Branches of Science

- Anatomy
- Physiology

It provides the information about different body parts and their functions

Anatomy :- It is derived from the Greek word 'anatemno' = cut open

* Studies of the body parts and their relationships

Physiology :- It came from the greek word 'physis' = nature, person and 'Logia' = 'study' study of the body function

Levels of Structural Organisation

Chemical → combination of atom to form molecules

↓

Cell → Basic living units.

↓

Tissue → a group of cells with similar structure and function epithelial, nervous, connective

Serial No. .....

Dated .....

Organ :- Two or more tissue work together
e.g. eye, skin, heart

↓

Organ System :- A group of organ of a common function ;- Skeletal, muscular, nervous, endocrine, CVS, RS.

Organismal :- It is an highest level of organisation. It is the sum total of all structural level working together

Levels of Body systems

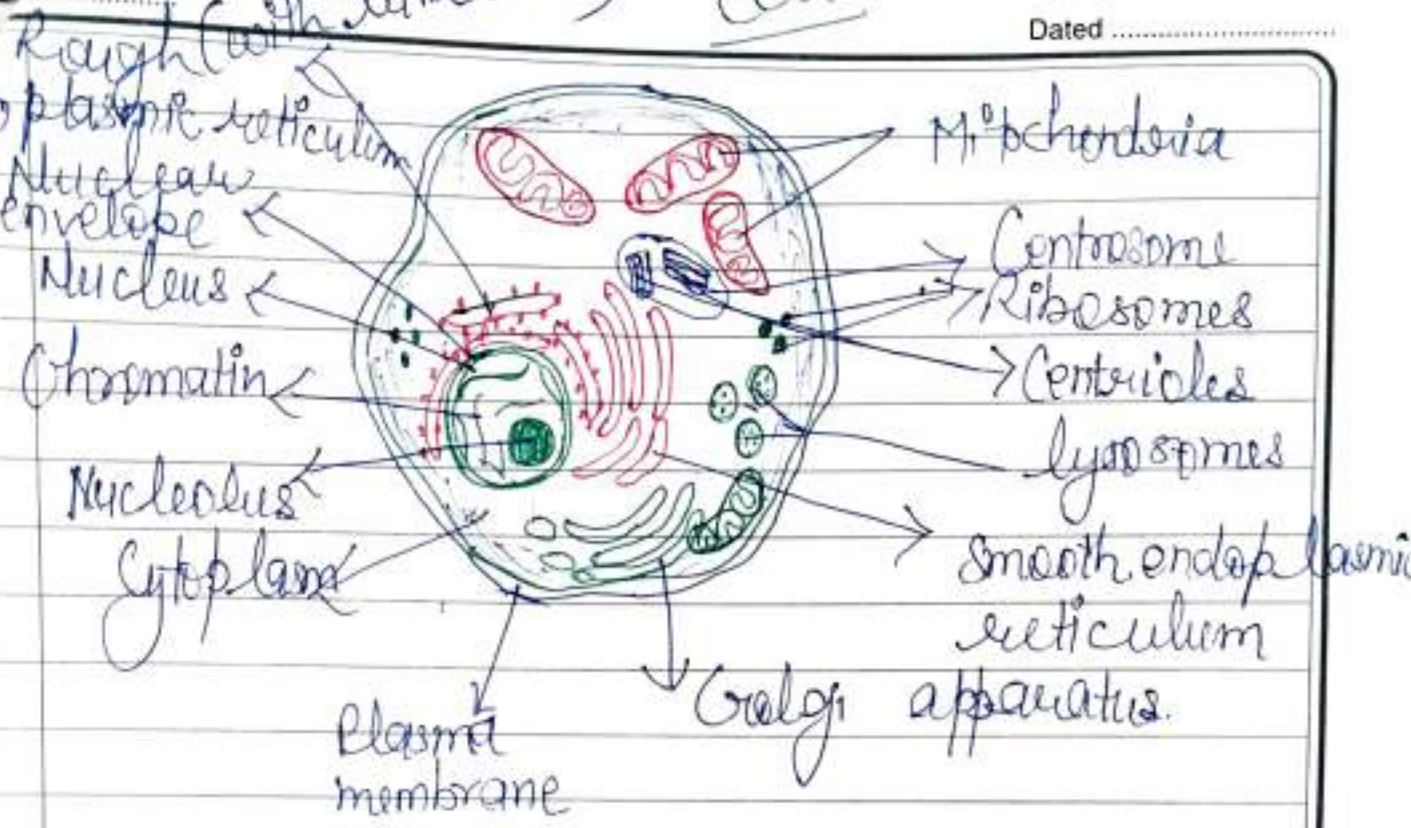
↓

Integumentary
→ Skeletal
→ Muscular
→ Nervous
→ Endocrine
→ Cardiovascular
→ Lymphatic
→ Respiratory
→ Digestive
→ Urinary
→ Reproductive

Signature

Cell

Dated .....



(1) Plasma membrane :- It is also called cell membrane. It separates the interior of the cell from the outside environment.

↓

consist of two layers of phospholipid with proteins and sugars embedded in it.

↓

They also found in prokaryotes as well as eukaryotic.

Functions :-

⇒ Provides and maintain the shape of the cell

⇒ It provides mechanical support for the protection of internal structure of the cell.

⇒ allows only useful substances to enter into the cells.

to enter allow harmful substances into the cells.
It provides specificity to the cells. (maintain the quality).

Organelles :-
↓ means small organs have individu specific infect functions.

↓ Nucleus
↓ Mitochondria
↓ Ribosomes
↓ Cytoplasm
↓ Endoplasmic reticulum
↓ Golgi apparatus
↓ Lysosom
↓ Centrosome

(1) Nucleus :- The most integral component of the cell is nucleus.
* A nucleus is defined as a double-membraned eukaryotic cell organelle that contains the genetic material.
⇒ Nucleus is completely bound by membranes.
⇒ It is contained within the nuclear envelope.
⇒ The membrane distinguishes the cytoplasm from the contents of the nucleus.
⇒ Cell chromosomes are also within it.
⇒ DNA is present in the chromosomes, and they provide the genetic information.

Signature

required for the creation of different cell components in addition to reproduction of life. Dated

→ store genetic information

* Functions:- Regulate cell function (metabolic and chemical activities)

⇒ DNA is present as a fine network of threads called chromatin, but when the cell prepares to divide, the chromatin forms different structures called chromosomes.

⇒ RNA also found in the nucleus

⇒ Different type of RNA, not all found in nucleus, but involve in protein synthesis

⇒ Nucleolus is involved in synthesis and assembly of the components of ribosomes.

⇒ Selective transportation of regulatory factors and energy molecules through nuclear pores.

Mitochondria ⇒ also called as "powerhouse of the cell". It is a double membrane - bound organelle found in most eukaryotic organisms.

⇒ Found inside the cytoplasm

⇒ Play a major role in breaking down nutrients and generating energy rich molecules (ATP) for the cell.

⇒ Biochemical reactions involved in cellular respiration take place within the mitochondria

⇒ The term 'Mitochondria' is derived from Greek words means thread / granules like.

⇒ German pathologist named Richard Altmann in 1890

⇒ Functions :— Regulate metabolic activity of the cell

Serial No. ..... Dated .....

⇒ Promotes the growth of new cells.
⇒ Helps in detoxifying ammonia in the liver cells.
⇒ Plays an important role in apoptosis or programmed cell death.
⇒ maintain concentration/level of Ca^{2+} ions
* ⇒ Most active cell types have the greatest number of mitochondria eg. liver, muscle and spermatozoa.

(2) Cytoplasm :- It is referred to as fluid that fills up to cells.
⇒ It is a semi-liquid jelly like material, which joins the nucleus and the cell membrane
⇒ Provide shape to the cells and regulate metabolic activities.
⇒ It contains molecules, enzymes that are crucial in the break down of the waste.

(4) Ribosomes :- Tiny granules → composed of RNA and protein ↓ that converts genetic code into chains of amino acids

Functions :- DNA produces mRNA by the process of DNA transcription.
⇒ mRNA is synthesized in the nucleus and transported to the cytoplasm for the process of protein synthesis.
⇒ Ribosomes are the site of protein synthesis

(5) Endoplasmic Reticulum :- It is an extensive series of interconnecting tubular membranes in the cytoplasm.

Signature

Two types

Smooth ER → Synthesize lipids and steroids hormones. → also associated with the detoxification of some drugs. Functions: S.E.R.
⇒ Also responsible for the metabolism of carbohydrates.
⇒ Store and release Calcium ions ⇒ Important for nerves and muscular system.

Rough ER → studded with ribosome → Synthesize and secretes proteins in the tissues, hormones and other substances in the glands.

*Functions of RER:- Protein Synthesis
⇒ Play vital role in protein folding.

(6) Golgi apparatus:- It consist of stacks of closely folded flattened membranous sacs.
⇒ largely present in those cells that synthesize and export proteins.
⇒ cisternae
Golgi stack mostly contains 4 to 8 cisternae.
*Functions:- Packaging and secretion of proteins. It receive proteins from ER.
⇒ To an subset of lipids and formation of lysosomes.

(7) Lysosomes:- It is also called "suicide bags".
↓
are sphere-shaped sacs filled with hydrolytic enzymes that have the capability to break down many types of biomolecules. (RNA, DNA, protein)

Functions:-
* Digestion and removal of waste.
* lysosomes in WBC contain enzymes that digest foreign material such as microbes.

(7) Centrosome :-

made up of two perpendicular centrioles.

a daughter centrioles

a mother centriole

linked together by

interconnecting fibers.

⇒ It consist of a complex of proteins that helps in the formation of additional microtubules.

⇒ It is involved in the nucleation and anchoring of cytoplasmic microtubules.

*Functions → (1) Cell division

(2) maintain the chromosome number during cell division

(3) Regulate the movement of microtubules and cytoskeletal structures.

(4) They also stimulate the changes in the shape of the cell membrane by phagocytosis.

Tissue → French word → To weave

It is a group of cells which have similar in origin, structure and function are called as tissues.

⇓

group of cells which performs specific activity of the blood.

⇓

Study of tissue is called "Histology".

* Classification of tissue (Animal tissue) on the basis of size, shape and function

- Epithelial Tissue
  - A) Simple E.
    - → Squamous E.
    - → Cuboidal E.
    - → Columnar E.
  - B) Stratified E.
    - → Transitional E.
    - → Stratified squamous E.
      - Keratinised stratified epithelium
      - Non-keratinised stratified epithelium.
- Connective tissue
  - Cells in C.T.
    - → Fibroblasts
    - → Fat cells
    - → Macrophages
    - → leukocytes
    - → Mast cells
  - (b) Adipose tissue
  - Fibres T.
    - → Collagen F.
    - → Elastic F.
    - → Reticular F.
- muscle tissue
  - (i) Skeletal muscles
  - (ii) Smooth muscle
  - (iii) Cardiac muscle
- Nervous tissue
  - → Central nervous system
  - → Peripheral nervous system
  - → Autonomic nervous system

Epithelial tissue

→ E.T

covers the body and lines the cavities

hollow organs and tubes.

Stomach, esophagus, urinary bladder, intestine

externally covers the body eg- skin

epidermis layer

epithelial tissue

also found in glands.

Cells are very closely packed in a form of continous sheet

(खाली जगह) space internally inter-lined by E.T. -nally

Two types

Endocrine (ductless)

Exocrine (duct)

Blood vessels veins

Internally lined by E.T.

Apical surface

intracellular substance is minimal.

tightly closely packed arranged.

Basement membrane

function → BM separate the epithelial cells from another.

separating the cell substance

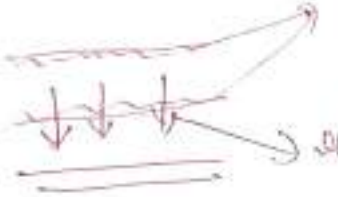
Basement membrane acts as a selective permeable membrane

ET has a nerve supply but no blood supply (receive nutrition from underlying tissue, blood vessels)

Functions of Epithelial tissue

(1) Protection :- Covers the entire body surface, act as first line of defence
↓ chemical
toxins, microbes.
↓ externally protect epidermis

(2) Absorption :- epithelial lining of digestive tract absorbs nutrient and water



(3) Secretion :- Secrete enzymes, mucus, saliva, hormones, sweat etc.

(3) Sensation :- Epithelial tissue of nose, (eyes), ears, tongue (tastebuds) has sensory receptors.
↓ Photoreceptor present.

(4) Exchange of substances :- b/w underlying tissues and body cavities.

Classification of Epithelial Tissue

Simple E.T.
(Single layer of cells)

⇒ Single layer of identical cells.
⇒ usually found on absorptive or secretory surfaces.
⇒ Types are named according to shape of cells, which differs according to function
⇒ most active tissue, taller the cell

Stratified E.P
(Several layers of cells)

⇒ Multiple layers of cells of various shape.
⇒ Continual cell division in the lower (basal) layer pushes cells above to the surface, where they are shed.
⇒ Protect underlying structure from abrasion and tear.

multiple layer

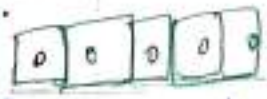
1) Simple E.T :- Three types of S.E.T.

Squamous

Basement membrane

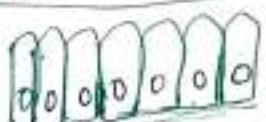
⇒ Single layers of flattened cells.
⇒ Cells fit closely together

Cuboidal



⇒ Cube shaped cells
⇒ fit together
⇒ lying on a basement membrane
⇒ It forms the walls of kidney

Columnar



⇒ It is formed by a single layer of tall, thin cells on a basement membrane.

⇒ It forms the lining of the following tubules, found in some glands such as the thyroid. It is involved in secretion absorption and excretion.

- heart → endothelium
- Blood vessels → where it is also known as endothelium
- lymphvessels
- alveoli of the lungs.

→ lining of stomach, small intestine is covered with microvilli

↓

Provide large surface area for absorption of nutrients

⇒ In trachea, E.E. is ciliated and also contain goblet cells ↓ secrete mucus

⑧ Stratified Epithelium

Squamous cells.

Columnar cells.

Basement membrane

Top layer

new cell growth → lower layer

old cell pushed by new cell

* Stratified Squamous epithelium :—

Top layer cuboidal

Keratinised S.E.

⇒ found on dry surfaces subjected to wear and tear i.e skin, hairs and nails

⇒ Surface layers consist of dead epithelial cells that have lost their nucleus and contain the protein keratin

Non-keratinised S.E.

⇒ Protect moist surface subjected to wear tear and prevent them from drying i.e conjuctive, lining of mouth, pharynx, oesophagus, vagina.

, Jugular notch.

- Sweat gland,
- Salivary gland

⇒ Protection of ducts of various glands

Stratified Cuboidal

Stratified columnar :-

⇒ Present in male urethra lobar ducts of salivary glands.

⇒ Protection and secretion

Transitional Epithelium :- Composed of several layer of pear-shaped cells. (S, C, E.)

⇒ It lines several part of urinary tract including bladder and allow for stretching as the bladder fills.

Relaxed

Streched

Connective Tissue

↓

It performs their special functions

↓

linking and supporting other tissues / organs of the body.

↓

most abundant and widely distributed in the body.

⇒ cells are more widely & separated from each other (large IS)

connective tissue

⇒ Intracellular substance (matrix) is present in considerably large amounts.

* Functions of C.T.

⇒ Binding and structural support
⇒ Transport
⇒ Insulation & energy store
⇒ medium for exchanges of nutrient and waste products.
⇒ Protection.
⇒ conserve heat

Connective Tissue

Cells
- ⇒ fibroblasts
- ⇒ fat cells.
- ⇒ macrophages.
- ⇒ Leukocytes.
- ⇒ mast cells
- ⇒ Plasma cells.

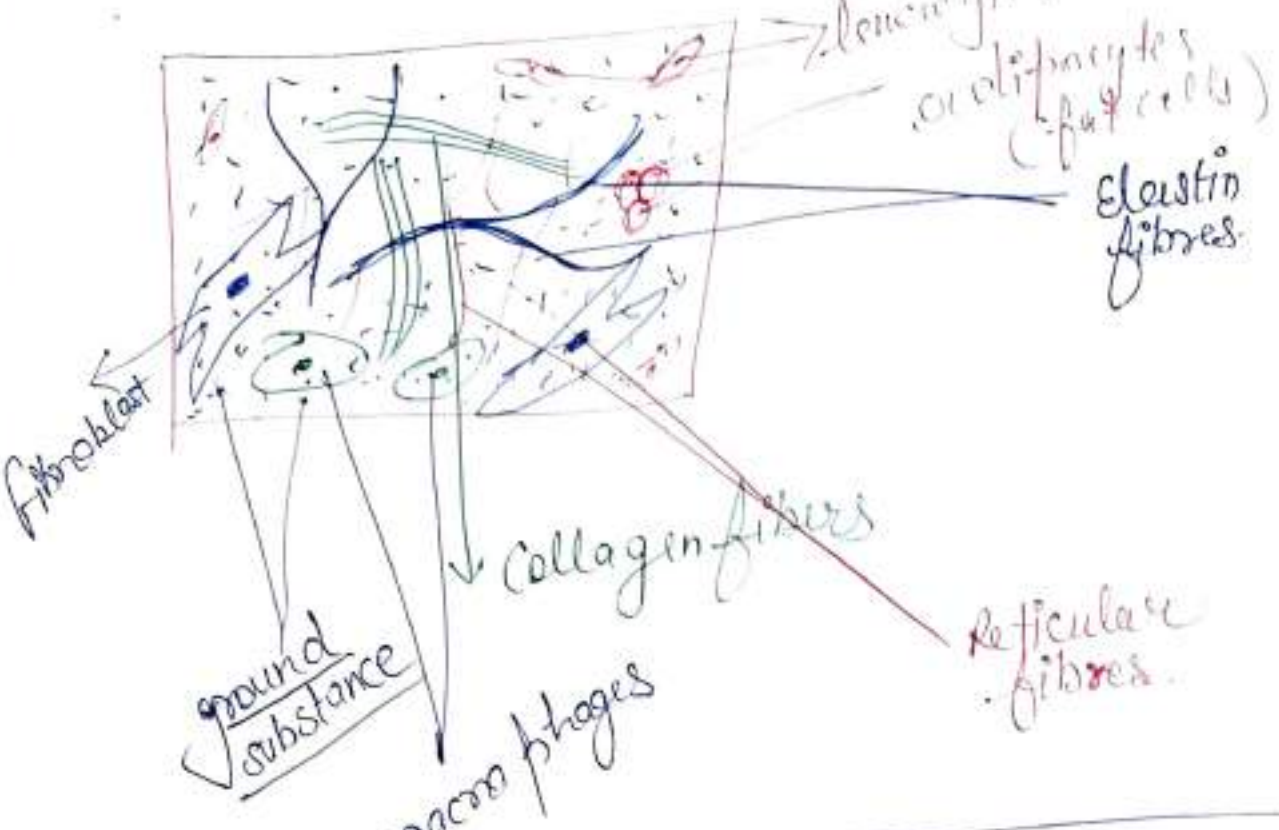
Extracellular matrix

Fibres
- ⇒ Collagen fi
- ⇒ Elastin fi
- ⇒ Reticular fi

Ground substance (polysaccharide)
- ⇒ Glycoproteins
- ⇒ Glycosaminoglycans
- ⇒ water

⇒ intracellular w.
⇒ extracellular w.

, Jugular notch.



* ~~Cells in connective tissue~~ :-

① fibroblast ⇒ large cells with irregular processes

⇒ They manufacture collagen and elastic fibres and a matrix of extracellular material.

⇒ Fibroblast mainly active is tissue repair (wound healing).

injury → Pink colour tissue formed after sometimes → fibroblast ~~connective~~ tissue form granulation tissue.

② Fat cells :- It is also called adipocytes present in adipose tissue

* Size depend on → storage of fat

③ Macrophages :- Large irregular - shaped cells with granules in the cytoplasm.

⇒ Important Role in Body defense mechanisms → Because act like as phagocytic, engulfing and digesting bacteria, cell debris.

④ Leukocytes :- Also called ~~leukocytes~~ WBC

↓

Synthesise and secrete specific defensive antibodies.

⑤ Mast cells :- Similar to basophil leukocytes.

Cytoplasm contain

- Heparin → Stimulate secretion of gastric juice → It is associated with the development of allergies and hypersensitivity states.
- Histamine → To prevent clot information → Start inflammatory reaction → Helps to maintain blood flow through inflamed tissue.

*(1) Loose areolar connective tissue

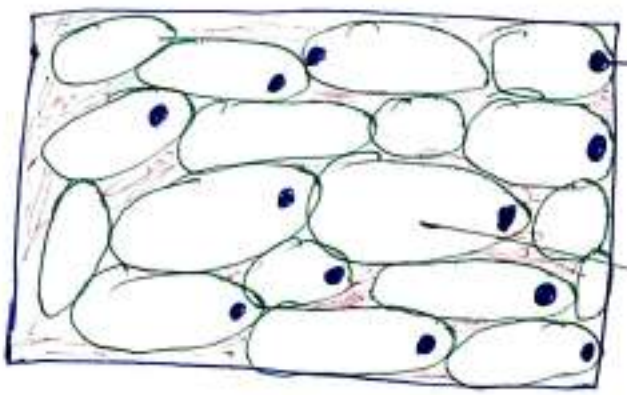
⇒ most generalised type of connective tissue
⇒ matrix is semisolid with many fibroblasts and some fat cells (adipocytes), mast cells and macrophages,
⇓ separated by elastic and widely collagen fibres.
⇒ It provide elasticity and tensile strength
⇒ It connects and supports other tissues.
e.g. ⇒ (a) under the skin, supporting blood vessels and nerves.
(b) Between muscles.

*(2) Adipose tissue

adipose tissue consists of fat cells (adipocytes)
↓ contain
large fat globules in a matrix of areolar tissue.

Two types

- White adipose tissue
- Brown adipose tissue



White A.T

This makes up 20-25% of body weight in adults with normal body mass index.

⇒ Mostly, it present in obese people.

⇒ It secretes the hormones leptin.

⇒ Kidneys and eyeballs are supported by adipose tissue.

⇒ It acts as a thermal insulator and energy store.

Brown A.T

⇒ Presence of more mitochondria.

⇒ a more extensive capillary network than white A.T.

⇒ more metabolically active

⇒ when it break down, it generates more heat than adipose tissue.

⇒ Present in newborn infant

⇒ In adults, brown fat is found in small amounts in the upper chest and neck areas.

③ Reticular Tissue :- RT has a semisolid matrix with fine branching reticulin fibres.

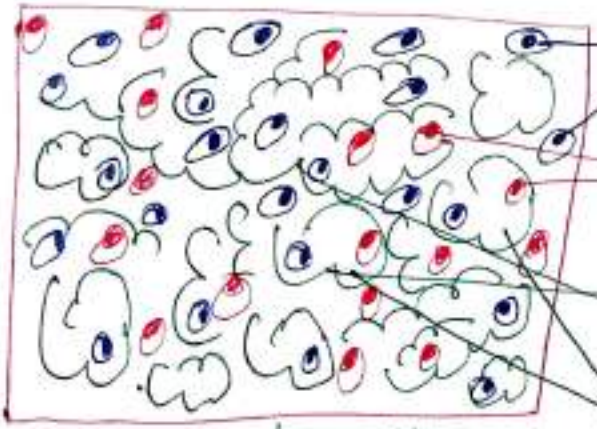
⇒ It contains reticular cells and WBC.

⇒ It is found in lymph nodes and Lymphatic organs.

④ Dense Connective tissue :-

↓

Contains more fibres and fewer cells than loose connective tisue.



∴ Reticular Tissue

Dense C.T

Fibrous connective T.

made up of closed packed bundles of collagen fibres.

with little matrix.

⇓

Fibrocytes are few in number and

⇓

Lie in rows b/w the bundles of fibres.

*Fibrous tissue is found:-

⇒ forming ligaments which bind bones together

⇒ outer protective covering for bone or some organs. eg., kidneys, lymph nodes ~~and the brain~~

collagen fibres.

fibrocyte.

Elastic Tissue

Few cells present in ~~the~~ and mat- rix consists mainly of masses of elastic fibres.

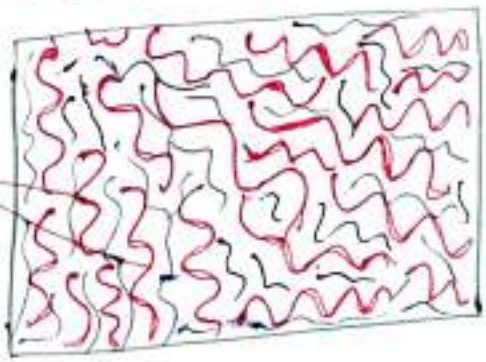
⇓

Secreted by fibroblasts

⇓

It is found in organs where stretching or alteration of shape is required eg. large blood vessels (walls), the trachea and bronchi, and the lungs.

Elastin fibres



(5) Blood :-

(6) Cartilage :- It is a strong, flexible connective tissue that protects your joints and bones.

⇒ It reduces joint friction.

⇒ It is found in joints, bones, spine, lungs, ears and nose.

Three types

- Hyaline C.
- Fibrocartilage
- Elastic fibre C.

① Hyaline Cartilage

Chondrocytes

in this tissue are arranged in small groups within cell nests

⇒ Bluish-white matrix is solid and smooth

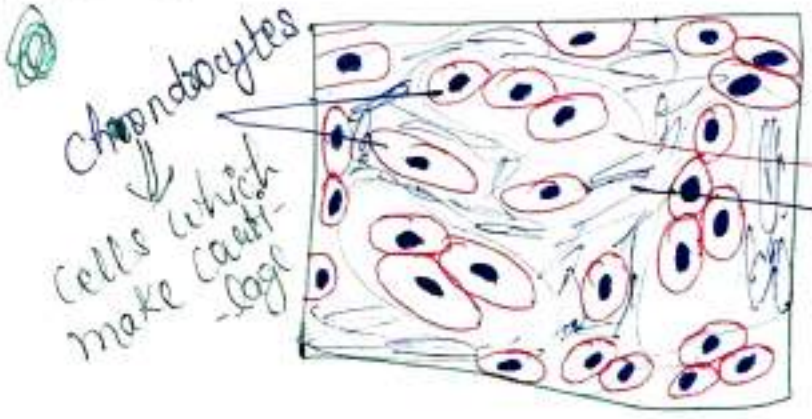
⇒ It provides flexibility, support and smooth surfaces for movements at joints.

⇒ It is found in :-

- on the ends of the long bones that forms joints.
- forming part of the Larynx, trachea and bronchi.

Larynx → voice box

trachea → J-shaped tube that connects your larynx to your lungs

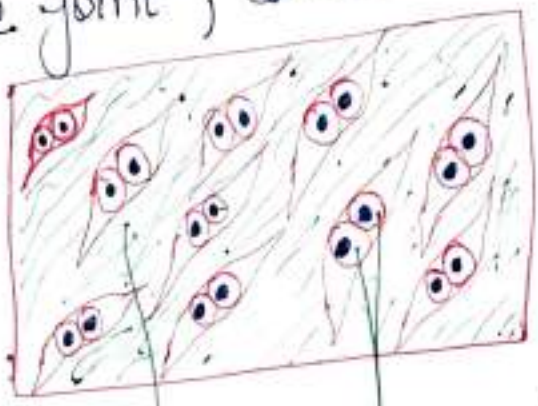


② fibrocartilage :— It consists of dense masses of white collagen fibres in a matrix similar to that of hyaline cartilage with the cells widely dispersed.

⇒ It is tough, slightly flexible.

⇒ It is found in —

- as pads b/w the bodies of the vertebrae
- b/w the articulating surfaces of the bones of the knee joint, called semilunar cartilages.



③ Elastic fibrocartilage :-

It is a flexible tissue → consist of yellow elastic fibres → lying in a solid matrix with chondrocytes lying b/w the fibres.

- It provides support and maintains the shape of pinna or lobe of the ear, and part of the tunica media of blood vessels.

⑦ Bone
matrix of Osteocytes are surrounded by a collagen fibres, strengthened by inorganic salts, calcium and phosphate
⇒ It provides strength and rigidity.

③ Muscle tissue

able to contract and relax

providing movement within the body.

muscle contraction requires a rich supply providing sufficient oxygen, calcium and nutrients and removing waste products.

3 M.T.

Skeletal muscle | Smooth muscle | Cardiac muscle

striated muscle → (stripes)

① Skeletal muscle:- It is attached to the bones and involved in the functioning of different parts of the body.

③ Most S.M moves bones, the diaphragm is made from this type of muscle to accommodate a degree of voluntary control in breathing.

⇒ These cells are cylindrical, contain multiple nuclei and can be up to 35 cm long

Provide

a thin S.M that sites at the base of the chest

Functions: helps in movements, maintaining proper posture of the body, generates energy and heat for the body, forms protects inner organs of the body.

(2) **Smooth muscle** — It is non striated muscle tissue.

⇒ It is found in the walls of hollow organs and blood vessels.

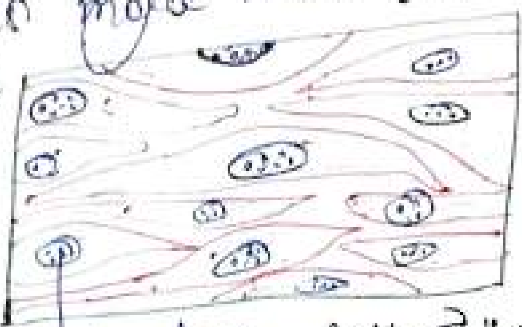
⇒ These muscles are also **involuntary, which** means the contraction of these muscles is not dependent on conscious thought.

⇒ They can contract in response to chemical or electrical signals, which they response to chemical or electrical signals, which they receive from autonomic nerves and hormones like epinephrine and vasopressin.

→ It is usually arranged as circular layers and tubes, no more than one nucleus.

hormone gland in adrenal makes to help you prepare for stressful or dangerous situation

that regulate involuntary physiological process e.g. the regulate BP, respiration



Nucleus

ADH → Urine production

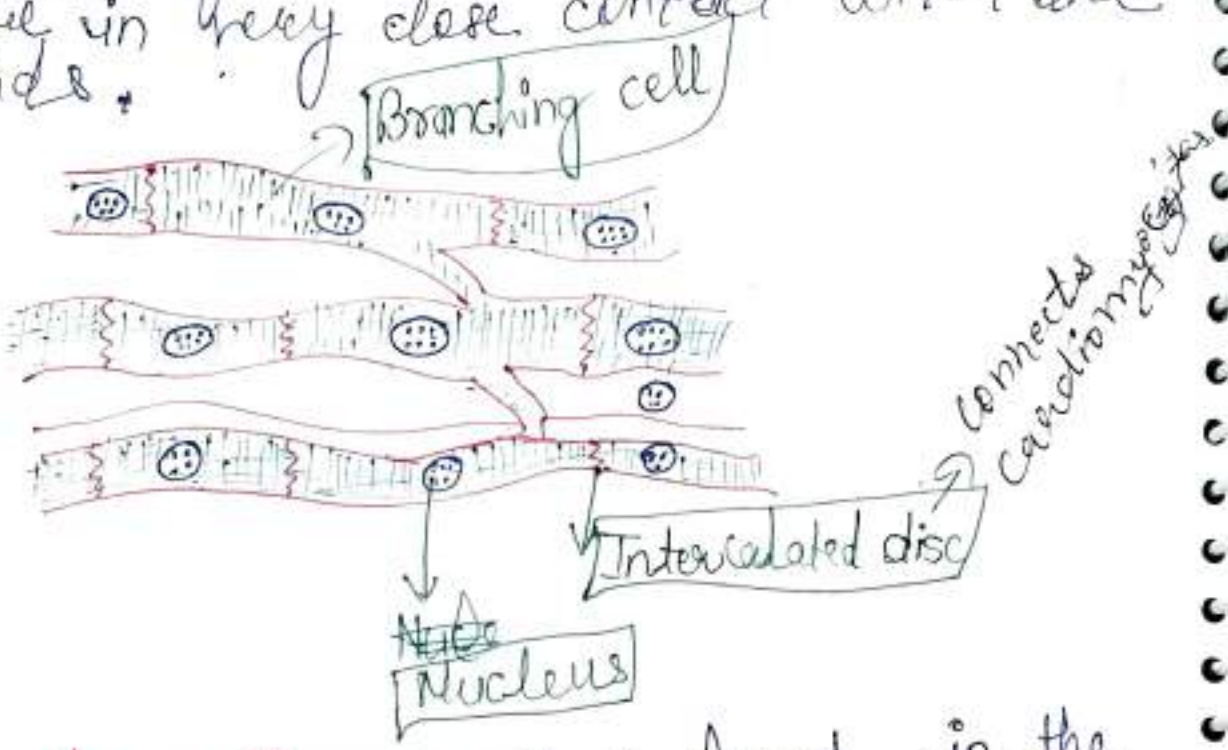
(3) Cardiac muscles: — found in the walls of the heart.

⇒ made up of specialised cells called **cardiomyocytes** → also called contractile myofibrils

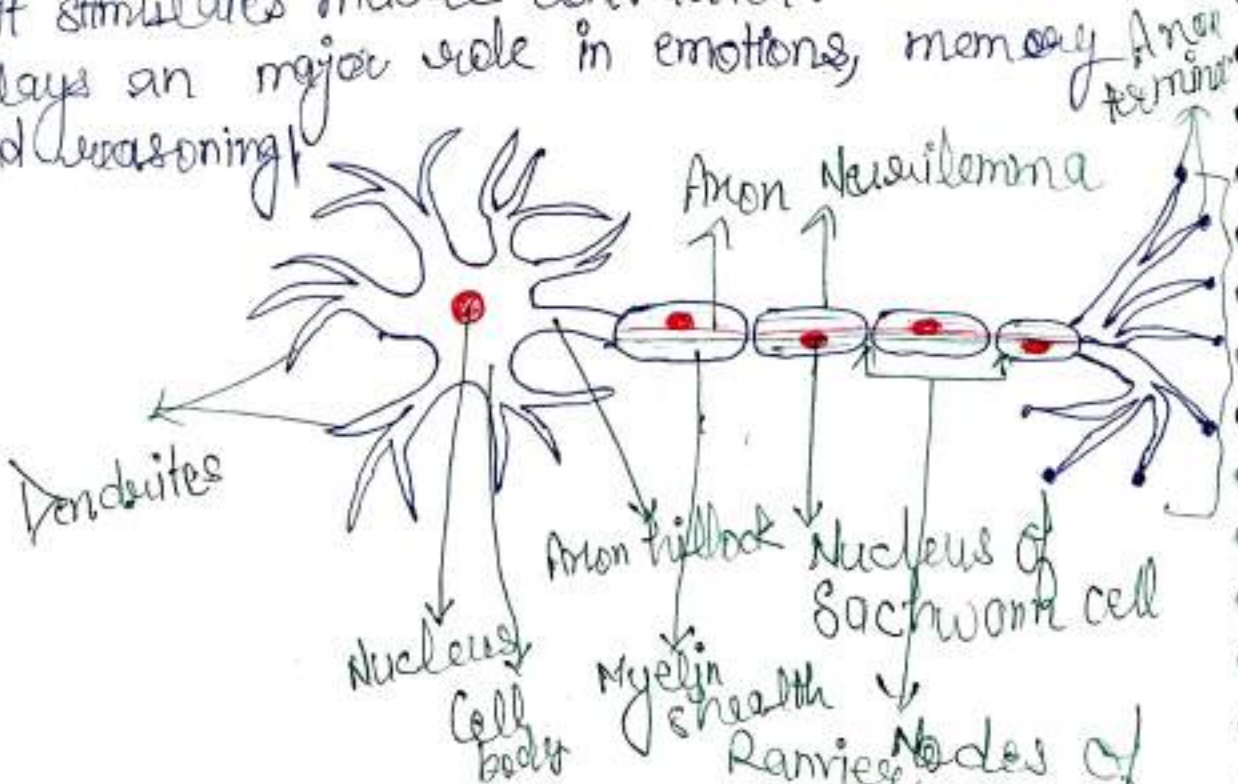
Because they are tiny and cylindrical

They contract at a regular rate to keep blood flowing through the heart.

⇒ Each cell has one nucleus and one or more branches.
⇒ ends of the cells and their branches are in very close contact with the ends.



④ Nervous Tissue:— It is found in the brain, spinal cord and nerves.
⇒ It is responsible for coordinating and controlling many body activities.
⇒ It stimulates muscle contraction.
⇒ Plays an major role in emotions, memory and reasoning.



, jugular notch.

(1) Cell bodies → It forms the grey matter of the nervous system and are found at the periphery of the brain and in the centre of spinal cord.

(2) Axon and dendrites:-

Structure of Nervous tissue:-

⇒ made up of nerve cells or neurons, all of which consists of an axon.
⇒ Axon are long stem-like projections emerging out of the cell.
⇒ It is responsible for communicating with other cells called target cells.
⇒ main part is the cell body which contains the nucleus, cytoplasm and cell organelles.
⇒ Dendrite is highly branched processes, responsible for receiving information from other neurons and synapses.
⇒ Information of other neurons is provided by dendrites to connect with its cell body.
⇒ Information in a neuron is unidirectional as it passes through neurons from dendrites, across the cell body down the axon.

Functions of Nervous Tissue:-

* Neurons generate and carry out nerve impulses. They produce electrical signal that are transmitted across distances, they do so by secreting chemical neurotransmitter.

neuronal junction site of transmission of electric impulses between two nerve cells.

⇒ responds to stimuli
⇒ carries out communication and integration.
⇒ Provides electrical insulation to nerve cells and removes debris.
⇒ Carries messages from other neurons to the cell body.

Types of nerves-

- Motor nerves
- Sensory nerves
- Autonomic nerves
- Cranial nerves

* Membranes
  - Epithelial membrane
    - mucous M.
    - Serous m.
  - Synovial membrane

* Glands:- Produce and release different hormones that target specific things in the body.
  Largest gland Pancreas

* Cell death
  - Apoptosis → Programmed cell death → It occurs normally during development and ageing and as a homeostatic mechanism to maintain cell populations in tissues
  - Necrosis → death of cell in tissue body occurs due to injuries infection or disease.

* Osseous System

Human skeletal system

network of many different parts that work together to help you move.

Bones:- It is a rigid body tissue.

It is a connective tissue

that is made up of different types of cells.

Internally it has a honey comb-like matrix that gives rigidity to bones.

Functions of bones:-

⇒ Providing the body framework. (shape to the body)

⇒ giving attachment to muscles and tendons

⇒ Haemopoiesis, the production of blood cells in red bone marrow.

⇒ Bones act as a protection to internal organs like brain, heart, lungs etc.

⇒ Bones serves as storage space for minerals like calcium and phosphate.

∴ adult skeleton consists of 206 bones

⇒ Infants — 275 bones. —(fusion)→ 206 bones

↓ High percent of cartilage

↓ Low % of cartilage

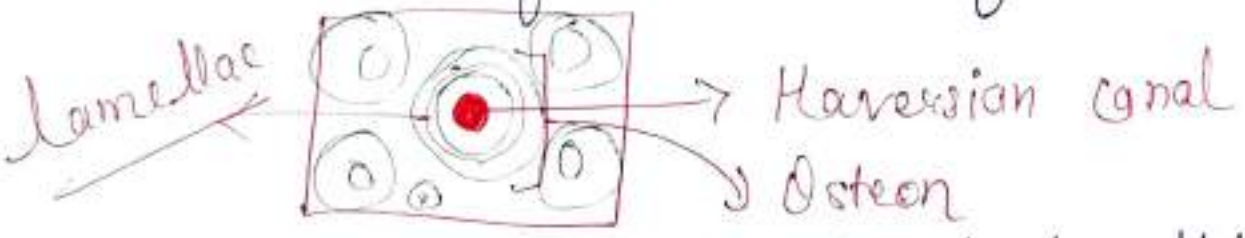
* Also at birth → greater amount of cartilage → After replaced by bones
* Over a period of about 7 years, each bone in our body is slowly replaced by a new bone

↓

Cartilaginous ossification

* Histological features of Bone :-

* Bone consist of large number of tree like structures called Haversian system or Osteon.
* Osteon. is the function unit of bones



* Haversian Canal :- Nerve and blood supply is present → Here O_2 is supplied, and CO_2 is taken away.
* Lamellae :- Plate like structures around the haversian canal.

→ Osteoblasts are bone cells contained in lamellae of bones.

* Composition of bones :-

- Bone cells
  - Osteoblast
  - Osteocytes
  - Osteoclasts
  - Osteoprogenitor cells
- Extracellular matrix
  - Collagen fibers
  - Inorganic min...

Bone cells

Bones are living tissues, so they contain metabolically active.

- Osteocytes
- Osteoblasts

→ Derived from Osteoprogenitor cells.

- Osteoclasts → derived from the same cells from which macrophages and monocytes are formed.

Osteocytes / Osteoblasts:
- → forms bone matrix
- → Provide minerals to the bone tissue.
- → maintain bone tissue

Osteoclasts:
- → Bone reabsorbing cells.
- → responsible for demineralization of bone.
- → also recycle the matrix

Extracellular matrix

contains collagen fibers and inorganic minerals.

Collagen fibers

- → Protein in human body
- → Fibrous connective tissue
- → Holds together all the body structure.

Inorganic minerals

60% bones are made up of IM.

Ca, phosphorous, Mg, K+, Na+, citrate

↓

major minerals.

25% Bones etc

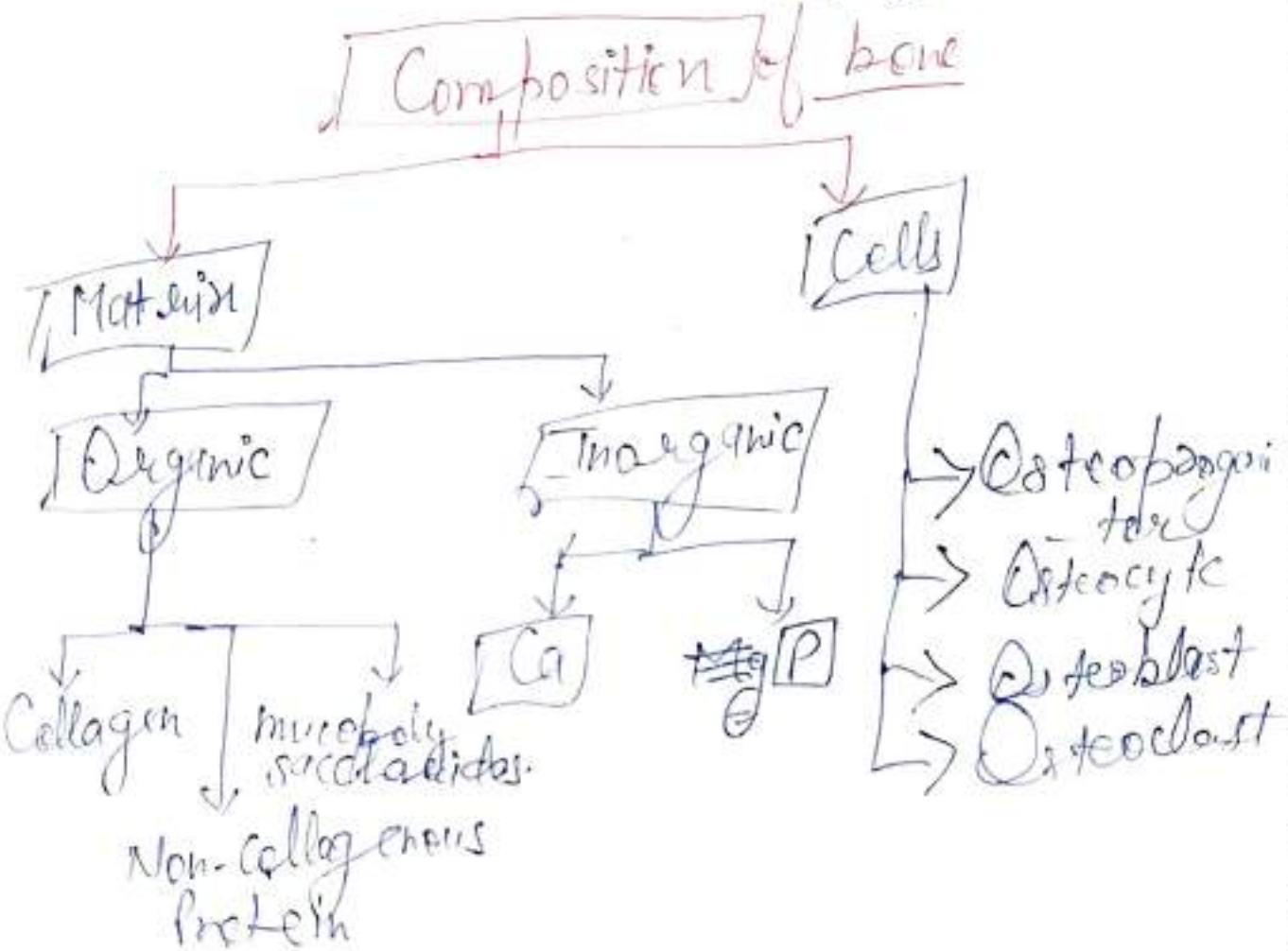
Organic substances

composed of organic sub.

① Collagen fibers → mainly type I collagen

② Ground substances → Glycoproteins
→ mucopolysaccharides

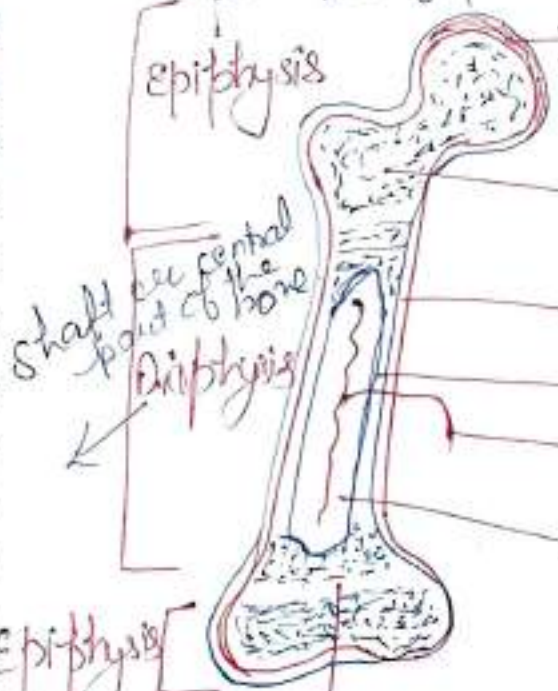
Composition of bone



Types of Bones

- **Long Bone**
  - → Femur
  - → Tibia
  - → Fibula
- Short, irregular, flat and sesamoid bone
  - → carpals (wrist)
  - → metacarpals (ankle)
  - → vertebrae and some skull bones
  - → Sternum, ribs and most skull bones
  - → Patella (knee cap)

Bone structure



- → Articular (hyaline) cartilage.
- → spongy bone (contains red bone marrow)
- → Periosteum
- → Compact bone
- → nutrient artery in foramen
- → medullary canal (Contains yellow bone marrow)

Epiphyseal line → Growth plate

* A mature long bone thin layer of cartilage.

⇒ Diaphysis

↓

1

↓

composed of compact bone

↓

central medullary canal containing yellow bone marrow

Epiphyses

↓

2

↓

it consist of outer covering of compact bone with spongy bone inside

separated by

Epiphyseal cartilages

⇒ long bones are completely covered by a vascular membrane the periosteum

↓ Two layers

Inner layer

⇒ contain

- osteoblasts
- osteoclasts
- the cells responsible for bone production and breakdown

• important in repair of the bone.

Outer layer

⇒ Tough and fibrous

⇒ Protect the bone

Short, I, and sesamoid bones.

flat bone
eg skull

Irregular bone

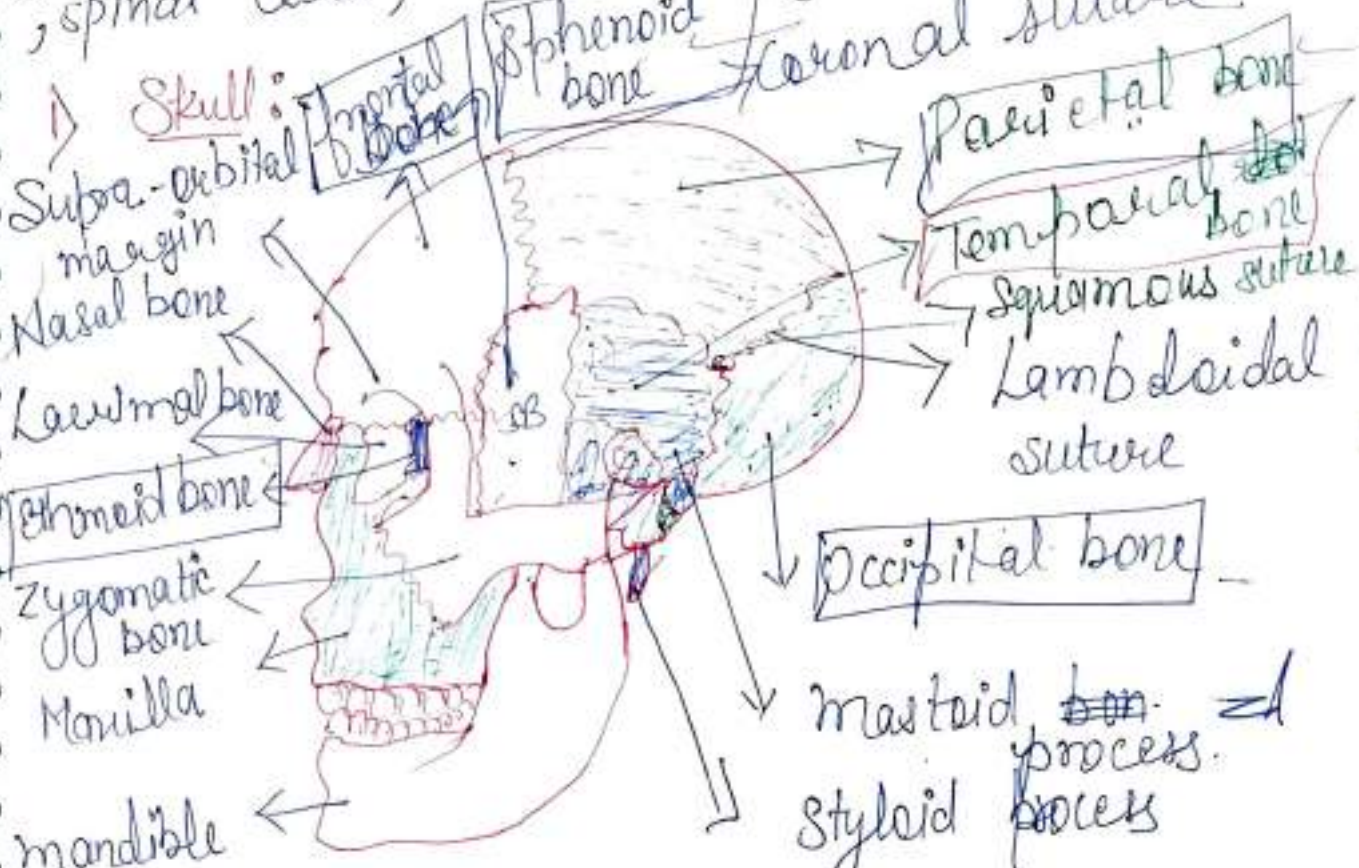
vertebral bone

Regional classification of Bones

- Axial skeleton
- Appendicular skeleton

Axial skeleton :- It consist of skull, thoracic cage and vertebral column
⇒ It is of protective nature.
⇒ It protects our vital organs such as brain, spinal cord, heart, lungs etc.

1) **Skull :**



cranium :- 8 Bones
facial = 14 Bones
Auditory ossicles = 6 Bones.

22 Bones skull

Cranium :- It is also called brain box,
↓
Because it encloses the brain
⇒ It has paired bones which are parietal and temporal bones.
⇒ And others are unpaired, these are frontal occipital, sphenoid and ethmoid.

Frontal bone :- It includes eight cranial bones
↓
which makes the skull.
* Facial expression depends, on the muscles surrounding and attached to the frontal bone.
* 2 main functions → supporting the head structures
protecting the brain, including the eyes and nasal passages.

② Parietal bones :- It covers the centre of the brain. It also called, flat cranial bone.
located on the sides and top of the skull.
* soft tissue protected by skull
which also inhibits infection, excessive CSF production, or Haemorrhage → Bleeding (Blood)

③ Temporal Bones :- lie on each side of the head and form sutures with the parietal, occipital, sphenoid and zygomatic Bones.
→ To forming the external auditory canal.
→ It also protects the middle and inner ear structures

sutures :- fibrous bands of tissue that connect the bones of the skull.

(4) Occipital bone: It forms the back of the head.
It forms sutures with the parietal, temporal and Sphenoid bones.
⇒ Its inner surface is deeply concave to accommodate the occipital lobes of the cerebrum and the cerebellum

(5) Sphenoid Bone:- It occupies the middle portion of the base of the skull and articulates with the occipital, temporal, parietal and frontal bones.
It links the cranial and facial bones.

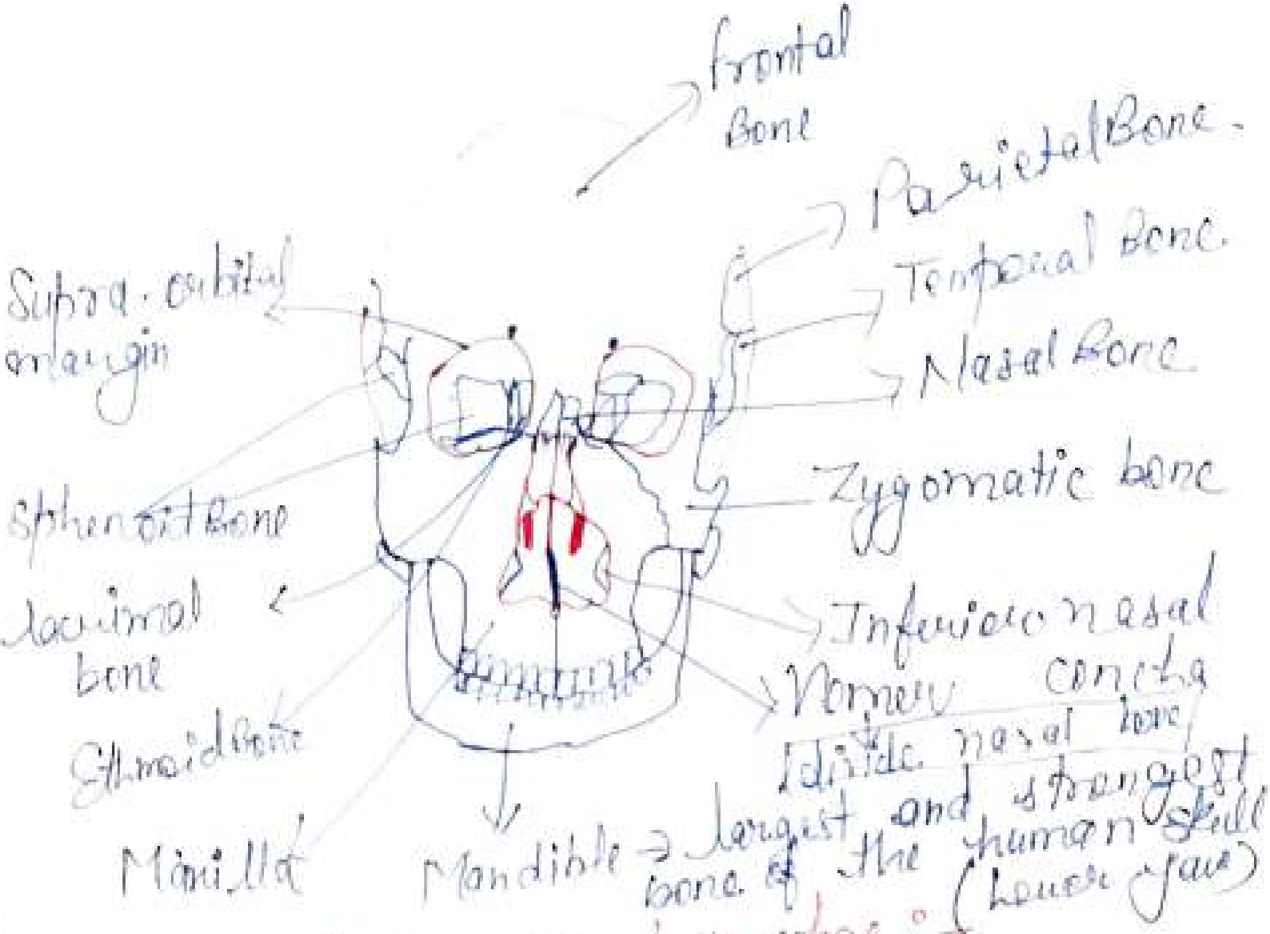
(6) Ethmoid bone:- It occupies the anterior part of the base of the skull and helps to form the orbital cavity, the nasal sptum and the lateral walls of the nasal cavity.
⇒ Ethmoid bone is very delicate (easy to break or damage).
⇒ It contains many air (sinuses) lined with ciliated epithelium and with openings into the nasal cavity.
air filled space in the skull.

Facial Bones

Facial bones (Six paired and two unpaired) face skeleton consists of 14 with different anatomic structures.

- ⇒ 2 zygomatic Bones (cheek Bone)
- ⇒ 2 maxilla
- ⇒ 2 nasal Bones
- ⇒ 2 lacrimal Bones
- ⇒ 1 vomer
- ⇒ 2 inferior Conchae
- ⇒ 2 palatine Bones.
- ⇒ 2 inferior.
- ⇒ 1 mandible

Functions of Epithelial tissue



(1) Two inferior nasal conchae :- At the top of the nasal cavity, two pairs of inferior nasal conchae articulate with the palatine, maxilla, ethmoid and lacrimal bones.

(2) Two lacrimal bones, There are two lacrimal bones on the interior of the eye socket. It joins with the ethmoid, maxilla, and frontal bone along with the inferior nasal concha

(3) Two nasal Bones :- At the Bridge of the nose, two nasal bone joins with the frontal, maxilla, and ethmoid bones and with one another.

Fontanelles of the skull

- soft spot of a newborn baby's skull.
- At birth, sutures b/s ossification of the cranial bones are incomplete.

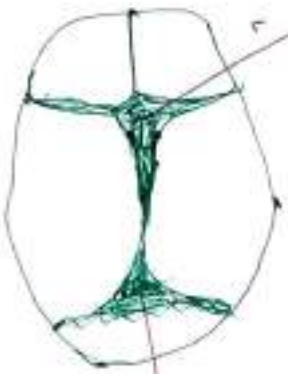
⇒ Fontanelles are two large soft patches on the top of a baby's head that are present at birth.

⇒ Soft patches are places b/w the bones of the skull.

