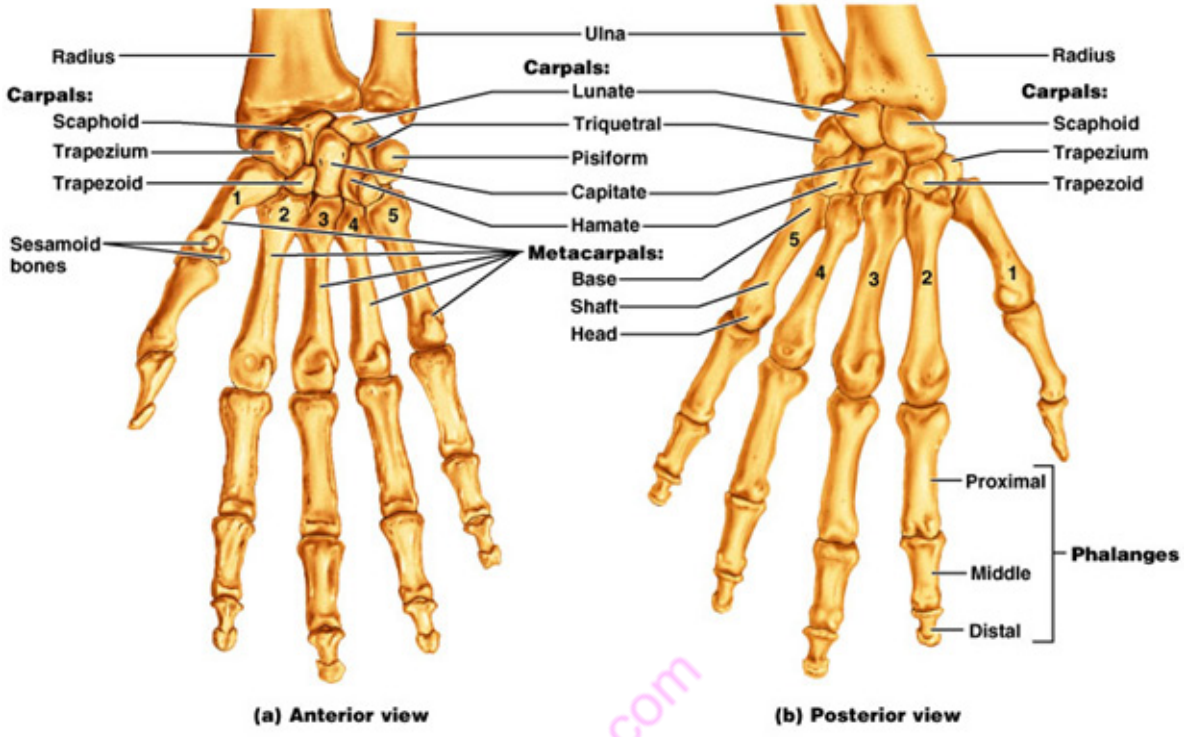
Four Proximal

Scaphoid | Lunate | Triquetrum | Pisiform

Four Distal

Trapezium | Trapezoid | Capitate | Hamate

Scaphoid is frequently fractured



Hand = Manus

Five metacarpal bones (1-5)

Five fingers

Labeled 1-5

Thumb = Pollex = digit 1

Two phalangeal bones

Fingers = phalanges = digits 2-5

Three phalangeal bones

Proximal, middle, distal

The Girdles

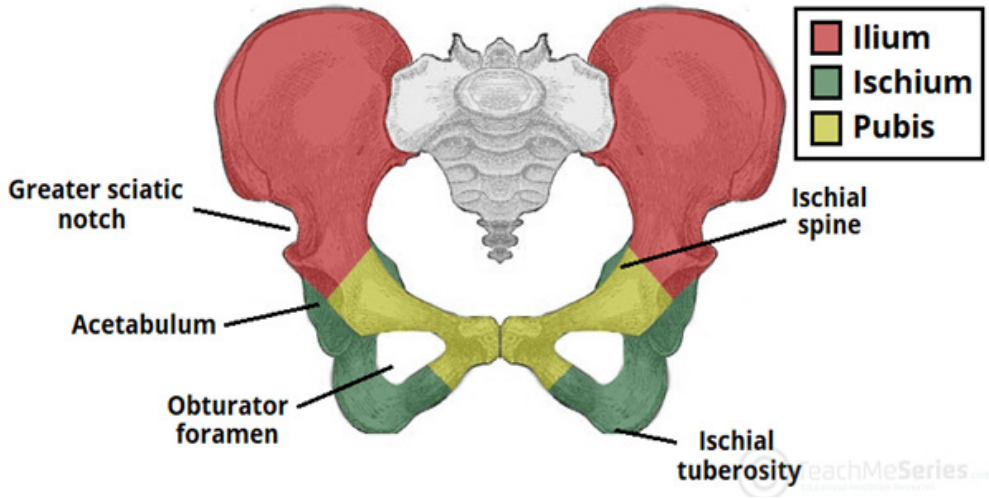
Pectoral Girdle

Supports the Arms | Clavicle and Scapula

Pelvic Girdle

Supports the Legs | Pelvis

Pelvis = hip bone = (innominate bone)



Three bones: Ilium, Ischium, Pubis

- Anterior and posterior iliac spines meet to form the iliac crest
- Greater and Lesser Sciatic Notches
- Ischial Tuberosity

Acetabulum

Acetabular fossa—head of the femur enters.

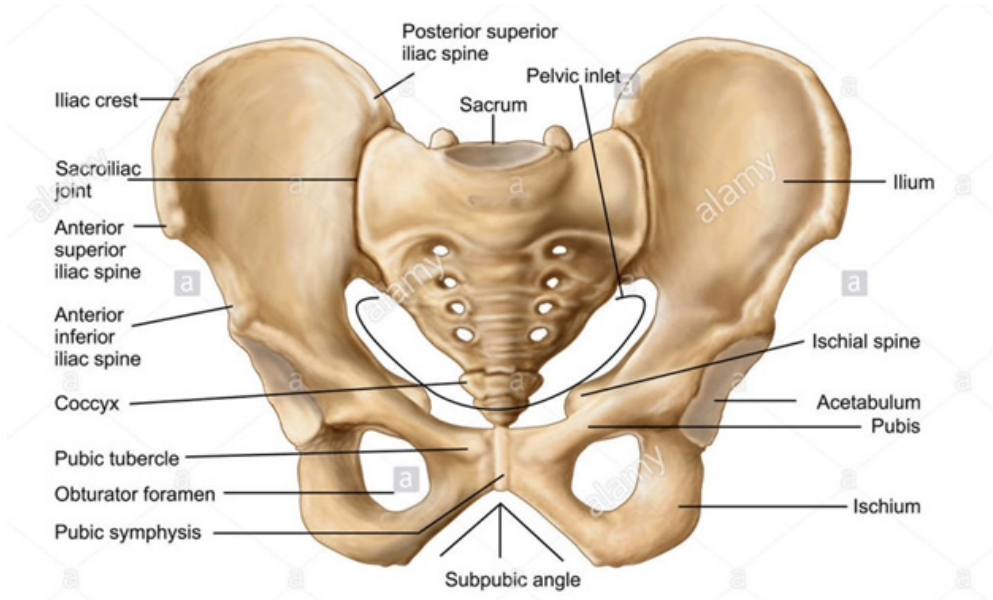
Obturator Foramen– nerves & muscles pass thru'

- Articular Surface for Articulation with Sacrum

Different between male and female

Pubic symphysis | Fibrocartilage

- Stretches at childbirth (Relaxin)

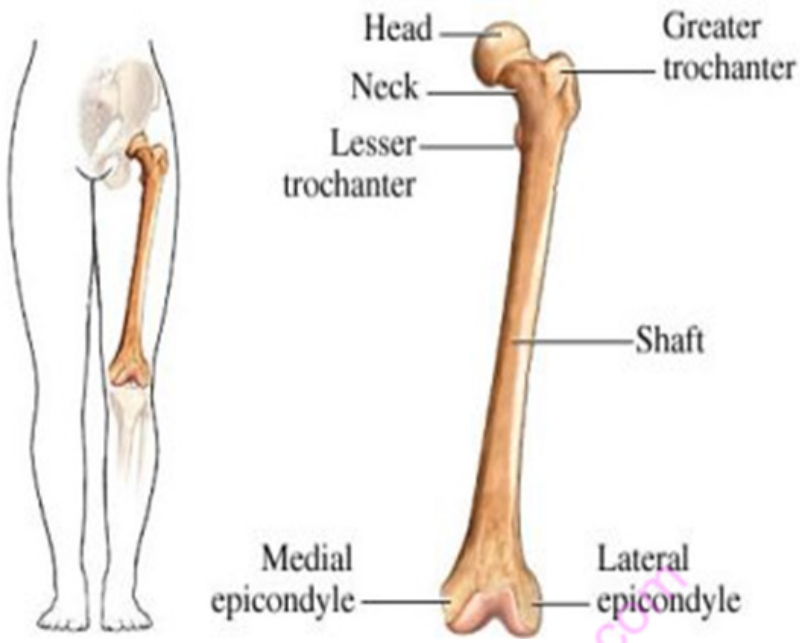


The leg

AKA Lower Limb

Femur | Patella | Tibia/fibula | Tarsus | Foot

Femur



Head and fovea capitus

Articulate with pelvis

Neck

Greater and Lesser Trochanters

Shaft

Lateral and medial condyles and epicondyles

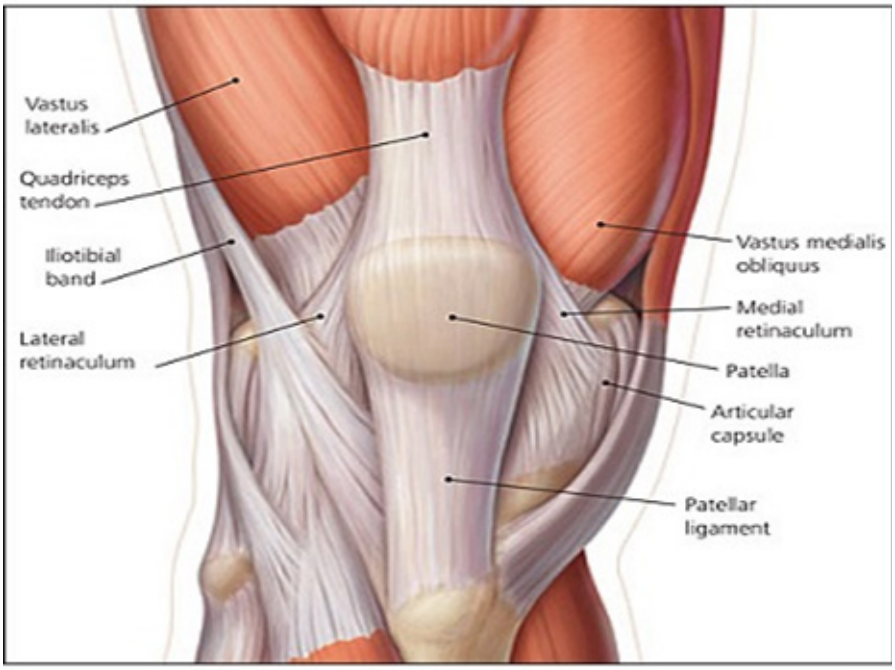
Intercondylar fossa

Patellar Surface

Patella = knee cap

Sesamoid Bone

Enclosed in the tendon of the quadriceps group of muscles



Tibia = shin bone

Lateral and medial condyles

Intercondylar eminence

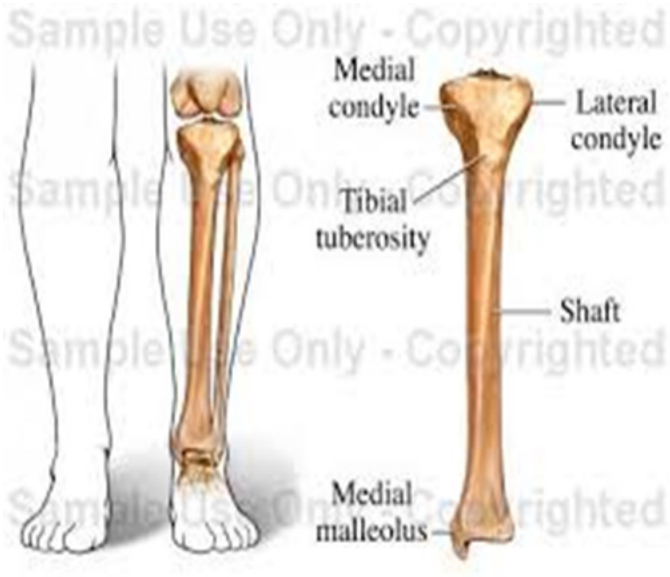
Tibial tuberosity

Inferior articular surface

Medial malleolus

(= ankle bone)

Interosseous Membrane—attaches it to fibula



Fibula

Head | Shaft

Lateral malleolus (= ankle bone)

Not weight bearing

Stabilizes the ankle and offer attachment to muscles in the lower leg.

Tarsus (7 bones)

Cute Tillie Never Could Cooperate

Foot

Metatarsals (1-5)

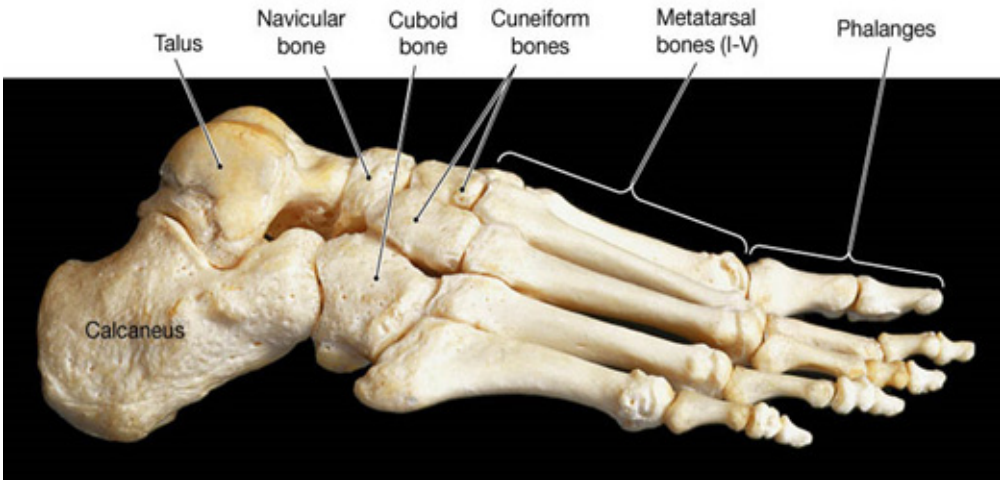
Phalanges (3 per toe except big toe)

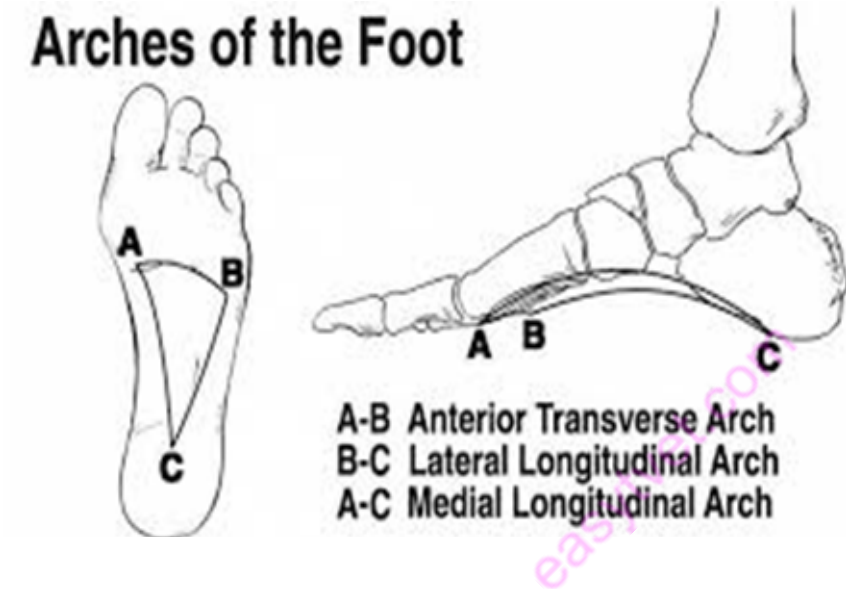
Longitudinal Arches

Medial and lateral

Transverse Arch

Cute Tillie Never Could Cooperate





Fractures (a review)

Bleeding, then clot

Periosteal reaction

Fibroblasts | Osteoblasts

Callus

New bone "collar"

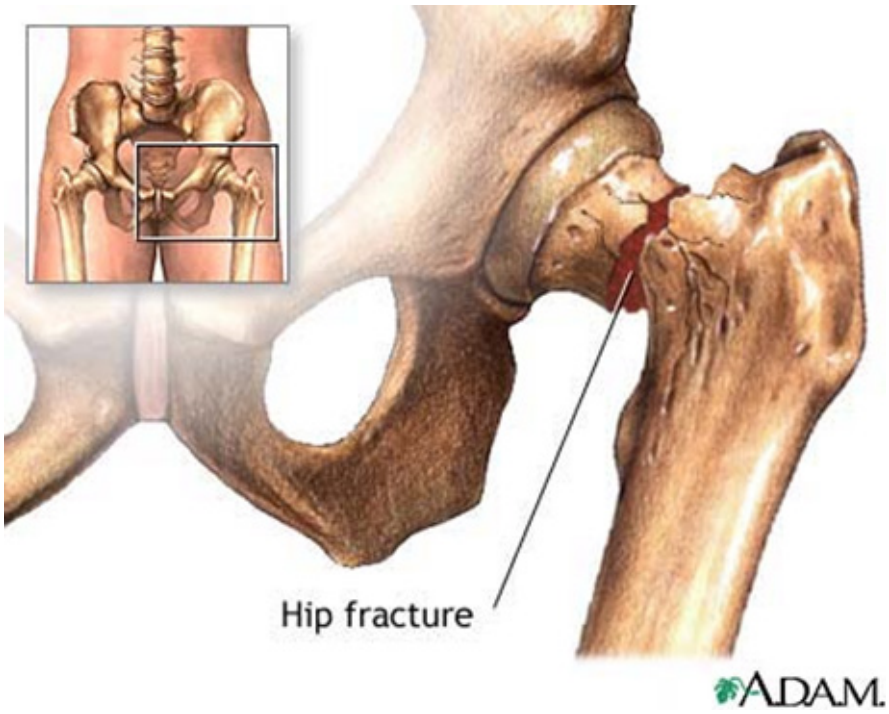
Remodeling

"Hip" fracture

"Grandma fell and broke her hip."

More accurately, "Grandma broke her femoral neck and then fell."

Sometimes the fix is at the intertrochanteric line



Diabetes, hypertension, osteoporosis

25% die from complications in first year mostly related to immobility:

Anesthesia | Muscle Atrophy | Pneumonia | Decubitus ulcers | Depression and disorientation

CAVITIES OF THE BODY

4 cavities:

1. Cranial | 2. Thoracic | 3. Abdominal | 4. Pelvic.

1) Cranial Cavity

Contains the brain

Boundaries formed by the bones of the skull:

Anteriorly — 1 frontal bone

Laterally — 2 temporal bones

Posteriorly — I occipital bone

Superiorly — 2 parietal bones

Inferiorly — 1 sphenoid and 1 ethmoid bone and parts of the frontal, temporal and occipital bones.

2) Thoracic Cavity

Situated in the upper part of the trunk.

Boundaries formed by a bony framework and supporting muscles :

Anteriorly — the sternum and costal cartilages of the ribs

Laterally — 12 pairs of ribs and the intercostal muscles

Posteriorly — the thoracic vertebrae and the intervertebral discs between the bodies of the vertebrae

Superiorly — the structures forming the root of the neck

Inferiorly — the diaphragm, a dome-shaped muscle.

Contents of thoracic cavity

The trachea, 2 bronchi, 2 lungs, the heart, aorta, superior and inferior vena cava, numerous other blood vessels, the oesophagus, lymph vessels and lymph nodes, and nerves.

The mediastinum: refers to the space between the lungs including the structures found there, such as the heart, oesophagus and blood vessels.

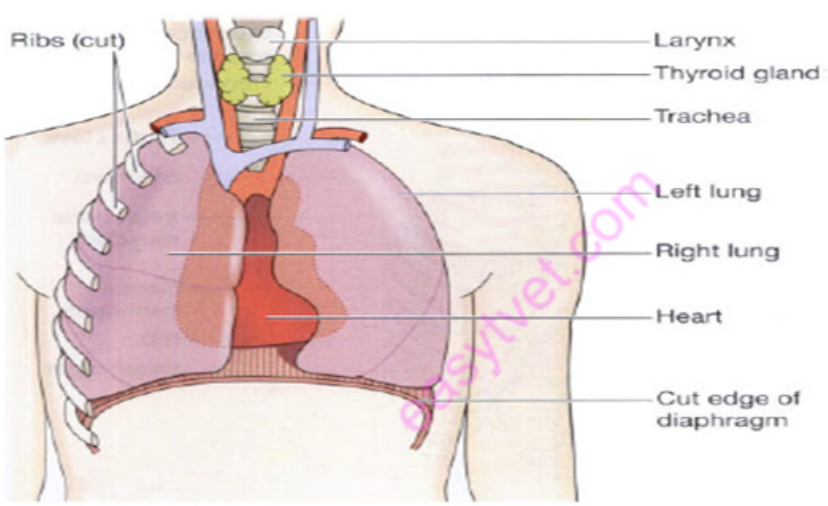


Figure 3.34 Some of the main structures in the thoracic cavity and the root of the neck.

3) Abdominal Cavity

Largest cavity in the body. It's oval in shape

Situated in the main part of the trunk and its boundaries are:

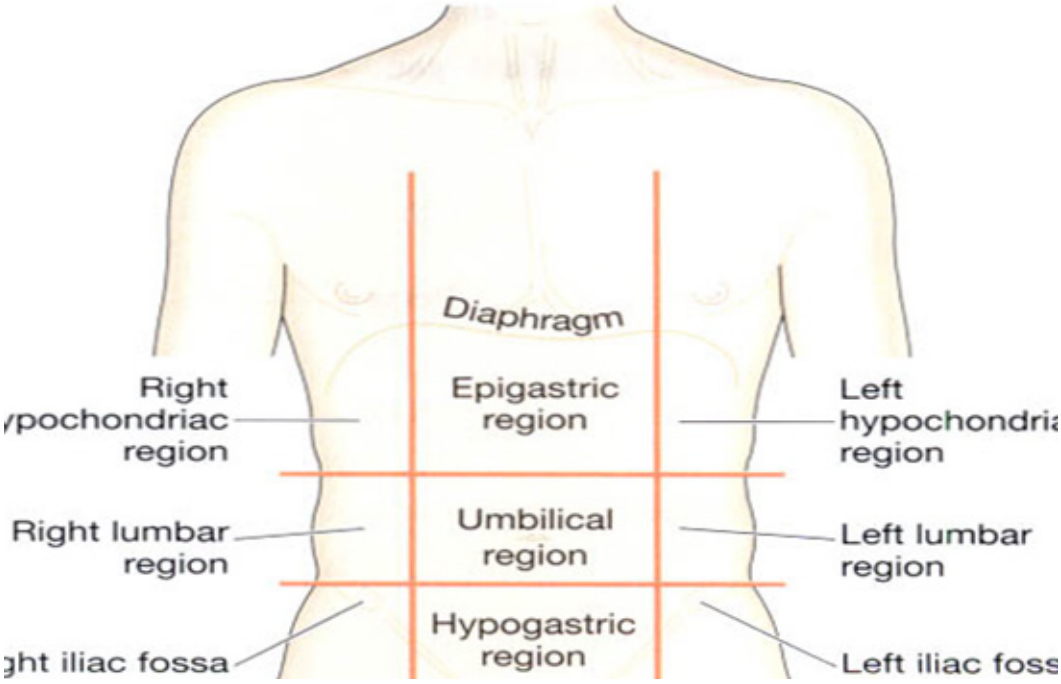
Superiorly — the diaphragm, which separates it from the thoracic cavity

Anteriorly — the muscles forming the anterior abdominal wall

Posteriorly —the lumbar vertebrae and muscles forming the posterior abdominal wall

Laterally — the lower ribs and parts of the muscles of the abdominal wall

Inferiorly — the pelvic cavity with which it is continuous.



Contents of abdominal cavity

Organs and glands involved in the digestion and absorption of food. These are:

the stomach, small intestine and most of the large intestine

the liver, gall bladder, bile ducts and pancreas.

Other structures include:

1. the spleen
2. 2 kidneys and the upper part of the ureters
3. 2 adrenal (suprarenal) glands
4. numerous blood vessels, lymph vessels, nerves
5. lymph nodes.

4) Pelvic Cavity

Roughly funnel shaped and extends from the lower end of the abdominal cavity.

Boundaries are:

Superiorly — continuous with the abdominal cavity

Anteriorly — the pubic bones

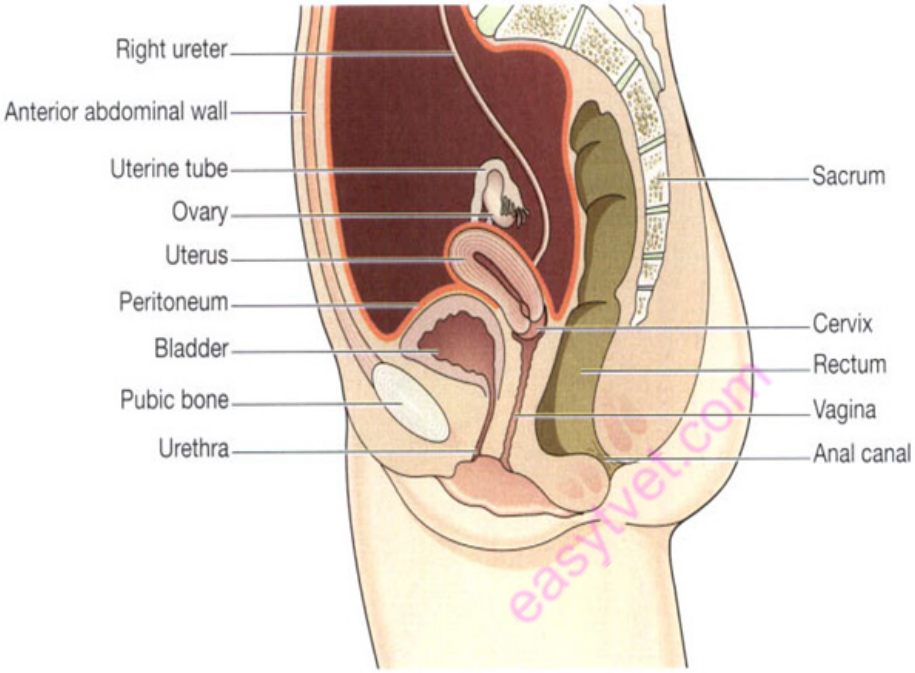
Posteriorly — the sacrum and coccyx

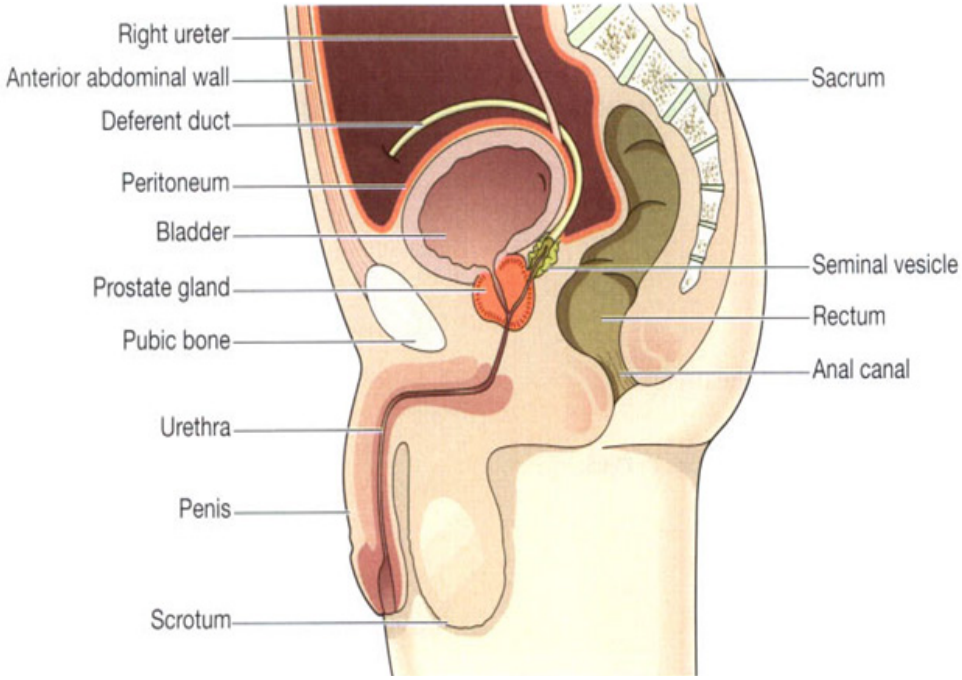
Laterally — the innominate bones

Inferiorly — the muscles of the pelvic floor.

Contents of pelvic cavity

- Sigmoid colon, rectum and anus
- Some loops of the small intestine
- Urinary bladder, lower parts of the ureters and the urethra
- In the female, the organs of the reproductive system: the uterus, uterine tubes, ovaries and vagina.
- In the male, some of the organs of the reproductive system: the prostate gland, seminal vesicles, spermatic cords, deferent ducts (vas deferens), ejaculatory ducts and the urethra (common to the reproductive and urinary systems)





Joints (Joint Classification)

The structural classification of joints

- Fibrous joints (bones held together by dense collagen fibers)
- Cartilaginous joints (bones held together by cartilage)
- Synovial joints (bones held together by ligaments)

The functional classification of joints

- Synarthrosis (an immovable joint)
- Amphiarthrosis (a slightly movable joint)
- Diarthrosis (a freely movable joint)

1. Joints (Fibrous Joints)

Lack a synovial cavity

The articulating bones are held very closely together by dense irregular connective tissue

Fibrous joints permit little or no movement

Three types of fibrous joints

- Sutures
- Syndesmoses
- Gomphoses

Sutures

Occur only between bones of the skull

Syndesmoses

- Permits slight movement
- Interosseous membrane
- Between the tibia and fibula in the leg

Gomphoses

- Immovable joint
- Joint in which a cone-shaped peg fits into a socket
- Articulations of the teeth with the sockets of the maxillae and mandible

2. Joints (Cartilaginous Joints)

Lacks a synovial cavity

- Allows little or no movement
- Joint is tightly connected by either cartilage

Two types of cartilaginous joints

1. Synchondroses
2. Symphyses

Synchondroses

- Connecting tissue is hyaline cartilage
- Epiphyseal (growth) plate

Symphyses

Slightly movable joint

Ends of the articulating bones are covered with hyaline cartilage, but a disc of fibrocartilage connects the bones

Pubic symphysis

Between the anterior surfaces of the hip bones

Intervertebral joints between the vertebrae

3. Joints (Synovial Joints)

Synovial cavity allows a joint to be freely movable

Ligaments hold bones together in a synovial joint

Articular Capsule

A sleeve-like capsule of fibrous tissue encloses the synovial cavity

The articular capsule allows movement and protects the joint from injury

Synovial Fluid

Thick sticky fluid with egg white consistency

The synovial membrane secretes synovial fluid

Functions to reduce friction by:

- lubricating the joint
- absorbing shocks
- supplying oxygen and nutrients to the cartilage

– removing carbon dioxide and metabolic wastes from the cartilage

– Creates surface tension and prevents bones from separating.

Synovial membrane

Composed of epithelial cells

It lines the capsule, covers part of the bone within the joint not covered by articular cartilage, & covers intracapsular structures that do not bear weight,

Articular (Hyaline cartilage)

Covers parts of the bone in contact

Provides smooth articular surface, adsorbs and bears the body weight. Has no blood supply, nourished by the synovial fluid.

Bursae (sacs of synovial fluid) are present in some joints, e,g knee joint that acts as a cushion to prevent friction between a bone and a ligament or tendon or skin.

Other intracapsular structures

– Are found within the capsule e.g menisci and fat pads at the knee joint –maintains stability of the joint

– Extracapsular structures: ligaments, muscles and tendons. Provides the joint with stability.

– Nerve and blood supply.

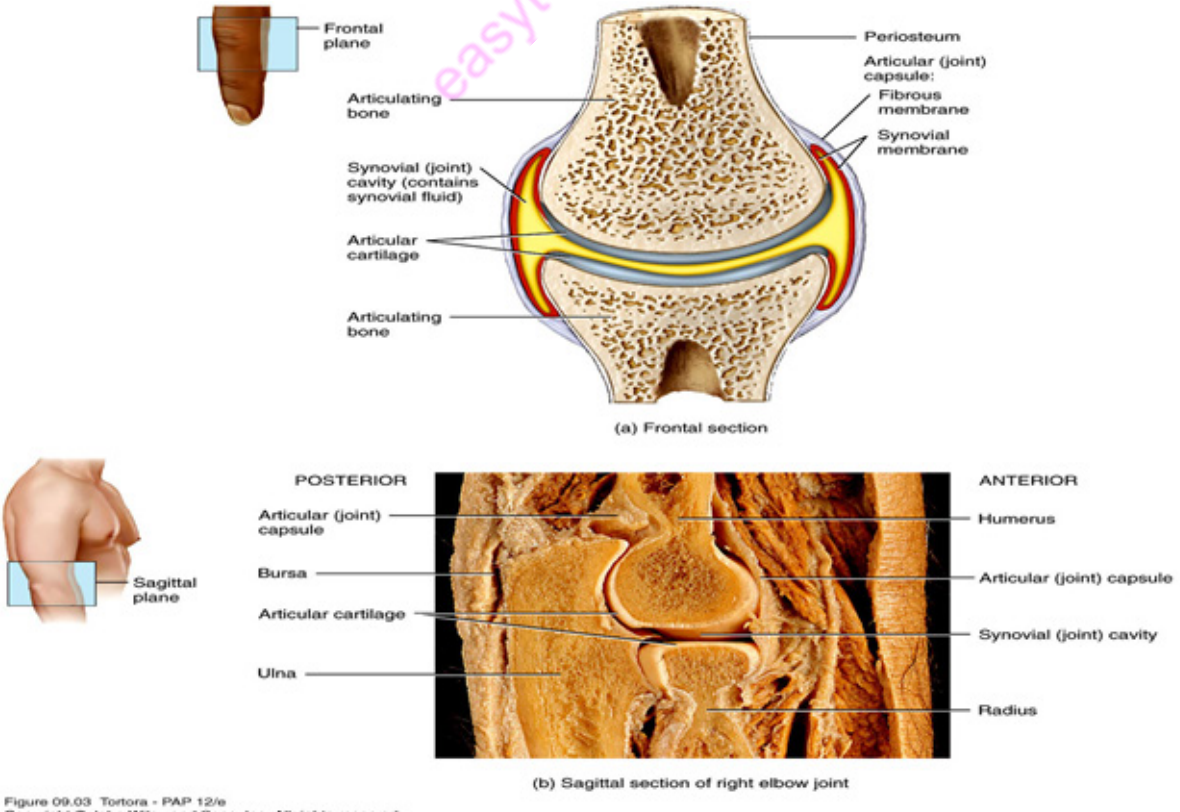


Figure 09.03 Tortora - PAP 12/e

Accessory Ligaments and Articular Discs

- Collateral ligaments of the knee joint
- Anterior and posterior cruciate ligaments of the knee joint
- Menisci
- Pads of cartilage lie between the articular surfaces of the bones
- Allow bones of different shapes to fit together more tightly

Nerves and Blood Supply

Nerve endings convey information about pain from the joint to the spinal cord and brain

Nerve endings respond to the degree of movement and stretch at a joint

Arterial branches from several different arteries merge around a joint before penetrating the articular capsule

Bursae and Tendon Sheaths

Bursae

Sac-like structures containing fluid similar to synovial fluid

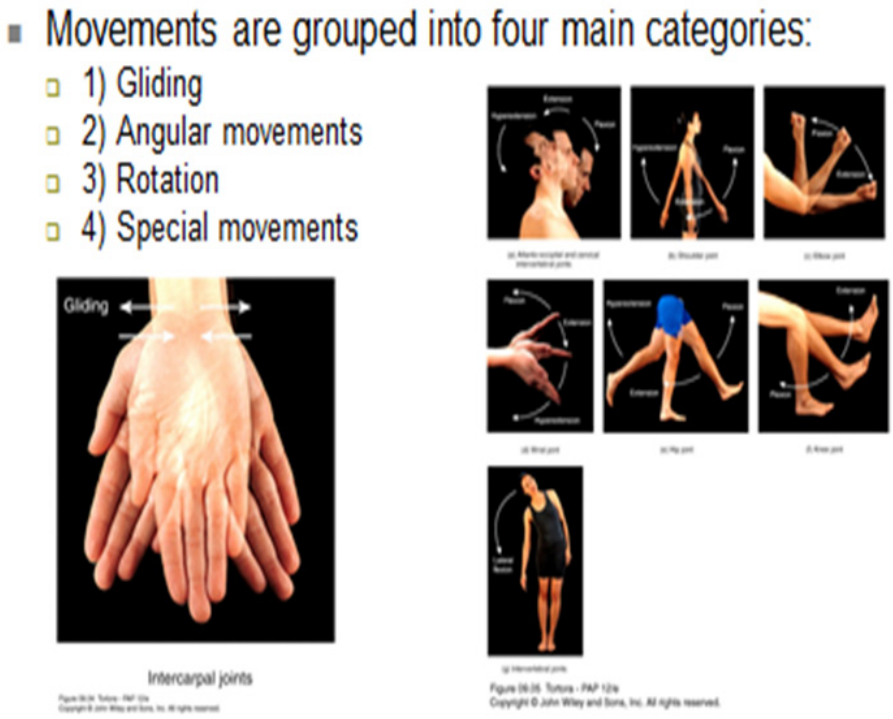
Located between tendons, ligaments and bones

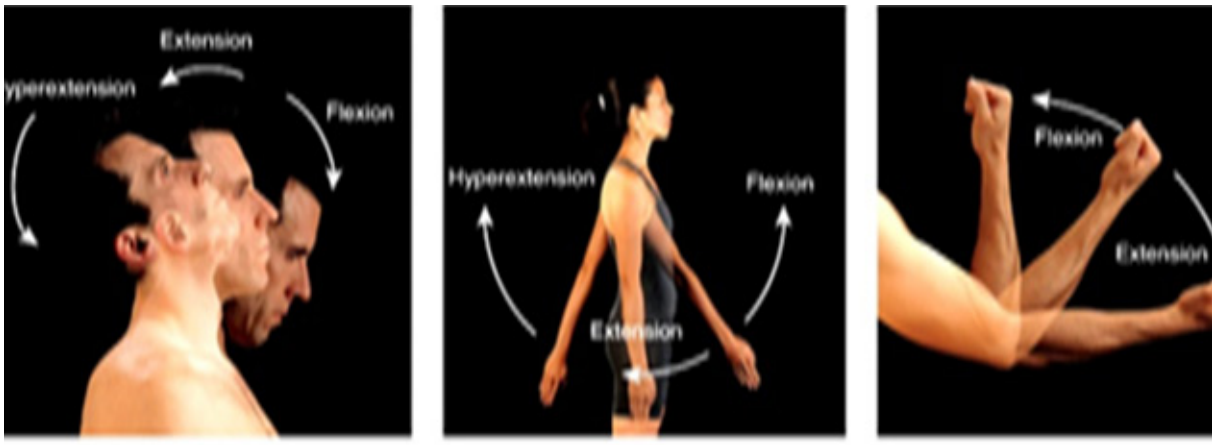
Cushion the movement of these body parts

***Tendon* sheaths**

Wrap around tendons | Reduce friction at joints

Joints (Types of Movements at Synovial Joints)





(a) Atlanto-occipital and cervical intervertebral joints

(b) Shoulder joint

(c) Elbow joint

(d) Wrist joint

(e) Hip joint

(f) Knee joint

(g) Intervertebral joints

Gliding

Simple movement back-and-forth and from side-to-side

There is no significant alteration of the angle between the bones

Limited in range

Intercarpal joints

Angular Movements

Increase or a decrease in the angle between articulating bones

Angular movements include

- Flexion
- Lateral flexion
- Abduction
- Circumduction
- Extension
- Hyperextension
- Adduction

Flexion

Decrease in the angle between articulating bones

Bending the trunk forward

Extension

Increase in the angle between articulating bones

Flexion and extension are opposite movements

Lateral flexion

Movement of the trunk sideways to the right or left at the waist

Hyperextension

Continuation of extension beyond the normal extension

Bending the trunk backward

Abduction

Movement of a bone away from the midline

Moving the humerus laterally at the shoulder joint

Adduction

Movement of a bone toward the midline

Movement that returns body parts to normal position from abduction

Figure 09.08 Tortora - PAP 12/e

Circumduction

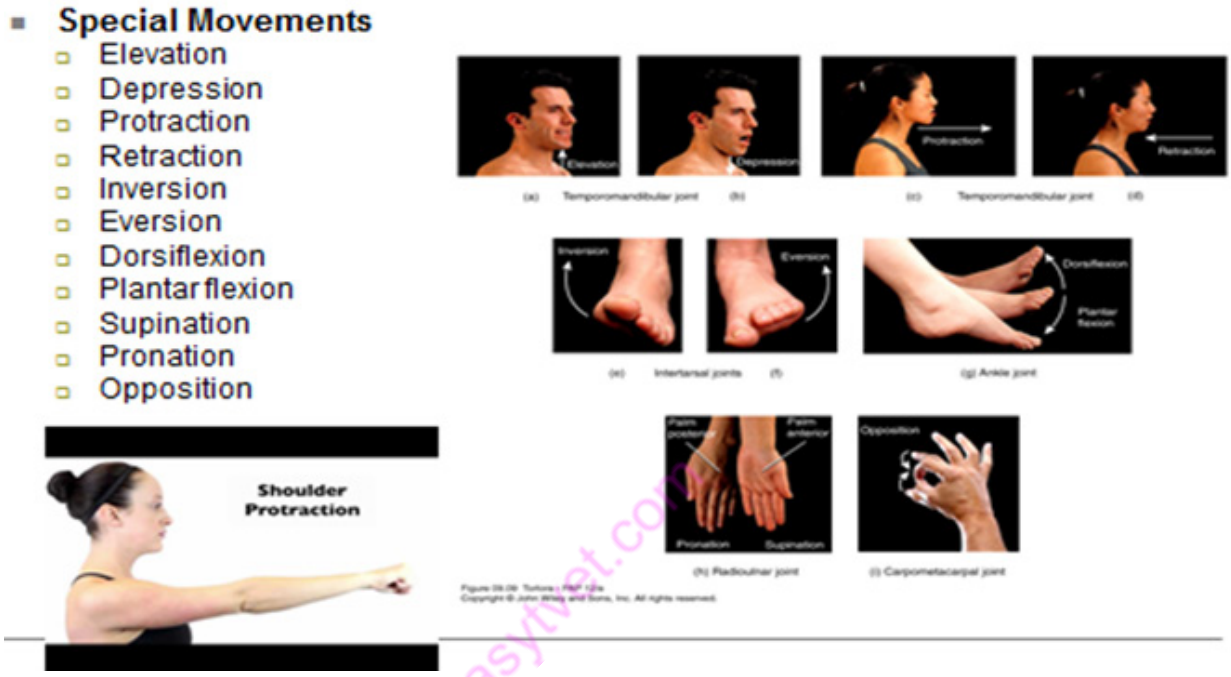
Movement of a body part in a circle

Moving the humerus in a circle at the shoulder joint

Rotation

A bone revolves around its own longitudinal axis

Turning the head from side to side as when you shake your head “no”



Elevation

Upward movement of a part of the body

Closing the mouth

Its opposing movement is depression

Depression

Downward movement of a part of the body

Opening the mouth

Protraction

Movement of a part of the body anteriorly

Thrusting the mandible outward

Its opposing movement is retraction

Retraction

Movement of a protracted part of the body back to normal

Inversion

Movement of the foot medially

Its opposing movement is eversion

Eversion

Movement of the sole laterally

Dorsiflexion

Bending of the foot at the ankle in an upward direction

Its opposing movement is plantar flexion

Plantar flexion

Bending of the foot at the ankle in a downward direction

Supination

Movement of the forearm so that the palm is turned upward

Its opposing movement is pronation

Pronation

Movement of the forearm so that the palm is turned downward

Opposition

Movement of the thumb in which the thumb moves across the palm to touch the tips of the fingers on the same hand

Joints (Types of Synovial Joints)

Synovial joints are classified based on type of movement

- Planar
- Pivot
- Saddle
- Hinge
- Condyloid
- Ball-and-socket

Planar Joints

Primarily permit back-and-forth and side-to-side movements

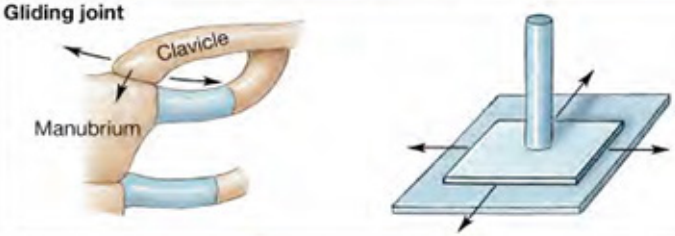
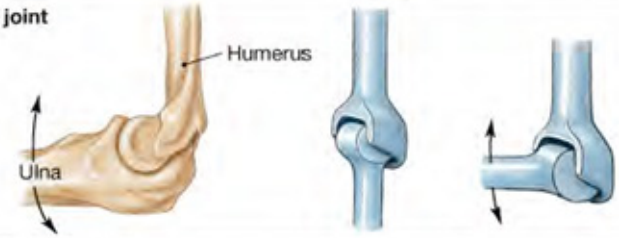
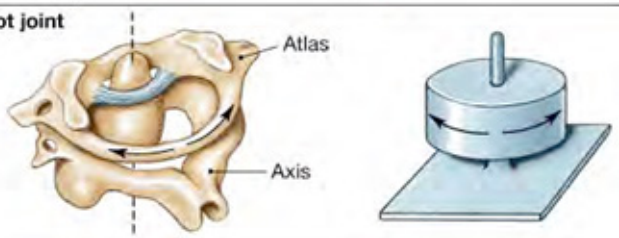
Intercarpal joints

Hinge Joints

Produce an opening and closing motion like that of a hinged door

Permit only flexion and extension

Knee and elbow, phalanges of the fingers and toes

Types of Synovial Joints	Movement	Examples
Gliding joint 	Slight nonaxial or multiaxial	• Acromioclavicular and claviculosternal joints • Intercarpal and intertarsal joints • Vertebrocostal joints • Sacroiliac joints
Hinge joint 	Monaxial	• Elbow joint • Knee joint • Ankle joint • Interphalangeal joint
Pivot joint 	Monaxial (rotation)	• Atlas/axis • Proximal radioulnar joint

Pivot Joints

Surface of one bone articulates with a ring formed partly by another bone, together with a hoop shaped ligament that holds the bone to form the ring e.g head on the axis, odontoid process of the atlas & transverse ligament.

Joints that enable the palms to turn anteriorly and posteriorly

Allows rotation of a bone or limb.

Condyloid Joints

A condyle is a smooth rounded projection on a bone.

The projection of one bone fits into the oval-shaped depression of another bone. Permits flexion, extension adduction, abduction & circumduction

Wrist

Saddle Joints

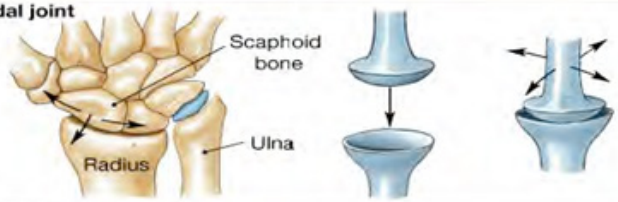
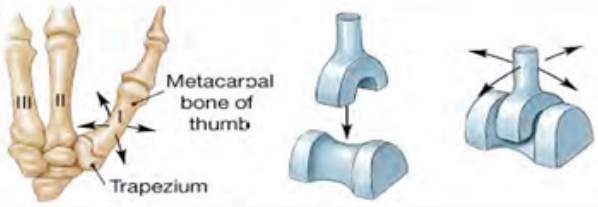
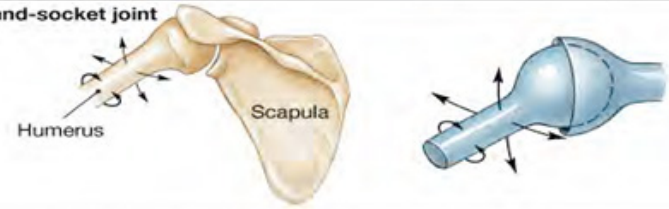
Articular surface of one bone is saddle-shaped, and the articular surface of the other bone fits into the “saddle”

Thumb (trapezium and 1st metarcarpal). Movts similar to condyloid joint with addition to opposition.

Ball-and-Socket Joints

Ball-like surface of one bone fitting into a cuplike depression of another bone. Has wide range of movements.

Shoulder and hip

Types of Synovial Joints	Movement	Examples
Ellipsoidal joint 	Biaxial	• Radiocarpal joint • Metacarpophalangeal joints 2–5 • Metatarsophalangeal joints
Saddle joint 	Biaxial	• First carpometacarpal joint
Ball-and-socket joint 	Triaxial	• Shoulder joint • Hip joint

Joints (Factors Affecting Contact and Range for Motion at Synovial Joints)

– Range of motion (ROM)

Refers to the range, measured in degrees of a circle, through which the bones of a joint can be moved

Factors contribute to keeping the articular surfaces in contact and affect range of motion:

– Structure or shape of the articulating bones

Shape of bones determines how closely they fit together

– Strength and tension of the joint ligaments

Ligaments are tense when the joint is in certain positions

Tense ligaments restrict the range of motion

Arrangement and tension of the muscles

Muscle tension reinforces the restraint placed on a joint by its ligaments , and thus restricts movement

Contact of soft parts

The point at which one body surface contacts another may limit mobility

Movement be restricted by the presence of adipose tissue

Hormones

Flexibility may also be affected by hormones

Relaxin increases the flexibility of the pubic symphysis and loosens the ligaments between the sacrum and hip bone toward the end of pregnancy

Disuse

Movement may be restricted if a joint has not been used for an extended period

Joints (Selected Joints of the Body)

The selected joints described are:

- Temporomandibular joint
- Shoulder joint
- Elbow joint
- Hip joint
- Knee joint

Temporomandibular Joint

Combined hinge and planar joint formed by the mandible and the temporal bone

Only movable joint between skull bones

Only the mandible moves

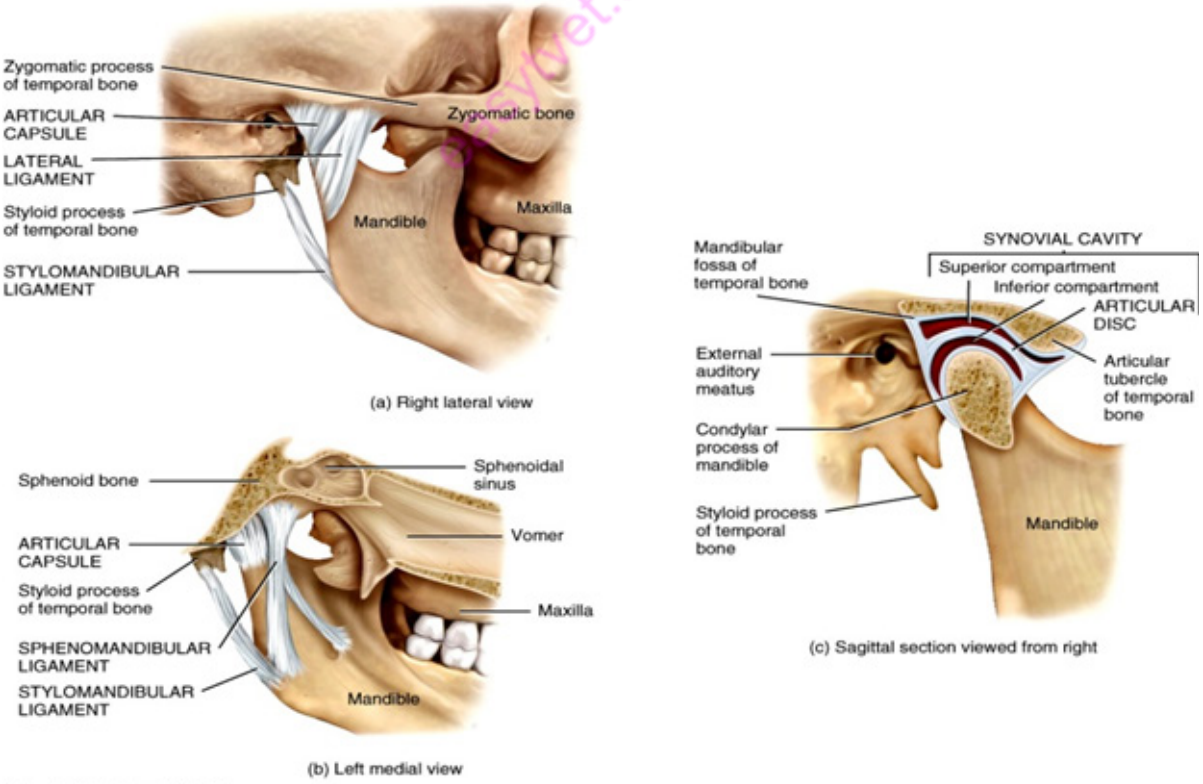


Figure 09.11 Tortora - PAP 12/e

Shoulder Joint

Ball-and-socket joint formed by the head of the humerus and the glenoid cavity of the scapula

More freedom of movement than any other joint of the body

Numerous protective bursae,

Capsular ligament is loose inferiorly to allow free movement.

Glenoid cavity is deepened by a rim of fibrocartilage,glenoid labrum which provides additional stability.

Biceps tendon is held at the intertubercular groove of the humerus by tranverse humeral ligament extends through the joint cavity to attach at the rim of glenoid cavity.

Synovial membrane covers the glenoid labrum with a sleeve round the biceps tendon.

The joint is stabilised by glenohumeral, coracohumeral, and transverse humeral ligaments.
Muscles and there tendons in the shoulder. (rotator cuff)

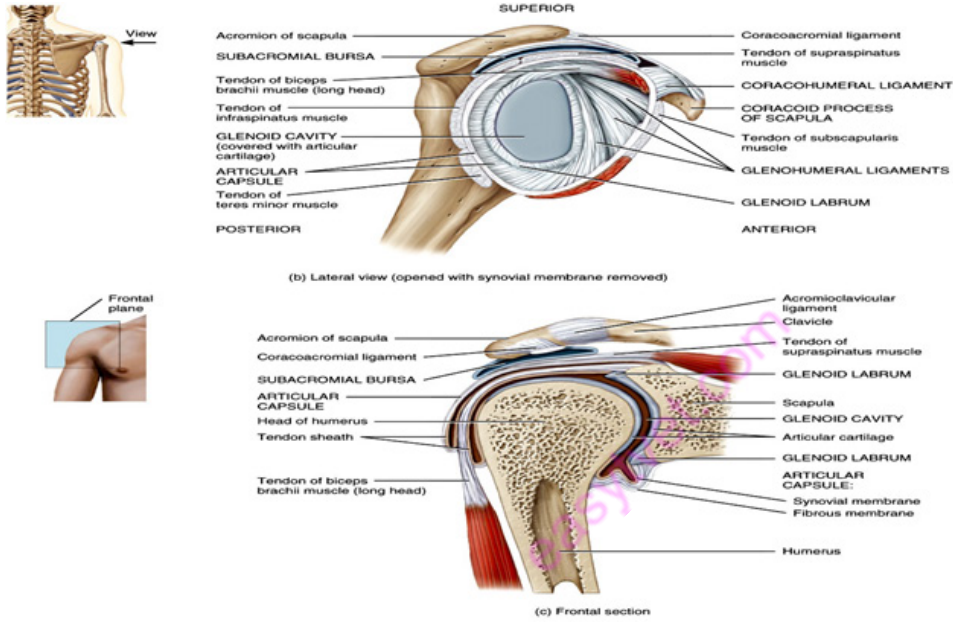
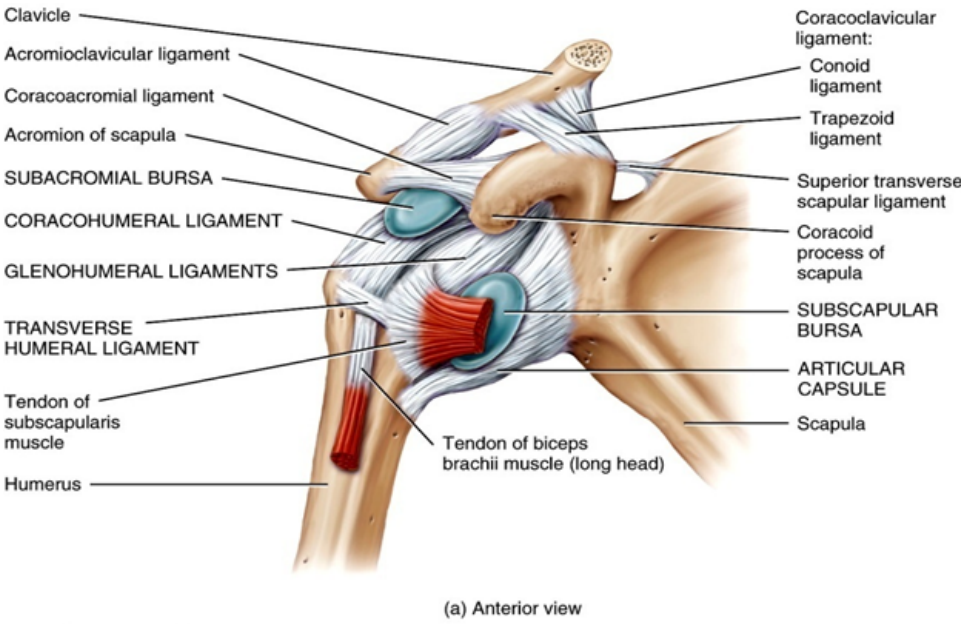


Figure 09.12bc Tortora - PAP 12/e



(a) Anterior view

Figure 09.12a Tortora - PAP 12/e

Elbow Joint

Hinge joint formed by the trochlea and the capitulum of the humerus, the trochlear notch of the ulna, and the head of the radius

The humeral and ulna surfaces interlock making it a stable joint. It is supported by the annullar ligament of the radius, radial collateral ligamentt, tendon of the biceps brachii and the ulna collateral ligament.

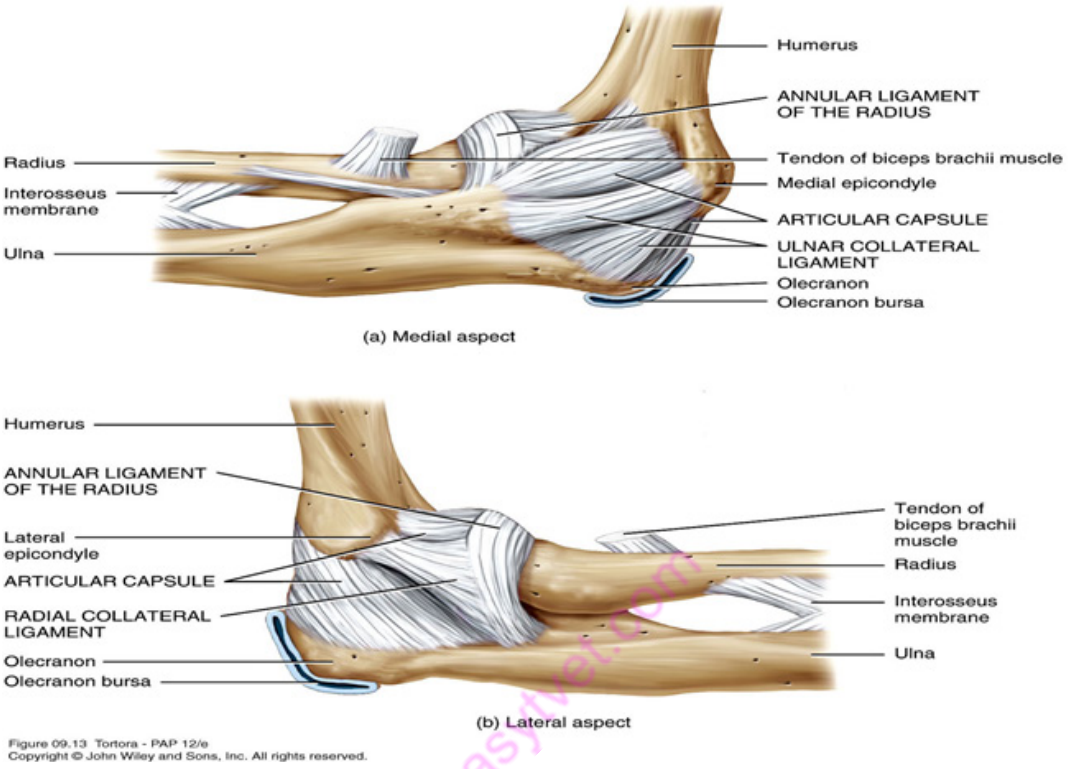


Figure 09.13 Tortora - PAP 12/e

Hip Joint

Ball-and-socket joint formed by the head of the femur and the acetabulum of the hip bone

The head and neck off the femur is enclosed by the capsular ligament.

The cavity is deepened by the acetabular labrum for stability.

It is a sturdy joint stabilized by muscles and ligaments.

Ligaments: iliofemoral, ischiofemoral, pubofemoral.

A ligament of the head of the femur; ligamentum teres attaches the femoral head to the acetabulum.

Movts: flexion, extension, abduction, adduction, rotation, circumduction.

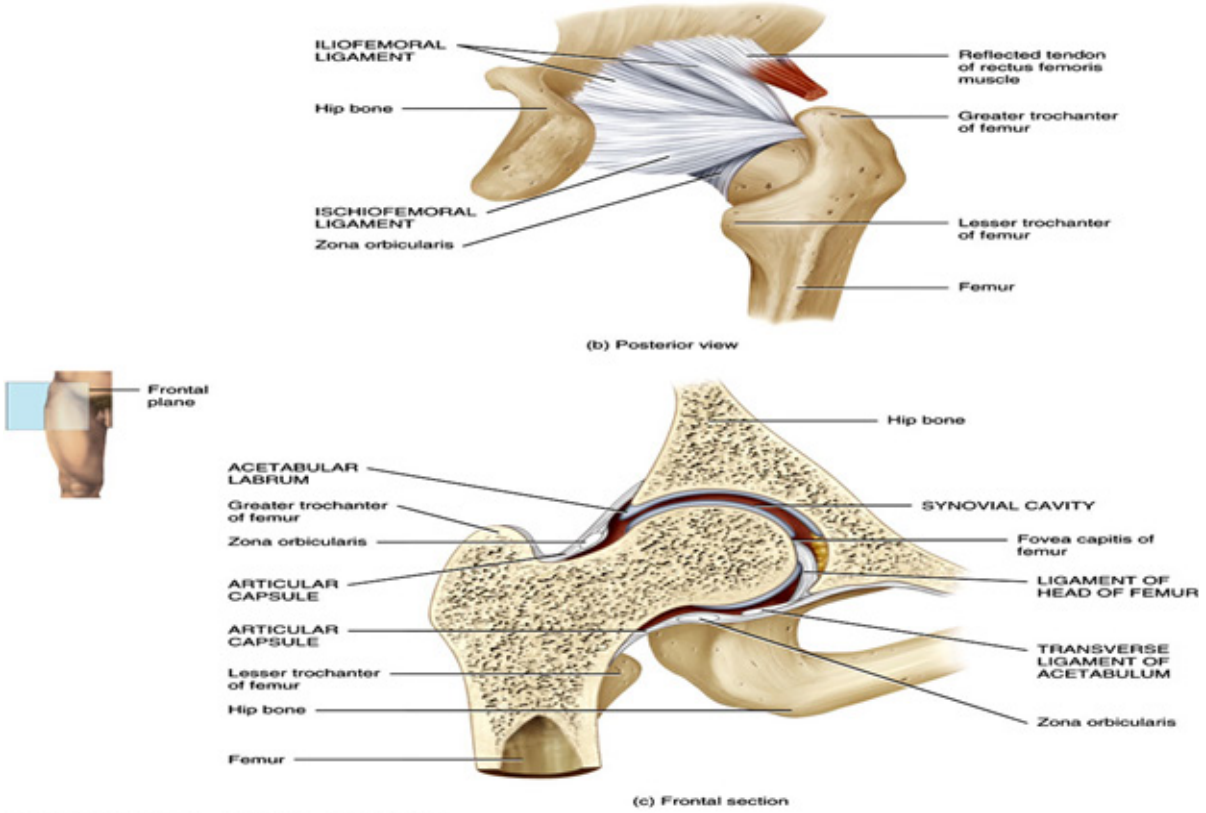


Figure 09.14bc Tortora - PAP 12/e

Knee Joint

Largest and most complex joint of the body

Modified hinge joint formed by condyles of the femur, condyles of the tibia and the posterior surface of the patella. anteriorly is the tendon of the quadriceps femoris muscle. (supports the patella)

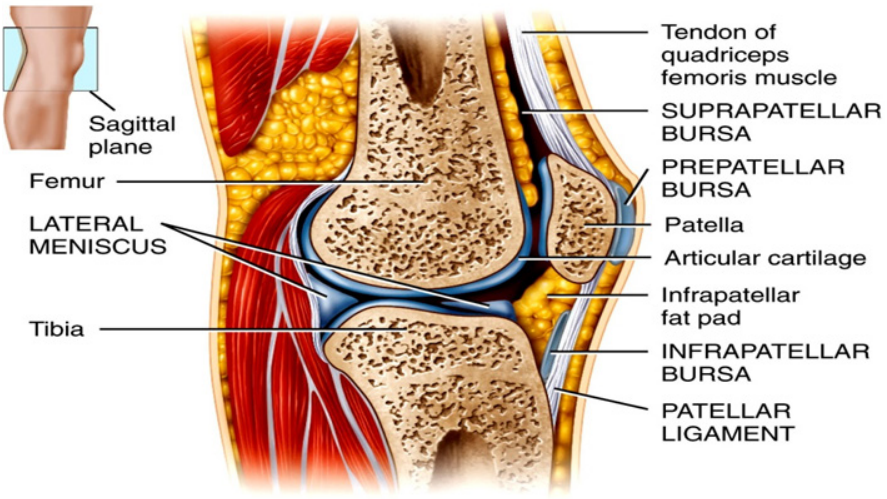
Two cruciate ligaments found intracapsularly extends from the intercondylar notch of the femur to the intercondylar eminence of the tibia crossing each other. It is covered by synovial membrane. It stabilises the joint.

The wedge shaped Semilunar cartilages/menisci lies on top of the articular condyles of the tibia provides stability, prevents lateral displacement of the bones and cushions the moving joint by shifting within the joint space in accordance with the relative positions of the articulating bones.

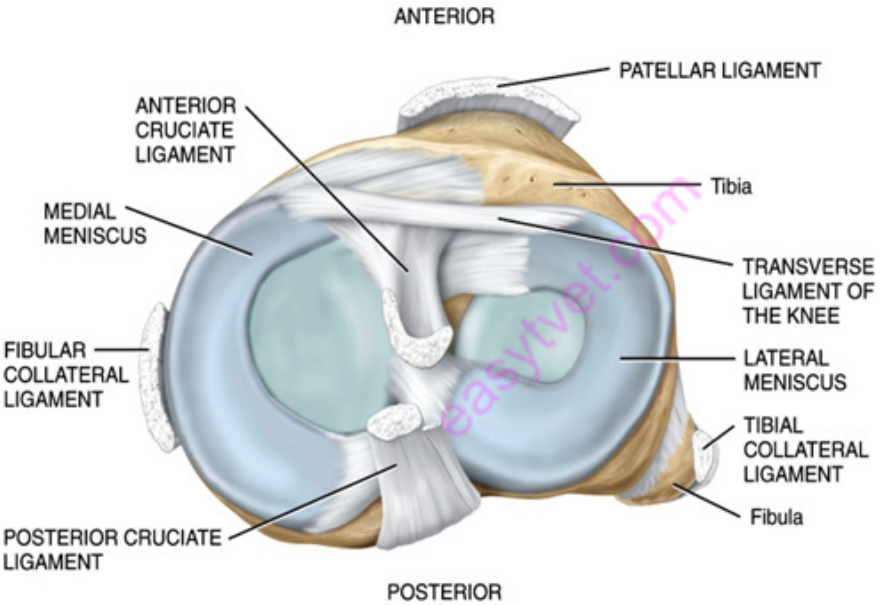
Bursae and fat pads covered by synovial membrane prevent friction between a bone and a ligament or tendon and between the skin and the patella.

Support ligaments include: patellar ligament, popliteal ligaments, and collateral ligaments.

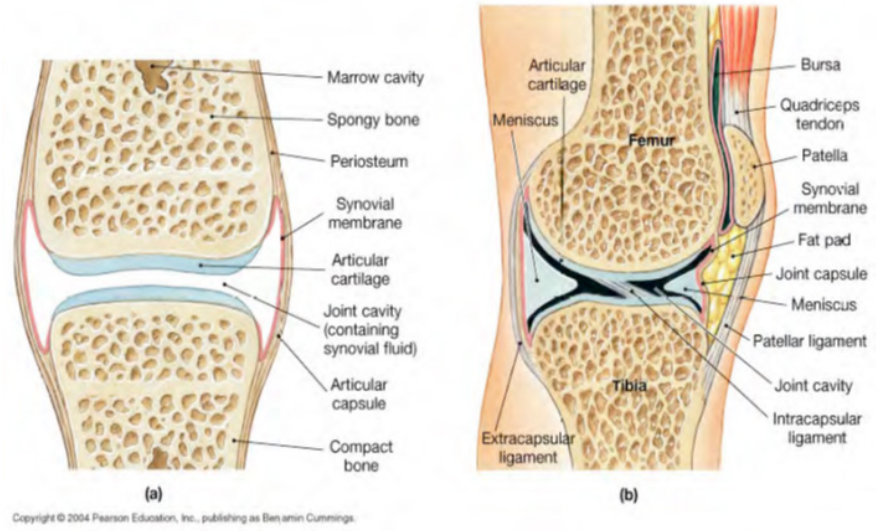
Movts: flexion, rotation, extension.



(c) Sagittal section



(e) Superior view of menisci



Joints (Aging and Joints)

Aging

May result in decreased production of synovial fluid

The articular cartilage becomes thinner

Ligaments shorten and lose some of their flexibility

Osteoarthritis is partially age-related

Stretching and aerobic exercises are helpful in minimizing the effects of aging

Help to maintain the effective functioning of ligaments, tendons, muscles, synovial fluid, and articular cartilage

Joints (Arthroplasty)

Arthroplasty

Joints may be replaced surgically with artificial joints

Most commonly replaced are the hips, knees, and shoulders

Hip Replacements

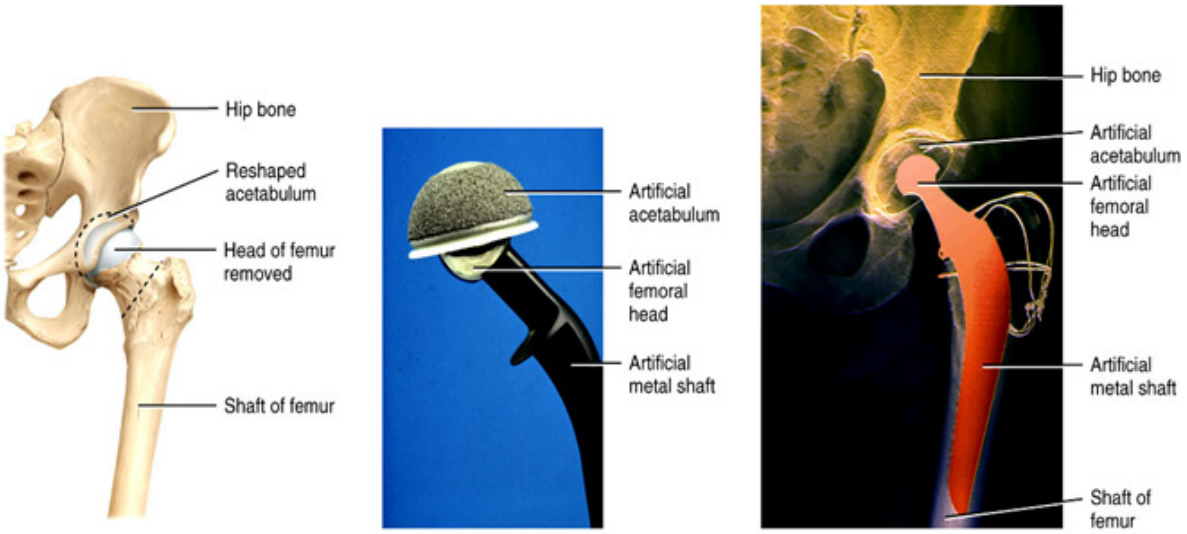
Partial hip replacements involve only the femur

Total hip replacements involve both the acetabulum and head of the femur

Knee Replacements

Actually a resurfacing of cartilage and may be partial or total

Potential complications of arthroplasty include infection, blood clots, loosening or dislocation of the replacement components, and nerve injury



(a) Preparation for total hip replacement (b) Components of an artificial hip joint (c) Radiograph of an artificial hip joint

Figure 09.16abc Tortora - PAP 12/e

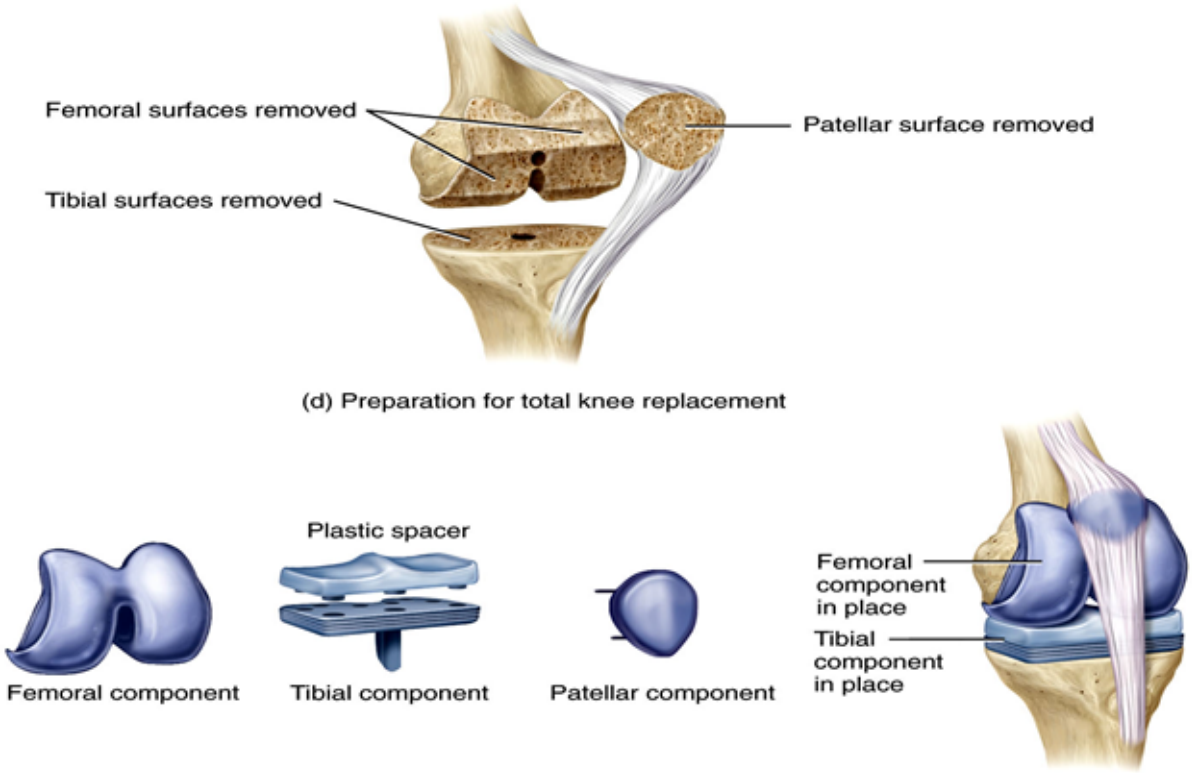


Figure 09.16de Tortora - PAP 12/e

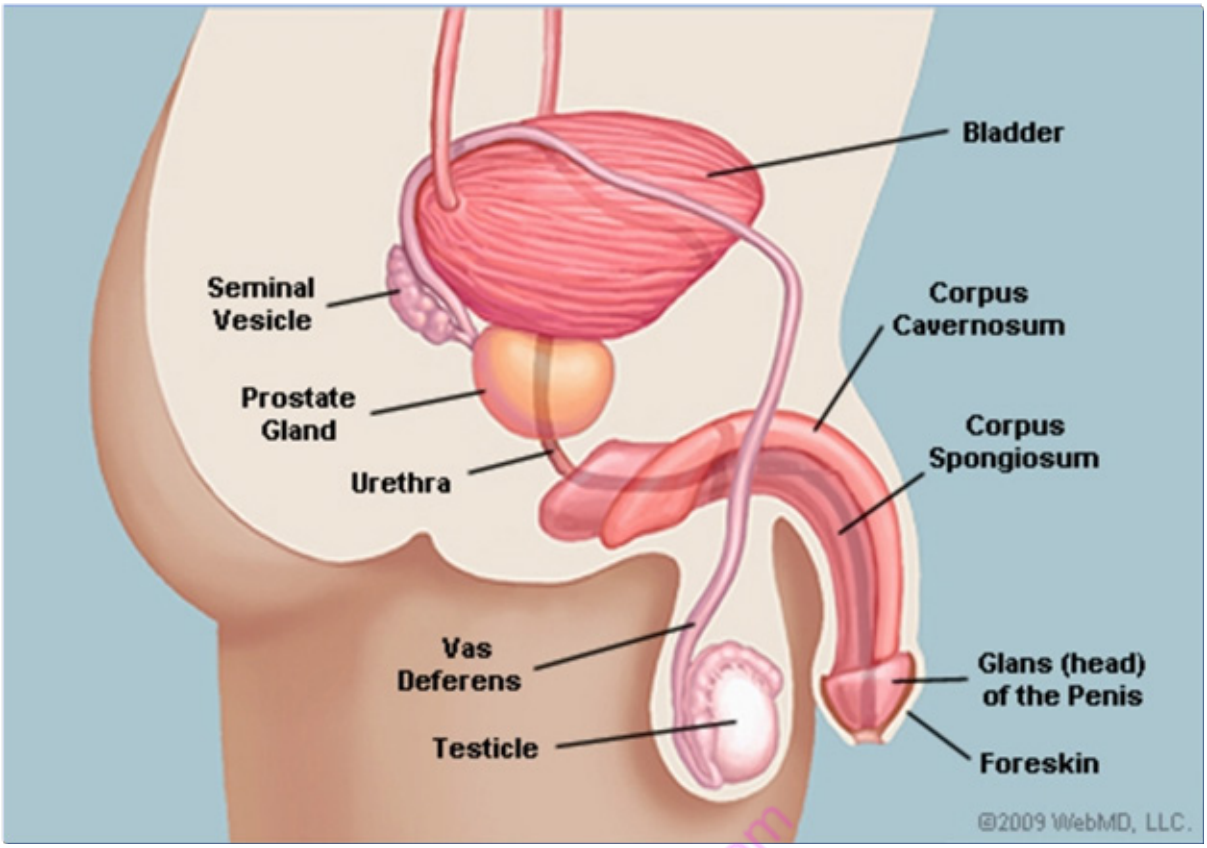
REPRODUCTIVE SYSTEM

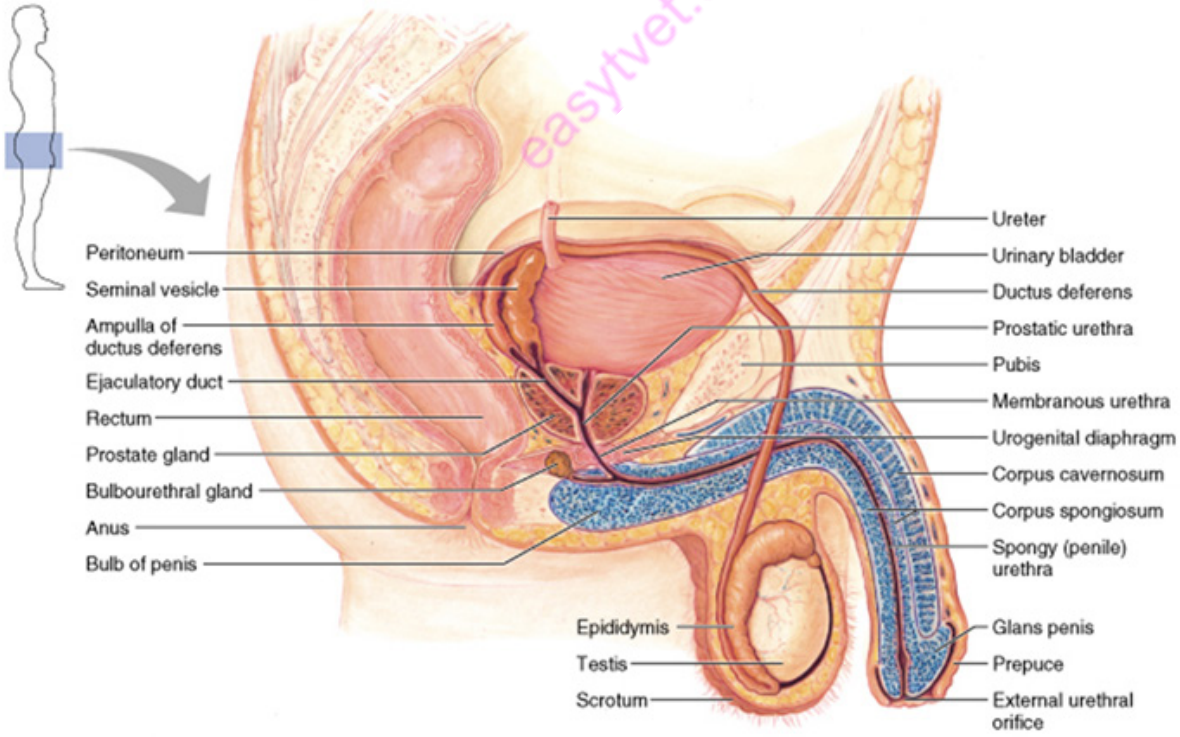
Introduction

Male and female reproductive systems function together to produce offspring

Female reproductive system nurtures developing offspring, and produce important hormones

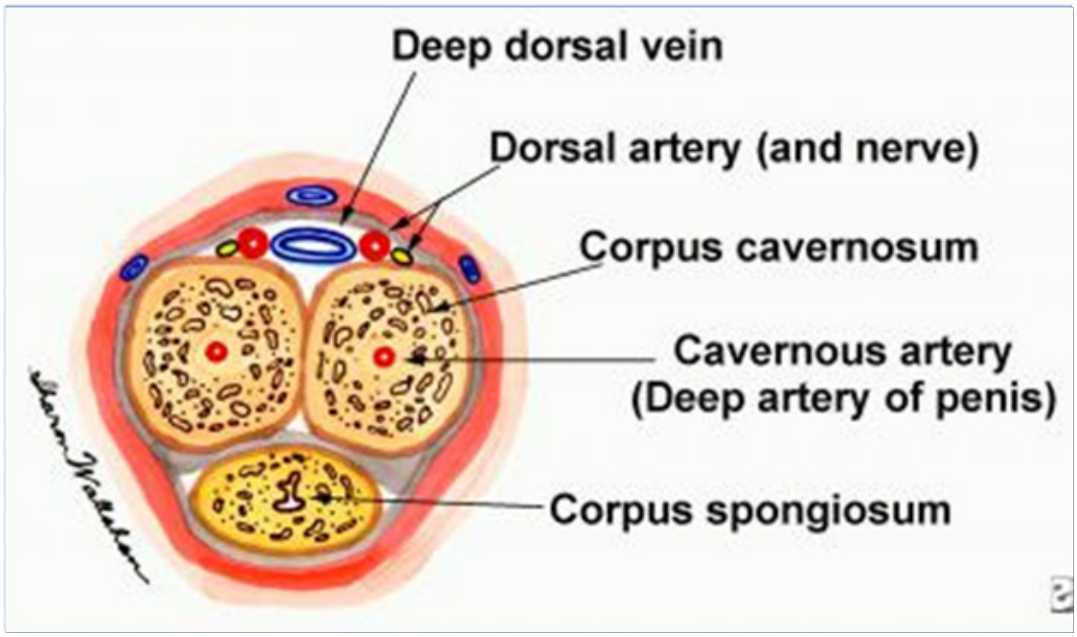
The Male Reproductive System

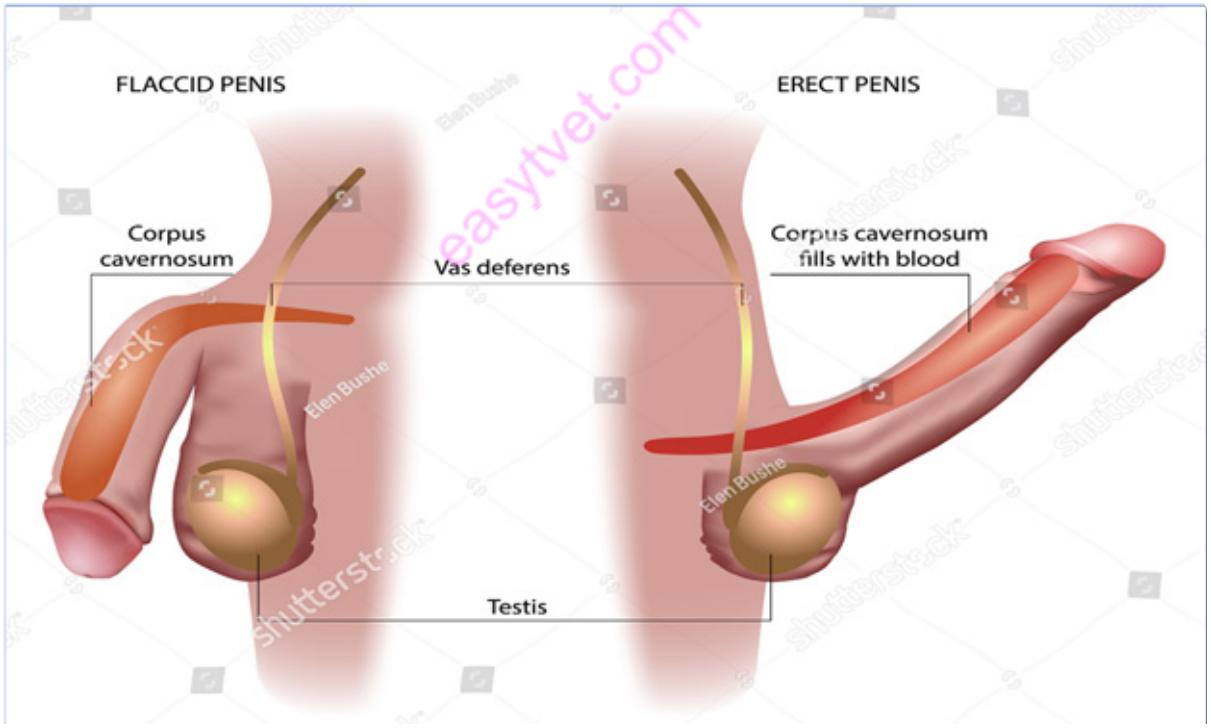




The Two Erectile Tissue of the Penis

1. Corpus cavernosum
2. Corpus spongiosum





Testes

Primary organs

Develop in the abdominal pelvic cavity of fetus

Descend into scrotal sac shortly before or after birth

Produce the male sex cells (sperm)