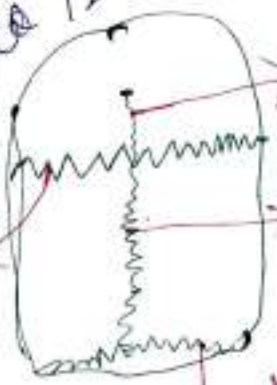
⇒ The newly created embryo's skeleton is made up of a fibrous membrane and cartilage components which are replaced by bones during the ossification process.

Function: Allows for accelerated brain development during childhood.

Anterior fontanelle → not fully ossified until the child is b/w 12 and 18 months old.



Posterior fontanelle → ossified 2-3 months after birth.



* Vertebral Column

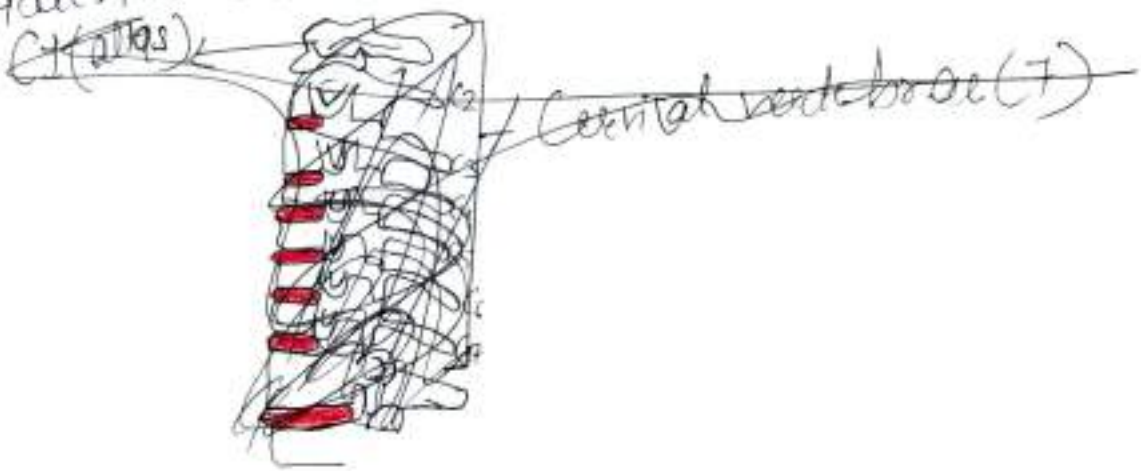
26 bones in V.C.

⇒ 24 - separate vertebrae extend downwards from the occipital bone of the skull than there is the sacrum → formed 5 fused vertebrae → coccyx → tail, which is formed from 3 to 5 small fused vertebrae.

* Vertebrae divided into different regions.

⇒ 1st 7 vertebrae in the neck to form the cervical spine.

⇒ Next 12 vertebrae are the thoracic spine, and the next 5 the lumbar spine → lowest V. which articulates with the sacrum.



① Cervical – 7 vertebrae (C_1 to C_7) →

the first vertebra, C_1 or atlas articulates with the two occipital condyles of the skull.

⇒ It allows the maximum movement of neck

⇒ It is responsible for the yes movement of the head.

⇒ C_2 and C_1 joints allow the 'no' movement of the head.

It supports the wt of the head.

② Lumbar :- 5 lumbar (L_1 to L_5) – Lumbar vertebrae support the weight of the body
– They are larger in size and help in carrying heavy objects.

~~③ Sacral – 1 (fused~~

③ Thoracic :- 12 vertebrae (T_1 to T_{12})
Vertebrae of the thoracic region have limited movement and provide support to the rib cage and protect the lungs and heart. 12 pairs of rib bones articulate with the thoracic vertebrae on the posterior side.

④ Sacral :- (fused 5 vertebrae, S_1 to S_5)
– The five sacral vertebrae are fused together
→ They connect the vertebral column to the hip bones and form pelvic girdle along with them.

4) Coccygeal :- 4 (fused bones of the coccyx region fuse together to form the tailbone).

Calculate with vertebrae formula :-

CF = C7 T12 L5 S5 C3-5 = 33-35.

⇒ Hollow cavity formed by the central portion of each vertebrae bone forms the spinal canal.

⇒ It encloses the spinal cord and provides protection.

⇒ There are various ligaments, which help in the movement and holding vertebrae together.

⇒ Injury in any of the vertebrae can result in various complications and a restricted movement like pain, numbness, tingling sensation, breathing difficulty and paralysis etc.

Functions of V.C

① Supports the head
② Help maintain balance in the upright position.
③ Enclose and protect the spinal cord.
④ Permits movements.
⑤ Absorbs shocks during walking.

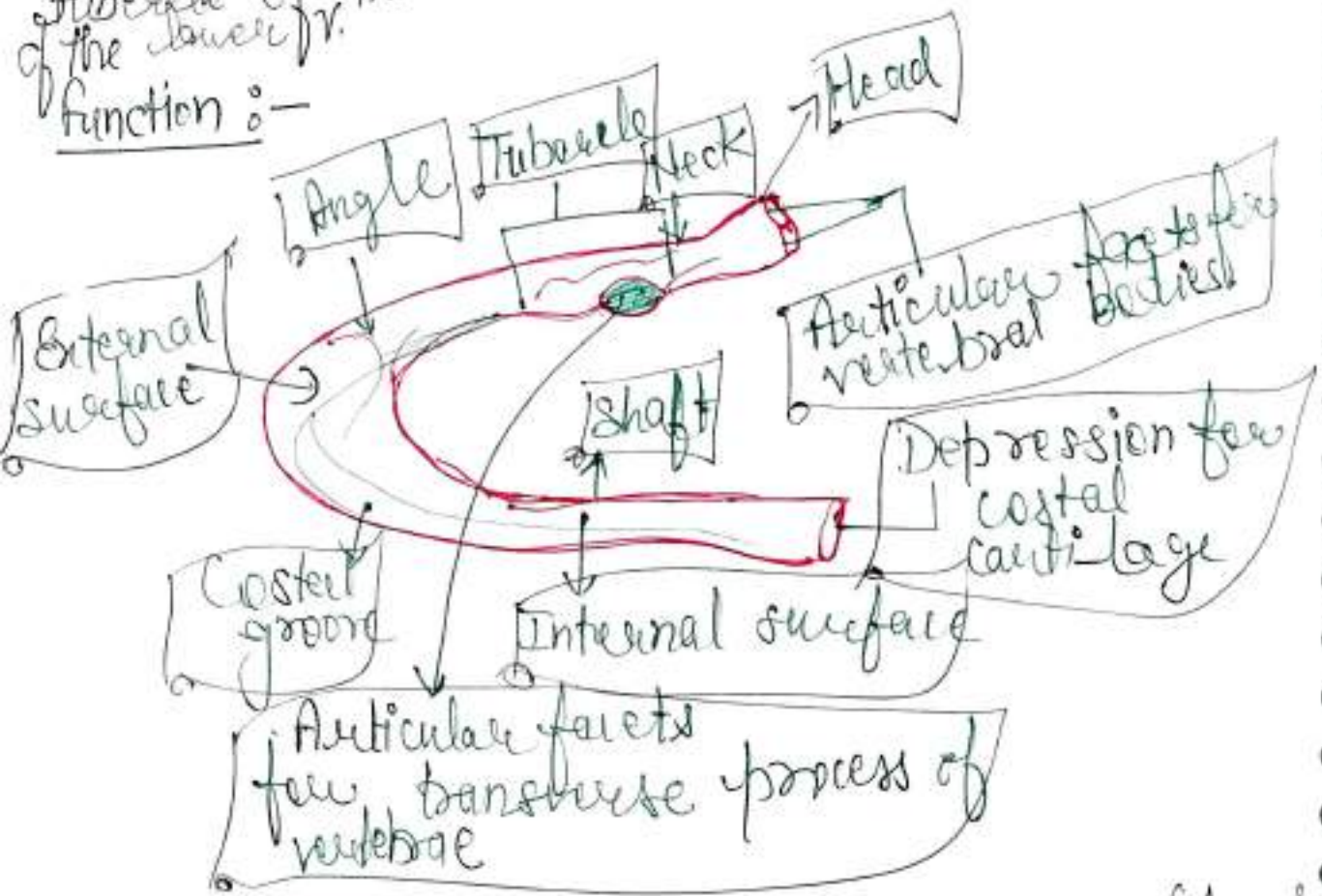
About 71 cm ⇒ adult male
61 cm ⇒ adult female

Functions of

Thoracic (cage)

* In Both cases, costal cartilages attach the ribs to the sternum.
* Lowest 2 pairs of ribs, do not join the sternum at all.
* Each rib forms ~~up~~ to 3 joints with the vertebral column.
* Two of these joints are formed b/w facets on the head of the rib and facets on the bodies of 2 vertebrae, the 1 above the rib and the one below.
* Ten of the ribs also form joints b/w the tubercle of the rib and the transverse process of the lower vertebra.

Function :-



⇒ Protecting the thoracic ~~cage~~ organs (lungs, heart).

⇒ ~~Thoracic~~ Due to the arrangement of the ribs and quantity of cartilage present in the ribcage, it is a flexible structure that can change its

shape and size during breathing.

Appendicular skeleton

Shoulder girdle and the upper limbs
- → Two clavicles
- → Two scapulae
- → Humerus
- → ulna and radius (2)
- → carpal bones (wrist) (8)
- → metacarpals (5)
- → Phalanges of finger bone (14)

Pelvic girdle with the lower limbs
- → Two hip bones
- → Pelvis
- → Femur (thigh bone)
- → Tibia
- → fibula
- → Patella (knee cap)
- → tarsal (7) (ankle bones)
- → metatarsal (bones of the foot) (5)
- → Phalanges (toe bones) (14)

1) Shoulder girdle

2) Clavicle (collar bone) (2)

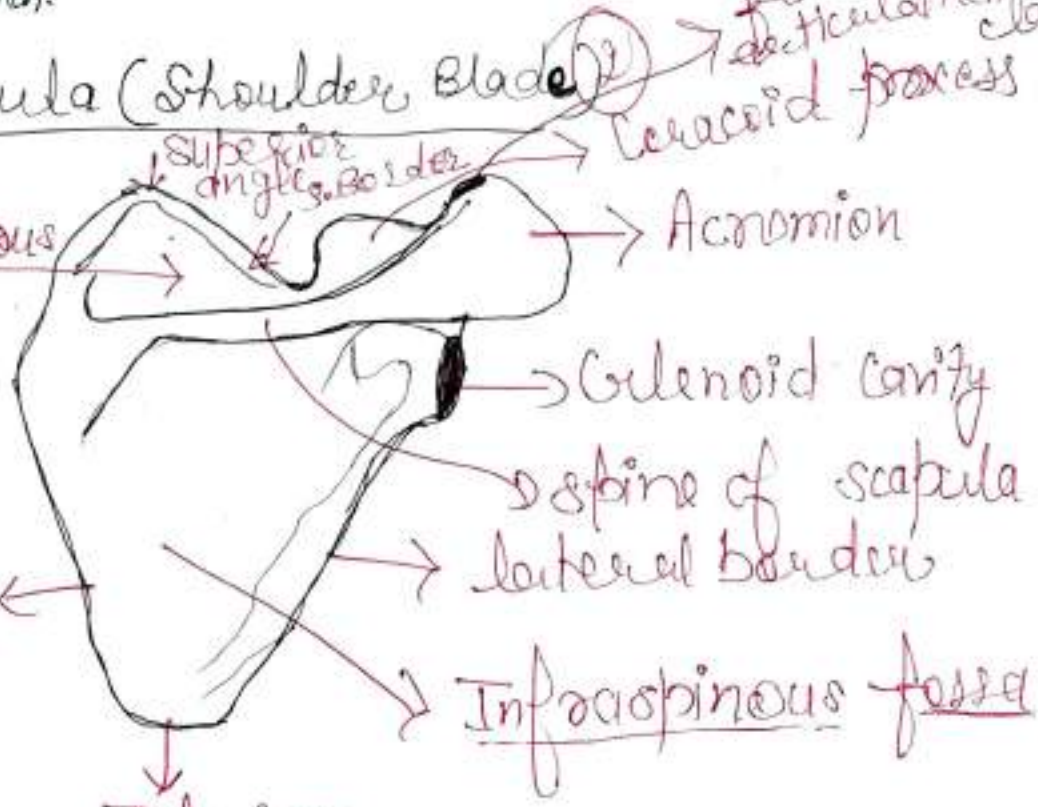
→ It is a S-shaped long bone.

→ It articulates with the manubrium of the sternum at the sterno-clavicular joint and forms the acromioclavicular.

joint with the acromion process of the scapula.

⇒ Clavicle provides the only bony link b/w the upper limb and the axial skeleton.

b) Scapula (Shoulder Blade)



⇒ It is a flat, triangular shaped bone.

⇒ It lies on the posterior chest wall superficial to the ribs. and separated from them by muscles.

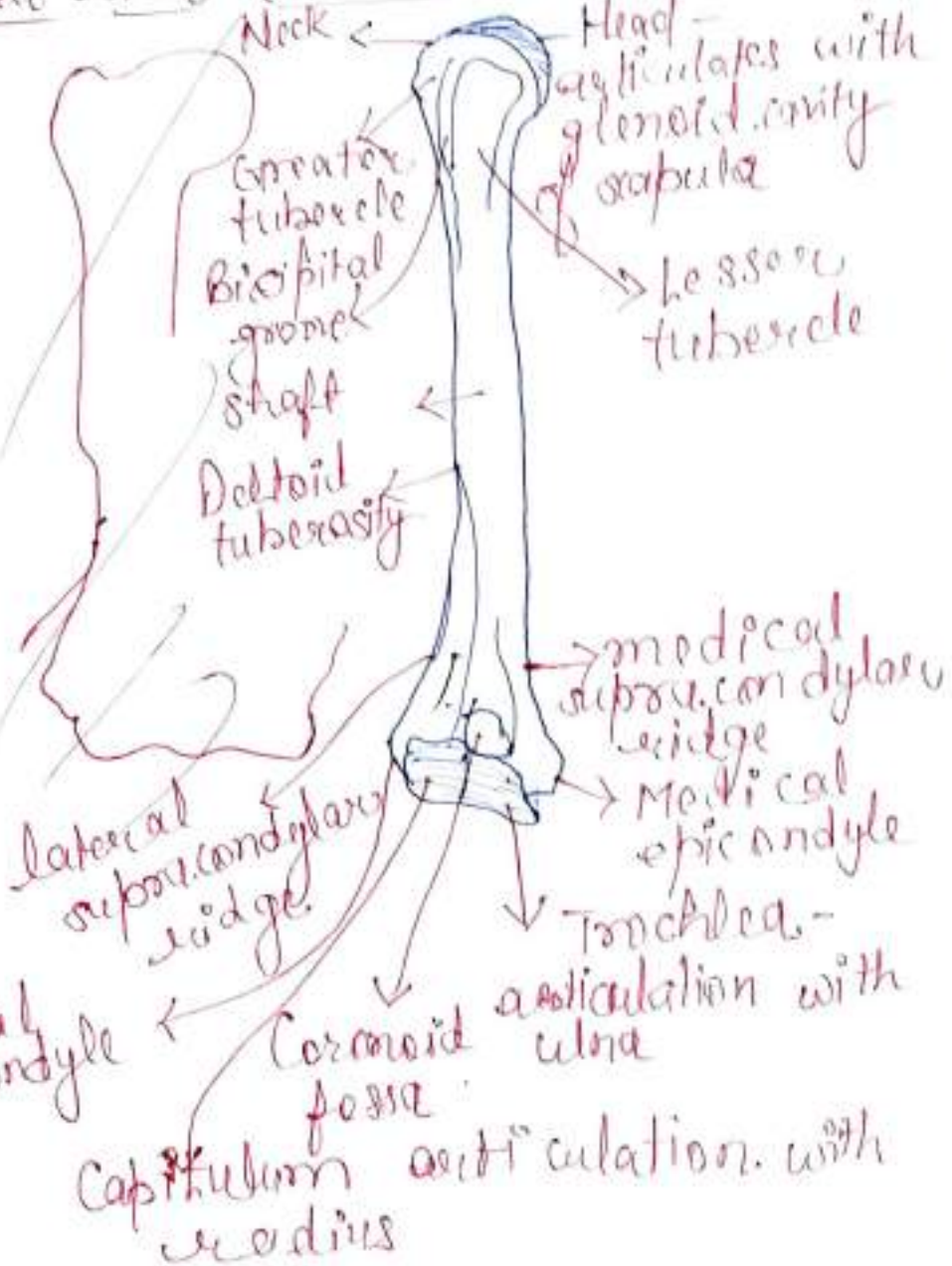
⇒ At the lateral angle there is a shallow articular surface, the glenoid cavity which with the head of the humerus forms the shoulder joint.

⇒ On the posterior (Back part) surface runs a rough ridge called the spine

⇒ The important landmark, which can be felt through the skin, as the highest point of the shoulder is called acromion process.

and forms a joint with the clavicle slightly is the acromioclavicular joint, to the slightly moveable joints that keys the movement of the shoulder girdle.
=> Coracoid process, the projection from the upper part of the bone, gives attachment to muscles that move the shoulder joint.

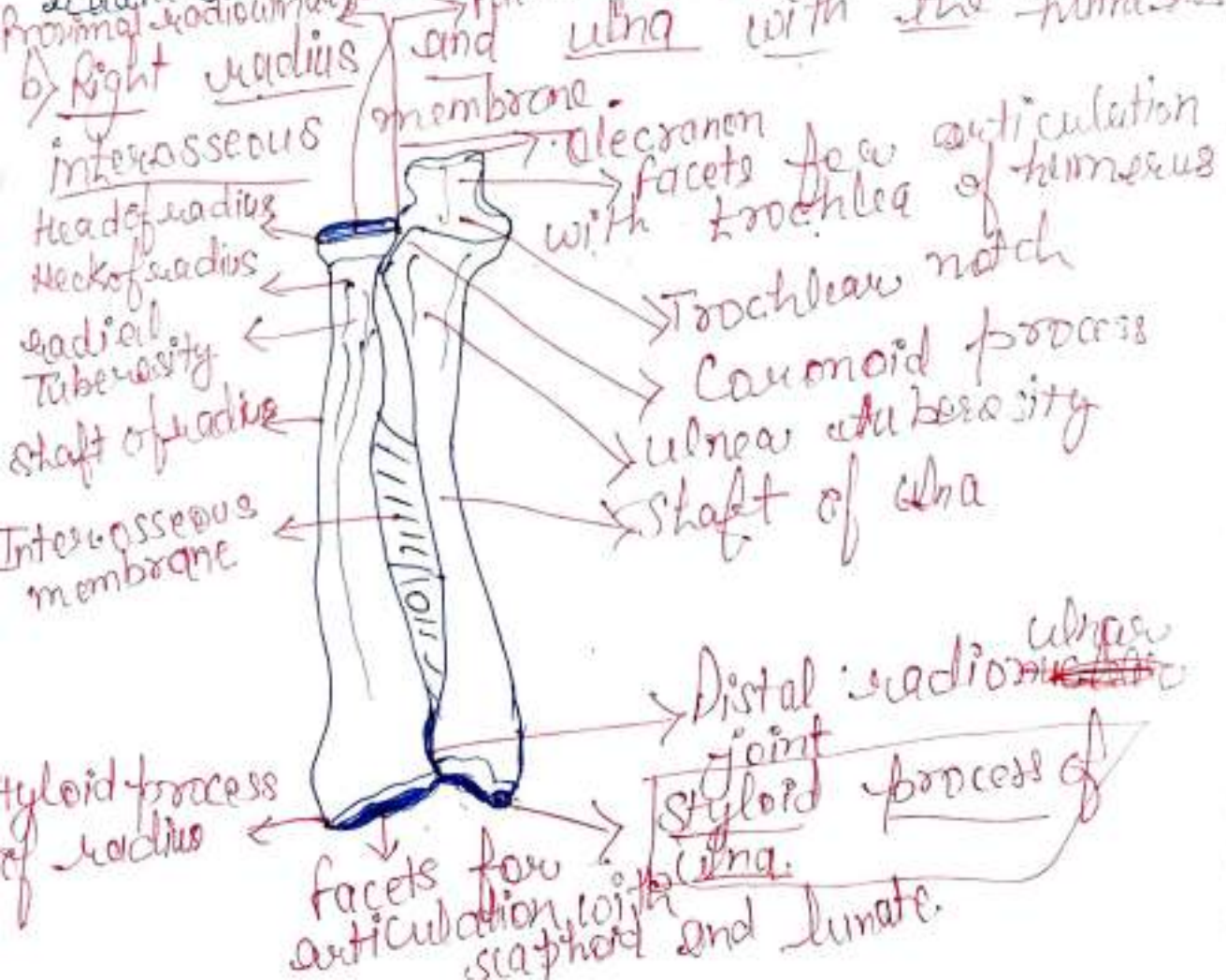
2) The upper limb (Humerus)



⇒ It is the bone of upper arm.
⇒ The head fit within the glenoid cavity of the scapula, forming the shoulder joint
⇒ Distal to the head are two roughened projections of bone

Greater tubercle | Lesser tubercle | Between these → there is a deep groove, ⇒ Bicipital groove, or inter tubercular sulcus

⇒ The end of the bone has two surface that articulate with the radius & and ulna to form the elbow joint.
↓
occupied by one of the tendons of the biceps muscle.



⇒ Radius is situated towards the side of the thumb and ulna on the opposite side.

⇒ The ulna forms a true hinge joint with the elbow that provides extension and flexion movement. It also articulates with the wrist bones.

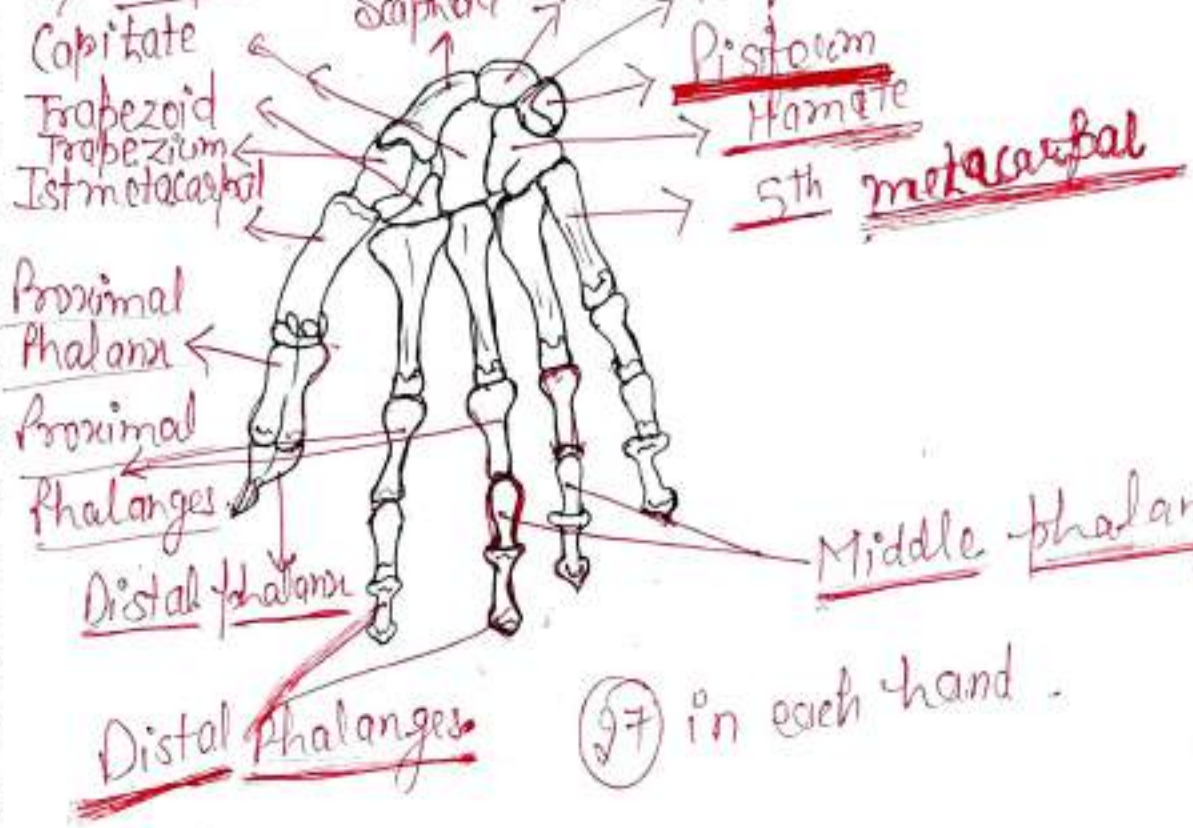
⇒ Radius has a smooth concave surface articulates with the capitulum of head of the humerus.

⇒ articulates with the ulna on the side surfaces.

⇒ Radius and ulna bones run parallel to each other. The ulna is longer than the radius but radius is thicker.

⇒ Interosseous membrane → a fibrous joint
Connect the bones along their shafts.
maintain their relative positions.

⇒ Carpals, metacarpals and phalanges.



(27) in each hand.

Functions of Axial skeleton

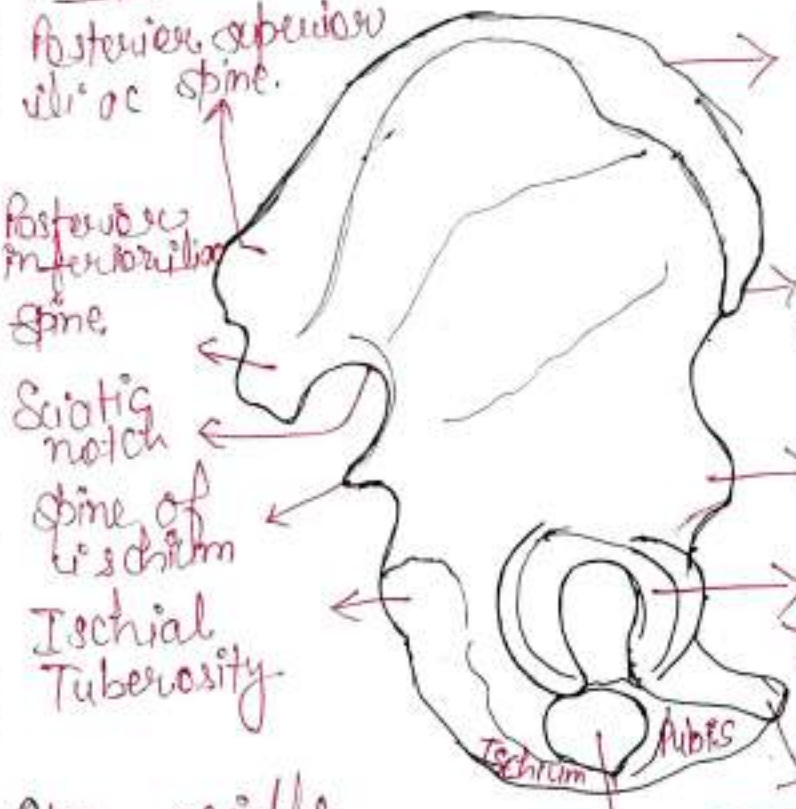
1) Carpal bones → 8 irregular bones → It connect the proximal ends of the metacarpal bones to the distal ends of the long forearm bones.
⇒ It gives the soft tissue of hand flexibility and movements, structure of wrist

2) Metacarpal bones → It is a collection of 5 bones blw the carpal bones and phalanges

3) Phalanges :- The small bones that constitute the bony centre of fingers are known as the phalanges. According to the structure they are referred to as long bones.
⇒ Each hand has 14 phalanges & the thumb only has 2. smallest bone in the human hand — trapezoid

2) Pelvic guidle with the lower limbs. Appendicular skeleton - 126 bone

a) Hip Bone (2)



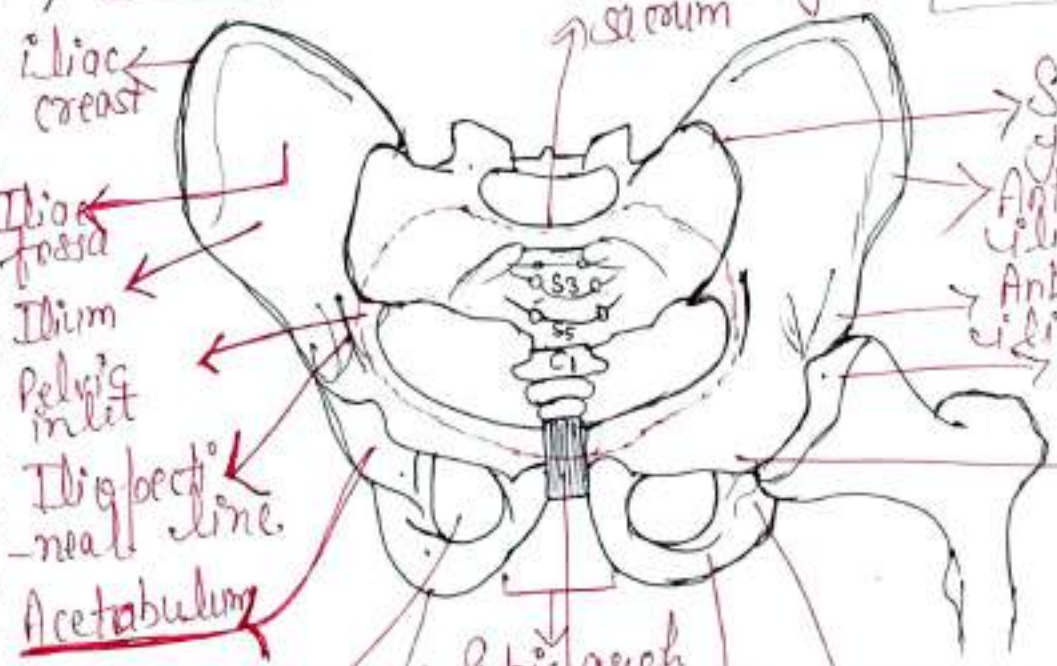
Pelvic guidle

↳ Region blw the thighs and abdomen is called the pelvic region. It connects the lower limbs to the axial skeleton.

large opening blw the ischium and the pubis bone. It is round or oval in shape, lining of connective tissue filled with

Each hip bones consist of three fused bones
1) Ilium → largest part of hip bone, fan-like
fractures. Ilium forms a synovial joint with the sacrum.
2) Ischium :- it makes the back part of the pelvic girdle below the Ilium. It forms the lower anterior sitting. 3) Pubis :- part of the pelvic girdle
4) Pubic symphysis :- joint b/w the pubis part of the 2 hip bones in the middle portion contains fibrous cartilage 5) Acetabulum :- cavity formed by the fusion of Ilium, Ischium and pubis.

b) Pelvis :- function of HB - largest wt bearing portion of the body → allows mobility



⇒ Pelvis is formed by the hip bones and the sacrum and the coccyx.
⇒ It is divided ~~by the~~ ~~hip bones~~ into upper and lower parts by the brim of the pelvis → consisting of the promontory of the sacrum, and the iliopectineal lines of the innominate bones.

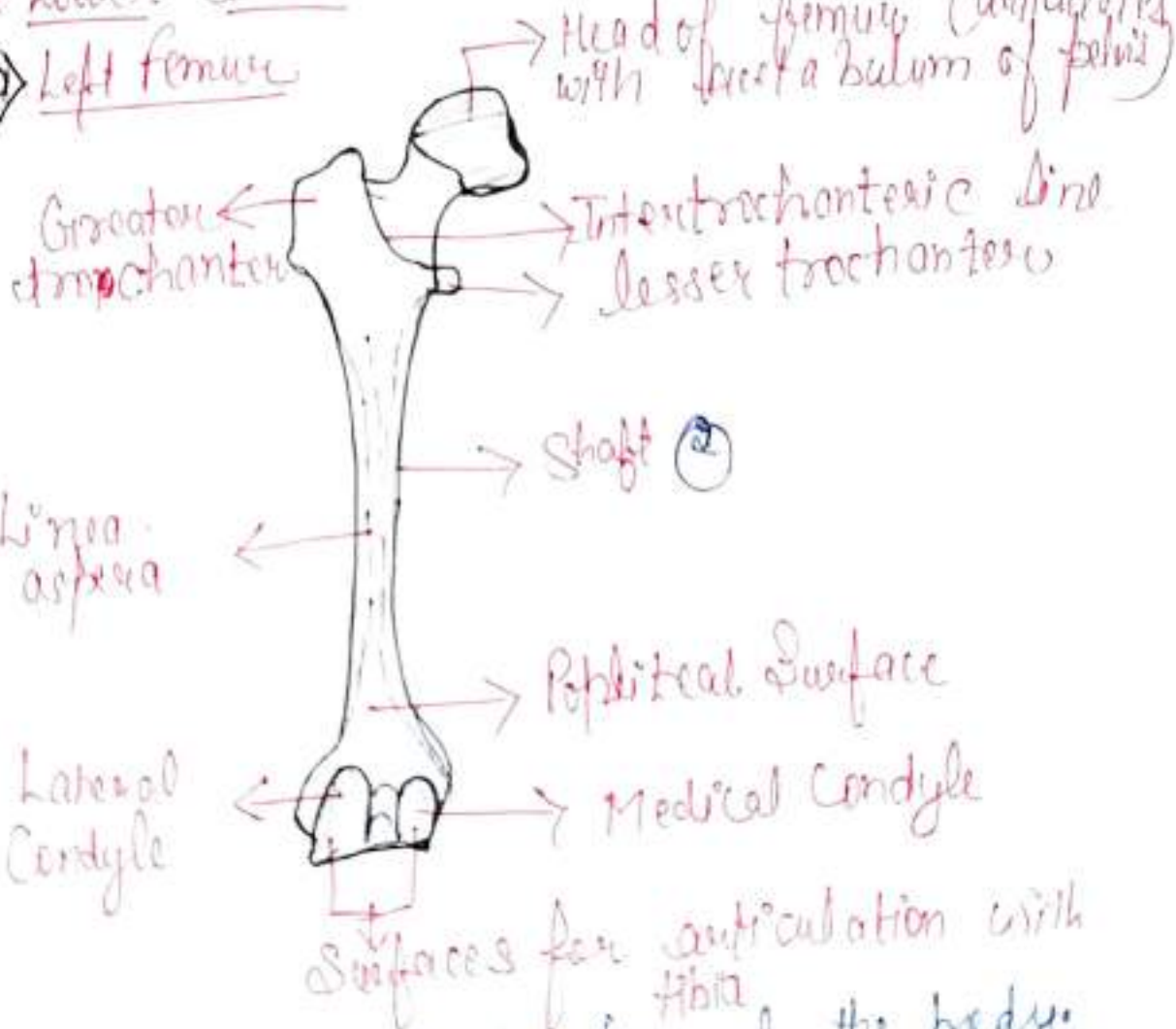
⇒ Difference b/w male and female pelvis

⇒ Shape of the female pelvis allows easy the passage of the baby during child-birth.

⇒ Female pelvis has higher bones.

* Lower limb

9) Left femur



⇒ longest and heaviest bone of the body.

⇒ Head is spherical and fits into the acetabulum of the hip bone to form the hip joint.

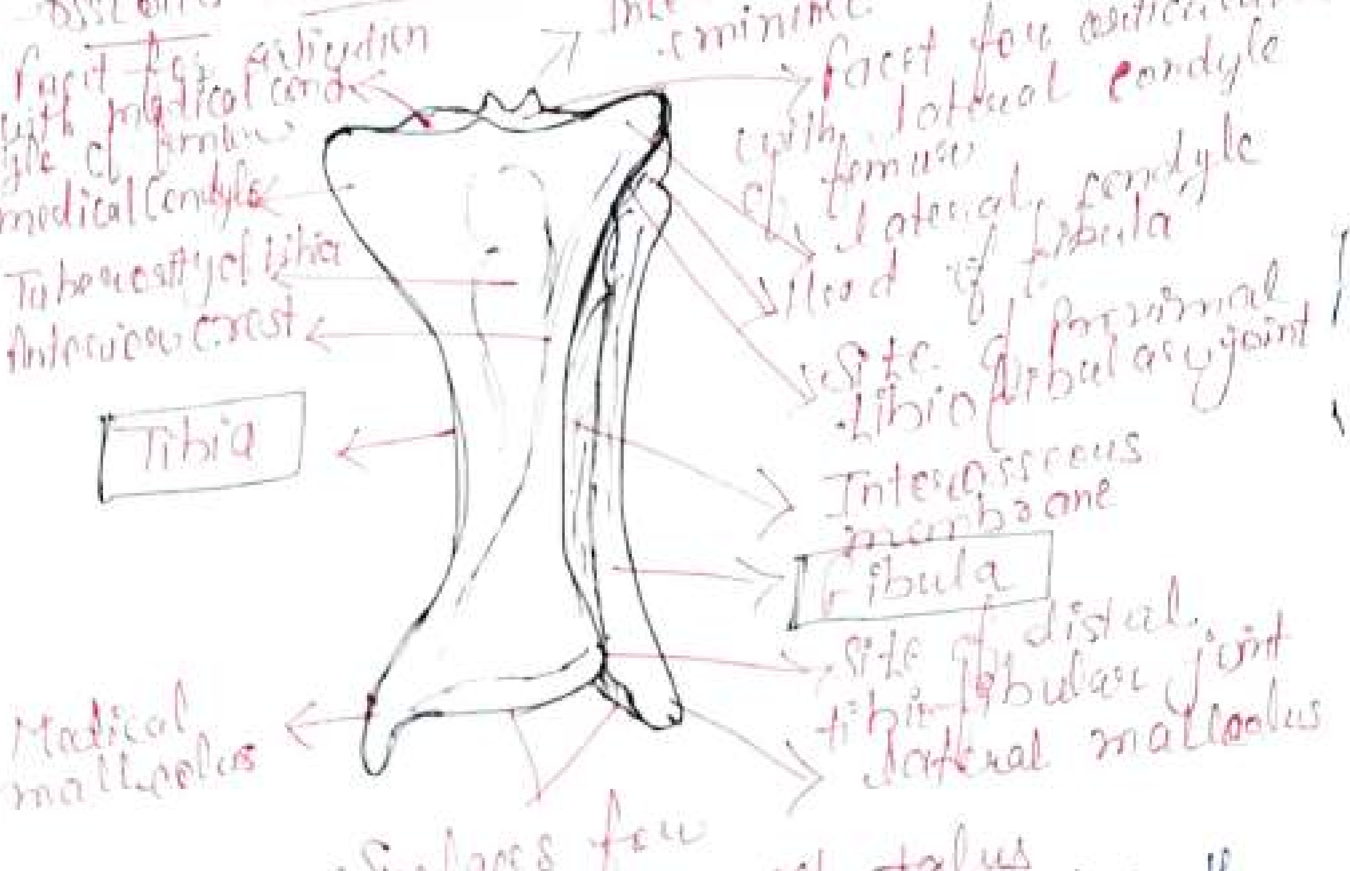
⇒ Neck extends outwards and slightly downwards from the head to the shaft of ~~and~~

⇒ Posterior surface ⇒ referred to as the thigh bone.

⇒ femur also supports various vital organs, its muscles, ligaments, tendons, and components of the circulatory system.

⇒ It extends from the knee to the hip. The femur comprises long shaft in the middle and two rounded ends

b) Left tibia and fibula with the interosseous membrane



→ Tibia is one of the two bones present in the lower leg. It is also known as shinbone

⇒ Tibia is longer and stronger.

⇒ Anatomically, the tibia connects the ankle bone with the knee

Fibula → also called ~~tail~~ calf bone. (Smaller)
⇒ It connects to the tibia above and below.
⇒ Bottom part of the fibula extends well past the tibia and forms the lateral part of the ankle.
⇒ Combine with the tibia and provide stability to the ankle joint.

C) Left foot → Tarsals
→ Metatarsals.
→ Phalanges.

⇒ It is situated at the distal part of the lower limb
⇒ Foot contains 14 toe bones or phalanges, 7 tarsals and 5 metatarsals
⇒ Upper surface of the foot is called dorsum of the foot, and the lower surface is called the plantar surface or sole.
⇒ 7 Tarsal Bones are arranged in two rows.
⇒ Calcaneus is the largest bone that forms the prominence of the heel.
⇒ Talus is the 2nd largest bone.
⇒ ~~It includes scaphoid, cuboid, 03 smallest bone~~

Joints

also known as an articular surface

It is a connection that occurs b/w bones in the skeletal system.

→ Joints provide the movement.

1) Fibrous joints :- It is defined as the joints in which the bones are connected by fibrous tissue.

⇒ They are called fixed or immovable joints as they do not allow any movement b/w the bones.

⇒ They do not have a joint cavity and the bones is made up of collagen fibres.

eg. ① Skull
② Interosseous membrane.

Types of F.J

- Sutures → Flat bones of the skull
- Gomphosis → connects teeth with the bone cavity.
- Syndesmoses → present in forearms (b/w radius and ulna) eg. (between tibia and fibula.

2) Cartilaginous joints :- These joints are formed by fibrocartilage that a pad of tough shock absorber.

1) Immovable joints

Functions of Bitheline ...

Features of C.J.

- These joints are slightly moveable joints.
- Bones are connected by cartilage.
- Vertebral column.
- These joints are found in those places where stability and strength are required instead of free movement.

Types of Cartilaginous joints

1° cartilaginous joints (synchondrosis) (seen in appendicular bone)
- first sternocostal joint
- Neurocentral joints of vertebrae
- sphenо-occipital synchondrosis.

2° cartilaginous joints (symphysis) (seen in axial skeleton)
- In vertebral discs
- Sacro-coccygeal symphysis
- Symphysis btw the right and left pubic bones

(1) Shoulder joint :-

Structure :-
- It is a ball and socket joint
- most mobile in the body.
- It is formed by the glenoid cavity of scapula and the head of the humerus
- It is also called glenohumeral joint
- articulating surface are covered with hyaline cartilage.
- Head of the humerus is much larger than the glenoid fossa.

Joint capsule :- A joint capsule is a fibrous sheath which encloses the structure of the joint.

⇒ Synovial membrane lines the inner surface of the joint capsule and produce Synovial fluid to reduce the friction b/w the articular surfaces.

③ Ligments :-

⇒ Glenohumeral ligments
⇒ Coracohumeral L.
⇒ Transverse H.L.
⇒ Coracoacromio. ligment

④ Bursae :- It is a synovial fluid filled sac, which acts as a cushion b/w tendons and other joints structures.

⑤ Elbow Joint :- It connecting the upper arm to the forearm. It is a type of hinge-type S.J.

*Structure of E.J. — E.J consist of two separate articulations.

- Trochlear notch of the ulna and the trochlea of the humerus
- Head of the radius and the capitulum of the humerus.

*Joint capsule and Bursae :-

⇒ Elbow joint has a capsule enclosing the joint.
⇒ It is strong and fibrous and strengthening the joint
⇒ Joint capsule is thickened medially and laterally to form collateral ligaments.
⇒ Bursa is a membranous sac filled with synovial fluid.

Functions of Epithelial tissue

⇒ It acts as a cushion to reduce friction b/w the moving part of a joint.

Ligaments :- Radial collateral
lateral epicondyle
Ulnar collateral
Medial epicondyle

③ Wrist joint :-

(radiocarpal joint)

⇒ An articulation b/w the radius and the carpal bones of the hand.

⇒ It is condyloid-type synovial joint.

Anatomical structure of wrist j.

[It is formed by an articulation b/w.

Distal end of the radius and the articular disk.

Proximal row of the carpal bones

⇒ Carpal bones forms a convex surface, which fits into the concave shape of the radius and articular disk.

** Joint capsule :- Joint capsule of the wrist joint attaches to the radius, ulna and the proximal row of the carpal bones.

* It is internally lined by a synovial membrane which produce (synovial fluid to reduce friction b/w the articulating structures.

Ligaments :- ① Palmar radiocarpal
② Dorsal radiocarpal
③ Ulnar collateral
④ Radial collateral

Movements :- Flexion, extension, Adduction abduction.

Mobility and stability :- Highly mobile joint allow the more in several directions.
↓
It maintain stability.

Blood supply :-
↓
receive blood from branches of the dorsal and palmar carpal arches, which are derived from the ulnar and radial arteries.

(4) Hip joint :- It is a type of Ball and socket synovial joint formed by an articulation b/w the pelvic acetabulum and the head of the femur.

Structure of hip joint

① Articulating Surfaces :- Hip joint consists of an articulation b/w the head of femur and acetabulum of the pelvis.

⇒ Acetabulum is a cup like depression located on the inferolateral aspect of the pelvis.

⇒ Its cavity is deepened by the presence of a fibrocartilaginous collar of the acetabular labrum.

⇒ Head of the femur is hemispherical, and fits into the concavity of the acetabulum.

⇒ Acetabulum and head of femur are covered in articular cartilage.

Ligaments

Intracapsular
↓
It is the ligament of head of femur

Extracapsular
- Iliofemoral ligament
- Pubofemoral
- Ischiofemoral

Neurovascular Supply
Circumflex femoral arteries
medial & lateral

Movements and muscles :-
flexion, extension, abduction, adduction, lateral rotation, medial rotation.

Knee joint :- It is a hinge type synovial joint which mainly allows flexion and extension. It is formed by articulations between the patella, femur and tibia.

Articulating surface :-
[Two articulations.

Tibiofemoral
↓
medial and lateral condyles of the femur articulate with the tibial condyles.

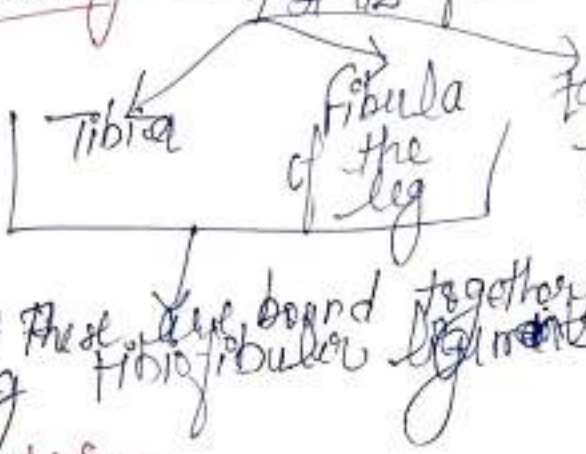
Patellofemoral
↓
anterior aspect of the distal femur articulates with the patella.

Neurovascular supply :- The blood supply to the knee joint is through the genicular anastomosis around the knee, which are supplied by the genicular branches of the femoral and popliteal arteries.

(6) Ankle joints :- It is also known as Talocrural joint. It is formed by an articulation of the foot (talus) and the leg (tibia and fibula).

It is a hinge type joint, permitting dorsiflexion and plantarflexion of the foot.

Articulating surfaces :- It is formed by three bones.



These are bound together by strong tibiofibular ligaments

Ligaments :-

Medial ligament

↓

It is attached to the medial malleolus

Lateral ligament

↓

originates from the lateral malleolus

Muscles and movements at the ankle joints.

Movement	muscles
Dorsiflexion	Anterior tibialis and toe extensors
Plantar flexion	Gastrocnemius, soleus and toe flexors

Storage function :- Blood serves as a source for substances like proteins, glucose, sodium and potassium.

⇒ Defensive mechanism :- Neutrophills and monocytes engulf the bacteria by phagocytosis.

⇒ Lymphocytes are involved in development of immunity.

⇒ Eosinophills are responsible for detoxification, disintegration and removal of foreign proteins

Process of Hemopoiesis

Hematopoiesis

⇒ The process of formation of blood cellular components, RBC, WBC and platelets is called as haematopoiesis.

⇒ All cellular blood components are derived from hemato-poietic stem cells.

⇒ Approximately 10¹¹ - 10¹² new blood cells are produced daily in order to maintain steady state levels in the peripheral circulation.

⇒ The sites where it occurs are known as hematopoietic tissue or organs (bone marrow, liver, spleen).

Flat bones

Location :-

① In developing embryos :- Blood formation occurs in aggregates of Blood cells in the yolk sac, called blood islands.

② In children :- Hemotopoiesis occurs in the marrow of the long bones such as the femur and tibia

Blood → derived from mesoderm

⇒ Blood is a fluid connective tissue that consist of plasma, blood cells and platelets

⇒ It circulates throughout our body delivering oxygen and nutrients to various cells and tissue

⇒ It transport hormones, heat, antibodies and cells of the immune system, clotting factors and wastes.

Composition of Blood

- Plasma
- RBC / Erythrocytes
- WBC / Leukocytes
- Platelets / Thrombocytes

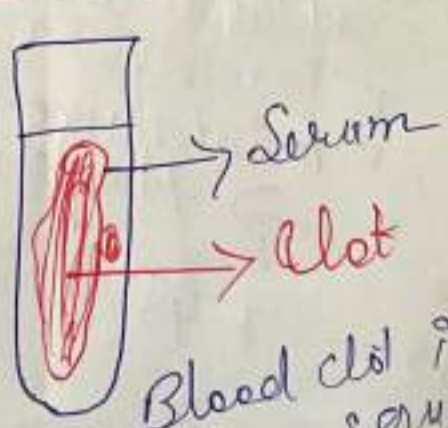
Plasma

- Nitrogenous waste
- Electrolytes
- Gases.
- amino acids
- Nutrients
- Proteins
- Albumins
- Fibrinogen ⇒ most abundant clotting factors.
- Globulins

Plasma normally constitutes 55%

WBC

- Granulocytes
  - Neutrophills.
  - Basophills
  - Eosinophils.
- agranulocytes
  - Lymphocytes
  - Monocytes.



Blood clot in serum

Plasma :-

It is a liquid component of your blood that carries cells. It makes up to 55% of your blood total volume. Plasma is about 92.1% water ⇒ main constituent of blood.

⇒ To help your body recover from injury, distribute nutrients, remove waste and prevent infection, maintain pH balance in the body, BP, blood clotting.

Yellow Liquid

⇒ **Plasma Proteins** ⇒ It make up about 7% of Plasma

⇒ They are responsible for creating the osmotic pressure of blood which keeps plasma fluid within the circulation.

⇒ **Albumins :-** These are the most abundant plasma proteins (about 60%) and their main function is to maintain normal plasma osmotic pressure. It acts as a carrier molecule for free fatty acids, some drugs and steroid hormones.

⇒ **Globulins :-** Globulins are a group of proteins in your blood. It is made in your liver by your immune system. It plays important role in liver function, blood clotting and fighting infection.

⇒ **Clotting factors :-** 12 clotting factors. These are responsible for coagulation of blood.

Electrolytes :-
* Muscle contraction → Ca^{2+}
* Transmission of nerve impulse - Ca^{2+}, K^+ and Na^+
* Maintenance of acid-base balance → phosphate PO_4^{3-}.

pH of Blood

↓ 7.35 – 7.45

Nutrients:- Essential for cellular growth and metabolism, include glucose, amino acids and vitamins.

Waste products:- urea, creatinine and uric acid are the waste products of protein metabolism.
⇒ They are formed in the liver and carried in blood to the kidneys for excretion.

Hormones:- chemical messengers synthesised by endocrine glands; they are secreted into the blood and transported to their target tissues

Gases:- Oxygen, is not very soluble in H_2O, but it can be transported dissolved in plasma. >2%
⇒ Oxygen is bound to haemoglobin in RBC.

Process of Haemopoiesis:-

Process of formation of blood cells ie RBC, WBC and platelets is called as haemato-poiesis and the sites where it occur are known as hemopoietic tissue or organs (bone marrow, liver, spleen.

Regulation of water balance water content of the blood is body interchangeable with interstitial fluid.

⇒ **Regulation of acid base balance** Plasma proteins and haemoglobin act as buffers and helps in the regulation of acid-base balance.

⇒ **Regulation of Body temperature:-** Because of the high specific heat of blood, it is responsible for maintaining the thermoregulatory mechanism in the body

The branch of science concerned with the study of blood, blood-forming tissues, and the disorders associated for th terms is called hematology.

Properties of Blood

Colour:- Blood is red in colour

⇒ Arterial blood is scarlet red because it contains more oxygen

⇒ Venous blood → purple reds because of more CO_2.

Functions of Blood:-

① **Nutritive F.** = Nutritive substances like glucose, amino acids, lipids and vitamins are absorbed from GIT and carried by blood to different parts of the body for growth and production of energy.

② **Respiratory function:-** = Transport of respiratory gases is done by the blood.
⇒ It carries oxygen from alveoli of lungs to different tissues and carbon dioxide from tissues to alveoli.

③ **Excretory function:-** waste products are removed by blood and carried to the excretory organs like kidney, skin, liver etc. for excretion.

④ **Transport of hormones and enzymes-** Blood transports endocrine hormones and enzymes to their target organ/tissue.

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Defensive mechanism :- Neutrophills and monocytes engulf the bacteria by phagocytosis.

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flat bones

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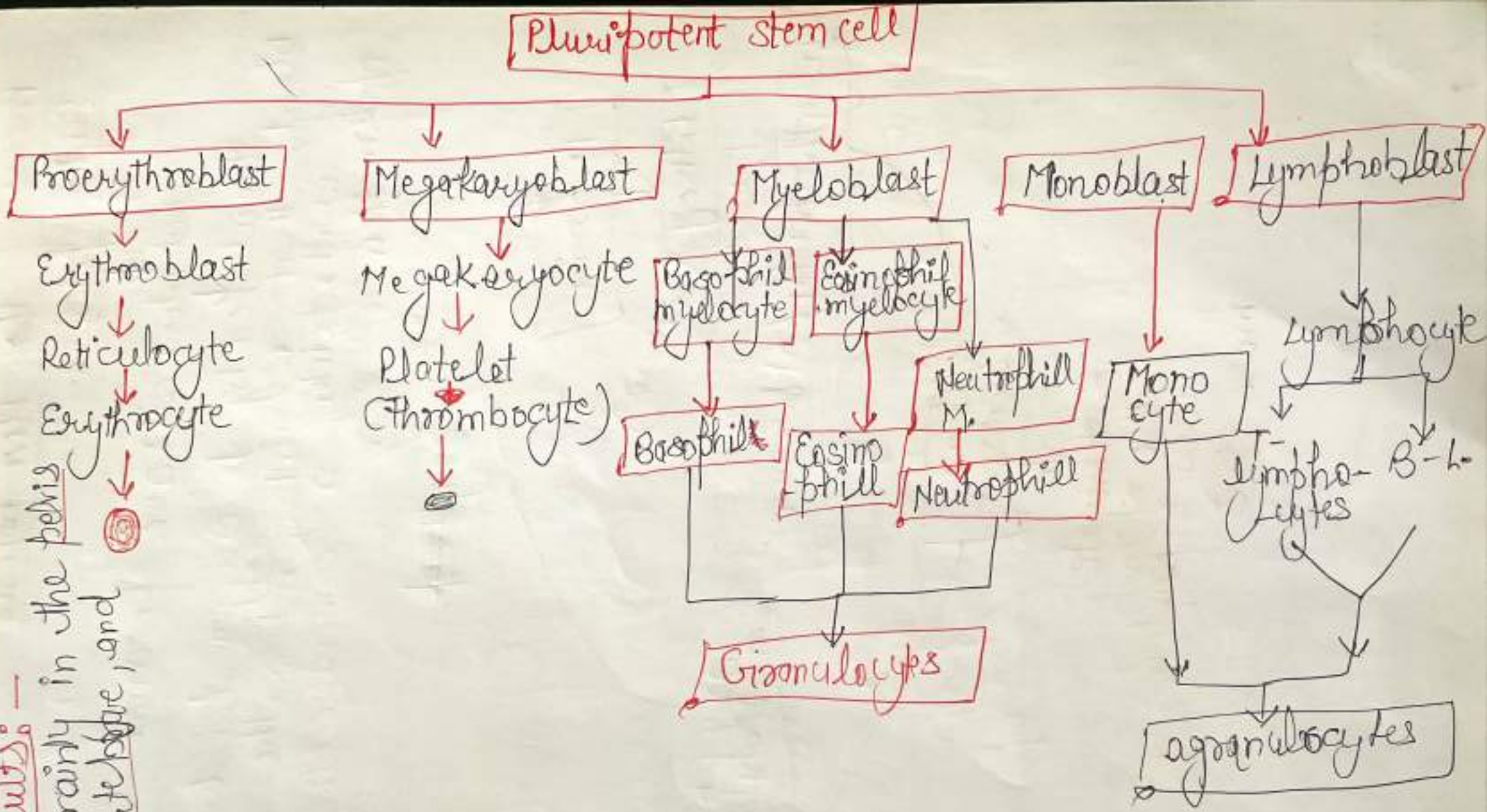


(3) In adults — It occurs mainly in the bone marrow, reticulum, and sternum.

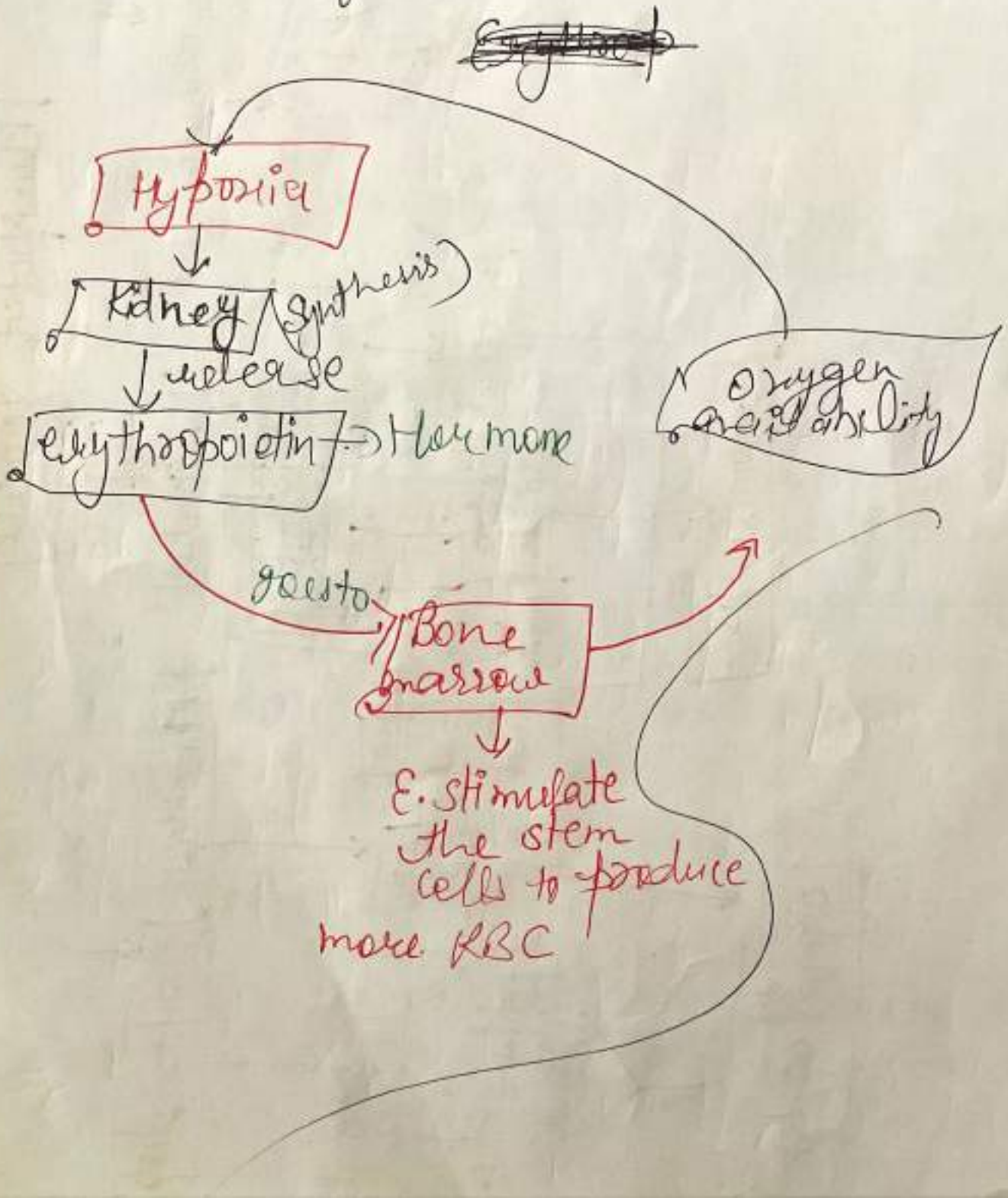
Process of Hemopoiesis

Erythropoiesis :-

↓

Red blood cells are formed.