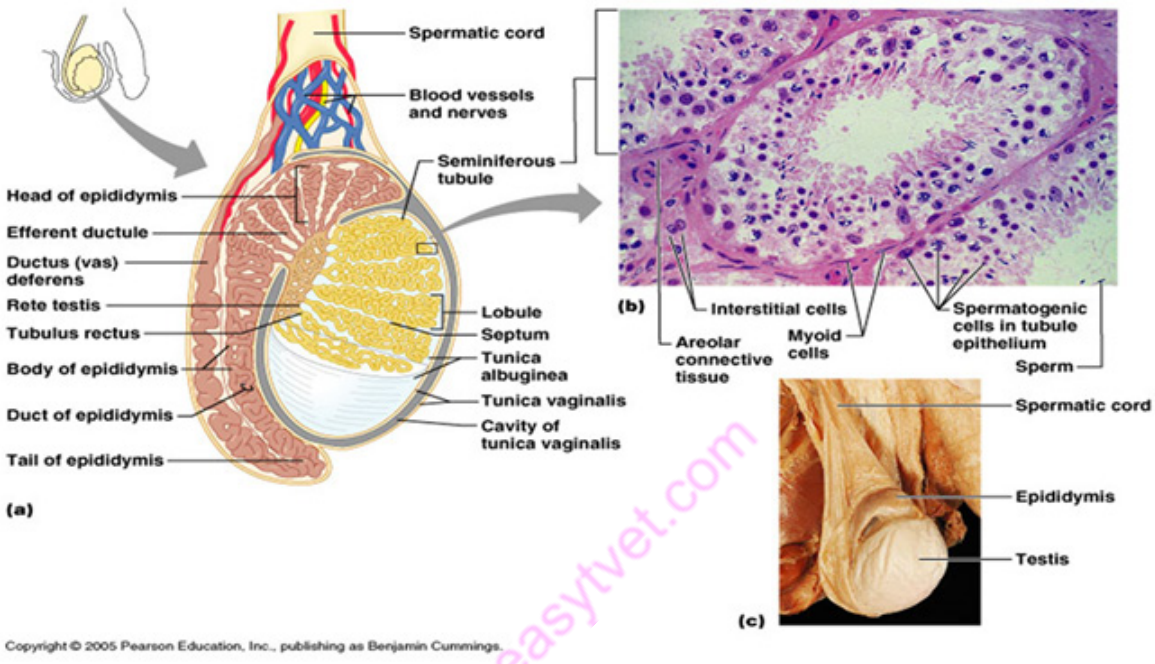
Produce the male hormone testosterone

Scrotum – sac that holds the testes

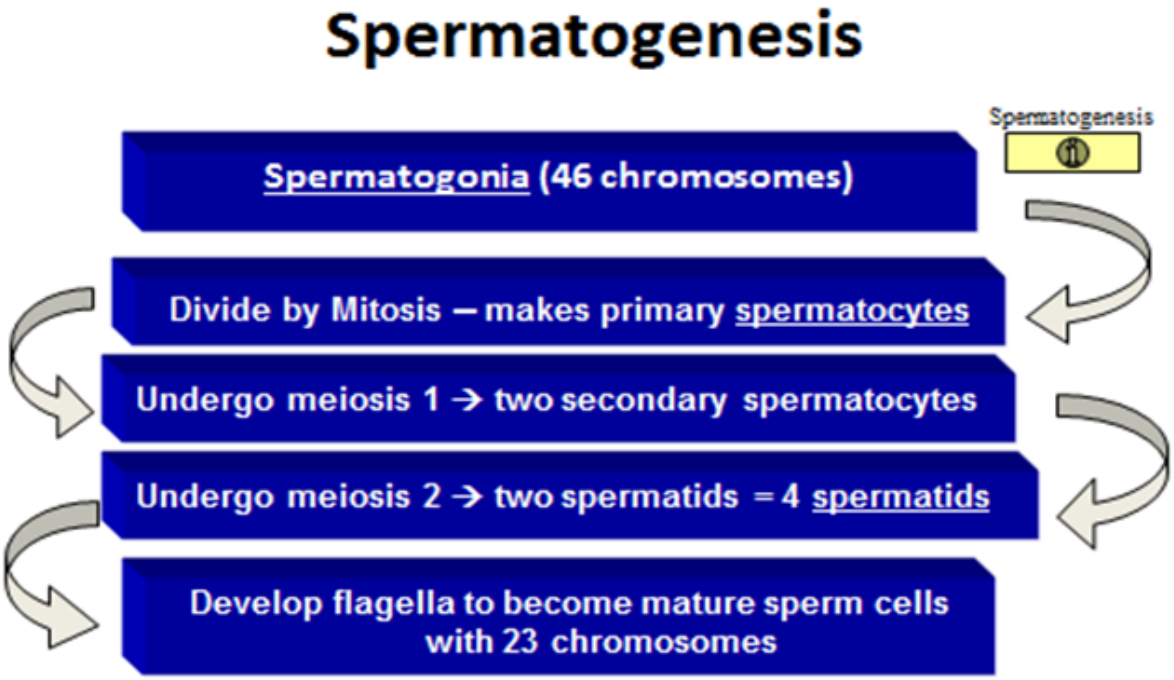
Seminiferous tubules

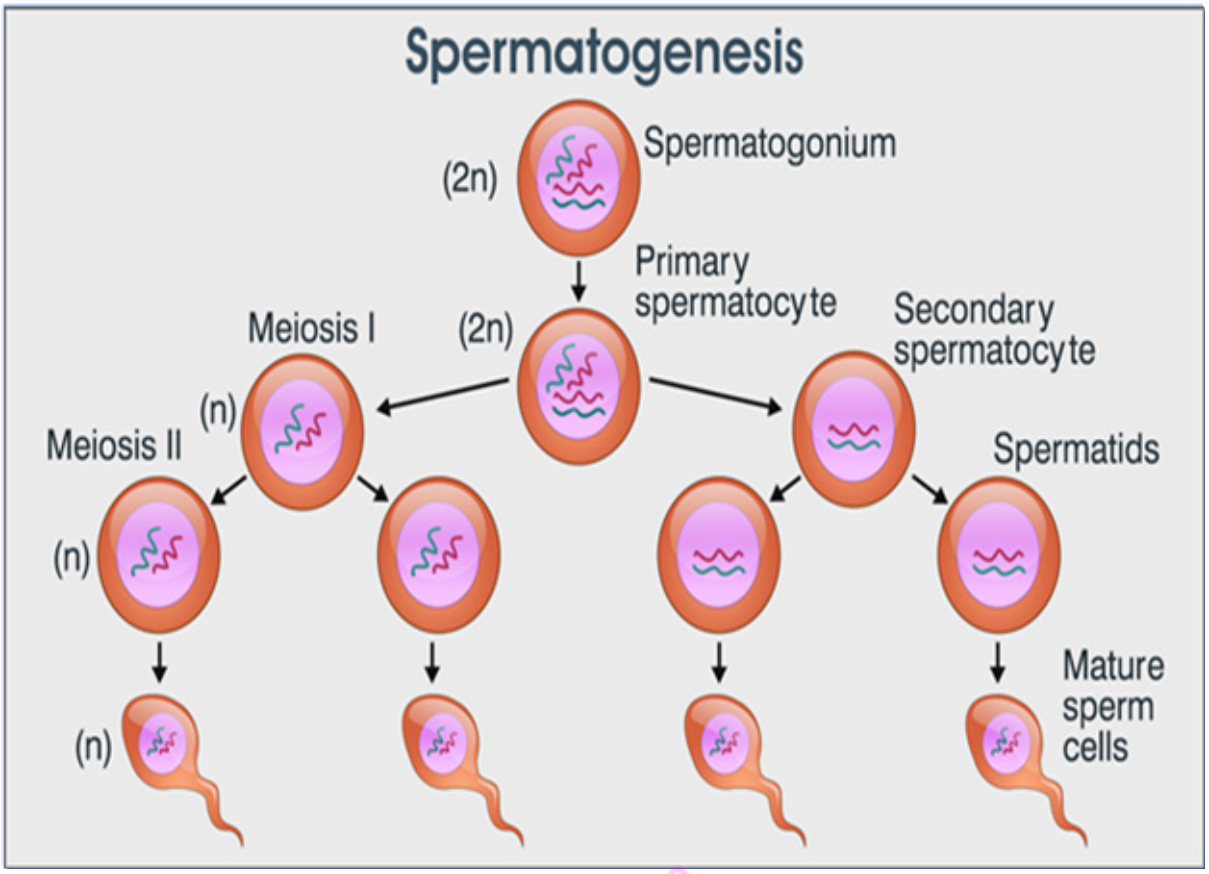
Located within the testes

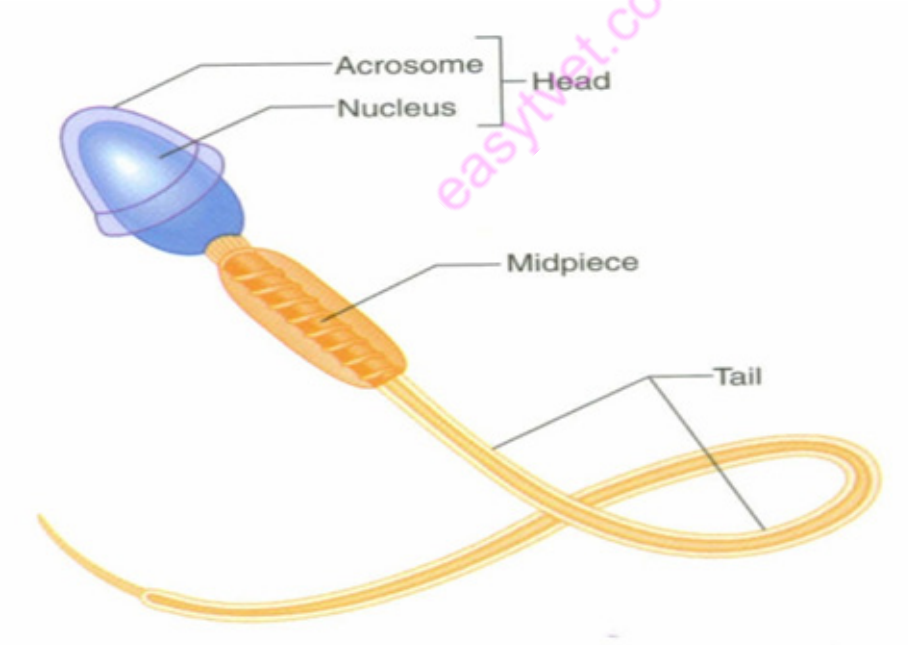
Filled with spermatogenic cells that produce sperm cells



Sperm Cells







Head

Nucleus with 23 chromosomes

Acrosome – enzyme-filled sac

Helps sperm penetrate ovum

Mid-piece

Mitochondria that generate cell's energy

Tail

Flagellum that propels sperm forward

Male Internal Accessory Organs

Epididymis

Sits on top of each testis

Receives spermatids from seminiferous tubules

Spermatids become sperm cells

Vas deferens

Tube connected to epididymis

Carries sperm cells to urethra

Seminal Vesicle

Secrete

Fluid rich in sugar used to make energy

Prostaglandins – stimulate muscular contractions in female to propel sperm forward

Seminal fluid

Released into vas deferens just before ejaculation

60% of semen volume

Prostate gland

Surrounds urethra

Produces and secretes a milky, alkaline fluid into urethra just before ejaculation

Fluid protects sperm in the acidic environment of the vagina

40% of semen

Bulbourethral (Cowper's) glands

Produce a mucus-like fluid

Secreted just before ejaculation

Lubricates end of penis

Semen

Alkaline mixture

Nutrients

Prostoglandins

to 5.0 ml per ejaculate

Sperm count of 40 to 250 million/mL

Male External Accessory Organs

Scrotum

Holds testes away from body

Temperature 1° below body temperature

Lined with serous membrane that secrets fluid

Testes move freely

Penis

Shaft

Erectile tissues surround urethra. That is

Corpus Cavernosum

Corpus spongiosum

Glans penis

Cone-shaped structure on end of penis

Contain sensory nerve endings which causes an orgasm--ejaculation

Prepuce

Skin covering glans penis in uncircumcised males

Functions

Deliver sperm

Urination

Sexual Response Cycle

It has four phases.

Phase 1: Excitement

General characteristics of the excitement phase, which can last from a few minutes to several hours, include the following:

Muscle tension increases.

Heart rate quickens and breathing is accelerated.

Skin may become flushed (blotches of redness appear on the chest and back).

Nipples become hardened or erect.

Blood flow to the genitals increases, resulting in swelling of the woman's clitoris and labia minora (inner lips), and erection of the man's penis.

Vaginal lubrication begins.

The woman's breasts become fuller and the vaginal walls begin to swell.

The man's testicles swell, his scrotum tightens, and he begins secreting a lubricating liquid.

Phase 2: Plateau

General characteristics of the plateau phase, which extends to the brink of orgasm, include the following:

The changes begun in phase 1 are intensified.

The vagina continues to swell from increased blood flow, and the vaginal walls turn a dark purple.

The woman's clitoris becomes highly sensitive (may even be painful to touch) and retracts under the clitoral hood to avoid direct stimulation from the penis.

The man's testicles are withdrawn up into the scrotum.

Breathing, heart rate, and blood pressure continue to increase.

Muscle spasms may begin in the feet, face, and hands.

Muscle tension increases.

Phase 3: Orgasm

The orgasm is the climax of the sexual response cycle. It is the shortest of the phases and generally lasts only a few seconds.

General characteristics of this phase include the following:

Involuntary muscle contractions begin.

Blood pressure, heart rate, and breathing are at their highest rates, with a rapid intake of oxygen.

Muscles in the feet spasm.

There is a sudden, forceful release of sexual tension.

In women, the muscles of the vagina contract. The uterus also undergoes rhythmic contractions.

In men, rhythmic contractions of the muscles at the base of the penis result in the ejaculation of semen.

A rash, or "sex flush" may appear over the entire body

Phase 4: Resolution

During resolution, the body slowly returns to its normal level of functioning, and swelled and erect body parts return to their previous size and color.

This phase is marked by a general sense of well-being, enhanced intimacy and, often, fatigue.

Some women are capable of a rapid return to the orgasm phase with further sexual stimulation and may experience multiple orgasms.

Men need recovery time after orgasm, called a refractory period, during which they cannot reach orgasm again.

Erection, Orgasm & Ejaculation

Erection

Parasympathetic nervous system stimulates erectile tissue i.e. corpus cavernosum and corpus spongiosum

Becomes engorged with blood

Orgasm

Rhythmic peristaltic contractions of the smooth muscles of the urethra and accessory glands.

Sperm cells propelled out of testes into urethra

Secretions from accessory organs also released into urethra

Emission and Ejaculation

Emission --Semen is forced into the urethra

Ejaculation– forceful expulsion of semen from the urethra out of the penis

Emission and ejaculation are stimulated by sympathetic nervous system , which cause peristaltic contractions of the tubular system, contractions of the seminal vesicle and prostate and contractions of the muscles at the base of the penis.

Sympathetic nerves then stimulate erectile tissue to release blood

Penis returns to flaccid state

Male Reproductive Hormones

- Hypothalamus
- Gonadotropin-releasing hormone (GnRH)
- Stimulates anterior pituitary to release
- Follicle-stimulating hormone (FSH) – initiates spermatogenesis
- Luteinizing hormone (LH) – stimulates interstitial cells in the testes to produce testosterone
- Testosterone

Secondary sex characteristics

Maturation of male reproductive organs

Regulated by negative feedback

Diseases and Disorders of the Male Reproductive System

- Prostate cancer—most common form of cancer for men over 40 years. Risk factor of getting it increases with age.
- Prostatitis—inflammation of the prostate gland. It may be acute or chronic
- Testicular cancer—malignant growth in one or both testis. More common in men between 15-30 years; more aggressive malignancy
- Benign prostatic hypertrophy (BPH)—non-malignant enlargement of the prostate gland. Common among older men
- Epididymitis—inflammation of the epididymitis. Common cause is lower urinary tract inflammation.
- Impotence or erectile dysfunction—disorder in which erection cannot be achieved or maintained. About 50% of men between 50 and 70 experience some degree of erectile dysfunction

Female Reproductive System

Two Ovaries

Primary sex organs produce sex cells called ova, Hormones estrogen and progesterone

Located in the pelvic cavity

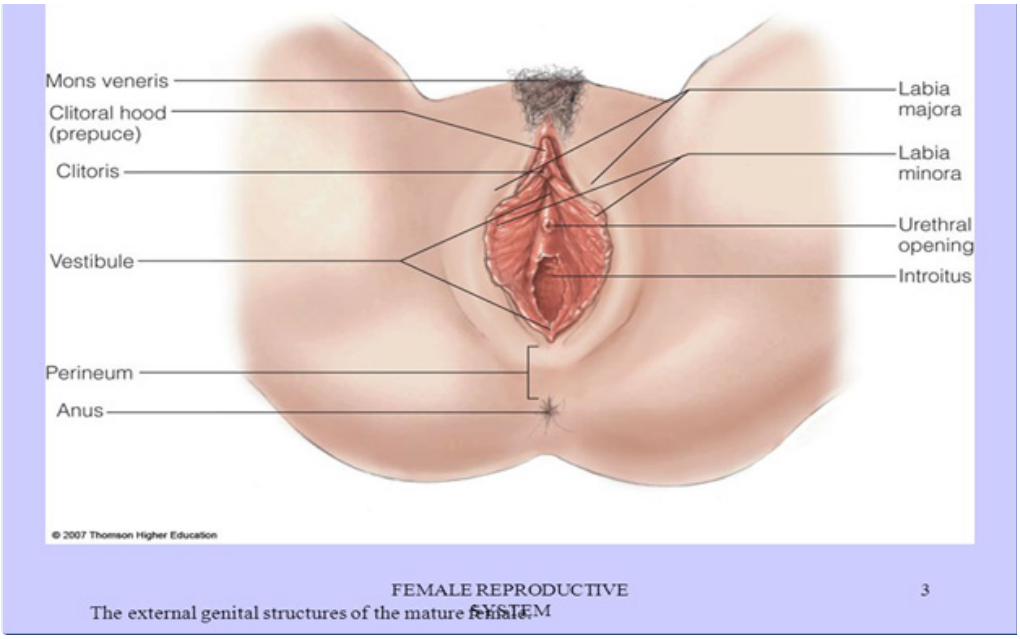
Medulla

Inner area; contains nerves, lymphatic vessels, and blood vessels

Cortex

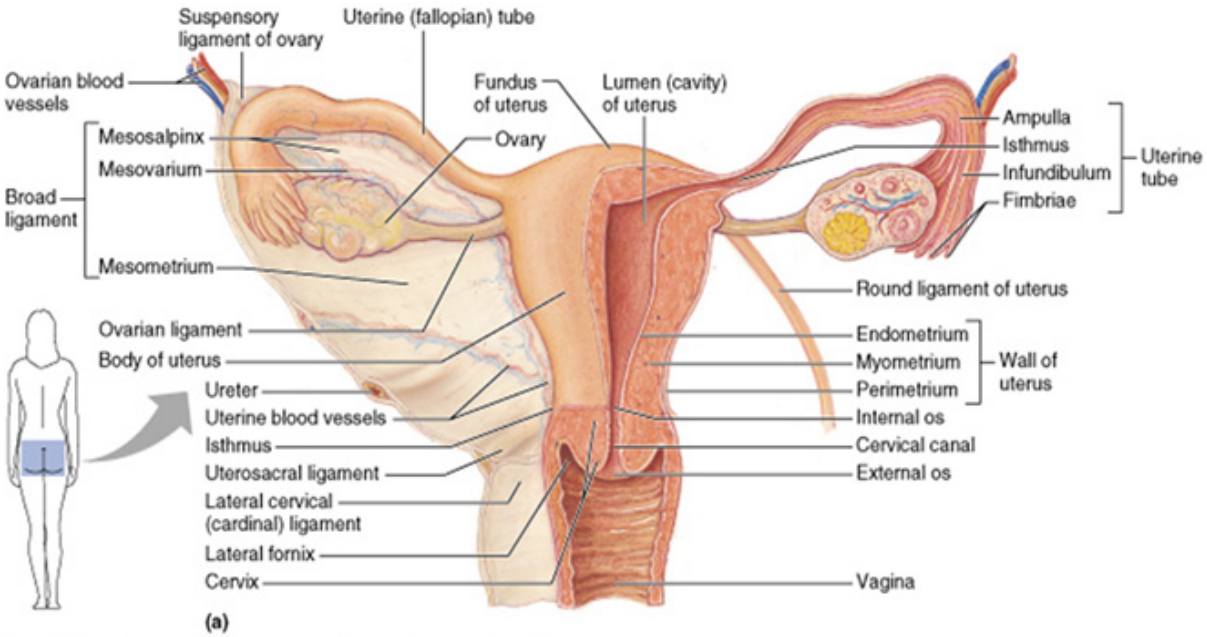
Outer area; contains ovarian follicles

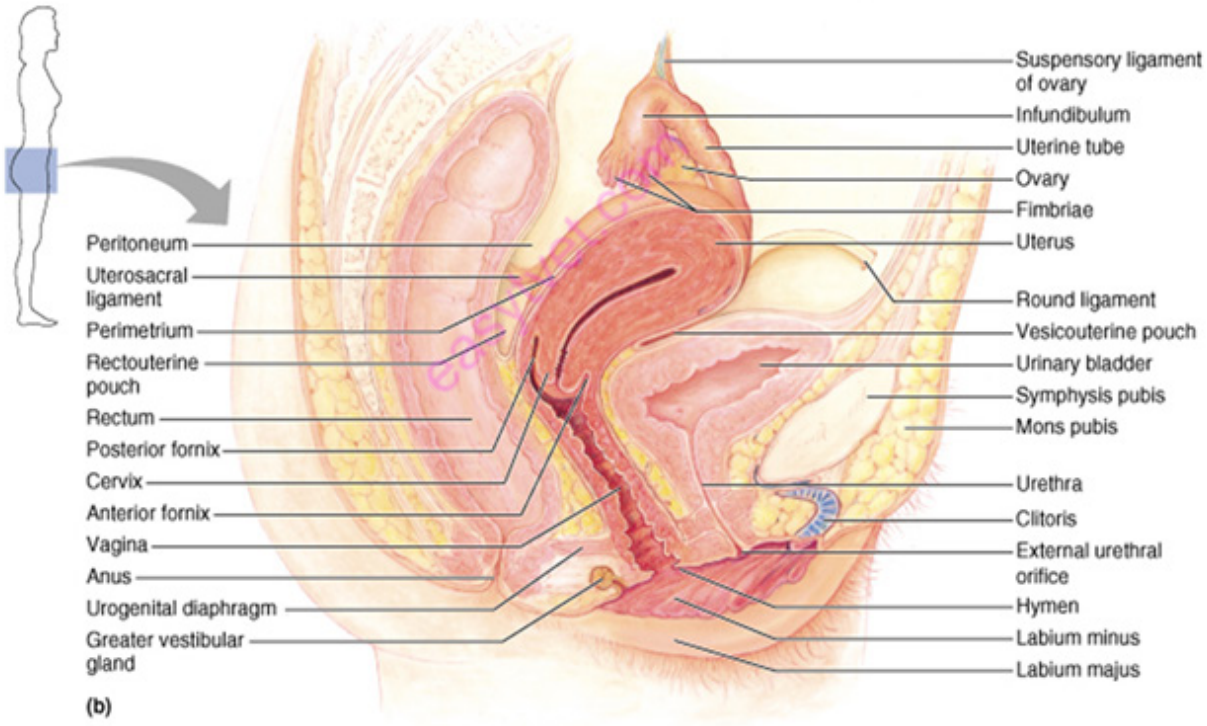
Covered by epithelial and dense connective tissues



FEMALE REPRODUCTIVE SYSTEM 3

The external genital structures of the mature female.





Ovum Formation (cont.)

Primordial follicles develop before birth and contain a primary oocyte or immature ovum (born with maximum number) *Follicular cells*

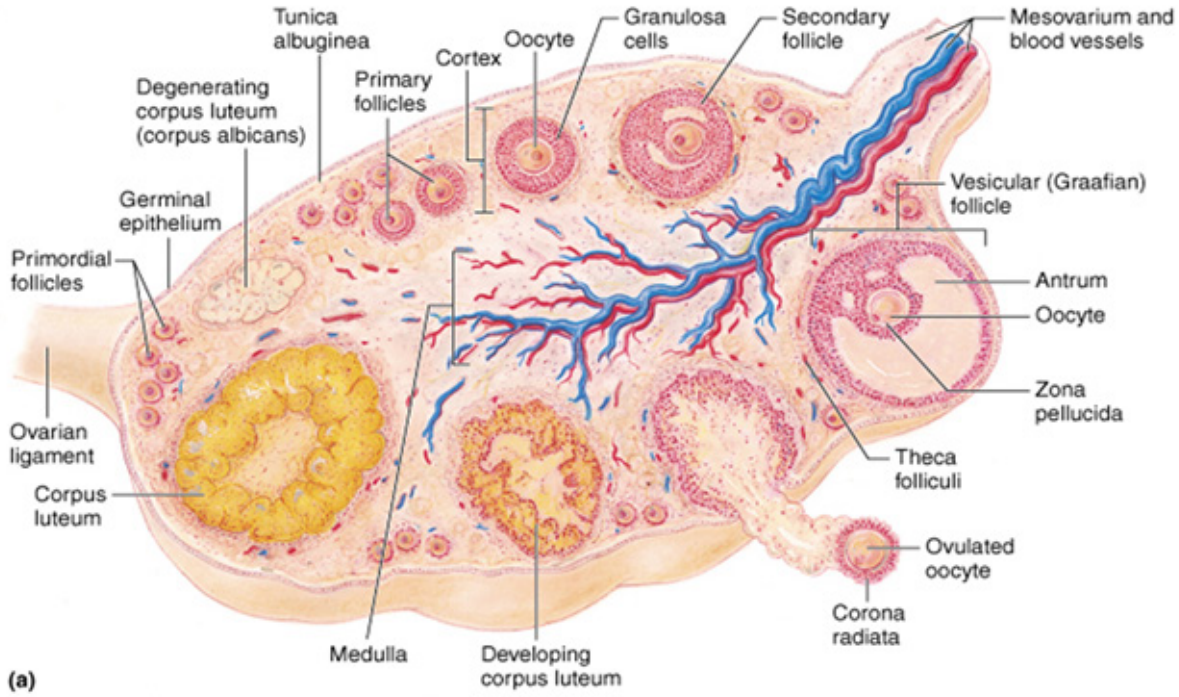
Oogenesis is the process of ovum formation

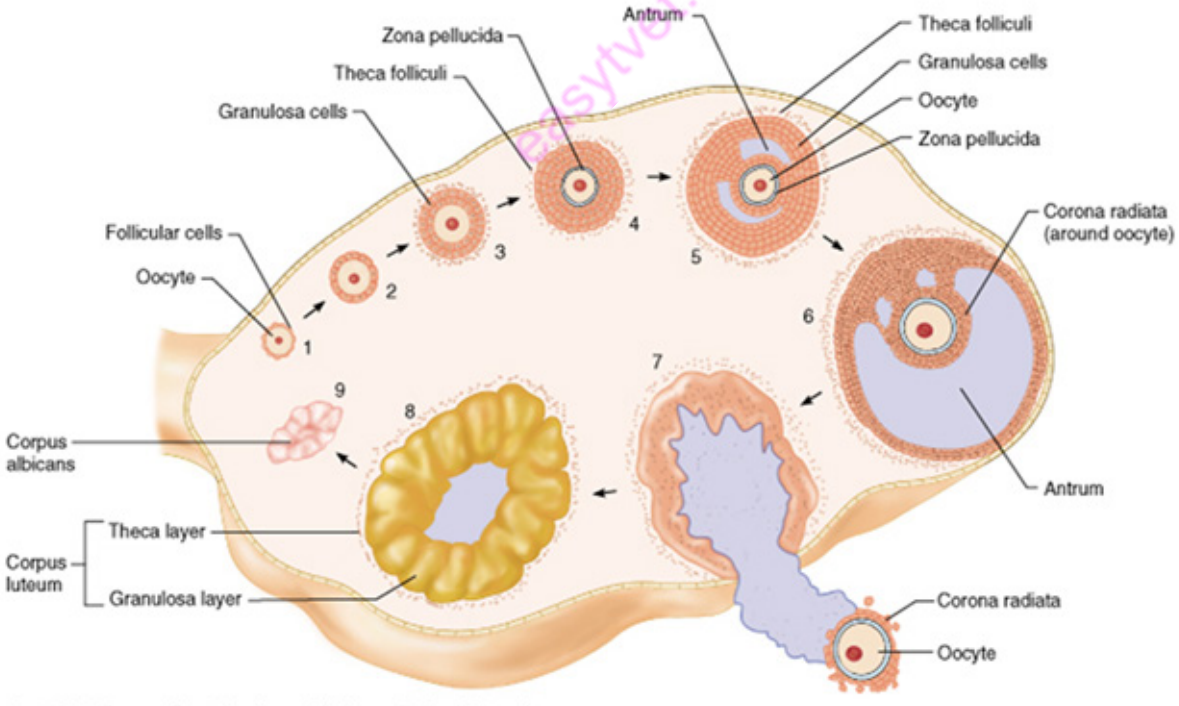
At puberty, primary oocytes are stimulated to continue meiosis

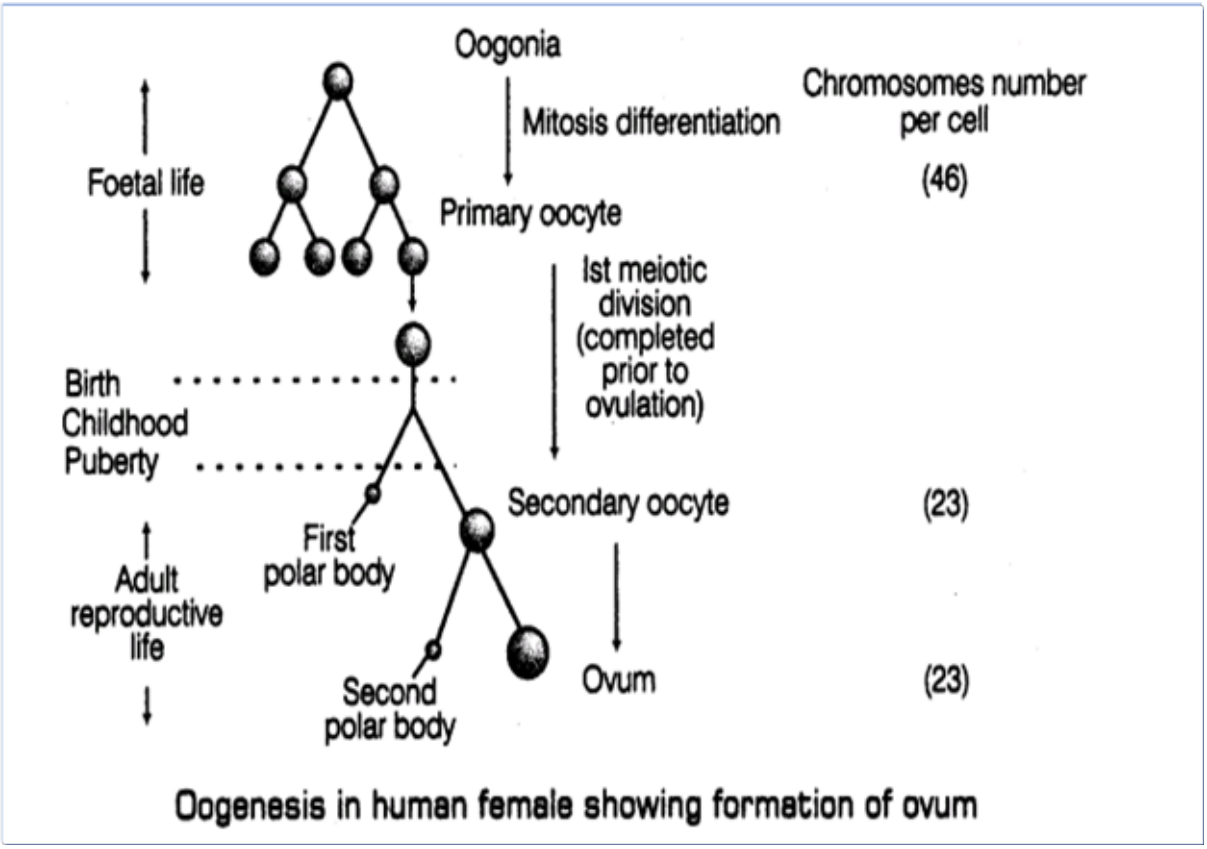
Becomes 1 polar body (a nonfunctional cell) and a secondary oocyte

Secondary oocyte released during ovulation

If fertilized, the oocyte divides to form a mature, fertilized ovum







Oogenesis in human female showing formation of ovum

Female Internal Accessory Organs

Fallopian tube – oviduct

***Infundibulum and fimbri*ae**

Fringed, expanded end of fallopian tube near ovary

Function to "catch" an ovum

Muscular tube

Lined with mucous membrane and cilia

Propels ovum toward uterus

Uterus

Hollow, muscular organ, and receives embryo and sustains its development

Divisions

- Fundus – domed upper portion
- Body – main portion
- Cervix – narrow, lower section extending into vagina (cervical orifice)

Wall of uterus

Endometrium

Innermost lining

Vascular

Tubular glands – mucus

Myometrium

Middle, thick, muscular layer

Perimetrium

Thin layer covering the myometrium

Secretes serous fluid to coat and protect uterus

Vagina

Tubular, muscular organ which extends from uterus to outside body (vaginal introitus)

Muscular folds – rugae – enable expansion

Receive erect penis

Passage for delivery of offspring and uterine secretions

Wall

Innermost mucosal layer

Middle muscular layer

Outer fibrous layer

External Accessory Organs

Mammary glands

Secretion of milk

Structures

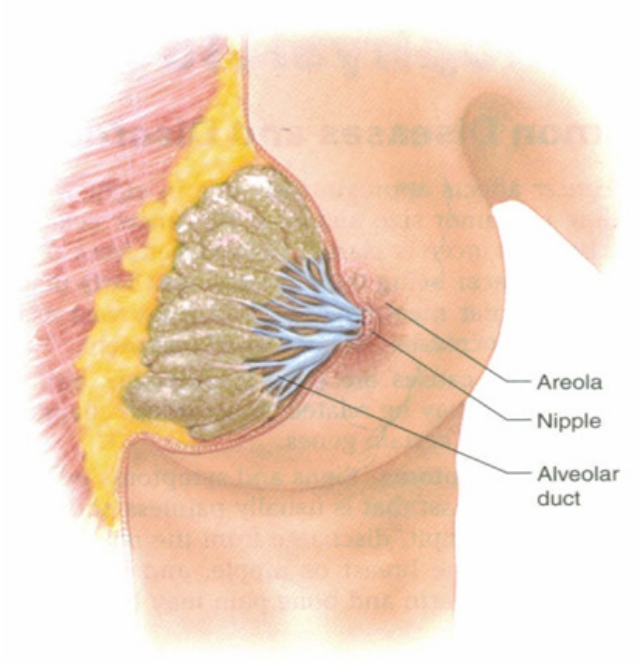
Nipple

Oxytocin induces lactiferous ducts to deliver milk through openings

Areola – pigmented area around nipple

Alveolar glands – within mammary glands

Make milk when stimulated by prolactin



External Genitalia

Collectively known as the vulva

Labia majora

Rounded folds of adipose tissue and skin

Protect other external reproductive organs

Labia minora

Folds of skin between labia majora

Very vascular

Merge to form hood over clitoris

Vestibule – space enclosed by labia minora

Bartholin's glands secrete mucus during sexual arousal

Clitoris

Anterior to urethral meatus

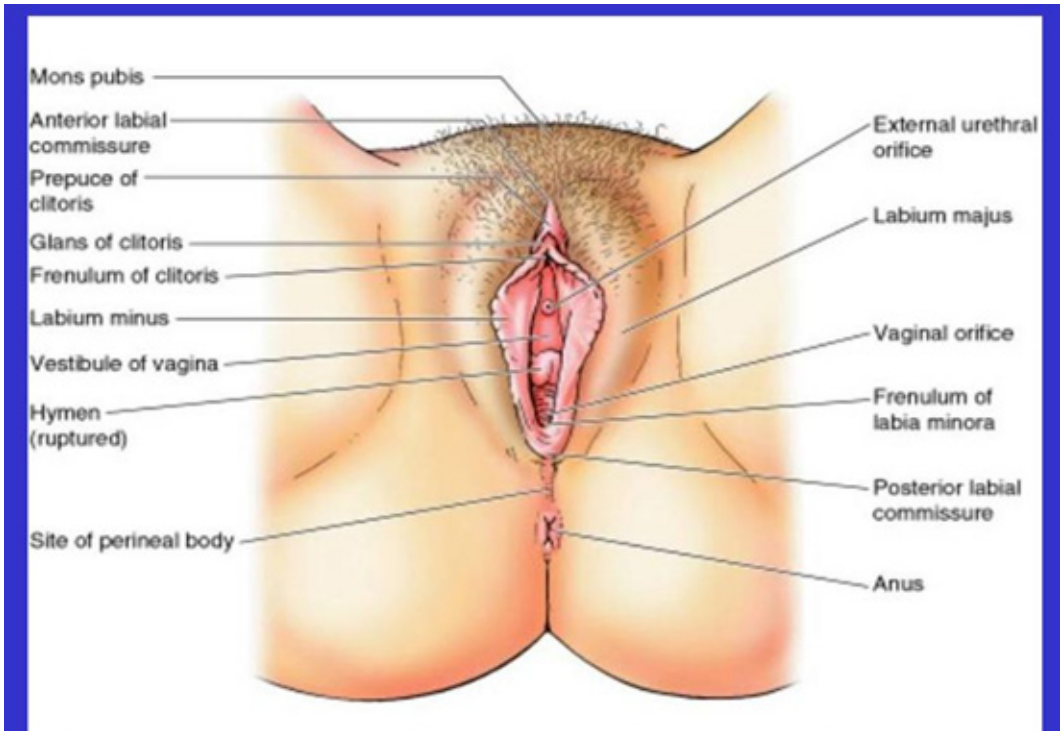
Contains female erectile tissue

Rich in sensory nerves

Perineum

Between vagina and anus

Area for episiotomy, if needed, during birth process



Erection, Lubrication, and Orgasm

Nervous stimulation

Clitoris becomes erect

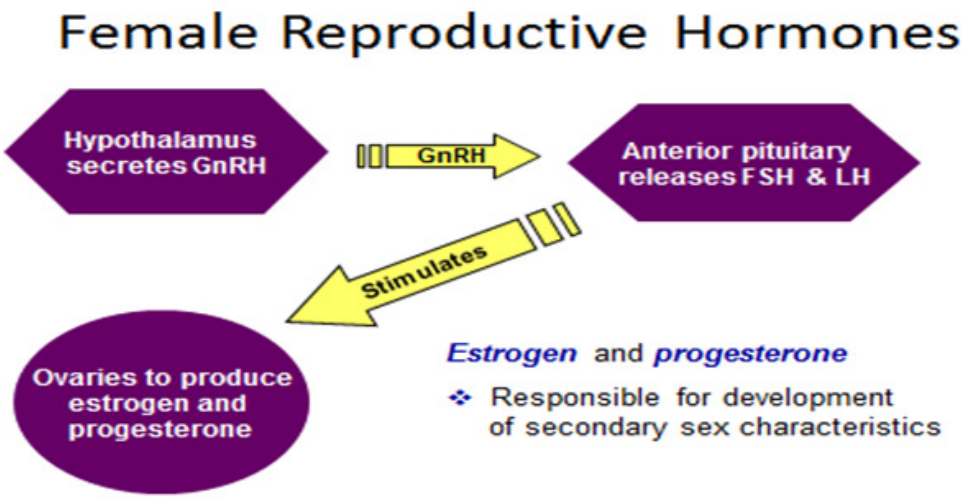
Bartholin's glands activated – lubrication

Vagina elongates

Orgasm

Sufficient stimulation of clitoris

Walls of uterus and fallopian tubes contract to propel sperm up tubes



Reproductive Cycle

Menstrual cycle

Regular changes in uterine lining, resulting in monthly bleeding

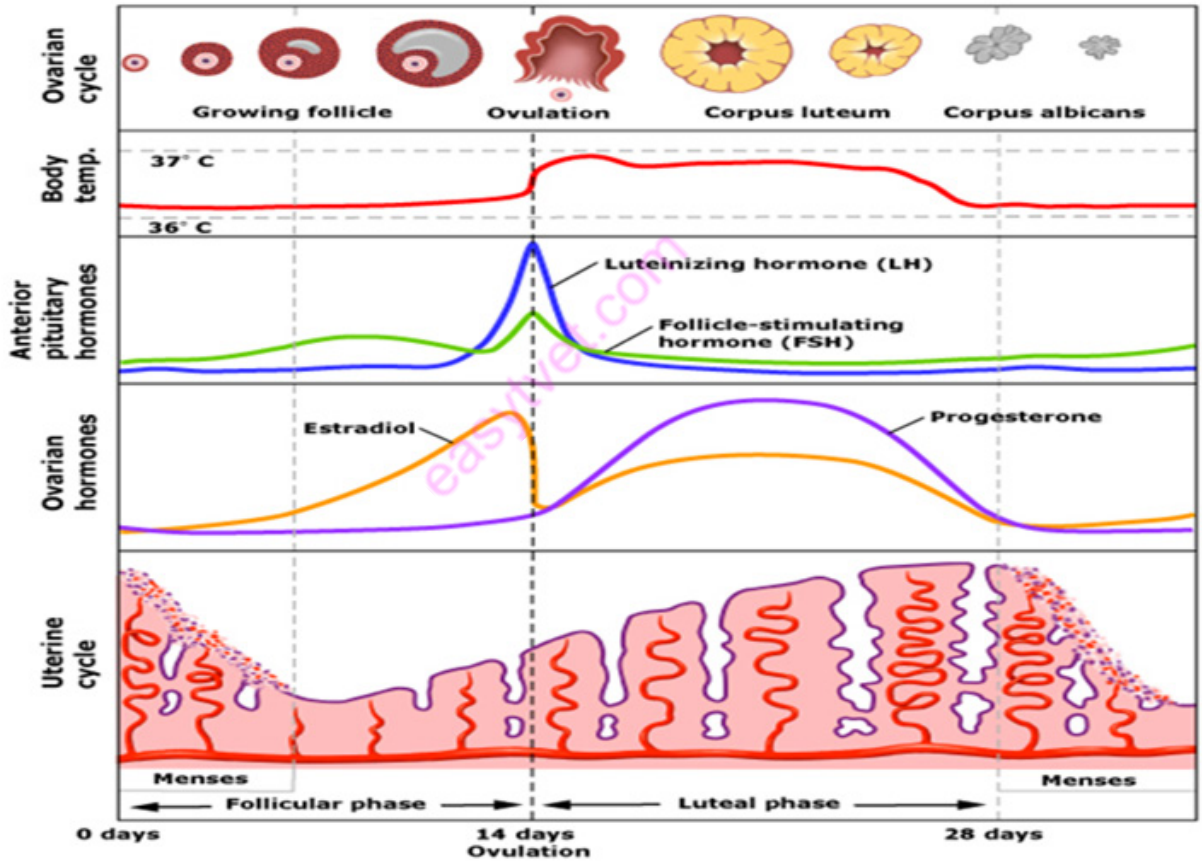
Ovarian Cycle

Menarche – first menstrual period

Menopause – termination of cycle due to normal aging of ovaries

Phases of the Menstrual Cycle

1. ***The Menstrual Phase:*** Day (1-5) – During this phase the endometrium is shed. There is bleeding.



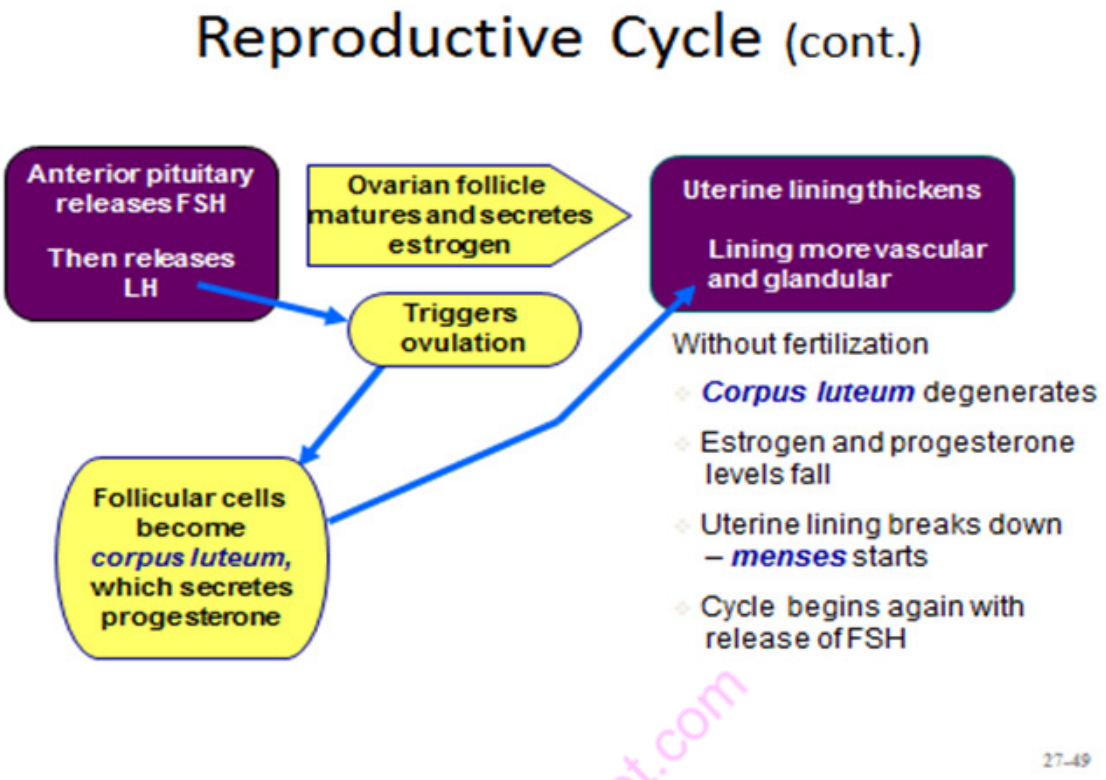
2. Proliferative Phase: Day (6-14)

During this phase the endometrium builds a new stratum functionalis as it responds to rising estrogen levels. As the layer thickens glands secrete a clear sticky mucus that help the sperm to find the egg.

3. Secretory phase: Day (15-28)

During this phase the stratum functionalis is highly vascularised and there is secretion of glycoproteins to support a developing embryo incase the fertilization occurs. These changes are response to progesterone released by the corpus luteum in the ovary. If there is no

fertilization, the progesterone level drops signaling changes that cause death of the stratum functionalis. The arteries constrict cutting out blood supply and suddenly opens again but the weak capillaries fragment and the menstrual phase begins again.



Diseases and Disorders of the Female Reproductive System

- Breast cancer—second leading cause of cancer deaths in women; classified as stage 0 to 4
- Cervical cancer—slow to develop; pap smear detects abnormal cervical cells
- Cervicitis—inflammation of the cervix often due to infection
- Dysmenorrhea—a condition with severe menstrual cramps that limit daily activities
- Endometriosis—tissues of the uterine lining growing outside the uterus
- Fibrocystic breast disease—abnormal cystic tissue in the breast; size varies according to the menstrual cycle; common in 60% of women between 30 and 50 years.
- Fibroids—benign growth in the uterine wall; affects 25% of women in their 30s and 40s
- Ovarian cancer—considered more deadly than other types; detection difficult and only detected when it has spread to other areas
- Premenstrual syndrome (PMS)—collection of symptoms occurring just before a menstrual period
- Vaginitis/vulvo-vaginitis—inflammation of the vagina/inflammation of the vagina and vulva; both associated with abnormal vaginal discharge

- Uterine/endometrial cancer—most common in post-menopausal women; causes about 6% of cancer deaths among women

Pregnancy

Pregnancy – condition of having a developing offspring in the uterus

Fertilization – process in which a sperm cell unites with an ovum; results in pregnancy

Only one sperm cell penetrates the follicular cells and the zona pellucida that surround the ovum's cell membrane

After fertilization, ovum releases enzymes that cause the zona pellucida to become impenetrable to other sperm

Zygote forms from union of ovum and sperm, it contains 46 chromosomes.

The Prenatal Period

Time before birth

Zygote – undergoes rapid mitosis

First week after fertilization

Cleavage – rapid cell division

Morula – ball of cells resulting from cleavage

Travels down fallopian tube to uterus

Becomes blastocyst, which implants in endometrial wall

Blastocyst

Some cells (inner cell mass) become embryo

Others, along with cells from uterus, form placenta

Embryonic period

Week 2 through 8

Inner cell mass organizes into three primary germ layers

Ectoderm | Mesoderm | Endoderm

Formation of

Placenta | Amnion | Umbilical cord | Yolk sack

Most internal organs and external structures of embryo

Last 3 months – fetal brain cells rapidly divide

GI and respiratory systems last to develop.

Fetal period

Week 8 through birth

Rapid growth

5th month – skeletal muscles active

6th month – gains weight

Fetal Circulation

Placenta and umbilical blood vessels carry out the exchange of nutrients, oxygen, and waste products.

Unique differences from normal circulation

Foramen ovale – hole between right and left atria enables most of fetal blood to bypass lungs

- Ductus arteriosus – connection between pulmonary artery and aorta.
- Ductus venosus – vessel that bypasses liver

Hormonal Changes During Pregnancy

Embryonic cells secrete human chorionic gonadotropin (HCG)

Maintains the corpus luteum

Estrogen and progesterone

Secreted by corpus luteum and placenta

Functions

Stimulate uterine lining to thicken, development of mammary glands, enlargement of female reproductive organs

Inhibit release of FSH and LH from anterior pituitary gland (preventing ovulation) and uterine contractions

Relaxin

From corpus luteum

Inhibits uterine contractions and relaxes ligaments of pelvis

Lactogen

From placenta

Stimulates enlargements of mammary glands

Aldosterone

From adrenal gland

Increases sodium and water retention

Parathyroid hormone (PTH)

Helps maintain high calcium levels in the blood

The Birth Process

Begins when progesterone levels fall

Prostaglandins secreted by uterus stimulate uterine contractions

Uterine contractions stimulate posterior pituitary gland to release oxytocin

Oxytocin stimulates strong uterine contractions

Three stages

Dilation

Cervix thins and softens (effacement)

Lasts 8 – 24 hours

Expulsion or parturition

Actual birth

May take 30 minutes or less

Placental stage – 10 to 15 minutes after the birth, the placenta separates from uterine wall and is expelled.

The postnatal period

Six-week period following birth

Neonatal period – first four weeks

Neonate is adjusting to life outside uterus

Milk production and secretion

Prolactin – production of milk

Oxytocin – ejection of milk from mammary gland ducts

Production continues as long as breast-feeding continues

GASTRO INTESTINAL SYSTEM

Digestive System

Responsible for providing raw materials to support life:

Food molecules catabolized for energy and building blocks to supply anabolic reactions (cell division, repair, secretions, etc.)

Digestive System Organization

1. Gastrointestinal (Gl) tract (Alimentary canal)

Tube within a tube

Direct link/path between organs

Structures

- Mouth
- Oral Cavity
- Pharynx
- Esophagus
- Stomach
- Duodenum
- Jejunum
- Ileum
- Caecum
- Ascending colon
- Transverse colon
- Descending colon
- Sigmoid colon
- Rectum
- Anus

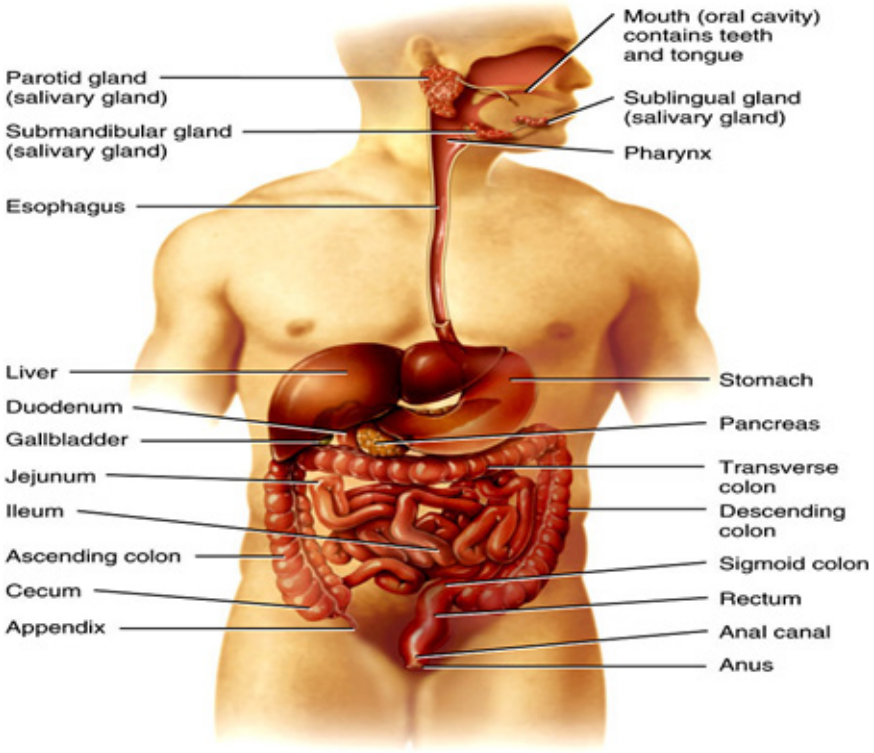
2. Accessory structures

Not in tube path

Organs

- Teeth
- Tongue
- Salivary glands
- Liver
- Gall bladder
- Pancreas

Organs of the digestive system



(a) Right lateral view of head and neck and anterior view of trunk

Figure 24.01a Tortora - PAP 12/e

The Digestive Process

Ingestion

Taking in food through the mouth

Propulsion (movement of food)

Swallowing

Peristalsis – propulsion by alternate contraction & relaxation

Mechanical digestion

Chewing

Churning in stomach

Mixing by segmentation

Chemical digestion

By secreted enzymes: see later

Absorption

Transport of digested end products into blood and lymph in wall of canal

Defecation

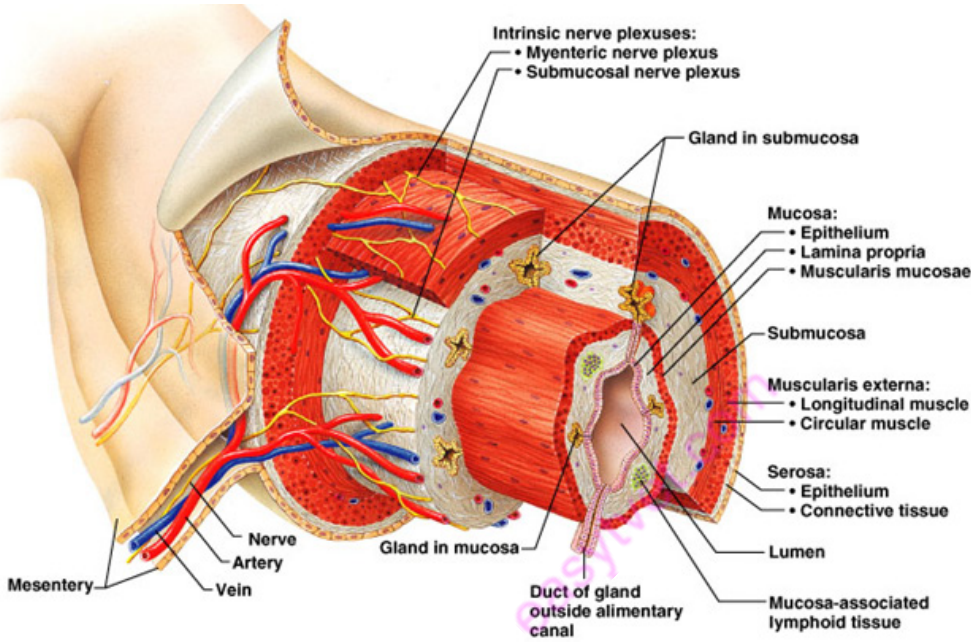
Elimination of indigestible substances from body as feces

Histology of alimentary canal wall

Same four layers from esophagus to anal canal

Mucosa | Submucosa | Muscularis externa | Serosa

from lumen (inside) out



Peritoneum

Largest serous membrane of the body

Divided into

- Parietal peritoneum – lines wall of cavity
- Visceral peritoneum – covers some organs

Also called serosa

Space between the two is peritoneal cavity

5 major peritoneal folds

1. Greater omentum 2. falciform ligament 3. lesser omentum 4. mesentery 5. mesocolon

Weave between viscera binding organs together

Neural innervation of the GIT

1. Enteric nervous system (ENS)

Intrinsic set of nerves - "brain of gut"

Neurons extending from esophagus to anus

2 plexuses

Myenteric plexus – GI tract motility

Submucosal plexus – controlling secretions

2. Autonomic nervous system

Extrinsic set of nerves

Parasympathetic stimulation increases secretion and activity by stimulating ENS

Sympathetic stimulation decreases secretions and activity by inhibiting ENS

Review of some definitions….

Peritoneum: serous membranes of the abdominopelvic cavity

Visceral peritoneum: covers external surfaces of most digestive organs

Parietal peritoneum: lines body wall

Peritoneal cavity: slit-like potential space between visceral and parietal peritoneum

Serous fluid – lubricating

Mouth/Oral cavity

The mouth is a mucosa-lined cavity. It's bounded by the lips anteriorly, hard & soft palate superiorly, and tongue inferiorly, muscles of the cheeks laterally.

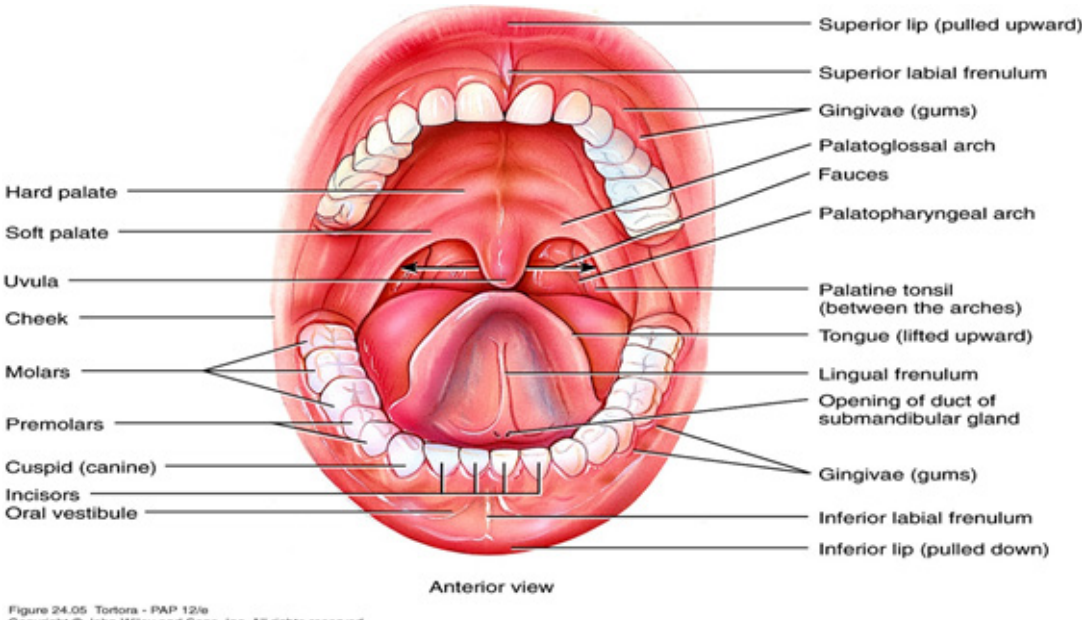


Figure 24.05 Tortora - PAP 12/e

The anterior opening is the oral orifice. It's continuous posteriorly with the oropharynx via the fauces. The space btwn the lips and the teeth and gums is the oral vestibule, while the space btwn the teeth/gums and oropharynx is the oral cavity proper.

It's lined by stratified squamous epithelium, which provides protection against heat, chemicals, abrasion, and pathogens.

Tongue

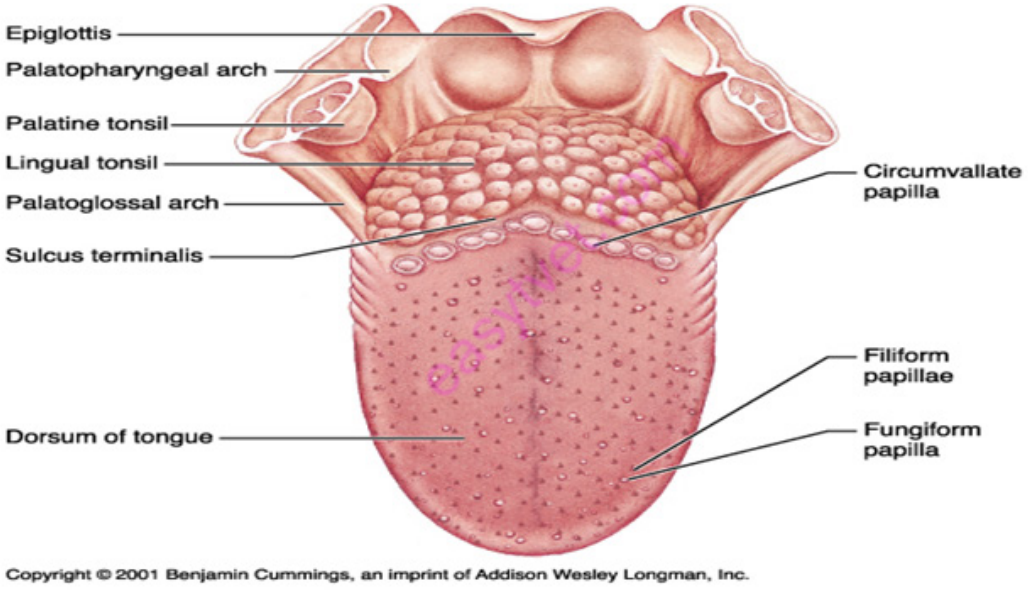
The tongue is composed of interlacing bundles of skeletal muscle.

Intrinsic muscles of the tongue are confined to the tongue and adjust its shape.

Extrinsic muscles of the tongue are anchored to skull structures and adjust the tongue's position.

The superior tongue surface bears papillae, projections of the mucosa.

Papillae increase surface area, which creates friction that can assist in eating/manipulating foods. Papillae also contain sensory receptors for taste in the taste buds.



Dorsal Surface of the Tongue

Functions of the tongue

- Speech
- Manipulate food into teeth for mastication
- Compress food into bolus for swallowing
- Analyze food for texture, taste, temp
- Produce secretions:
    i. Mucin - lubrication
    ii. Lingual lipase - start lipid digestion

Teeth

Called “dentition” (like dentist)

Teeth are classified according to shape and function

Incisors: chisel-shaped for chopping off pieces

Canines: cone shaped to tear and pierce

Premolars (bicuspids) and

Molars - broad crowns with 4-5 rounded cusps for grinding

Tooth structure

Two main regions

Crown (exposed)

Root (in socket)

Meet at neck

Enamel

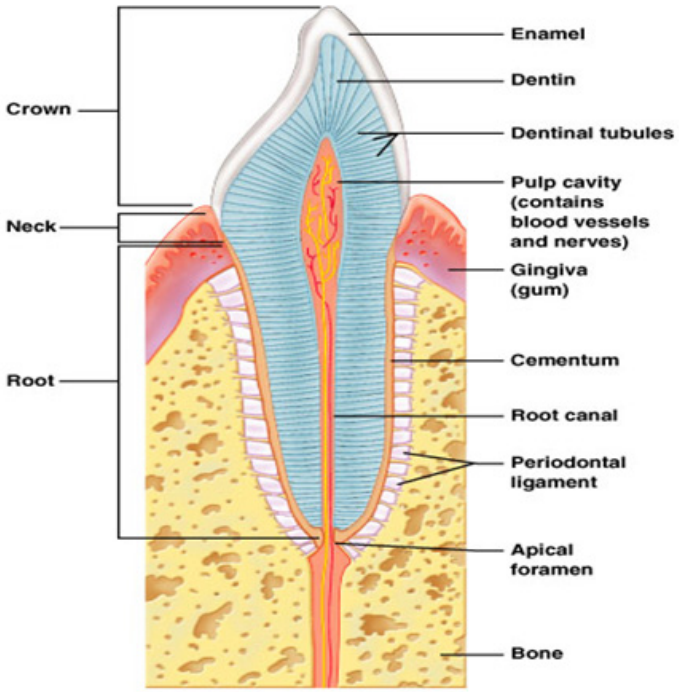
99% calcium crystals

Hardest substance in body

Dentin – bulk of the tooth (bone-like but harder than bone, with collagen and mineral)

Pulp cavity with vessels and nerves

Root canal: the part of the pulp in the root



Cementum – bone layer of tooth root

Attaches tooth to periodontal ligament

Periodontal ligament

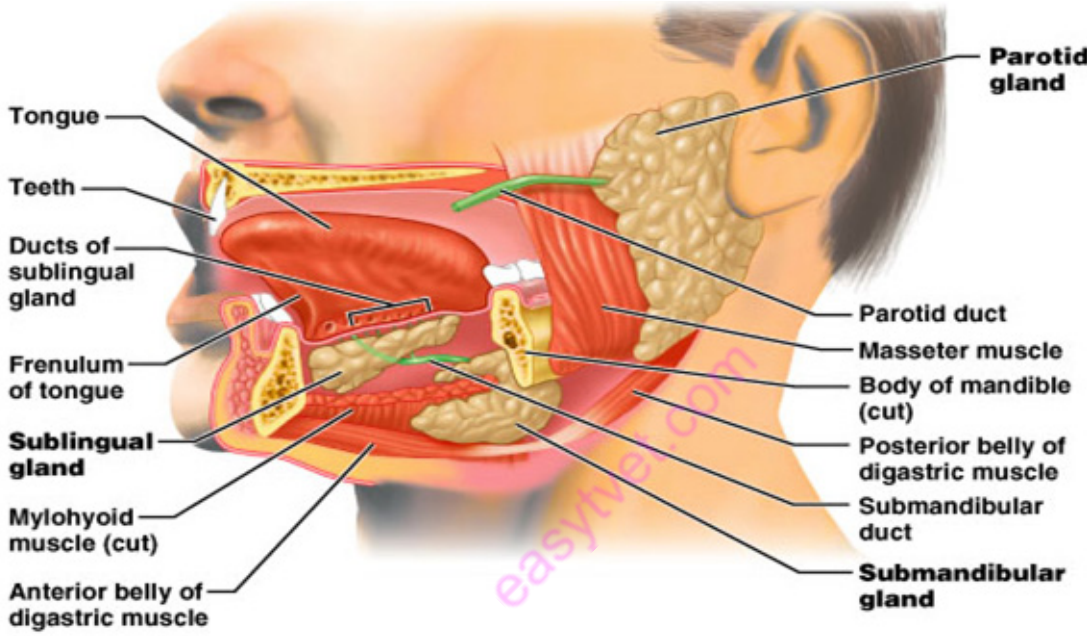
Anchors tooth in boney socket of the jaw

Continuous with gingiva (gums)

Cavities or caries - rot

Plaque – film of sugar, bacteria and debris

The Major Salivary Glands



Saliva: mixture of water, ions, mucus, enzymes

- Keep mouth moist
- Dissolves food so can be tasted
- Moistens food
- Starts enzymatic digestion
- Buffers acid
- Antibacterial and antiviral

Intrinsic salivary glands – within mucosa

Secrete saliva all the time to keep mouth moist

Extrinsic salivary glands

Paired (2 each)

Parotid | Submandibular | Sublingual | External to mouth | Ducts to mouth

Secrete saliva only right before or during eating

Parotid salivary glands: inferior to zygomatic arch, thick secretion, high salivary amylase. A duct opens into the mouth (25% of saliva)

Sublingual salivary glands: inferior to tongue, watery secretion, high in buffers (5% of saliva)

Submandibular salivary glands posterior ducts opens on the near on each side of the frenulum at the floor of mouth, buffers, mucin, amylase (70% of saliva)

Pharynx

The pharynx, or throat, is the passageway leading from the mouth and nose to the esophagus and larynx.

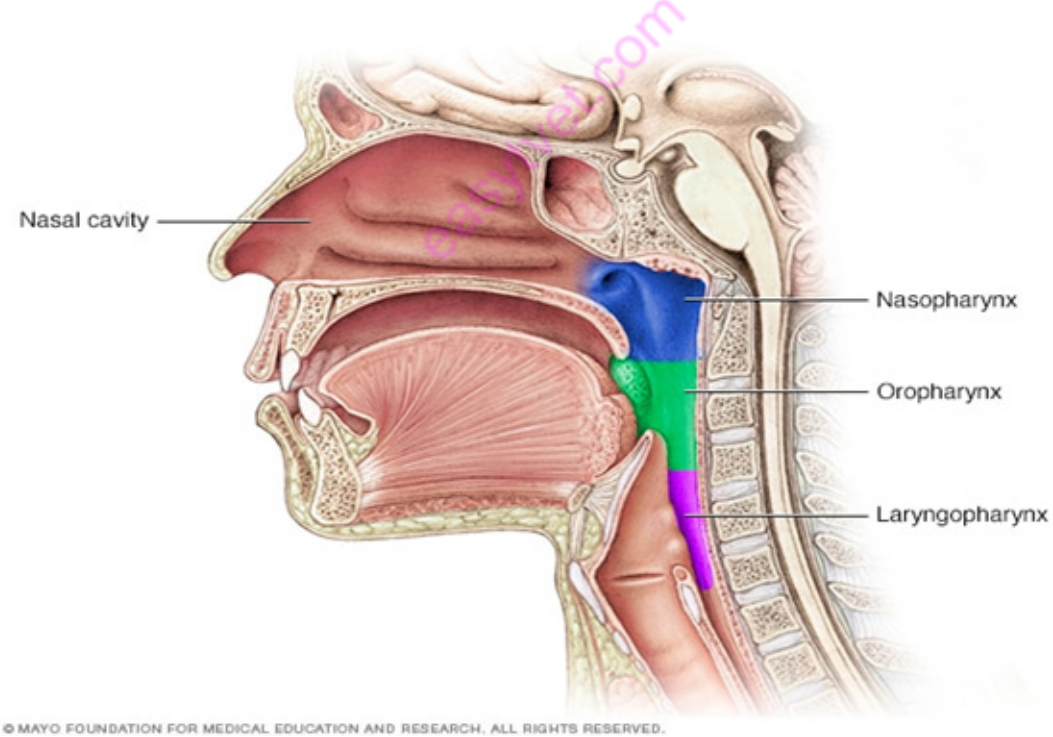
Food Passes from mouth into pharynx then into the oesophagus.

Three parts of the Pharynx

Nasopharynx--Functions only in respiration

Oropharynx--Digestive and respiratory functions

Laryngopharynx--Digestive and respiratory functions



Esophagus

Continuation of pharynx in mid neck, 25cm long & 2cm in diameter

Muscular tube collapsed when lumen empty

Descends through thorax

Abdominal part only 2 cm long

Joins stomach at cardiac orifice*

Cardiac sphincter at cardiac orifice to prevent regurgitation (food coming back up into esophagus)

Gastroesophageal junction and GERD (Gastro-esophageal Reflux Disease)

Functions of the mouth, pharynx & esophagus

Formation of a bolus

Swallowing (Deglutition)

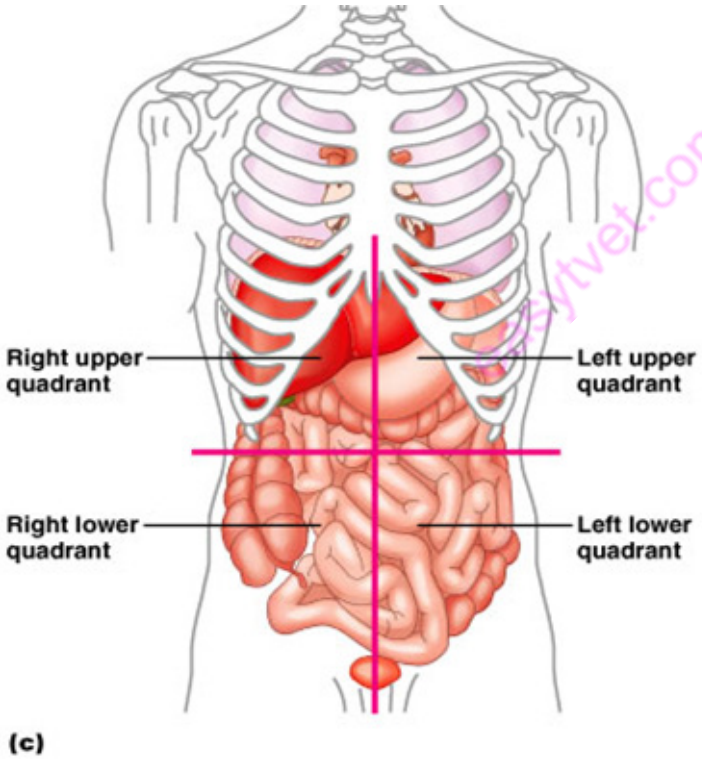
Peristalsis

Stomach

Lies mostly in LUQ

Anchored at both ends but mobile in between

Capacity: 1.5 L food; max capacity 4L (1 gallon)



Usually "J" shaped

Lies epigastric, umbilical and left hypochondriac regions of the abdomen.

Anteriorly: left lobe of the liver, anterior abdominal wall

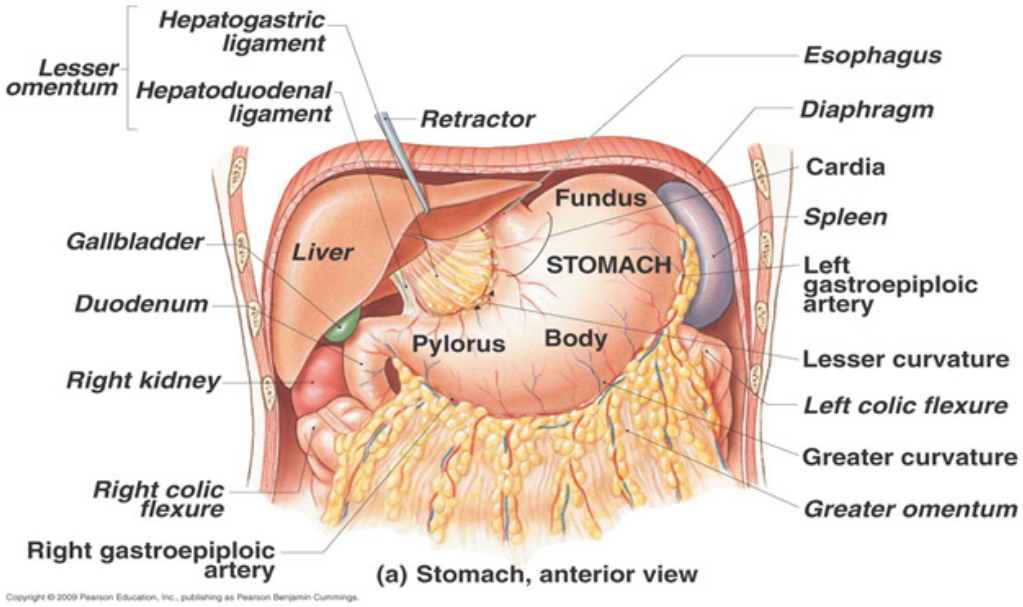
Posteriorly: abdominal aorta, spleen, pancreas, left kidney, & adrenal gland

Superiorly: diaphragm, esophagus, left lobe of the liver

Inferiorly: transverse colon, small intestine

To the left: diaphragm

To the right: liver and duodenum



Stomach Regions

Four Major Regions:

1. *Cardia*

   -where esophagus connects via gastroesophageal sphincter

   -gastric glands produce mucus to protect esophagus

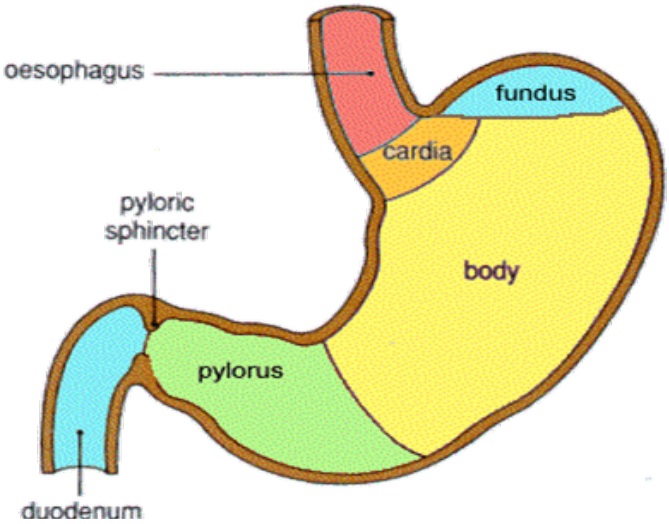
2. *Fundus* -superior region, contact with the diaphragm

3. *Body* -majority of stomach

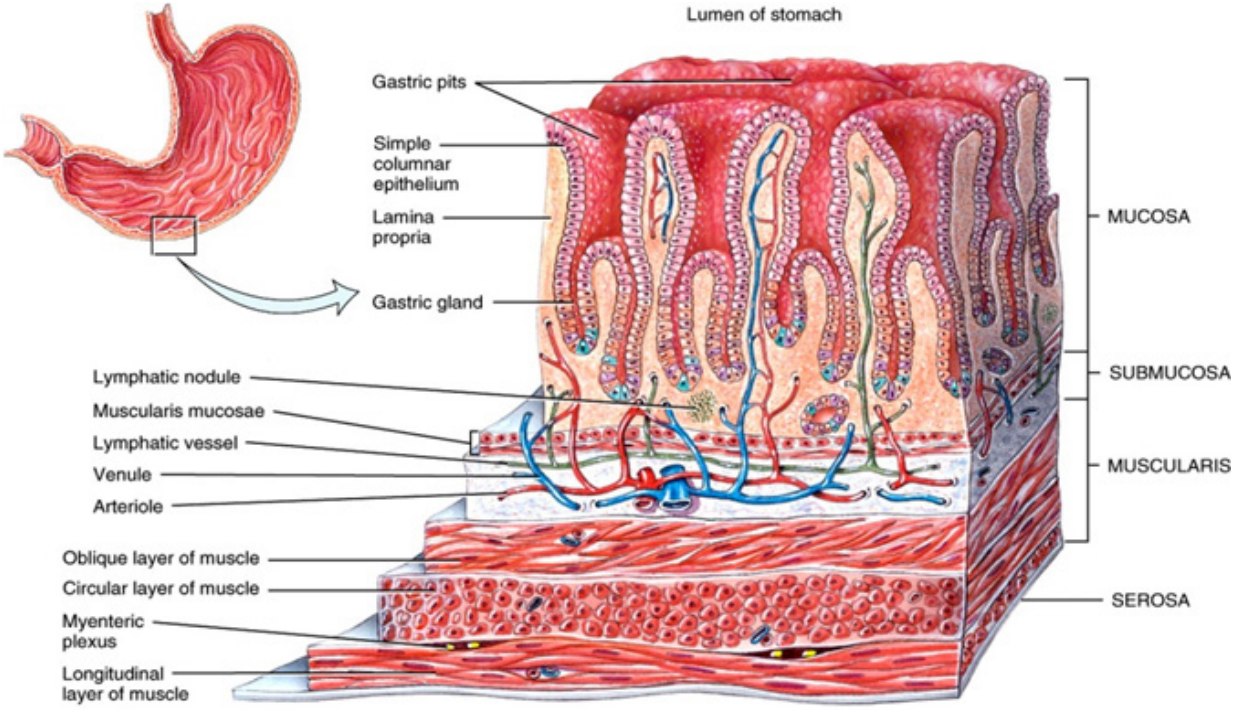
   -holds chyme

   -gastric glands secrete enzymes and acids for digestion

4. *Pylorus*



Histology of the stomach



(a) Three-dimensional view of layers of the stomach

Figure 24.12a Tortora - PAP 12/e

Mucosa

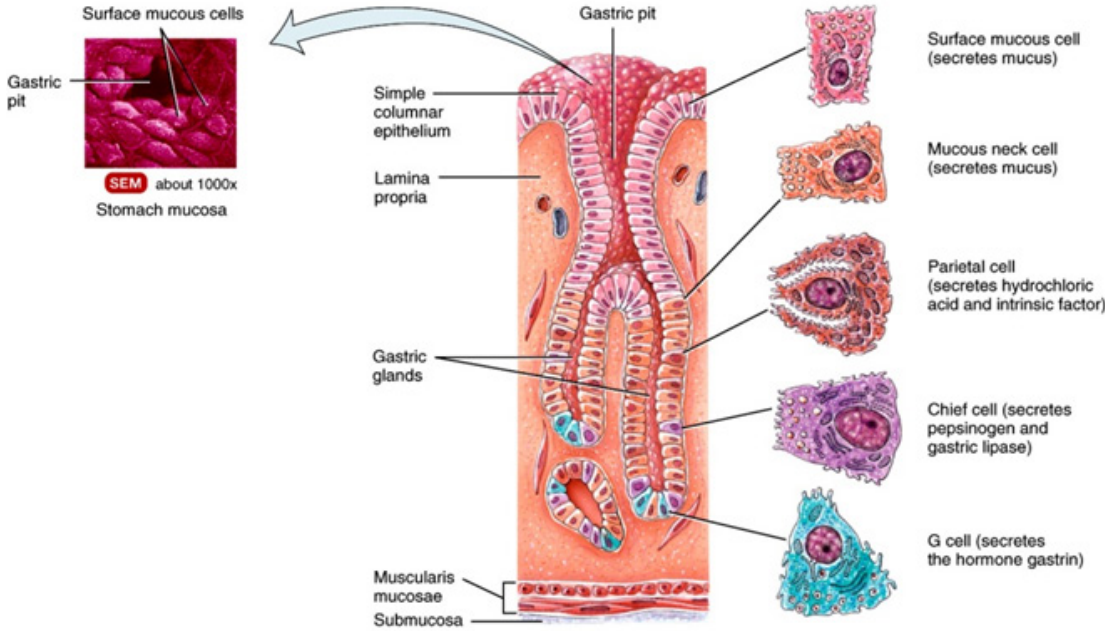
The basic cell types of Mucosa are:

Mucous neck cells – found in the upper portion of the gland. Secrete acidic mucus and function as stem cells for surface mucous cells.

Chief cells – primary function is the secretion of pepsinogen, an inactive form of the protease, pepsin. Pepsinogen is activated by HCl and by pepsin itself.

Parietal cells – found in the mid-portion of the glands. Secrete hydrochloric acid (which gives the stomach its low pH – usually 1-3) as well as intrinsic factor.

Enteroendocrine cells – secrete multiple hormones into the plasma. An example is gastrin released by G cells. Gastrin is a hormone that regulates the stomach's motility and secretory activity.



(b) Sectional view of the stomach mucosa showing gastric glands and cell types

Figure 24.12b Tortora - PAP 12/e

Functions of the Stomach

Store ingested food (~1 L)

Mechanical breakdown of food (churning)

Chemical breakdown of food (denature and digest proteins)

Produce intrinsic factor for Vitamin B12 uptake (Vit B12 necessary for erythropoiesis)

Gastric Glands: Gastric Juice

Produce 1-3 L gastric juice / day: secretions.

Gastric juice stops the action of salivary amylase.

Gastric muscles helps in breaking down the bolus, churning of food and peristaltic movement propels the food towards the pylorus.

PNS increases gastric motility & secretion of gastric juices while SNS decreases.

Gastric juice

Vary per region: water-liquifies swallowed food

Cardia gastric glands (goblet) = mucus

Fundus and Body gastric glands =digestive enzymes and acid

Two Types of Cells:

A. Parietal cell secretions:

Intrinsic factor (Vit B12 uptake)

H+ and Cl- ions - combine to make HCl in stomach

B. Chief cell secretions:

Pepsinogen -converted to pepsin by acid in stomach; hydrolyzes proteins

Renin -infants only; curdles milk protein to aid digestion

Acid production important to gastric function: (HCL)

Kill microbes

Denature proteins (digestion, destroy enzymes in food)

Break down plant cell walls and animal connective tissue

Activate pepsin

Pyloric gastric glands = mucus and hormones

Two important hormone producing cells:

G cells: Produce gastrin

Stimulates secretion by parietal and chief cells

Promotes contraction of gastric wall

Secreted in response to food or parasympathetic stimulation

D cells: Produce somatostatin

Inhibits release of gastrin (thus inhibits gastric activity)

Secreted in response to sympathetic stimulation

Regulation of Gastric Activity

Secretion and motility controlled by 3 factors:

1. Innervation from CNS (ANS)
2. Reflexes of the ENS
3. Hormones

Mechanisms rely on stimuli from three regions: head, stomach and small intestine

Three Phases of regulation: all may act simultaneously to alter gastric activity

Secretion of Gastric Juice Phases

1. Cephalic Phase:

Prepares stomach for food

Triggered by seeing, smelling, or thinking of food

Lasts a few minutes

Neural response: parasympathetic triggers increase in all gastric secretions (mucus, enzymes, acid) and triggers G cells to release Gastrin (causes secretion and motility)

2. Gastric Phase

Initiates stomach digestive activities

Triggered by food entering stomach (stimuli = distension, peptides, low acidity)

Lasts 3-4 hours (Three Responses:)

Neural Response: stretch receptors activate ENS reflexes and parasympathetic ANS innervation, both stimulate secretions from parietal cells (acid), Chief cells (pepsin) and G cells (Gastrin)

Hormonal Response: triggered by neural response, peptides and increased pH, G cells release Gastrin which trigger secretion by parietal and chief cells and also gastric mobility

Local Response: triggered by distortion, Mast cells release histamine which stimulates parietal cells

Gastrin secretion is inhibited by a pH less than 1.5

3. Intestinal phase

Controls chyme entry into duodenum. Triggered by chyme entering duodenum.