Stimulated by ↓ Oxygen level in the blood, that sets into motion the secretion of erythropoietin, a hormone central to the formation of RBC.



Stages of development of RBCs

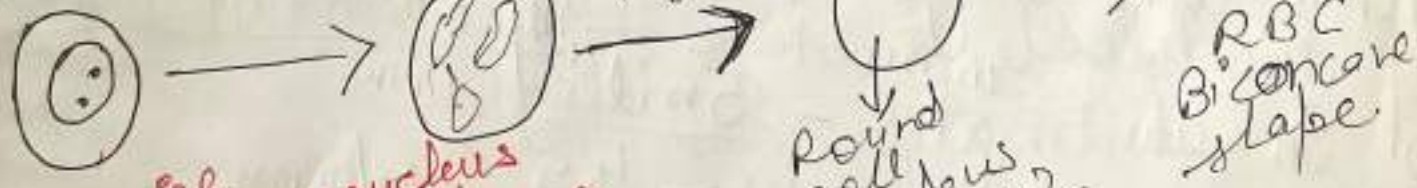
(1) Proerythroblast → It is the earliest stage in the maturation of RBCs. The unipotential cell becomes with nucleus. At this stage it does not have haemoglobin.

(2) Normoblast - It is the 2nd stage. At this stage cell is smaller in size with degenerated nucleus. Haemoglobin is fully present.

(3) Reticulocyte :- In the reticulocyte stage the red blood cell has no nucleus but hemoglobin is fully present.

(4) Erythrocyte :- In this stage the RBC is fully developed which has no nucleus and no reticulum.

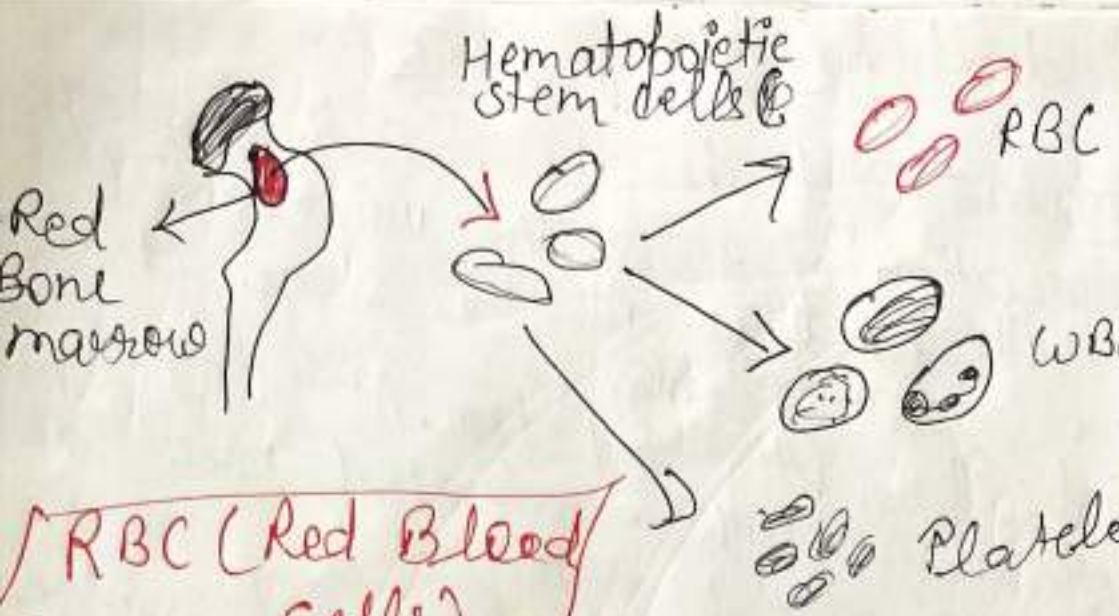
Vitamin B12 and folic acid both are necessary for the development of RBC



P
large size
Nucleus present
Hb absent

nucleus shrink (Picknosis)
(disappear of nucleus)

Round cell
Nucleus disappear
Hb present



RBC (Red Blood Cells)

RBC are the non-nucleated formed elements in the blood.
Also known as Erythrocytes. (Red — cell)

Characteristics of RBC

⇒ Red colour of the RBC is due to the presence of colouring pigment called Hemoglobin.
⇒ RBC count stage b/w 4 and 5.5 million/cu mm of the blood. In mountains — more than 7 million/cu mm
⇒ In adult males — 5 million/cu mm
⇒ In adult females — 4.5 m/cu mm.
⇒ Average Lifespan of RBC is about 120 days.
⇒ After the lifetime for old RBC are destroyed in reticuloendothelial system.
⇒ Spleen is called Graveyard of RBC
⇒ Hypoxia stimulates kidney to secrete a hormone called Erythropoietin → It stimulates the bone marrow to produce more RBC.

Thickness of RBC:- 2.5 μm.
Diameter :- 7.5 μm.

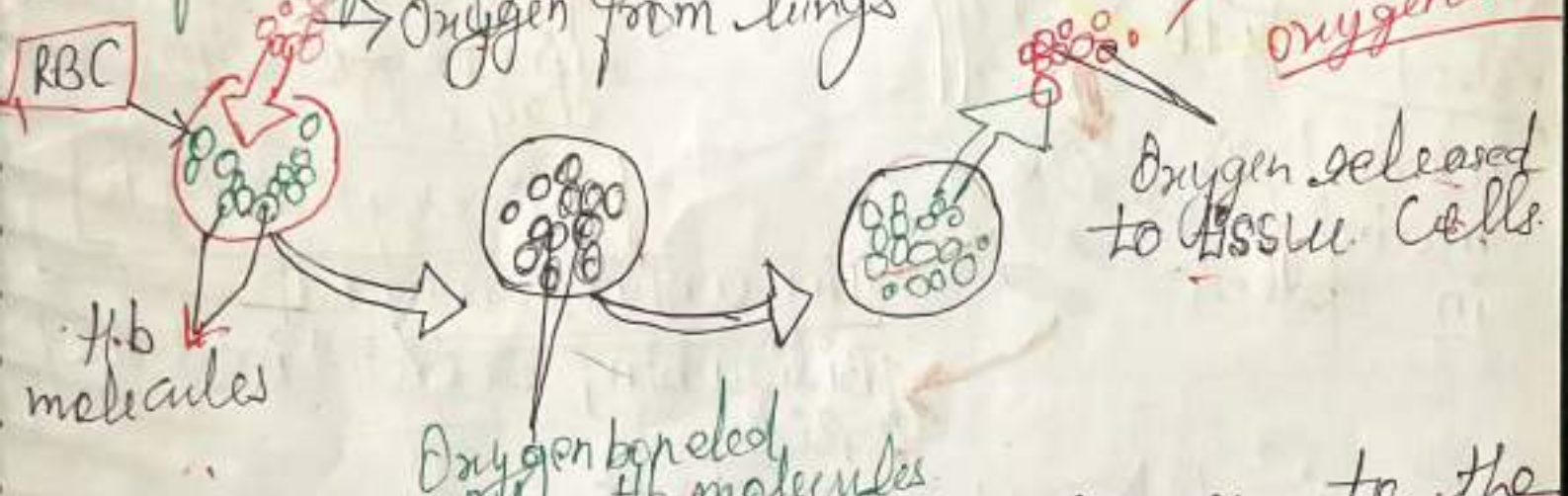
(Biconcave form)

Functions of RBC:-

(1) Transport of oxygen from the lungs to the tissues

⇒ Hb in RBC combines with oxygen to form oxyhemoglobin.

⇒ About 97% of oxygen is transported in blood in the form of oxyhemoglobin



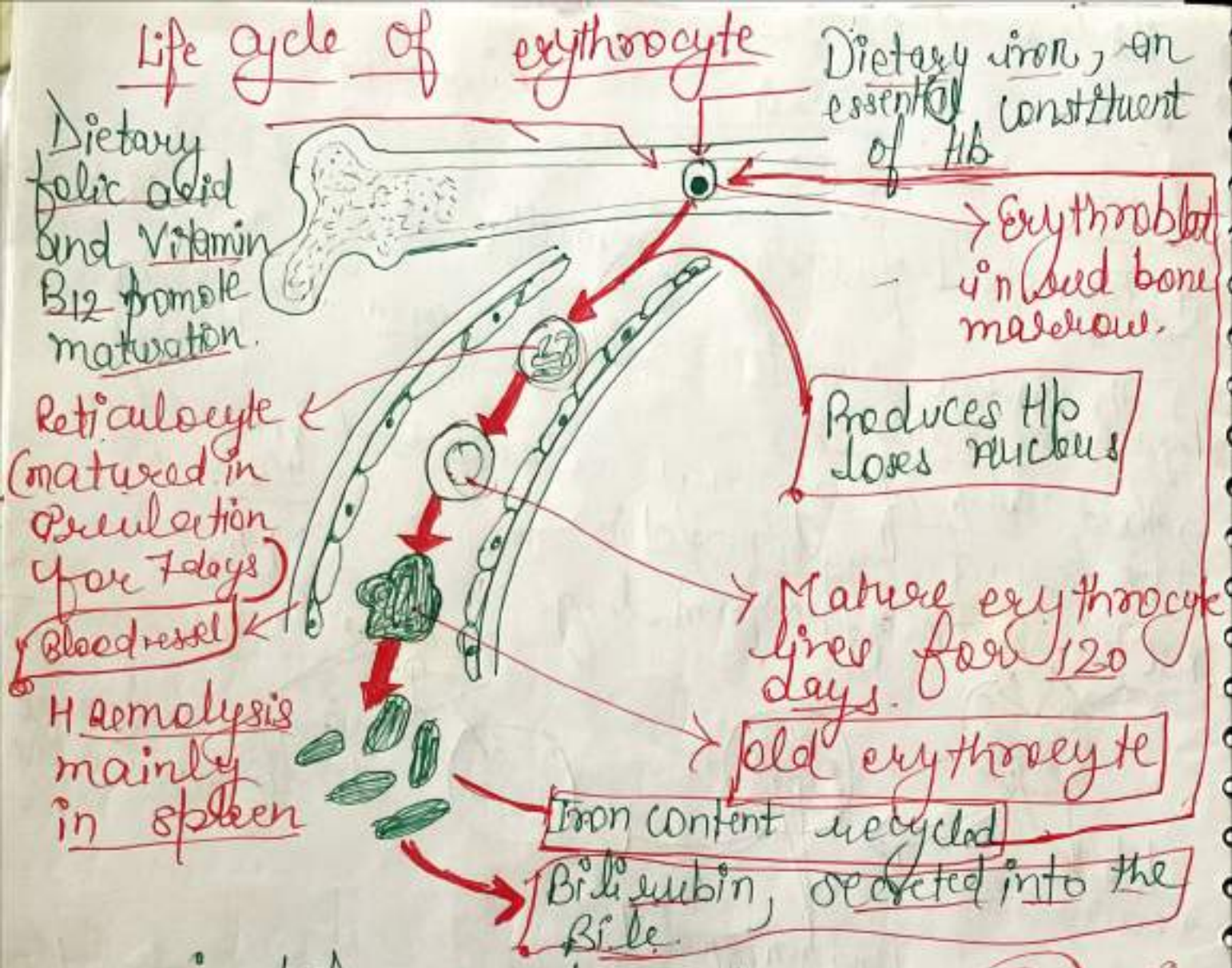
(2) Transport of CO_2 from the tissues to the lungs.

⇒ 70% bicarbonate ⇒ synthesize in RBC

Hb combines with CO_2 and to form carbhemoglobin.

⇒ About 30% of CO_2 is transported in this form.

Life cycle of erythrocyte



∴ Life cycle of Erythrocyte (120) 4+3

Haemoglobin :-

- HAEM (Pigment Part)
  - Iron
    - ↓
    - ferrous Fe^{++} form
  - Porphyrin
    - ↓
    - (Tetra pyrole structure linked with Fe^{++})
- Globin (Protein Part)
  - α-chains Pair
    - 141 × 2 = 282 amino acid
  - Poly peptide chain
  - β-chain (Pair) Pair
    - 146 × 2 = 292 A.A.

574 amino acids

⇒ It is a large, complex molecule containing a globular protein and a pigmented iron-containing compound called haem.

⇒ Each molecule of Hb contains 4 globin chains and 4 haem units

↓

each with one atom of iron

Each atom of iron can combine with an oxygen molecule ——→ i.e Single molecule of Hb contain 4 molecules of oxygen

⇒ RBC carries 280 million Hb molecules

* Terminology related to RBC Cells

① Hypoxia:— ↓ se Oxygen level in the blood

② Rouleaux formation:- It is the tendency of RBC to stick to one another like coins.

③ Polycythemia:- ↑ increase number of RBC in blood.

④ Anaemia:— ↓ se in RBC or Hb

Erythrocyte Sedimentation Rate:- Blood test that can show inflammatory activity in the body.

~~Average~~ Normal Hb content:—

Hb ~~con~~

① Average blood — Haemoglobin (Hb) content in the 14 to 16 g/dl

② In adult male — 15 g/dl

③ " females — 14.5 g/dl

* ESR :- ② RBC remain suspended uniformly in circulation.
(Sodium citrate) (EDTA) anticoagulant
③ Blood is mix with and allowed to stand on a vertical tube, the RBC settle down due to gravity with a supernatant layer of clear plasma.
④ ESR is also called sedimentation rate or Biernacki reaction.
⑤ It was first demonstration by Edmund Biernacki in 1897.

Carboxyhemoglobin or carbonmonoxyhemoglobin is the abnormal hemoglobin derivative formed by the combination of Carbonmonoxide with Hb.
⇒ Carbon monoxide is a colourless and odourless gas.
⇒ Since Hb has 200 times more affinity for Carbon monoxide than oxygen its hinders the transport of Oxygen resulting in tissue hypoxia.

Methemoglobin :- It is the abnormal Hb derived formed when iron molecule of Hb is oxidized from normal ferrous state to ferric state
⇒ Methemaglobin is also called ferrihemoglobin

Leukocytes ⇒ WBC

Colourless cell

⇒ They are colourless. Much larger than RBC.
⇒ 1 cubic mm of blood contains 4000 – 8000 WBC.
⇒ Formed in bone marrow.
⇒ Their life span depends on the body need so they have life span of months or even years.

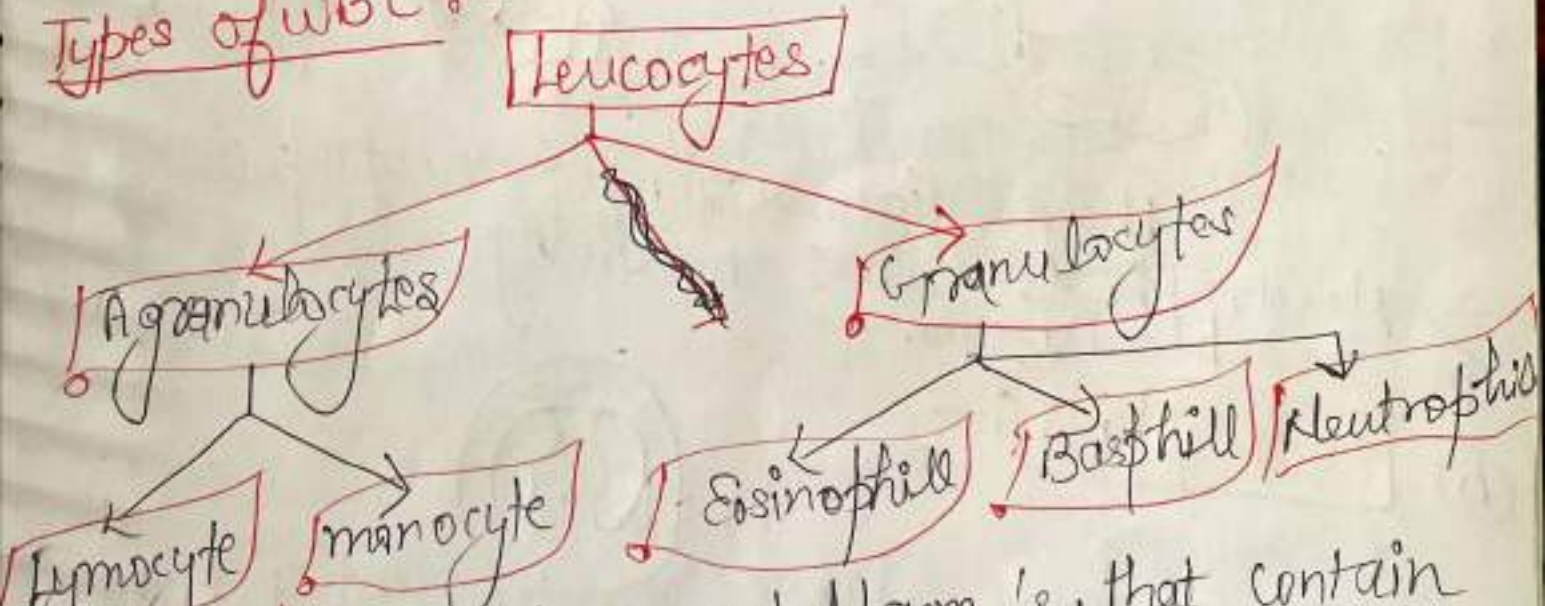
Functions of WBC

⇒ These are the cells of the immune system that are involved in protecting body against both infectious disease and foreign invaders.

Others functions are:-

⇒ Scavenging, Pus formation, Phagocytosis, Inflammation, Inflammation, Antibodies formation.

Types of WBC:-



⇒ Granulocytes have cytoplasm's that contain organelles that appear as coloured granules through light microscopy. Granu. consist of neutrophils, eosinophills and Basophills.

⇒ Eosinophils take up the red acid dye eosin; Basophils take up methylene blue; neutrophils are purple because they take up both dyes.

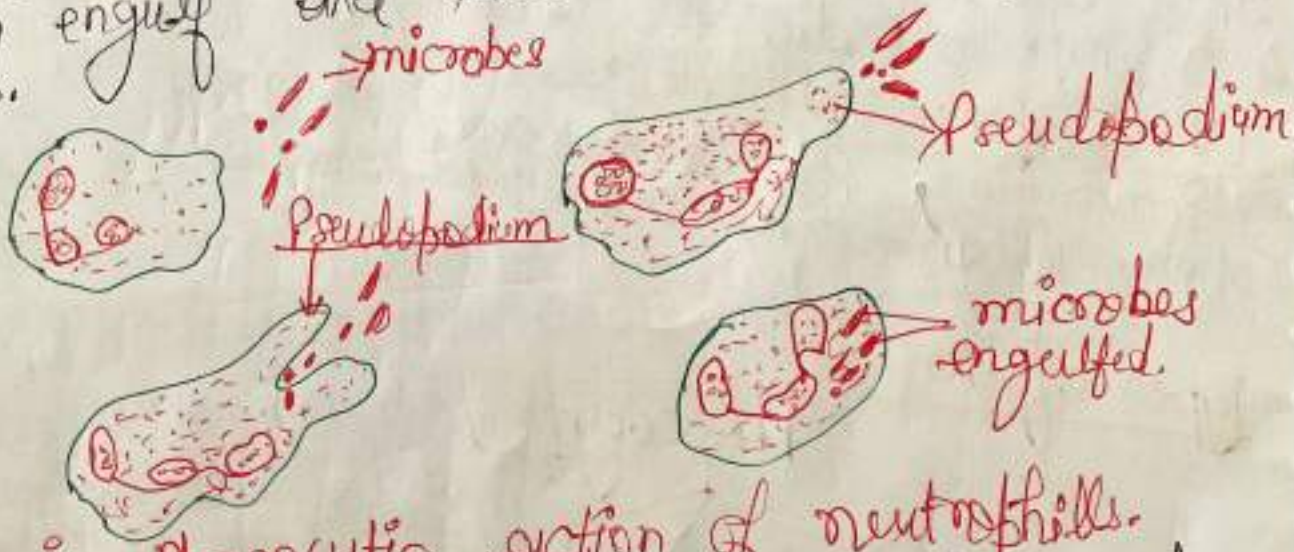
(a) Neutrophils :-

⇒ These contain very fine cytoplasmic granules.

⇒ Neutrophils are called polymorph nuclear having variety of nuclear shape.

⇒ These small, fast and active scavengers protect the body against bacteria and remove dead cells and debris from damaged tissue.

⇒ They engulf and kill bacteria by phagocytosis.



∴ Phagocytic action of neutrophils.

⇒ Neutrophils lives on average for 6 hours in the bloodstream.

(b) Eosinophils :-

⇒ These have large granules and a prominent nucleus that is divided into two lobes.

⇒ They function in the destruction of allergens and inflammatory chemicals and secrete enzymes that disable parasites.

⇒ local accumulation of eosinop. may occur in allergic inflammation, such as the asthmatic airway and skin allergies.

c) **Basophils** :-

⇒ They have bilobed nucleus that is usually hidden by granules.

⇒ They are closely associated with allergic reactions, contain cytoplasmic granules packed with heparin (an anticoagulant), histamine (an inflammatory agent).

⇒ They secrete histamine causing dilation of the blood vessels, and also secrete heparin which is an anticoagulant that promote mobility of other WBCs by preventing clotting.

2) **Agranulocytes** :- donot contain granules.

a) **Lymphocytes** :- These are usually classified as small, medium or large.

⇒ medium are large lymphocytes are generally seen mainly in fibrous connective tissue and only occasionally in the circulation bloodstream.

⇒ lymphocytes destroys cancer cells, cell infected by viruses and foreign invading cell.

T-lymphocytes

↓

Cellular immunity

Lymphocyte

B-lymphocytes

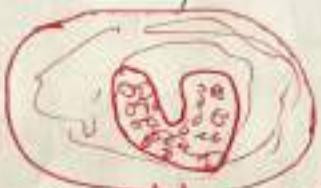
↓

make antibodies.

b) Monocytes:- They are the largest of the formed elements. Their cytoplasm is abundant and clear.

⇒ They function by activating other immune cells

⇒ They differentiates into macrophages, which are large phagocytic cells, and digest pathogens, dead neutrophils, and the debris of dead cells.



→ monocytes

*Body main fixed macrophage collections = microglia in the brain, Alveolar macrophages in lungs, Hepatic macrophages in liver, synovial cells in joints, osteoclast in bone, dendritic cells in skin, kidney, lymph nodes

Platelets

↓

Thrombocytes

⇒ Small colourless, non-nucleated and moderately refractive bodies

⇒ Average lifespan of platelets is 10 days.

⇒ Normal platelet count is 2,50,000/cumm of blood.

⇒ It ranges between 2,00,000 and 4,00,000/cumm of blood

Alpha granules	Dense granules.
Clotting factors: Fibrinogen, V and XIII	~~Nucleotides~~
Platelet-derived growth factor	~~Serotonin~~ Nucleotides
Vascular endothelial growth factor	~~Phospholipid~~ serotonin

Basic fibroblast growth factor → Phosphalipid
Endostatin → Calcium
Thrombospodin → Lysosomes.

Functions of platelets :—

(1) **Blood clotting** :— Platelets are responsible for the formation of intrinsic prothrombin activator which is responsible for the onset of Blood clotting.

(2) **Clot retraction** :— Cytoplasm of platelets contain the contractile proteins namely actin, myosin and thrombosthenin, which are responsible for clot retraction.

(3) **Prevention of Blood loss (Hemostasis)** :— Platelets accelerate the hemostasis by three ways :—

a) Platelets secrete 5-HT, which causes the constriction of Blood vessels.

b) Due to the adhesive property, the platelets seal the damage in blood vessels like capillaries.

c) By formation of temporary plug, the platelets seal the damage in blood vessels.

(4) **Repair of ruptured Blood vessel** :— Platelet derived growth factor formed in cytoplasm of platelets is useful for the repair of the endothelium and other structures of the ruptured blood vessels.

(5) **Defence mechanism** :— By the property of agglutination, platelets encircle the foreign bodies and destroy them

Activators of Platelets

Act in.

1) ⇒ Collagen, which is exposed during damage of blood vessels.
2) Von Willebrand factor
3) Thromboxane A2
4) Platelet activating factor
5) Thrombin
6) ADP
7) Calcium ions
8) P-selectin: Cell adhesion molecules secreted from endothelial cells.
9) Convulxin: Purified protein from snake venom

*Inhibitors of Platelets

1) Nitric oxide
2) Clotting factors: II, IX, X, XI and XII
3) Prostacyclin
4) Nucleotidases which breakdown the ADP.

*Platelet Disorders

(1) Thrombocytopenia:- Decrease in platelet count (1.60,000/mm^3)

(2) Thrombocytosis:- ↑se in Platelet count

(3) Thrombocythemia:- Persistent and abnormal increase in platelet count.

following conditions:
1) Carcinoma, chronic leukemia, Hodgkin disease

④ Glanzmann's thrombasthenia:- It is an inherited hemorrhagic disorder, caused by structural or functional abnormality of platelets.

⑤ Vitamin K deficiency → liver → ↓ synthesis various clotting factor

Leucocyte disorders

- Leukopenia → ↓ WBC count
- Granulocytopenia (neutropenia) → abnormal low no. of circulating granulocytes
- Leukocytosis → ↑se WBC count
- Leukaemia → Blood cancer

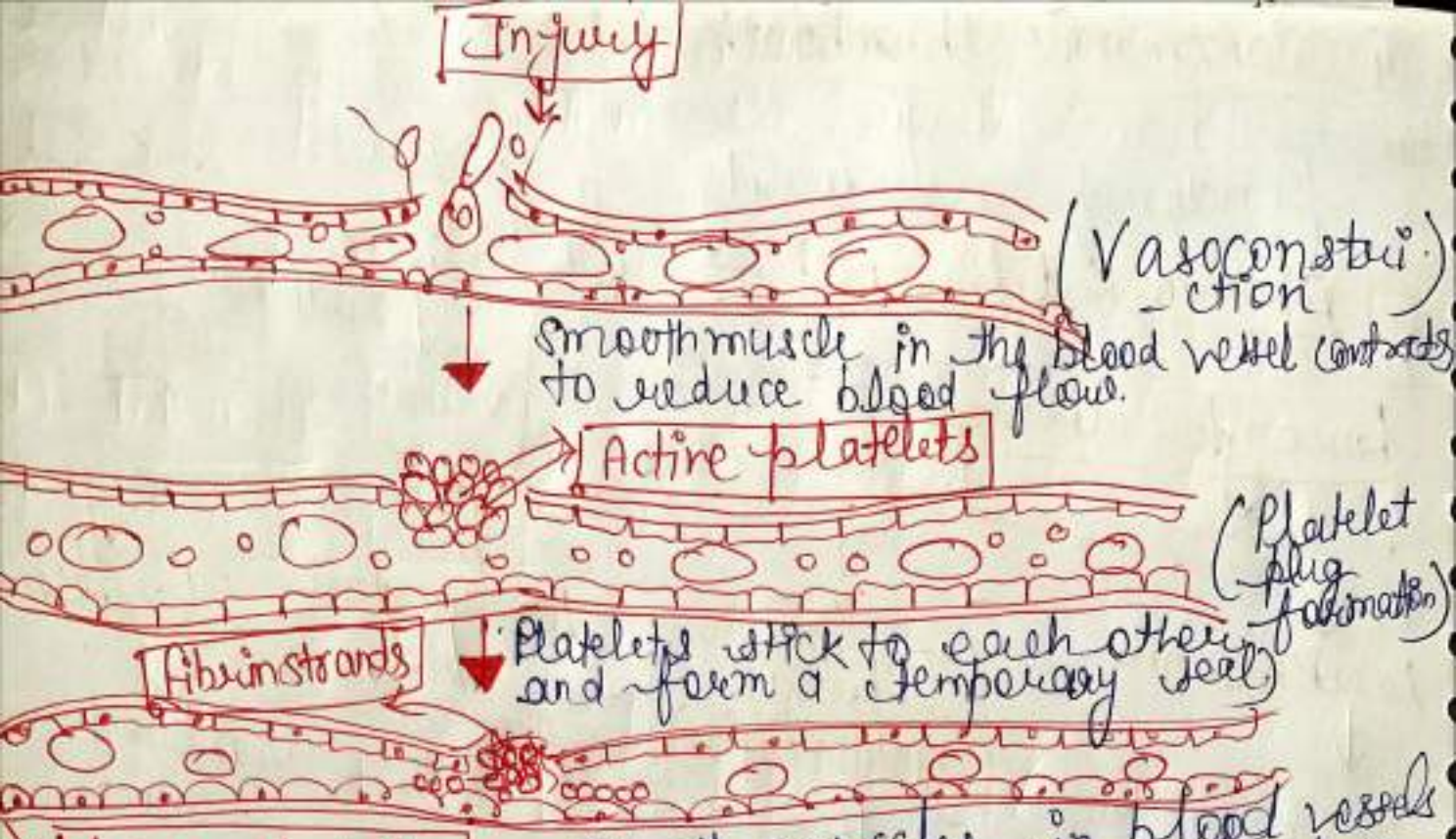
* Mechanism of Blood clotting

* Blood clotting, or coagulation, is the process by which blood changes from a liquid to a gel forming a blood clot. It potentially results in hemostasis, the cessation of blood loss from a damaged vessel, followed by repair.

The substance which are necessary for clotting are normal present in blood, but in inactive form. They are known as procoagulants which are activated (during injury) and clot is formed.

M.O.B.P. :-

- Vasoconstriction (Activation)
- Platelet plug formation (aggregation and adhesion)
- Coagulation of blood



1) **Vasoconstriction** - Smooth muscles in blood vessels walls contracts immediately the blood vessel is broken. This response reduces blood loss for some time while the other haemostatic mechanism become active.

2) **Platelet plug formation** - when blood platelets encounter a damaged blood vessel they form a "platelet plug" to help to close the gap in the broken blood vessel. The key stages of this process are called platelet adhesion, platelet release reactions and platelet aggregation).

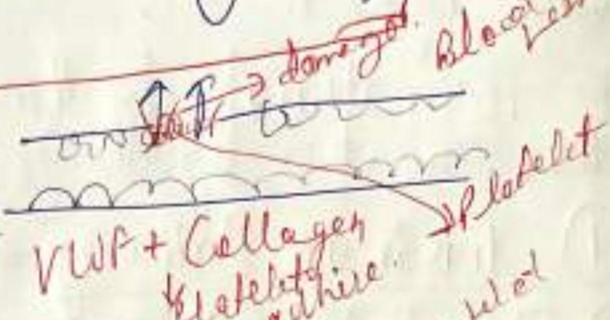
3) **Blood clotting or Coagulation**:- It is the process in which blood losses its fluidity and become a jelly like mass - few minutes after it is shed outer collected in a container. It results in haemostasis, the cessation of blood loss from a damaged vessel, followed by repair

States of Hemostasis

Injury to blood vessel and damage of endothelium

↓

Expose of collagen



Von-willebrand factor →

↓

Adherence of platelet to collagen

↓

Active of platelets

release ← platelet → ADP → activation of platelets of aggregation

release vasoconstriction of blood vessels

- secrection of serotonin → Vasoconstriction — Stage 1
- secrection of ADP and thromboxane A2 → (← PAF) Aggregations of platelets → formation to platelet plug — Stage 2
- formation to prothrombin activator → Blood clotting — Stage 3

*Stages of Blood clotting

Stage 1:- Formation of Prothrombin activator

⇒ Blood clotting commences with the formation of a substance called prothrombin activator (enzyme) → which converts prothrombin into thrombin.

* Its formation is initiated by substance produced either within the blood or outside the blood.

* Formation of prothrombin activater occurs through two pathways :-

① Intrinsic Pathway → Trauma in Blood vessel

② Extrinsic Pathway → wound or external to Blood vessel.

Injured Tissue → Tissue factor

Tissue Thromboplastin → (local chemical release)

By the presence of Ca++ and Factor VII

Correct X to activated X

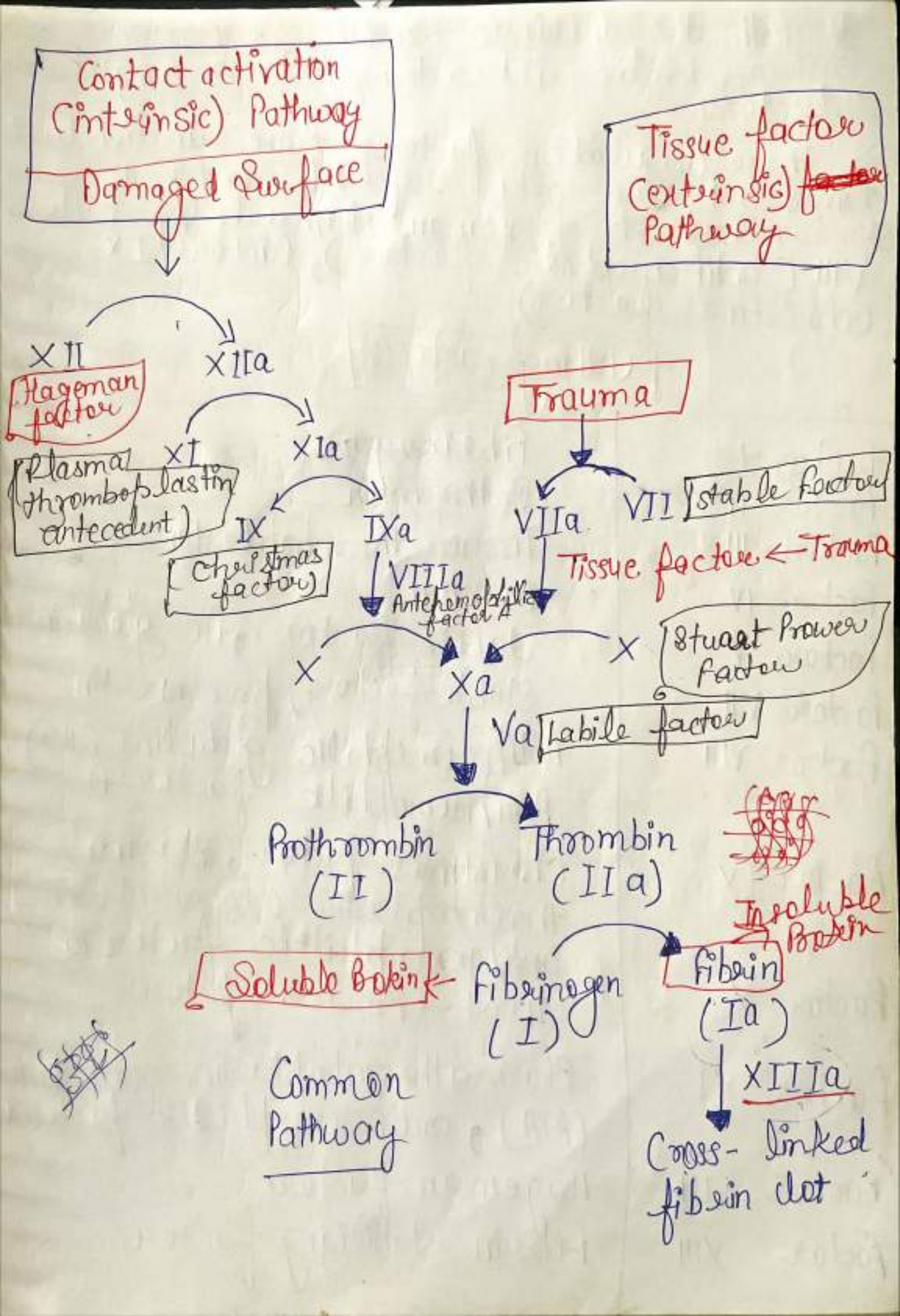
X --- VII, Ca++ ---→ activated Xa

Xa → Prothrombin Activator

1) Intrinsic System

This is initated by liquid blood making contact with a foreign surface i.e. something that is not part of the body.

2) Extrinsic System :- This is initiated by liquid blood making contact with damage tissue.


Contact activation (intrinsic) Pathway
Damaged Surface
Tissue factor (extrinsic) Pathway
XII
Hageman factor
XIIa
XI
Plasma thromboplastin antecedent
XIa
IX
Christmas factor
IXa
VIIIa
Antihemophilic factor A
Trauma
VIIa
VII
Stable factor
Tissue factor ← Trauma
X
Xa
X
Stuart Prower factor
Va
Labile factor
Prothrombin (II)
Thrombin (IIa)
Insoluble Fibrin
Soluble Fibrin
Fibrinogen (I)
Fibrin (Ia)
Common Pathway
XIIIa
Cross-linked fibrin clot

* Both the intrinsic and the extrinsic system involve interactions between coagulation factors.

=> These coagulation factors have individual names but are often referred to by a standardized set of Roman Numerals (eg. factor VIII (antihemophilic factor), factor IX (Christmas factor)

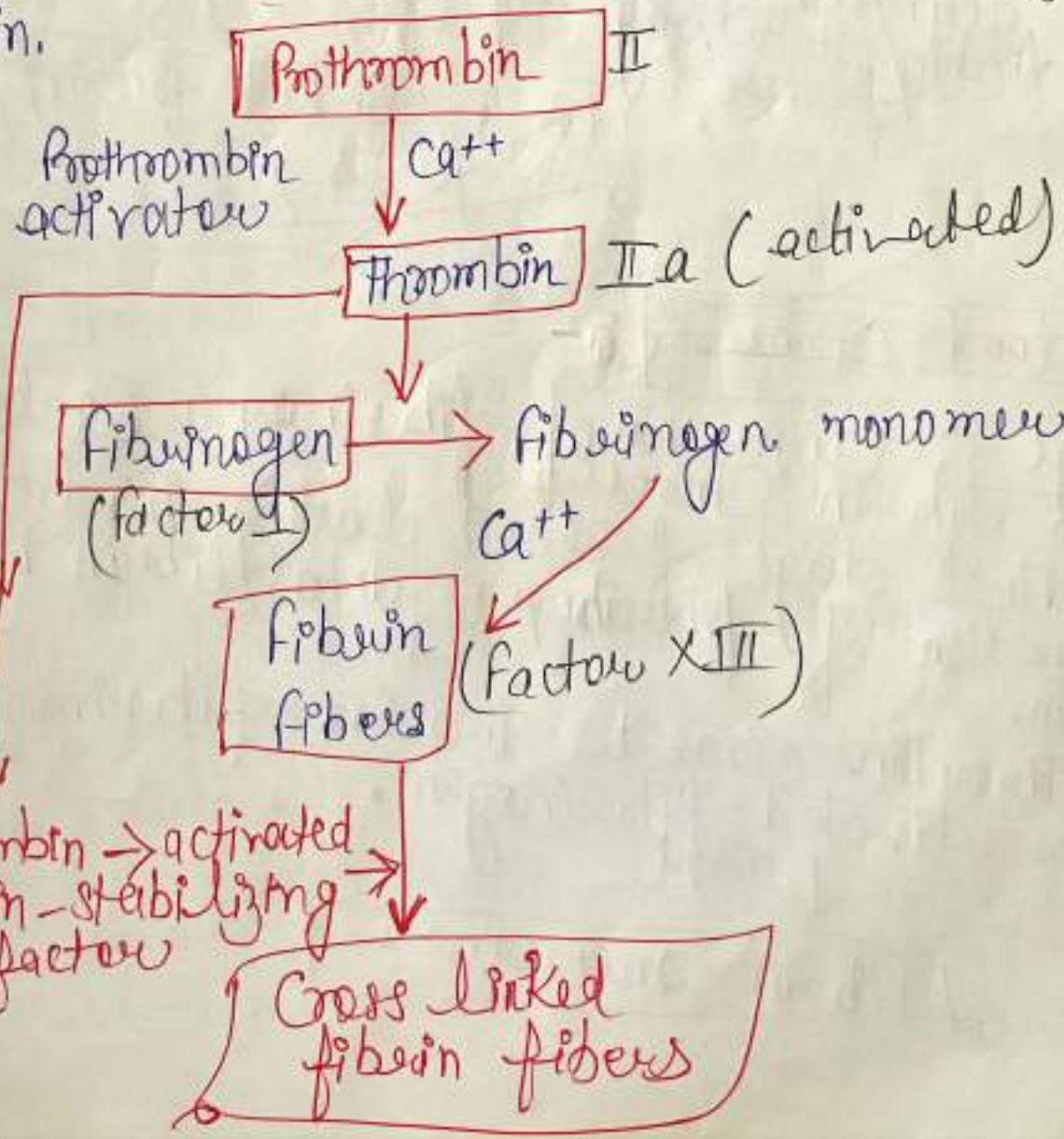
Clotting factors

Factor I	Fibrinogen
Factor II	Prothrombin
Factor III	Tissue Thromboplastin
Factor IV	Ca^{+} ion
Factor V	labile factor, AC-globulin
Factor VII	Stable factor, proconvertin
Factor VIII	Antihaemophilic globulin (AHG) Antihaemophilic factor A
Factor IX	Christmas factor, Plasma thromboplastin component (PTC) antihaemophilic factor B
Factor X	Stuart – Prower factor
Factor XI	Plasma thromboplastin antecedent (PTA), antihaemophilic factor C
Factor XII	Hageman factor
Factor XIII	Fibrin stabilizing factor

* Vitamin K is essential for synthesis of factor II, VII, IX and X.

Stage 2:- Conversion of Prothrombin into Thrombin

* Blood clotting is all about thrombin formation.
* Once thrombin is formed, it definitely leads to clot formation.
* Prothrombinase (formed in stage 1) converts prothrombin, which is a plasma protein that is formed in the liver, into the enzyme thrombin.



~~Blood Groups~~

Stage 3:- Conversion of fibrinogen (soluble) into fibrin (insoluble)

⇒ Final stage of Blood clotting involves the conversion of fibrinogen into fibrin by thrombin.

⇒ Thrombin converts inactive fibrinogen into activated fibrinogen.

↓ called

Fibrin monomer

⇒ Fibrin is insoluble and forms the threads that bind the clot. Fibrin monomer polymerizes and form loosely arranged strands of fibrin.

⇒ Loose strands are modified into dense and tight fibrin threads by fibrin-stabilizing factor (factor XIII) in the presence of calcium ions.

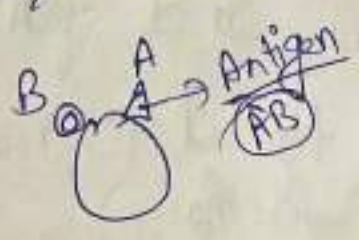
* All the tight fibrin threads are aggregated to form a meshwork of stable clot.

* **Blood Groups** :- It is discovered by the Austrian scientist Karl Landsteiner, in 1901.
* He was honored with Nobel Prize in 1930 for this discovery.

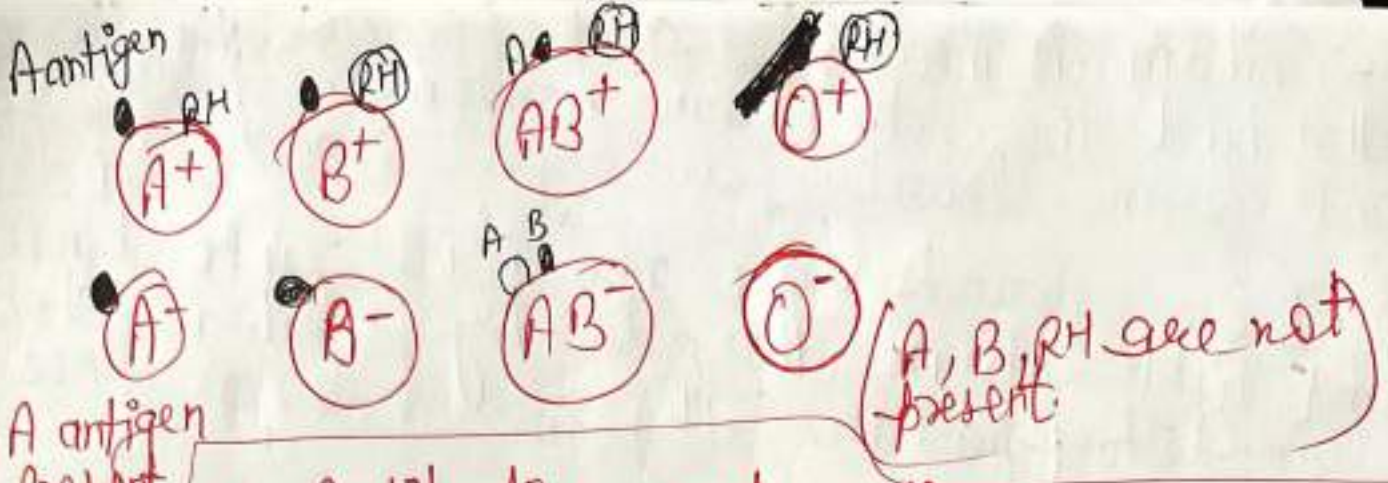
Blood Group systems :-

* These two blood groups systems are the most important ones that are determined before blood transfusions. (to donate)
* There are four main blood groups types- A, B, AB and O. Blood group is determined by the genes you inherit from your parents.
* Each group can be either RH positive or RH negative, which means in total there are 8 main Blood groups.

cell → nucleus → DNA → genes make protein



↓
out from the cell surface
↓
A protein, B protein



A antigen present

* Antibodies and antigens

* Blood is made up of RBC, WBC and platelets in a liquid called plasma.
* The blood group is identified by antibodies and antigens in the blood.
* Antibodies are protein found in plasma. They are part of your body's natural defenses. They recognise foreign substances, such as germs, and alert your immune system, which destroy them.
* Antigens are protein molecules found on the surface of RBC.

Importance of Blood grouping:-

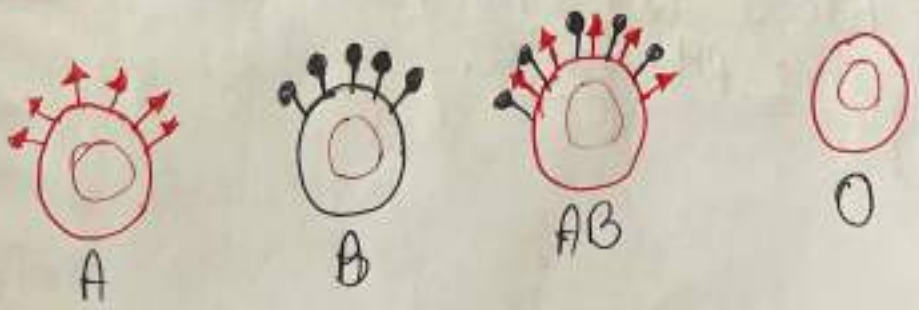
1. In Blood transfusion
2. In preventing haemolytic disease (RH incompatibility between mother and foetus)
3. In paternity disputes (to determine the father)

④ In medicolegal cases.
⑤ In knowing susceptibility to disease:-
✓ Group O :- Duodenal cancer
✓ Group A :- Carcinoma of stomach pancreas and salinary glands.

ABO system :- Based on the presence or absence of antigen A and antigen B, blood is divided into four groups.

1. **Blood group A** → has A antigens on the RBC with anti-bodies in the plasma.
2. **Blood group B** → has B antigens with anti-A antibodies.
3. **Blood group O** → has no antigens, but both
④ **Blood group AB** → has both A and B antigens, but no antibodies in the plasma.

* **ABO Blood Group System**



~~RH factor~~

*Summary of ABO Blood grouping system

Blood Type	Antigen on RBC	Antibody in Plasma	Can donate to	Can receive from
A	A	Anti-B	A, AB	A, O
B	B	Anti-A	B, AB	B, O
AB	A and B	None	AB	A, B, AB, O
O	None(Zero)	Anti-A and anti-B	A, B, AB, O	O

*Rh factor :- Rh factor is an antigen present in RBC.

* This antigen was discovered by Landsteiner and Wiener.
* It was first discovered ~~by landste~~ in Rhesus monkey and hence the name 'RH factor'.
* The persons having D antigen are called 'Rh Positive' and those without D antigen are called 'RH negative'.
* During the identification of patients blood type, the Rh group is represented by adding the word positive or negative to the ABO system.
* Rh-positive blood is compatible with both positive and negative RH factor.

Sewerage system

Lymphatic System :- It maintains fluid level in our body tissues by removing all leaks & that leak out of our blood vessels

Lymph :- A fluid that contains white WBC that defend against germs.

Lymph vessels :- vessels that carry lymph throughout body.

Lymph nodes :- Glands found throughout the lymph vessels. eg. spleen, these nodes are where WBC fight infection.

Lymphatic System :- Protects body against foreign material.

⇒ Assists in circulation of body fluids b/w cells and bloodstream.

⇒ Transport dietary fats.

Lymphatic System consist of

- Lymph
- Network of vessels
- Lymph nodes and nodules
- Tonsils
- Spleen
- Thymus gland
- Bone marrow

Function of Lymphatic System

⇒ Production, storage, maintenance and distribution of lymphocytes.

⇒ Maintenance of normal blood volume.

⇒ Transport clear fluids back to blood.

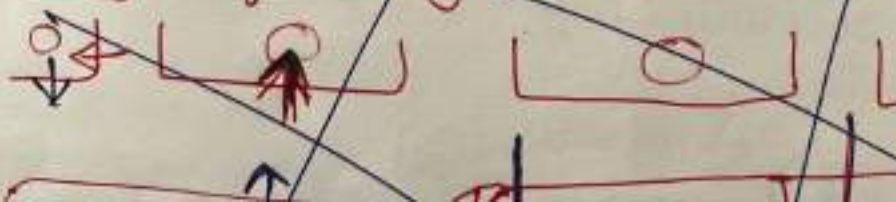
Serial No. ..... Date

⇒ Drains excess fluids from tissues.
⇒ Absorbs lipids from the intestine and transport them to the blood.
⇒ Play important role in body defense and resistance to disease.
⇒ Carry out immune responses.

Lymphatic Pathways :-

Lymphatic capillary
↓
Lymphatic vessel
↓
L. Node → L. vessel → L. Trunk
↓
Subclavian vein

Origin of a lymph capillary.



Lymph:- clear fluid.

↓

Derived from tissue fluid.

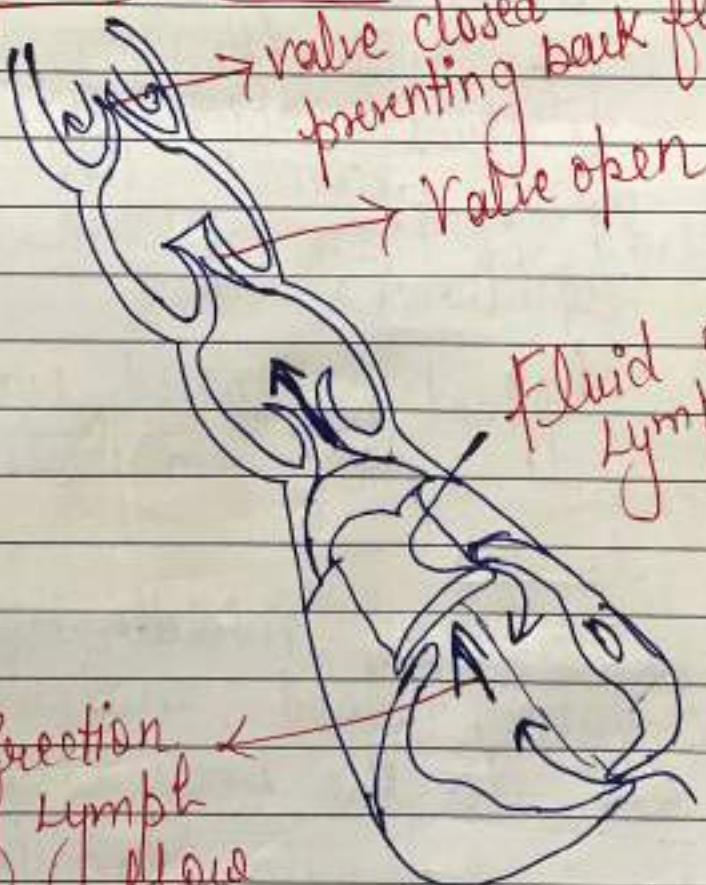
⇒ It contain less protein

⇒ Contain more WBC than plasma.

⇒ Enters node through afferent lymphatic vessels.

⇒ It also carries away larger particles eg. bacteria and cell debris from damaged tissues, which can be filtered out and destroyed in the Lymph nodes.

Lymphatic vessels:-



Serial No. Components Dated

Composition of Lymph:-

→ Carbohydrates, Lymphocytes, creatinine, water - 96%, Urea, chlorides, enzymes, Proteins - Albumin, globulin and fibrinogen, Non-Protein nitrogenous substance.

Origin of Lymph:-

Cardiovascular system pumps blood through its system but it cannot return all the fluid from the body cells.

↓

The lymph system picks up 60% of the fluid dropped off at the cellular level.

↓ In this point Interstitial fluid picks up plasma and becomes tissue fluid.

Tissue fluid is then picked up by lymph capillaries

↓

Tissue fluid is called lymph

Lymph - alkaline (pH > 7.0)

* Function of lymph

* Lymph acts as a "middle man" which transports oxygen, food materials, hormones, etc to the body cells.

* Lymph is involved in transportation of substances where blood vessels do not reach.

Signature

Dated .....

⇒ It helps in removing waste materials from the cells in the body to drain into the blood
⇒ Lymph protects cells in the tissue from infection
⇒ It transport antibodies and lymphocytes to the blood.

2) Lymph capillaries Blind-ended tubes in the interstitial spaces. → lies b/w blood vessels and cells provide fluid
⇒ Same structure as Blood capillaries
⇒ large diameter than blood capillaries.
⇒ They are very permeable and collect tissue fluid and proteins.
⇒ Lymph C. join up to form larger Lymph vessels.

(3) Lymph vessels :- Return to the blood of any fluids that have escaped from the circulation.
⇒ Lymphatic vessels are connected to blood vessels.

Distribution of lymphatic vessels :-

⇒ Lymphatic V. travel alongside blood vessels
⇒ Lymphatic vessels are absent from bones, teeth, bone marrow, and CNS.

* Lymph vessels become larger when they join together and form two large ducts.
thoracic duct and right lymphatic duct

Serial No. ..... Dated .....

(1) Left thoracic duct :- collects lymph from the left side of the body and regions of the left side of the body below the thorax.

⇒ It ultimately drains lymph into the left subclavian vein.

⇒ It begins at the cisterna chyli, ~~an enlarged region of the lymphatic vessel that forms~~ which dilated lymph channel situated in front of the bodies of the first two lumbar vertebrae

(2) The Right thoracic duct :- It is a dilated Lymph vessels about 1cm long. It lies in the root of the neck and opens into the right subclavian veins. It drains lymph from the right half of the thorax, head and neck and the right arm.

functions :-

⇒ Managing fluid levels in the body

⇒ Dealing with cancer cells.

⇒ Absorb fat in our diet from the intestine

Signature

Date _____ Expt. No. _____

Expt. Name _____ ~~Lymph Nodes~~ Page No. _____

Lymphoid Organs

Primary Lymphatic Organs.	Secondary lymphatic organs.
→ Thymus gland	→ Spleen and Lymph nodes. (encapsulated) diffuse lymphoid tissue)
→ Bone marrow	→ unencapsulated diffuse lymphoid tissue includes gut-associated lymphoid tissues and tonsils.

* **Lymph nodes** It is oval to bean-shaped organs of Lymphatic system distributed throughout the body including the GIT and neck.
also called Lymph glands.

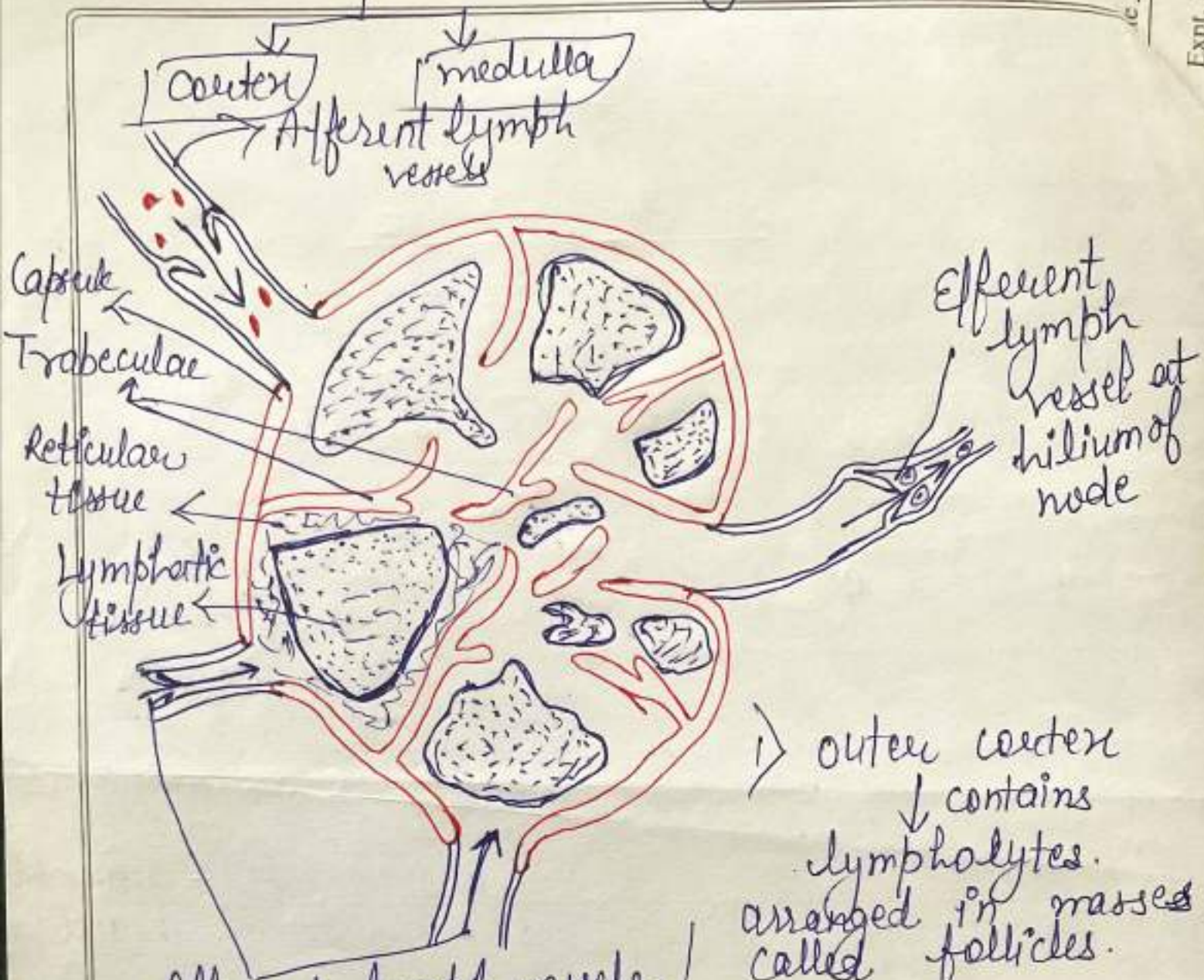
⇒ Size range 1 to 25mm in length and look like as small seeds.