Last many hours . Involves excitatory and inhibitory control of gastric activity depending on chyme composition.

Neural Response: stretch receptors trigger Enterogastric Reflex which turns off ENS and parasympathetic stimulation of G cells and stimulates sympathetic stimulation of pyloric sphincter (contracts)

Hormonal Responses: (different hormones depending on chyme composition:

Stomach

Much digestion occurs in stomach but not much absorption (except alcohol and drugs)

Food does not usually remain in stomach for more than 4 hrs but total time depends on chemical makeup of food (how long it will take to digest in small intestine:

Carbohydrate rich: pass quickly

Fatty foods can cause chyme to remain in stomach 6+ hrs

Small Intestine

Extends from pyloric sphincter ⟶ ileocecal valve

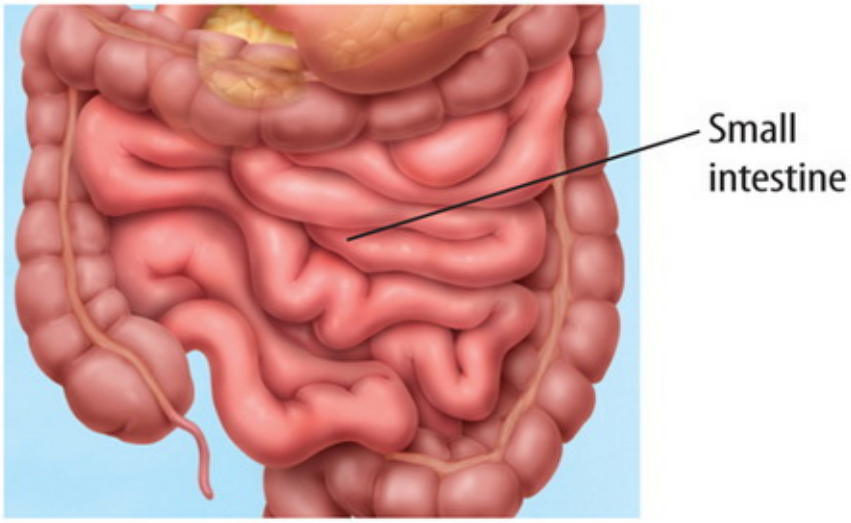
Regions

- Duodenum
- Jejenum
- Ileum

Movements

Segmentation

Peristalsis



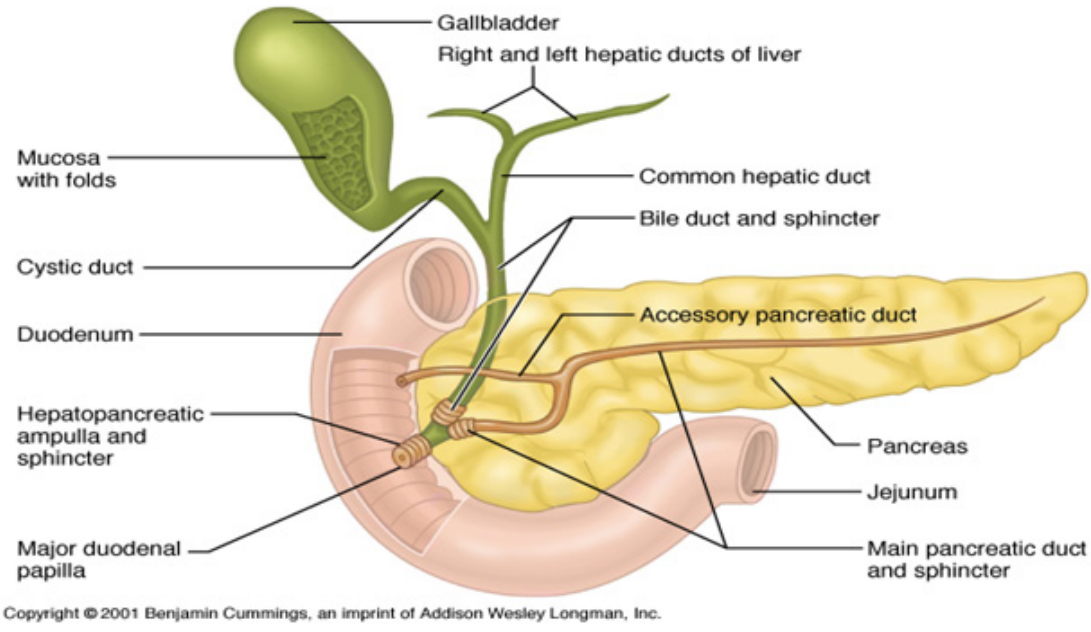
The duodenum is the shortest of the 3 divisions – about 25cm. It's mostly retroperitoneal and curves almost 180° around the head of the pancreas.

It receives the common bile duct and the main pancreatic duct. These 2 ducts unite in the duodenal wall to form the hepatopancreatic ampulla.

The ampulla opens into the duodenum via the major duodenal papilla.

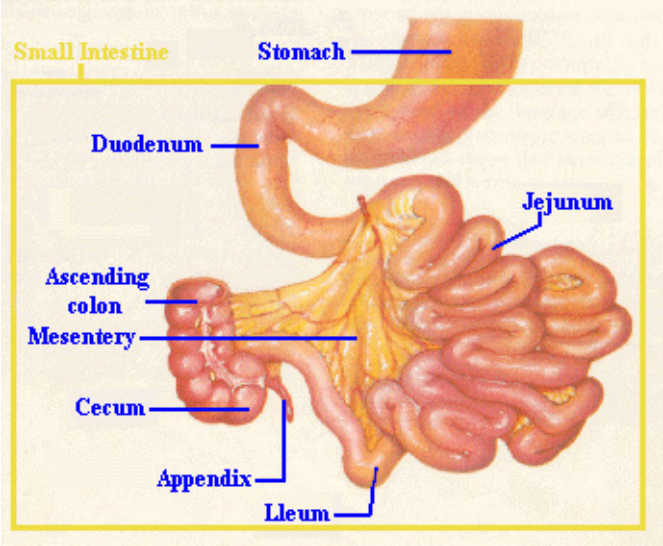
The hepatopancreatic sphincter (of oddi) controls entry of bile and pancreatic juice into the intestinal lumen.

The Duodenum and Related Organs



The *jejunum* is intraperitoneal and 2m long. It extends from duodenum to ileum and is suspended by mesentery. It's the primary site of digestion and absorption.

The *ileum* is intraperitoneal and 3m long. It's also suspended by mesentery and joins the colon at the ileocecal valve. It's primarily involved in absorption of electrolytes and vitamins.



Small intestine: Histology

Same 4 layers, but adapted for absorption:

Mucosa

Plicae: are deep, circular, permanent folds of the mucosa and submucosa. They increase surface area and slow the movement of chyme. This provides more time for absorption and digestion to occur.

Villi: plicae covered with finger-like projections of mucosa called intestinal villi.

Absorptive epithelial cells (enterocytes) line their surface. Within the core of each villus is the lamina propria, which contains blood capillaries (for absorption of amino acids and monosaccharides) and a lacteal (for absorption of fatty acids).

Microvilli: simple columnar epithelial cells (enterocytes) have microvilli on apical surfaces: membrane collectively called brush border of intestine.

The epithelium is a simple columnar with goblet cells (secretes mucus).

Epithelial invaginations known as intestinal glands (crypts of Lieberkuhn) secrete over 2 L/day of intestinal juice, which consists primarily of mucus, electrolytes, and water.

The intestinal glands also contain enteroendocrine cells (which secrete hormones like intestinal gastrin, secretin, and cholecystokinin into the plasma)

New cells created, migrate up villus, shed at tip, complete turnover 3-6 days.

Shed cells carry digestive enzymes in plasma membrane that function in lumen:

Brush border enzymes: complete digestion of carbohydrates and proteins.

Specializations/Adaptations in small intestine:

Duodenum has duodenal glands in submucosa: produce mucus to protect against acidic chyme from stomach.

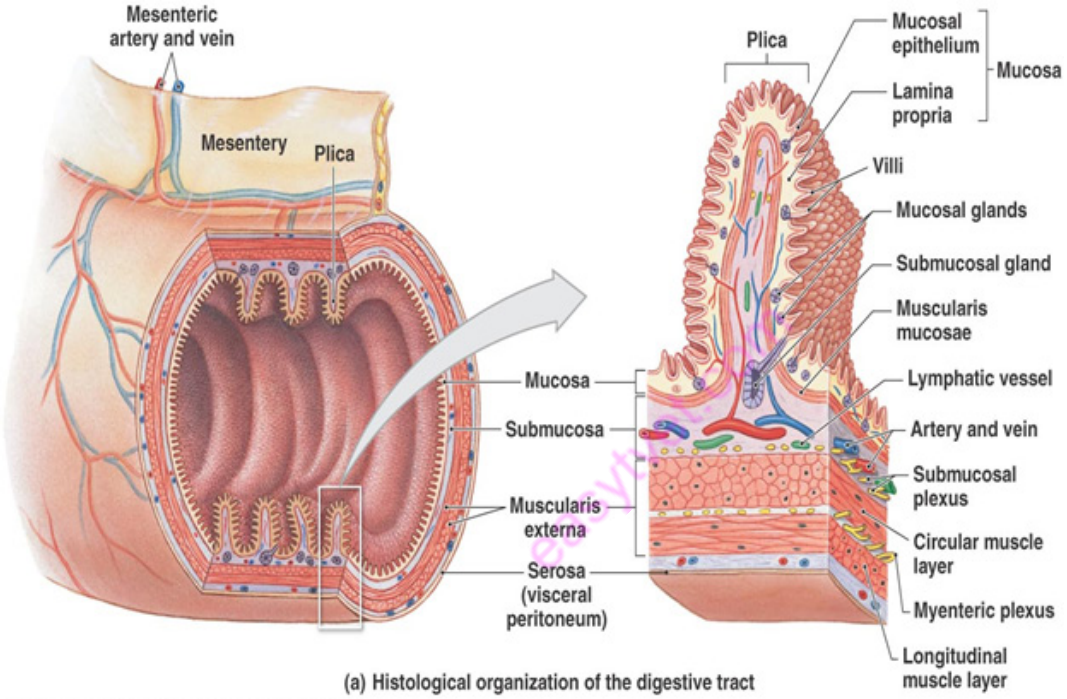
It contain the crypt of lieburkuhn which contain intestinal glands which secrete intestinal juice which help in digestion.

It has plicae which increase the surface area and slow down the movement of food in the small intestine

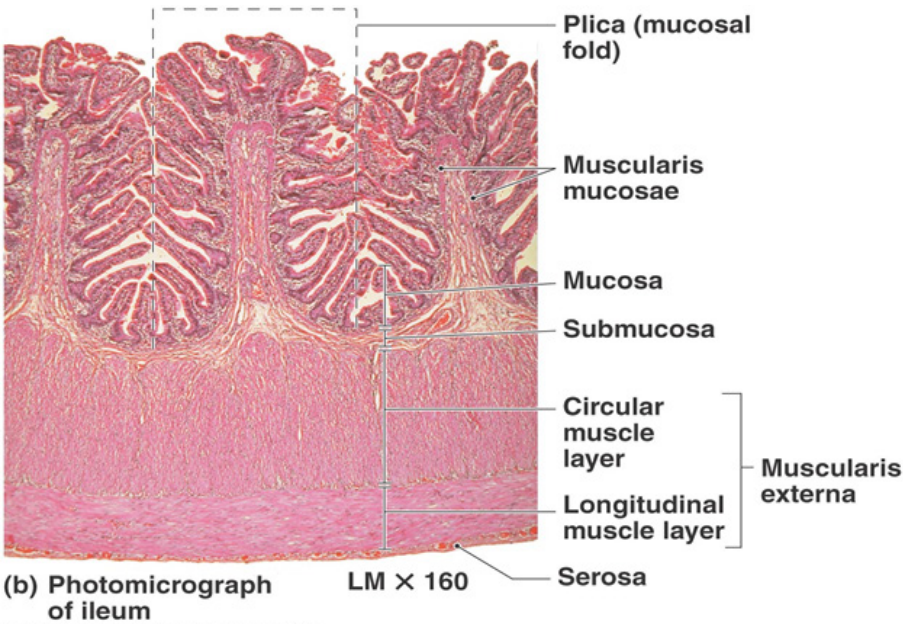
Ileum has aggregated lymphoid nodules called Peyer's Patches for immune defense

It is very long to give enough time for digestion and absorption of food.

It has villi and microvilli which increases the surface area for absorption.



(a) Histological organization of the digestive tract



(b) Photomicrograph of ileum

Histology Cont.

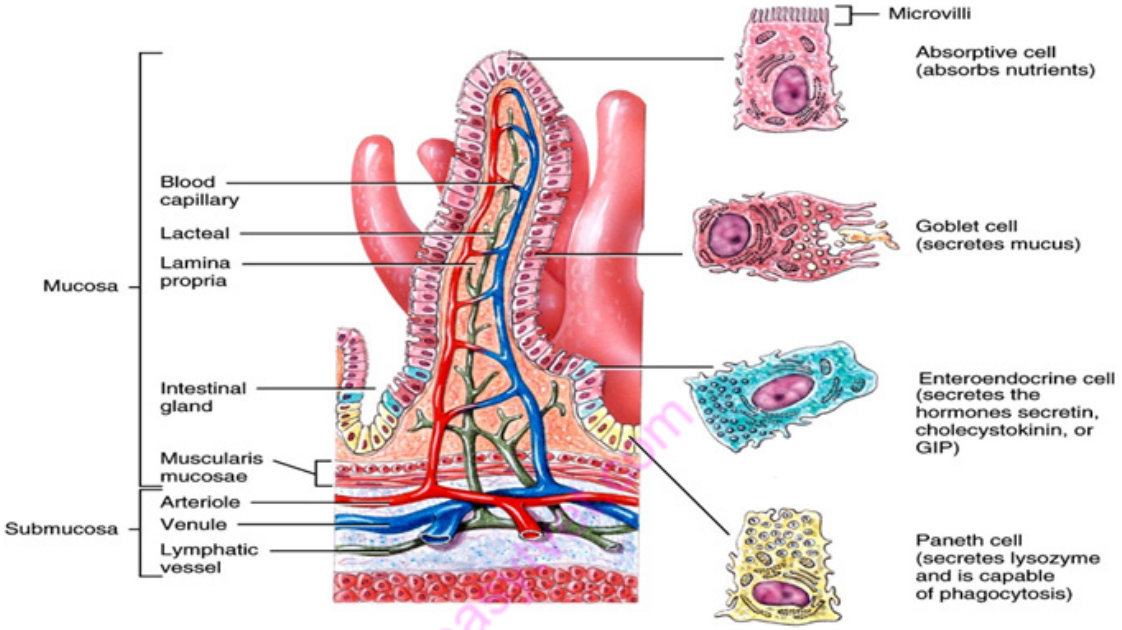
Paneth cells (which secrete antimicrobial chemicals like lysozyme),

Intraepithelial lymphocytes (which kill antigens without any need to ask permission).

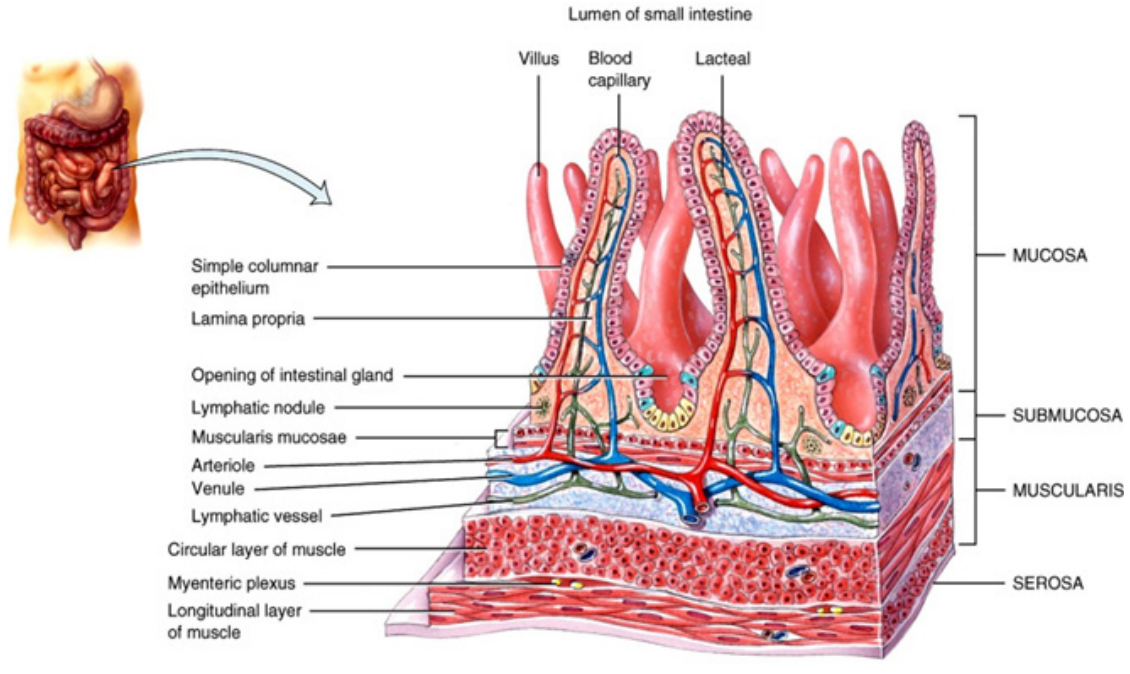
The submucosa is the same except in the proximal duodenum and terminal ileum.

The proximal duodenal submucosa contains alkaline mucus glands that help counteract the acidic chyme.

The terminal ileal submucosa contains Peyer's patches (aggregated lymphatic follicles) which neutralises antigens or foreign bodies.



(b) Enlarged villus showing lacteal, capillaries, intestinal glands, and cell types



(a) Three-dimensional view of layers of the small intestine showing villi

Blood supply: superior mesenteric artery; venous drainage; superior mesenteric vein, joins the portal vein

Functions of Small intestines

- Onward movements of its contents by peristalsis
- Secretion of intestinal juice
- Completion of chemical digestion of carbohydrates, fats & proteins
- Protection against infection
- Secretion of hormone cholecytokinin and secretin
- Absorption of nutrients
- Chemical Digestion in the Small Intestine
- Chyme in the small intestine mixes with pancreatic juice, intestinal juice and bile juice to complete digestion.
- Carbohydrates to monosaccharide like glucose by amylase
- Proteins to amino acids by peptidase
- Fats to fatty acids and glycerol by lipase

Pancreatic Juice

~ 1.5 L /day in response to parasympathetic and hormonal control. pH of 8

Water + proenzymes (trypsinogen, chymotrypsinogen, procarboxypeptidase) + electrolytes (buffer)+ enzymes (amylase and lipase)

Hormonal Control from Duodenum:

Secretin: released in response to acid chyme, triggers pancreas to secrete bicarbonate and phosphate buffers

Cholecystokinin: released in response to lipids and peptides in chyme or parasympathetic stimulation, triggers pancreatic enzyme secretion and release of bile from the gall bladder.

Pancreatic Enzymes

~70% secreted as proenzymes, activated in gut

Pancreatic alpha-amylase: hydrolyzes starch

Pancreatic lipase: hydrolyzes lipids and fatty acids

Proteolytic enzymes (majority): many, each digests specific peptide bond

2 main Classes:

A. proteases: hydrolyze large proteins into peptides

B. peptidases: hydrolyze peptide chains into amino acids

All proteolytic enzymes are secreted inactive, must be activated in gut (prevent autolysis)

Enterokinase, a brush border enzyme, activates pancreatic trypsinogen to trypsin

Trypsin activates all other pancreatic proteolytic pro-enzymes via cleavage

Bile

Bile flow: bile secreted by hepatocytes cells of the liver

It is stored in the gall bladder

pH 8

500-100ml secreted daily

Composition: water, mineral salts, mucus, bile salts, bile pigments (bilirubin), cholesterol

Functions:

Emulsify fats

- Increases solubility of cholesterol and fatty acid and enhance absorption of fat soluble vitamins A,D, E & K.
- Allows excretion of bilirubin, as urobilinogen in urine and stercobilinogen which colors and deodorizes feces.

Large Intestine

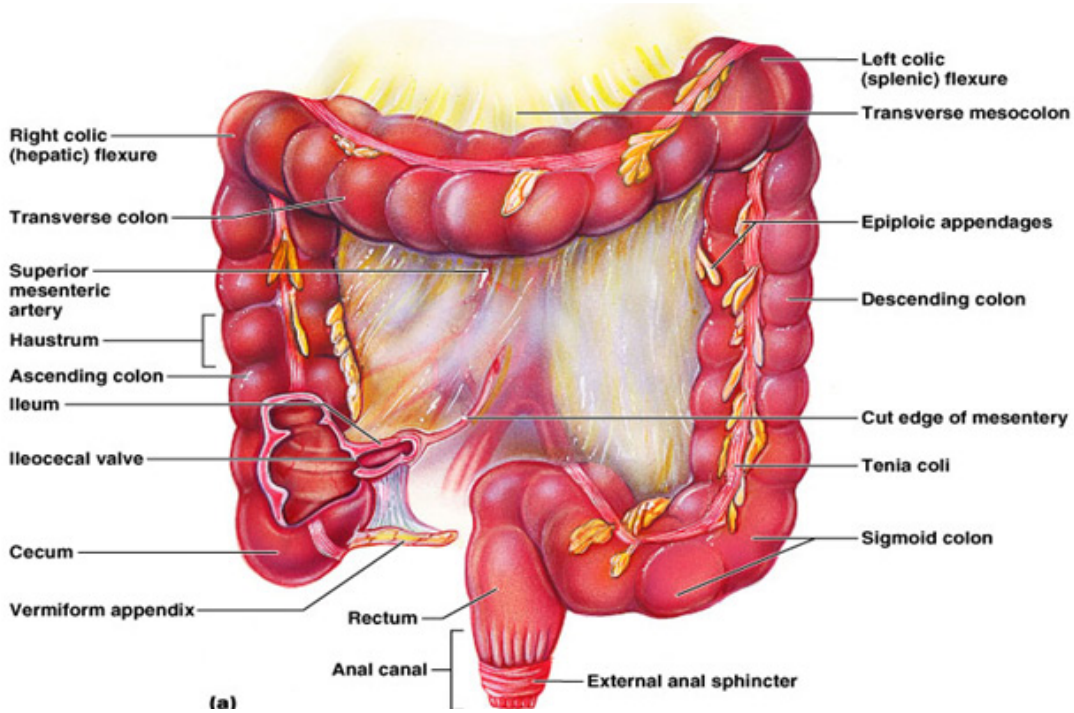
Subdivisions

Cecum | Appendix | Colon | Rectum

Anal canal

-Digested residue reaches it

-Main function: to absorb water and electrolytes



Anatomy of the large intestine

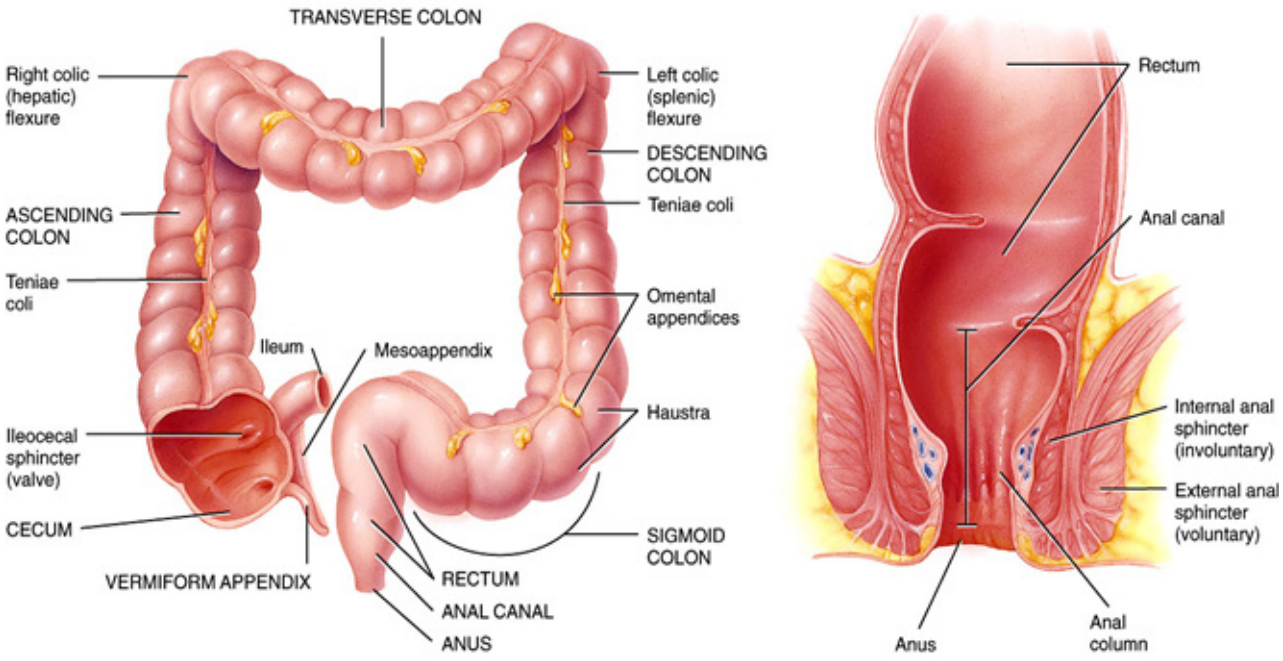


Figure 24.22 Tortora - PAP 12/e

The large intestine functions primarily to propel indigestible food remains and then expel them as feces. As it does it also absorbs any excess water remaining.

It's about 1.5m in length. Its name arises from the size of its diameter; 6.5cm.

It begins at the ileocecal valve and terminates at the anus.

Functions

Absorption:

Reabsorb any remaining water.

Absorb vitamins and electrolytes & some drugs

No digestion, except by microbes

Water absorption important to feces consistency:

Too much water = diarrhea

Too little water = constipation

Pancreas

(exocrine and endocrine)

Lies in LUQ kind of behind stomach

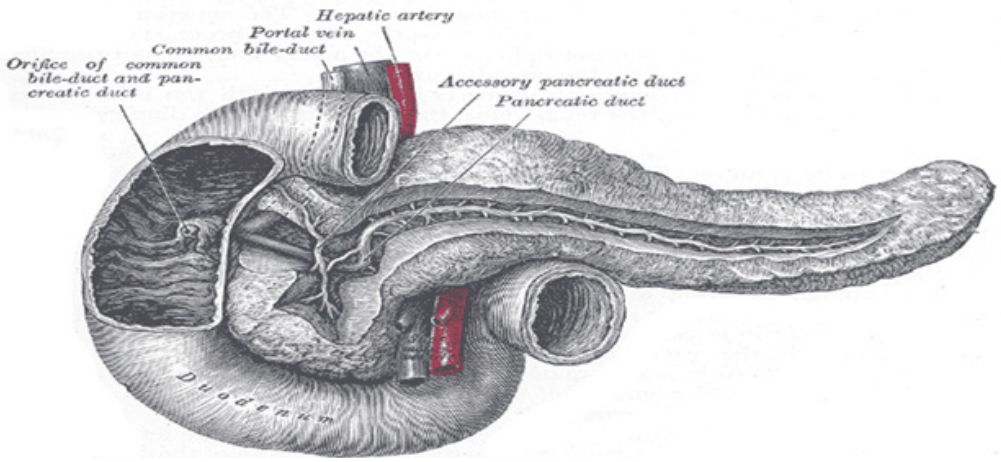
Is retroperitoneal, 60g, 12 to 15 cm long

Has a head, body and tail

Head is in C-shaped curve of duodenum

Body lies behind the stomach

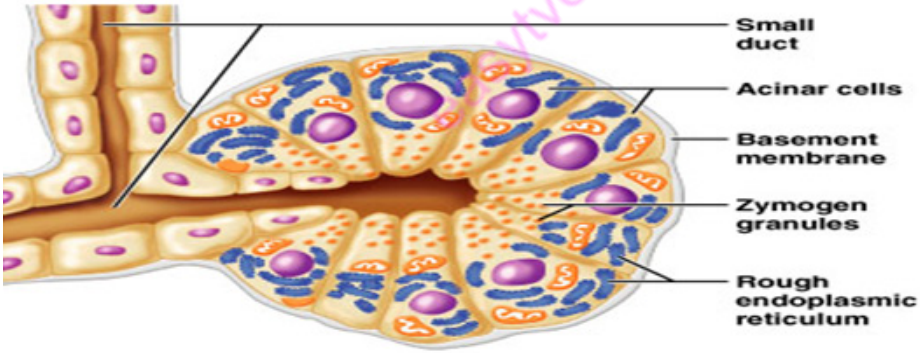
Tail extends left to touch spleen



Pancreatic exocrine function

Consists of large lobules made of small alveoli with secretory cells that drains into tiny ducts which unite to form pancreatic duct.

Secretes pancreatic juice under PNS & SNS stimulation



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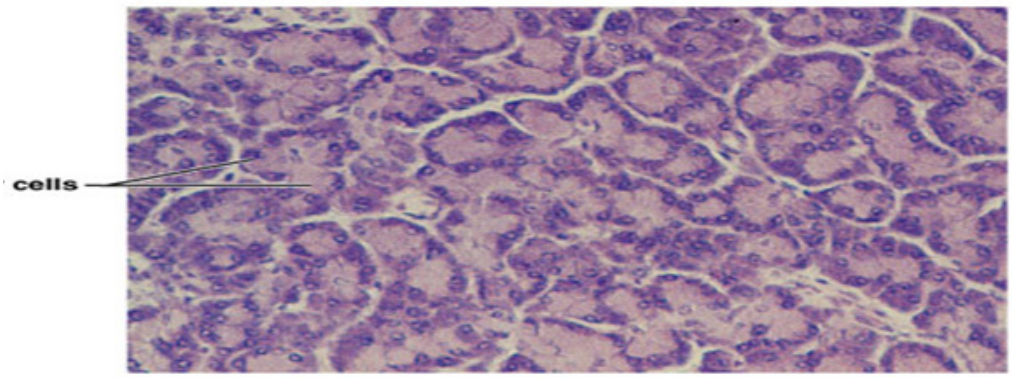


(b)

arson Education, Inc., publishing as Benjamin Cummings.

Pancreas: Endocrine

Specialised cells; islets of langerhans

Ductless

Secretes insulin & glucagon for blood glucose control.

The Liver

– Largest gland in the body (about 1 and 2.3 kg), and has over 500 functions

– Inferior to diaphragm in RUQ and epigastric area protected by ribs

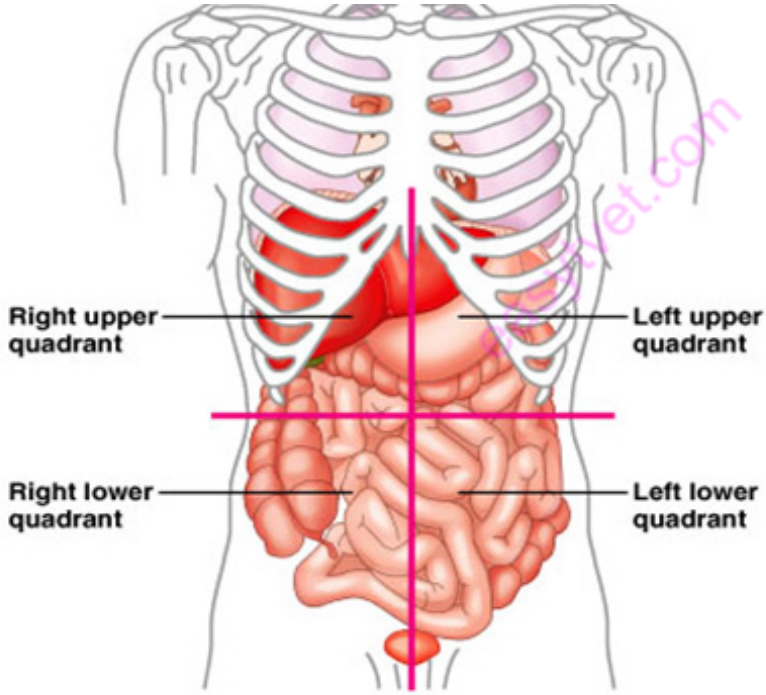
– R and L lobes

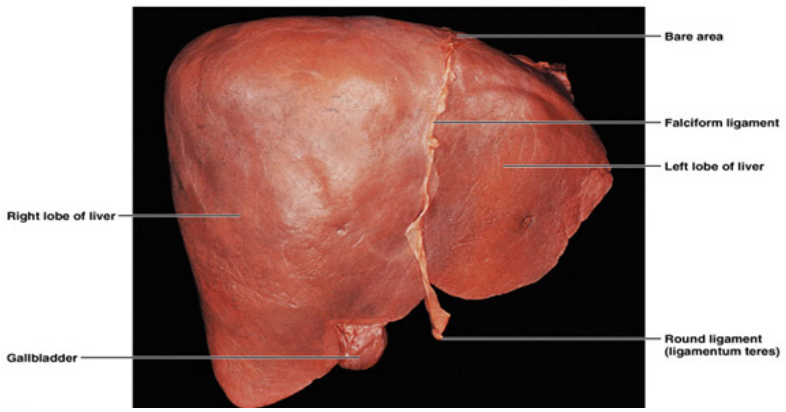
– Plus 2 smaller lobes

– Falciform ligament

– Mesentery binding liver to anterior abdominal wall

– Covered by peritoneum except “bare area” fused to diaphragm





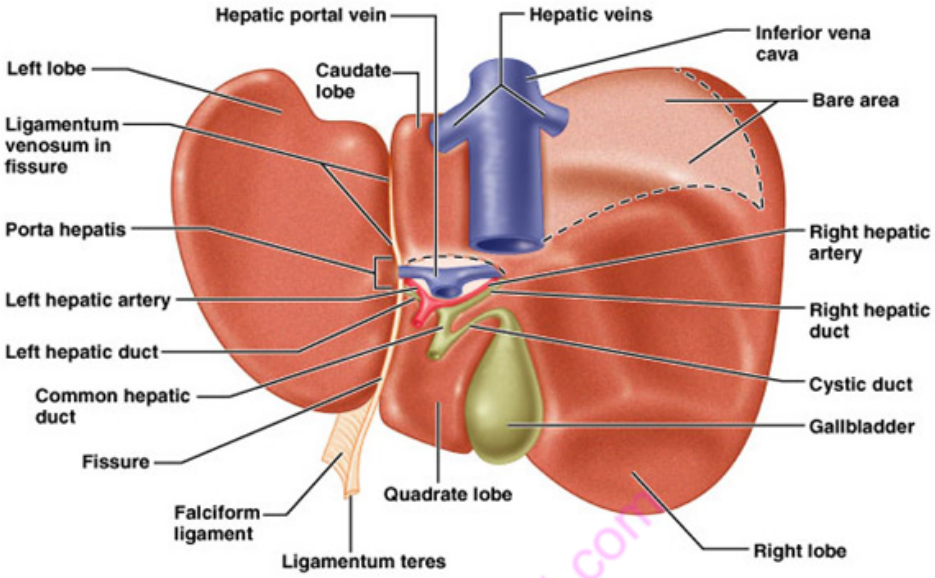
Relations:

Superiorly & anteiorly; diaphragm & ant.abdominal wall

Inferiorly: stomach, bile ducts, duedenum, right kidney, adrenal gland, hepatic flexure of colon

Posteriorly: oesophagus, inferior venacava, aorta, gall bladder, vertebral column, diaphragm

Laterally: lower ribs & diaphragm



Liver: Structure

A connective tissue capsule and visceral peritoneum almost completely surround the liver.

The capsule sends septa within the liver to provide structural support.

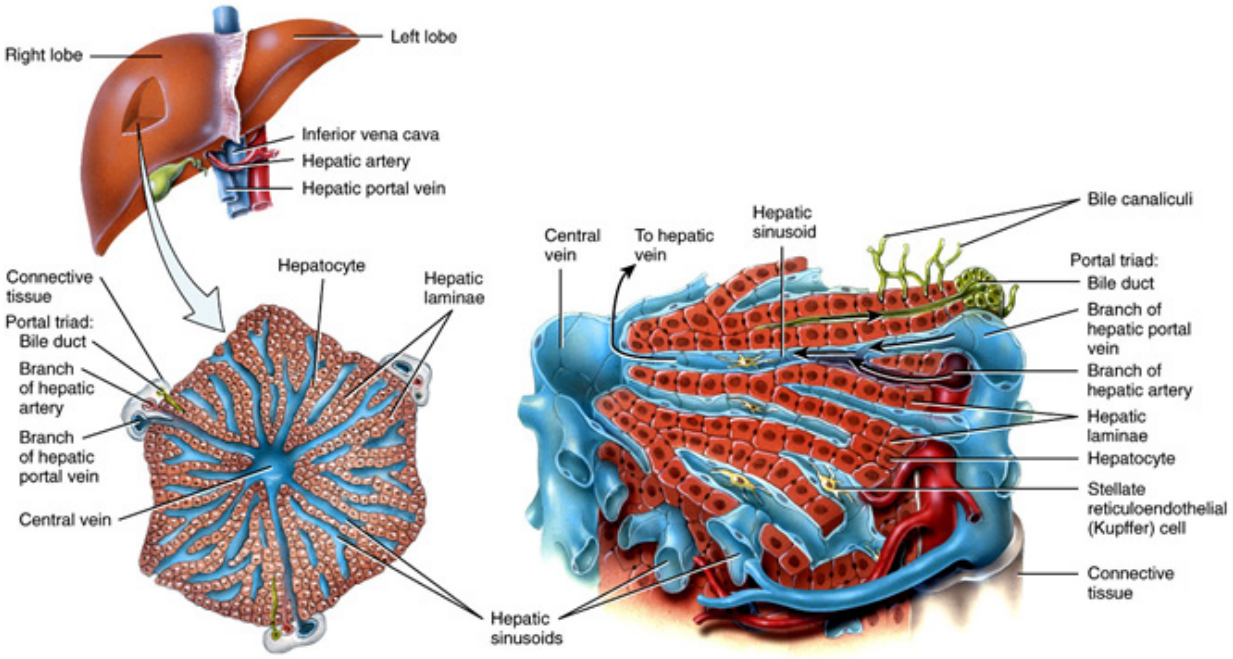
The septa divide the liver interior into hexagonal shaped liver lobules.

The center of each lobule contains a central vein. Extending out from the central vein like spokes (column) are the hepatic cords, which are composed of hepatocytes.

At each of the 6 corners of a lobule is a portal triad – a branch of the hepatic artery (a portal arteriole), a branch of the hepatic portal vein (a portal venule), and a bile duct.

The portal venules and the portal arterioles are linked to the central vein by capillaries known as liver sinusoids, which run btwn the hepatic cords.

Histology of the Liver



(a) Overview of histological components of liver

(b) Details of histological components of liver

Figure 24.15ab Tortora - PAP 12/e

Portal Triad

1. Portal arteriole
2. Portal venule

   Branch of hepatic portal vein

   Delivers substances from intestines for processing by hepatocytes

3. Bile duct

   Carries bile away

Liver Sinusoids

Large capillaries between plates of hepatocytes

Contribute to central vein and ultimately to hepatic veins and inferior venecava

Kupffer Cells

Liver macrophages

Old blood cells and microorganisms removed

Hepatocytes (Liver Cells)

Many organelles

Rough ER – manufactures blood proteins

Smooth ER – help produce bile salts and detoxifies blood-borne poisons

Peroxisomes – detoxify other poisons, including alcohol

Golgi apparatus – packages

Mitochondria – a lot of energy needed for all this

Glycosomes - role in storing sugar and regulation of blood glucose (sugar) levels

Produce 500-1000 ml bile each day

Functions of the liver

Carbohydrate metabolism: glucose is converted to glycogen for storage and vice versa under influence of insulin and glucagon respectively.

Fat metabolism: stored fat is converted to produce energy

Protein metabolism: It is broken down to produce energy during starvation

Breakdown of erythrocytes and defense against microbes: (kuppfer cells)

Detoxification of drugs and noxious substances

Inactivation of hormones: insulin, glucagon , cortisol, aldosterone, thyroid and sex hormones.

Production of heat: has high metabolic rate

Secretion of bile: synthesize bile in hepatocytes

Storage: glycogen, fat soluble vitamins A,D,E, & K, iron, copper, vitamin B12

METABOLISM

Metabolism = sum of all chemical reactions in body

To provide energy by chemical oxidation of nutrients

Make new replacement of body substances

Two Types of Metabolic Reactions

1**. Catabolism:** breakdown of organics materials

Hydrolysis: breakdown of large molecules into monomers

Cellular Respiration: oxidation of monomers in mitochondria

40% of energy ! ATP

60% of energy ! Heat (which maintains the core body temp. for optimal body activity; 36.8 °c)

2. Anabolism: synthesis of new organic material from small ones, requires energy (ATP).

Cell maintenance and repair

Growth

Formation of secretions

Nutrient reserves

Metabolic Pathway

Involves a series of chemical reactions (metabolic pathways).

The steps are controlled and involves gradual transfer of energy from ATP.

Regulated by hormones

Occurs continually in cells to maintain energy balance

Energy

Energy is the capacity to change something; it is the ability to do work.

Is measured in units of work (joules) or units of heat: kilocalories (kcal)

A kcal: amount of heat required to raise 1 litre of water by 1º c.

The body generates about 3million kcal per day.

1 kcal= 4184 joules

1gm of carbohydrates= 17 kj (4 kcal)

1gm of proteins= 17 kj(4 kcal)

1 gm of fat= 38 kj (9 kcal)

Energy balance: body weight remains constant when intake = use.

Energy intake exceeds requirements, weight increases; weight decreases when intake does not meet requirements.

Metabolic Rate

Is the rate at which energy is released from the fuel molecules inside the cell.

Can be estimated by measuring O2 uptake and CO2 excretion.

BMR—Basal metabolic rate: is the rate of metabolism of a person at rest at a warm environment and in post-absorptive state. (12hrs)

The energy released in this state is sufficient to meet the needs of vital organs such as the heart, lungs, nervous system & kidneys.

The main sources of energy for the body include; carbohydrates (55-75 %), proteins (10-15 %) and fats (15-3 %).

Central Metabolic Pathways

Involves a series of steps in which fuel molecules are broken down forming a series of intermediate molecules with energy release.