⇒ Each lymph node is covered by a capsule of fibrous connective tissue.

⇒ Capsular extension are called trabeculae that contain Lymphatic tissues, reticular fibers and Lymphatic sinuses.

Teacher's Signature : _____

It is divided into two regions.



Afferent lymph vessels.

1) outer cortex
↓ contains
lympholytes.
arranged in masses called follicles.
↓
the outer rim of each follicles contain
⇒ T- lymphocytes
⇒ B - lymphocytes.
⇒ macrophages. and
⇒ follicular dendritic cells.

(2) Inner medulla consist
↓
medullary cords containing macrophages, plasma cells and lymphocytes.

Date _____ Expt. No. _____

Expt. Name _____ Page No. _____

③ Lymphatic vessels that enters.

↓

the lymph node are called afferent lymphatic vessels.

↓

lymph flows through the sinus. in the cortex

↓

and then into medulla

↓

exits the lymph node via efferent lymphatic vessels.

Functions :- It filters foreign substance and cancer cells from lymph, as it passes back towards the cardiovascular system.

- These substance trapped by the reticular fibers within the lymph node

⇒ ~~also produce lymphocytes~~ production and growth of WBC/lymphocytes

⇒ Proliferation of Lymphocytes

- Activated T and B lymphocytes multiply in lymph nodes.

- Antibodies produced by sensitised B-lymphocytes enter lymph and blood from the node

Teacher's Signature : _____

* Spleen

oval in shape and is single largest organ of lymphatic system in the body.

⇒ It is located in the left hypochondrium and partly in the epigastrium

⇒ Situated b/w the fundus of the stomach and the diaphragm.

⇒ About 12cm in length, 7 cm in height and 4cm thick

⇒ spleen consists of two different kinds of tissue

- white pulp
  - It is made up of lymphatic tissue mostly lymphocytes
- Red pulp
  - consist of sinuses (splenic cord zone) and marginal zone
    - consist of RBC, macrophages, B- and T lymphocytes, plasma cells and granulocytes

⇒ Average wt (adult) – 200g

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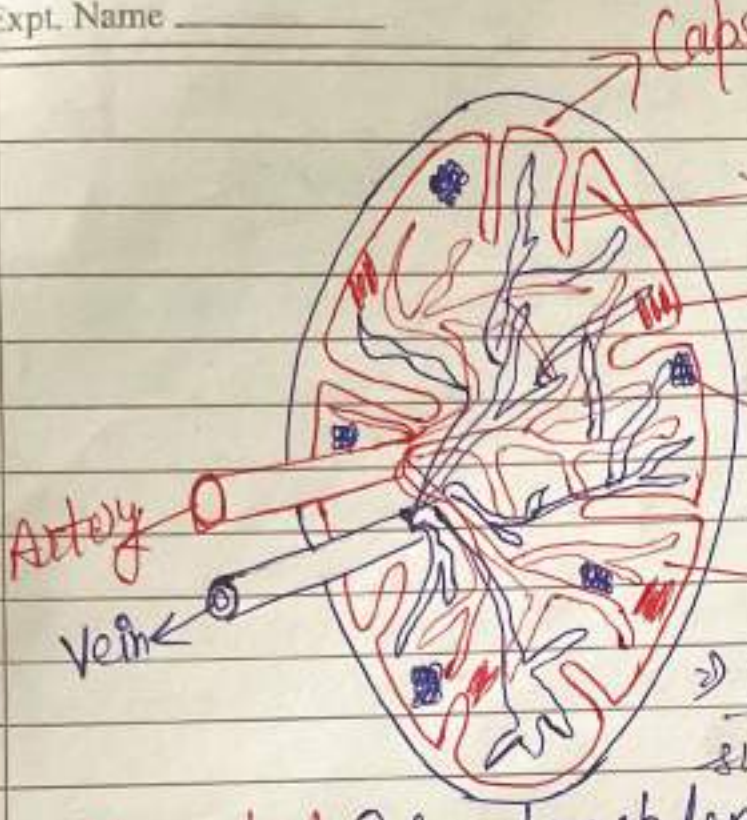


⇒ It is covered by fibro-elastic capsule and is surrounded by peritoneum

Ligaments: ① Gastrosplenic Omentum
② Splenicorenal Ligament

⇒ Blood supply :- splenic artery
⇒ Venous drainage :- splenic vein

Functions of spleen

① Storage of blood :- 350 ml of blood
During haemorrhage, the spleen will release blood into the blood circulation.

② Immune response → B and T lymphocytes → produce antibodies
fight against foreign antigens

Teacher's Signature :

Phagocytosis:—

Haemolysis:— ~~dea~~ macrophage digest old blood cells → form Bilirubin ↓ Bilirubin sent to the liver for excretion in bile

Erythropoiesis:-

spleen and liver are produce blood cells for fetal development

Respiratory System

* **Respiration** :→ It is a metabolic process, wherein, the living cells of an organism obtains energy (in the form of ATP) by taking in oxygen and liberating CO_2 from the oxidation of complex organic substances.

* Normal Respiratory Rate AT Different age

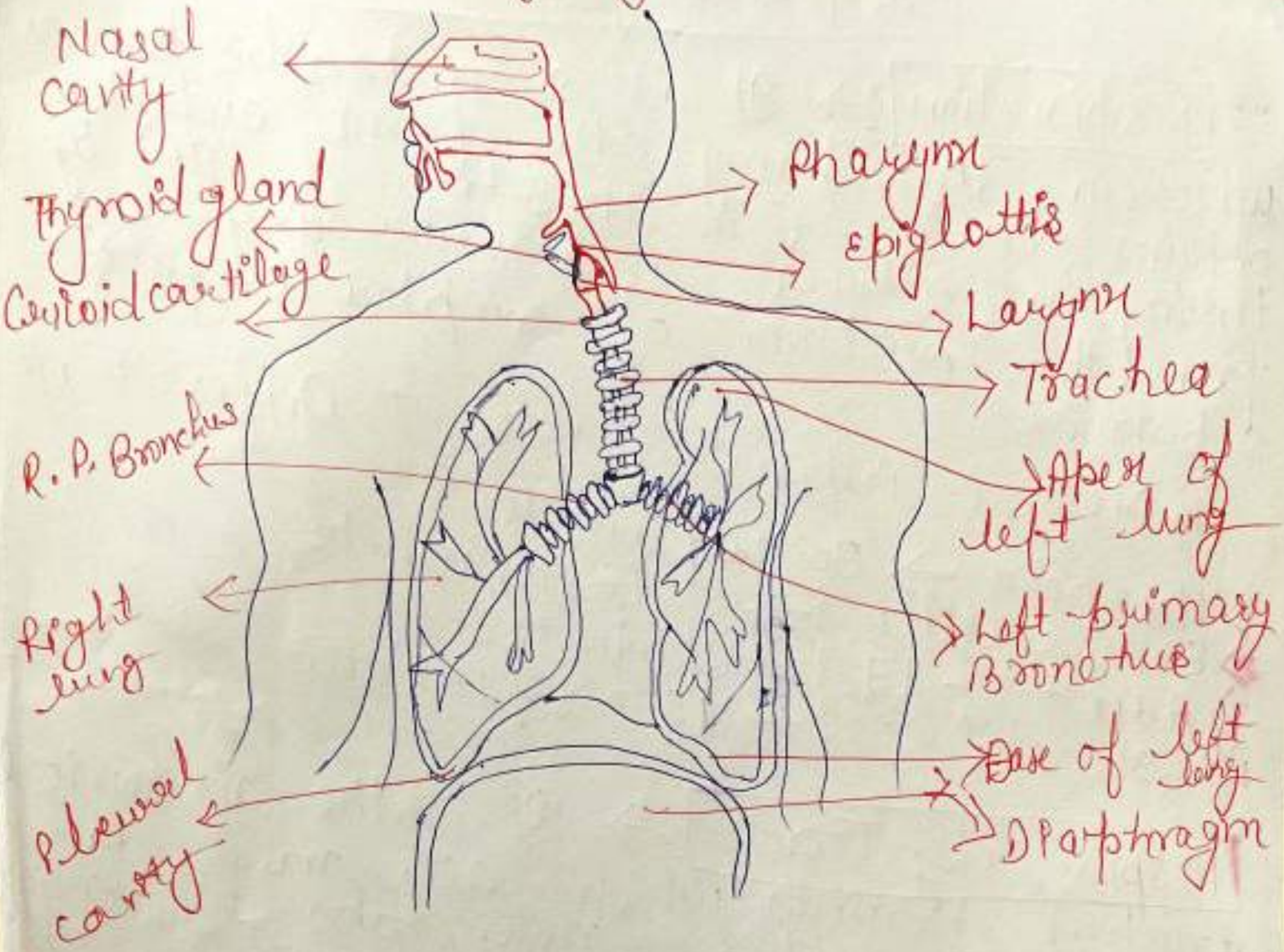
1) New born → 30 to 60/ minute
2) Early childhood → 20 to 40/ minute
3) Adult :- 12 to 16/ minute
4) Late childhood → 15 to 25/ minute

Respiratory Tract :→ It is the anatomical structure through which air moves in and out. It includes nose, pharynx, larynx, trachea, bronchi and lungs.

* Generally respiratory tract is divided into two parts:-

1) Upper respiratory tract that includes all the structures from nose up to vocal cords; vocal cords are the folds of mucous membrane within larynx that vibrates to produce the voice.
2) Lower respiratory tract, which includes trachea, bronchi and lungs.

∴ Respiratory System



*Nose and Nasal cavity :→

⇒ It includes external nose that part of the upper respiratory tract that prot-udes from the face.

⇒ Nasal cavity is lined by mucous membrane and small hairs are present.

⇒ It is the main route of air entry

⇒ Two cavities divided by a septum.

⇒ Anteriorly consist hyaline cartilage

⇒ The roof is formed by ethmoid bone.

⇒ The medial wall formed by the septum.
⇒ The lateral wall formed by the maxilla.

Functions :-

1) Warming → Due to the immense vascularity of the mucosa.

2) filtering and cleaning → This occurs due to hair which trap larger particles.

3) Humidification → As air travels over the moist mucosa, it becomes saturated with water vapour.

Pharynx :→ It is the part of the throat that is behind the mouth and nasal cavity and above the esophagus and the larynx.

Length → 12-14cm

The Pharynx compurised into three parts-

1) The nasopharynx :- Nasopharynx is the nasal part of the → ~~throat that is behind the mouth and nasal cavity and above the esophagus and the larynx~~ pharynx lies behind the nose.

2) The oropharynx :→ The oral part of the pharynx lies behind the mouth.

3) The laryngopharynx → The laryngeal part of the pharynx extends from the oropharynx

*Functions

→ Passageway of air and food.

⇒ Warming and humidifying

→ Taste → These are olfactory nerve endings

→ Hearing :- The auditory tube, extending from the nasopharynx to each middle ear, allows air to enter the middle ear.

→ Protection :- The lymphatic tissue of the pharyngeal tonsils produces antibodies.

⇒ Speech → act as a resonating chamber for sound ascending from the larynx.

Larynx :→ [Voice Box] → It links the laryngopharynx and the trachea.

⇒ It extends from the root of the tongue.

⇒ Composed of cartilages, ligaments, muscles and a mucosal surface.

⇒ It contains the vocal cords which produce speech sounds.

⇒ It lies in the front of the laryngo-pharynx at the level of 3rd, 4th, 5th and 6th cervical vertebra.

⇒ untill the puberity there is little difference in the size of the larynx between the sexes.
⇒ It grows larger in the male.
⇒ It is called Adam's apple in man.
⇒ Structure :→ 1 thyroid cartilage
1 cricoid cartilage
2 arytenoid cartilages
1 epiglottis
Hyaline cartilage

Functions :→ 1) Production of sound
2) speech
3) Protection of the lower respiratory tract
4) Passageway for air
5) Humidifying, filtering and warming.

Trachea :→ The trachea or windpipe is a continuation of the larynx and extends downwards to about the level of T-5 where it divides into right and left primary bronchi
length : 10 - 11cm

⇒ carries air between the larynx and the bronchi are supported by incomplete rings of C-shaped cartilage (Hyaid bone) in its wall.

⇒ The lower part of the trachea branches into two bronchi, one to each lung and these branch within lungs into many smaller Bronchiales.

Functions:-

1) Support and patency :- Tracheal cartilages hold the trachea permanently open, but the soft tissue bands in between the cartilages allow flexibility so that the head and neck can move freely without obstructing the trachea.

2) Mucociliary escalator :- This is the synchronous and regular beating of the cilia of the mucous membrane lining that wafts mucus with adherent particles upward towards the larynx.

3) Cough reflex :- Nerve endings in the larynx, trachea and bronchi are sensitive to irritation → which generates nerve impulses conducted by the vagus nerves to the respiratory centre in the brain stem.

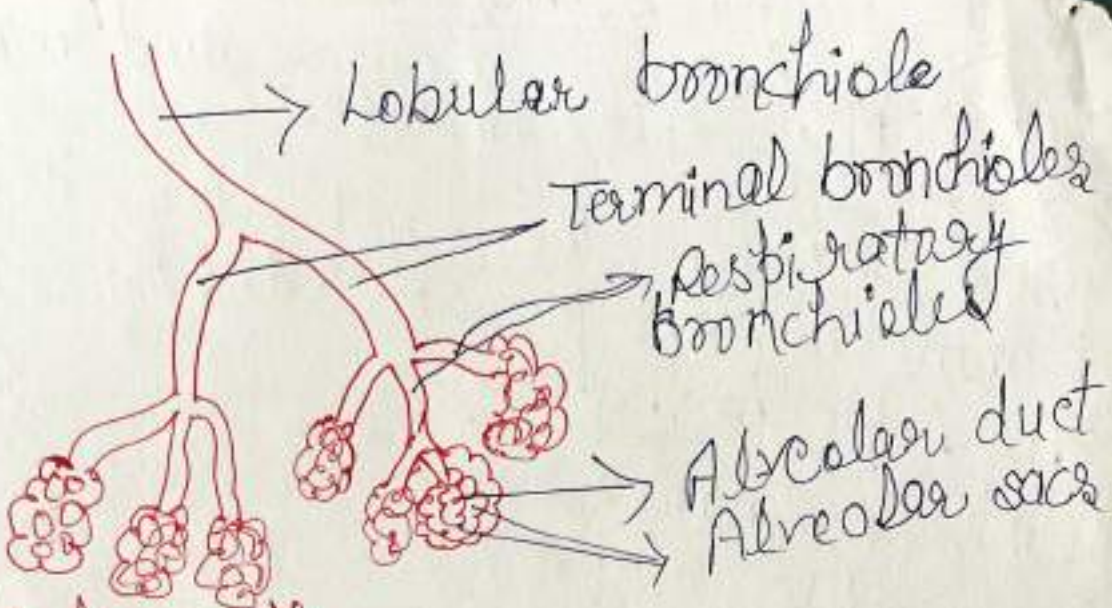
4) Warming, humidifying and filterings.

* The right Bronchus.
⇒ This is wider, shorter and more vertical than the left bronchus
⇒ Length - 2.5cm
⇒ After entering the right lung, it divides into 3 branches, one to each lobe.

* The Left bronchus:-
⇒ This is narrower than the right
⇒ Length - 5cm
⇒ After entering the left lung, it divides into 2 branches, one to each lung lobe.

* Function of bronchi:-
⇒ Control of air entry
⇒ warming and humidifying
⇒ Support and potency
⇒ Removal of particulate matter
⇒ Cough reflex

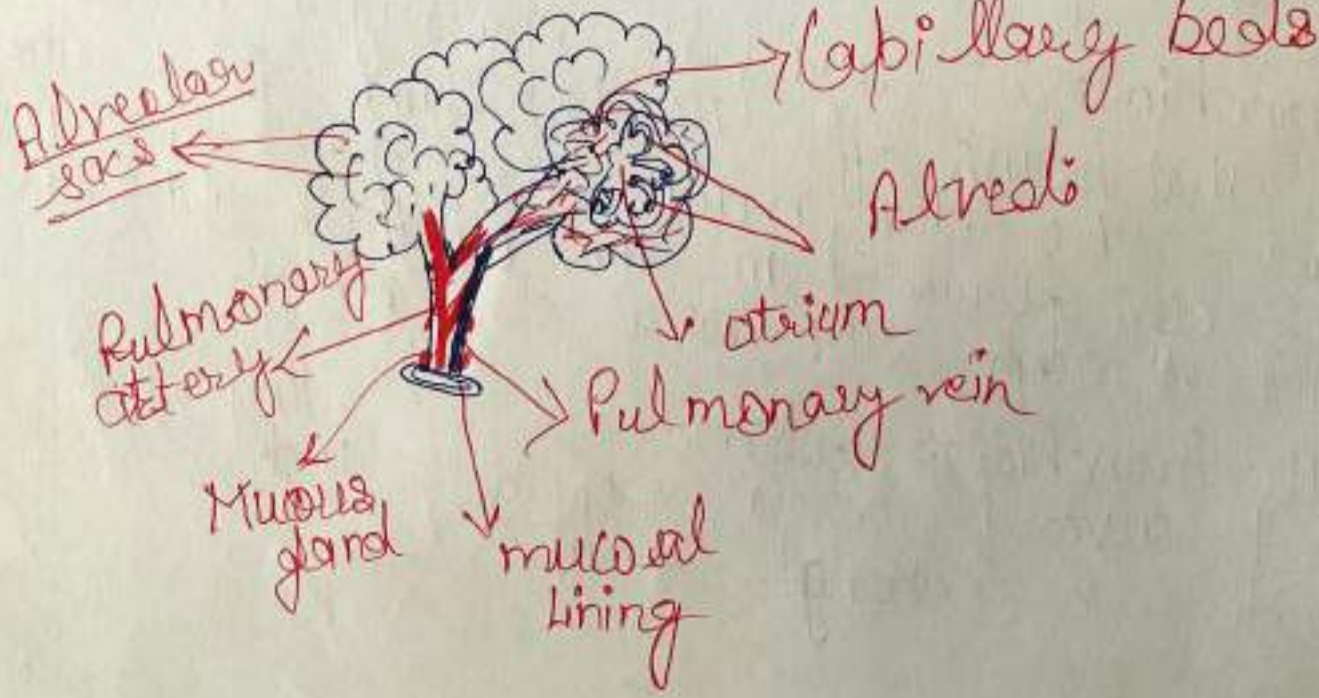
* Bronchioles:- are air passages inside the lungs that branch off like tree limbs from the bronchi - the two main air passages into which air flows from the windpipe after being inhaled through the nose and mouth.
⇒ The bronchioles deliver air to tiny sacs called alveoli where oxygen and carbon dioxide are ~~exchanged~~ exchanged.



* Bronchiolar cells (clara cells)

⇒ The clara cells are a group of cells, sometimes called "nonciliated bronchiolar secretory cells", found in the bronchiolar epithelium of mammals including man, and in the upper airway of some species such as mice.

* Alveoli :-



⇒ Alveolar ducts are tiny ducts that connect the respiratory bronchioles to alveolar sacs, each of which contains a collection of alveoli.

⇒ The alveolar ducts in turn give rise to alveoli.

⇒ These are surrounded by capillaries.

⇒ About 150 million alveoli in the adult lung

* **Lungs**:- There are two lungs, one lying on each side.

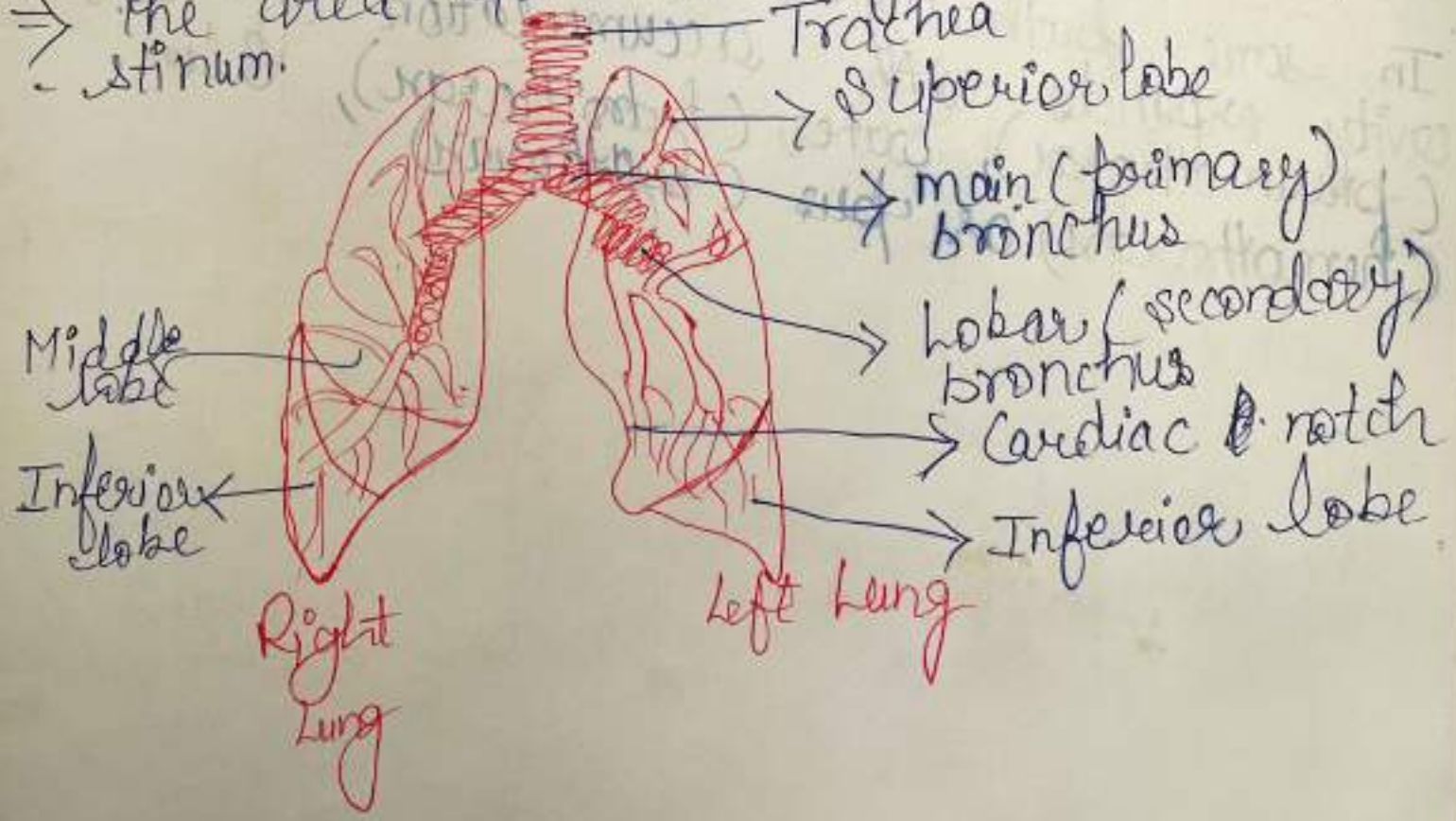
→ Shape → Cone → Length → 20-24cm

→ wt → 600-700gm → Colour → Pinkish

→ **Lobes** → Three lobes in the right lung and two lobes in the left lung

⇒ Lobes are separate by the fissures.

⇒ The area b/w the lungs is the mediastinum.



* Functional anatomy of Lungs

1) **Pleura**:- Each lung is enclosed by a bilayered serous membrane called pleura or pleural sac. Pleura has two layers namely inner visceral and outer parietal layers.

2) **Intrapleural space or pleural cavity**
It is the narrow space in ~~the~~ between the two layers of pleura.

3) **Intrapleural fluid**:- Intrapleural space contains a thin film of serous fluid called intrapleural fluid, which is secreted by the visceral layer of the pleura.

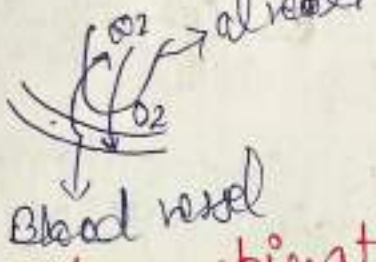
4) **Pleural cavity in abnormal conditions**:-
In some pathological conditions, the pleural cavity expands with accumulation of air (pneumothorax), water (hydrothorax), blood (hemothorax) or pus (pyothorax).

Types of Respiration

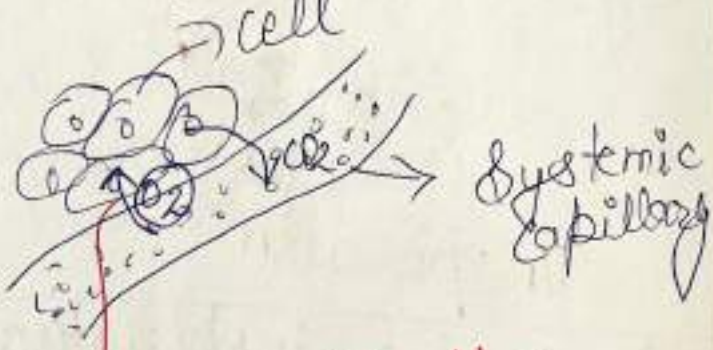
Respiration is classified into two types:-

1) External respiration :- It involves exchange of respiratory gases, i.e oxygen and CO_2 b/w lungs and blood.

2) Internal respiration :- It involves exchange of gases b/w blood and tissues



* External respiration

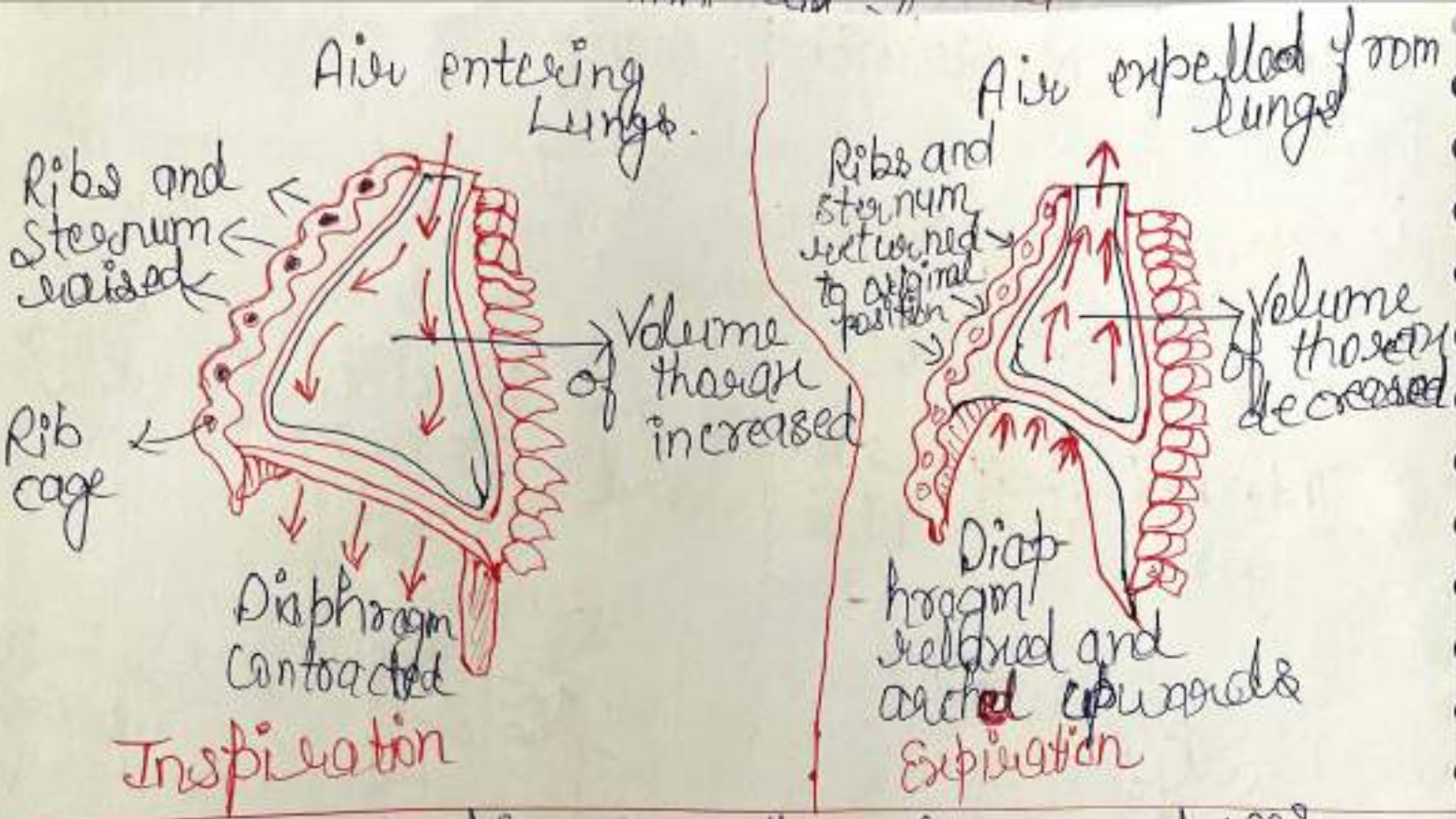


→ For respiration
→ For ATP production
* Internal respiration

* Phases of respiration :-

- Inspiration
  - ⇓
  - air enters the lungs from atmosphere
- Expiration
  - ⇓
  - air leaves the lungs

⇒ During normal breathing, inspiration is an active process and expiration is a passive process.



⇒ During inspiration, thoracic cage enlarges and lungs expand so that air enters the lungs easily.

During expiration, the thoracic cage and lungs decrease in size, and attain the preinspiratory position so that air leaves the lungs easily.

* Muscles of respiration

- Inspiration muscles
- Expiratory muscles

However, respiratory muscle are generally classified into two types:-

1) Primary or major respiratory muscle – These are responsible for change in size of thoracic cage during normal quiet breathing.

2. Accessory respiratory muscles – This help primary respiratory muscles during forc respiration.

* Inspiratory muscles :-

Primary inspiratory muscles

⇒ Primary I.M. are the diaphragm, which is supplied by phrenic nerve (C_3 to C_5) and external intercostal muscles, supplied by intercostal nerves (T_1 to T_{11}).

Accessory I.M.

Sternocleidomastoid, scalene, anterior serrati, elevators of scapulae and pectorals are the accessory inspiratory muscles.

* Expiratory muscles :-

⇒ Primary Expiratory muscles are the internal intercostal muscles, which are innervated by intercostal nerves.

⇒ Accessory EM are the abdominal muscles.

⇒ Respiratory unit :- It is defined as the structural and functional unit of lung. Exchange of gases occurs only in this part of the respiratory tract.

Respiratory unit includes :-

1. Respiratory bronchioles
2. Alveolar ducts
3. Alveolar sacs
4. Antrum
5. Alveoli

Each alveolus is like a pouch with the diameter of about 0.2 to 0.5 mm. It is lined by epithelial cells

* Non- respiratory functions of respiratory tract :-

⇒ Olfactory sensation
⇒ Vocalization
⇒ Prevention of dust particles
⇒ Defense mechanism
⇒ Maintenance of water balance
⇒ Regulation of Body temperature.
⇒ Regulation of acid base balance
⇒ Anticoagulant function.
⇒ Synthesis of hormonal substances
⇒ Secretion of angiotensin converting enzyme.

Pulmonary function Tests-

It is useful in assessing the functional status of the respiratory system both in physiological and pathological conditions.

⇒ Lungs function test are based on the measurement of volume of air breathed in and out in quiet breathing and forced breathing.

⇒ These test are carried out mostly by using spirometer.

* Types of lung function test-

a) Static lung function test:- It is based on volume of air that flows into or out of lungs.

⇒ These test dont depend upon the rate at which air flows.

⇒ Static lung function tests include static lung volumes and static lung capacities.

b) Dynamic lung function test:- It is based on time, i.e the rate of which air flows into or out of lungs.

⇒ These tests include forced vital capacity, forced expiratory volume, maximum ventilation volume and peak expiratory flow

⇒ Dynamic L.F.T are useful in determining the seperity of obstructive and restrictive lung diseases.

* Lung Volumes

⇒ Static lung volumes are the volume of air breathed by an individual.

⇒ Each of these volumes of air present in the lung under a specified static condition.

Static lung volumes are of four types

1) **Tidal volume:-** Tidal volume of air breathed in and out of lungs in a single normal quiet respiration. It signifies the normal depth of breathing.

[Normal volume — 500 ml (0.5L)]

2) **Inspiratory reserve volume:-** It is an additional volume of air that can be inspired forcefully after the end of normal inspiration.

Normal volume - 3,300 ml (3.3L)

3) **Expiratory reserve volume:-** It is an additional volume of air that can be expired out forcefully after normal expiration.

Normal value → 1000 ml (1L)

4) Residual volume:- It is the volume of air remaining in lungs even after forced expiration. Normally, lungs cannot be emptied completely even by forceful expiration. Some quantity of air always remains in the lungs even after the forced expiration.

R.V. is significant because of two reasons
⇒ It helps to aerate the blood in b/w breathing and during expiration.
⇒ It maintains the contour of lungs.

[Normal value → 1200 ml (1.2 L)]

Lung capacities:-
⇒ Static lung capacities are the combination of two or more lung volumes.
⇒ Static lung capacities are of four types.

1) Inspiratory capacity (IC) → It is the maximum volume of air that is inspired after normal expiration
⇒ It includes tidal volume and inspiratory reserve volume.

[IC = TV + IRV]
= 500 + 3,300 = 3,800 ml

2) Vital capacity:- It is the maximum volume of air that can be expelled out forcefully after a deep (maximal) inspiration.

⇒ It includes respiratory reserve volume, tidal volume and expiratory reserve volume.

$$VC = IRV + TV + ERV$$
$$= 3,300 + 500 + 1000$$
$$= 4,800 \text{ ml}$$

3) Functional Residual Capacity (FRC):-

⇒ It is the volume of air remaining in lungs after normal expiration (after normal tidal expiration).

⇒ It includes expiratory reserve volume and residual volume.

$$FRC = ERV + RV$$
$$= 1,000 + 1,200 = 2,200 \text{ ml}$$

4) Total lung capacity (TLC)

It is the volume of air present in lungs after a deep (maximal) inspiration.

⇒ It includes all the volumes.

$$TLC = IRV + TV + ERV + RV$$
$$= 3,300 + 500 + 1000 + 1,200$$
$$= 6000 \text{ ml}$$

Digestive System

Digestion:- It is defined as the process by which food is broken down into simple chemical substances that can be absorbed and used as nutrients by the body.

⇒ Functions of digestive system

- Ingestion — Consumption of food substances
- Breaking down — them into small particles
- Transport — of the small particles to different areas of digestive tract
- Secretion — of necessary enzymes and other substances for digestion.
- Digestion — of the food particles
- Absorption — of the digestive products (nutrients)
- Removal — of unwanted substances from the body.

*pH of digestive System:-

1) Saliva — 6.5 - 7.5
2) Upper stomach — 4.0 - 6.5
3) Lower stomach — 1.5 - 4.0
4) Duodenum — 7.0 - 8.5
5) Large intestine — 4.0 - 7.0
6) Small intestine — 6 - 7.4

Fresh milk → 6.5 - 6.9
Hair → 4.5 - 5.5
Sugar → 6 - 7

⇒ Pepsin, pepsin like enzymes, chymosin, renin, and other acid proteases have an activity pH :— 2.0 - 3.5

⇒ Trypsin, chymotrypsin, papain → pH - (6-8)

Human Digestive system

⇒ It comprises of alimentary canal and accessory digestive glands which help in digestion.

⇒ Alimentary canal is a long coiled tube having muscular wall and glandular epithelium extending from mouth to anus

⇒ GI tract is formed by two type of organs

1) Primary digestive → Organs: These are the organs where actual digestion takes place.
   a) Mouth
   b) Pharynx
   c) Esophagus
   d) Stomach
   e) small intestine
   f) large intestine

2) Accessory Digestive Organs — It helps the primary digestive organ in the process of digestion.
   a) Teeth
   b) Tongue
   c) salivary glands
   d) exocrine part of pancreas
   e) Liver
   f) Gall bladder

* Enteric nerves of GIT:-

1) Auerbach's plexus → also known as myenteric nerve plexus, present between the inner circular muscle and outer longitudinal muscle layer.
   ⇒ It regulate the movement of GI tract

2) Meissners nerve plexus:- also known as submucus nerve plexus, situated b/w the muscular layer and sub mucosal layer of GI tract.
   ⇒ It regulate the secretory function of GI tract

1) Mouth and salivary glands:

⇒ It is known as oral cavity or buccal cavity
⇒ It is formed by cheeks, lips and palate
⇒ It encloses the teeth, tongue and salivary glands.

Functions of mouth:-

a) Ingestion of food materials
b) Chewing and mixing the food with saliva
c) Appreciation of the taste
d) Transfer of food to esophagus by swallowing
e) Role in speech

2) Teeth:- Teeth are small calcified, hard, whitish structures found in the mouth for mechanically breaking down items of food by cutting and crushing them.

* Types of Teeth:-

- Incisors → Helps in cutting and biting
- Canines → Helps in holding and tearing
- Premolars → Helps in chewing and grinding
- Molars → Helps in chewing and grinding

Dental formula:-

$$2\left[i\frac{2}{2}\,c\frac{1}{1}\,Pm\frac{2}{2}\,m\frac{3}{3}\right]$$

Upper jaw = 16
Lower jaw = 16

$\frac{2123}{2123}$ = for adult
i c Pm m

$\frac{2102}{2102}$ = for children.

3) Taste Buds:- It contains the taste receptor cells, which are also known as gustatory cells.

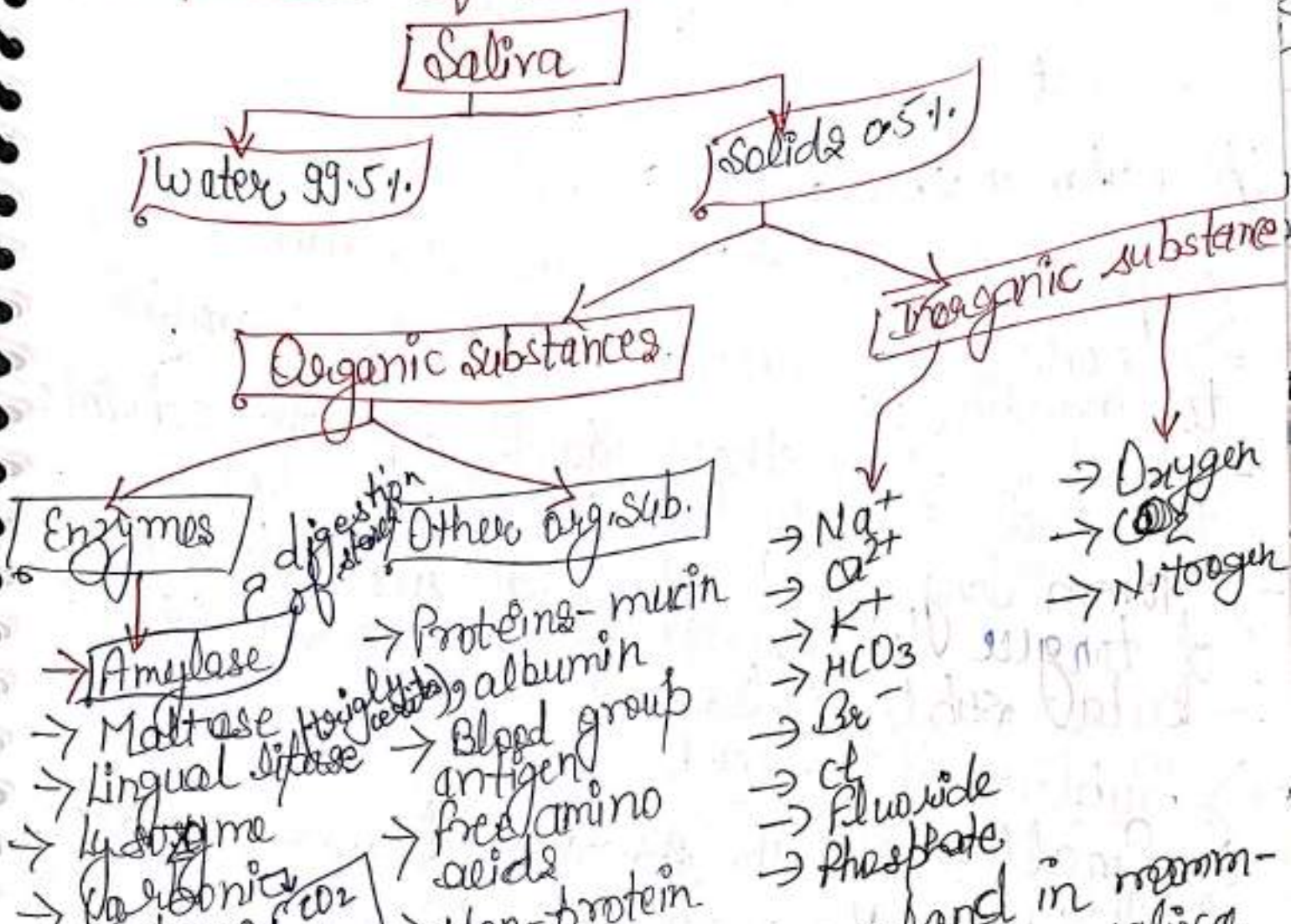
⇒ The taste receptors are located around the small structures known as papillae found on the upper surface of the tongue.

⇒ Human can detect sweet, sour, salty, bitter and savory tastes.

⇒ Each taste is caused by chemical substances that stimulate receptors on our taste buds.

4) Salivary Gland:- Saliva is a thick, colourless, opalescent fluid that is constantly present in the mouth of human and other vertebrates.

*Composition of saliva :-



* Salivary Glands :-

- Salivary glands are exocrine glands that produce saliva through a system of ducts. Human have three paired major salivary glands as well as hundreds of minor salivary glands.

a) Parotid glands

- largest of the salivary glands.

=> Situated at the side of the face just below and in front of the ear.

⇒ secretion of these glands. Save empties into oral cavity by stenson's duct.
⇒ 30-40mm long and opens inside the cheek against the upper second molar tooth.

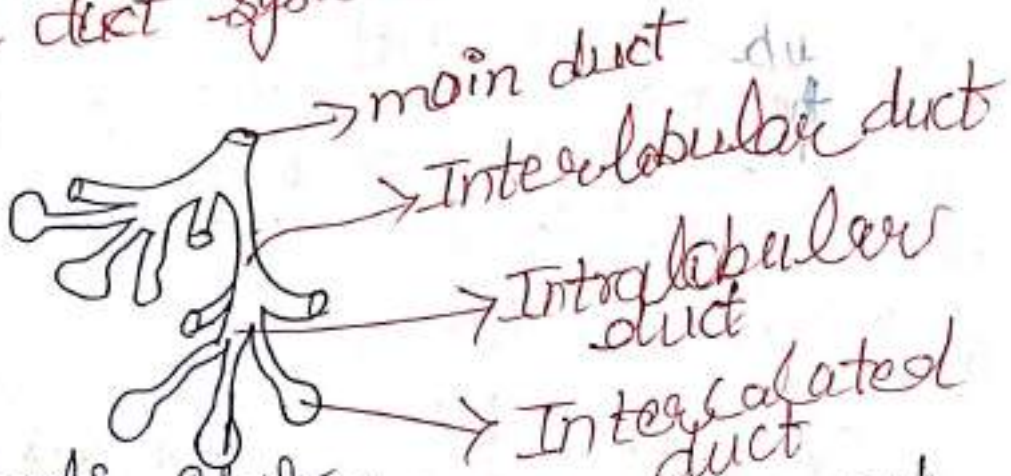
b) Submandibular glands:-
⇒ It is also known as submaxillary glands.
⇒ Located in submaxillary triangle medial to mandible.
⇒ Saliva from these glands is emptied into the oral cavity by Wharton's duct.
⇒ 40mm long and opens at side of frenulum of tongue by small opening called caruncula sublingualis.

c) Sublingual glands:-
⇒ Smallest of the 3-pairs of major salivary glands.
⇒ Situated in the mucosa at the floor of the mouth.
⇒ Saliva of these glands is poured into 5-15 small ducts called ducts of Rivinus the largest one is Bartholin's duct.
⇒ Ducts opens on small papillae beneath of tongue.

d) Minor Salivary glands:-
1) Lingual mucus glands.
2) Lingual serous glands.
3) Buccal glands

4) Labial glands
5) Palatal glands.

Structure and duct system in salivary gland



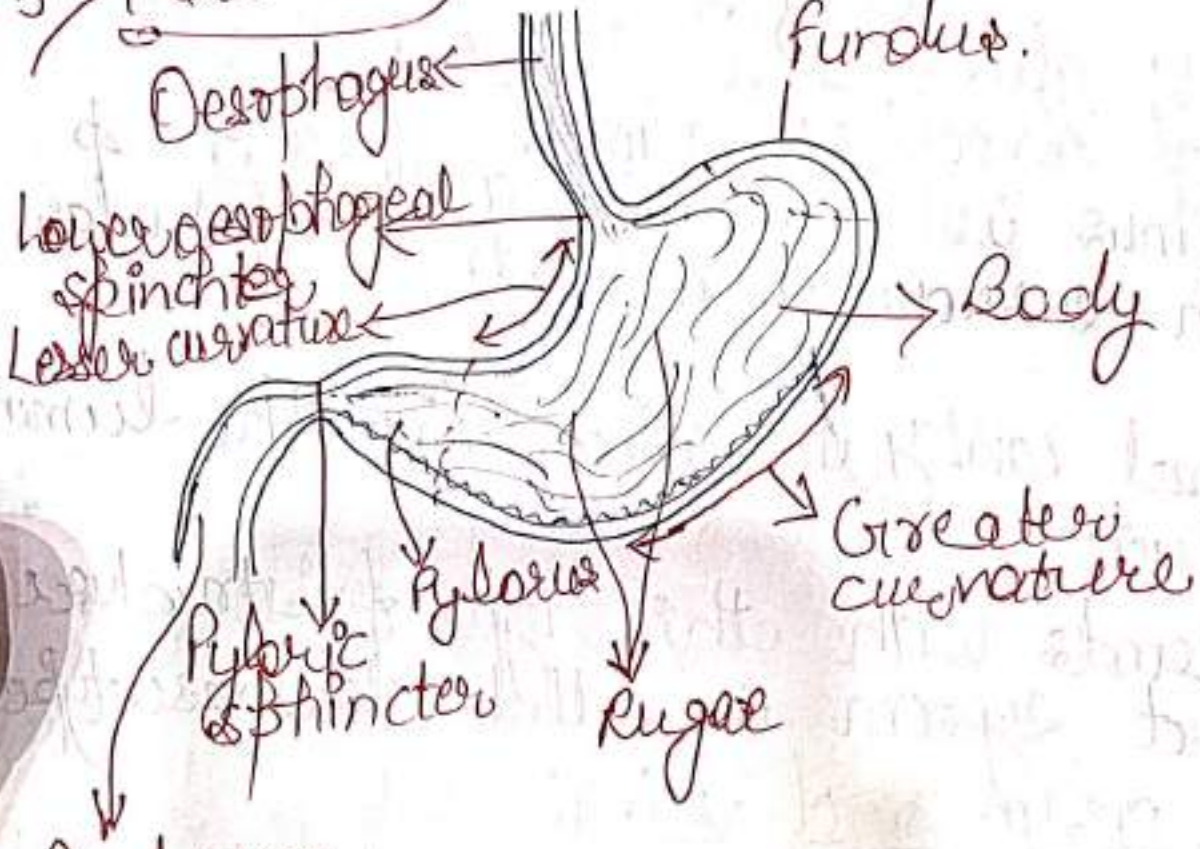
⇒ Salivary glands are made up of alveoli or acinus.
⇒ Each acinus is formed by a small group cells. which surrounds a central globular cavity.
⇒ The central cavity is continous with the lumen of the duct.
⇒ The glands with this type of structure and duct system is called racemose type

* Digestive enzymes of saliva:-

1) Salivary amylase:- converts starch into maltose.
2) Maltase:- converts maltose into glucose.
3) Lingual Lipase:- Converts triglycerides of milk fat into fatty acids and diacy ~~glycerol~~ glycerol

Functions of saliva:-

1) chemical digestion
2) Helps chewing and swallowing
3) Lubricating effect:- moisturizes the inside of the mouth and creates smoother speech.
4) Solvent effect:- dissolves food and allows the tongue to taste food.
5) Stomach:-



⇒ The human stomach is a muscular, elastic, pear-shaped bag, lying crosswise in the abdominal cavity beneath the diaphragm.

⇒ Volume of empty stomach is 50 ml.

⇒ Under normal-conditions, it can expand to accodate 1-1.5 ~~Litres~~ liters of solid and liquids.

Sphincters of stomach

a) Esophageal sphincter:- Junction b/w the esophagus and stomach. prevent the entry of the reflux of gastric contents into the esophagus.

b) Pyloric Sphincter:- Junction b/w the stomach and duodenum - allows partly digested foods and other stomach contents to pass from the stomach to the small intestine and prevents partially digested food and digestive juices from ~~ret~~ reentering the stomach.

⇒ The stomach is located b/w the esophagus and the small intestine.

⇒ Located on the left side of the abdominal cavity, J shaped.

* Parts of stomach:-

a) Cardiac region:- upper part of stomach where esophagus opens.

⇒ The opening is guarded by cardiac sphincter.

b) Fundus:- It is a small dome shaped structure.

⇒ It is elevated above the level of esophageal opening

c) Body of Corpus:- It is the largest part of stomach forming about 75-80% of the whole stomach.

⇒ It extends from just below the fundus upto the pyloric region.

d) Pylaric region:- The pylaric region has two parts-

⇒ The body of stomach ends in antrum

⇒ The junction b/w the body and antrum is marked by an angular notch called incisura angularis.

⇒ antrum is continued as the narrow canal which is called pyloric canal or pylaric end. Pylaric canal's open into Ist part of small intestine called duodenum

⇒ The opening of pylaric canal is guarded by pylaric sphincter.

*Structure of stomach wall:-

1) Outer serous layer:- It is formed by peritoneum which covers the stomach.

2. Muscular layer:- It is made up of three layers of muscle fibers namely, Inner oblique, middle circular and longitudinal layers.

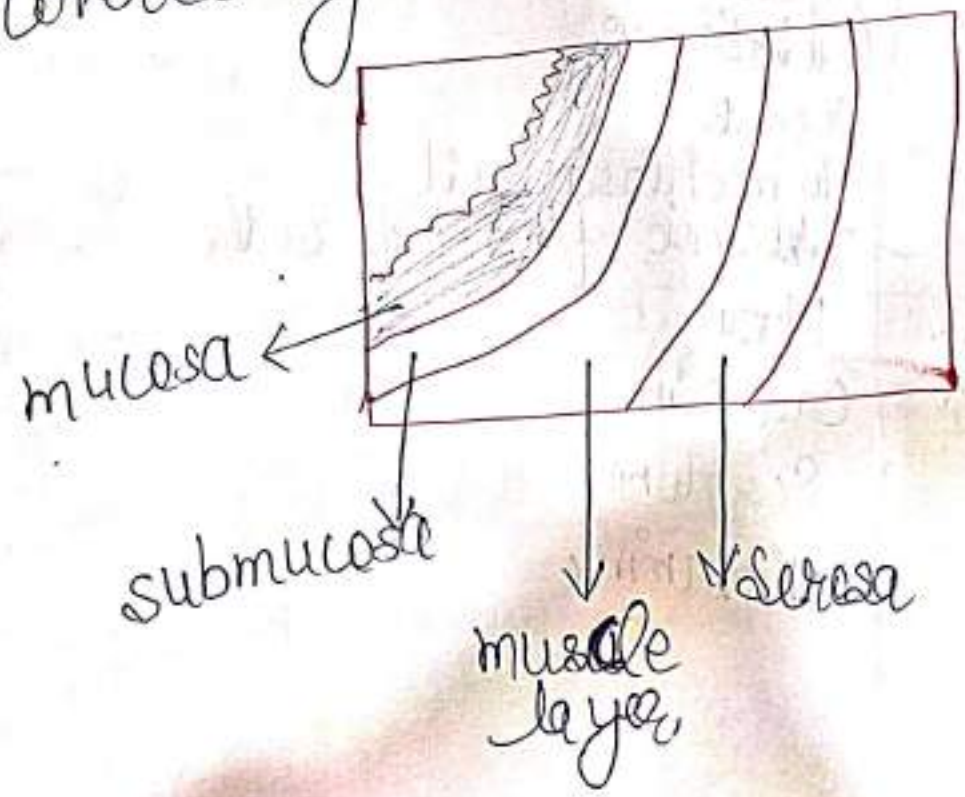
3.) Submucus layer:- It is formed by areolar tissue, blood vessels, lymph vessels and meissner's nerve plexus

4) Inner mucus layer:- lined by mucus secreting columnar epithelial cells.

⇒ The gastric glands are situated in this layer.

⇒ The folds of the mucosa of stomach is called rugae.

⇒ The inner surface of mucus layer is covered by 2mm thick mucus.



* Glands of stomach :-

1) Fundic glands

- situated in Fundus Body and Antrum of stomach.
- also called gastric glands.

2) Pyloric gland

- present in the pyloric part of the stomach

3) Cardiac glands.

- located on the cardiac region of the stomach.

Secretary function of cells in gastric glands

Cell.	Secretary products.
1) chief cells	Pepsinogen Renin Lipase Gelatinase Urease
2) Parietal cell	Hydrochloric acid Intrinsic factor of castle
3) Mucus neck cells	Mucin
4) G-cells	Gastrin
5) Enterochromaffin	Serotonin
6) Enterochromaffin like cells.	Histamine.

* Composition of gastric juice

Gastric Juice (99.5% H_2O and 0.5% solids)

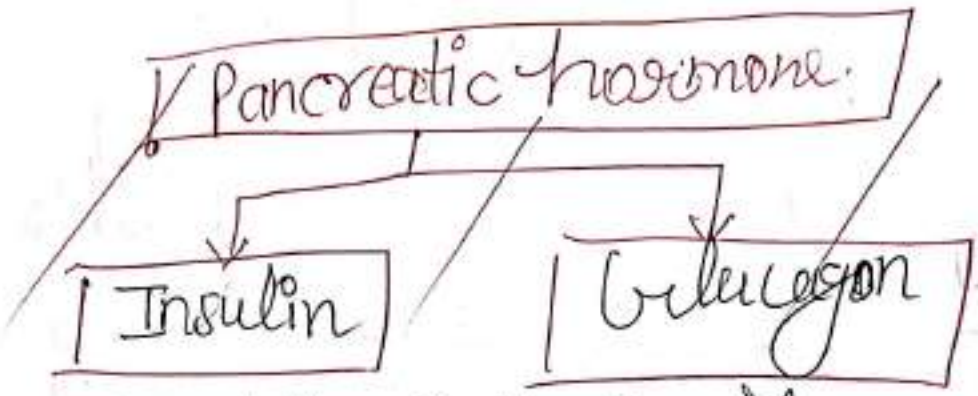
- Water 99.5%
- Solids 0.5%
  - Organic Substances
    - Enzymes
      - → Pepsin
      - → Renin (animal only)
      - → Gastric Lipase
      - → Gelatinase
      - → Urease
    - Other organic substances
      - → Mucus
      - → Intrinsic factor
  - Inorganic substances
    - → HCl
    - → Na^+
    - → Ca^{2+}
    - → K^+
    - → HCO_3^-
    - → Cl^-
    - → P
    - → Sulfate

Concentration of HCl = upto 150 mEq/L

* Digestive enzymes of gastric juice

Enzyme	Activators	Substrate	End products
1) Pepsin	HCl	Proteins	Proteases, peptones and polypeptides
2) Gastric Lipase	acid medium	Triglycerides of butter	Fatty acids and glycerols
3) Gastric amylase	acid medium	Starch	Dextin and maltose
4) Gelatinase	"	Gelatin and collagen of meat	Peptides
5) Urease	"	Urea	Ammonia

Pancreas



* Pancreatic islets - α-cells, β-cells.

⇒ The pancreas is an organ of the digestive system and endocrine system of vertebrates.

⇒ In humans, it is located in the abdomen behind the stomach and functions as a gland.

⇒ It is about 15-20 cm long, 2.5-3.8 cm broad and 1.2-1.8 cm thick and weighs about 90g and slightly alkaline (PH 7.5-8).

Functions:-

⇒ As an endocrine, it functions mostly to regulate Blood sugar levels secreting the hormones insulin, glucagon, somatostatin, and pancreatic polypeptide.

⇒ As a part of the digestive system, it functions as an exocrine gland secreting pancreatic juice into the duodenum through the pancreatic duct.

pancreatic juice contains bicarbonate, which neutralizes acid entering the duodenum from the stomach, and digestive enzymes, which break down carbohydrates, proteins and fats in food entering the duodenum from the stomach.

Division of Pancreas :-

⇒ The pancreas is divide into the head, the neck, the body and tail.

⇒ The head is enlarged and lies within the concavity of the duodenum.

⇒ The tail reaches the hilum of the spleen.

⇒ The entire organ lies posterior to the stomach separated from it by the lesser etc.

Ducts of the pancreas :-

The exocrine pancreas is drained by two ducts :-

1) The main pancreatic duct (Duct of wirsung).
2) The accessory pancreatic duct (duct of Santorini).

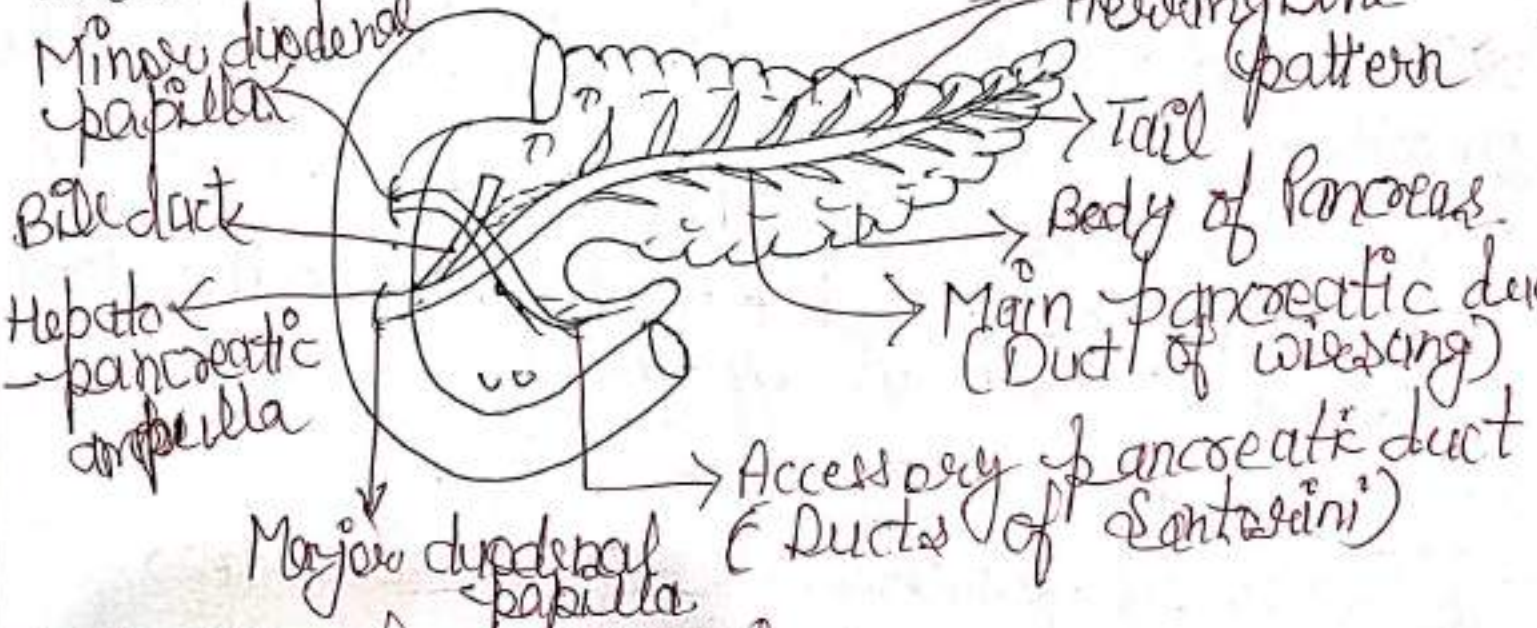
* Duct of wirsung :-

⇒ It lies near the posterior surface of the pancreas, and is recognized easily by its white colour.

⇒ With in the head of the pancreas the pancreatic duct is related to the bile duct which lies on its right side.

⇒ The two ducts enter the wall of the second part of the duodenum, and join to form the hepatopancreatic ampulla of vater.

2. Duct of Santorini:- It begins in the lower part of the head, crosses the front of the main duct with which it communicates and open into the duodenum at the minor duodenal papilla.

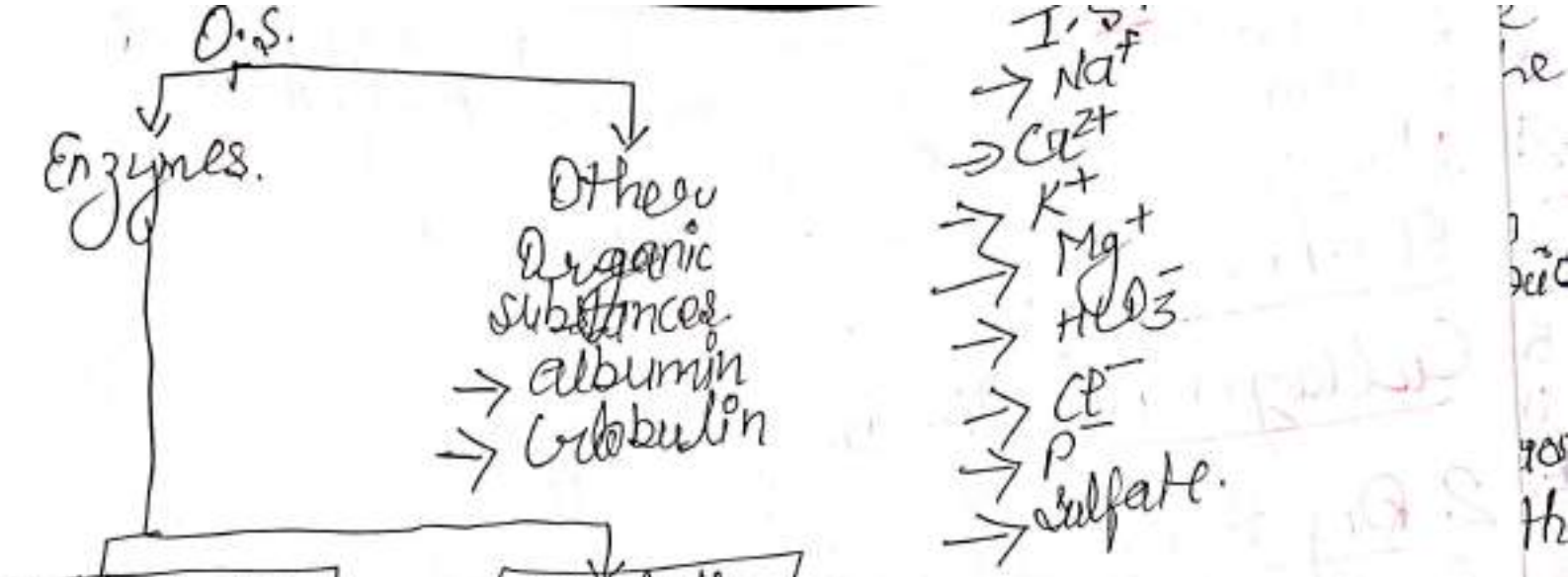


Composition of pancreas :-

Pancreatic juice contains 99.5% of water and 0.5% of solids

Pancreatic Juice

- Water - 99.5%
- Solids 0.5%
  - Organic substances
  - Inorganic substances



Proteolytic enzymes.

→ Trypsin
→ Chymotrypsin
→ Carboxy peptidases
→ Nuclease
→ Elastase
→ Collagenase

Lipolytic enzymes.

→ Pancreatic lipase
→ Cholesterol esterhydrolase
→ Phospholipase A
→ P. B
→ Colipase
→ Bile salt activated lipase

Amylolytic enzymes.

→ Pancreatic amylase.

Bicarbonate content = 110 to 150 mEq/L

Functions of Pancreas:-

(1) Digestion of proteins:- The proteolytic enzymes of pancreatic juice are:-

→ Trypsin:- Digestion of protein and milk, converts trypsinogen into trypsin.

→ Chymotrypsin:- Digestion of protein and milk.

Carboxypeptidases:- Breaks the terminal bond of protein molecules carboxypeptidase A splits the protein into amino acids.

Nuclease:- Digestion of nucleic acids.

Elastase:- " " elastic fibres.

Collagenase:- Digestion of collagen.

2. Digestion of carbohydrates:- Pancreatic amylase is the digestive enzyme present in pancreatic juice.
→ It converts starch into dextrin and maltose.

3) Digestion of Lipids:- The lipolytic enzymes present in pancreatic juice are:-

Pancreatic lipase:- Hydrolyses the triglycerides into monoglycerides and fatty acids.

Cholesteral ester hydrolase:- Converts cholesteral ester into free cholesteral and fatty acids

Phospholipase A:- Digestion of phospholipids i.e lecithin and cephalin.

Phospholipase B:- Converts lysophospholipids to phosphoryl choline and free fatty acids.

Colipase:- Facilitates the efficient hydrolyse of fats by pancreatic lipase.

Enzymes.	Activator	Acts on	End products.
Trypsin	Enterokinase Trypsin	Proteins.	Proteoses and polypeptides.
Chymotrypsin	Trypsin	〃	Polypeptides.
Carboxypeptidases	〃	Polypeptides.	Amino acids.
Nucleases.	〃	RNA and DNA	Mononucleotides
Elastase	〃	Elastin	amino acids.
Collagenase	〃	Collagen	〃
Pancreatic lipase	alkaline medium	Triglycerides	monoglycerides and fatty acids
Cholesterol esterhydrolase	〃	cholesterol ester	cholesterol and fatty acid.
Phospholipase A	Trypsin	Phospholipids	~~Lysophospholipids~~ Lecithin and cephalin.
P-L-B	〃	Lysophospholipids.	Phosphoryl choline and fatty acids.
Colipase	〃	facilitates action of pancreatic lipase	—

Digestive Enzymes of pancreatic Juice

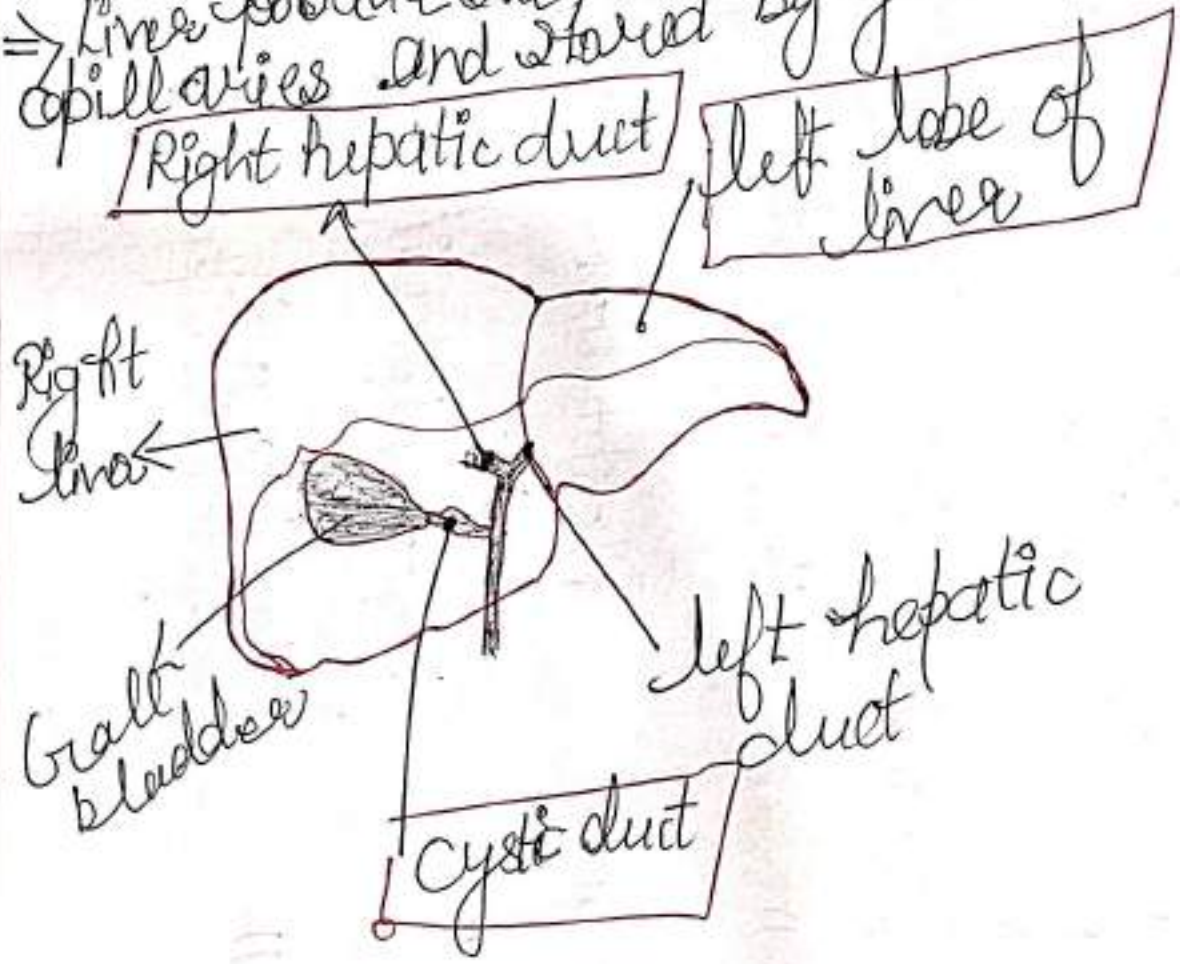
Liver and Gall bladder

Liver:- liver is a dual organ having both secretory and excretory functions.

⇒ It is the largest gland in the body weighing about 1.5kg in man.

⇒ It is located in the upper and right side of the abdominal cavity immediately beneath diaphragm.

⇒ Liver produce bile, which is collected by bile capillaries and stored by gall bladder.



Functional anatomy of liver

1. Hepatic lobes.

⇒ liver is made up of many lobes called hepatic lobes.
⇒ Each lobe consists of many lobules called hepatic lobules.

2. Hepatic lobules:-

⇒ The hepatic lobules is the structural and functional unit of liver.
⇒ There are about 50,000–100,000 lobules in the liver.
⇒ The lobule is honeycomb like structure and it is made up of liver cells called hepatocytes.

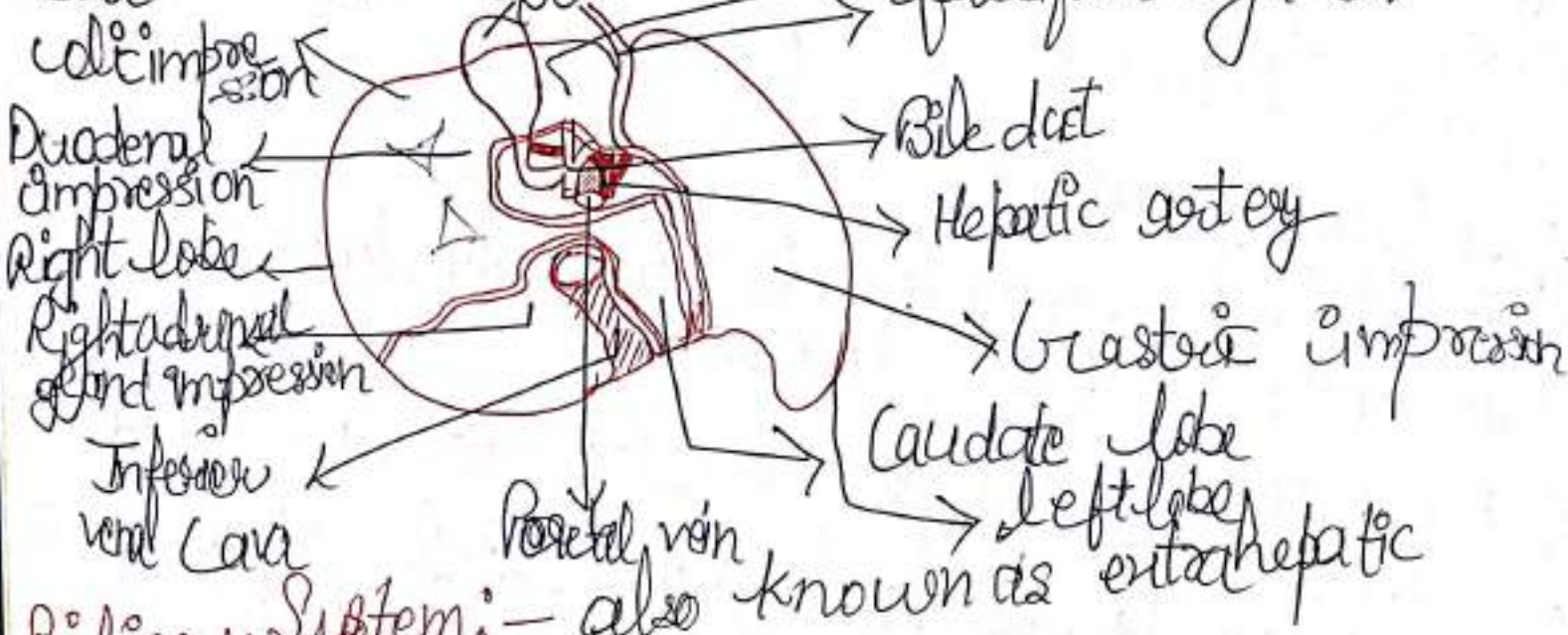
3. Hepatocytes and hepatic plates.

⇒ Hepatocytes are arranged in columns which form the hepatic plates.
⇒ Each plate is made up of two columns of cells
⇒ In between the two columns of each plate, lies a bile canaliculus.
⇒ In between the neighboring plates a blood space called sinusoid is present.

4) Portal triads:- Each lobule is surrounded by many portal ~~tracts~~ triads. Each portal triad consists of three vessels:-

→ A branch of hepatic artery
→ A branch of portal vein
→ A tributary of bile duct

→ Bile is secreted by hepatic cells and emptied into bile canaliculus.



Biliary System - also known as extrahepatic biliary apparatus.

⇒ It is formed by gallbladder and extrahepatic bile ducts.

⇒ The bile produced in the liver is collected in bile canaliculi, small grooves between the faces of adjacent hepatocytes.

⇒ The canaliculi radiate to the edge of the liver lobules where they merge to form bile ducts.

⇒ The intrahepatic ducts eventually drain into the right and left hepatic ducts, which exit the liver at the transverse fissure, and merge to form the common hepatic duct.

⇒ The cystic duct from the gallbladder joins with the common hepatic duct to form the common bile duct.

⇒ Bile either drains directly into the duodenum via the common bile duct, or is temporarily stored in the gallbladder via the cystic duct.

⇒ The common bile duct and the pancreatic duct enter the second part of the duodenum together at the hepatopancreatic ampulla, also known as ampulla of Vater.

* Bile acids:-

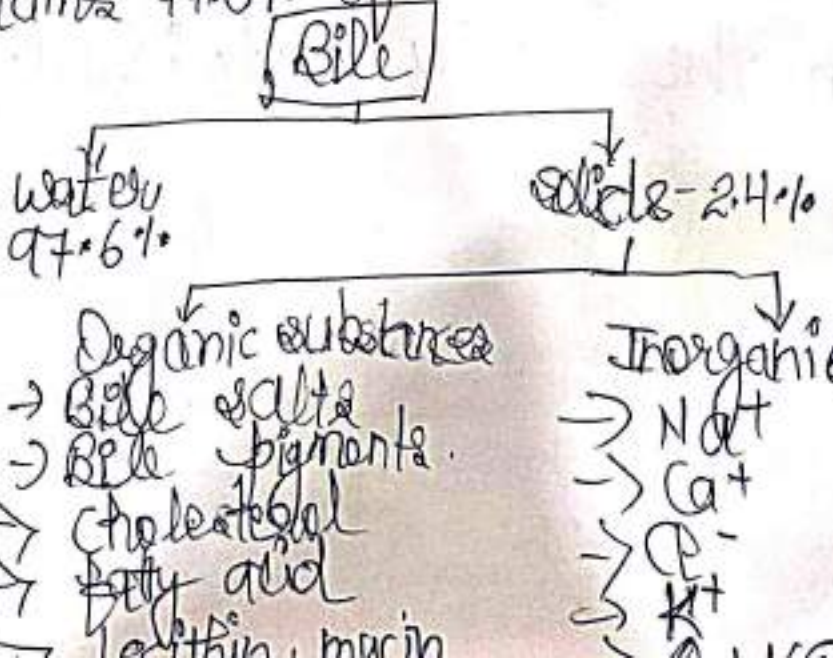
⇒ Bile is a golden yellow or greenish fluid.

⇒ It enter the digestive tract along with pancreatic juice through the common opening called ampulla of vater.

- Volume — 800–1200 ml/day.
- Reaction — alkaline
- pH 8-8.6
- Specific gravity - 1.010-1.011

* Composition of Bile

Bile contains 97.6% of water and 2.4% of solid

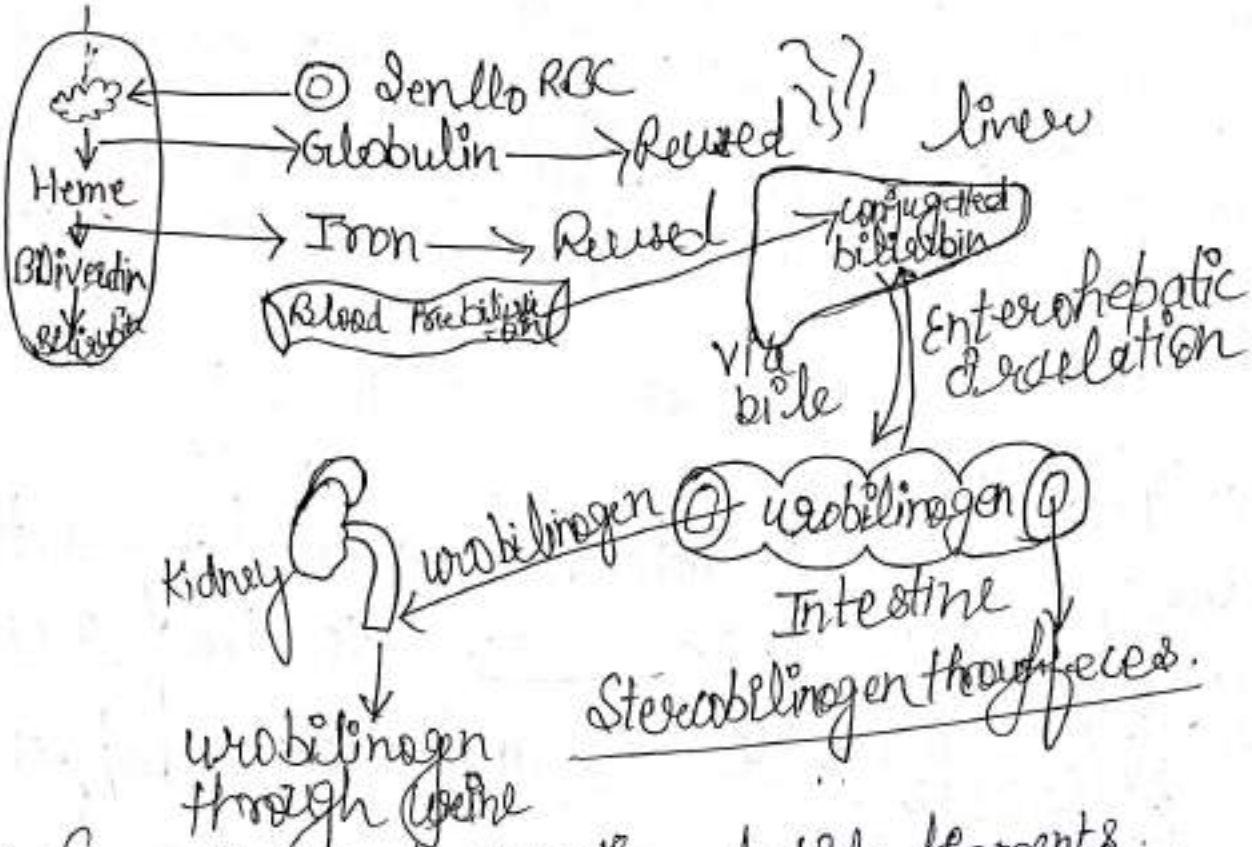


Storage of Bile:-

* Most of the bile from liver enters the gall-bladder where it is stored.
⇒ It is released from gallbladder into the intestine whenever it is required.
⇒ It undergoes many changes in gallbladder:-
o- A large amount of H_2O and electrolytes are absorbed resulting in high conc. of bile salts, bile pigments, cholesterol, fatty acids and lecithin.
o- The pH and specific gravity of bile are altered in gallbladder.
o- some amount of mucin is added to bile.

Bile pigments:-

⇒ Bile pigment are the excretory products in bile.
⇒ Bilirubin and Biliverdin are the two bile pigments.
⇒ Bilirubin is the major bile pigment in human being.
⇒ The bile pigments are formed during the breakdown of Hb, which is released from the destroyed RBCs in the reticuloendothelial system



∴ formation and excretion of bile pigments.

Functions of Bile :-

→ Emulsification and absorption of fats.
→ Excretory - Heavy metals, bacteria, cholesterol, Lecithin etc.
→ Laxative action.
→ Antiseptic action.
→ Prevention of gallstone formation.

Functions of gall bladder :-

(1) Storage of Bile :- Bile is stored in gall bladder till it is required for digestion process.

(2) Concentration of Bile :- Bile is concentrated while it is stored in gallbladder. The mucosa of gall-bladder rapidly reabsorbs water and electrolytes (except Ca^{++} and K^{+}).

(3) Alteration of PH of Bile:- The pH of bile decreases from 8–8.6 to 7–7.6 and it becomes less alkaline when it stored in gallbladder.

(4) Secretion of mucus:- Gallbladder secretes mucin, which acts as a lubricant for movement of chyme in the intestine.

(5) Maintence of pressure in Biliary system.

Intestines :→ The intestine are a long, continous tube running from the stomach to the anus.

⇒ Most absorption of nutrients and water happen in the intestines.

⇒ The intestines include the small intestine, large intestine and rectum.

Small intestine :→

⇒ Small intestine is the part of gastrointestinal tract, extending b/w the pyloric sphincter of stomach and ileocecal valve, which opens into large intestine.

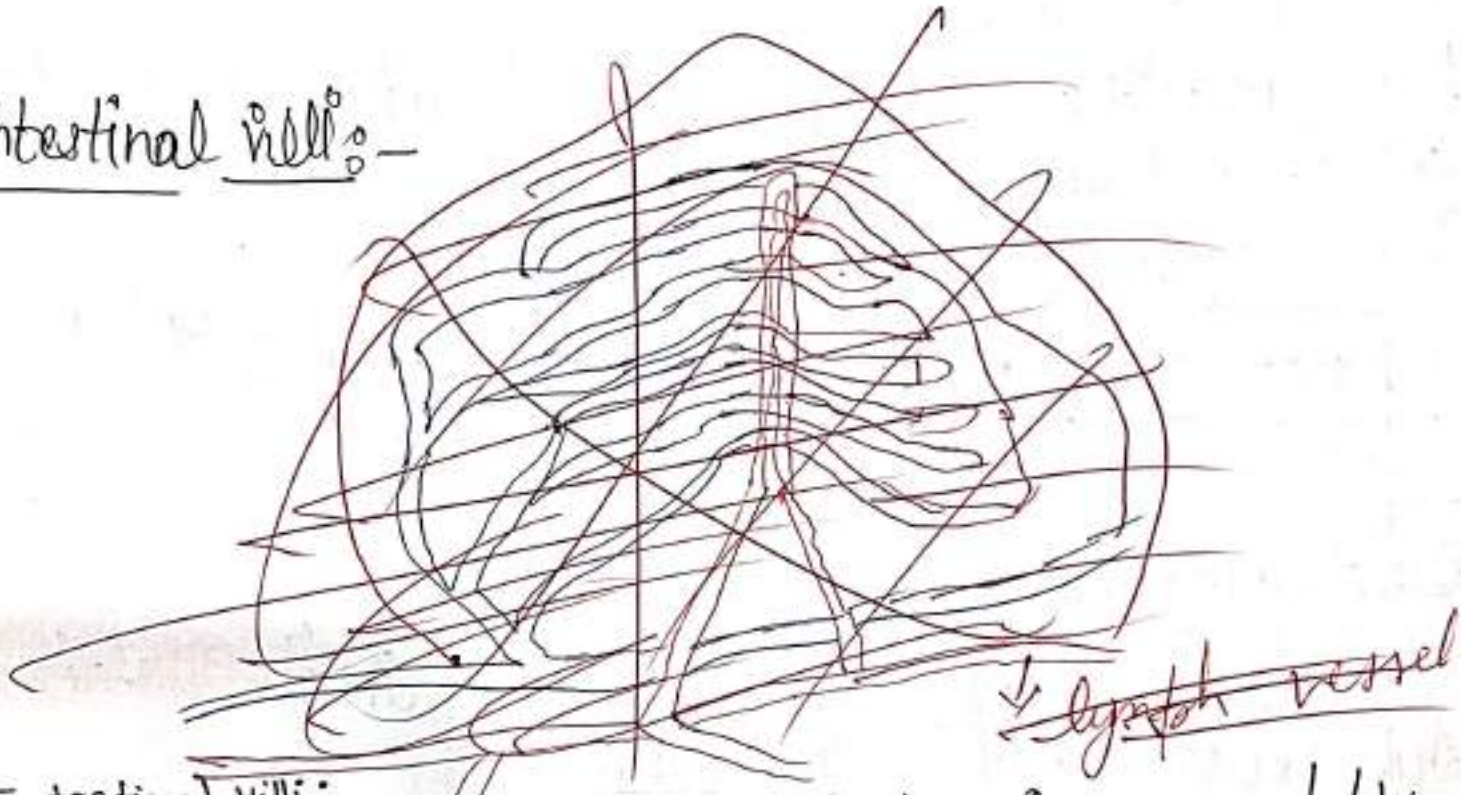
⇒ The small intestine is about 20 feet long and about an inch in diameter.

⇒ Its function is to absorb most of the nutrients from what we eat and drink.

⇒ Small intestine consists of three portions –

1.) Proximal part known as Duodenum
2.) Middle part known as Jejunum
3.) Distal part " " Ileum.

Intestinal villi:-



Intestinal villi:

⇒ Mucous membrane of small intestine is covered by minute projections called villi.

⇒ The height of villi is about 1mm and the diameter is less than 1mm.

⇒ Villi are lined by columnar cells, which are called enterocytes.

⇒ Each enterocytes gives rise to hair-like projections called microvilli.

⇒ Villi and microvilli increase the surface area of mucous membrane by many folds.

⇒ within each villus, there is a central channel called lacteal, which opens into lymphatic vessels

Intestinal Glands:-

⇒ Crypts of Lieberkuhn or intestinal glands are simple tubular glands of intestine.

⇒ Types of cells interposed b/w columnar cells of intestinal glands;-

1. Argentaffin cells or enterochromaffin cells, which secrete intrinsic factor of castle.
2. Goblet cells - which secrete mucus.
3. Paneth cells which secrete the cytokines called defensins.

Brunner glands:-

⇒ Brunner's glands are located in the submucosa of the duodenum.

⇒ They secrete an alkaline fluid containing mucin which protects the mucosa from the acidic stomach contents entering the duodenum.

⇒ These glands penetrate muscularis mucosa and extend up to the submucus coat of the intestinal.

Properties of succus entericus.

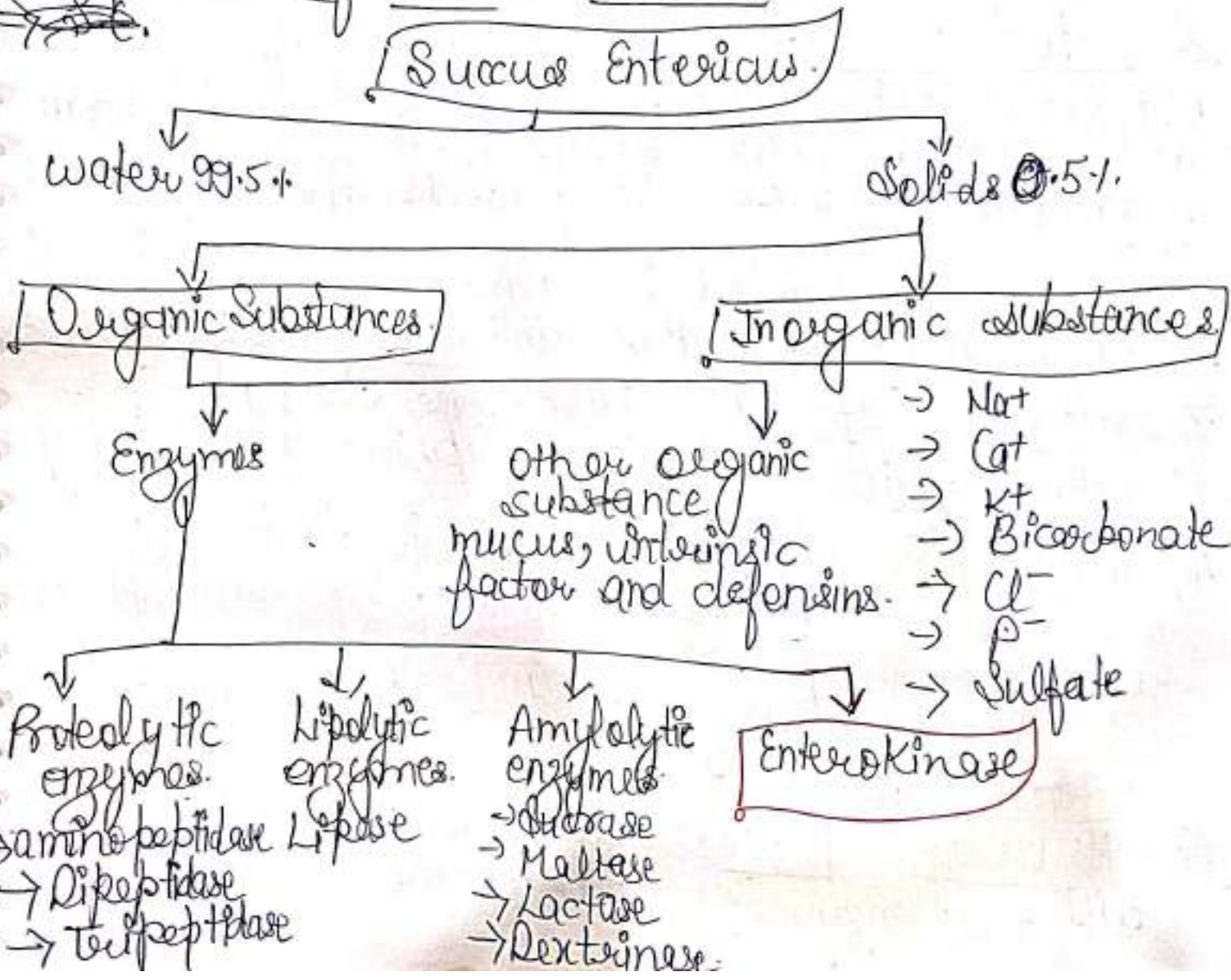
⇒ Secretion from small intestine is called succus entericus.

bicarbonate of water, mucoproteins and hydrogen ions.

⇒ It helps to counteract the highly acidic and proteolytic chyme entering the small intestine from the stomach, and thus protects the duodenum from damage.

Volume: 1800 ml/day
Reaction:- alkaline
pH :- 8.3

Composition of Succus entericus-



Functions of succus entericus.

1. Digestive function:-

- Proteolytic enzymes:- Proteolytic enzymes present in succus entericus are the peptidases. These peptidases convert peptides into amino acids.
- Amylolytic enzymes:- Digestion of starch.
- Lipolytic enzymes:- Intestinal lipase acts on triglycerides and converts them into fatty acids.

2. Protective function:- mucus present in the succus entericus protects the intestinal wall from the acid chyme, which enters the intestine from stomach; thereby it prevents the intestinal ulcer.

⇒ Defensins secreted by Paneth cells of intestinal glands are the antimicrobial peptides.

3. Activator function:- Enterokinase present in intestinal juice activates trypsinogen into trypsin.

4. Hemopoietic function:- Intrinsic factor of castle present in the intestine plays an important role in erythropoiesis.

⇒ It is necessary for the absorption of Vitamin B12.

5. Hydrolytic process:- Intestinal juice helps in all the enzymatic reactions of digestion.

*Large intestine:- also known as the large bowel, is the last part of the GIT and of the digestive system in vertebrates.
⇒ water is absorbed here and the remaining waste material is stored as feces before being removed by defecation.
⇒ Large intestine or colon extends from ileocecal valve upto anus.

Parts of large intestine:-
→ Cecum with Appendix
→ Ascending colon
→ Transverse colon.
→ Descending colon.
→ Sigmoid or pelvic colon
→ Rectum
→ Anal canal.

*Composition of large intestinal juice:-
*large intestinal juice contains 99.5% water and 0.5% of solids.
⇒ Digestive enzymes are absent.
⇒ pH - 8.0

* Functions of large intestine juice

1) Neutralization of Acids:- Strong acids formed by bacterial action in large intestine are neutralized by the alkaline nature of large intestinal juice.
⇒ alkaline due to bicarbonate.

2) Lubrication activity:- Mucin present in the secretion of large intestine lubricates the mucosa of large intestine and the bowel contents and thus the movement of bowel is facilitated.
⇒ Mucin also protect the mucus membrane of large intestine by preventing the damage caused by mechanical injury or chemical substances.

* Function of large intestine:-

1) Absorptive function:- water, electrolytes, organic substance like glucose, alcohol, Drugs like anaesthetic agents, sedatives and steroids.

2) Formation of feces:- After the absorption of nutrients water and other substances, the unwanted substances in the large intestine form feces. This is excreted out.

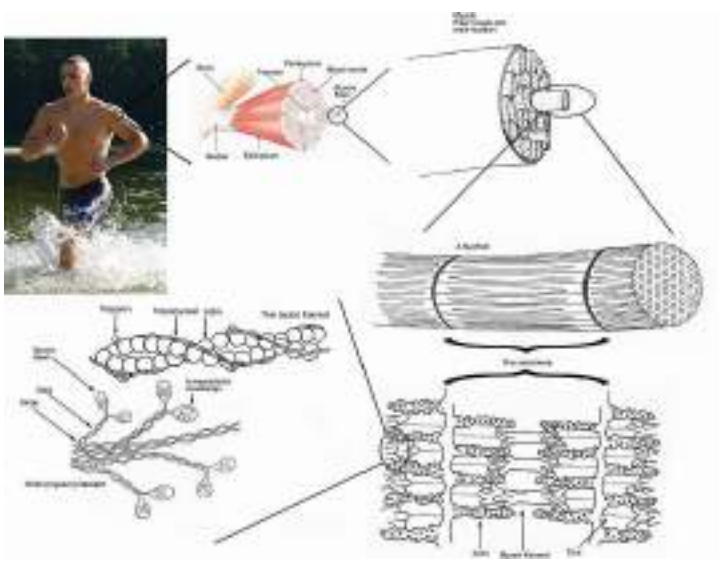
3) Excretory function:- It excretes heavy metals like mercury, lead, bismuth and arsenic through feces.

4) Secretory function:- large intestine secretes mucin and inorganic substances like Cl⁻ and bicarbonate

5) Synthetic function:- Bacterial flora of intestine synthesizes folic acid, vitamin B12 and vitamin K. (Phylloquinone)

⇒ By this function, large intestine contributes in erythropoietic activity and blood clotting mechanism.

Muscle contraction



A top-down view of skeletal muscle

Muscle fiber generates tension through the action of actin and myosin cross-bridge cycling. While under tension, the muscle may lengthen, shorten or remain the same. Although the term 'contraction' implies shortening, when referring to the muscular system, it means muscle fibers generating tension with the help of motor neurons (the terms *twitch tension*, *twitch force* and *fiber contraction* are also used).

Voluntary muscle contraction is controlled by the central nervous system. Voluntary muscle contraction occurs as a result of conscious effort originating in the brain. The brain sends signals, in the form of action potentials, through the nervous system to the motor neuron that innervates several muscle fibers. In the case of some reflexes, the signal to contract can originate in the spinal cord through a feedback loop with the grey matter. Involuntary muscles such as the heart or smooth muscles in the gut and vascular system contract as a result of non-conscious brain activity or stimuli proceeding in the body to the muscle itself.

Contractions, by muscle type

For voluntary muscles, contraction occurs as a result of conscious effort originating in the brain. The brain sends signals, in the form of action potentials, through the nervous system to the motor neuron that innervates several muscle fibers [1] . In the case of some reflexes, the signal to contract can originate in the spinal cord through a feedback loop with the grey matter. Involuntary muscles such as the heart or smooth muscles in the gut and vascular system contract as a result of non-conscious brain activity or stimuli endogenous to the muscle itself. Other actions such as locomotion, breathing and chewing have a reflex aspect to them: the contractions can be initiated consciously or unconsciously.

There are three general types of muscle tissues:

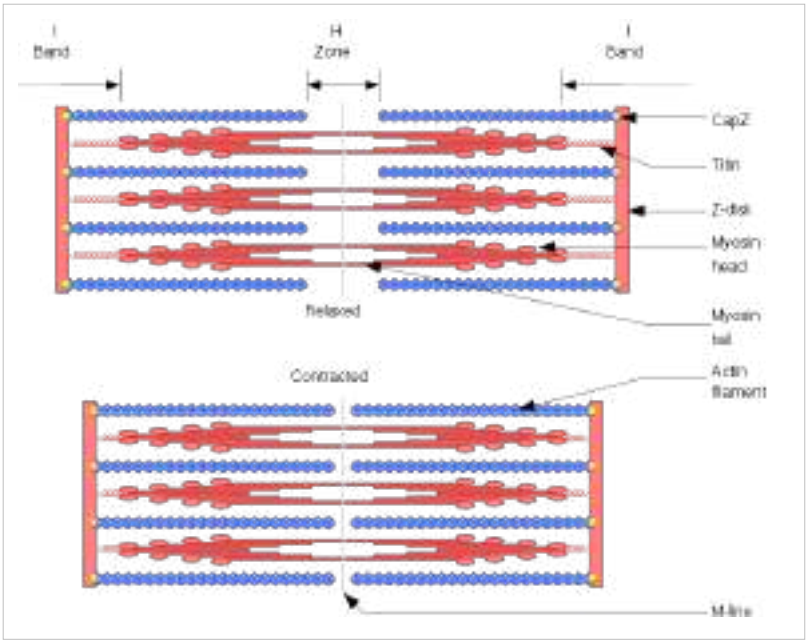
- Skeletal muscle responsible for movement
- Cardiac muscle responsible for pumping blood
- Smooth muscle responsible for sustained contractions in the blood vessels, gastrointestinal tract, and other areas in the body

Skeletal and cardiac muscles are called striated muscle because of their striped appearance under a microscope, which is due to the highly organized alternating pattern of A band and I band.

While nerve impulse profiles are, for the most part, always the same, skeletal muscles are able to produce varying levels of contractile force. This phenomenon can be best explained by Force Summation. Force Summation describes the addition of individual twitch contractions to increase the intensity of overall muscle contraction. This can be achieved in two ways [2] : (1) by increasing the number and size of contractile units simultaneously, called *multiple fiber summation*, and (2) by increasing the frequency at which action potentials are sent to muscle fibers, called *frequency summation*.

- **Multiple fiber summation –** When a weak signal is sent by the CNS to contract a muscle, the smaller motor units, being more excitable than the larger ones, are stimulated first. As the strength of the signal increases, more motor units are excited in addition to larger ones, with the largest motor units having as much as 50 times the contractile strength as the smaller ones. As more and larger motor units are activated, the force of muscle contraction becomes progressively stronger. A concept known as the size principle allows for a gradation of muscle force during weak contraction to occur in small steps, which then become progressively larger when greater amounts of force are required.
- **Frequency summation** - For skeletal muscles, the force exerted by the muscle is controlled by varying the frequency at which action potentials are sent to muscle fibers. Action potentials do not arrive at muscles synchronously, and, during a contraction, some fraction of the fibers in the muscle will be firing at any given time. In a typical circumstance, when a human is exerting a muscle as hard as he/she is consciously able, roughly one-third of the fibers in that muscle will be firing at once, yet can be affected by various physiological and psychological factors (including Golgi tendon organs and Renshaw cells). This 'low' level of contraction is a protective mechanism to prevent avulsion of the tendon - the force generated by a 95% contraction of all fibers is sufficient to damage the body.

Skeletal muscle contractions

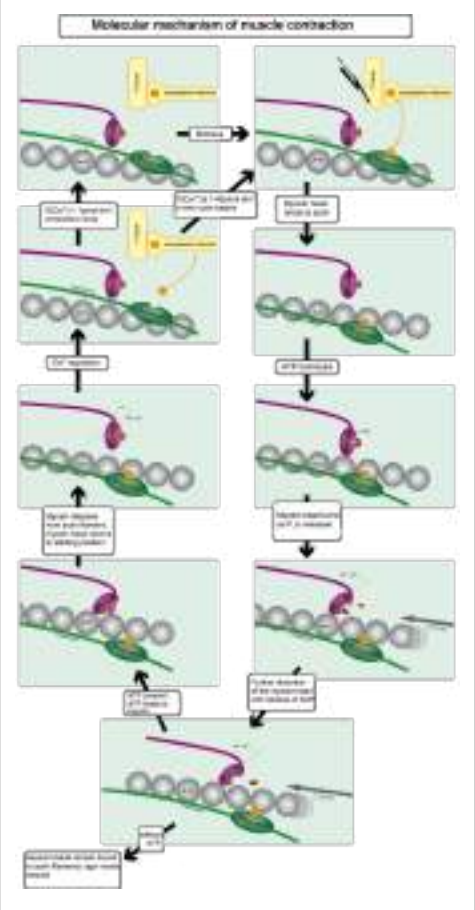


Skeletal muscles contract according to the *sliding filament model*:

1. An action potential originating in the CNS reaches an alpha motor neuron, which then transmits an action potential down its own axon.
2. The action potential propagates by activating voltage-gated sodium channels along the axon toward the synaptic cleft. Eventually, the action potential reaches the motor neuron terminal and causes a calcium ion influx through the voltage-gated calcium channels.
3. The Ca^{2+} influx causes vesicles containing the neurotransmitter acetylcholine to fuse with the plasma membrane, releasing acetylcholine out into the extracellular space between the motor neuron terminal and the motor end plate of the skeletal muscle fiber.
4. The acetylcholine diffuses across the synapse and binds to and activates nicotinic acetylcholine receptors on the motor end plate of

the muscle cell. Activation of the nicotinic receptor opens its intrinsic sodium/potassium channel, causing sodium to rush in and potassium to trickle out. Because the channel is more permeable to sodium, the muscle fiber membrane becomes more positively charged, triggering an action potential.

5. The action potential spreads through the muscle fiber's network of T-tubules, depolarizing the inner portion of the muscle fiber.
6. The depolarization activates L-type voltage-dependent calcium channels (dihydropyridine receptors) in the T tubule membrane, which are in close proximity to calcium-release channels (ryanodine receptors) in the adjacent sarcoplasmic reticulum.



7. Activated voltage-gated calcium channels physically interact with calcium-release channels to activate them, causing the sarcoplasmic reticulum to release calcium.
8. The calcium binds to the troponin C present on the actin-containing thin filaments of the myofibrils. The troponin then allosterically modulates the tropomyosin. Under normal circumstances, the tropomyosin sterically obstructs binding sites for myosin on the thin filament; once calcium binds to the troponin C and causes an allosteric change in the troponin protein, troponin T allows tropomyosin to move, unblocking the binding sites.
9. Myosin (which has ADP and inorganic phosphate bound to its nucleotide binding pocket and is in a ready state) binds to the newly uncovered binding sites on the thin filament (binding to the thin filament is very tightly coupled to the release of inorganic phosphate). Myosin is now bound to actin in the strong binding state. The release of ADP and inorganic phosphate are tightly coupled to the power stroke (actin acts as a cofactor in the release of inorganic phosphate, expediting the release). This will pull the Z-bands towards each other, thus shortening the sarcomere and the I-band.
10. ATP binds myosin, allowing it to release actin and be in the weak binding state (a lack of ATP makes this step impossible, resulting in the rigor state characteristic of rigor mortis). The myosin then hydrolyzes the ATP and uses the energy to move into the "cocked back" conformation. In general, evidence (predicted and *in vivo*) indicates that each skeletal muscle myosin head moves 10-12 nm each power stroke, however there is also evidence (*in vitro*) of variations (smaller and larger) that appear specific to the myosin isoform.
11. Steps 9 and 10 repeat as long as ATP is available and calcium is present on thin filament.
12. While the above steps are occurring, calcium is actively pumped back into the sarcoplasmic reticulum. When calcium is no longer present on the thin filament, the tropomyosin changes conformation back to its previous state so as to block the binding sites again. The myosin ceases binding to the thin filament, and the contractions cease.

The calcium ions leave the troponin molecule in order to maintain the calcium ion concentration in the sarcoplasm. The active pumping of calcium ions into the sarcoplasmic reticulum creates a deficiency in the fluid around the

myofibrils. This causes the removal of calcium ions from the troponin. Thus, the tropomyosin-troponin complex again covers the binding sites on the actin filaments and contraction ceases.

Classification of voluntary muscular contractions

Skeletal muscle contractions can be broadly separated into twitch and tetanic contractions. In a twitch contraction, a short burst of stimulation causes the muscle to contract, but the duration is so short that the muscle begins relaxing before reaching peak force. The shape of the graph of force vs time in a twitch contraction can give information about the relative rates of calcium release and re-uptake from the sarcoplasmic reticulum. If the stimulation is long enough, the muscle reaches peak force and plateaus at this level, resulting in a tetanic contraction. If the stimulation is not intense enough, force will oscilate during the plataeu and be submaximal, but with sufficient stimulation, there will be a constant force level until stimulation stops.

Voluntary muscular contractions can be further classified according to either length changes or force levels. In spite of the fact that the muscle actually shortens only in concentric contractions, all are typically referred to as "contractions".

- In *concentric* contraction, the force generated is sufficient to overcome the resistance, and the muscle shortens as it contracts. This is what most people think of as a muscle contraction.
- In *eccentric* contraction, the force generated is insufficient to overcome the external load on the muscle and the muscle fibers lengthen as they contract. An eccentric contraction is used as a means of decelerating a body part or object, or lowering a load gently rather than letting it drop.
- In *isometric* contraction, the muscle remains the same length. An example would be holding an object up without moving it; the muscular force precisely matches the load, and no movement results.
- In *isotonic* contraction, the tension in the muscle remains constant despite a change in muscle length. This can occur only when a muscle's maximal force of contraction exceeds the total load on the muscle.
- In *isovelocity* contraction (sometimes called "isokinetic"), the muscle contraction velocity remains constant, while force is allowed to vary. True isovelocity contractions are rare in the body, and are primarily an analysis method used in experiments on isolated muscles that have been dissected out of the organism.

In reality, muscles rarely perform under any sort of constant force, velocity, or speed, but these contractions are useful for understanding overall muscle properties present in more complex contractions that occur in vivo. Cyclic in vivo contractions can be modeled using work loops.

Smooth muscle contraction

The interaction of sliding actin and myosin filaments is similar in smooth muscle. There are differences in the proteins involved in contraction in vertebrate smooth muscle compared to cardiac and skeletal muscle. Smooth muscle does not contain troponin, but does contain the thin filament protein tropomyosin and other notable proteins - caldesmon and calponin. Contractions are initiated by the calcium-activated phosphorylation of myosin rather than calcium binding to troponin. Contractions in vertebrate smooth muscle are initiated by agents that increase intracellular calcium. This is a process of depolarizing the sarcolemma and extracellular calcium entering through L-type calcium channels, and intracellular calcium release predominately from the sarcoplasmic reticulum. Calcium release from the sarcoplasmic reticulum is from Ryanodine receptor channels (calcium sparks) by a redox process and Inositol triphosphate receptor channels by the second messenger inositol triphosphate. The intracellular calcium binds with calmodulin, which then binds and activates myosin light-chain kinase. The calcium-calmodulin-myosin light-chain kinase complex phosphorylates myosin on the 20 kilodalton (kDa) myosin light chains on amino acid residue-serine 19, initiating contraction and activating the myosin ATPase. The phosphorylation of caldesmon and calponin by various kinases is suspected to play a role in smooth muscle contraction.

Phosphorylation of the 20 kDa myosin light chains correlates well with the shortening velocity of smooth muscle. During this period, there is a rapid burst of energy utilization as measured by oxygen consumption. Within a few

minutes of initiation, the calcium level markedly decreases, the 20 kDa myosin light chains' phosphorylation decreases, and energy utilization decreases; however, force in tonic smooth muscle is maintained. During contraction of muscle, rapidly cycling crossbridges form between activated actin and phosphorylated myosin, generating force. It is hypothesized that the maintenance of force results from dephosphorylated "latch-bridges" that slowly cycle and maintain force. A number of kinases such as Rho kinase, Zip kinase, and Protein Kinase C are believed to participate in the sustained phase of contraction, and calcium flux may be significant.

Invertebrate smooth muscles

In invertebrate smooth muscle, contraction is initiated with calcium directly binding to myosin and then rapidly cycling cross-bridges generating force. Similar to vertebrate tonic smooth muscle, there is a low calcium and low energy utilization catch phase. This sustained phase or catch phase has been attributed to a catch protein that is similar to myosin light-chain kinase and titin, called twitchin.

Contractions

Concentric contraction

A **concentric contraction** is a type of muscle contraction in which the muscles shorten while generating force.

During a concentric contraction, a muscle is stimulated to contract according to the sliding filament mechanism. This occurs throughout the length of the muscle, generating force at the musculo-tendinous junction, causing the muscle to shorten and changing the angle of the joint. In relation to the elbow, a concentric contraction of the biceps would cause the arm to bend at the elbow and hand to move from near to the leg, to close to the shoulder (a biceps curl). A concentric contraction of the triceps would change the angle of the joint in the opposite direction, straightening the arm and moving the hand towards the leg.

Eccentric contraction

During an **eccentric contraction**, the muscle elongates while under tension due to an opposing force being greater than the force generated by the muscle.[3] Rather than working to pull a joint in the direction of the muscle contraction, the muscle acts to decelerate the joint at the end of a movement or otherwise control the repositioning of a load. This can occur involuntarily (when attempting to move a weight too heavy for the muscle to lift) or voluntarily (when the muscle is 'smoothing out' a movement). Over the short-term, strength training involving both eccentric and concentric contractions appear to increase muscular strength more than training with concentric contractions alone.[4]

During an eccentric contraction of the biceps muscle, the elbow starts the movement while bent and then straightens as the hand moves away from the shoulder. During an eccentric contraction of the triceps muscle, the elbow starts the movement straight and then bends as the hand moves towards the shoulder. Desmin, titin, and other z-line proteins are involved in eccentric contractions, but their mechanism is poorly understood in comparison to cross-bridge cycling in concentric contractions.[3]

Muscles undergoing heavy eccentric loading suffer greater damage when overloaded (such as during muscle building or strength training exercise) as compared to concentric loading. When eccentric contractions are used in weight training, they are normally called *negatives*. During a concentric contraction, muscle fibers slide across each other, pulling the Z-lines together. During an eccentric contraction, the filaments slide past each other the opposite way, though the actual movement of the myosin heads during an eccentric contraction is not known. Exercise featuring a heavy eccentric load can actually support a greater weight (muscles are approximately 10% stronger during eccentric contractions than during concentric contractions) and also results in greater muscular damage and delayed onset muscle soreness one to two days after training. Exercise that incorporates both eccentric and concentric muscular contractions (i.e. involving a strong contraction and a controlled lowering of the weight) can

produce greater gains in strength than concentric contractions alone.[4] [5] While unaccustomed heavy eccentric contractions can easily lead to overtraining, moderate training may confer protection against injury.[4]

Eccentric contractions in movement

Eccentric contractions normally occur as a braking force in opposition to a concentric contraction to protect joints from damage. During virtually any routine movement, eccentric contractions assist in keeping motions smooth, but can also slow rapid movements such as a punch or throw. Part of training for rapid movements such as pitching during baseball involves reducing eccentric braking allowing a greater power to be developed throughout the movement.

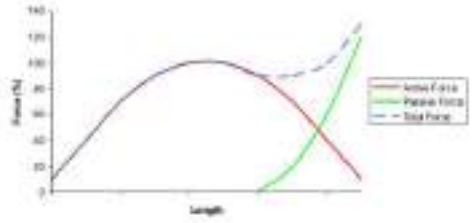
Eccentric contractions are being researched for their ability to speed rehab of weak or injured tendons. Achilles tendinitis has been shown to benefit from high-load eccentric contractions.[6] [7]

Isometric contraction

An **isometric contraction** of a muscle generates force without changing length. An example can be found when the muscles of the hand and forearm grip an object; the joints of the hand do not move, but muscles generate sufficient force to prevent the object from being dropped.

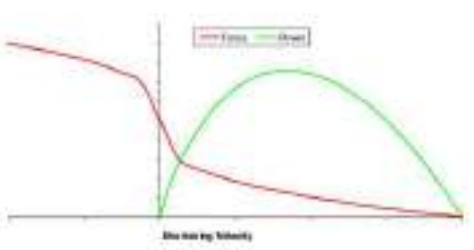
Force-length and Force-velocity relationships

Unlike mechanical systems such as motors, the force a muscle can generate depends upon both the length and shortening velocity of the muscle.



Muscle length vs. Force.

Force-Length relationship, also called the Length-Tension curve, relates the strength of an isometric contraction to the length of the muscle at which the contraction occurs. Muscles operate with greatest active force when close to an ideal length (often their resting length). When stretched or shortened beyond this (whether due to the action of the muscle itself or by an outside force), the maximum active force generated decreases[8] . This decrease is minimal for small deviations, but the force drops off rapidly as the length deviates further from the ideal. As a result, in most biological systems, the range of muscle contraction will remain on the peak of the length-tension curve, in order to maximize contraction force. Due to the presence of elastic proteins within a muscle, as the muscle is stretched beyond a given length, there is an entirely passive force, which opposes lengthening. Combined together, we see a strong resistance to lengthening an active muscle far beyond the peak of active force.



Muscle shortening velocity vs. Force & Power.

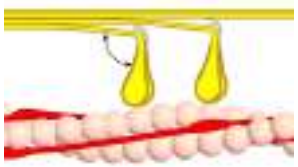
Force-Velocity relationship: The speed at which a muscle changes length (usually regulated by external forces, such as load or other muscles) also affects the force it can generate. Force declines in a hyperbolic fashion relative to the isometric force as the shortening velocity increases, eventually reaching zero at some maximum velocity. The reverse holds true for when the muscle is stretched - force increases above isometric maximum, until finally reaching an absolute maximum. This has strong implications for the rate at which muscles can perform mechanical work (power). Since power is equal to force times velocity, the muscle generates no power at either isometric force (due to zero velocity) or maximal velocity (due to zero force). Instead, the optimal shortening velocity for power generation is approximately one-third of maximum shortening velocity.

These two fundamental properties of muscle have numerous biomechanical consequences, including limiting running speed, strength, and jumping distance and height.