The end result is energy production, carbon dioxide and water.

Energy is stored as ATP, some lost as heat and CO2 excreted through the lungs.

The main fuel molecule is glucose but if not present then amino acids, fatty acids and glycerol and occasionally nucleic acid may be used.

The Three Main Central Metabolic Pathways Are:

Glycolysis

The citric acid cycle (kreb's Cycle)

Oxidative phosphorylation

Definition of Terms

NAD or NADH- Nicotinamide Adenine Dinucleotide

FAD or FADH- Flavin Adenine Dinucleotide

Both NAD and FAD are co-enzyme in cellular respiration

ADP- Adenosine Diphosphate

ATP- Adenosine Triphosphate

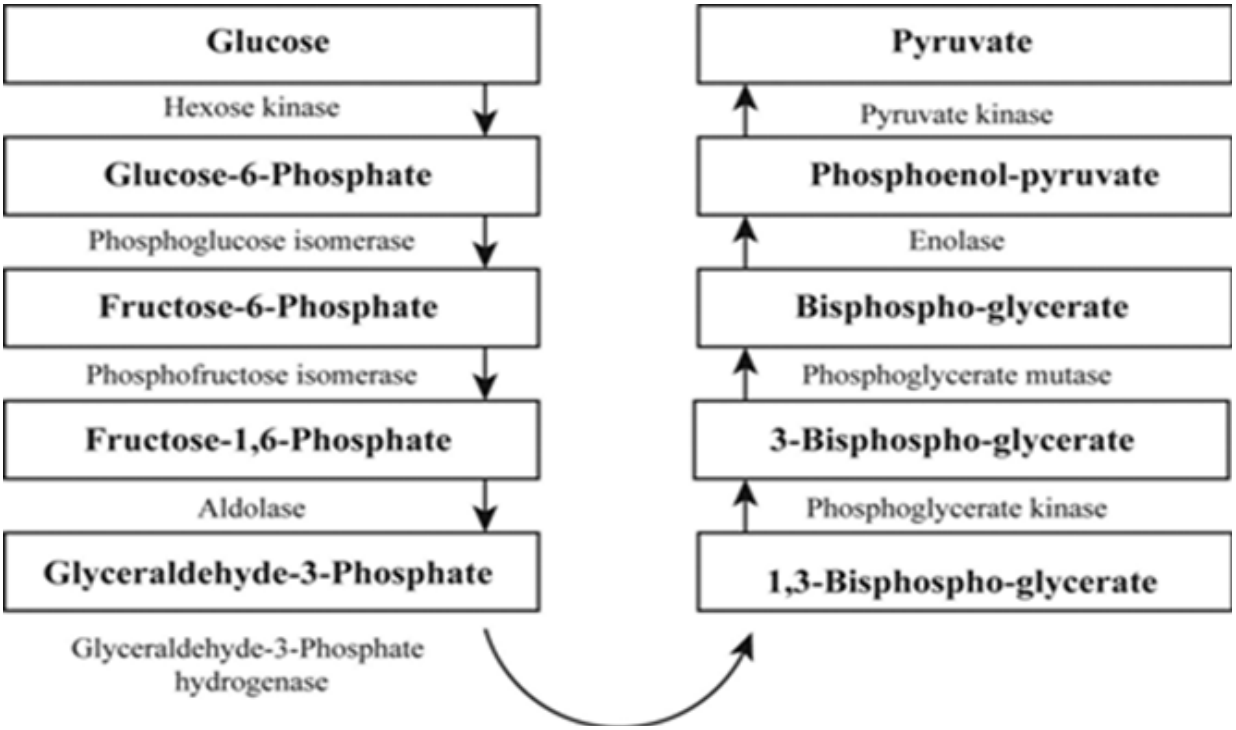
Glycolysis

Glycolysis is the metabolic pathway that converts glucose $C_6H_{12}O_6$, into pyruvate, $CH_3COCOO^- + H^+$.

The free energy released in this process is used to form the high-energy molecules ATP and NADH.

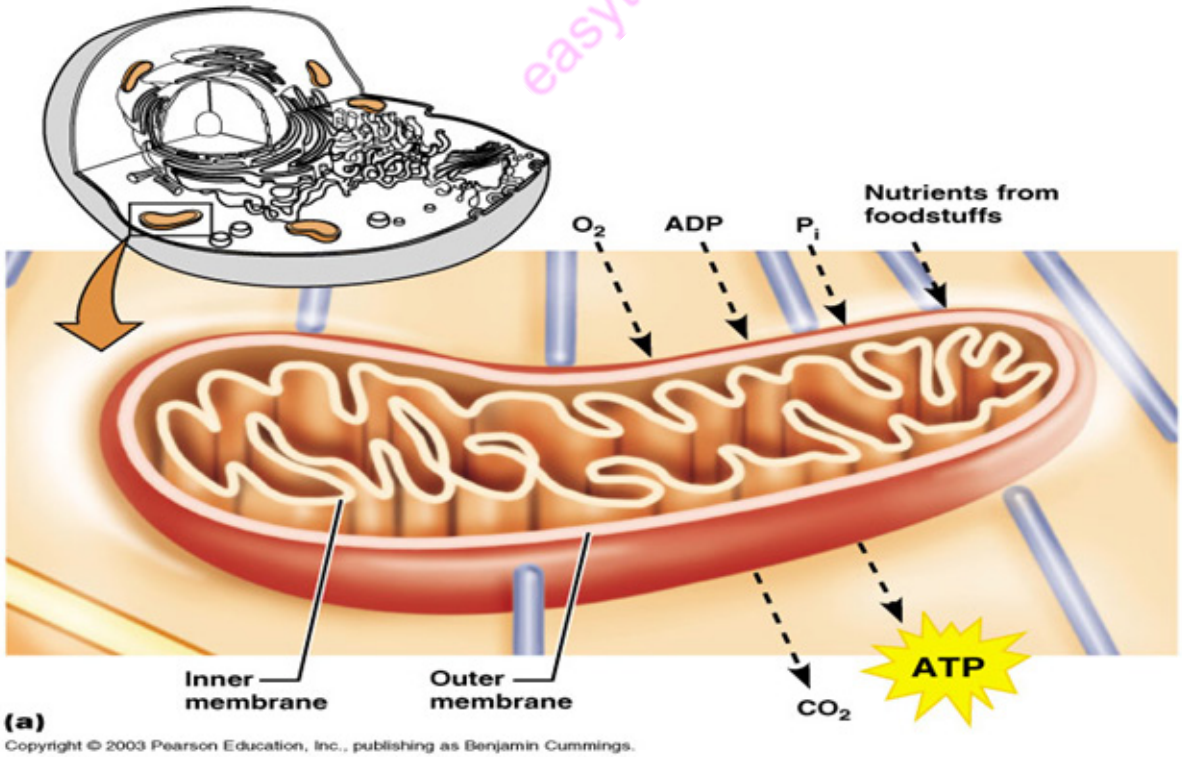
Glycolysis is a sequence of ten enzyme-catalyzed reactions.

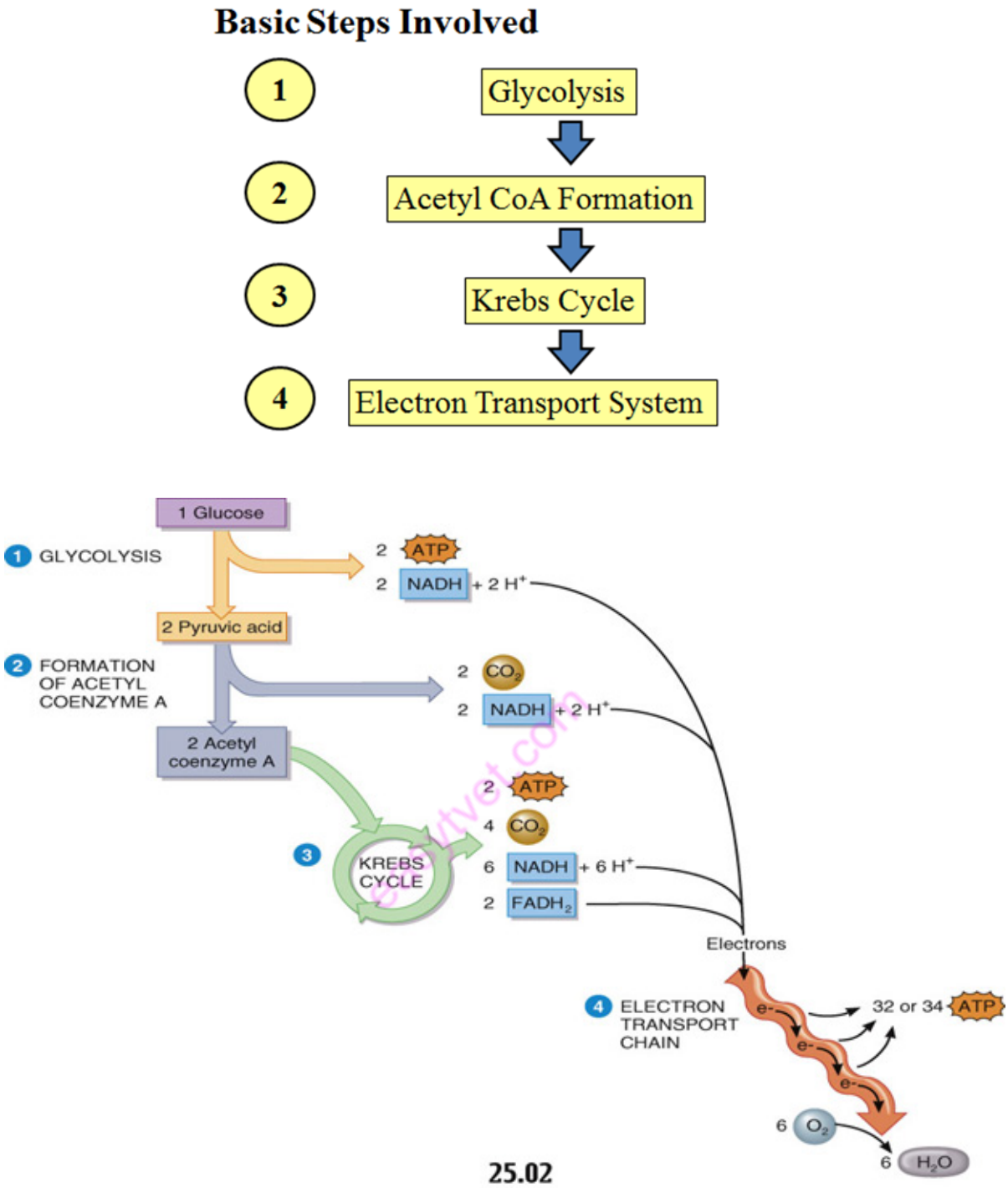
Glycolysis



Cellular Respiration

$C6H12O6 + 6O_2 + 36ADP + 36Pi \longrightarrow 6CO_2 + 6H_2O + 36ATP$



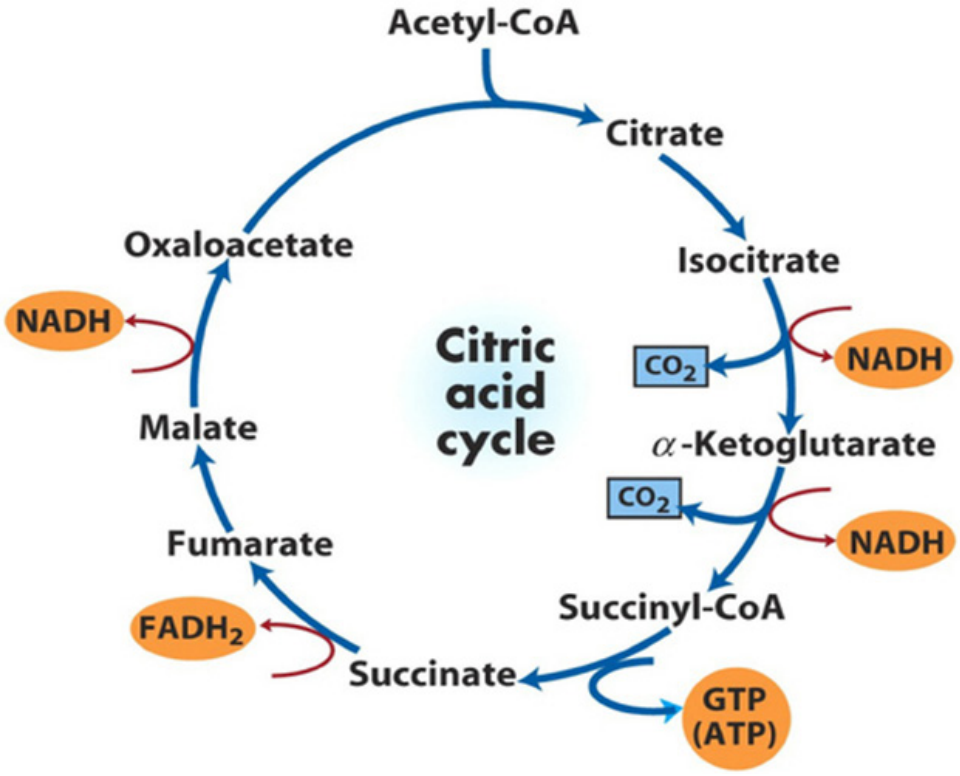


Overview of Glycolysis

Krebs Cycle

The citric acid cycle (CAC) – also known as the (TCA) cycle or the Krebs cycle – is a series of chemical reactions used by all aerobic organisms to release stored energy through the oxidation of acetyl-CoA derived from carbohydrates, fats, and proteins into adenosine triphosphate (ATP) and carbon dioxide.

Krebs Cycle



3. Oxidative Phosphorylation

Oxidative phosphorylation is the process in which ATP is formed as a result of the transfer of electrons from NADH or FADH 2 to O 2 by a series of electron carriers.

This process, which takes place in mitochondria, is the major source of ATP in aerobic organisms

Carbohydrate Metabolism

Required by all the body cells for metabolic processes

Formation of glucose from other non- carbohydrate sources such as amino acids or fatty acids is called gluconeogenesis.

Protein and Fat metabolism

In absence of carbohydrates they are metabolized to produce energy inform of ATP.

ENDOCRINE SYSTEM

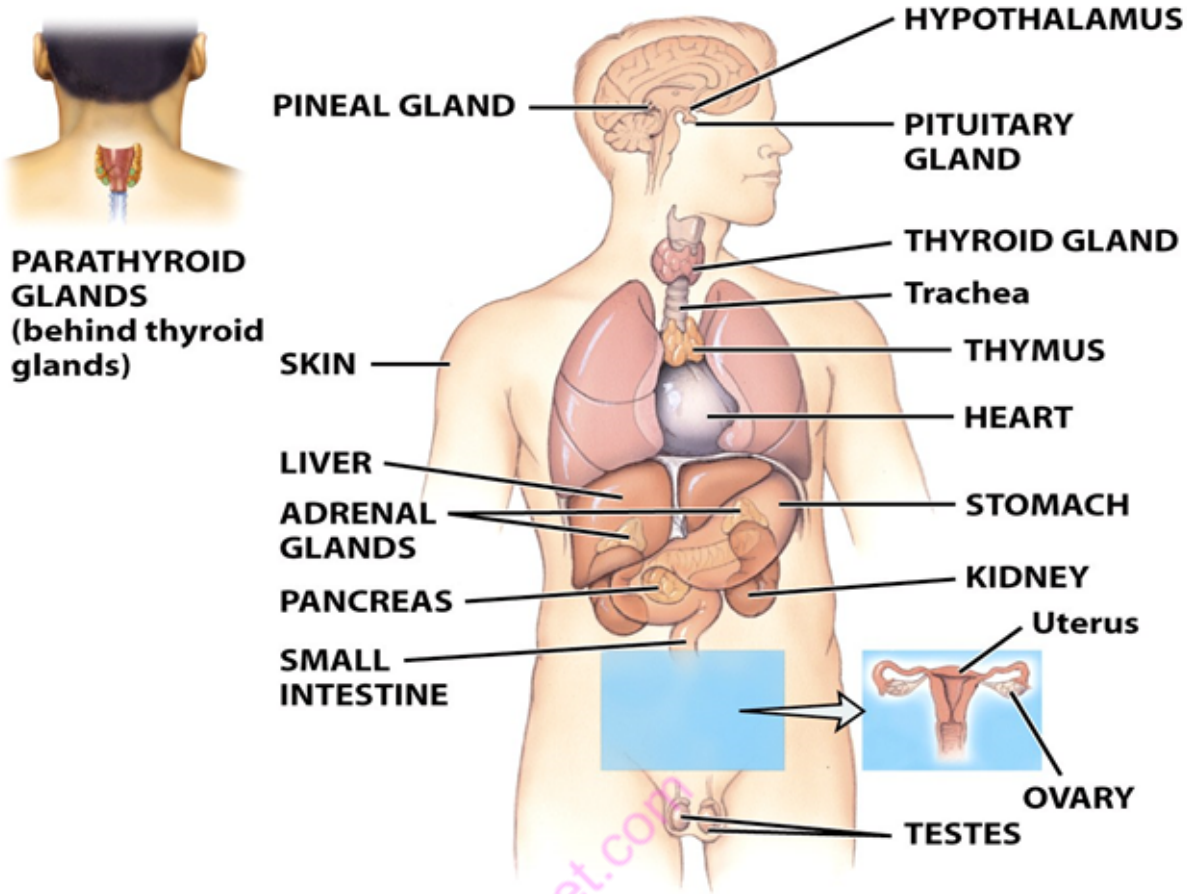


Figure 17-1 Anatomy and Physiology: From Science to Life
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Definition, Secretion and Function

The endocrine system refers to the hormone system of the body. Consists of widely separated glands with no physical connections

Hormones are chemicals produced by living cells in very small amounts. They are transported around the body in the blood.

Hormones regulate and co-ordinate different organs in the body.

Pheromones: organism to organism communication

Hormones: cell to cell communication molecules

Made in gland(s) or cells

Distant or local target tissue receptors

Activates physiological response

Endocrine Organs

Thyroid gland
Parathyroid gland
Adrenal medulla
Pituitary gland
Pancreas
Testes & ovaries
Pineal gland

MAJOR ENDOCRINE GLANDS		
Gland	**Hormone(s)**	**Target Tissues**
Pituitary gland	Thyroid-stimulating hormone (TSH)	Thyroid gland
	Adrenocorticotropic hormone (ACTH)	Adrenal gland
	Follicle-stimulating hormone (FSH)	Gonads
	Luteinizing hormone (LH)	Gonads
	Antidiuretic hormone (ADH)	Kidneys
	Prolactin	Mammary glands
	Oxytocin	Mammary glands, Uterus
	Growth hormone (GH)	Bone, cartilage, muscle
Hypothalamus	Releasing hormones	Pituitary gland
Thyroid gland	Thyroxine	Most cells
Parathyroid gland	Parathyroid hormone (PTH)	Bone
Adrenal glands	Adrenalin (epinephrine)	Most cells
	Cortisol	Most cells
Pancreas	Insulin	Muscle, fat, liver
Testis	Testosterone	Reproductive tract, bone, muscle
Ovaries	Estrogen	Reproductive tract, mammary glands, bone
	Progesterone	Reproductive tract, mammary glands

Types of Hormones

Functional Types of Hormones

Endocrine Hormones – Travel through the blood to act at a site distant from the secreting cell or gland

Paracrine Hormones – Act on cells near the secreting cell

Autocrine Hormones – Act on the secreting cell

Neurocrine Hormones – Secreted by neural cells

Neurotransmitters

Neurohormones

Chemical Types of Hormones

Protein & Polypeptide

Amine (amino acid derived)

Steroid

Pituitary Gland & Hypothalamus

They act as a unit.

Controls the activities of other endocrine glands.

The pituitary is located in the sella-turcica of the skull below the hypothalamus, attached by a stalk.

Pea size, 500mg., and contains two lobes; adenohypophysis (the anterior lobe and glandular portion) and the neurohypophysis (the posterior lobe and nervous portion).

Contains an intermediate lobe in between.

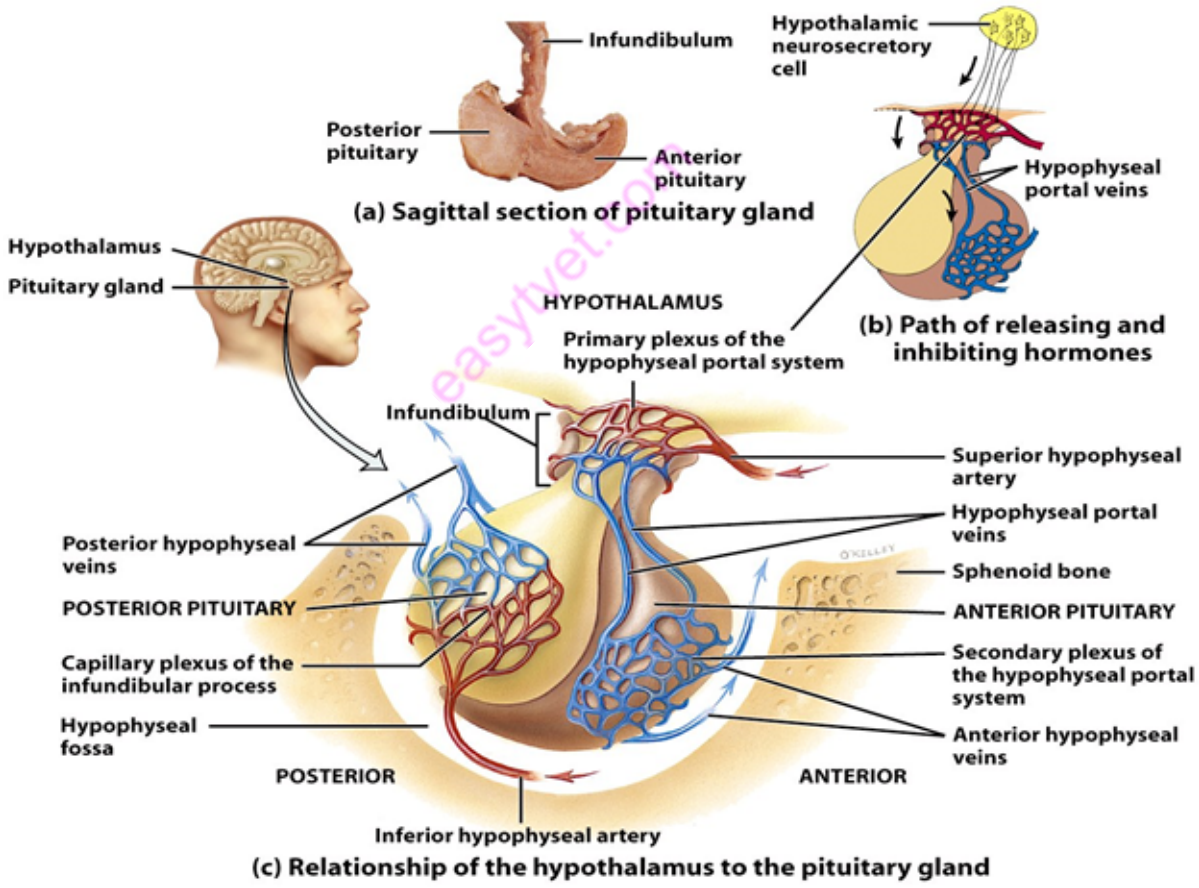
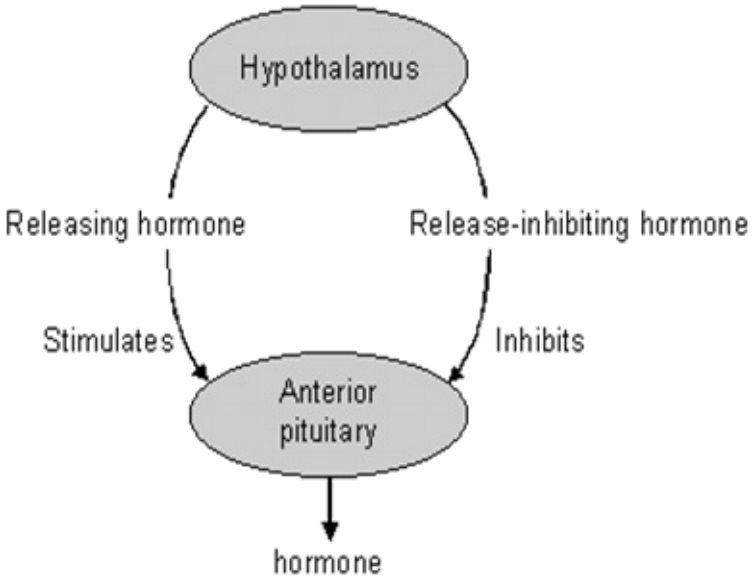


Figure 17-4 Anatomy and Physiology: From Science to Life

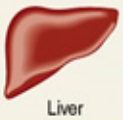
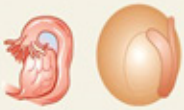
Anterior Pituitary

The hypothalamus produces hormones that travel in blood vessels to the anterior pituitary, stimulating it to produce other hormones.

The hormones produced by the hypothalamus are called hypothalamic-releasing & inhibiting hormones.



Summary of principal actions of the anterior pituitary hormones

Hormone and Target Tissues	Principal Actions
Human growth hormone (hGH)  Liver	Stimulates liver, muscle, cartilage, bone, and other tissues to secrete insulinlike growth factors (IGFs); IGFs promote growth of body cells, protein synthesis, tissue repair, lipolysis, and elevation of blood glucose concentration.
Thyroid-stimulating hormone (TSH)  Thyroid gland	Stimulates secretion of thyroid hormones by thyroid gland.
Follicle-stimulating hormone (FSH)  Ovaries Testes	In females, initiates development of oocytes and induces ovarian secretion of estrogens. In males, stimulates testes to produce sperm.
Luteinizing hormone (LH)  Ovaries Testes	In females, stimulates secretion of estrogens and progesterone, ovulation, and formation of corpus luteum. In males, stimulates interstitial cells in testes to secrete testosterone.

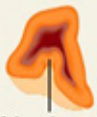
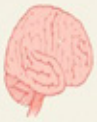
Hormone and Target Tissues	Principal Actions
Prolactin (PRL)  Mammary glands	Together with other hormones, promotes milk secretion by the mammary glands.
Adrenocorticotropic hormone (ACTH) or Corticotropin  Adrenal cortex	Stimulates secretion of glucocorticoids (mainly cortisol) by adrenal cortex.
Melanocyte-stimulating hormone (MSH)  Brain	Exact role in humans is unknown, but may influence brain activity; when present in excess, can cause darkening of skin.

Table 17-4 part 2 Anatomy and Physiology: From Science to Life

Posterior Pituitary

Also known as neurohypophysis. Stores and releases two hormones produced by hypothalamus

Anti-Diuretic Hormone (ADH)

Oxytocin.

Summary of principal actions of the posterior pituitary hormones

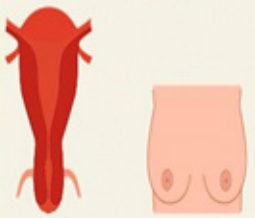
Hormone and Target Tissues	Control of Secretion	Principal Actions
Oxytocin (OT)  Uterus Mammary glands	Neurosecretory cells of hypothalamus secrete OT in response to uterine distention and stimulation of nipples.	Stimulates contraction of smooth muscle cells of uterus during childbirth; stimulates milk ejection from mammary glands.
Antidiuretic hormone (ADH) or vasopressin  Kidneys Sudoriferous (sweat) glands Arterioles	Neurosecretory cells of hypothalamus secrete ADH in response to elevated blood osmotic pressure, dehydration, loss of blood volume, pain, or stress; low blood osmotic pressure, high blood volume, and alcohol inhibit ADH secretion.	Conserves body water by decreasing urine volume; decreases water loss through perspiration; raises blood pressure by constricting arterioles.

Table 17-5 Anatomy and Physiology: From Science to Life

Thyroid Gland

Located in front of the larynx and trachea at C5,C6 & C7.

Butterfly shaped gland.

Follicular cells secretes colloid that will be used to produce

thyroxine (T_4)

triiodothyronine (T_3)

Thyroid Hormone's Effects

Metabolic rate: increased basal metabolic rate (BMR).

Calorogenic: increased heat production

Sympathomimetic: flight or fight

Cardiovascular: increases responsiveness of heart

Growth: essential for normal growth

Nervous system: development

Abnormalities of Thyroid Function

1. Hypothyroidism

Reduced bmr

Gain of weight

Slow, weak pulse

Constipation

Depression

Poor tolerance of cold

Fatigue, anorexia

Slow reflexes and mentation

Dry skin, brittle hair,

2. Goiter

Is a bulge in the neck caused by iodine deficiency

3. Hyperthyroidism

Increased BMR

Exophthalmos in Grave's dissease

Hair loss

Anxiety, physical restless, mental excitability

Warm sweaty skin, heat intolerance

Diarrhea

Tachycardia, atrial fibrillation, palpitations

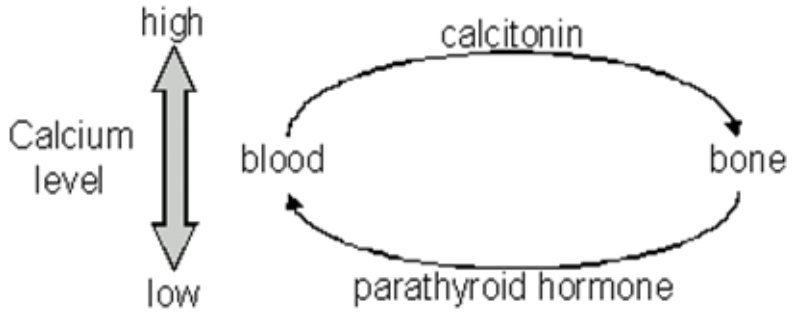
Weight loss, good appetite

Calcitonin

Secreted by parafollicular cells in the thyroid glands.

Lowers the blood calcium levels when raised

Promotes bone storage of calcium ions and inhibits calcium reabsorption by the kidneys



Parathyroid glands

Four small glands embedded on the posterior surface of the thyroid gland.

Calcium is needed for:

Muscle contraction

Nerve transmission

Blood clotting

Enzyme activity

Parathyroid Hormone (PTH)

Major regulator of calcium, magnesium, and phosphate ions in blood.

PTH increases blood levels of calcium when too low.

Increases calcium absorption in the small intestine, reabsorption of calcium in the kidneys and bone resorption (break down) to increase calcium levels in the blood.

Adrenal Glands

The adrenal glands are located superior to the kidneys.

They consist of an outer cortex and inner medulla.

Adrenal Cortex

Divided into three zones

Each secretes its own hormone from cholesterol.

- Mineralocorticoids
- Glucocorticoids
- Androgens

Glucocorticoid

Produced in response to stress.

Cortisone, hydrocortisone, corticosterone; cortisol

Stimulated by adrenocorticotropic hormone (ACTH)

Glucocorticoid Functions

Protein breakdown

Glucose formation-gluconeogenesis

Triglyceride breakdown-lipolysis

Weak mineralocorticoid activity

Resistance to stress

Anti-inflammatory effects

Depression of immune responses

Delayed wound healing

Mineralocorticoids (Aldosterone)

Maintains water and electrolyte balance.

Stimulates reabsorption of sodium ions in the kidneys and excretion of potassium ions in urine.

Sodium reabsorption is accompanied by water retention therefore aldosterone is used in regulation of blood pressure.

Stimulus for production is through high blood potassium levels and angiotensin.

Renin-angiotensin-aldosterone system

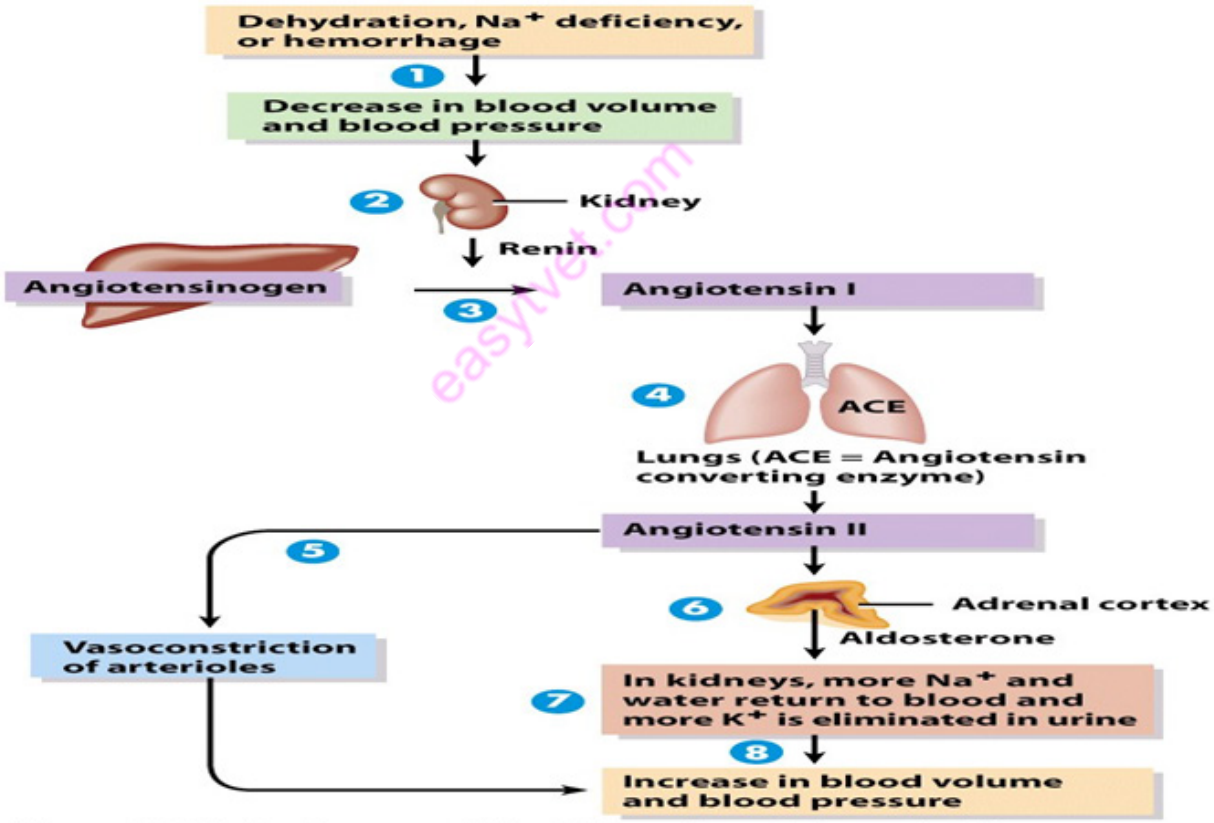


Figure 17-15 Anatomy and Physiology: From Science to Life
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Androgens (Sex Hormones)

Secreted in small amounts if compared with those secreted in the testes and the ovaries.

An example of androgen is testosterone in males responsible for the development of secondary sex characteristics in males like voice deepening and development of male sex organs.

In females androgens increases sex drive.

Adrenal Medulla

When stimulated it produces adrenaline and noradrenaline.

Adrenaline and Noradrenaline

Potentiates fight or flight response by:

Increasing heart rate

Increasing blood pressure

Diverting blood to essential organs: heart, brain, skeletal muscles

Increasing metabolic rate

Dilating pupils

Pancreas

The pancreas is posterior and slightly inferior to the stomach.

Histologically, it consists of islets of Langerhans (endocrine cells)-ductless; and acini (enzyme-producing cells).

Three types of cells in the endocrine portion are alpha cells, beta cells, and delta cells.

Alpha cells secrete glucagon, beta cells secrete insulin, and delta cells secrete growth hormone inhibiting factor (GHIF) or somatostatin.

RBS: 3.5 to 8 mmol/l (63 to 144 mg/100ml)

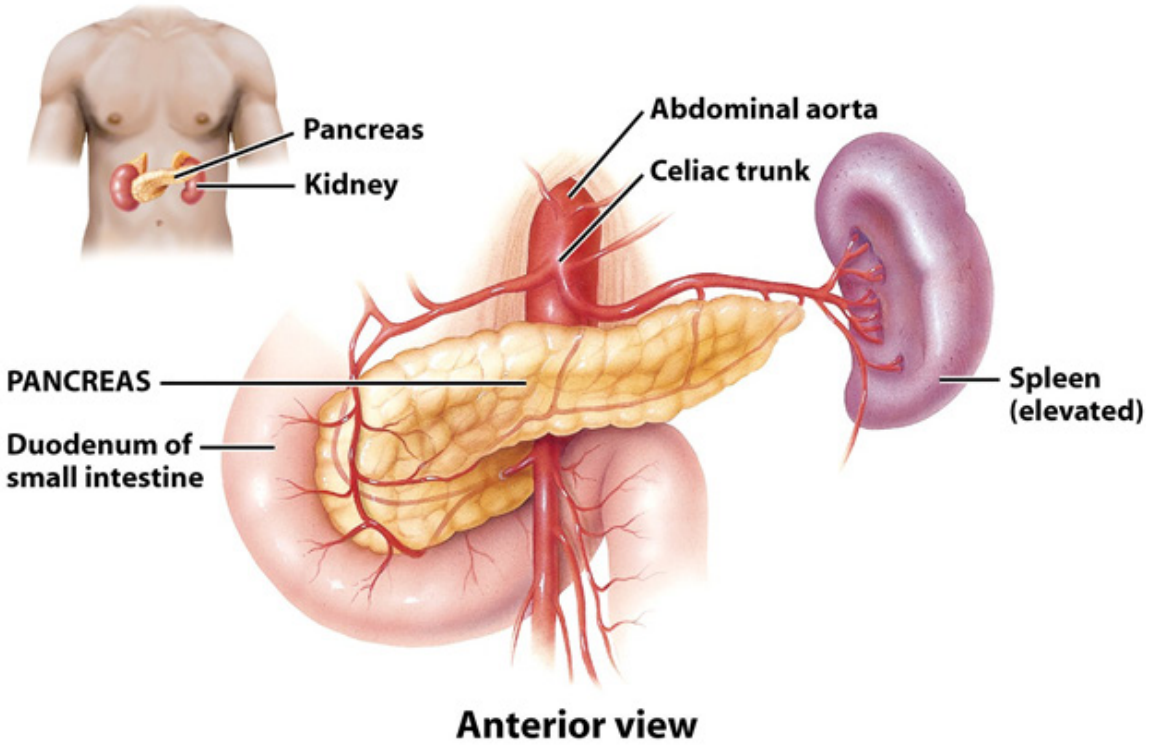

Figure 17-17a Anatomy and Physiology: From Science to Life
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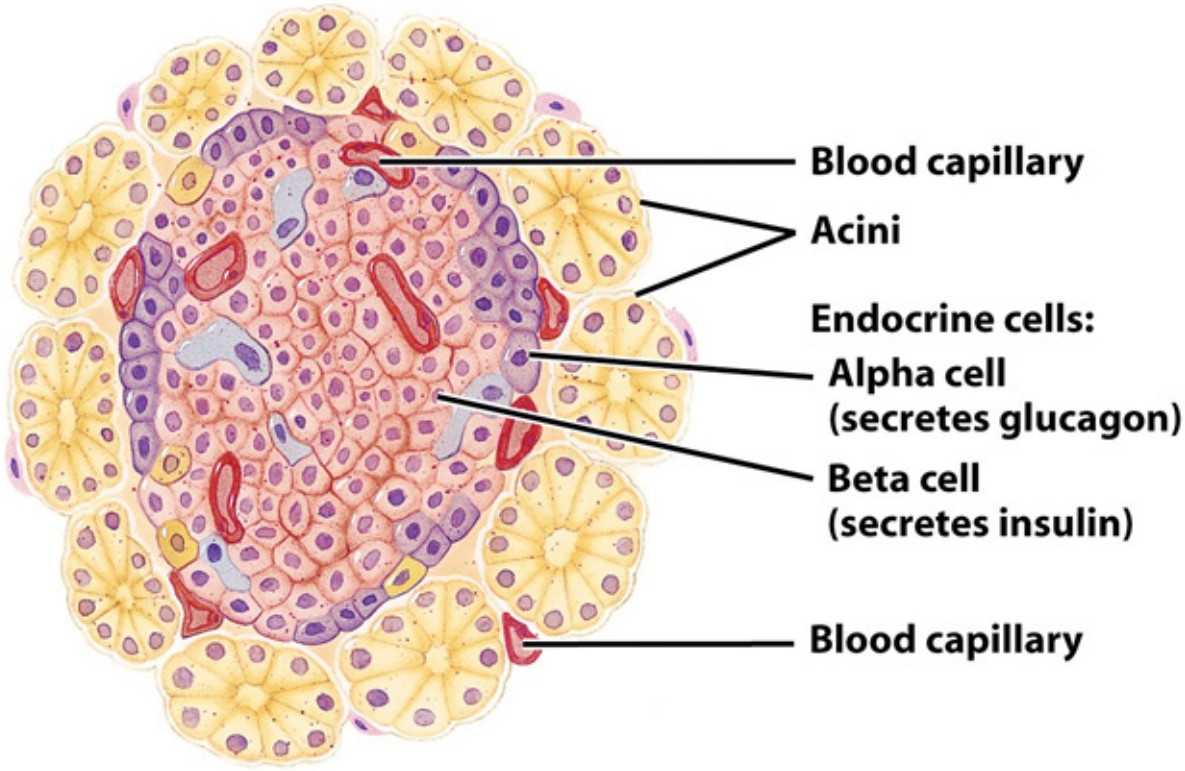

Pancreatic islet and surrounding acini

Figure 17-17b Anatomy and Physiology: From Science to Life
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Insulin

Function:

It lowers raised blood sugar levels i.e. glucose

Promotes storage of nutrients.

Insulin: Action on Blood Sugar

Facilities glucose entry into cells: muscle and connective tissue

Stimulates glycogenesis

Inhibits glycogenolysis

Inhibits gluconeogenesis

Insulin: Action on Fat

Increases transport into adipose cells

Promotes triglyceride synthesis-lipogenesis

Inhibits lipolysis

Insulin: Action on Protein

Promotes uptake of amino acids by muscle and other tissue.

Promotes protein synthesis

Inhibits protein degradation

Glucagon

Increases blood glucose levels by:

Glycogenolysis

Gluconeogenesis

Summary of selected pancreatic islet hormones

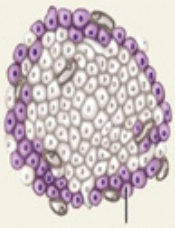
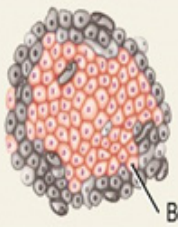
Hormone and Source	Control of Secretion	Principal Actions
Glucagon from alpha cells of pancreatic islets 	Decreased blood level of glucose, stimulation by sympathetic division of ANS during exercise, and mainly protein meals stimulate secretion. Insulin inhibits secretion.	Raises blood glucose level by accelerating breakdown of glycogen into glucose in liver, converting other nutrients into glucose in liver, and releasing glucose into the blood.
Insulin from beta cells of pancreatic islets 	Increased blood level of glucose, stimulation by parasympathetic division of ANS following high carbohydrate meals, hGH, and ACTH stimulate secretion.	Lowers blood glucose level by accelerating transport of glucose into cells, converting glucose into glycogen, and stimulating protein and fatty acid synthesis.