See also

- Exercise physiology
- Cramp
- Dystonia
- Fasciculation
- Hypnic jerk
- In_vitro_muscle_testing
- Myoclonus
- Spasm
- Supination

Additional images



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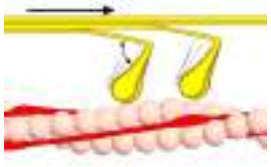

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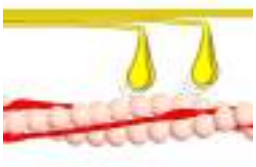
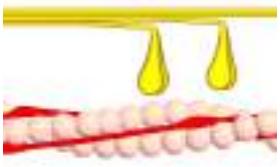


Phase 3



Phase 4

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External links

- Animation: Myofilament Contraction (http://highered.mcgraw-hill.com/sites/0072495855/student_view0/chapter10/animation__myofilament_contraction.html)

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SENSE ORGANS HANDOUT

Sensory Receptors **-** receive input, generate receptor potentials and with enough summation, generate action potentials in the neurons they are part of or synapse with

5 Types of Sensory Receptors - based on the type of stimuli they detect:

1. **Mechanoreceptors** - pressure receptors, stretch receptors, and specialized mechanoreceptors involved in movement and balance.
2. **Thermoreceptors** - skin and viscera, respond to both external and internal temperature
3. **Pain receptors** - stimulated by lack of O_2, chemicals released from damaged cells and inflammatory cells
4. **Chemoreceptors** - detect changes in levels of O_2, CO_2, and H^+ ions (pH) as well as chemicals that stimulate taste and smell receptors
5. **Photoreceptors** - stimulated by light

Distribution of Receptors in the body:

Special Senses

- mediated by relatively complex sense organs of the head, innervated by cranial nerves
- vision, hearing, equilibrium, taste and smell

General (somesthetic, somatosensory)

- receptors widely distributed in skin, muscles, tendons, joints, and viscera
- they detect touch, pressure, stretch, heat, cold and pain, blood pressure

Special Senses

Sensation and perception

- Vision – Eye
- Hearing – Ear
- Equilibrium – Ear
- Taste – Taste receptors
- Smell – Olfactory system

General Senses

- Skin – Hot, cold, pressure, pain
- Muscles, joints, and tendons – proprioceptors- stretch receptors respond to stretch or compression
- Pain Receptors – somatic or visceral

SPECIAL SENSES

Eye - Vision

Processes

- Light energy is transduced into neural activity
- Neural activity is processed by the brain
- ***Note:*** For an analogy, you can imagine taking a picture with a camera. The eye is the camera, the retina, which is a specialized part of the brain at the back of the eye, is the film, and the parts of the brain that process visual information is the photoshop.

Human visual systems permit light reflected off distant objects to be:

- Localized relative to the individual within his or her environment
- Identified based on size, shape, color, and past experience
- Perceived to be moving (or not)
- Detected in a wide variety of lighting conditions

Sequence of events

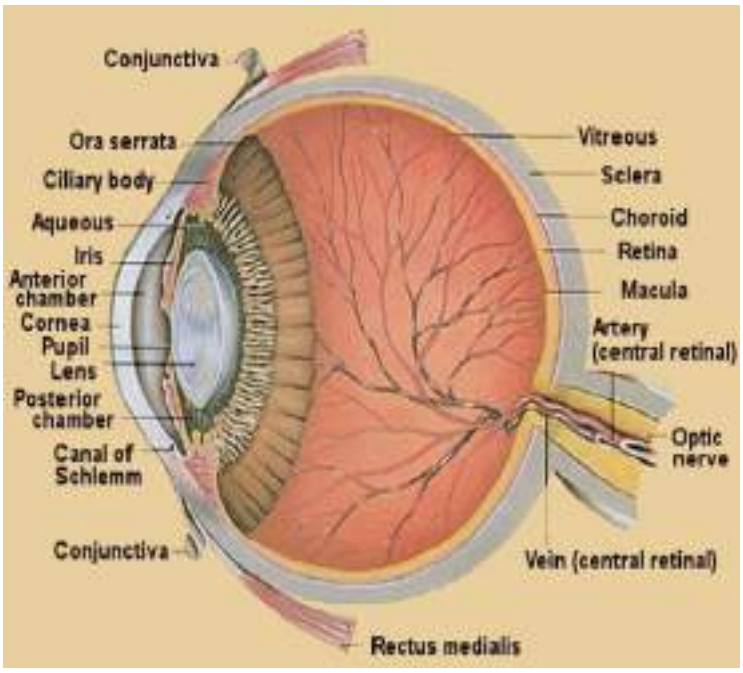
- Light entering the eye is focused on the retina
- Retina converts light energy into neuronal activity
- Axons of the retinal neurons are bundled to form the optic nerves
- Visual information is distributed to several brain structures that perform different functions

Eye – the organ used to sense light

Three layers –

1. ***Outer layer*** consists of sclera and cornea
2. ***Middle layer*** consists of choroid, ciliary body and iris
3. ***Inner layer*** consists of retina

Extraocular muscles--attached to the eye and skull and allow movement



Anatomy of the Eye

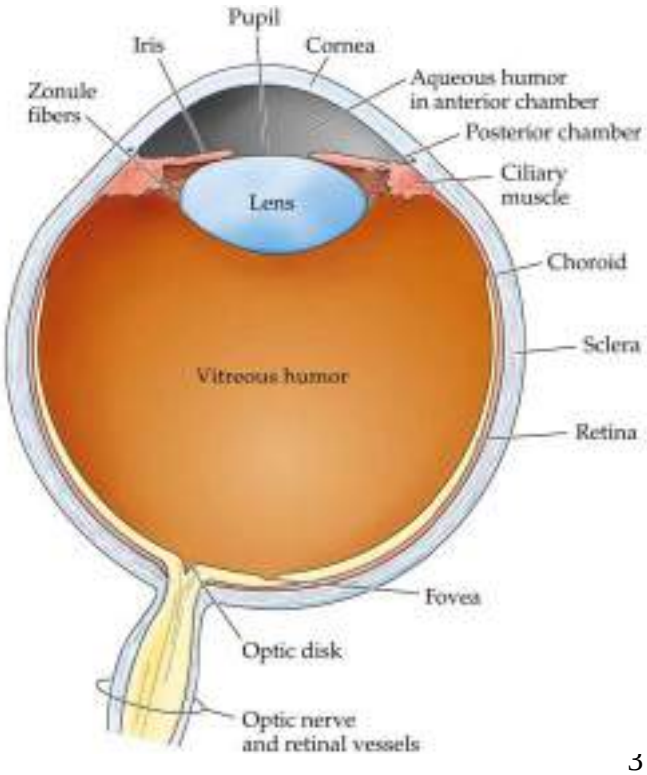
Gross anatomy

Functions of the major parts of the eye:

- **Sclera or Scleroid Layer – (white of eye)** the outermost layer that forms the eyeball- a tough protective layer of connective tissue that helps maintain the shape of the eye and provides an attachment for the muscles that move the eye
- **Conjunctiva**--membrane inside the eyelid attached to the sclera
- **Cornea** - the transparent surface covering the iris and pupil- a clear, dome-shaped part of the sclera covering the front of the eye through which light enters the eye
- **Anterior Chamber** – a small chamber between the cornea and the pupil
- **Aqueous Humor** - fluid behind the cornea - the clear fluid that fills that anterior chamber of the eye and helps to maintain the shape of the cornea providing most of the nutrients for the lens and the cornea and involved in waste management in the front of the eye
- **Choroid Layer** - middle layer of the eye containing may blood vessels
- **Ciliary Body** - the ciliary body is a circular band of muscle that is connected and sits immediately behind the iris- produces aqueous humor, changes shape of lens for focusing, and
- **Iris** - circular muscle that controls the diameter of the pupil - the pigmented front portion of the choroid layer and contains the blood vessels - it determines the eye color and it controls the amount of light that enters the eye by changing the size of the pupil (an albino only has the blood vessels – not pigment so it appears red or pink because of the blood vessels)
- **Lens** - a crystalline structure located just behind the iris - it focuses light onto the retina
- **Pupil** - the opening in the center of the iris- it changes size as the amount of light changes (the more light, the smaller the hole) and it allows light to reach the retina
- **Vitreous** - a thick, transparent liquid that fills the center of the eye - it is mostly water and gives the eye its form and shape (also called the **vitreous humor**)
- **Retina** - axons of the retina leaving the eye - sensory tissue that lines the back of the eye. It contains millions of photoreceptors (**rods for black & white and cones for color**) that convert light rays into electrical impulses that are relayed to the brain via the optic nerve
- **Optic nerve** - the nerve that transmits electrical impulses from the retina to the brain

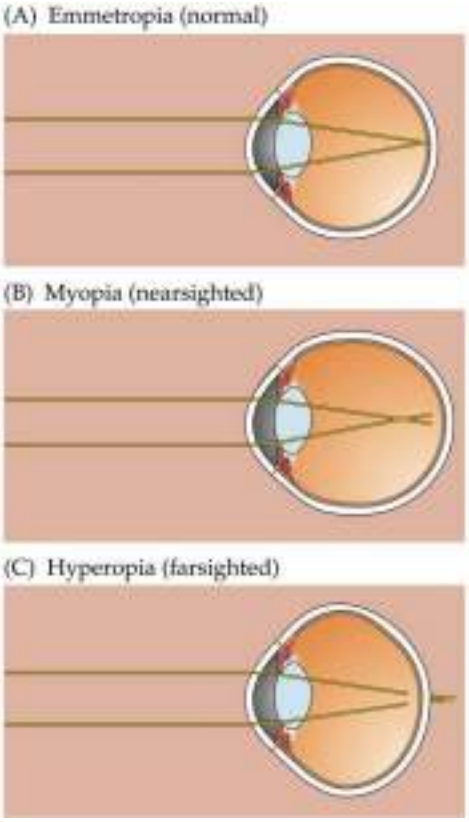
Opthalmoscopic appearance (Retina as seen through the pupil)

- **Note:** in photographs, the red appearance of the eye is actually the retina photographed. Double flash camera causes the pupil to constrict.
- **Optic disk (blind spot)**--no vision is possible
  - Blood vessels originate here. The vessels shadow the retina
  - Optic nerve fibers exit here
  - No photoreceptors
- **Macula**--area of the retina responsible for central vision (vs. peripheral)
- **Fovea**--center of the retina (where most of the cones are)



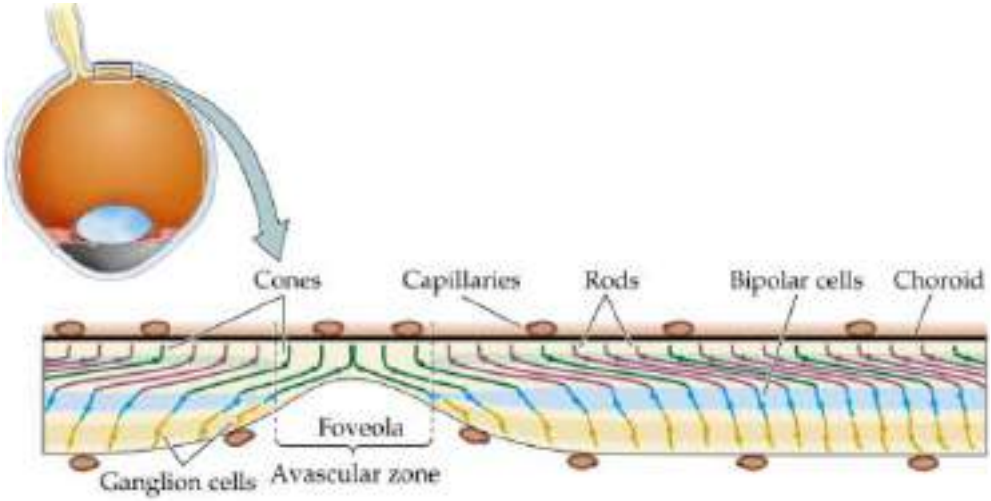
Common eye defects include

- **myopia** or nearsightedness where the eyeball is too long or the cornea is too steep;
- **hyperopia** or far sightedness where the eyeball is short or lens cannot become round enough:
- **presbyopia** where the muscles controlling the bulging of the lens become weak as we age;
- **cataracts** where the lens becomes fogged;
- **nyctalopia** or night blindness where vision is impaired in dim light and in the dark due to pigment rhodospin in the rods not functioning properly External features of the eye



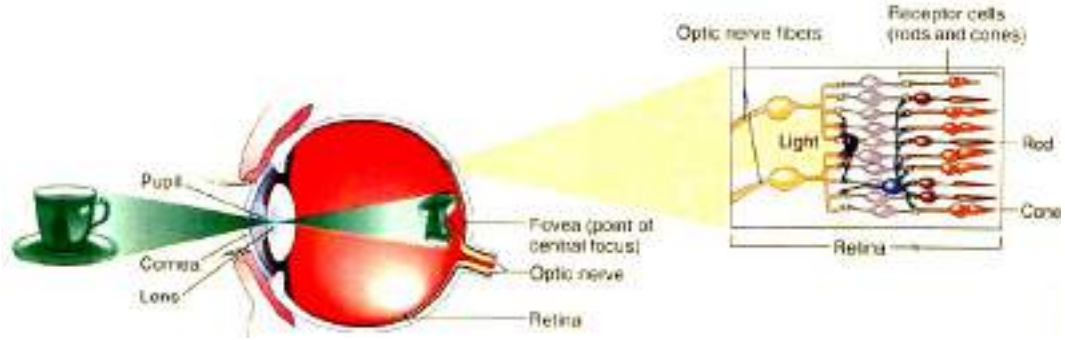
Cross sectional anatomy

- **Lens**--transparent surface that contributes to the formation of images (w/i 9 meters)
- **Ciliary muscles**--change the shape of the lens and allow focusing
- **Vitreous humor**--more viscous than the aqueous humor - Lies between the lens and the retina and provides spherical shape
- **Retina** - inner most layer of cells at the back of the eye - Transduces light energy into neural activity

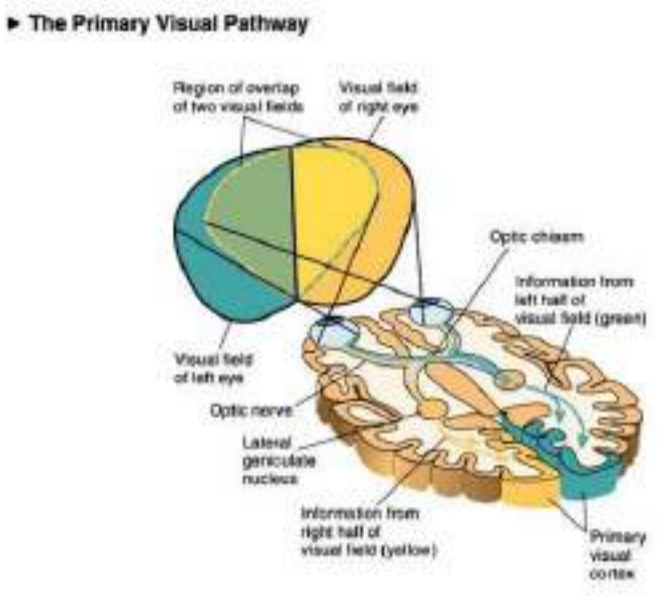


Images

- the cornea and the lens help to produce the image on the retina
- images formed by the lens are upside down and backwards when they reach the retina
- two types of receptors on the retina
- **Rods** – 125 million on a single retina – extremely sensitive to all wavelengths of visible light but do not distinguish different color – in dim light only rods are activated where one can see objects but not as sharp images and are not able to distinguish their color – most dense in peripheral view – **nighttime vision** Rods have a pigment called rhodospin
- As amount of light increases, the **cones** – 7 million on a single retina – mainly in central view are stimulated and the color becomes clear – **daytime vision**
- There are three types of cones which distinguish the three colors – blue, red, green
- **Fovea** – point of central focus – great density of cones - center of the eye's sharpest vision and the location of most color perception - the layers of the retina spread aside to let light fall directly on the cones



- Light stimulates rods and cones and sends impulse via optic nerve to brain areas for vision
- The Optic Nerve exits the eye just off center near the Fovea - the Optic Nerve exits is referred to as the Blind Spot due to the lack of the receptors in this area
- The two Optic Nerves come together at the **Optic Chiasm** located just under the hypothalamus - a crucial part of vision and perception must happen - cross-over of information from the right eye crosses over to the left side and visa versa happens here at the Optic Chiasm
- Information from each eye must be processed in both halves of the brain
- Information leaves the chiasm via the optic tract.
- Reorganized optic tract leaves the Optic Chiasm and passes onto the lateral geniculate nucleus
- At the lateral geniculate nuclei the information is separated, organized, and relayed to different areas of the visual cortex
- The different zones of the visual cortex process the different aspects of vision and information, taken from both visual fields, is processed and an image is perceived

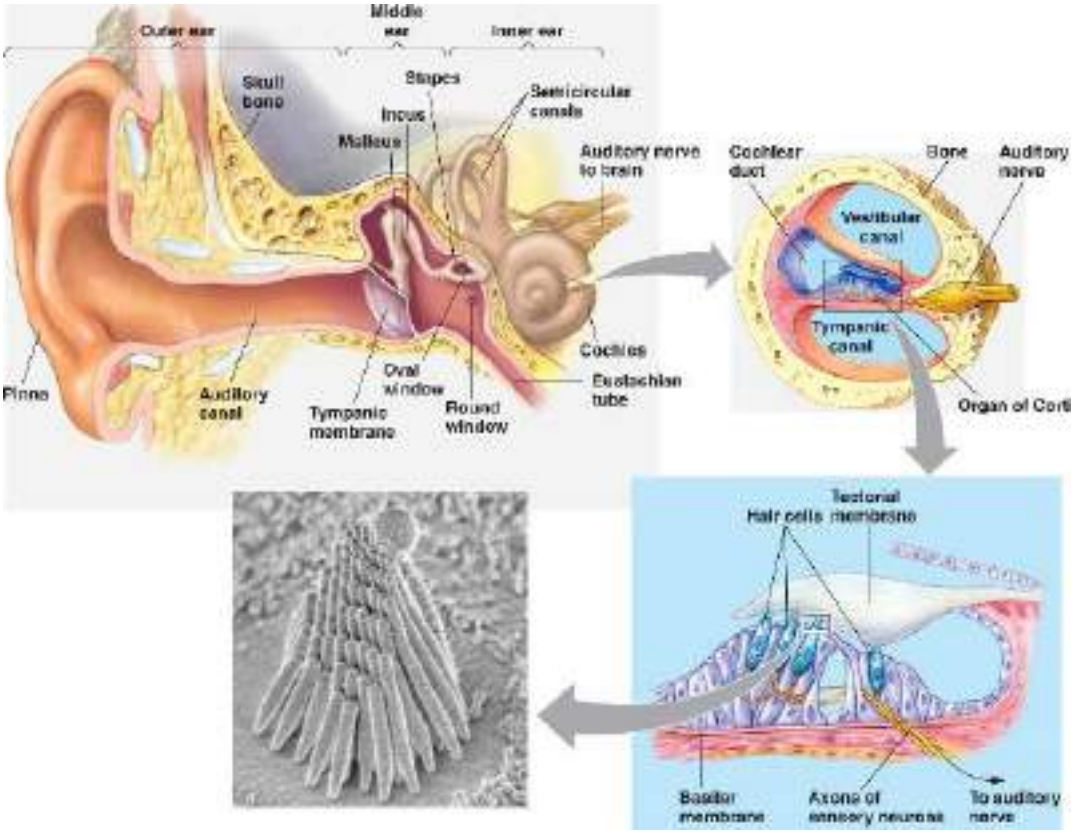


EAR – HEARING

Outer Ear & ear canal – brings sound into eardrum
Eardrum – vibrates to amplify sound & separates inner and middle ear
Middle ear has 3 small bones or **Ossicles =** anvil, stirrup, stapes – amplify sound (small bones) which vibrate sound
Eustachian tube – connects middle ear to throat and equalizes pressure on eardrum
Cochlea – in inner ear – has receptors for sound & sends signals to brain via Auditory Nerve

Process of hearing:

- Sound waves enter your outer ear and travel through your ear canal to the middle ear.
- The ear canal channels the waves to your eardrum, a thin, sensitive membrane stretched tightly over the entrance to your middle ear.
- The waves cause your eardrum to vibrate.
- It passes these vibrations on to the hammer, one of three tiny bones in your ear. The hammer vibrating causes the anvil, the small bone touching the hammer, to vibrate. The anvil passes these vibrations to the stirrup, another small bone which touches the anvil. From the stirrup, the vibrations pass into the inner ear.
- The stirrup touches a liquid filled sack and the vibrations travel into the cochlea, which is shaped like a shell.
- Inside the cochlea, a vestibular system formed by three semicircular canals that are approximately at right angles to each other and which are responsible for the sense of balance and spatial orientation. It has chambers filled with a viscous fluid and small particles (**otoliths**) containing calcium carbonate. The movement of these particles over small hair cells in the inner ear sends signals to the brain that are interpreted as motion and acceleration. The brain processes the information from the ear and lets us distinguish between different types of sounds.



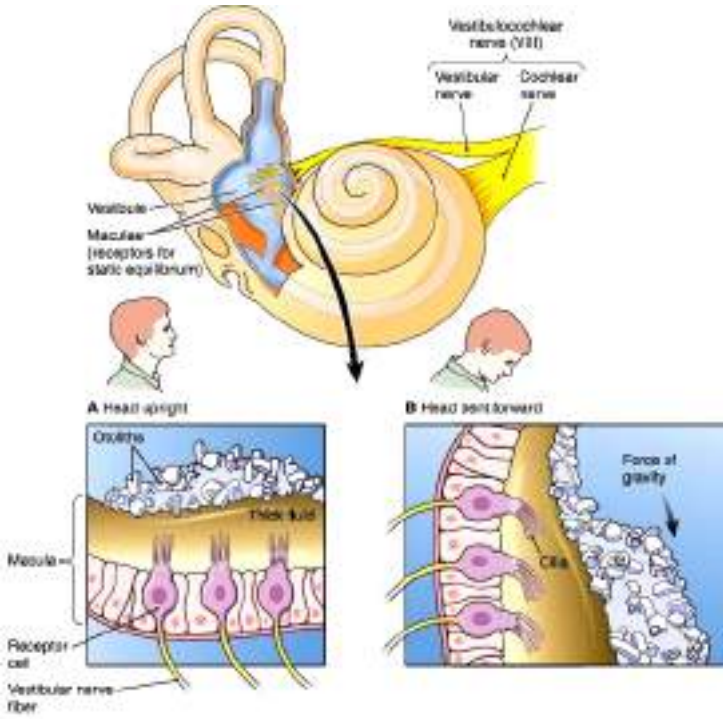
Ear – Equilibrium

Equilibrium

- Equilibrium is a response to movements of the head - Example: a cat landing on its feet if dropped from upside down
- Vestibular Apparatus: the equilibrium receptors of the inner ear
- Divided into static and dynamic equilibrium

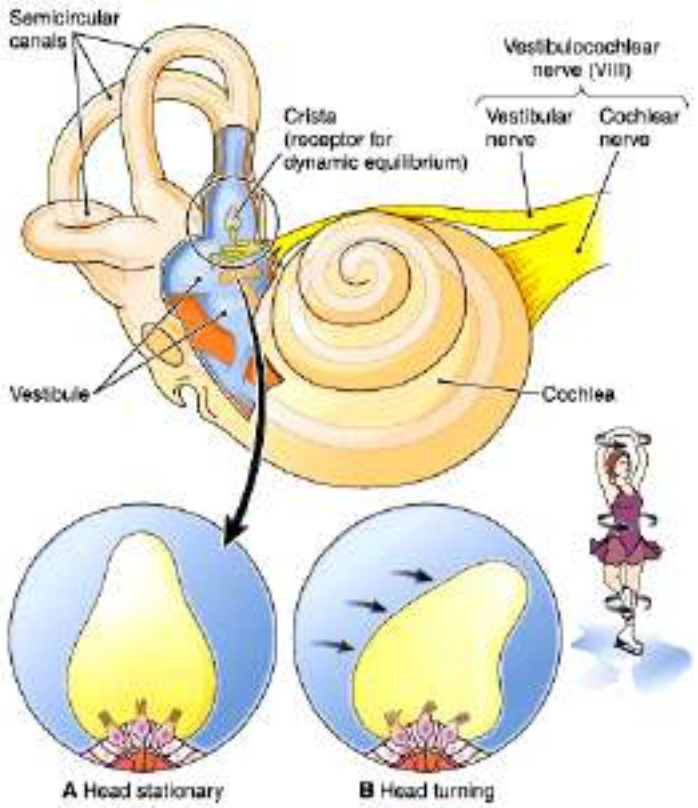
Static Equilibrium

- When the body is not moving
- **Maculae**: receptors within the membrane sacs of the vestibule that report on the position of the head with respect to the pull of gravity when the body is not moving.
- Each macula is a patch of receptor cells with their "hairs" embedded in the otolithic membrane
- **Otolithic Membrane**: a jelly-like substance containing otoliths
- **Otoliths**: tiny stones made of calcium salts that roll in response to changes in the pull of gravity.
  When otoliths move, they pull on the gel and this bends the hairs.
  Activated hair cells send impulses along the vestibular nerve
- **Vestibular Nerve:** (Cranial Nerve VIII) transmits signals to the cerebellum



Dynamic Equilibrium

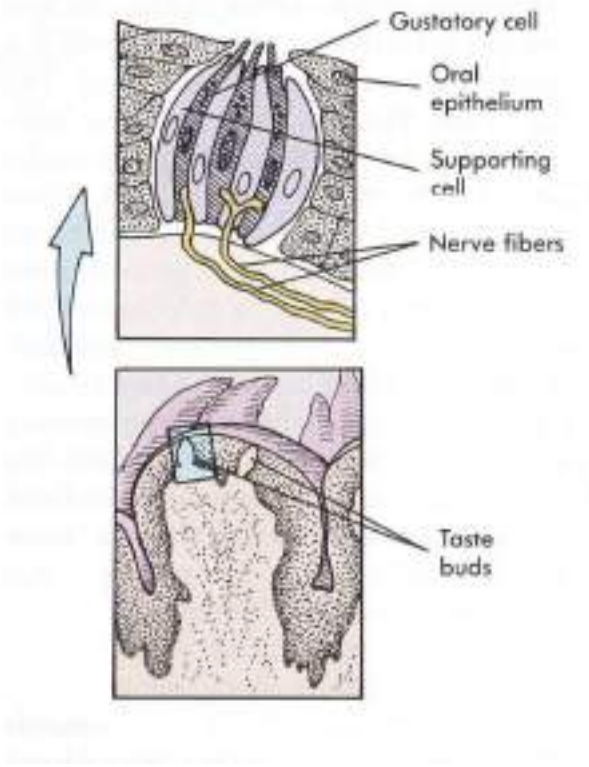
- Receptors in the semicircular canals respond to angular or rotary movements of the head.
- Semicircular canals are oriented in the three planes of space
- **Crista Ampullaris**: receptor region that consists of a tuft of hair cells covered with a gelatinous cap called the **cupula**
- When the head moves in an angular direction:
  - The endomlymph lags behind
  - As the cupula drags against the stationary endolymph, the cupula bends
  - This stimulates hair cells to transmit signals to the vestibular nerve
- When you are moving at a constant rate, receptors stop sending impulses
- You no longer have the sensation of motion until you change speed or direction



Vision plays a significant role in balance. Approximately twenty percent of the nerve fibers from the eyes interact with the vestibular system.

Taste and Smell – Chemical Receptors

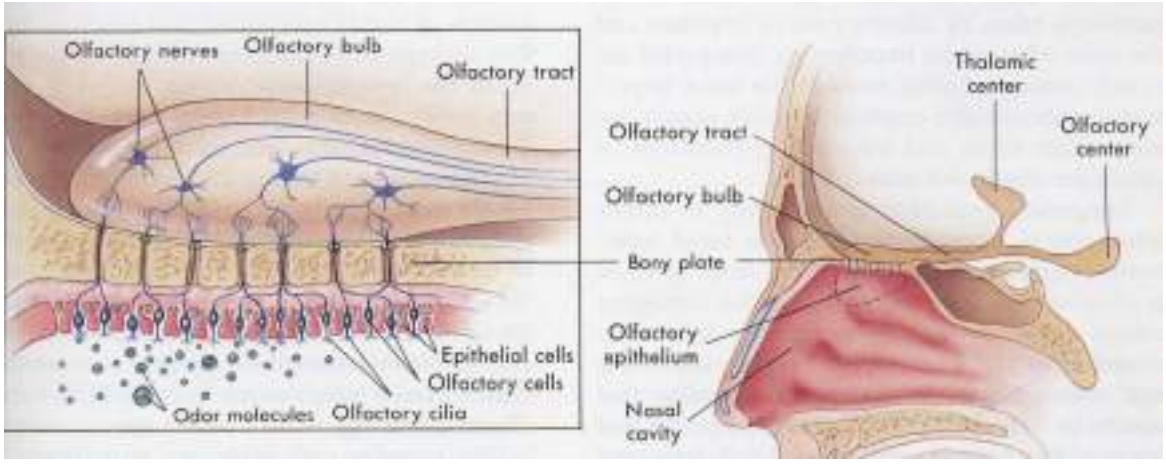
Taste buds



- The mouth contains around 10,000 taste buds, most of which are located on and around the tiny bumps on your tongue.
- Every taste bud detects **five primary tastes**:
  - Sour
  - Sweet
  - Bitter
  - Salty
  - Umami - salts of certain acids (for example monosodium glutamate or MSG)
- Each of your taste buds contains 50-100 specialised receptor cells.
- Sticking out of every single one of these receptor cells is a tiny taste hair that checks out the food chemicals in your saliva.
- When these taste hairs are stimulated, they send nerve impulses to your brain.
- Each taste hair responds best to one of the five basic tastes.

Smell Receptors or Olfactory receptors

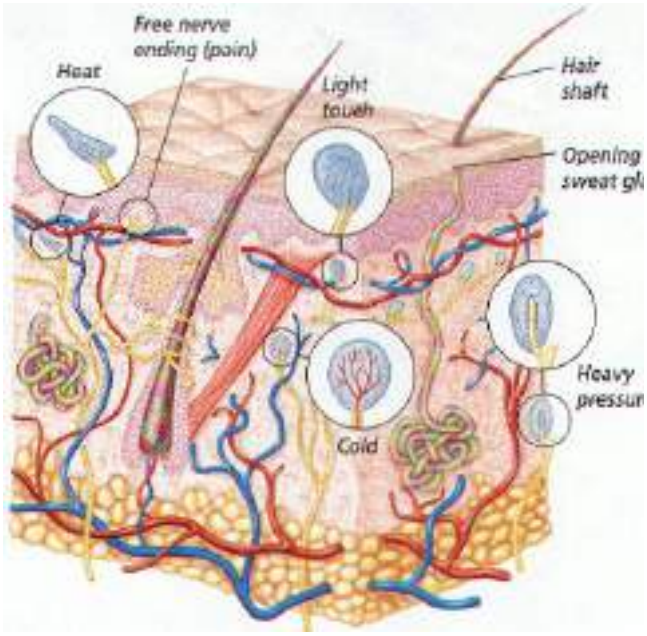
- Humans able to detect thousands of different smells
- Olfactory receptors occupy a stamp-sized area in the roof of the nasal cavity, the hollow space inside the nose
- Tiny hairs, made of nerve fibers, dangle from all your olfactory receptors. They are covered with a layer of mucus.
- If a smell, formed by chemicals in the air, dissolves in this mucus, the hairs absorb it and excite your olfactory receptors.
- A few molecules are enough to activate these extremely sensitive receptors.
- Olfactory Hairs easily fatigued so you do not notice smells
- Linked to memories - when your olfactory receptors are stimulated, they transmit impulses to your brain and the pathway is directly connected to the limbic system - the part of your brain that deals with emotions so you usually either like or dislike a smell
- Smells leave long-lasting impressions and are strongly linked to your memories
- **Much of what we associate as taste also involves smell – that is why hot foods "taste" different than "cold" foods**



General Senses

Skin receptors*:*

Your skin and deeper tissues contain millions of sensory receptors. Most of your touch receptors sit close to your skin's surface.

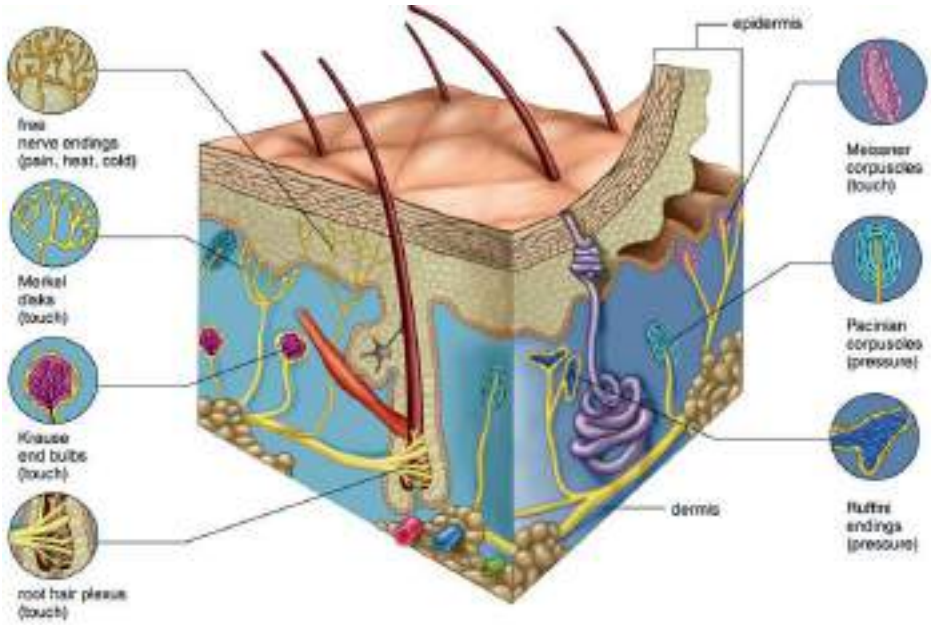


Touch Receptors – fine touch

- **Meissner's corpuscles** are enclosed in a capsule of connective tissue
- They react to light touch and are located in the skin of your palms, soles, lips, eyelids, external genitals and nipples
- these areas of your body are particularly sensitive.
- **Merkel disks** – found deep at junction of epidermis and dermis
- Root hair plexus – at base of hair follicle

Touch receptors – Pressure sensitive

- **Pacinian corpuscles** sense pressure and vibration changes deep in your skin.
- Every square centimeter of your skin contains around 14 pressure receptors
- **Pacinian corpuscles** – deep pressure sensors, onion shaped capsule (layers of Schwann cells enclosed in a connective tissue membrane), respond to *on-off* pressure or *vibration*
- **Ruffini's endings** and **Krause's end bulbs** – encapsulated pressure sensors, dermis (and elsewhere), respond to *continuous* pressure



Pain

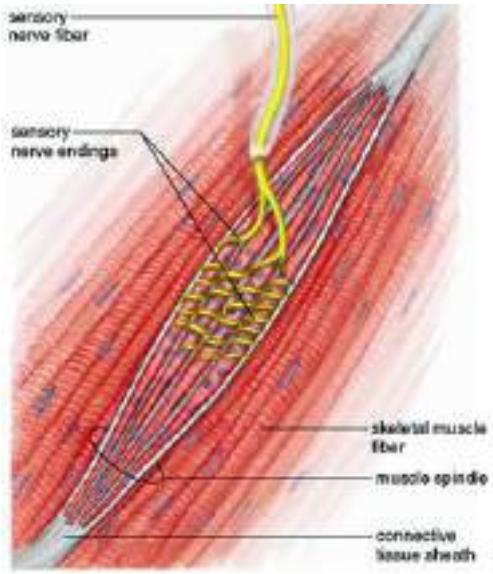
- skin receptors register pain
- pain receptors are the most numerous
- each square centimeter of your skin contains around 200 pain receptors

Temperature

- skin receptors register warmth and cold
- each square centimeter of your skin contains 6 receptors for cold and 1 receptor for warmth
- **Cold receptors** start to perceive cold sensations when the surface of the skin drops below 95 º F. They are most stimulated when the surface of the skin is at 77 º F and are no longer stimulated when the surface of the skin drops below 41 º F. This is why your feet or hands start to go numb when they are submerged in icy water for a long period of time.
- **Hot receptors** start to perceive hot sensations when the surface of the skin rises above 86 º F and are most stimulated at 113 º F. Beyond 113 º F, pain receptors take over to avoid damage being done to the skin and underlying tissues.
- thermoreceptors are found all over the body, but cold receptors are found in greater density than heat receptors – most of the time of our environment is colder than our body temperature
- The highest concentration of thermoreceptors can be found in the face and ears so your nose and ears always get colder faster than the rest of your body on a chilly winter day

Proprioceptors - Stretch receptors located in joints, ligaments, and tendons (respond to either stretch or compression)

- Maintain some degree of continuous contraction (partial sustained contraction) or **muscle tone**
- **Muscle spindles** – modified muscle fibers with sensory nerve endings wrapped around the middle (and also found at the ends)
- Detect stretch and stimulate a reflex contraction; think about banging on your patellar ligament (just an extension of a quadriceps tendon) and watching your knee jerk up – the quadriceps contracted in response to the stretch of the patellar ligament, which stretched muscle spindles and) impulses are sent to the hamstring group (the antagonists) to cause them to relax, so they don't oppose the contraction of the quadriceps



Pain Receptors – nociceptors

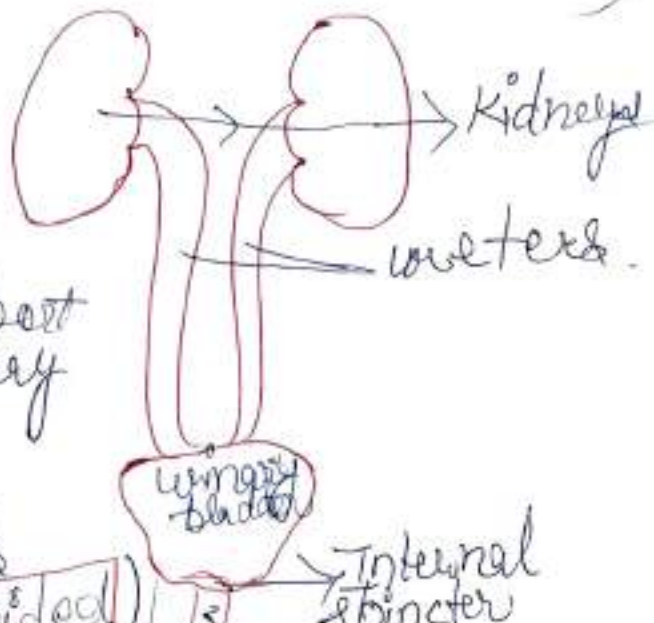
- **Somatic nociceptors -** from skin and skeletal muscle
- **Visceral nociceptors -** receptors that help maintain internal homeostasis
  - Respond to stretch, lack of O_2, chemicals released from damaged cells and inflammatory cells.
  - ***Referred pain*** – visceral pain afferents travel along the same pathways as somatic pain afferents, so sometimes the brain interprets the visceral pain as the more common somatic pain. Example – Often pain from the heart felt during a heart attack is perceived as a pain that originates in the left arm.

Urinary System

Main excretory system (produce, stores and eliminates urine). Blood (1 barrel/min)

Renal System

A pair of kidneys (which produce and secrete urine)



⇓

A pairs of ureters (transport urine from kidneys to urinary bladder).

⇓

A urinary bladder (collects & store urine untill it is voided)

⇓ Transfuse

urethra (urine is voided from urinary bladder through urethra)

urine :- Clear, amber (due to urobilin) coloured
Specific gravity :- 1020–1030
pH :- around 6 (4.5 to 8)

⇒ A healthy adult passes around 1000–1500ml of urine per day.

Composition of urine ⇒

water (96%)	uric acid	Chlorides
urea (2%)	creatinine	Phosphates
	Ammonia	Sulphates
	Sodium	Oxalates
	Potassium	

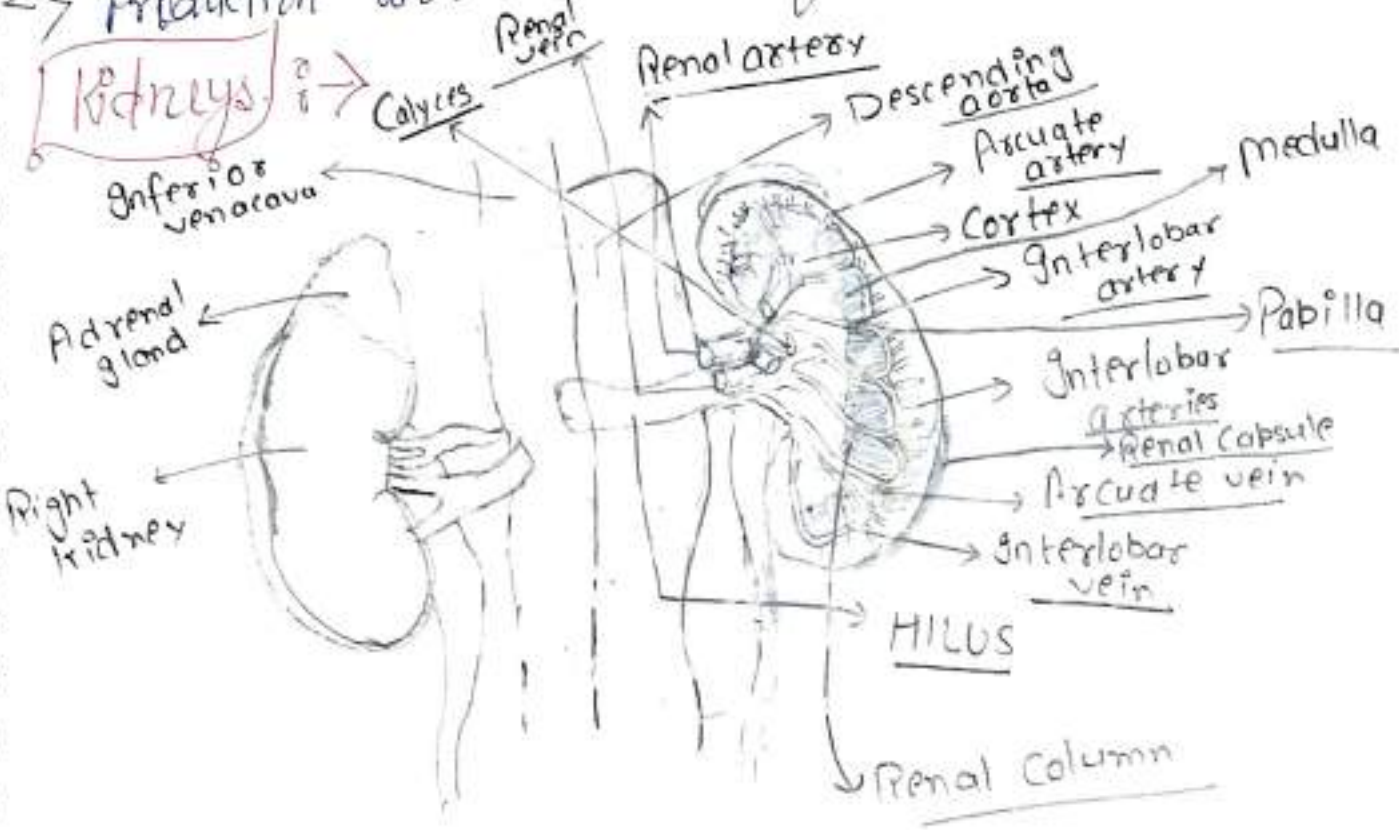
2%

⇒ urine output is controlled by ADH from posterior pituitary.

Functions of urinary system -

- Formation of urine
- maintain water - electrolytes, acid-base balance.
- Production and secretion of Erythropoietin.
- Production and secretion of Renin.

Kidneys :-



⇒ Kidneys are bean-shaped organs of the renal system

⇒ 11cm long, 6cm wide, 3cm thick

⇒ weight → 150g. 1) Male (125-170g) 2) Female (115-155g)

Location :- Lie on the posterior abdominal wall, one on each side of the vertebral column, below the diaphragm. Right kidney posterior to liver, left posterior spleen.

⇒ T12 - L3 (Right kidney slightly lower than left because of space occupied by the liver.

*Functions of Kidneys:- formation of urine
⇒ Maintain water-electrolyte ballance (acid-base balance)
⇒ Production and secretion of erythropoietin and renin.

Gross structure of kidney:-
longitudinal section → three areas of tissue.

- Outer fibrous capsule
- Cortex (reddish brown)
- Inner medulla (pyramids)

Take the shape of 18 cones shaped renal lobes.

⇒ They produce urine through which waste materials such as urea and ammonia are excreted.
⇒ It also performs some secretary functions. eg. Calcitriol, erythropoietin and renin.

⇒ Nephrons → urine producing functional and structural unit of the kidneys.
and medulla.

Pyramides:- Pale, conical shaped steriations.

Hilum:- (concave border), renal artery, renal vein and ureter

urine formed passes through renal papilla → minor calyx → major calyx → renal pelvis → Becomes the ureter

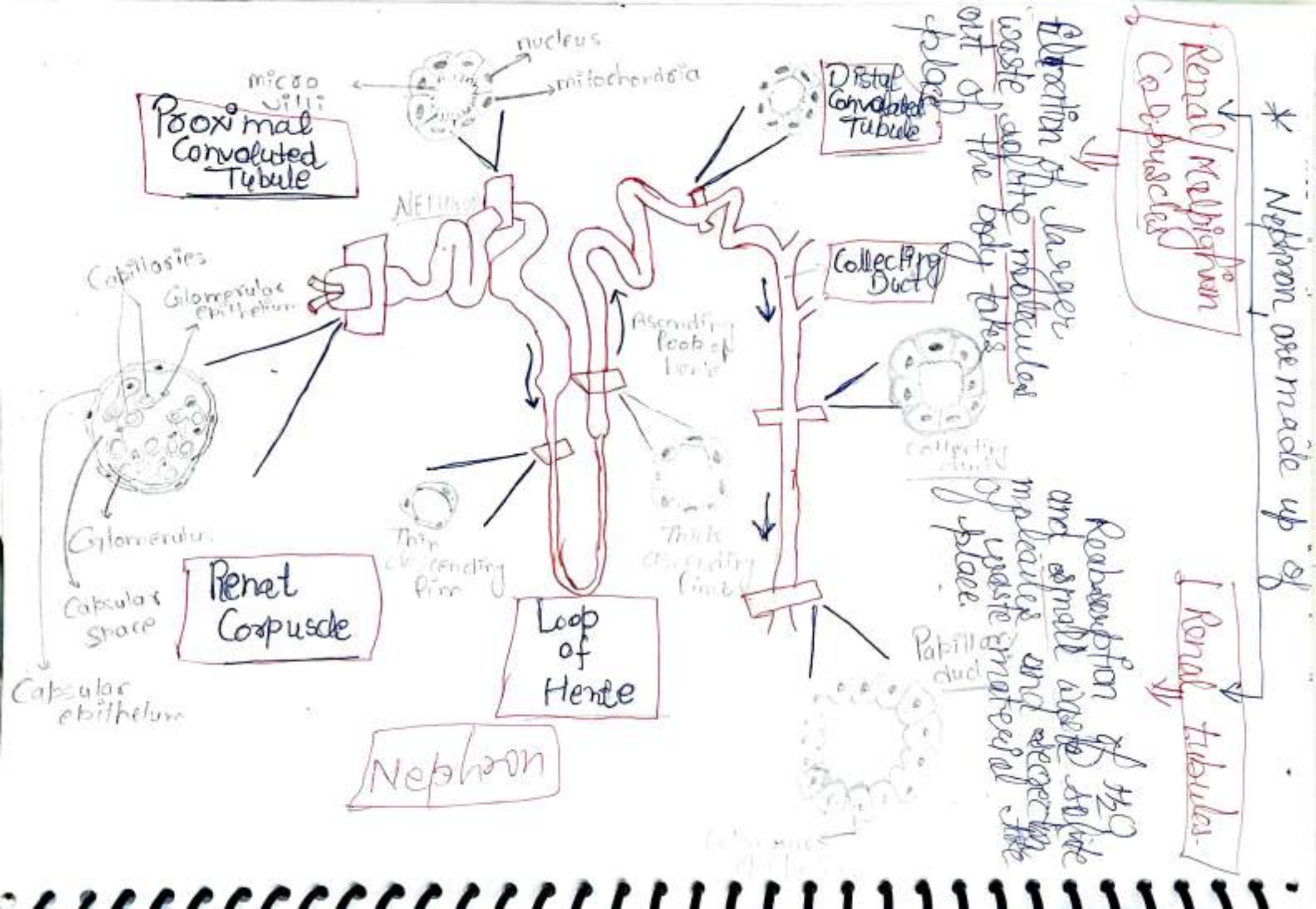
Functions of Kidney:-

- Regulate the conc^{n} of Na^+, K^+, Ca^{2+}, Cl^- in the blood.
- Regulation of Blood pH.
- Regulation of blood volume.
- Regulation BP.
- Regulation Blood osmolarity.
- Production of hormones
- Regulation Blood glucose level
- Excretion of waste and foreign substance

Nephron :- It is the basic structural and functional unit of kidney. It filtered the waste products from the blood. Reabsorbs the required nutrients in to the body. It regulate the water and sodium salt conc^{n} in the blood.

Types of nephrons

1. Cortical N.
   - renal corpuscles present near the renal cortex
2. Juxtamedullary N.
   - Renal corpuscles present near the renal medulla


Nephron are made up of
Renal Medigion Corpuscles
Renal Tubules
Elimination of larger molecular waste out of the body from blood
Reabsorption of H2O and small waste molecules and selective waste emptied from the body
Proximal Convoluted Tubule
Distal Convoluted Tubule
Collecting Duct
Renal Corpuscle
Loop of Henle
Nephron
Capillaries
Glomerular Epithelium
Glomerulus
Capsular Space
Capsular epithelium
micro villi
nucleus
mitochondria
Ascending Limb of Loop
Thin descending limb
Thick ascending limb
Collecting duct
Papillary duct

Malpighian corpuscles.

* It is also known as malpighian body.
* It involved in the initial filtering of components.

=> Each M.C. is made up of

- Glomerulus
- Bowman's/Glomerular capsule

(1) Glomerulus :=> It is the mass of the capill. aries which is supplied with blood by an afferent arteries of the renal circulation.

=> Blood pressure with in the glomerulus provides the driving force for H_2O and solutes to be filtered out of the blood and reach the Bowman's capsule.

=> The remaining blood passes into the efferent arteriole.

=> Blood along with reabsorbed substances reaches the vasa recta (collecting capillaries attached to the convoluted tubules

=> The vasa recta and the efferent venules coming from others nephroons combine to join the renal vein and the main blood circulation.

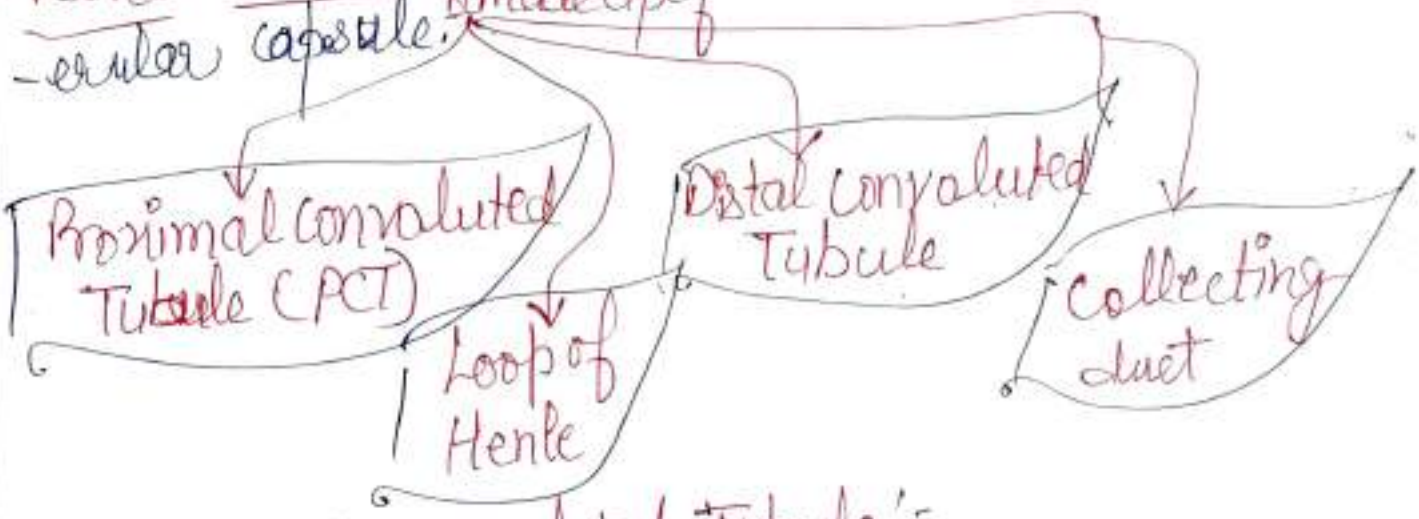
(2) Bowman's or glomerular Capsule:-

=> It is the capsules surrounds the glomerulus

=> It is made up of visceral inner layer contains single layer of flat cells called podocytes. ~~simple squamous epithelium~~

→ Parietal outer layer – contain single layer of flat cells called simple squamous epithelium
→ Fluids from the glomerulus blood for filter through the podocytes.
→ The glomerular filtrate is then processed along the nephron to form urine.

*Renal Tubule:- This can tubule exits the glomerular capsule. It made up of



① Proximal convoluted Tubule:-
⇒ It is the inital and longest sub-division of the renal tubule through which the glomerular filtrate flows.
⇒ It is made up of simple cuboidal epithelial cells.
⇒ They have prominent microvilli projecting into the lumen of the proximal tubule.
⇒ These microvilli forms brush-border which ↑ses the surface area.

2) Loop of Henle:-
⇒ This loop recieves the remaining glomerular filtrate.
⇒ It is the only part of the renal tubule which dips into the renal medulla.
⇒ The loop of henle is sub divided into the following two limbs.

Descending loop of Henle | Ascending loop of Henle

(a) Descending loop of Henle:→
⇒ This loop travels towards the renal medulla and turns 180° to become the ascending loop,
→ Descending loop contains simple squamous epithelium — named as the thin descending loop
b) Ascending loop of Henle:- It is made up of thicker simple cuboidal epithelium, thus is referred to as the thick ascending loop.
(3) Distal convoluted Tubule (DCT):→
⇒ It is the final sub-division of the renal tubule, through which the glomerular filtrate flows.
⇒ It contains simple cuboidal epithelium, but lacks the brush border.
(4) Collecting duct:- ⇒ Each collecting duct travels through the medullary pyramids.
⇒ The collecting tubules after receiving glomerular filtrate from many nephrons, approach the renal pelvis.

⇒ where they fuse together and empty urine into the minor calyces via papillae of the pyramids.

* Functions of nephron:-

⇒ The bowman's capsule and the glomerulus of the nephron as a filtration unit

⇒ Glomerular filtrate that enters the tubule where reabsorption takes place.

⇒ This process of the glomerular filtration produces the tubular fluid which secreted across the epithelial cells of the tubule wall.

other function includes:-

a) They undergo glomerular filtration in which the water and solutes from the blood plasma enter the nephron via wall of glomerular capillaries into glomerular capsule.

b) They undergo Tubular secretion in which the substances are transported to the lumen.

c) They also undergo tubular reabsorption in which water or solutes are transported from the tubular lumen into the kidney.

Ureters:- ⇒ Ureters are paired tubes through which the flows from the kidneys to the urinary bladder.

⇒ Both the tubes begin from the sinus of the corresponding kidney as calyces surrounding the renal papillae.

⇒ One minor calyx contains more than one papillae.
⇒ The minor calyx ~~contains more~~ combines with each other to form major calyces.
⇒ which further combine to form renal pelvis.
⇒ It is a funnel-shaped dilatation with wide above and narrow below, and situated partially inside and partially outside the renal sinus.

*anatomy of ureters :-
⇒ ureters are 20-30cm long.
⇒ They are thick-walled, narrow cylindrical tubes.
⇒ Lower end of the kidney - run downward enter the pelvic cavity and terminate in the fundus of the urinary bladder.
⇒ Ureter contains three coats -

- fibrous coat → Tunica adventitia
- Muscular coat → Tunica muscularis
- Mucous coat → Tunical mucosa

*function :- ⇒ They transport urine from the renal pelvis of the kidney to urinary bladder.
⇒ During micturition when pressure in the bladder is high the uterus are compressed and back flow of urine is prevented. Otherwise, ~~cystitis~~ inflammation of ureter - which may lead to kidney infection.

* Urinary bladder

⇒ Urinary bladder is a hollow muscular organ, which rests on the pelvic floor.
⇒ It receives urine from the kidneys via the ureters; it expels during urination via urethra.
⇒ It is spherical in shape.
⇒ Capacity of the bladder is 400-600 ml.

Functions ⇒

(1) It acts reservoir for urine.
(2) It expels urine via urethra.

* A urinary bladder filled with urine becomes distended.
⇓
the starch receptors on the urine stimulates bladder wall,
⇓
which in turn trigger a reflex contraction of the bladder wall (muscle) and relax the internal sphincter (a wall which remains close so that the urine remains in the bladder till urination).
⇓
soon the external sphincter relaxes and the bladder expels the urine.

Urethra :- ⇒ It is a tube like structure which transport urine from the urinary bladder to the exterior of the body
⇒ It forms the exit tube of the body for liquid wastes.

⇒ It is closed by the urethral sphincter which keeps the urine in the bladder till urination.

⇒ urethra is made up of 2 seperate urethral sphincter muscles.

- Internal urethral sphincter
  - consist of involuntary smooth muscles
- External urethral sphincter.
  - ~~the~~ lower voluntary muscles.

*Functions:- It is the passageway through which urine is expelled out of the body.

*Functions of urinary system:-

* eliminate the waste product produced by the body cells.

→ Biligubin obtained from haemoglobin breakdown.

→ uric acid from nucleic acid in cells.

→ creatine from creatine phosphate in muscle

→ urea and ammonia from amino acid metabolism are the organic waste products presents in the extracellular fluid.

→ It involves in nutrients preservation by eliminating only the unwanted products from the body.

→ Regulate the osmolarity, volume and pressure of blood by altering the volume of H_2O lost with urine.

→ Electrolyte balance:-

* Physiology of urine formation

cells of the body produce nitrogeneous waste

which are transported via blood to the Kidneys

where they are converted into urine by the following 3 process

- ultrafiltration or glomerular filtration
- Tubular reabsorption
- Tubular secretion (augmentation)

▷ ultrafiltration / Glomerular filtration :-

⇒ It is a passive process involving hydrostatic pressure to force fluids and solutes across a membrane.

⇒ Glomerular filtration membrane is 40 times more permeable to solutes in comparison to the outer capillary beds because its larger surface area and is thousand

⇒ molecules having < 3nm like H_2O, glucose, amino acids and nitrogenous wastes can easily move into glomerular capsule from the blood.
⇒ molecules of 3-5nm enter the glomerular capsule with much difficulty.

filtration membrane: Glomerular capsules inner part is made up of 3 layers. Collectively called filteration membrane.
→ Filtration membrane consist of:

a) fenestrated glomerular capillary cells.
The glomerular endothelial cells are
⇒ fenestrated ie, they have perforations, thus making them leakier than the other capillaries.
⇒ These cells have gaps of 70-100nm btw. them but still prevent the exit of blood cells and platelets from the capillaries.

b) Basal lamina:- It is thin layer of extra cellular matrix gel, separating the glomerular endothelial cells from the podocytes.
⇒ Basal lamina consist of collagen fibres which form a meshwork and functions like a sieve to prevent the entry of substance having >8nm into the capsular space.
⇒ As a result, most of the plasma proteins are barred from entering the capsule.

c) Podocytes:- These cells form the visceral layers of the glomerular capsule.
⇒ Podocytes are the 3rd and finest filter of the filtration membrane.
⇒ The finger like pedicels of podocytes wrap around the glomerular capillaries and interlock to form narrow filtration slits, which allow the entry of substance having 6-7 nm into the capsular space.

*Net filtration Pressure:- It is total pressure gradient which drives water across the filtration membrane to reach the capsular space.
→ Glomerular Hydrostatic pressure:- 50mm Hg
→ Capsular Hydrostatic pressure:- 10mm Hg
→ Glomerular Colloid osmotic pressure:- 30mm Hg.

*Glomerular filtration Rate:- It is the amount of filtrate produced by both the kidney in a minute. (125ml/min)
⇒ Kidney form around 180L of filtrate in a single day.
⇒ Body contains only 3L of plasma, the kidneys filter this volume around 60 times each days.

Regulation of GFR:- GFR is regulated by intrinsic controls and extrinsic controls
Kidney to maintain GFR
(acting by nervous and endocrine systems to maintain BP)

2) Tubular reabsorption:-
It is a selecting transepithelial process initiates when the filtrate enters proximal tube.
The reabsorption substance enter the blood via—

*Transcellular route:- water and solutes pass through the luminal membrane.

⇓

they diffuse across the cytosol

⇓

they pass through the basolateral membrane of the tubule cell

⇓

finally, the substance enter the endothelium of peritubular blood capillaries.

* Paracellular Route:-
Movement of substance b/w the tubule cells connected by tight junctions.

⇓

thus the movement occurs in a restricted manner.

⇓

But these tight junctions are leaky in the proximal nephron.

⇓

allowing the passage of some essential ions (Ca2+, Mg2+, K+ and some Na+) through the paracellular route).

*Sodium reabsorption:- Glomerular filtrate contains Na+ ions mostly and 80% energy is utilized for active reabsorption of Na+ ions by the transcellular route.

Reabsorption of nutrients, H_2O and ions.

⇒ water, glucose, amino acid, lactate, vitamins are reabsorbed by secondary active transport and osmosis.

⇒ Transporter proteins helps in the transport of nutrients.

3) Tubular Secretion :→

⇒ Plasma is cleared from unwanted substance by tubular secretion.

⇒ The H^+, K^+, NH_4^+, creatinine and certain organic acids are secreted in to the tubules/pass through the tubule cells.

⇒ urine contains both filtered and secreted substances.

⇒ The PCT is the major secretion site.

Tubular secretions involved in

- Disposing of substances eg. some drugs.
- Eliminating end products eg. urea, uric acid
- Eliminating excess K^+ ions
- Controlling Blood PH

Composition of urine:-

water, urea → 2%
96%

uric acid, creatinine, ammonia, sodium, potassium, chlorides, phosphates, sulphates, oxalates → 2%

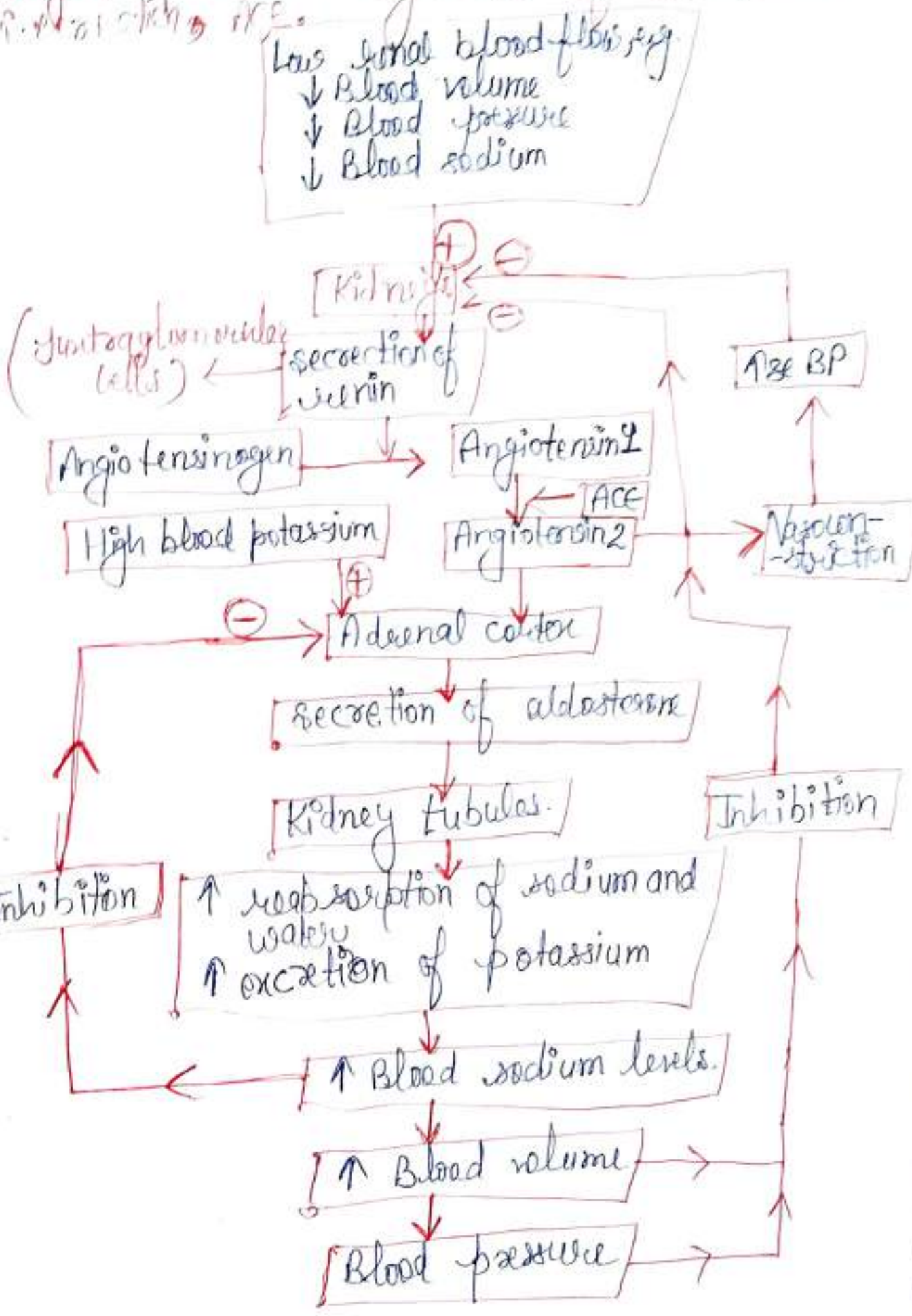
* Role of Renin angiotensin aldosterone system in kidneys:-

→ RAAS is essentially required for the regulation of cardiac output and arterial pressure.

⇒ Renin is a proteolytic enzyme released by the kidney into the blood circulation - facilitate angiotensin to be formed in the blood and tissues,

⇒ which further facilitates aldosterone to be released from the adrenal cortex

Negative feedback regulation of aldosterone secretion etc.



Micturition (urination) Reflex :→

when 300-400 ml of urine has been collected in a urinary bladder.

↓

Afferent autonomic nerve fibres send the impulse to the brain

↓

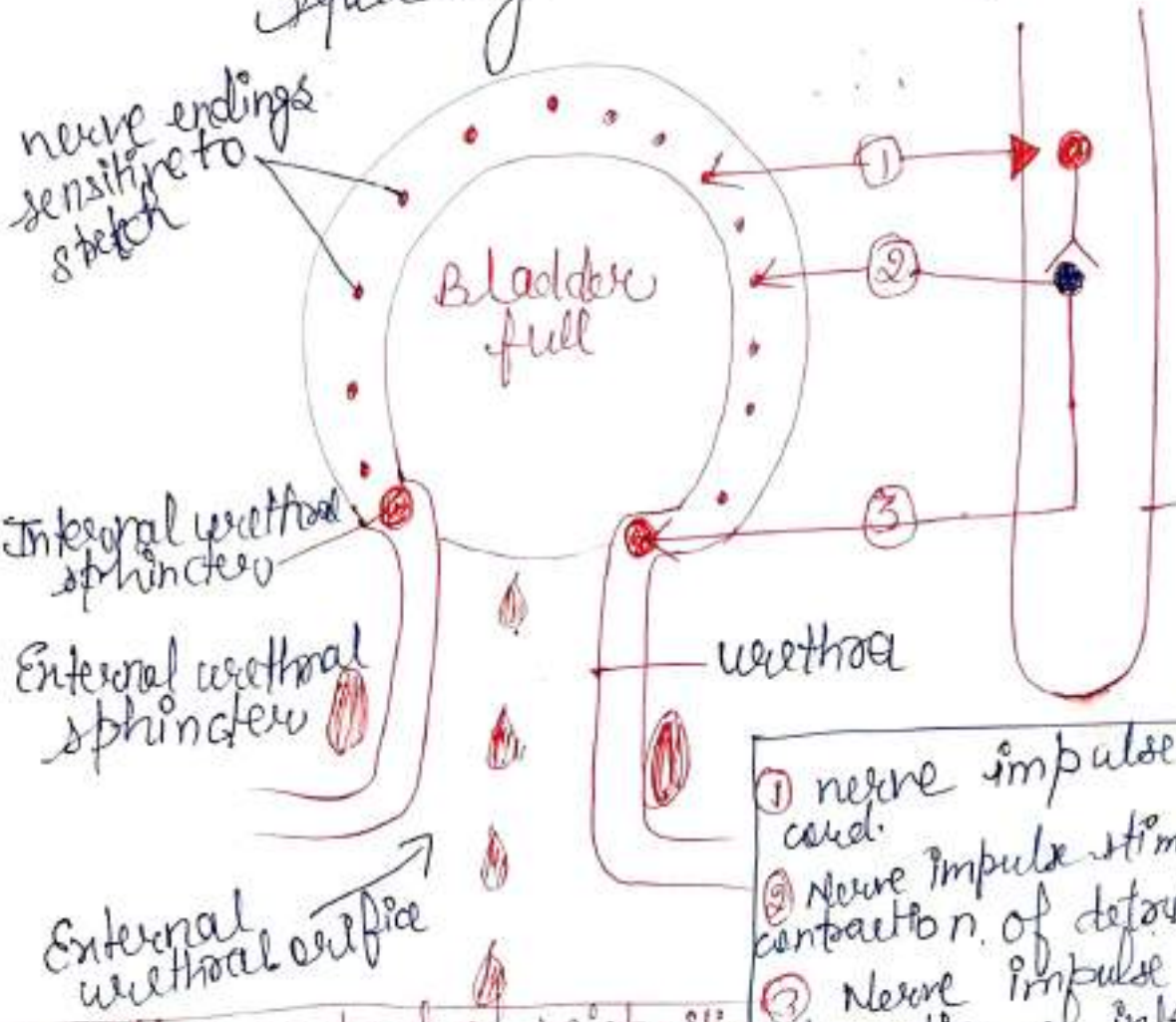
Brain send the efferent impulse to the bladder

↓

Relaxation of the urethral sphincter - bladder muscles to tightens.

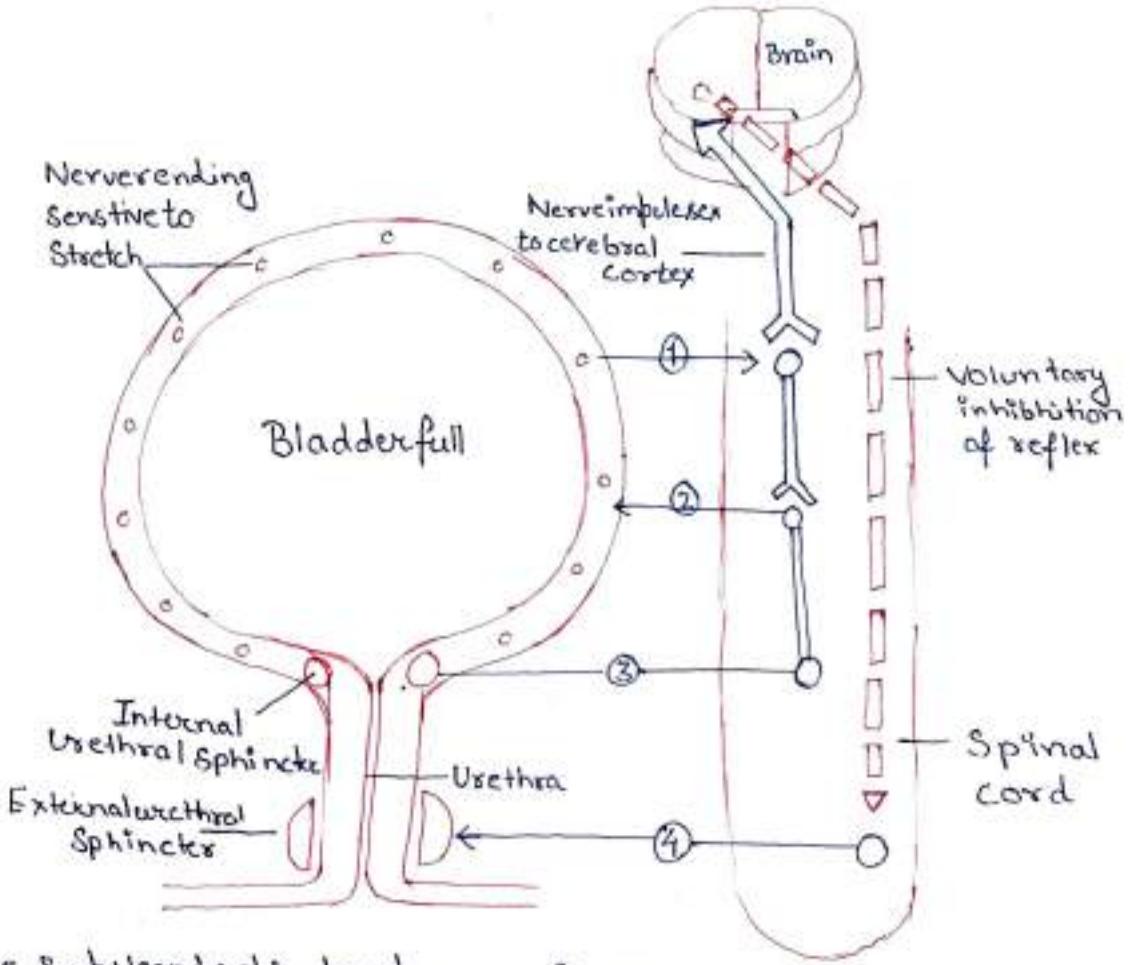
↓

squeezing urine out of the kidneys



① nerve impulse to spinal cord.
② Nerve impulse stimulate contraction of detrusor muscle.
③ Nerve impulse stimulate relaxation of internal urethral sphincter

* Reflex control of micturition when conscious effort cannot override the micturition.



① Nerve impulse to spinal cord

② Nerve impulses stimulate contraction of detrusor muscle

③ Nerve impulses stimulate relaxation of internal urethral sphincter

④ Conscious contraction of external urethral sphincter overrides reflex micturition.

→ Control of micturition after bladder control is established.

Endocrine System (Hormones and their functions)

1) Pituitary gland

⇒ Two body systems are responsible for sending and receiving sensory information and coordinating body responses. These are the nervous system and the endocrine system.

↓ also called as neuro-endocrine system.

⇒ It regulates body activities by releasing hormones into the blood stream, where they are carried throughout the entire body.

*Hormone functions:-

⇒ Regulate the chemical composition and volume of the internal environment.

⇒ regulate metabolism and energy balance.

⇒ regulate contraction of smooth and cardiac muscle fibers and secretion by glands.

⇒ Help maintain homeostasis, despite disruptions such as infection, trauma, emotional stress, dehydration, starvation, hemorrhage and temperature.

⇒ Regulate certain activities of the immune system.

⇒ Contribute to the basic processes of reproduction, including gamete production, fertilization

, nourishment of the embryo and fetus
, nourishment of the newborn.

⇒ Endocrine System is composed of

- Pituitary
- Thyroid
- Parathyroid
- adrenal
- Pineal glands
- Pancreatic islets.

Hormones - Hormones ~~can have root~~ are a chemical substances that are carried by a cell tissue and initiate specific action.

Pituitary Gland

Anterior Pituitary

- → Growth hormone (somatotrophin)
- → Thyroid stimulating hormone
- → Adrenocorticotrophic hormone (ACTH)
- → Prolactin
- → follicle stimulating hormone (FSH)
- → Leutenising hormone (LH)

→ Gonadotrophins

Posterior Pituitary

- → Oxytocin (OT)
- → Antidiuretic hormone (vasopressin) (ADH)

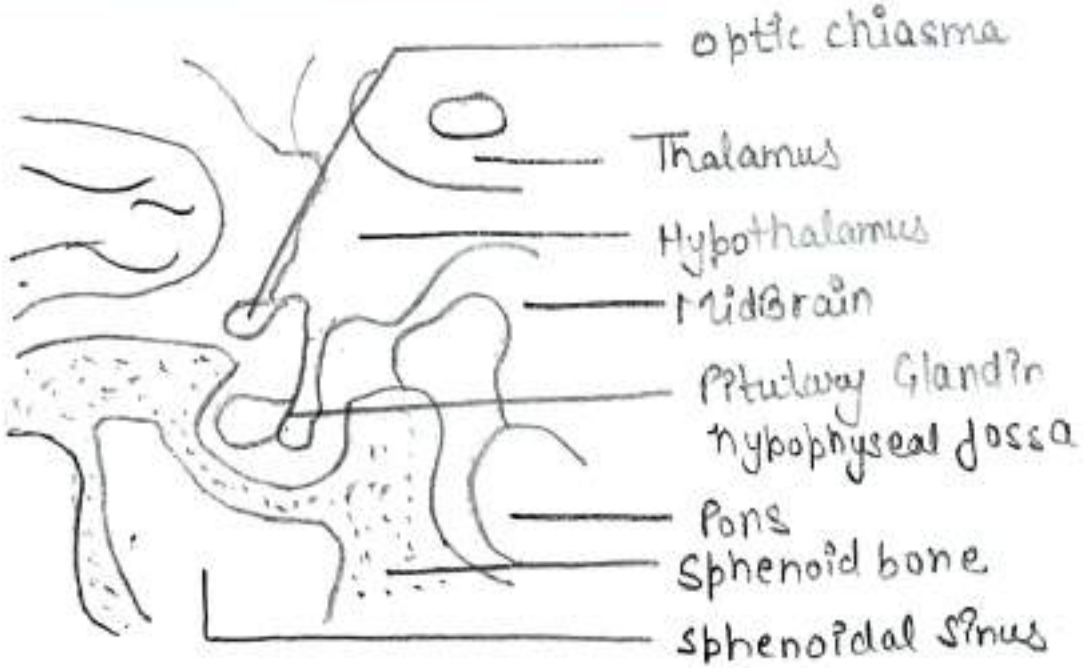
Pituitary Gland and Hypothalamus

⇒ It lies in the hypophyseal fossa of the sphenoid bone below the hypothalamus.
⇒ It is also called "master" endocrine gland
⇒ It is the size of pea, weighs about 500mg
⇒ It consist of two parts:

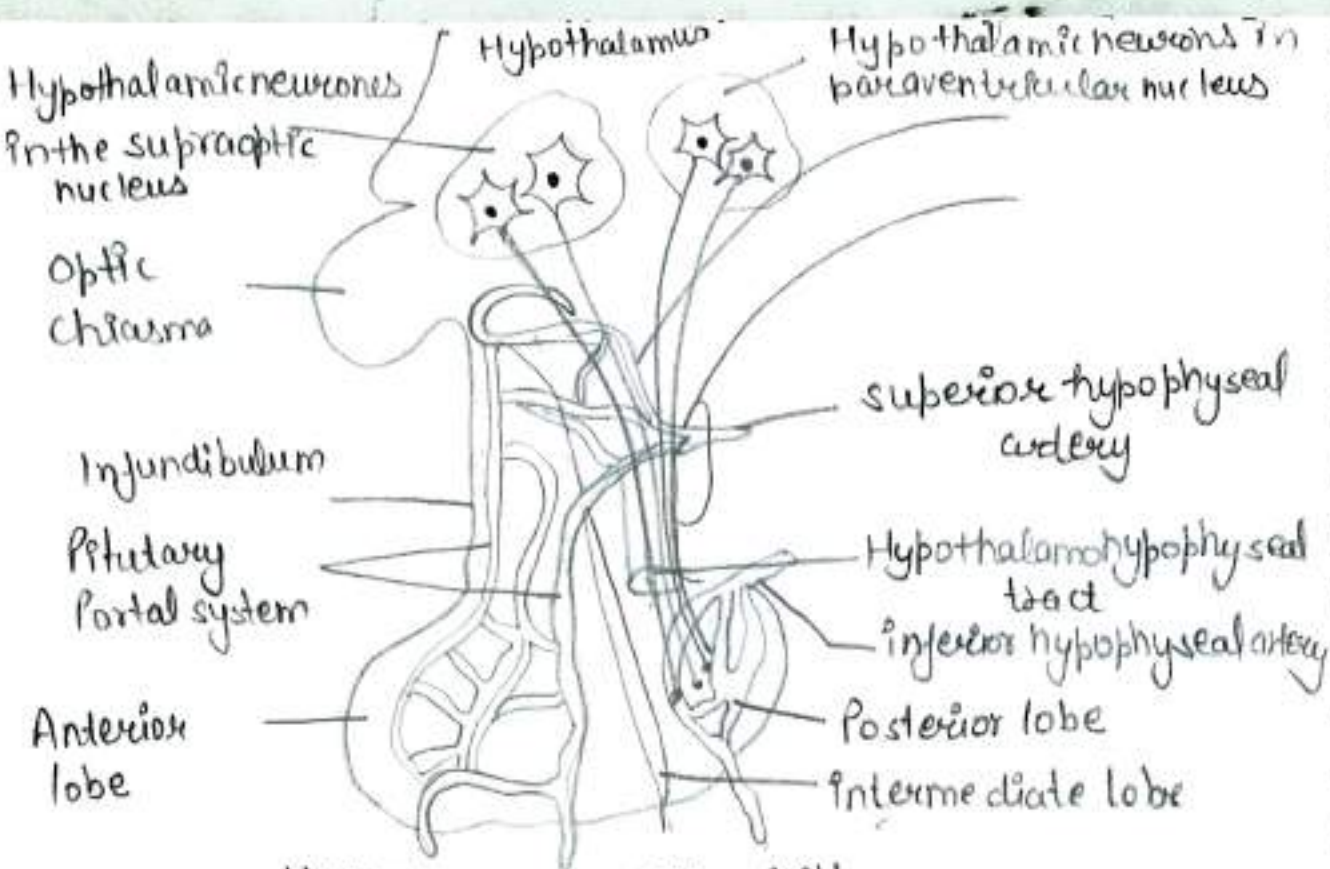
Anterior pituitary
is an upgrowth of glandular epithelium from the pharynx.

Posterior pituitary
is a downgrowth of nervous tissue from the brain.

⇒ There is a network of nerve fibres between the hypothalamus and the posterior pituitary



Pituitary Gland (Median Section)



Blood supply :- artery :→ internal carotid

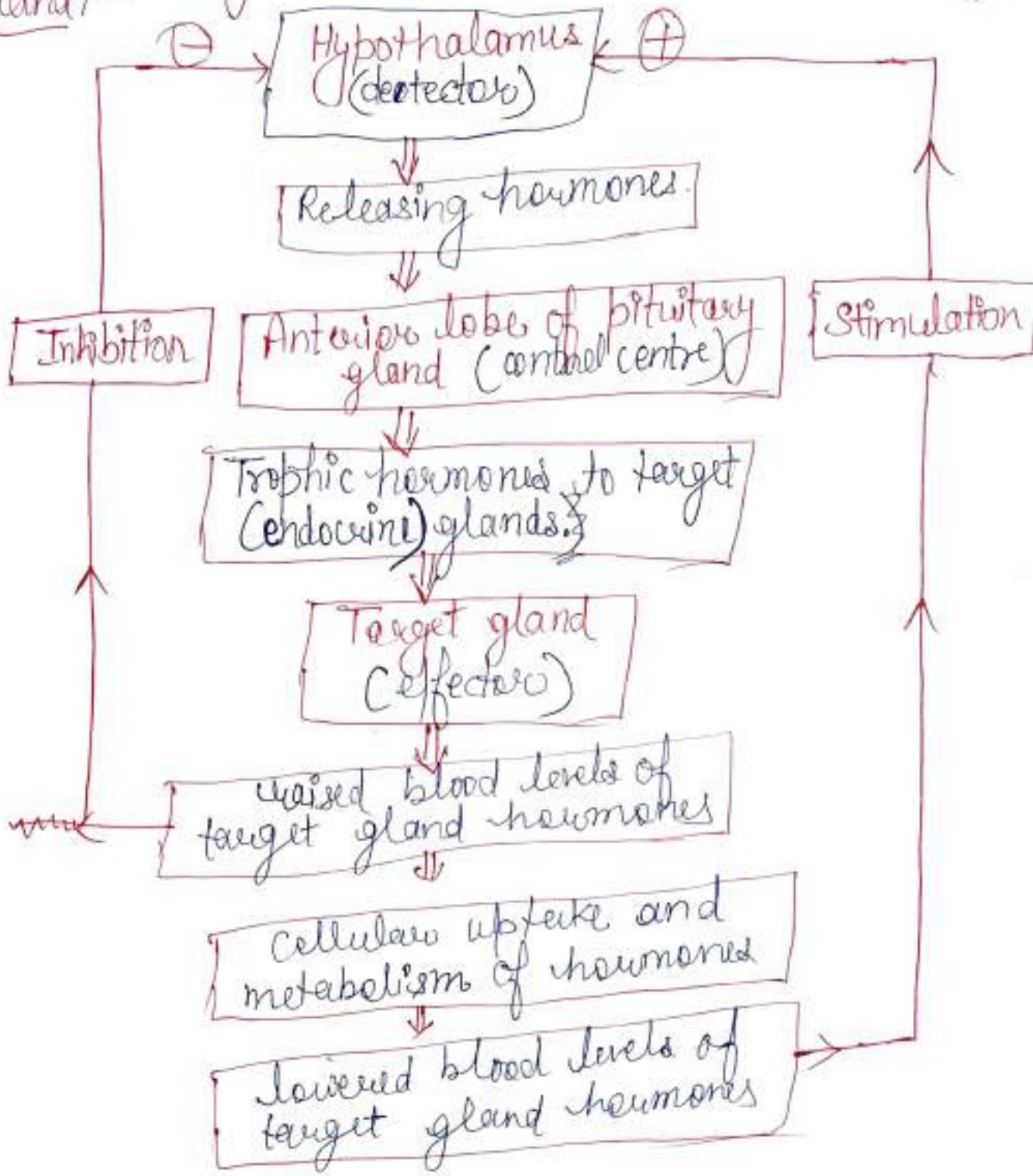
~~Inf~~ Anterior pituitary :-

⇒ It secretes hormones that control a wide range of bodily activities.

⇒ The hypothalamus regulates the anterior pituitary by producing releasing hormones.

⇒ that stimulate release of anterior pituitary gland hormones and inhibiting hormones that suppress release of anterior pituitary gland hormones.

* Negative feedback regulation of secretion of hormones by the anterior lobe of the pituitary gland:-



1) Growth hormone:-

⇒ It is the most abundant hormone synthesized by the anterior pituitary.

⇒ It stimulates growth and division of most body cells but especially those in the bones of skeletal muscles.

⇒ Highest secretion in childhood and adolescence and secretion of GH maintains the mass of bones and skeletal muscles.

⇒ It also regulates the metabolism in many organs eg. liver, intestine and pancreas.

⇒ Its release is stimulated by GHRH (growth hormone releasing hormone) and suppressed by GHRIH (growth hormone release inhibiting hormone), also known as somatostatin, both of which are secreted by hypothalamus.

⇒ Secretion of GH is greater at night during sleep and is also stimulated by hypoglycaemia, exercise and anxiety.

2) Prolactin:- It is secreted during pregnancy to prepare the breasts for lactation (milk production) after childbirth.

⇒ Blood level of prolactin is stimulated by prolactin releasing hormone (PRH) released from the hypothalamus and it is lowered by prolactin inhibiting hormone (PIH, dopamine) and by the increased blood level of prolactin.

Hormones of the hypothalamus, anterior pituitary and their target tissues.

Hypothalamus	Anterior Pituitary	Target gland or Tissue
Growth Hormone Releasing hormone (GHRH)	Growth hormone (GH, Somatotrophin)	Most Tissue Many organs
Growth hormone release inhibiting hormone (GHRIH Somatostatin)	GH inhibition Thyroid stimulating hormone (TSH) Inhibition	Thyroid gland Pancreatic Islets Most Tissue.
Thyrotrophin Releasing hormone (TRH)	TSH	Thyroid gland
Corticotrophin Releasing hormone (CRH)	Adrenocorticotrophic hormone (ACTH)	Adrenal Cortex.
Prolactin Releasing Hormone (PRH)	Prolactin (Lactogenic hormone, PRL)	Breast
Prolactin inhibiting hormone (dopamine PIH)	PRL inhibition	Breast
Luteinising hormone Releasing hormone (LHRH) or	Follicle stimulating hormone (FSH)	Ovaries and Testes
Gonadotrophin Releasing hormone (GnRH)	Luteinising hormone (LH)	Ovaries and Testes.

3) Thyroid stimulating hormone :-

→ TSH is stimulated by thyrotrophin releasing hormone (TRH) from the hypothalamus.

→ It stimulates growth and activity of the thyroid gland, which secretes the hormones thyroxine (T_4) and tri-iodothyronine (T_3).

→ Release is lowest in the early evening and highest during the night.

4) Adrenocorticotropic hormone :-

→ Corticotrophin releasing hormone from the hypothalamus promotes the synthesis and release of ACTH by the anterior pituitary.

→ This ↑s the concentration of cholesterol and steroids within the adrenal cortex.

→ ACTH level high at 8a.m. and fall to their lowest about midnight.

5) Gonadotrophins :-

⇒ Just before puberty two gonadotrophins are secreted in gradually increasing amounts by the anterior pituitary in response to luteinising hormone releasing hormone, are also known as gonadotrophin releasing hormone.

⇒ Level higher at puberty → promotes mature functioning of the reproductive organs.

• Follicle stimulating hormone:-

In Female:- regulated the development of sex organs in female, development of immature ovarian follicle from the ovary.

→ Secretes oestrogen and progesterone during menstrual cycle.

In male:- initiation of spermatogenesis.

• Luteinising hormone:-

In female:- ovulation, maintaining of corpus luteum and secretion of progesterone.

In male:- Testosterone secretion.

Posterior pituitary:

⇒ Posterior pituitary or neurohypophysis composed of mainly of glial like cells called pituicytes.

⇒ Pituicytes donot secrete hormones.

⇒ They act simply as a supporting structure for large numbers of terminal nerve fibres and terminal nerve endings from nerve tracts.

⇒ That originate in the supraoptic and paraventricular nuclei of the hypothalamus.

ADH ⇒ Synthesized by hypothalamus ⇐ Oxytocin

⇒ ADH and Oxytocin is primarily synthesized in supraoptic nucleus and paraventricular nucleus in hypothalamus.

ADH ⇒ It is a hypothalamic hormone. Synthesized primarily in the cells of the supraoptic nucleus

⇒ The hormones then pass through the axons bound to neurophysin II and stored in their endings in the posterior pituitary

Action of ADH :⇒

① On kidney :—

⇒ ADH binds with receptors (V2 receptor) present on epithelial cells of distal tubules and collecting duct.

⇒ It helps to rise permeability of distal tubules and collecting duct to water by increasing pore size through aquaporins 2.

⇒ It rise water reabsorption and it leads to increase in osmolality of urine.

② On Blood vessel :⇒ (High dose)

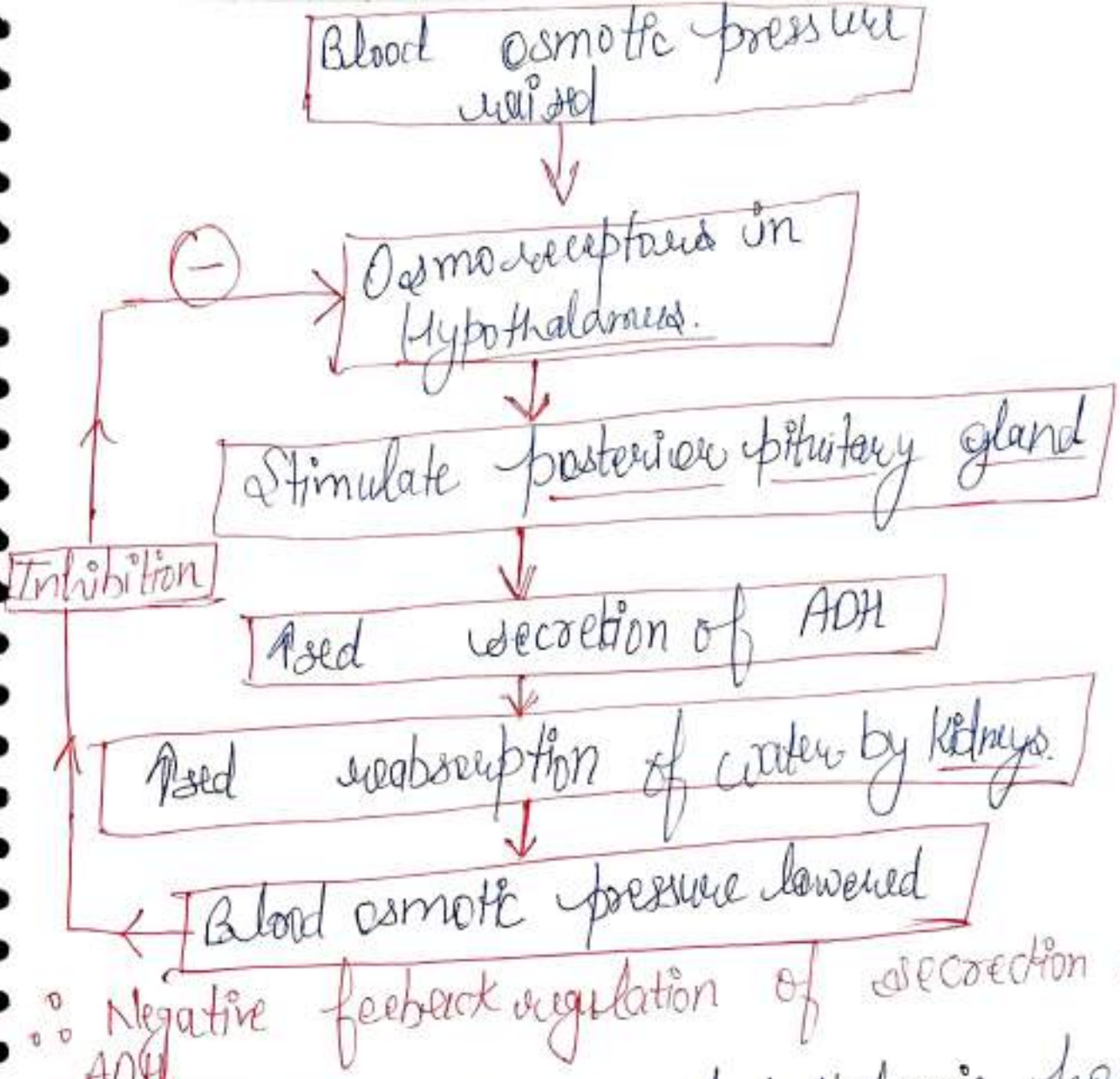
⇒ ADH acts as vasoconstrictor.

⇒ ADH binds with receptor present on vascular smooth muscle.

⇒ It leads to increase in Intracellular Ca^{2+}.

⇒ Rise in Intracellular Ca^{2+} helps in contraction of vascular smooth muscle.

⇒ It is also called Vasopression



∴ Negative feedback regulation of secretion of ADH.

Oxytocin :- It is a hypothalamic hormone synthesized primarily in the cells of the paraventricular nucleus.

⇒ The hormone then pass through the axons bound to neurophysin I (carrier protein) and stored in their endings in the posterior pituitary.

⇒ Oxytocin causes contraction of the pregnant uterus.

⇒ Oxytocin aids in milk ejection by the breasts.

Actions of Oxytocin

a) milk ejection:-> Oxytocin stimulates contraction of the smooth muscle cell (myoepithelium) lining the duct of mammary gland, therefore causes milk ejection from lactating breast.

b) stimulate contraction of the smooth muscle of the uterus (myometrium):-

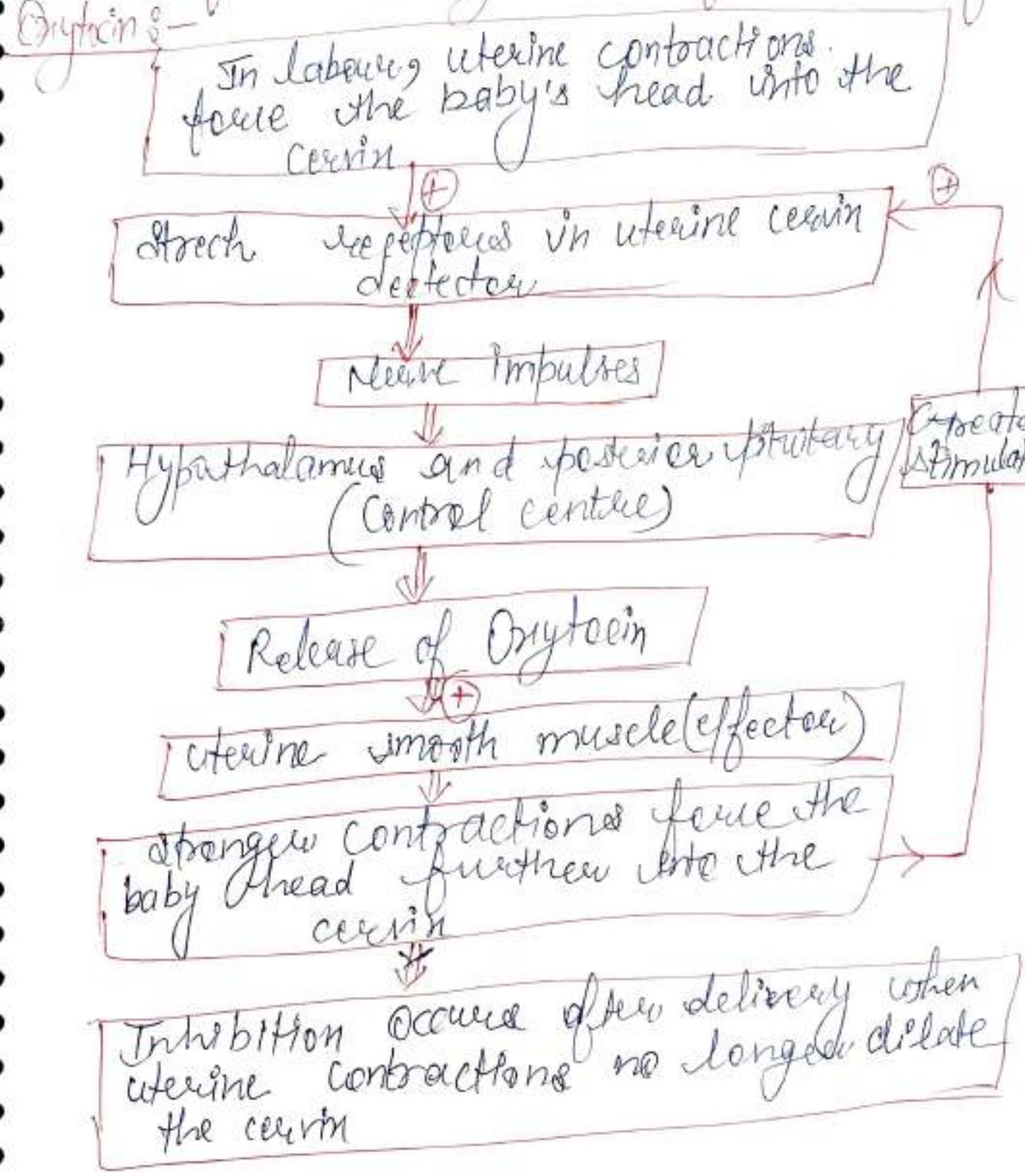
The sensitivity of the myometrium to endogenous oxytocin during pregnancy increase in pregnancy advances

=> It plays a role in labour.

3) In males, oxytocin receptors are found in the testis, epididymis and prostate gland.

— At the time of ejaculation, oxytocin facilitates the transport of sperm towards urethra by causing incd circulation of the smooth muscle of the vas deferens.

* Positive feedback regulation of secretion of Oxytocin :-



The Thyroid gland

⇒ It is situated in the neck in front of the larynx and trachea at the level of the 5th, 6th and 7th cervical and 1st thoracic vertebrae.

⇒ It is a highly vascular gland that weighs about 25g and is surrounded by a fibrous capsule.

⇒ It is butterfly in shape, consisting of two lobes, one on either side of the thyroid cartilage and upper cartilage and upper cartilaginous ring of the trachea.

⇒ The lobes are joined by a narrow isthmus, lying in front of the trachea.
⇒ Lobes are roughly cone shaped, about 5cm long and 3cm wide.
⇒ Arterial blood supply:-

- Superior thyroid arteries → Branch of the external carotid artery
- Inferior T.A. → ~~Inferior thyroid artery~~ Branch of the subclavian artery

Venous return:- By the thyroid veins, which drain into the internal jugular veins.

⇒ It is composed of largely spherical follicles formed from cuboidal epithelium
⇒ These secrete and store colloid, a thick sticky protein material. B/w the follicles are other cells found singly or in small groups, parafollicular cells, also called C-cells, which secrete the hormone calcitonin.

Thyroid hormones:->

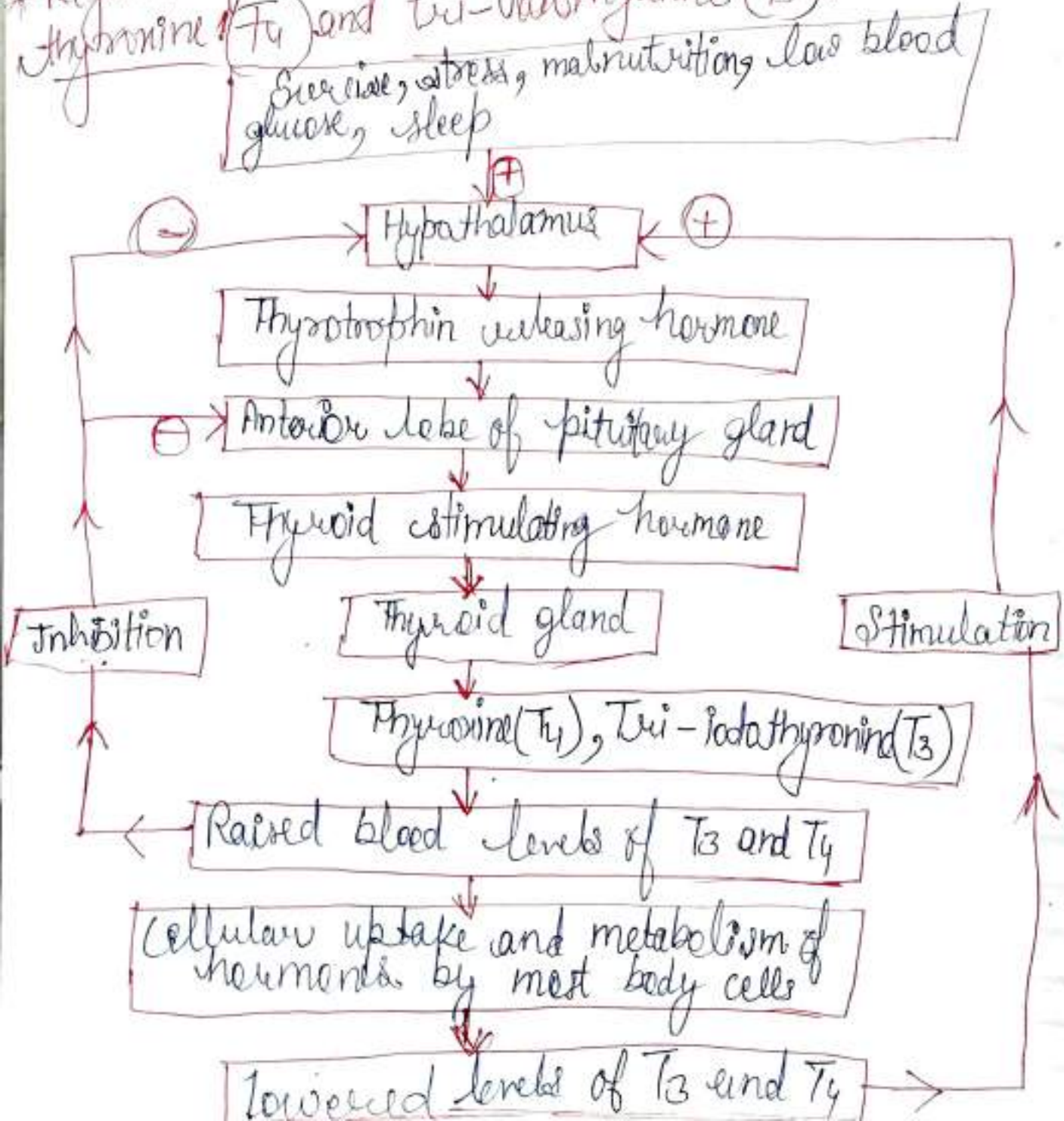
- T_4 Thyroxine
- T_3 Tri-iodothyronine

⇒ Iodine is essential for the formation of the thyroid hormone, T_3 and T_4.
⇒ Thyroid gland selectively takes up iodine from the blood, a process called iodine trapping.

⇒ The release of T_3 and T_4 into the blood is stimulated by thyroid stimulating hormone (TSH) from the anterior pituitary.

⇒ Secretion of TSH is stimulated by thyrotropin releasing hormone from the hypothalamus and secretion of TRH is stimulated by exercise, stress, malnutrition, low plasma glucose levels and sleep.

* Negative feedback regulation of secretion of thyroxine (T_4) and tri-iodothyronine (T_3).



Functions of T_3 and T_4 :-

⇒ T_3 and T_4 are essential for normal growth and development.

⇒ Secretion of T_3 and T_4 begins in about the 3rd month of fetal life and increase at puberty and in woman during the pregnancy.

⇒ Thyroid hormones enter the cell nucleus and regulate gene expression i.e. they increase protein synthesis.

*Calcitonin :-

⇒ This hormone is secreted by the parafollicular or C- cells in the thyroid gland.

⇒ Calcitonin lowers raised blood calcium (Ca^{2+}) levels.

⇒ It does this by acting on :-

- bone cells promoting their storage of calcium.
- Kidney tubules inhibiting the reabsorption of calcium.

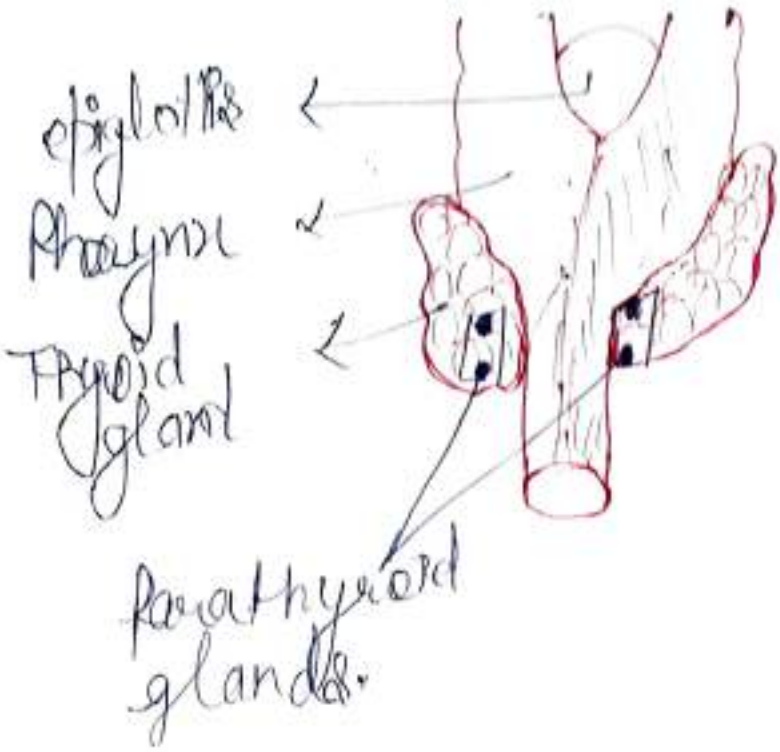
⇒ Release of calcitonin is stimulated by increased blood calcium levels.

Parathyroid Gland :-

There are four small parathyroid glands, each weighing around 50 mg, two embedded in the posterior surface of each lobe of the thyroid gland.

⇒ They are surrounded by fine connective tissue capsules that contain spherical cells arranged in columns with sinusoids containing blood in between them.

endothelial lined space.



*Functions:- These glands secrete parathyroid hormone (Parathormone). Secretion is regulated by blood calcium levels

⇒ Use blood calcium levels.

Adrenal glands :- ⇒ Two adrenal ~~kidney~~ glands are situated on the upper pole of each kidney, enclosed within the renal fascia.

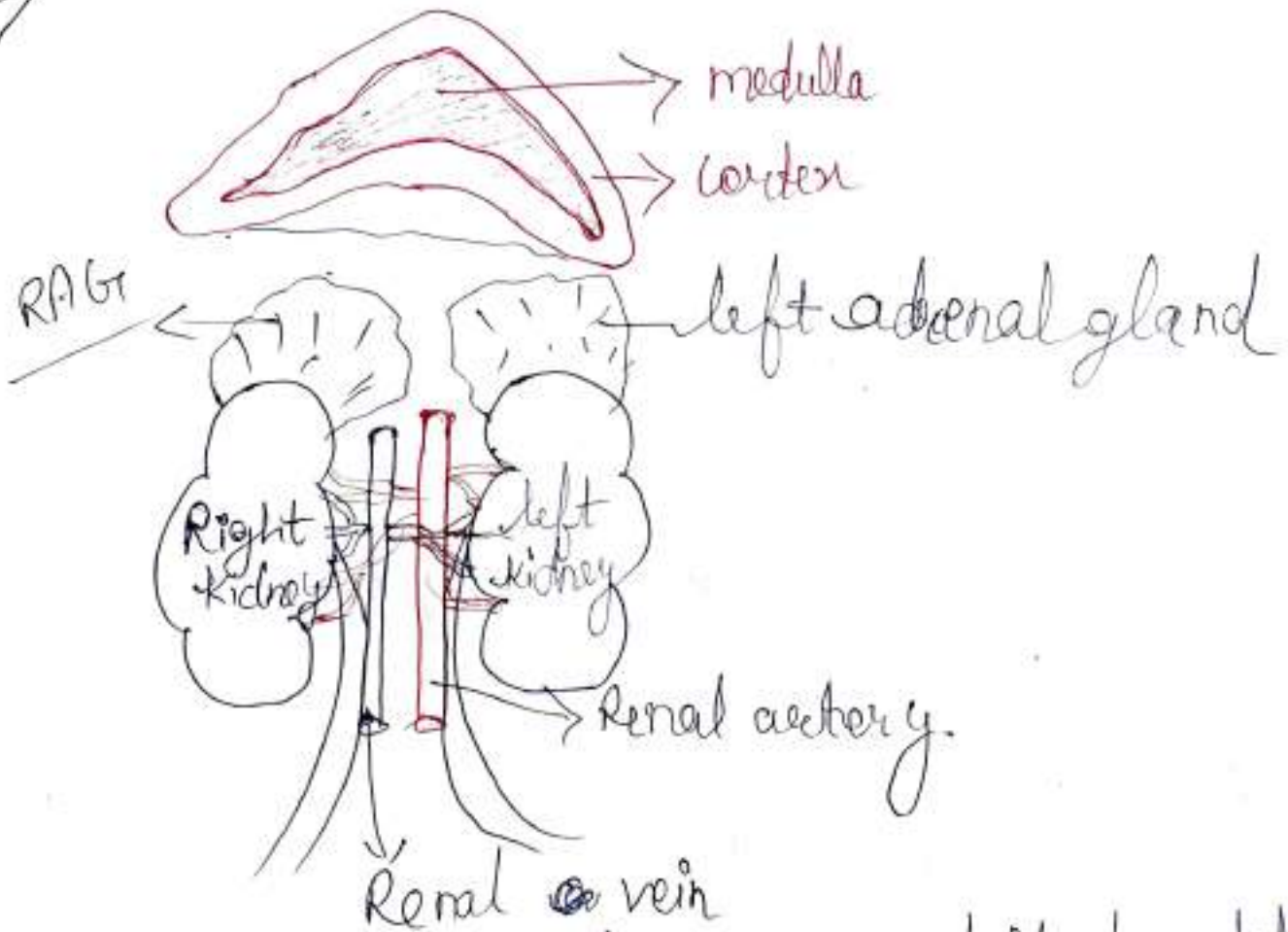
⇒ 4cm long and 3cm thick.

Glands are composed of two parts.

Outer layer is the cortex

Inner layer is medulla.

⇒ adrenal cortex produces a total of about 46 diff-erent hormones which are collectively known as corticosteroids.



⇒ They are composed of two parts which have different structure and functions.

Hormones of the adrenal gland:-

Adrenal cortex:- cortisol, corticosterone, cortisone aldosterone, androgens.

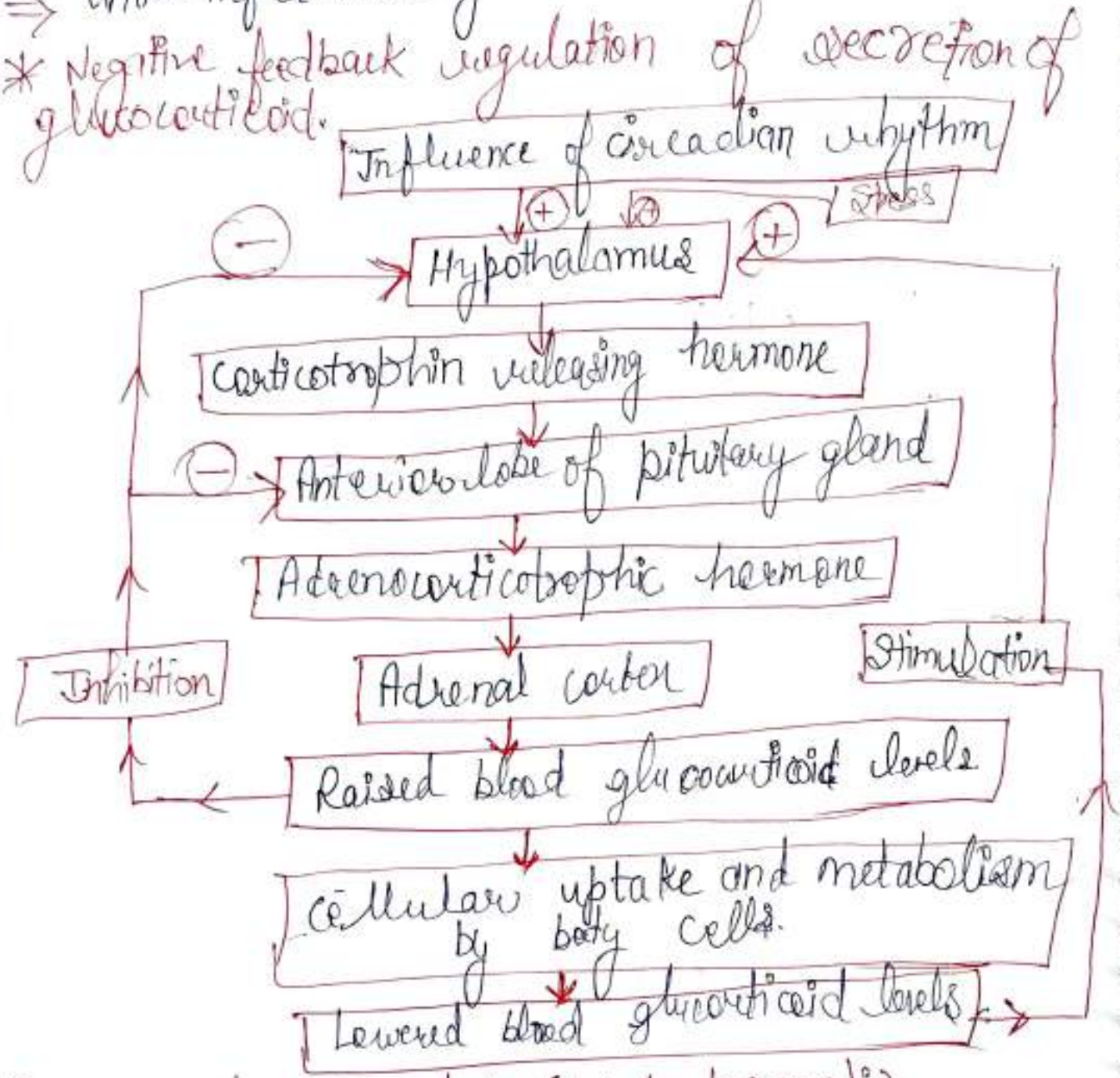
Adrenal medulla:- epinephrine, Nor-epinephrine.