Table 17-9 Anatomy and Physiology: From Science to Life

Pineal Gland

Located on the roof of the 3rd ventricle connected to it a short stalk containing nerves which terminate in the hypothalamus.

Atrophies after puberty

Hormone secreted is melatonin

Contributes to setting the body's biological clock

Promotes sleepiness in small doses

In animals with breeding seasons, melatonin inhibits reproductive functions outside the season.

Inhibits the growth and development of sex organs before puberty, by possibly preventing the synthesis or release of gonadotrophins.

Thymus Gland

Secretes thymosin hormone.

Used for development of T-lymphocytes for cell mediated immunity.

Local Hormones

Histamine: synthesised and stored by mast cells in the tissues and basophils of blood.

mediates inflammation, increases capillary permeability and causes vasodilation.

It also causes contraction of smooth muscle of bronchi and alimentary tract and stimulates secretion of gastric juice.

Gastrointestinal hormones: gastrin, cholecystokinin & secretin: influences the secretion of gastric juices.

Serotonin (5-hydroxyptamine, 5-HT)-present in the brain and intestinal wall. Causes intestinal secretion and contraction of smooth muscles.

Has a role in blood clotting.

Prostaglandins(PGs)

Lipid derivatives

Effects

Inflammatory response	Potentiates pain
Fever	Regulates blood pressure
Blood clotting	Uterine contractions during labour
Others: leukotrienes – inflammatory response	

Thromboxane A2- platelet aggregation

THE GENERAL & SPECIAL SENSES

Types of Senses

1. General senses

   Touch (tactile)

   Temperature- thermoreceptors (heat)

Pressure- mechanoreceptors (movement)

Pain- mechanoreceptors

2. Special senses

Smell- chemoreceptors (chemicals)

Taste- chemoreceptors

Sight- photoreceptors (light)

Hearing- mechanoreceptors

Equilibrium- (balance) mechanoreceptors

Introduction

Senses – our perception of what is "out there"

Differences between General and Special Senses

General senses

Includes senses that are not specific

Receptors are not specialized or free nerve endings

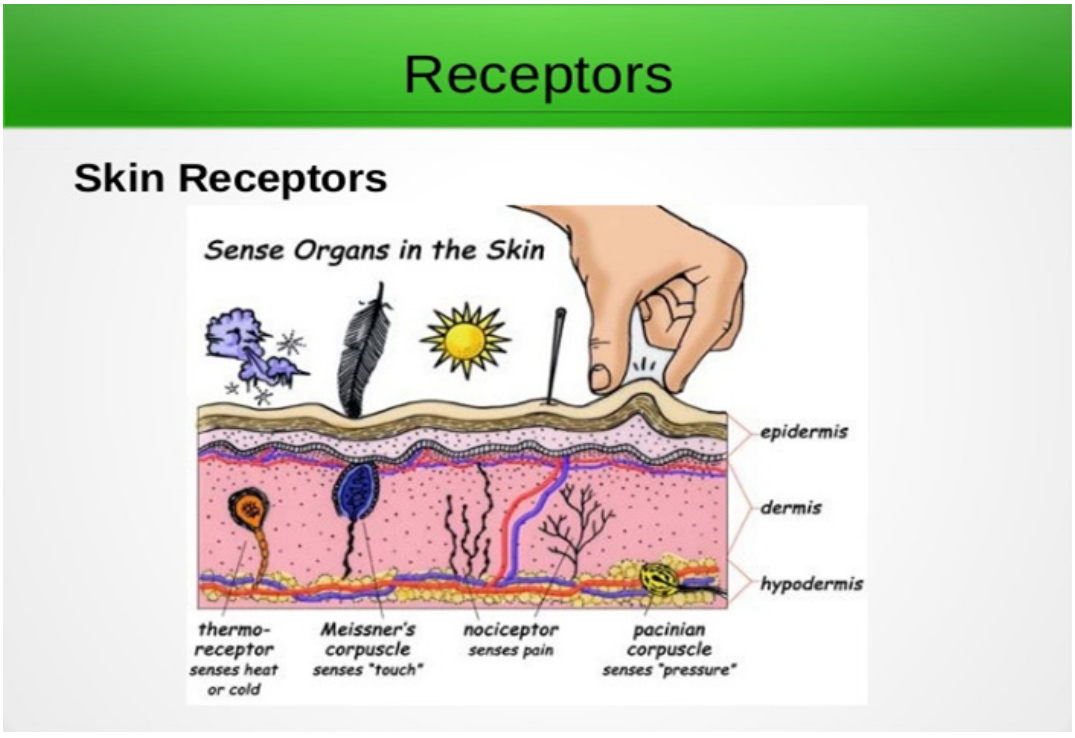
Pass information through spinal nerves

Special senses

Highly specialized receptors

Found within complex sense organs

Pass information through cranial nerves to cerebral cortex



Receptors

Sensory receptors are transducers

Change stimuli into electro-chemical impulses

Specific receptors can transduce only certain types of stimuli.

Interpretation of Sensory Information

Occurs in cerebral cortex in the brain.

Depends on the area of the cerebral cortex that receives the information.

Central Processing and Sensory Adaptation

Sensory adaptation – the loss of sensitivity after continuous stimulation

Occurs in some types of receptors

Role – prevents brain from being overloaded with unimportant information.

The Special Senses

Olfaction (the Nose)

Olfactory Receptors

Can detect at least 50 different primary smells.

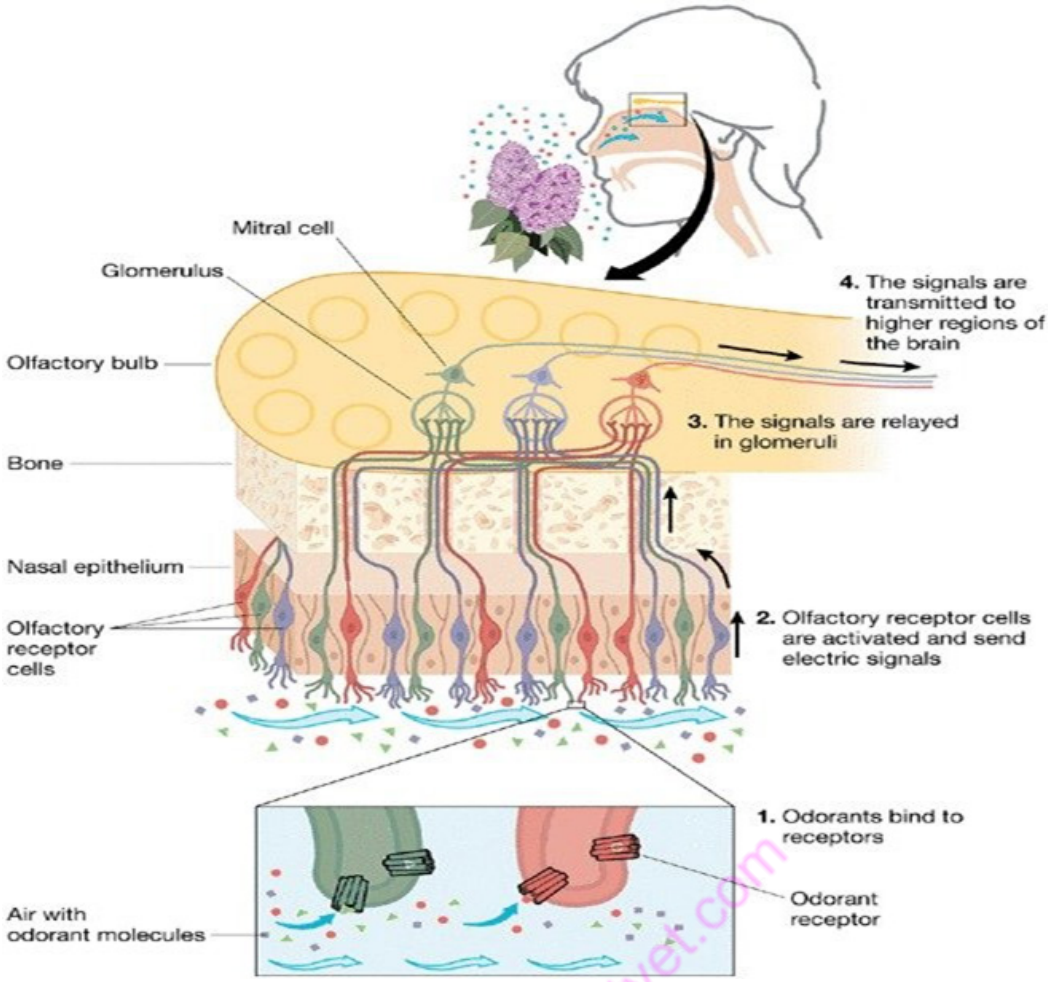
Located in the roof of nasal cavity.

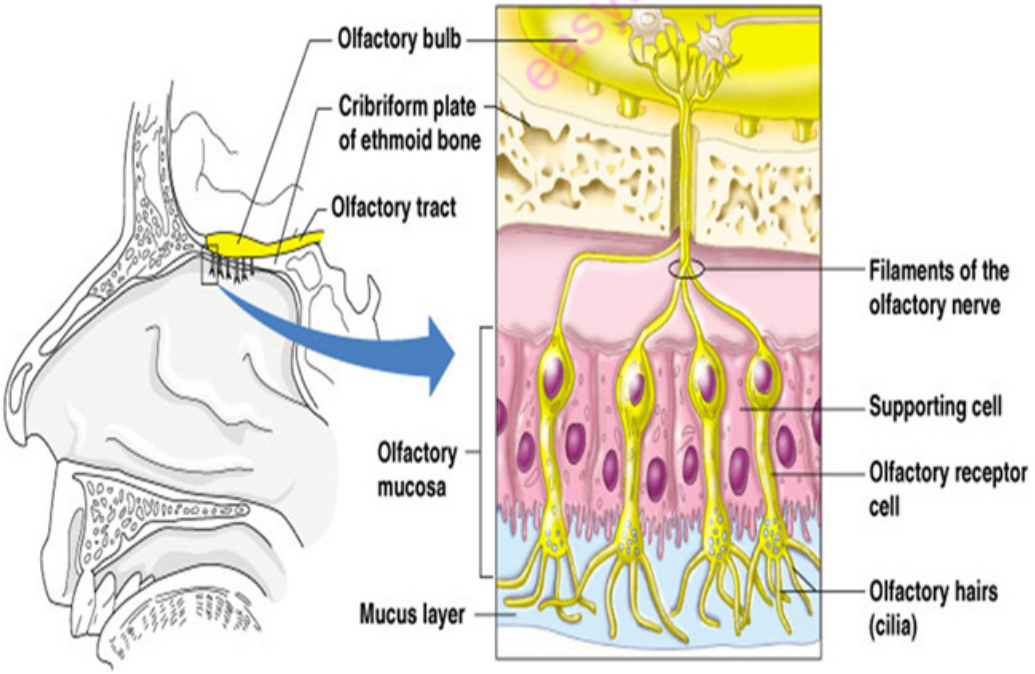
Molecules dissolve in the mucus or lipids of the epithelium

Olfactory neurons pass through the roof of the nasal cavity and synapse in the olfactory nerve.

Olfactory tracts go directly to the cerebral cortex

Interpretation occurs at the olfactory area of temporal lobe





TASTE (THE TONGUE)

Taste receptors are in the taste buds

Can detect 5 primary tastes

Sweet, sour, salty, bitter, umami

Located in papillae on the surface of the tongue

Taste buds contain the taste receptors

Molecules dissolve in saliva.

Cranial nerves relay sensory impulses to the cerebral cortex.

The Tongue and Taste Buds

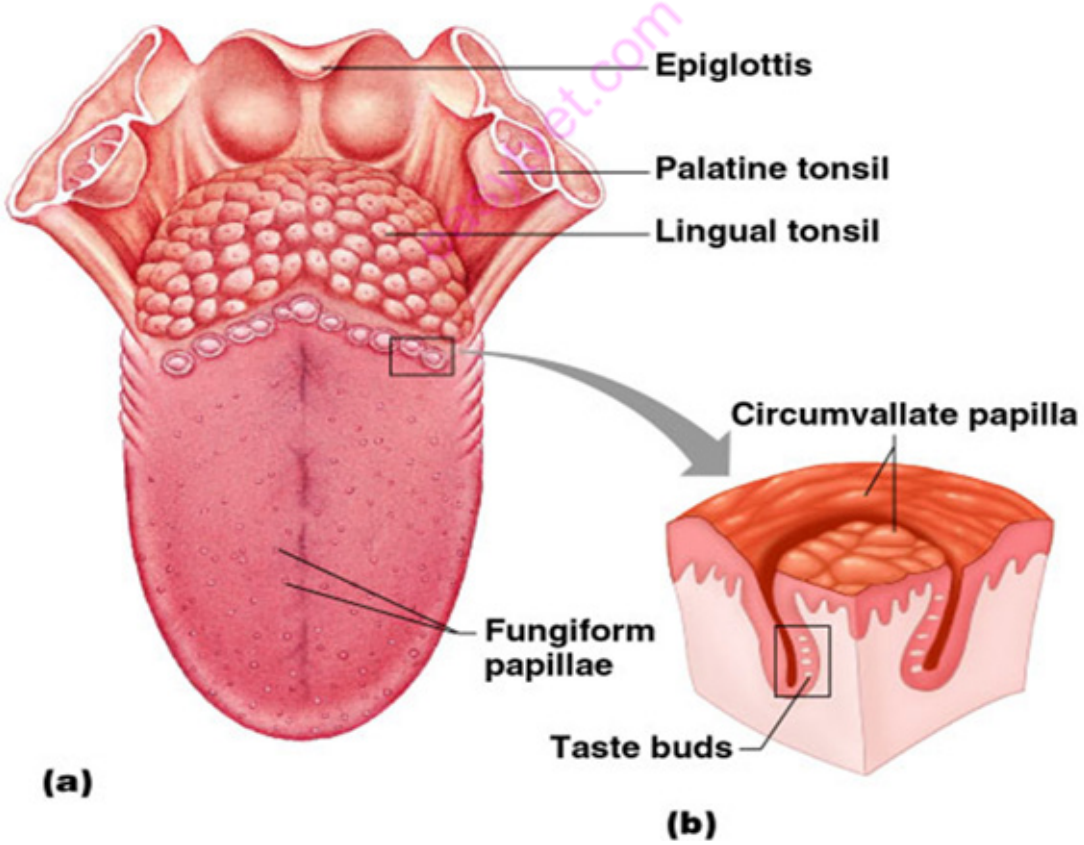
The tongue is covered with projections called papillae

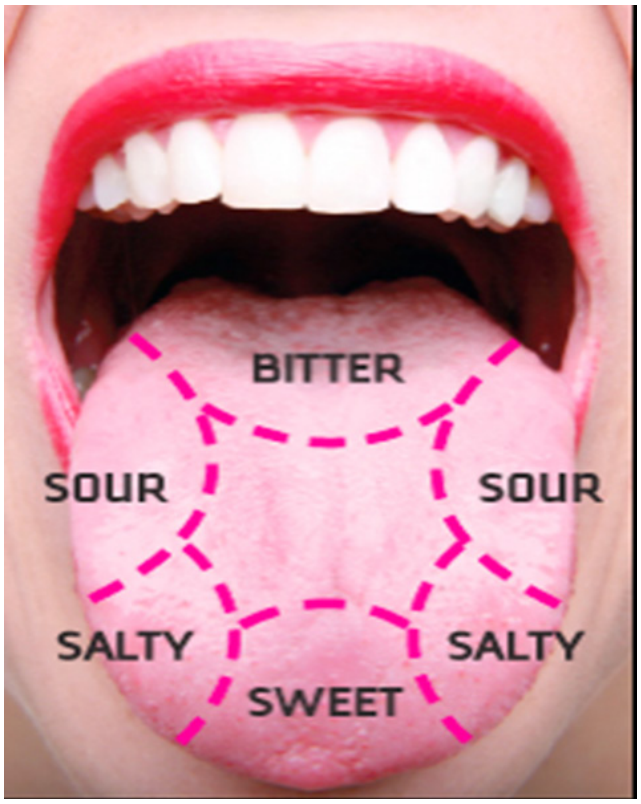
Filiform papillae – sharp with no taste buds

Fungifiorm papillae – rounded with taste buds

Circumvallate papillae – large papillae with taste buds

Taste buds are found on the sides of papillae



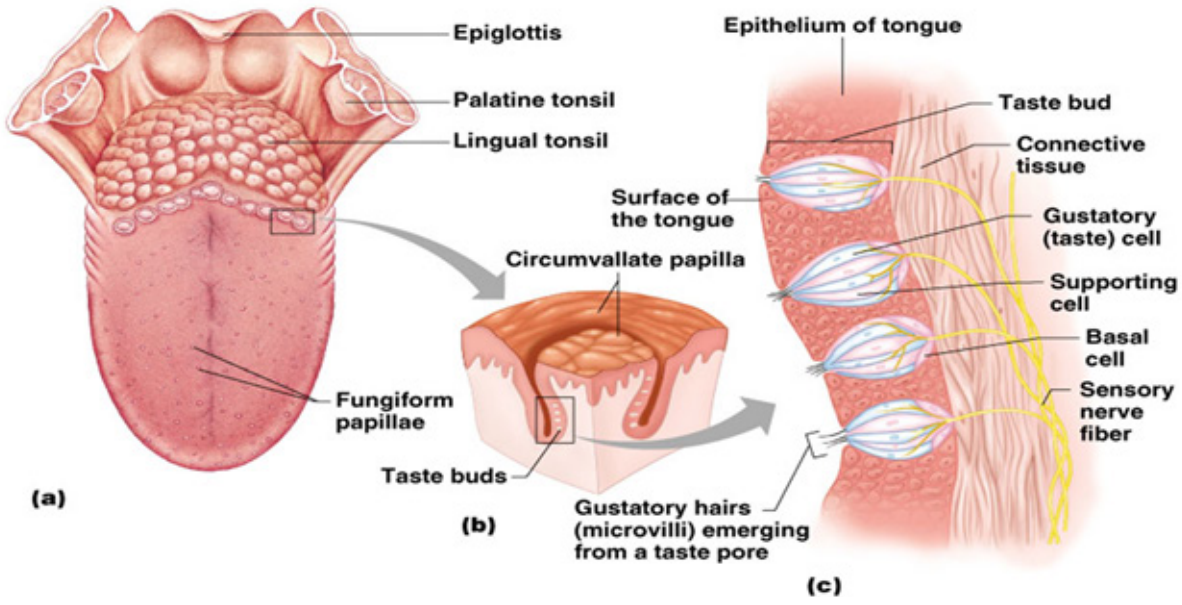


Structure of Taste Buds

Gustatory cells are the receptors

Have gustatory hairs (long microvilli)

Hairs are stimulated by chemicals dissolved in saliva



EQUILIBRIUM & HEARING (THE EAR)

External ear

The auricle directs sound waves into the external auditory meatus to the tympanic membrane

Middle ear

Contains the auditory ossicles

Malleus, incus, stapes

Connected to throat by the eustachian tube

Inner ear

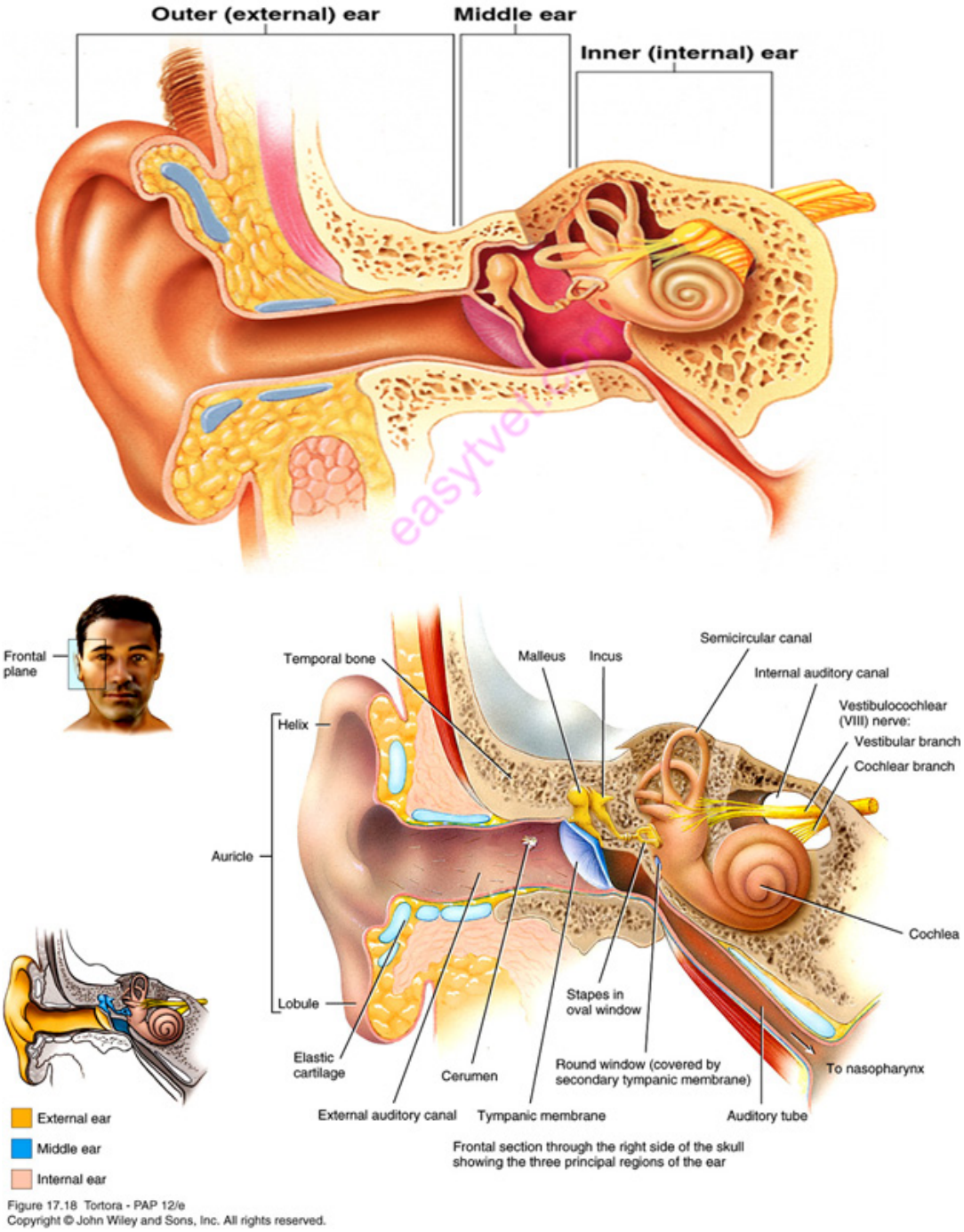


Figure 17.18 Tortora - PAP 12/e

The Inner Ear

Separated from the middle ear by the oval window

Consists of a series of canals filled with fluid

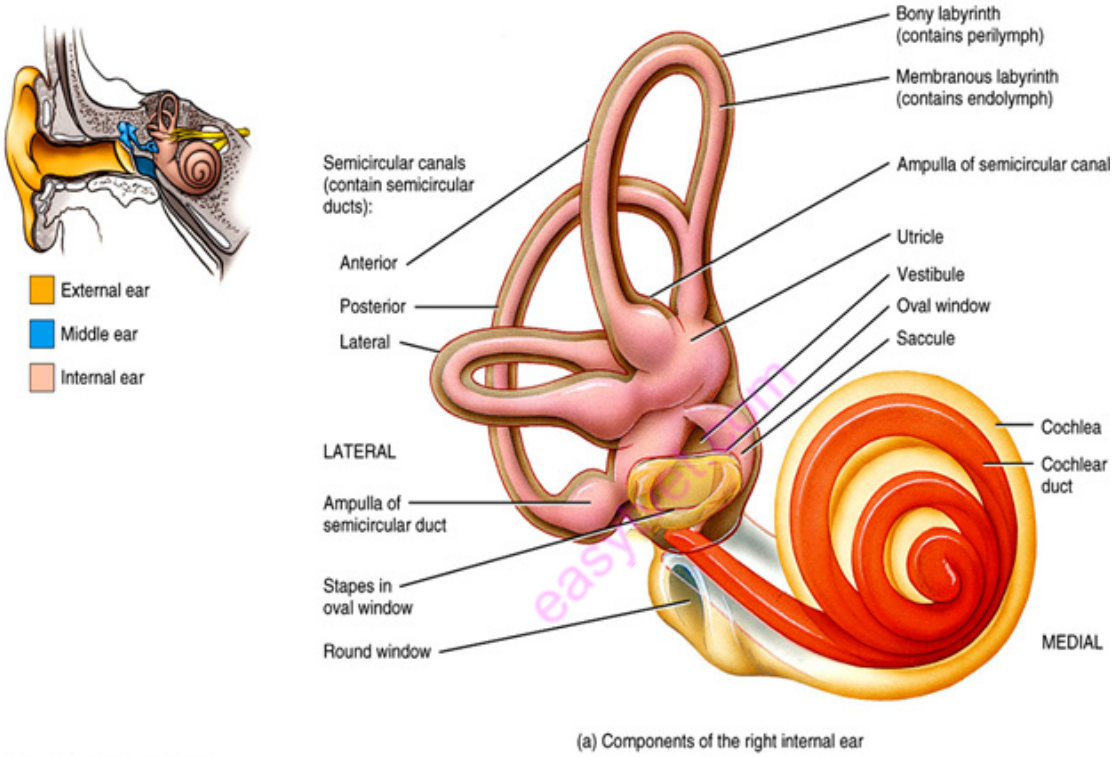
Three parts: the semicircular canals, the vestibule (both contain receptors for equilibrium/ balance) and the cochlea (contains receptors for hearing).

Semicircular canals

Contains receptors for head position

Cochlea

Contains the organ of Corti, the organ of hearing



(a) Components of the right internal ear

Figure 17.20 Tortora - PAP 12/e

The Semicircular Canals

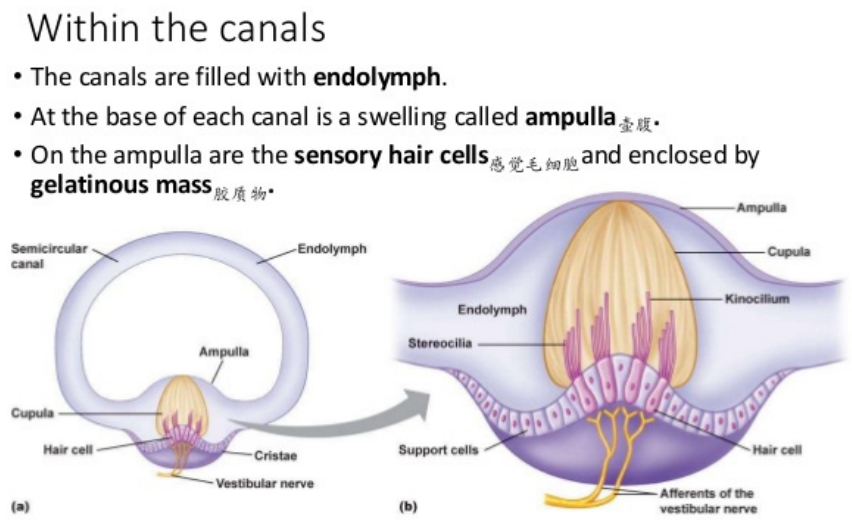
Detects balance.

Arranged at right angles to each other

Contain hair cells embedded in gelatinous material with fluid over it.

Detect movement of the head

Bends the hairs, creating nerve impulses



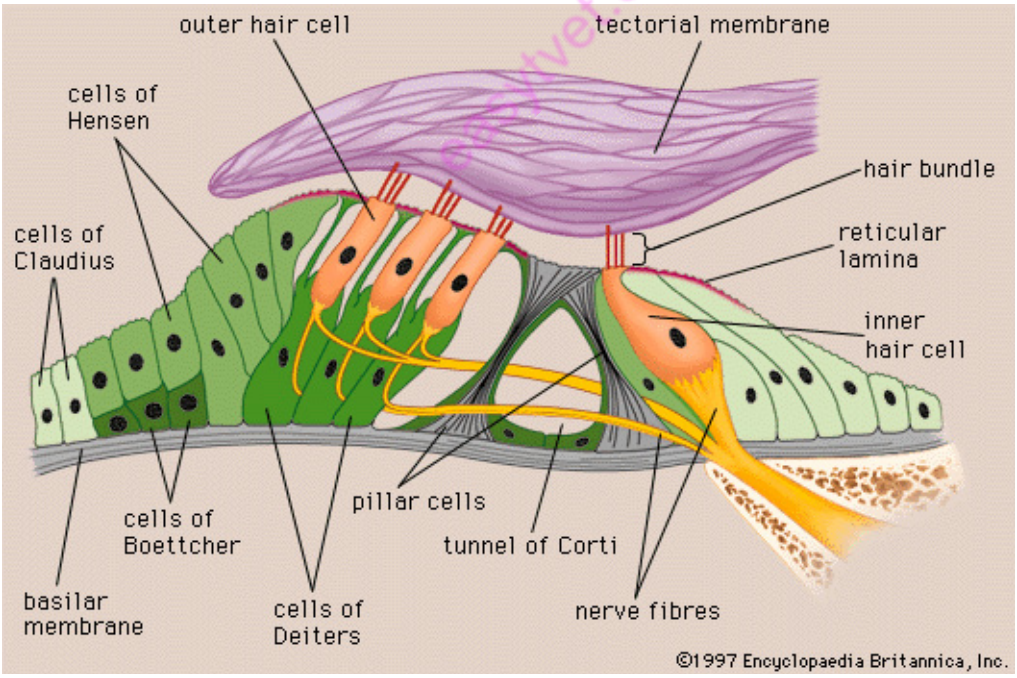
The Organ of Corti

Detects sound waves

Consists of hair cells on a basement membrane

Tips of hairs touch the tectorial membrane

When the basement membrane vibrates, the hair cells are bent, sending a nerve impulse



Summary of Hearing

Sound waves enter the external auditory meatus

Tympanic membrane vibrates

Auditory ossicles vibrate

Oval window vibrates

Fluid in inner ear vibrates

Basement membrane moves

Hairs rub against the tectorial membrane

Nerve impulse is sent along the auditory nerve to the brain.

Diseases of Hearing

External Otitis, the most common disorder of the outer ear, also know as Swimmer's ear. The process develops due to loss of the protective cerumen (wax) and excessive moisture in the ear canal.

Otitis Media is one of the most common diseases of children, due to chronic middle ear infection. Treatments: antibiotics, otomyringotomy (surgical insertion of rigid "ear tubes").

Conductive Hearing Loss, usually due to otosclerosis, progressive fixation of the stapes due to aging or disease.

4. VISION (THE EYE)

Accessory structures of the Eye

1. Eyelids protect the eye

    Conjunctiva lines the eyelid

    Lacrimal gland produces tears

2. Extrinsic muscles move the eyeball

Structure of the Eye

Consists of 3 tunics (layers)

1. Outer tunic – outermost layer

    Includes the cornea & sclera

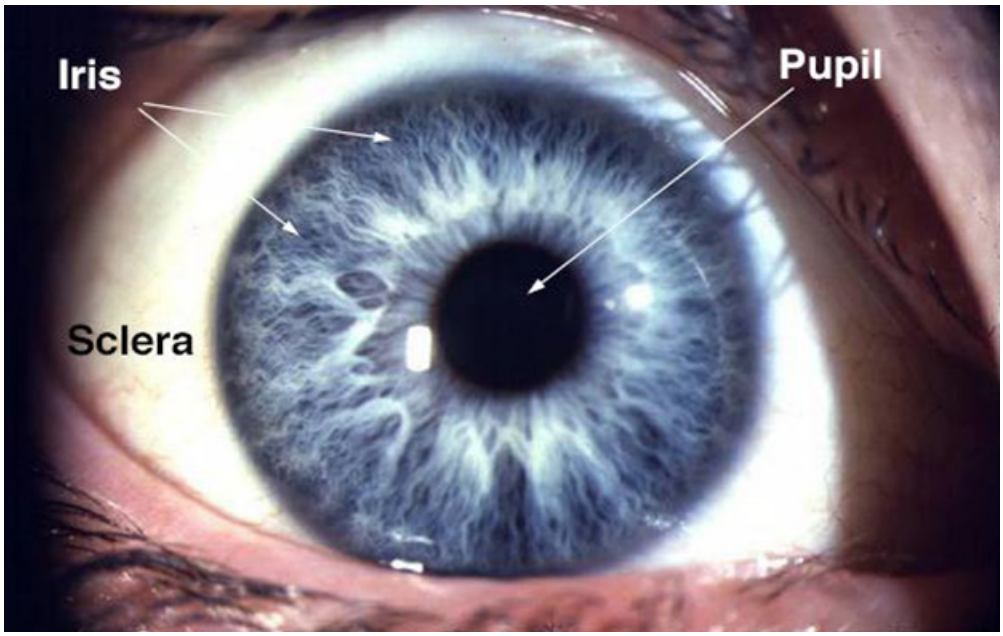
2. Middle tunic

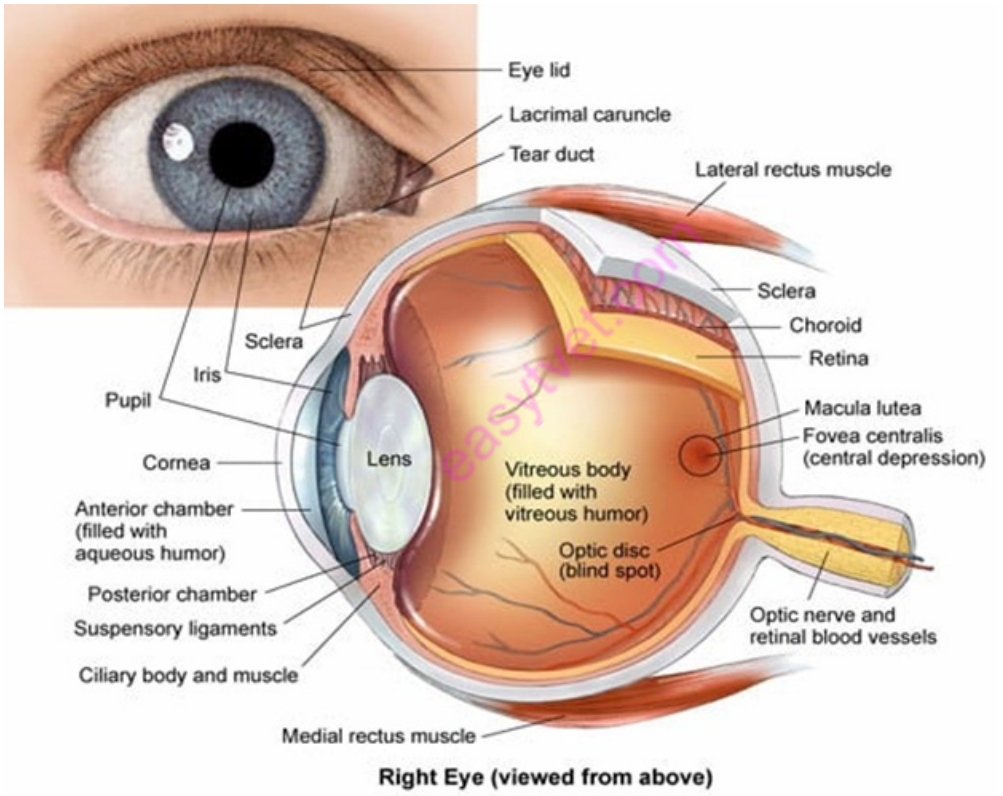
    Includes the choroid coat, ciliary body, lens, iris & pupil

3. Inner tunic (retina) – inner layer

    Contains the rods & cones (photoreceptors)

    Includes the optic disc (blind spot),





Right Eye (viewed from above)

The Cavities of the Eye

The lens separates the interior of the eye into 2 cavities:

Anterior cavity in front of the lens

Contains aqueous humor

Posterior cavity behind the lens

Contains vitreous humor

The Vascular Tunic

Contains many blood vessels & nerves

The iris controls the size of the pupil

Suspensory ligaments attach the lens to the ciliary body.

Controls the shape of the lens

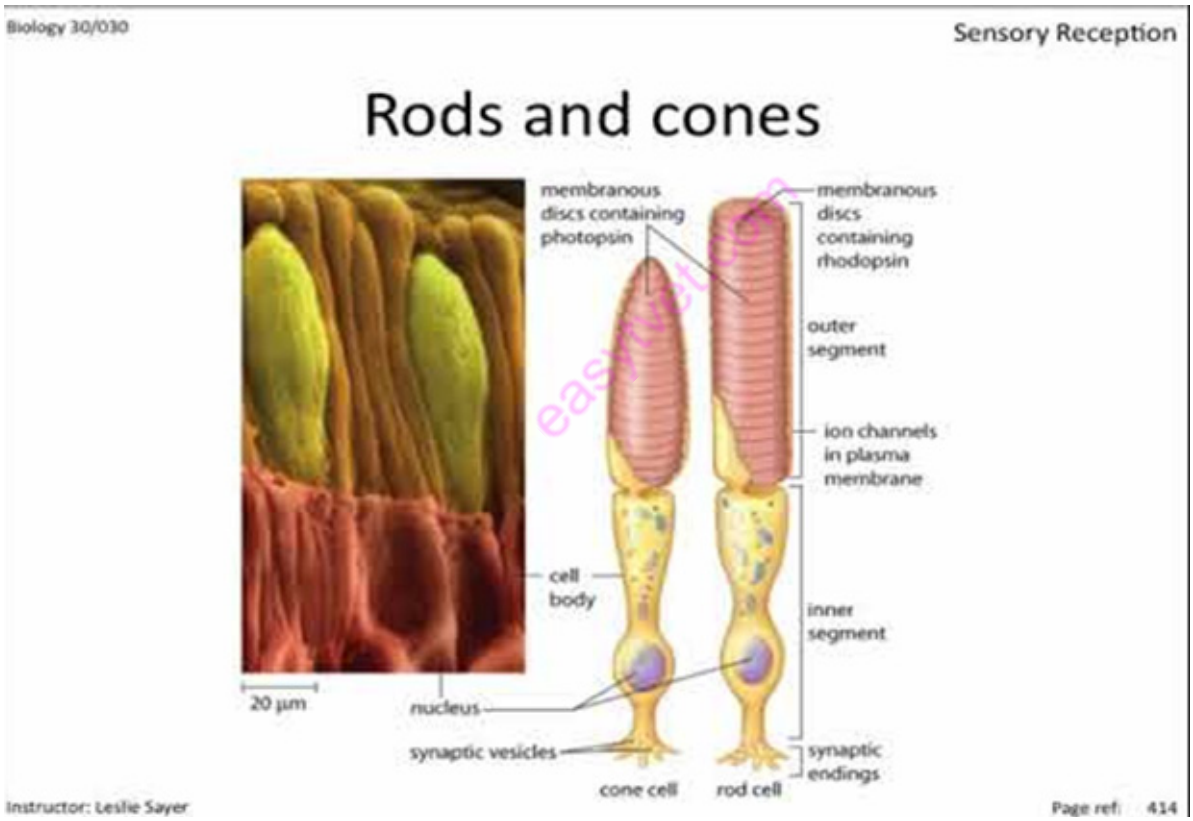
Allows focusing on near & distant objects.

Photoreceptors

Photoreceptor cells have two parts, the inner segment and the outer segment.

The inner segment contains the nucleus and other common organelles of a cell, whereas the outer segment is a specialized region in which photoreception takes place.

There are two types of photoreceptors—rods and cones—which differ in the shape of their outer segment.



The Retina—Photoreceptors

Cones

They contain photosensitive pigment called opsins.

Allow for sharp color vision in bright light

3 types, red, green and blue each with a different pigment.

Lack of any type leads to color blindness

Most dense in the center of the retina

Fovea centralis – area of the retina with only cones

NB: No photoreceptor cells are at the optic disk, or blind spot

Cones

They contain photosensitive pigment called opsins.

Allow for sharp color vision in bright light

3 types, red, green and blue each with a different pigment.

Lack of any type leads to color blindness

Most dense in the center of the retina

Fovea centralis – area of the retina with only cones

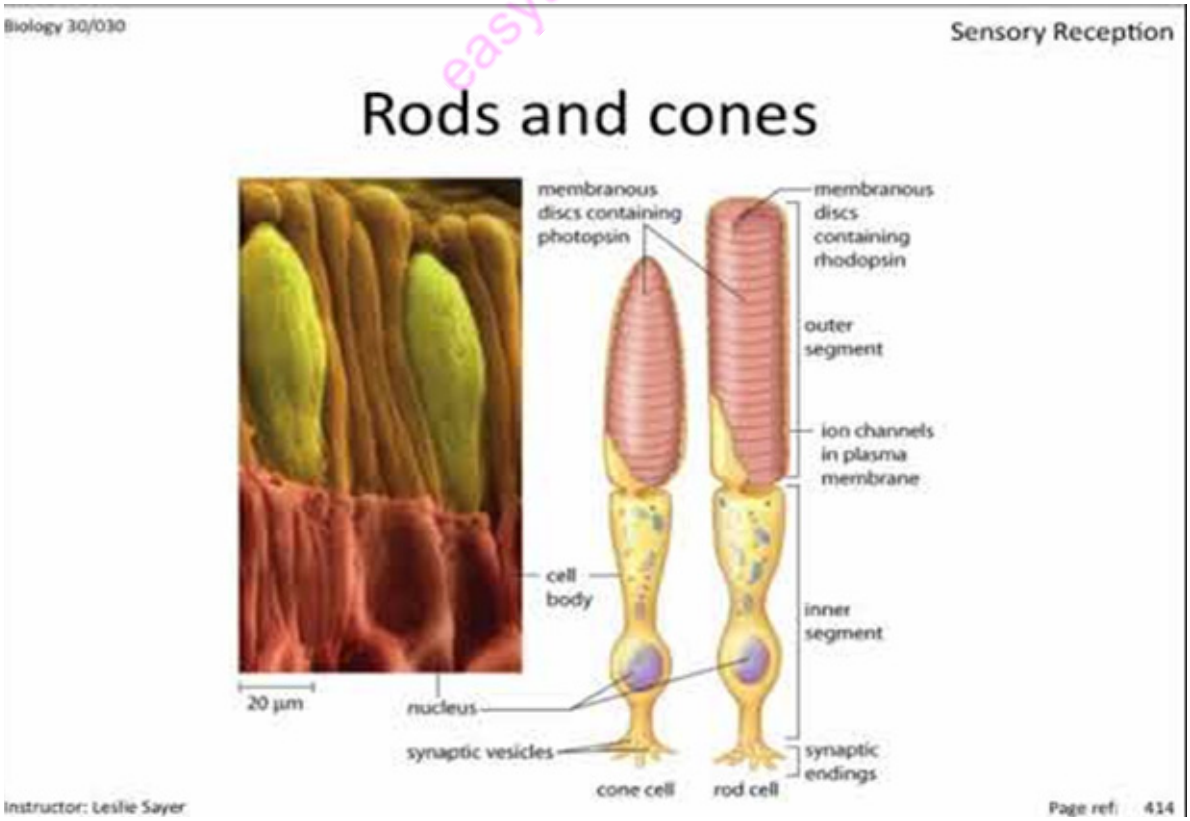
NB: No photoreceptor cells are at the optic disk, or blind spot

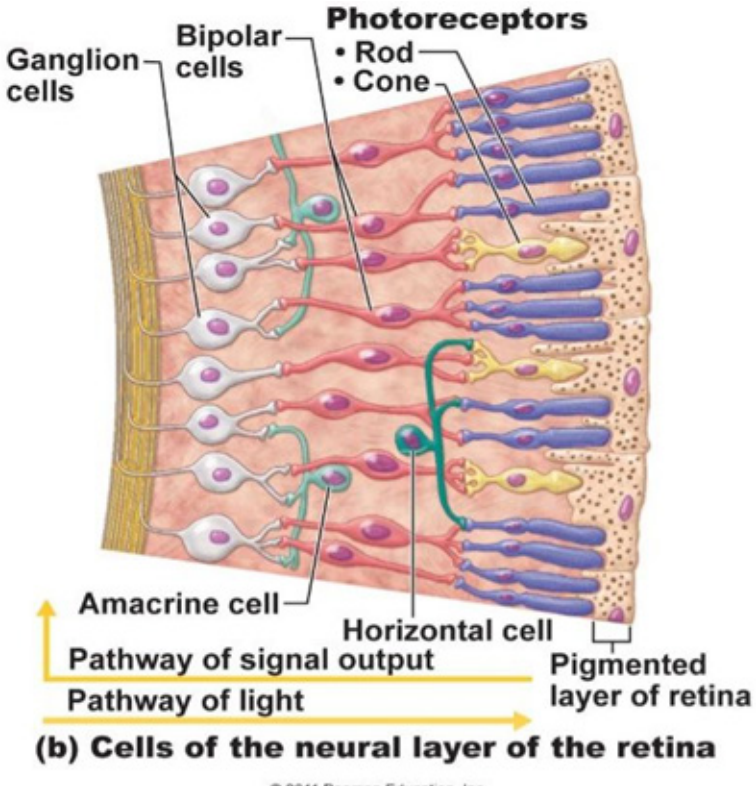
2. Rods

Provide for vision in dim light

Most dense at the periphery of the retina

Contain the photosensitive pigment called rhodopsin.





Summary of Vision

Light rays enters through the pupil

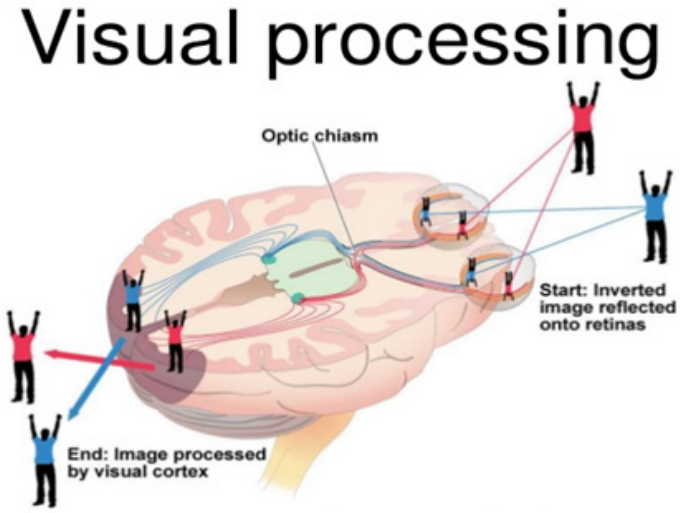
Light rays cross in the lens

Retina receives reversed & upside down image

Rods & cones are stimulated and they generate electrical impulses.

Optic nerve carries electrical impulses to the visual area of the cerebral cortex (occipital lobe).

Figure 7



Although images are inverted at the retina, the visual cortex of the brain reorients the images properly.

Visual Pathway

Photoreceptors of the retina

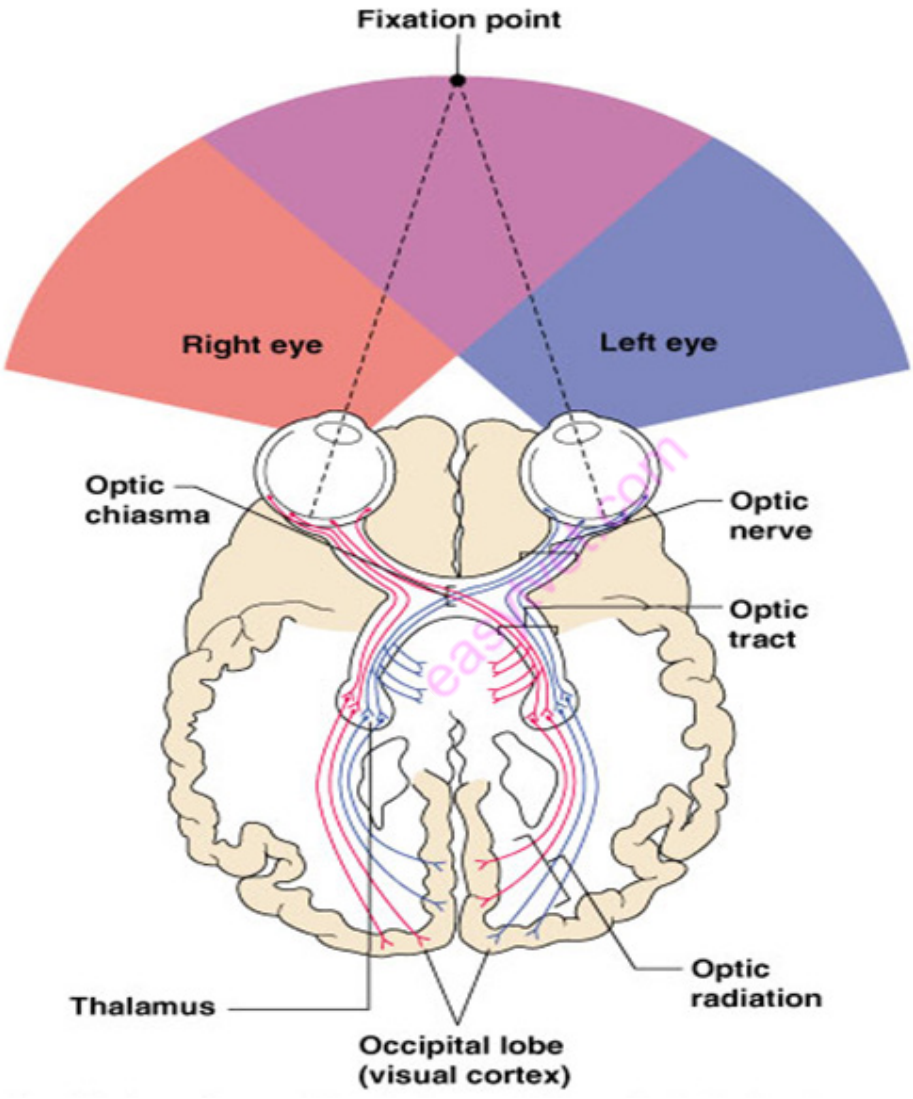
Optic nerve

Optic nerve crosses at the optic chiasma

Optic tracts

Thalamus (axons form optic radiation)

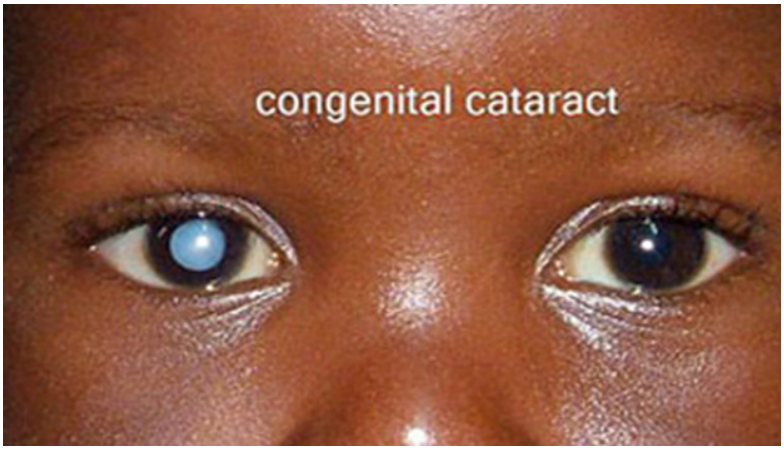
Visual cortex of the occipital lobe.



Abnormal Vision

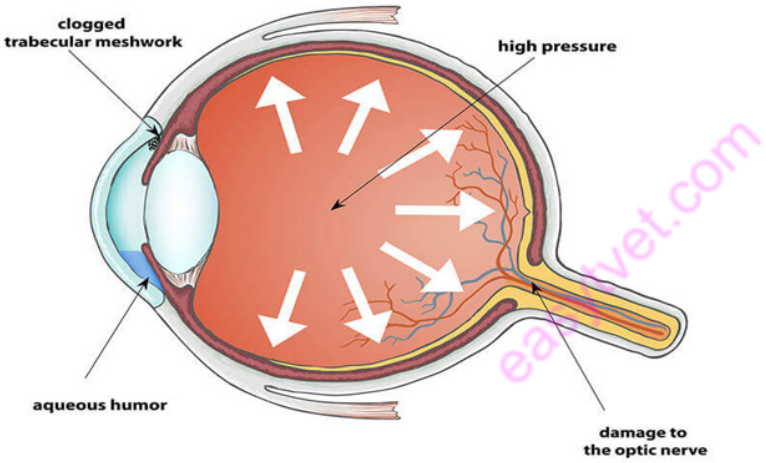
1. Cataracts

A clouding and hardening of all or part of the transparent lens located inside the eye, most often caused by the aging process, UV light exposure, etc.



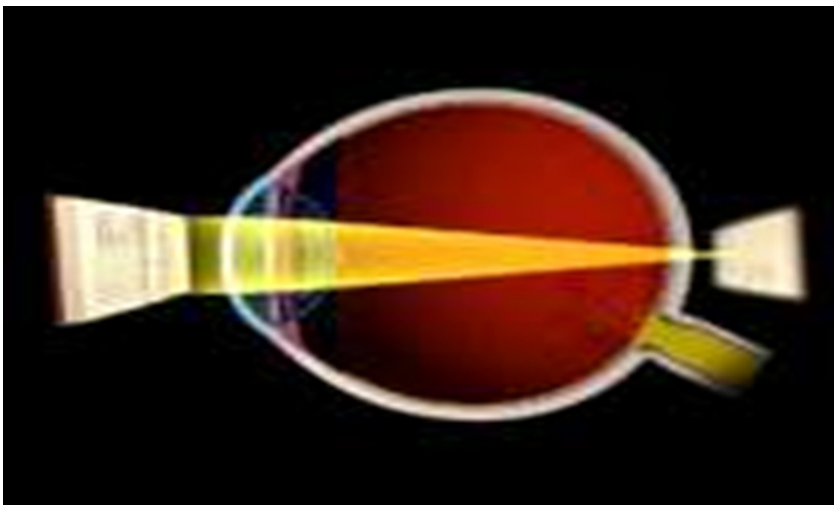
2. Glaucoma

A condition characterized by increased intraocular pressure- that can result in damage to the optic nerve and to retinal nerve fibers.



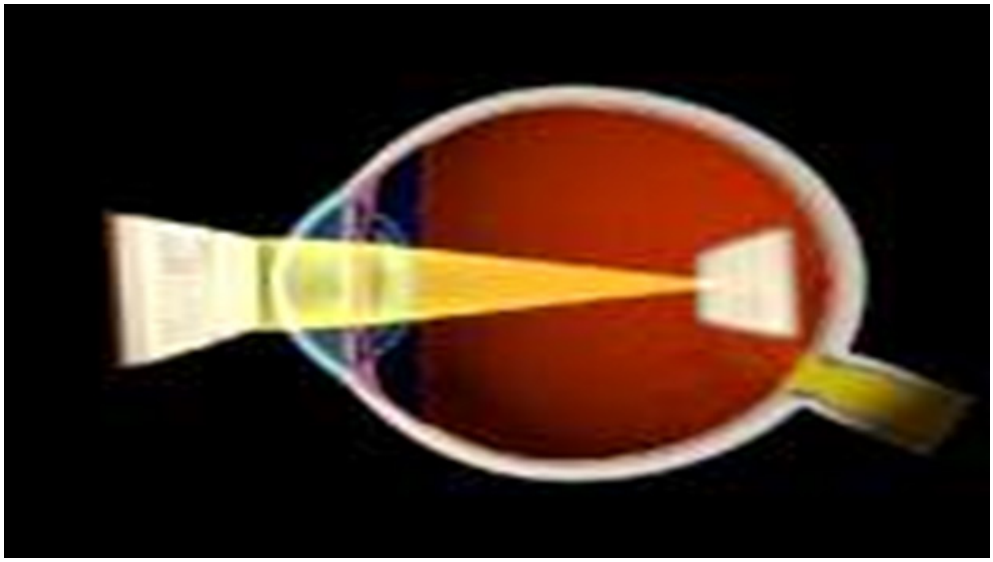
3. Hyperopia

Far sightedness. A condition in which rays of light are focused behind the retina, so distant objects appear clearer than near ones.



4. Myopia

Near sightedness. A condition in which light rays are focused in front of the retina instead of on it, so near objects appear more clear than far ones.



5. Retinoblastoma

Malignant tumor of the retina.

THE SKIN (INTEGUMENTARY SYSTEM)

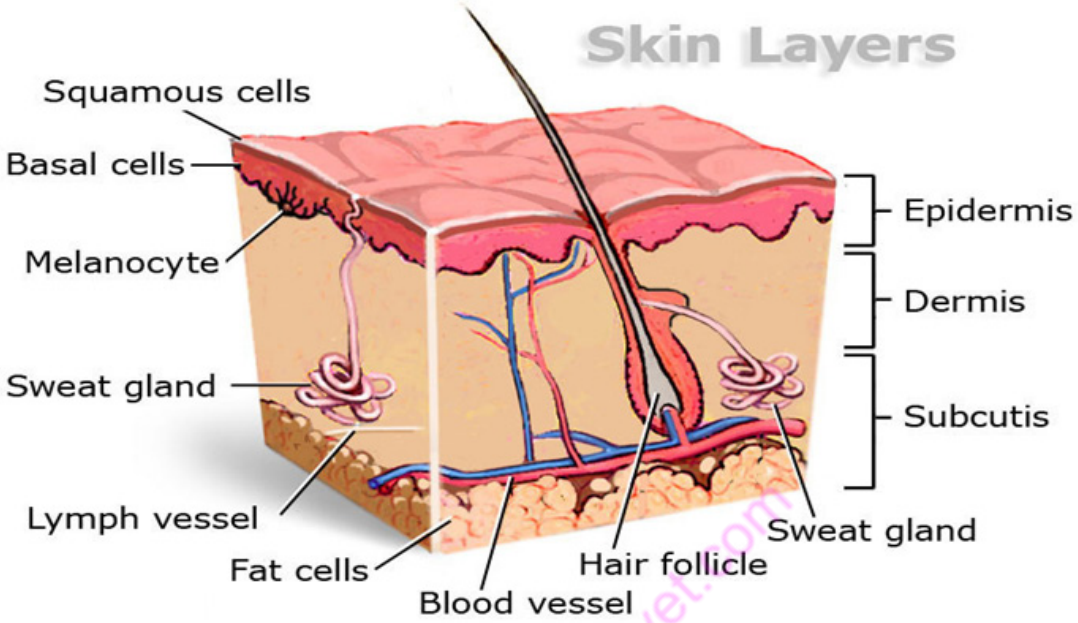
Introduction

Integument is skin

Skin and its appendages make up the integumentary system.

The three layers of the skin

Epidermis | Dermis | Hypodermis



Functions of Skin

1. Protection
2. Cushions and insulates and is waterproof
3. Protects from chemicals, heat, cold, bacteria
4. Screens UV rays
5. Synthesizes vitamin D with UV rays
6. Temperature regulation through sweating and vasodilation and vasoconstriction of vessels near the skin
7. Sensory reception (nerve endings)
8. Permitting Movement and Growth due to the elastic tissue that allow the underneath tissue to grow.
9. Excretion--wastes excreted through the skin include urea, water, uric acid and ammonia.

   Immunity--Those cells include epidermal dendritic cells, phagocytic cells and langerhans cells.

1. Epidermis

Keratinized stratified squamous epithelium

Four types of cells

Keratinocytes – deepest, produce keratin (tough fibrous protein)

Melanocytes - make dark skin pigment melanin

Merkel cells – associated with sensory nerve endings

Langerhans cells – macrophage-like dendritic cells

Layers of epidermis (from deep to superficial)

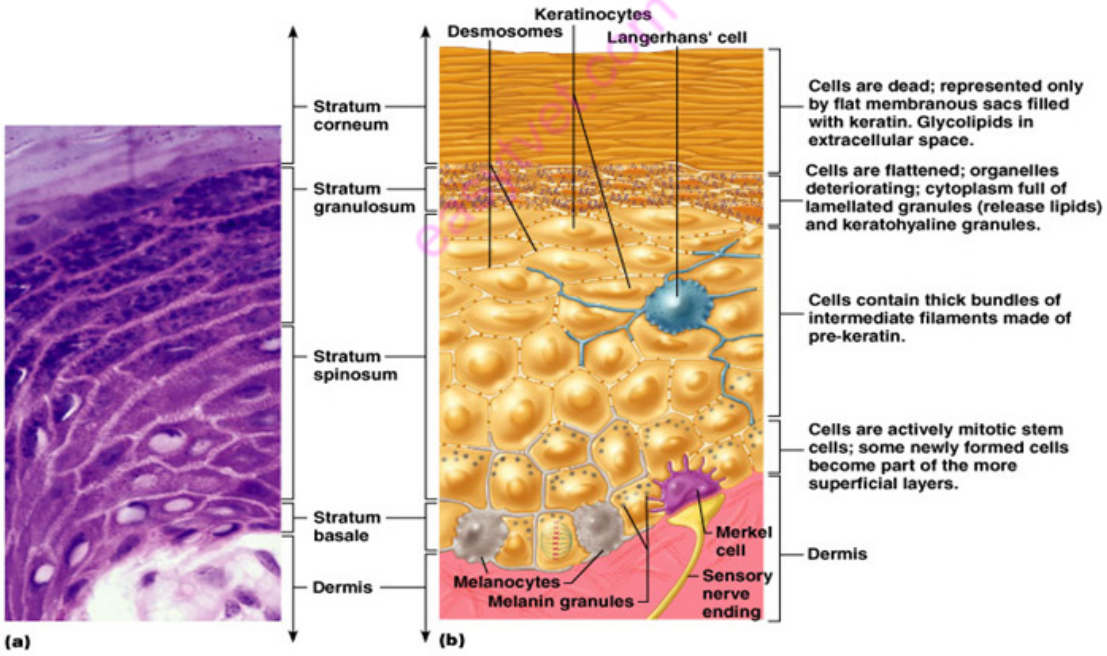
Stratum basale or germinativum – single row of cells attached to dermis; youngest cells

Stratum spinosum – spinous/prickle cell layer (bundles of protein) resist tension

Stratum granulosum – Contain granular layers of flattened keratinocytes producing keratin (hair and nails made of it also)

Stratum lucidum –clear or translucent layer (only on palms and soles)

Stratum corneum – horny layer (cells dead, many layers thick).



Remember

Four basic types of tissue

Epithelium – epidermis just discussed

Connective tissue - dermis

Muscle tissue

Nervous tissue

2. Dermis

Strong, flexible connective tissue: your “hide”

- Cells: fibroblasts, macrophages, mast cells, WBCs

- Fiber types: collagen, elastic, reticular

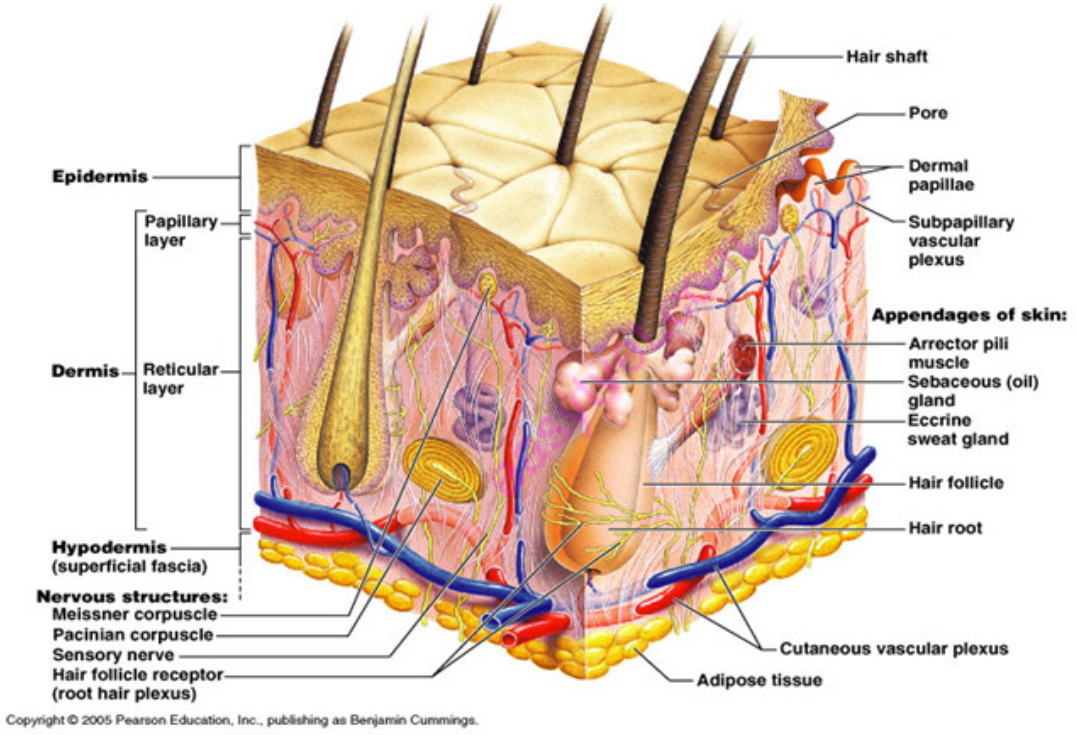
- Rich supply of nerves and vessels

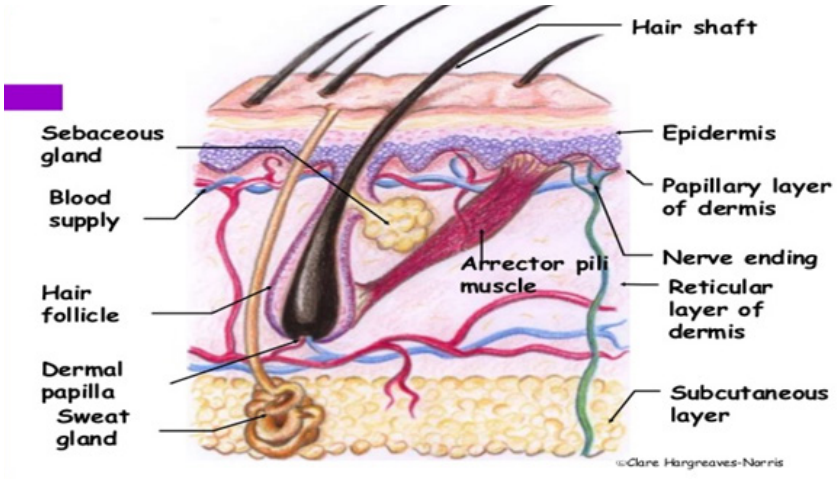
- Plays critical role in temperature regulation (the blood vessels)

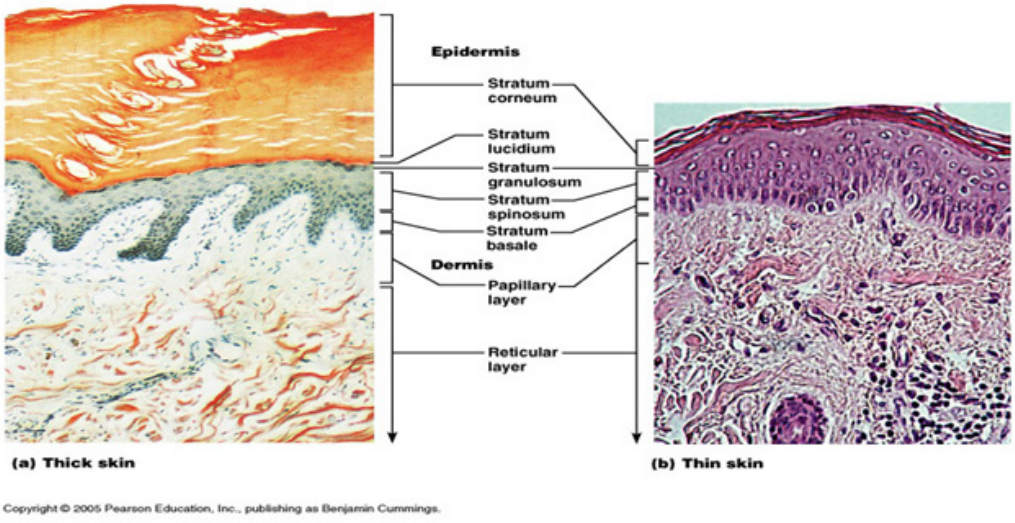
- Two layers of dermis

Papillary – areolar connective tissue; is loose connective tissue which hold organs in place and attaches epithelial tissue to other underlying tissues. This layer also includes dermal papillae

Reticular – “reticulum” (network) of collagen and reticular fibers.







Fingerprints, Palmprints, Footprints

Dermal papillae lie atop dermal ridges

Elevate the overlying epidermis into epidermal ridges

Are "sweat films" because of sweat pores

Genetically determined

Flexion Creases

Deep dermis, from continual folding

Fibers

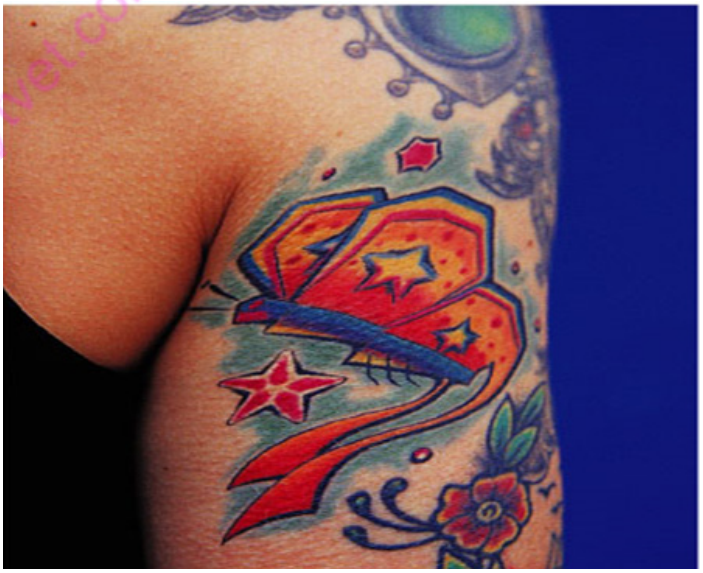
Collagen: strength and resilience

Elastic fibers: stretch-recoil

Striae: stretch marks

Tension lines (or lines of cleavage)

The direction the bundles of fibers are directed.



The dermis is the receptive site for the pigment of tattoos

3. Hypodermis

"Hypodermis" (Gk) = below the skin

"Subcutaneous" (Latin) = below the skin

Also called "superficial fascia"

"fascia" (Latin) =band; in anatomy: sheet of connective tissue

Fatty tissue which stores fat and anchors skin (areolar tissue and adipose cells)

Different patterns of accumulation in male and female.

Skin Color

Three skin pigments

Melanin: the most important

Carotene: from carrots and yellow vegies

Hemoglobin: the pink of light skin

Melanin in granules passes from melanocytes (same number in all races) to keratinocytes in stratum basale.

Digested by lysosomes

Variations in color

Protection from UV light

NB: Although all races have the same number of melanocytes in their skin, the amount of melanin pigment synthesized varies greatly and albinos have little or no melanin pigment in their skin which make them suffer from a condition called albinism.

Melanin also determine the color of hair and iris of the eye.

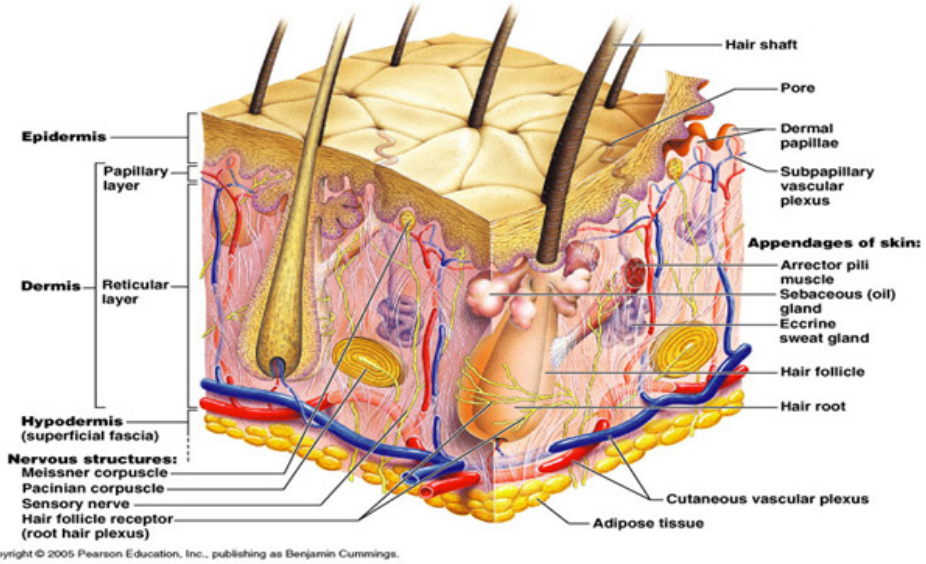
Skin Appendages

Skin appendages (or adnexa) are skin-associated structures that serve a particular function including sensation, contractility, lubrication and heat loss.

Derived from epidermis but extend into dermis.

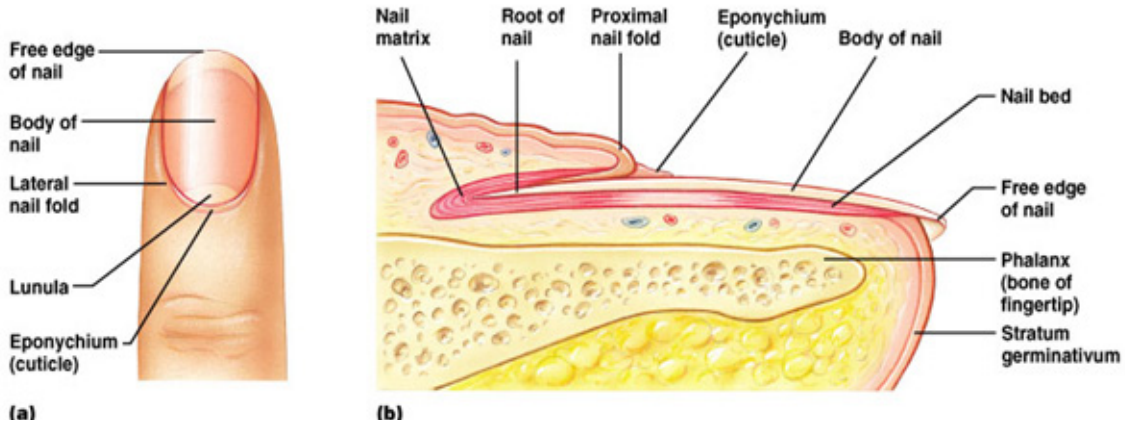
They include:

- Hair and hair follicles
- Sebaceous (oil) glands
- Sweat (sudoriferous) glands
- Nails



Nails

- Made of hard keratin
- Corresponds to hooves and claws
- Grows from nail matrix

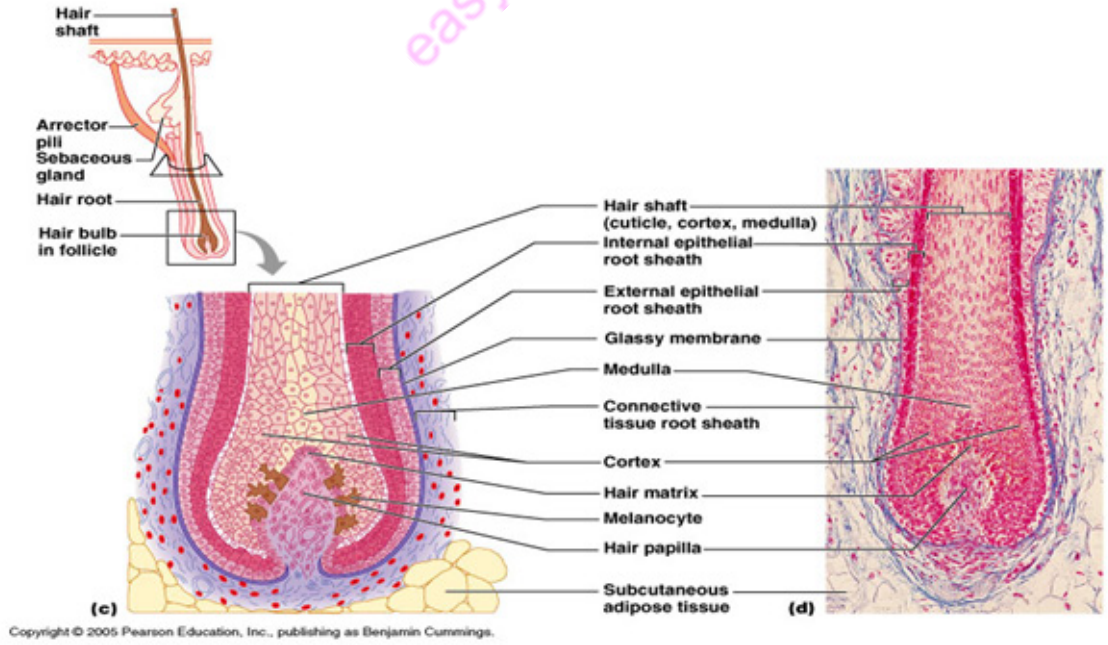


Hair and Hair Follicles: Complex

Derived from epidermis and dermis

They are found everywhere but palms, soles, nipples, parts of genitalia.

*"arrector pili" is smooth muscle that erect the hair follicle



Functions of hair

Warmth – less in man than other mammals

Sense light touch of the skin

Protection - scalp

Parts of the hair

Root imbedded in skin

Shaft projecting above skin surface

Make up of hair – hard keratin

Three concentric layers

Medulla (core)

Cortex (surrounds medulla)

Cuticle (single layers, overlapping)

Types of hair

Vellus: fine, short hairs

Intermediate hairs

Terminal: longer, courser hair

Hair growth: averages 2 mm/week

Active: growing

Resting phase then shed

Hair loss

Thinning – age related

Male pattern baldness

Hair color

Amount of melanin for black or brown; distinct form of melanin for red

White: decreased melanin and air bubbles in the medulla

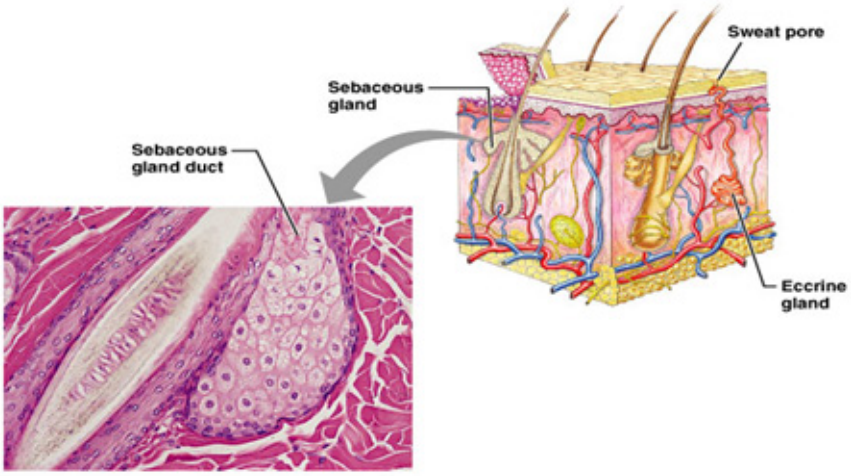
Genetically determined though influenced by hormones and environment

3. Sebaceous (Oil) Glands

Found on the entire body except palms and soles

Produce sebum by holocrine secretion---holocrine secretion is when gland secrete the whole cell.

Oils and lubricates



(a) Sectioned sebaceous gland

4. Sweat Glands

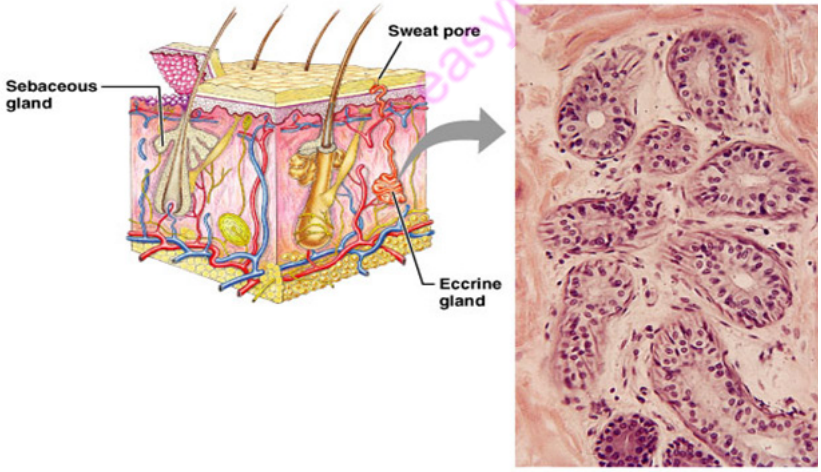
Entire skin surface except nipples and part of external genitalia

Prevent overheating

500 cc to 12 l/day! (is mostly water)

Humans most efficient (only mammals have)

Produced in response to stress as well as heat.



(b) Sectioned eccrine gland

Types of Sweat Glands

Eccrine or merocrine

- Most numerous
- True sweat: 99% water, some salts, traces of waste
- Open through pores

Apocrine

Axillary, anal and genital areas only

Ducts open into hair follicles

The organic molecules in it decompose with time – bad odor

Modified apocrine glands

Ceruminous – secrete earwax

Mammary – secrete milk

Disorders of the Integumentary System

- ***Burns***

Threatens life due to;

Catastrophic loss of body fluids

Dehydration and fatal circulatory shock

Infection

Types of burns

First degree – epidermis: redness (e.g. sunburn)

Second degree – epidermis and upper dermis: blister

Third degree - full thickness

- ***Infections***

Skin cancer

Tumors of the Skin

Benign, e.g. warts

Cancer – associated with UV exposure (also skin aging)

Aktinic keratosis - premalignant

Basal cell - cells of stratum basale

Squamous cell - keratinocytes

Melanoma – melanocytes: most dangerous; recognition:

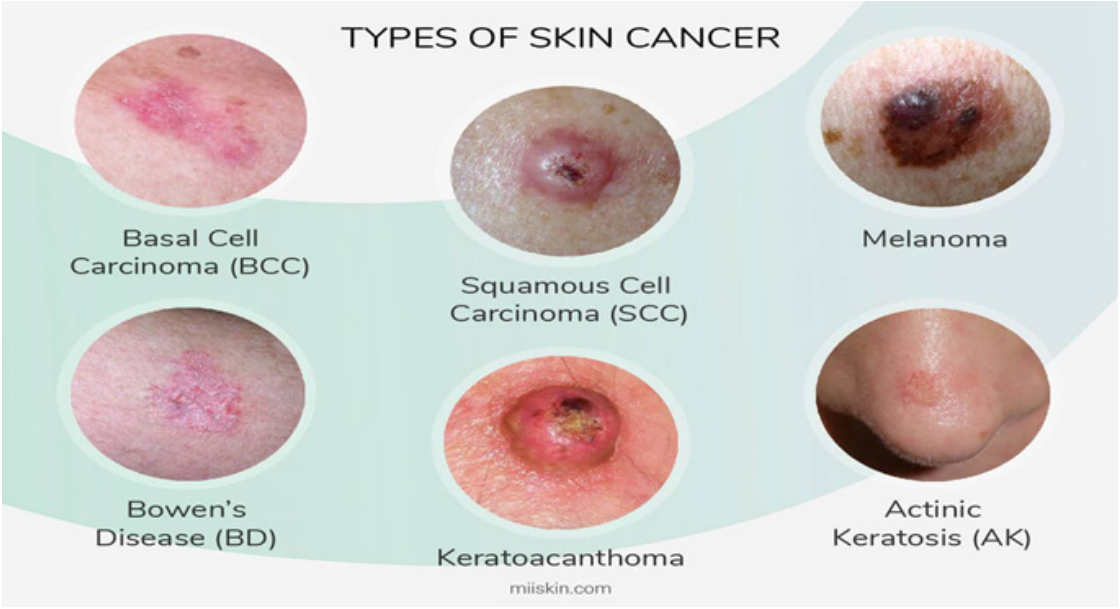
A - Asymmetry

B - Border irregularity

C - Colors

D - Diameter larger than 6mm

Skin Cancer



3.3.2.3 Self-Assessment

1. State the function of the following hormones in the digestive system
   A. Gastrin
   B. Secretin
2. State four (4) lymphatic organs and the function of each organ
3. State five (5) cells of the monocyte-macrophage system
4. State four (4) important electrolytes in the body and their
5. Outline the functions of any three hormones that influence selective reabsorption in the kidney
6. The following are common cardiovascular system disorders which one is not
   A. Hypertension
   B. Oedema
   C. Heart attack
   D. Stroke
7. State any four (4) functions of the pharynx
8. Describe the process of inspiration in the mammalian ventilation
9. Draw a well labeled diagram of a neuron
10. State four (4) types of membranes in the body
11. State four (4) factors affecting breathing

12. State any four types of synovial joints and the kind of movement they allow
13. State four (4) functions of the tongue
14. State the site of secretion of the following mammalian hormones and their functioning in the menstrual cycle
    i. Follicle stimulating hormone
    ii. Lutenising hormone
    iii. Oestrogen
    iv. Progesterone
15. State the function of the following cell organelles
    i. Cell membrane
    ii. Cilia
    iii. Nucleus
    iv. Golgi apparatus
16. State five (5) important electrolytes in the body and their function
17. State five functions of the small intestines
18. Mention six (6) anterior pituitary hormones
19. Differentiate between anabolism and catabolism
20. Briefly explain the five (5) essential parts of a reflex arc
21. List any ten (10) cranial nerves
22. Draw a well labeled diagram of the heart and use it to explain the blood flow through the heart.
23. State four (4) common pulse areas and where they are found
24. Briefly five (5) characteristics of normal urine
25. State five (5) hormones involved in hormonal regulation of tubular reabsorption and secretion in the kidney nephron
26. Mention three (3) organs of the lymphatic system and in each give a function
27. Define the following terms
    A. Integument
    B. Skin appendages
28. Explain the functions of skin

29. Which one of the following is TRUE about human skin
    A. Keratinocytes –macrophage-like dendritic cells
    B. Melanocytes - deepest, produce keratin (tough fibrous protein)
    C. Merkel cells – associated with sensory nerve endings
    D. Langerhans cells – make dark skin pigment melanin
30. Outline the components of integumentary system
31. Describe the layers of epidermis
32. Using a well labelled diagram, discuss the dermis
33. What are the functions of hair?
34. Describe the different types of sweat glands
35. Discuss the disorders of the integumentary system

3.3.2.4 Tools, Equipment, Supplies and Materials

Dummy human body, dummy internal organs, microscope, slides, cadaver, anatomy text books, white board, mark pen, charts, diagrams etc.

3.3.2.5 References

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