* Adrenal cortex:-

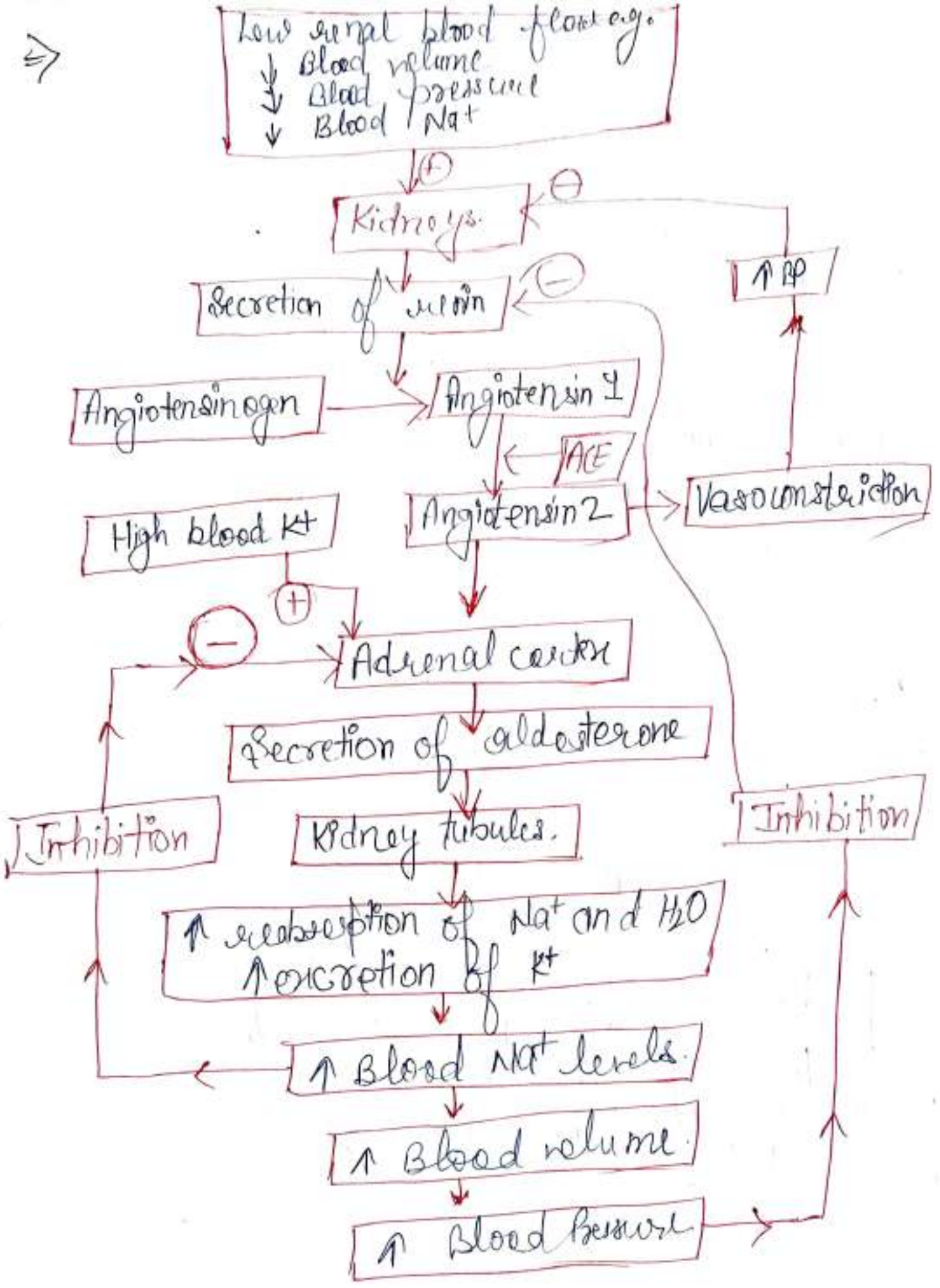
(1) Glucocorticoids:- cortisol is the main gluco-corticoid but small amounts of corticosterone

and cortisone are also produced. Commonly these are collectively known as steroids.
⇒ It is stimulated by ACTH from the anterior pituitary and by stress.
⇒ anti-inflammatory actions.

* Negative feedback regulation of secretion of glucocorticoid.



③ Mineralocorticoids (Aldosterone):⇒
⇒ maintain water-electrolyte balance.
⇒ Negative feedback system it stimulates the reabsorption of Na+ by the renal tubules. and excretion of K+ in the urine.


Low renal blood flow e.g.
↓ Blood volume
↓ Blood pressure
↓ Blood Na+
Kidneys
Secretion of renin
Angiotensinogen
Angiotensin 1
ACE
Angiotensin 2
Vasoconstriction
↑ BP
High blood K+
Adrenal cortex
Secretion of aldosterone
Kidney tubules.
↑ reabsorption of Na+ and H2O
↑ excretion of K+
↑ Blood Na+ levels.
↑ Blood volume
↑ Blood pressure
Inhibition
Inhibition

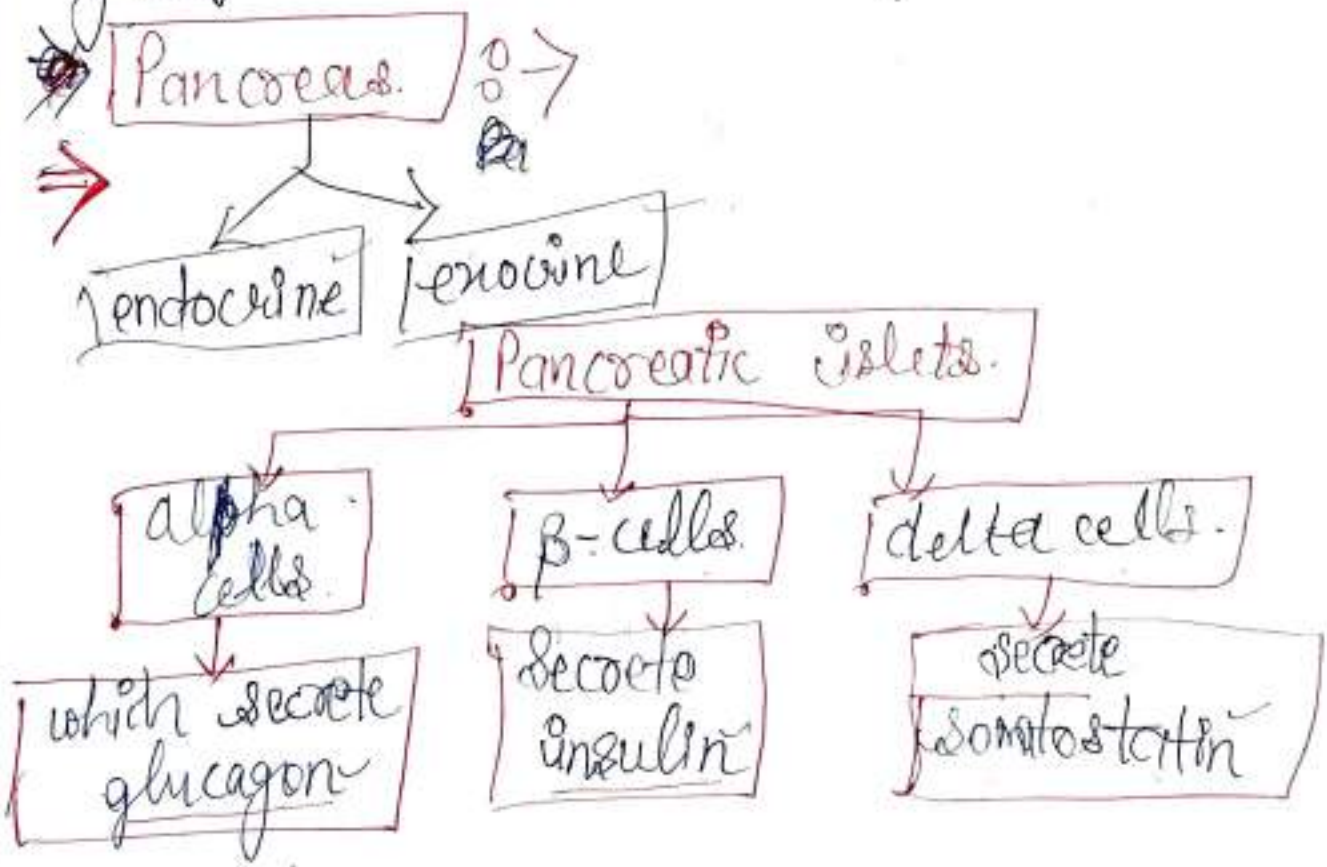
* Adrenal Medulla

⇒ It is surrounded by the adrenal cortex.

⇒ when stimulated by extensive sympathetic nerve supply, the glands release the hormones adrenaline (epinephrine 80%) and noradrenaline (norepinephrine 20%).

⇒ Noradrenaline is the postganglionic neurotransmitter of the sympathetic division of the autonomic nervous system.

⇒ Adrenaline and some noradrenaline released into the blood from the adrenal medulla during stimulation of the sympathetic nervous system.



Blood glucose level — 3.5 and 8 mmol/litre (63 to 144 mg/100 ml).

⇒ It can be controlled mainly by the opposing actions of insulin and glucagon.

- Glucagon → Raise Blood glucose levels.
- Insulin reduces blood glucose levels.

⇒ Insulin → Use blood glucose levels.
Use also amino acids and fatty acids.

↓
50 amino acids.

⇒ Glucagon → Use Blood glucose levels.
By stimulating

- conversion of glycogen to glucose in the liver and skeletal muscles.
- Secretion of glucagon is stimulated by low Blood glucose levels and exercise, and use by somatostatin and insulin.

⇒ Somatostatin → inhibits the secretion of both insulin and glucagon in addition to inhibiting the secretion of GH from the anterior pituitary.
It is also produced by hypothalamus.

* Pineal gland → Melatonin → Sleep-hormone.

* Gonads → ovaries and testes.

* Ovaries

Female gonads, located in the pelvic cavity.

Secrete estrogens and progesterone

which are responsible for the development and maintenance of female sexual characteristics.

as well as regulate the female reproductive system.

ovaries also produce relaxin, which soften connective tissues in preparation for childbirth.

* Testes → The testes are the male gonads

located in the scrotum.

secrete testosterone

which is responsible for male sexual characteristics, and inhibin which controls sperm production by inhibiting follicle stimulating hormone.

* Thymus Gland → Thymosin

related to complement system

↓

Promote the proliferation and maturation of T cells (WBC)

* Local hormones:-

Histamine

↓

Synthesised and stored by mast cells in tissue and basophils in blood.

Serotonin (5-HT)

↓

5-Hydroxy-tryptamine — neuro transmitter

↓

Present in platelet, in the brain and in the intestinal wall.

↓

It causes intestinal secretion and contraction of smooth muscle and its role in blood clotting.

Prostaglandins. ✓

↓

lipid substances found in most tissues.

physiological effects.

→ inflammatory response
→ pain
→ fever
→ regulating BP
→ blood clotting
→ uterine contractions during labour

Section Four: Chapter 23: The Female Reproductive System

The Female Reproductive System

The gonads of the female reproductive system are the ovaries and they function to produce gametes (**oocytes** or **egg cells**) in addition to the reproductive hormones, including estrogens and progesterone, as is the same concept for the male reproductive system. However, the female body has the additional role of supporting the developing embryo and fetus in the womb and delivering at birth a genetically unique baby into the world. There are many fundamental similarities in the male and female reproductive systems, and major differences too.

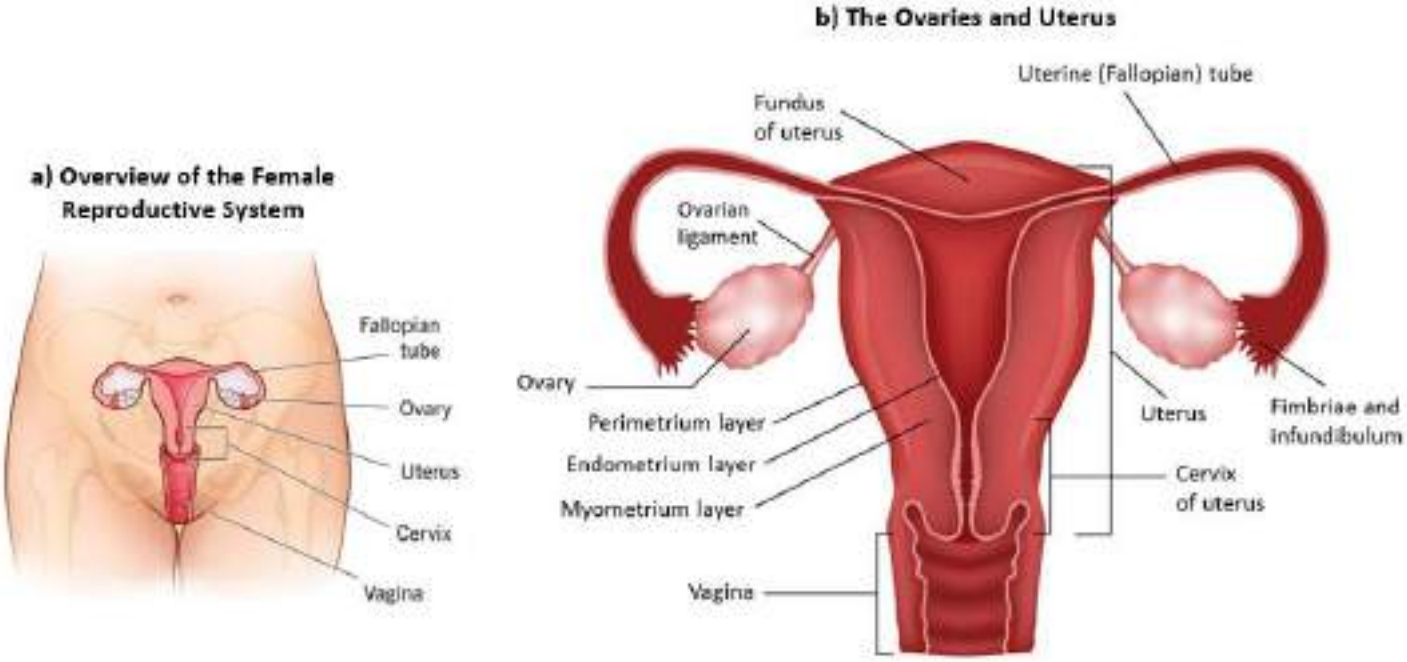


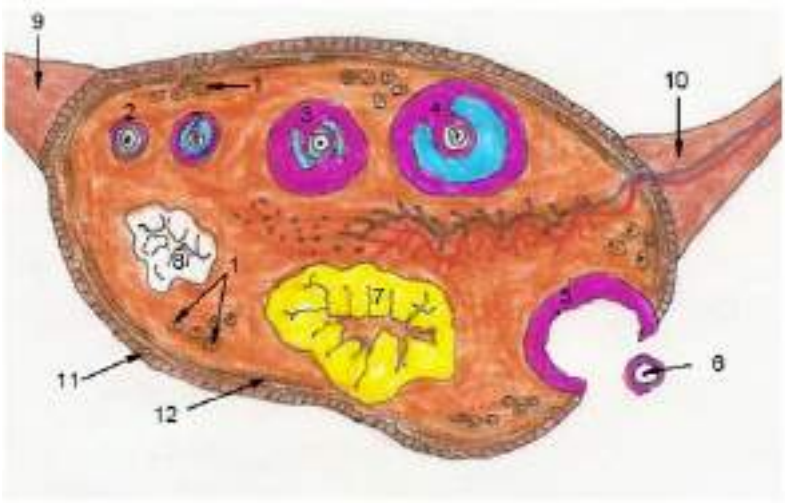
Figure 23.1 In **a)** is shown an overview of the position and arrangement of the female reproductive structures within the pelvic cavity. In **b)** is shown a more detailed representation of the ovaries and the uterus. The ovaries are the gonads and therefore where the egg cells are produced and released from. The oocytes flow onto the uterine tubes and travel to the uterus, where they will either continue out through the cervix and vaginal canal and exit the body, or if fertilized by a sperm cell to become a zygote, this will implant in the endometrial layer of uterus, usually in the fundus region. The thick myometrial layer of the uterus is made of smooth muscle and its contractions during labor push the baby out of the uterus into the vaginal canal during birth.

The Ovaries

The entire female reproductive system is snuggly nestled within the protection of the boney pelvic cavity, as seen in **Fig 23.1 a)** above. The **ovaries** are the primary reproductive structure of the female as these are the gonads that make the gametes and sex hormones. The paired oval-shaped ovaries can be seen in **Fig. 23.1 b)**, and within the body they are often remarkably small for all the things they do. The size can vary, but on average have the dimensions of 3.5 cm x 2 cm x 1 cm, in other words they are about the size and shape of a large **almond**. The size of a woman's ovary can have an impact, as women with larger ovaries have a greater egg reservoir which may mean they will have an easier time conceiving and also be able to conceive at older ages.

When examined closely, the ovary has many similarities to an elegant and meticulous cosmic clock! The processes that occur within the ovary have impeccable timing and are complexly cyclic in function. Like the gears and cogs of an intricate clock, the ovarian cycle depends on the cycles of the hypothalamus, and the uterine cycle depend of the cycles of the ovaries. Thus elements both upstream and downstream of the ovaries must be meticulously synchronized. As mentioned, the ovaries are contained within the pelvic cavity and they are tethered and supported in their position there by multiple ligaments, for example the ovarian, the suspensory and the broad ligaments. As will become clear, the ovaries are very closely associated with the uterus (seen in **Fig. 23.1 b**) both in proximity and in utility.

The drawing below (**Fig. 23.2**) is a representation of the histology of an ovary under microscopic examination. The figure is best read by going through the structures in order, from 1 to 12, flowing around the ovary in a clock-wise direction. This is how the clock-work elements of the ovary can be most appreciated. The central functional aspect of the ovary is to release a mature egg and then prepare the body for possible implantation of a zygote and pregnancy. If implantation does not occur, then the ovarian cycle moves on from ovulation to the end of the cycle, and repeats itself every other month. Since there are two ovaries, each takes a turn releasing a mature egg cell; one releases an egg one month, the other releases an egg the next month, and so on.



Structures of the Ovary

1. Primordial follicles (with oogonium)
2. Primary follicles
3. Secondary follicles with oocyte
4. Mature (Graafian) follicle with oocyte
5. Follicle at ovulation
6. Release of egg at ovulation
7. Corpus luteum
8. Corpus albicans
9. Suspensory ligaments
10. Ovarian ligament
11. Germinal epithelium
12. Tunica albuginea

Figure 23.2 This shows a drawing of the ovary indicating the cyclic nature of follicular and egg cell development. The important structures are highlighted with numbers and the numbered key to the right shows the usual progression of 'events' that occur.

As seen in **Figure 23.2** above, the ovary has a smooth outer covering of cuboidal epithelium called the **germinal epithelium**, it was so named because it was once (inaccurately) believed that the egg cells germinated from this layer of cells. Just deep to this is the **tunica albuginea**, which is a dense fibrous connective tissue that holds and protects the tissue organ.

Deep to the tunica albuginea is the **ovarian cortex** which is the large outer portion of the ovary, and is where all the action takes place! For instance, this is where the **oocytes** develop inside of **ovarian follicles**. Ovarian follicles are like a house that the egg cell (oocyte) matures in, becoming more developed as it cycles around the ovarian cortex in a very precise manner. In the deepest central region is the inner **ovarian medulla**, where blood and lymph vessels, the nerves supplying the ovary.

Once the mature cell is released from the mature ovarian follicle at **ovulation** (number 6 in **Fig. 23.2** above), the ovarian follicle become the **corpus luteum** (number 7 in **Figure 23.2** above) a name meaning 'yellow body'. This readies the body for pregnancy, should fertilization occur. If the egg is unfertilized, the corpus luteum becomes the **corpus albicans** (number 8 in **Fig. 23.2** above) a name meaning 'white body'. This structures is degraded by resident macrophages and the cycle begins again.

The Ovarian Cycle

Cycles are extremely meaningful and important in the body, and particularly in the reproductive system. The **ovarian cycle** is created by gonadotropic hormones form the anterior pituitary gland, and orchestrate the events that occur in the ovary. In healthy ovulating women these events are extremely predictable. During a woman's reproductive years, the ovarian cycle is usually 28 days. Yes, exactly like the cycles of the moon! To be clear, this is not the **uterine cycle** (what most know as the **menstrual cycle**), but the two are correlated because as we will see, it is the ovarian cycle that dictates the uterine cycle.

The ovarian cycle may be divided into three stages: **1)** the follicular phase, **2)** ovulation, and **3)** the luteal phase. Distilled into the simplest terms the sequence of events can be described as this:

- **Follicular Phase** – the follicles (with the oocyte inside) facilitate **oogenesis**, which is the growth and development of the primary ova into a mature ovum.

- **Ovulation** – triggers the release of the mature egg cell from the follicle and the ovary.

- **Luteal Phase** – the follicle becomes the corpus luteum, secreting estrogens and progesterone levels for potential implantation of a fertilized egg cell within the endometrium of the uterus.

Oogenesis

Now for some noteworthy details about how the primary egg cell (or ovum) becomes a mature ovum in the process called **oogenesis**.

This process actually begins with the ovarian stem cells called **oogonia**, this is basically a structure that is the prelude to the primordial follicle that can be seen under the microscope. The process of oogenesis is parallel to spermatogenesis in males. It requires **meiotic** cell divisions in order to reduce or half the number of chromosomes from 46 to 23, which then leads to the production of ova (eggs) in females.

However, unlike spermatogonia, the process of oogenesis is initiated very early in life, as in during the development of the fetal ovary. While the fetus is developing, the gametes begin as diploid (2n), then the oogonia cells divide by **mitosis** and differentiate to produce primary **oocytes** (still diploid with 46 chromosomes). The formation of cells around each of these primary oocytes combine and create an **ovarian follicle**. The primary oocytes that are housed inside a follicle commence **meiosis**, but only progresses to prophase I and are suspended in this stage until puberty and continuing until the woman is near menopause. The number of primary oocytes present in the ovaries declines from one to two million in an infant, to approximately **400,000** at puberty, to zero by the end of menopause.

The Female Egg Cell

The female egg cell is small, but it may be bigger than you realize! This cell is the largest cell in the human body and can be seen without a microscope. Thus, comparatively, the egg cells are huge. They measure between about 100 to 200 µm (microns) in diameter. On the small side of the scale that size is similar to the width of a strand of hair, and larger eggs can be about the size of a single grain of reined granular sea salt.

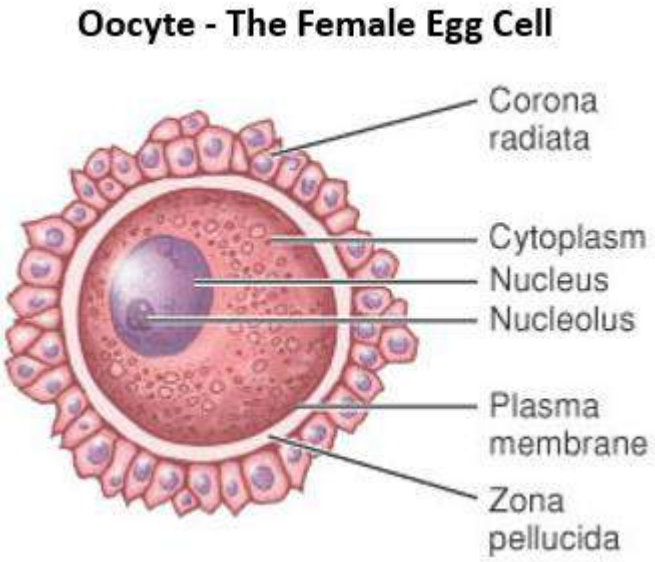


Figure 23.3 The oocyte is the immature or developing egg cell within the ovarian follicle. It contains a large nucleus with substantial cytoplasm. It is surrounded by a thick protective glycoprotein membrane called the zona pellucida (from Latin pellucerene, meaning to shine light through). The outer layer of follicular (granulosa) cells is called the corona radiate (from Latin meaning radiating crown) forming around the developing oocyte remaining present and in place at ovulation.

Why is the female egg cell so large? Like the male sperm cell, the female egg cell contains a large nucleus with haploid (half) the number of chromosomes as other body cells (see **Fig 23.3** above). Unlike a sperm cell, the egg contains a significant cytoplasm to ensure resources if it fertilized, which is why it is so big.

<u>The ovarian follicle have several stages of development</u>

1. **Primordial follicle**: An oocyte with a single layer of cells.

2. **Primary follicle**: Has two or more layers of encircling cells called **granulosa** cells.

3. **Secondary follicle**: Now contain the **antrum**, the fluid-filled central cavity.

4. **Mature follicle**: Also called a Graafian follicle (see **Fig. 23.4** below), the primary oocyte within it has completed meiosis I. Prior to its release at ovulation, the follicle will acquire these features:
   - **a)** The **zona pellucida** around the oocyte (a layer of transparent glycoprotein).
   - **b)** A ring of granulosa cells called the **corona radiata** encircle the zona pellucida.
   - **c)** The **cumulus oophorus**, the "egg-bearing little cloud" support cells.
   - **d)** Several layers of cells, called **theca cells**, surrounding the granulosa cells.

Mature (Graafian) Follicle

1. Oocyte
2. Zona pellucida
3. Corona radiate
4. Zona granulosa
5. Cumulus oophorus
6. Basement membrane
7. Theca interna
8. Antrum in follicular cavity

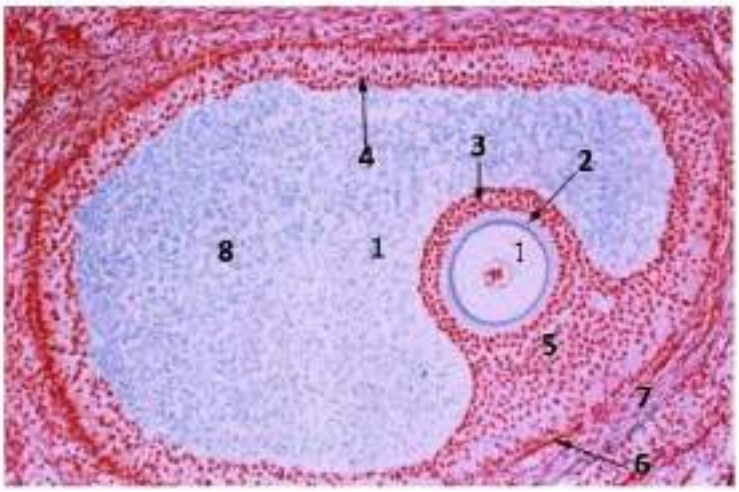


Figure 23.4 Shows the histology of the mature (Graafian) ovarian follicle with all of the structures listed to the left of the image to indicate the stage of development that precedes the release of oocyte at ovulation.

The Follicular Phase

Ovarian follicles grow and develop in a process called **folliculogenesis**, which just means 'follicle production', and this leads to ovulation of one follicle about every 28 days. It also involves the demise of other ovarian follicles, that process is called **atresia**. Put simply, the follicular phase is the time of the progression of follicular development from the tiny **primordial follicles**, which are actually present in newborn females and abundant in the adult ovary, to the fully **mature follicle** that is ready to release a mature egg cell. The primordial follicles residing within the ovary can remain in a dormant resting state in the ovary for many years, even decades, prior to being activated.

Once puberty starts, select primordial follicles respond to signals in the body to join a collection of growing **primary follicles** with their single layer of granulosa cells. These cell increase in size and proliferate to differentiate into **secondary follicles.** Becoming larger in diameter and adding **theca cells**, that together granulosa cells produce estrogens (see **Fig. 23.4** above).

At this stage the **primary oocyte** within the secondary follicle secretes a unique extracellular coat surrounding the maturing oocyte thin membrane called the **zona pellucida** which has an important role in fertilization. The zona pellucida prevents polyspermy (fertilization by more than one sperm) and enables the acrosome (at the tip of the sperm head) adhesion for penetration by the sperm cell into the egg.

The viscous follicular fluid fills the large space called the **antrum** (see **Fig. 23.4**) and when this is large and fully formed, it is then a **tertiary follicle** (antral follicles). Several tertiary follicles reach this stage at the same time, but most will undergo *atresia*. It is the one that does not die that will continue to grow and develop until ovulation. Throughout this entire process, about **99%** of the ovarian follicles undergo atresia.

At the very end of the follicular stage (just prior to ovulation), there is a surge of luteinizing hormone (LH) that triggers the resumption of meiosis in a primary oocyte. This initiates the transition from **primary to secondary oocyte**. This cell division does not result in two identical cells, but with an unequally divided cytoplasm. This larger daughter cell, the secondary oocyte, eventually leaves the ovary during ovulation. The smaller cell, called the first **polar body**, may or may not complete meiosis and produce second polar bodies; in either case, it eventually disintegrates, and again only one oocyte survives.

The Hormones Involved in the Ovarian Cycle

The **gonadotropic releasing hormones** (GnRH) from the hypothalamus signal the anterior pituitary to release the gonadotropins follicle stimulating hormone (**FSH)** and luteinizing hormone (**LH**) that bind to receptors on granulosa and theca cells of ovarian follicles.

As its name implies, follicle stimulating hormone (FSH) stimulates the growth and development of the ovarian follicles in females, including the development of the egg cell inside the follicle. It is the luteinizing hormone (LH) that binds to receptors on granulosa and theca cells of ovarian follicles to produce the sex steroid hormone estradiol, a type of estrogen, at ovulation. The LH also causes the release of progesterone by the corpus luteum after ovulation (see **Fig. 23.5** below).

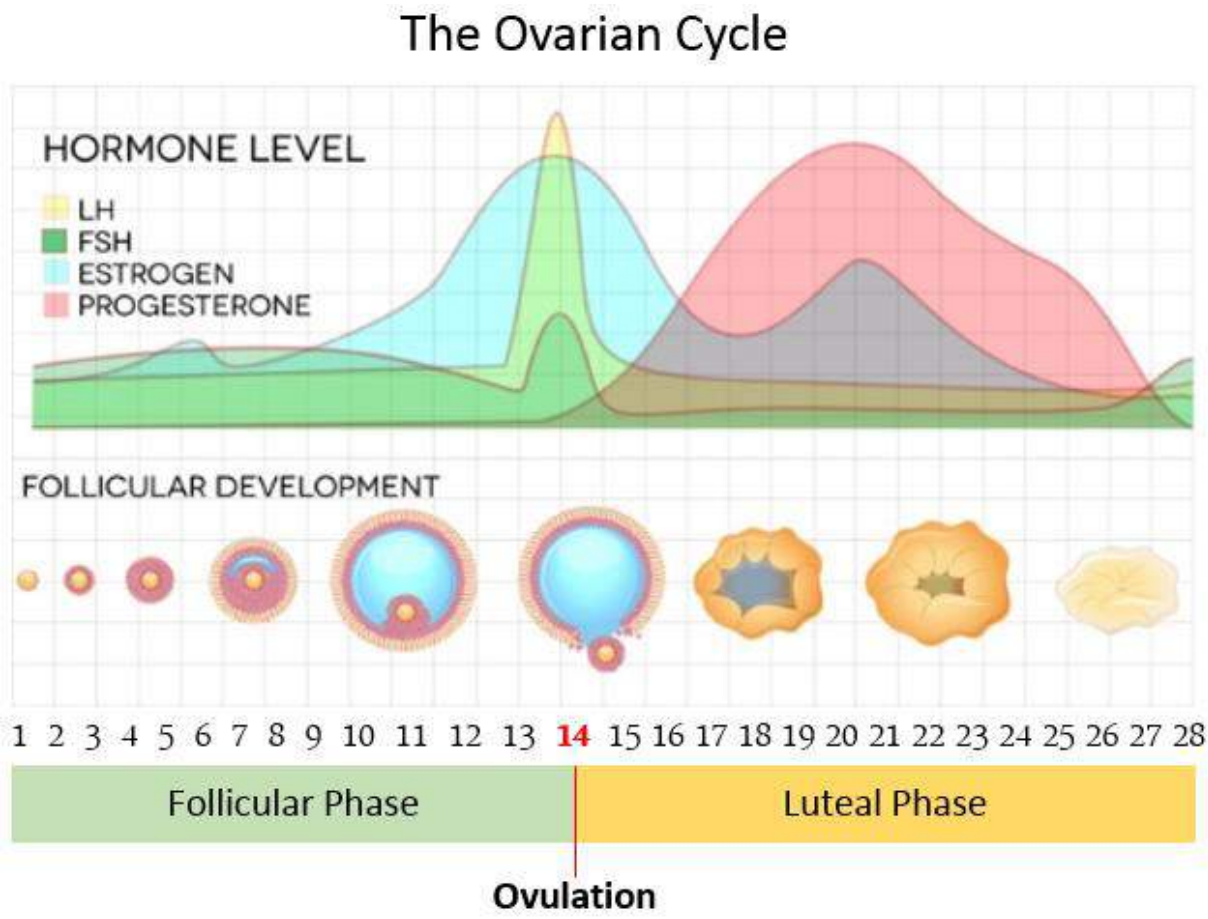


Figure 23.5 Shown above is a general graph of the changes in hormone levels during the 28 day ovarian cycle. There are three phases of this cycle, starting with the follicular phase when the follicle with the egg cell inside it develops. Then at ovulation, the mature egg cell is released at day 14. This triggers the last luteal phase in which the corpus luteum prepares for possible implantation of a fertilized egg cell (a zygote). LH stands for luteinizing hormone and FSH stands for follicle stimulating hormone.

As the ovarian follicle become larger and more developed, it produces more estrogen in response to LH, therefore as the follicular phase progresses, more and more estrogen is released, increasing systemic plasma estrogen concentrations (see **Fig. 23.5** above). The elevated estrogen levels stimulate a negative feedback loop in the hypothalamus and pituitary to reduce the production of GnRH, LH, and FSH. This decrease in FSH causes most follicles to die, except the **dominant follicle**, which will be the one that releases an oocyte.

Ovulation

Ovulation occurs approximately once every 28 days. In the very last portion of follicular development, the cells of the follicle start to produce more **estrogen** than all the follicles previously, such massive amounts that raise plasma estrogen enough to trigger the anterior pituitary to secret more **LH** and **FSH**, and this makes more estrogen, a positive feedback loop ensues that releases more LH and FSH, etc. It is the large **surge in LH** leads to **ovulation of the dominant follicle**. It also induces the dominant follicle to resume meiosis of a primary oocyte to a secondary oocyte. This spike in LH triggers proteases that break down structural proteins in the ovary wall on the surface of the bulging dominant follicle. This degradation of the wall, combined with pressure from the large, fluid-filled antrum, results in the expulsion of the oocyte surrounded by granulosa cells into the peritoneal cavity. This release of the egg cell at ovulation has the appearance of the structure in **Fig. 23.3**.

Interestingly, meiosis (the reduction division) of a released egg cell (oocyte) is only completed if a sperm cell penetrates its barriers. This action will trigger meiosis II to resume, producing a haploid (1n) genome and the cell is now called an **ovum**. It is not really necessary to be pedantic about the specific names of the egg cell, the best practice is to know that the mature egg cell is an oocyte that can become an ovum. Technically, the moment the haploid ovum is fertilized by a haploid sperm, it becomes the **fertilized egg cell** or a **zygote**. That union is the first diploid cell of the new offspring.

The cytoplasm of the female gamete is used to support the developing zygote in its journey to implantation into the endometrium of the uterus. As it turns out, the sperm cells provide their DNA at fertilization, not any cytoplasm because they do not really have any. They travel light. This is why all of the cytoplasmic organelles in the developing embryo are *from the mother*, because all of that extra material comes from the mother's egg cell. This includes **maternal mitochondria**, which has its own DNA.

The Luteal Phase

The surge of luteinizing hormone (LH) that triggers ovulation also converts the now empty follicle into the **corpus luteum** (yellow body) which is actually now acts as a secondary endocrine gland.

The granulosa and theca cells of the corpus luteum start to produce **progesterone** in very large amounts in preparation for the possibility of pregnancy. This occurs in order to support and maintain that condition, if it occurs. This high level of progesterone triggers a negative feedback of the hypothalamus and pituitary gland, which keeps GnRH, LH, and FSH release low in order to prevent any new dominant follicles to develop until the end of the luteal phase. This is sort of a failsafe mechanism so that no other egg cells are maturing in readiness for ovulation until the next cycle begins.

After ovulation, if pregnancy does not occur within about 10 to 12 days, the corpus luteum stops releasing progesterone and begins to transform into the **corpus albicans** (white body). This structure is then naturally degraded by resident ovarian macrophages. This change causes a reduction of progesterone, which then allows the release of FSH and LH to re-commence, and the ovary is now cycled back to the starting follicular phase, with a new bunch tertiary follicles start to develop and secrete estrogen.

The term *mittelschmerz* is a German word meaning "middle pain" and it is used to describe abdominal pain women have that is associated with ovulation, which of course occurs in the middle of both the ovarian and menstrual cycles. Some women can feel ovulation and this is accompanied by pelvic pain at about the 14 day of the typical 28 day cycle.

The Uterine Tubes

The **uterine tubes** (Fallopian tubes, or oviducts in other mammals) serve as a passageway for the oocyte as it departs the ovary and makes its way to the uterus. Each of the two uterine tubes is close to, but not directly connected to, the ovary and divided into sections. Looking at **Fig. 23.6** below it shows the close physical proximity of the ovary and the fimbriae at the entrance of the uterine tube. The egg cell is released into the abdominopelvic cavity and it is the billowing fimbriae that guide the egg into the uterine tube. It is the inner mucosal lining of this tube that has ciliated cells which rhythmically beat and create a current that pulls the oocyte in the direction of the uterus.

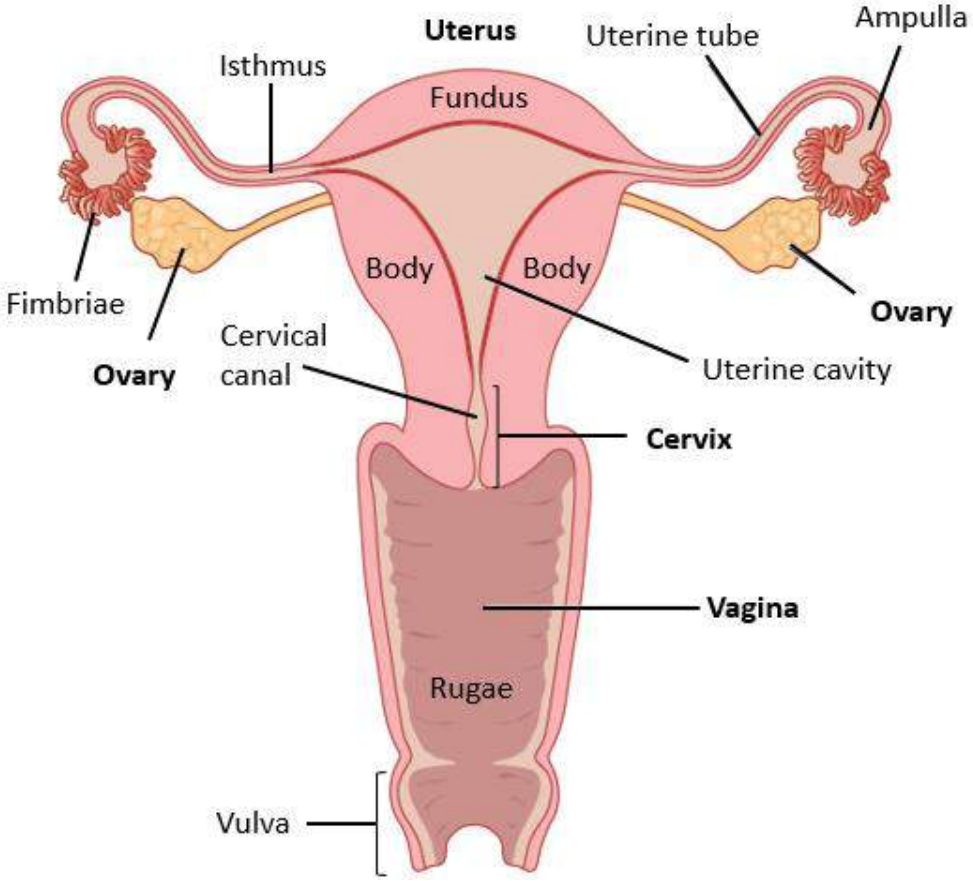


Figure 23.6 This diagram shows all of the internal reproductive structures of female as they are arranged in the pelvic region of the abdominopelvic cavity. Reading the figure from the ovaries first, flanking each side of the central uterus, the uterine tubes connect the ovaries to the fundus and body of the uterus. The lowest portion of the uterus is called the cervix which leads into the vagina and the vulva that becomes the external portion.

Hormonal Actions help Transport Gamete

The elevated **estrogen** levels around the time of ovulation cause the **smooth muscle** within the uterine tube to contract which helps the finger-like structures called fimbriae to sweep the egg into the fallopian tube. The egg travels through the fallopian tube, propelled in part by contractions in the **fallopian tube walls**. Here in the fallopian tube, the egg may be fertilized by a sperm. All of this contributes to the slow and steady movement of the oocyte toward the uterus, which typically takes about **3 days** if no fertilization occurs (see **Fig. 23.7** below). If fertilization occurs, the sperm usually makes contact with the egg while it is moving through the ampulla of the uterine tube. An **ectopic pregnancy** occurs when a fertilized egg grows outside of the uterus. It can occur if the egg cell travels into the abdominal cavity instead of the uterus. However, the vast majority of ectopic pregnancies (over 90%) occur in a fallopian tube.

The normal development of the blastula occurs in the uterine tube on the way to the uterus. There, it will implant in the nutrient laden inner endometrial layer and continue to develop and grow. If the egg is not fertilized, it will diminish in the uterine tube or in the uterus, and is usually shed during the following menstruation or menstrual period.

The Uterus

The **uterus**, also known as the **womb**, is the organ where the **embryo** becomes the **fetus** as it grows and develops. As we will see as we look more closely, the uterus is a very muscular organ, with about 90% of it being composed of smooth muscle. This component is an important structure that provides the very effective contractions during child birth. In females who are not pregnant, the uterus is surprisingly small, with an average size of 2 inches wide by 3 inches long (5 cm by 7 cm). The actual dimensions vary greatly, as all women are different, but this gives an idea of the relative size and how impressive it is that the uterus can dramatically change in order to accommodate a growing baby.

The superior portion that meets the uterine tubes of the uterus is called the **fundus** (a term which means 'opposite of the open end', like when a coin purse is tipped upside down, the top part in that position would be the fundus). The bulk of the uterus is the middle section called the **body of uterus** (or corpus). The lowest region is called the **cervix** (meaning neck) which contains the extremely narrow **cervical canal** that merges into the **vagina**. The cervix produces **mucus secretions** that become thin and stringy under the influence of high systemic plasma **estrogen** concentrations, and these secretions more effectively facilitate the movement of sperm through the female reproductive tract.

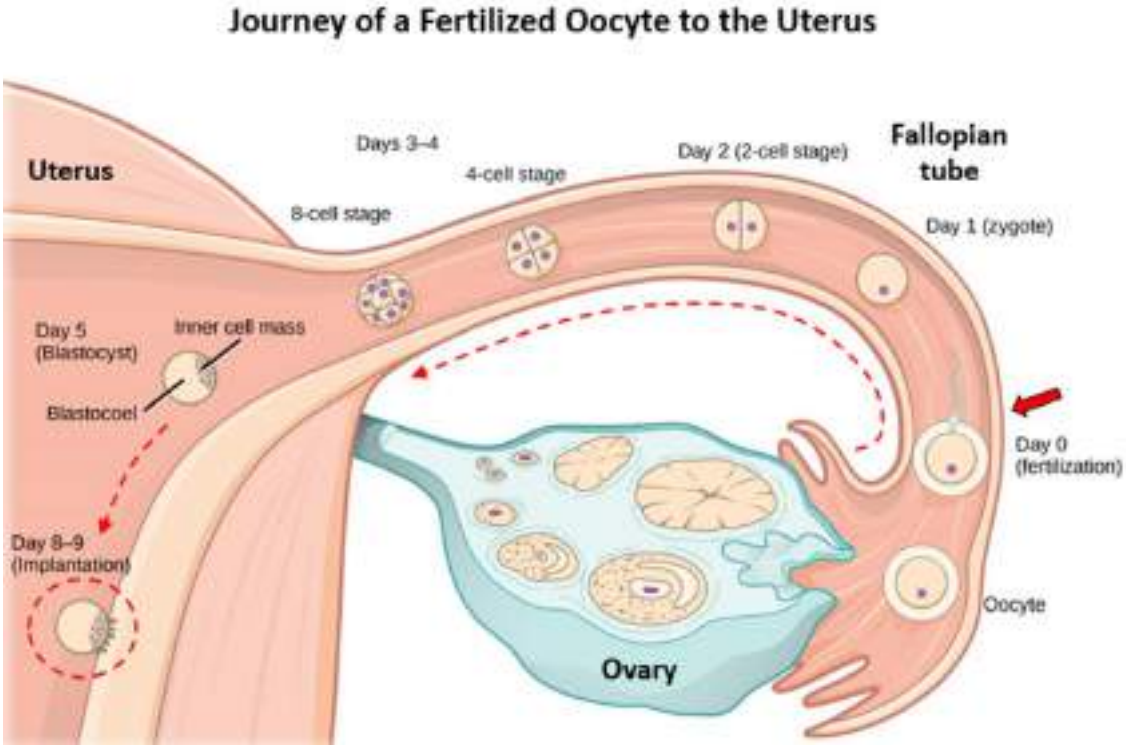


Figure 23.7 This image show the journey of a zygote (fertilized egg cell) if the oocyte that is released from the ovary at ovulation becomes fertilized by a sperm cell (red arrow). The process of fertilization must occur within 24 hours of ovulation and therefore occurs in the Fallopian (uterine) tube. The zygote starts to divide and multiply in the uterine tube on its way to the uterus, a journey that can take 3 to 4 days. Once in the uterus the blastocyst has formed, implantation of the embryo can occur into the endometrial layer of the uterus, about 8 or 9 days after fertilization occurs.

The Layers of the Uterine Wall

There are three layers of the uterine wall. From outermost to innermost they are the:
1) Perimetrium; 2) Myometrium; and **3) Endometrium.**

1) Perimetrium
The **perimetrium** is the most superficial exterior layer of the uterus that is in contact with the other organs and structures in the pelvic cavity. It is a slippery **serous membrane** that functions to protect the uterus and to reduce friction between it and the structures moving around.

2) Myometrium
The middle layer of the uterus is the **myometrium** and it is the thickest layer, making up about 90% of the uterine wall. It is composed of **smooth muscle** and this is the layer responsible for uterine contractions during childbirth.

The arrangement of the muscle fibers in the myometrial tissue is complicated and effective. The muscle fibers run horizontally, vertically, and diagonally, enabling for powerful and extremely effective contractions during child birth or labor. The myometrial layer of the uterus may also contract in a much more moderate way during menstruation or menstrual cycle. When prostaglandins are released they stimulate uterine contractions and this can cause discomfort and pain which are often experienced as cramps during the first two days of menses (menstruation) in order to facilitate menstrual blood flow from the endometrium.

In addition, myometrial contractions around the phase ovulation are thought to be a contributing factor in the transport of sperm cells from the cervix toward the uterine tubes of the female reproductive tract.

3) Endometrium
The innermost layer of the uterus is called the **endometrium**, this is the layer the fertilized egg cell would implant into. It consists of two layers: **a)** the **functional layer**, or stratum functionalis (the exposed surface), and **b)** the **basal layer**, or stratum basalis (on the bottom),

The thicker functional layer is the portion of the endometrial wall that is shed each month during **menses** (which means month in Greek), also called **menstruation**. The basal layer creates the lamina propria which connects to the myometrium below it. This bottom layer always remains and does not shed during menstruation or menses.

The condition of **endometriosis** can occur when tissue that is similar to the endometrial lining of the uterus grows outside the uterus, for example in the uterine tube or in the abdominal cavity. This tissue can thicken, break down, and bleed with each period, but is not able to be released the same way. It can lead to painful periods, heavy bleeding, pain during sexual intercourse or when having a bowel movement or urinating. Treatments can vary but the most fundamental issue is to determine the cause of this (or any) condition and address that directly, rather than suppress symptoms related to the issue.

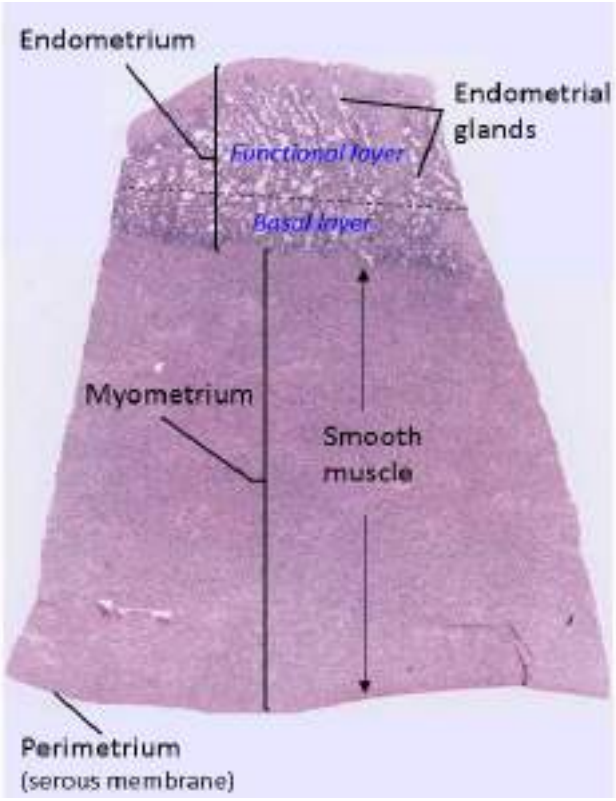


Figure 23.8 This is a histological section of the uterus showing the three layers of the uterine wall from top to bottom: The first is the innermost exposed endometrium (with two portions, the upper functional layer and lower basal layer); next is the deeper thick muscular myometrium in the middle; and lastly is the extremely thin serous membrane called the perimetrium on the outer surface of the uterus.

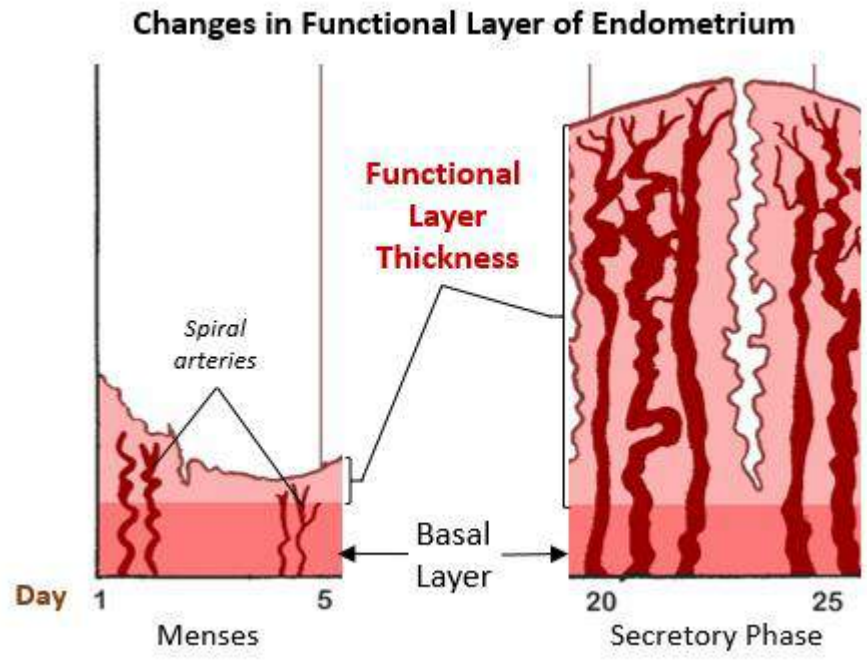
The Shedding of the Functional Layer

The most superficial exposed layer of the uterus is the stratum functionalis, or the functional layer. It is the ***functional layer*** that grows and thickens in response to increased levels of **estrogen** and **progesterone**. In the luteal phase of the ovarian cycle (and secretory phase of menstrual cycle) there are special branches coming off of the uterine artery called spiral arteries and these supply the thickened functional layer (**Fig 23.9** below). This inner functional layer provides the perfect site for implantation of a fertilized egg cell. Should fertilization *not* occur, it is then this functional layer *only* of the endometrium that sheds during menstruation. This layer is of course re-built every month.

The deeper stratum basalis or basal layer (meaning bottom layer) is the deepest tissue of the endometrium it sits atop muscular myometrium. It's the layer of endometrium that doesn't undergo any removal or structural changes during the uterine cycle and its purpose is to assist in the replacement of tissue that is loss during the menstruation.

Distal vessels are sloughed off, while the spiral arteries (named for their helical shape) retract into the stratum basalis and constrict to limit blood loss during menstruation

The uterine lining does not receive the progesterone, **causing the spiral arteries constrict and the endometrial tissue to become ischemic**. This causes cell death and the sloughing of the functional layer.



At the start of the ovarian cycle, estrogen release is stimulating ovarian follicles (in the follicular phase) and also during this phase the functional layer of the endometrium starts to rebuild from menses. It is the increase in progesterone after ovulation during the luteal phase which maintains the thick functional layer that steadily thickens in preparation for a potential implantation of a fertilized egg cell. If the corpus luteum in the ovary is still present and functioning, then the endometrial lining continues to prepare for implantation.

Figure 23.9 This shows the minimum and maximum thickness of the endometrial layer of the uterus from the start of the cycle at menses from days 1 to 5 (left), where the functional layer at its thinnest after being sloughed off, compared to the end of the secretory phase from days 20 to 25, where the functional layer has been restored to its maximum thickness in preparation for possible zygote implantation. Note the spiral arteries that retract down into the stratum basalis.

If no embryo implants into the endometrium, the corpus luteum will degrade and progesterone production will stop, ending the luteal phase of the ovarian cycle. In the uterus, the lack of progesterone, coupled with the impact of prostaglandins, causes the **spiral arteries** of the endometrium constrict and rupture, preventing oxygenated blood from reaching the endometrial tissue. As a consequence of this, the functional layer of the endometrium dies and blood along with endometrial tissue debris white blood cells are sloughed off and shed out via the vaginal canal during **menstruation,** which is also called the **menstrual period** or **menses**.

When an embryo does implant into the functional layer of the endometrium, a hormone called **human chorionic gonadotropin** (**hCG**) begins to be produced in the uterus. This hormone signals the corpus luteum to *continue* secreting progesterone in order to maintain the full state of the endometrium, and thus maintain the pregnancy. This is what prevents the uterine lining from being shed and this is why a woman does not have a period when she becomes pregnant. It is the levels of the hCG that a pregnancy test measures. Once hCG have reached high enough levels in the blood, which is usually 10 to 12 days after conception (after becoming pregnant), it can be detected in the urine with a pregnancy test.

The Uterine (Menstrual) Cycle

The ovarian cycle is determined by the hypothalamic and pituitary gonadotropic hormones, and the uterine cycle is dictated by the ovarian hormones. The **uterine** or **menstrual cycle** also has three phases:

1) Menses

2) Proliferative phase

3) Secretory phase

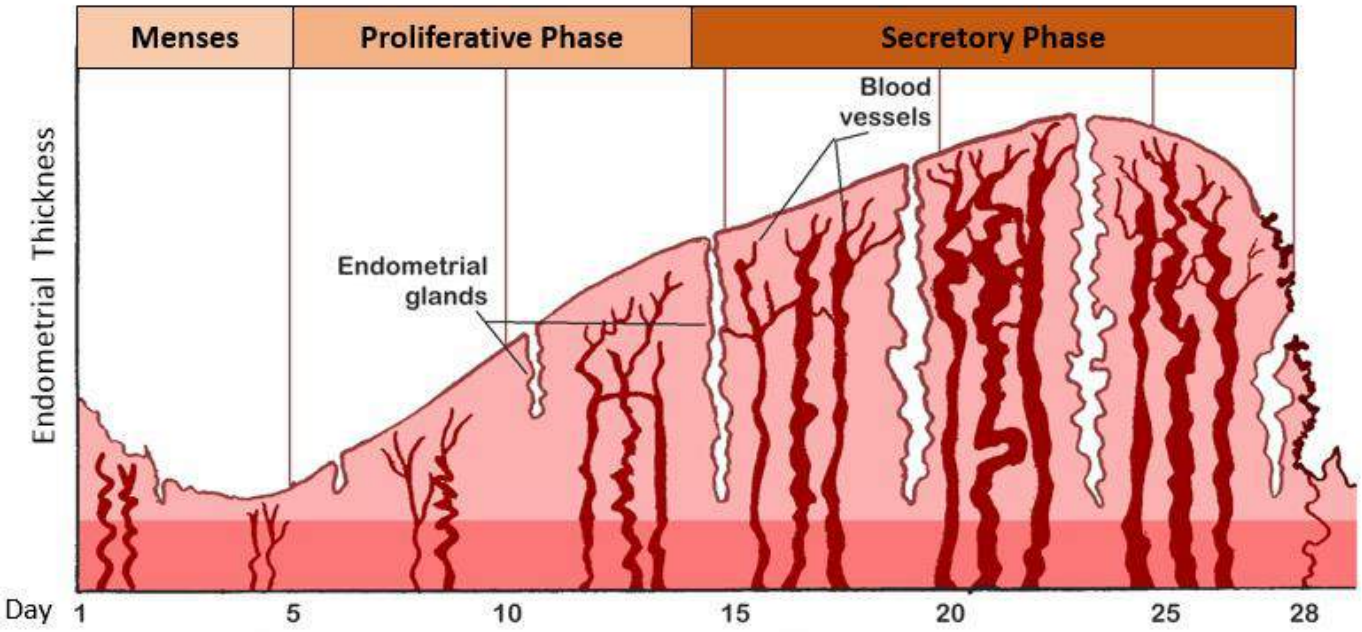


Figure 23.10 Shows the changes in the thickness of the endometrial layer of the uterus throughout the entire uterine cycle. At the end menses the functional layer is at its lowest thickness, having just been lost in menstruation (sloughing off during the menstrual period). This layer continues to build back steadily during the proliferative phase and reaches its maximum thickness right before the end of the secretory phase, where the cycle repeats.

Menses or Menstruation

As discussed earlier, **menses** means 'month' in Greek and it is the monthly shedding of the functional layer of the endometrium, which is also called the **menstrual period**, or **menstruation**. This phases typically goes from day 1 to day 5 of the 28 day cycle (see **Fig. 23.10** above), though it can be as short as 2 days or longer than 7. This time of menses coordinates with the early stages of the follicular phase of the ovarian cycle. The sloughing off of the functional layer occurs particularly significantly when progesterone (plus FSH and LH) hormone levels are low. It is important to note that menstrual flow is not composed of just blood but also contains remnants of the cellular debris from the functional layer of the endometrium. The first menses at the onset of puberty is called **menarche** and can occur before or after the first ovulation.

Proliferative Phase

Once menstrual flow ceases, the re-building of the endometrium commences making it the start of the **proliferative phase** of the uterine cycle. The increasing levels of estrogen from the granulosa and theca cells of the ovarian follicles stimulate the endometrial lining to increase and thicken. Ovulation on day 14 marks the end of the proliferative phase in the uterus (and the end of the follicular phase in the ovary).

Secretory Phase

The last phase on the uterine cycle starts with elevated **progesterone** that is produced by the corpus luteum, as the **secretory phase** centers on preparing the endometrial lining for possible implantation of a fertilized egg cell. The second peak of elevated estrogen levels is what facilitates the contractions of the uterine tube in order to conduct the oocyte to the uterus after ovulation. The corpus luteum within the ovary now pivots its activity into the luteal phase of the ovarian cycle which toward the end of it coincides with the start of the secretory phase of the uterine cycle.

During the secretory phase, the endometrial glands become long and twisted, and the secretion of a fluid rich in **glycogen** starts to occur. The uterine epithelial cells express the enzymes necessary to make and catabolize glycogen (glucose-6-phosphotase) that is necessary to liberate the glucose stored as glycogen. If an **embryo** does implant in the endometrium this nutrient rich fluid is perfect to nourish it. The **spiral arteries** develop in order to provide plenty of blood to the thickened functional layer. The estrogen levels during this phase also tend to lower the acidity of the vagina, making it more hospitable to sperm.

If no pregnancy occurs after about 10 to 12 days from the start of this phase, no signal will be sent for the corpus luteum to continue on, and thus it will degrade into the **corpus albicans**. The estrogen and progesterone levels fall (see **Fig. 23.5**) and the endometrium will not get any thinker but will start to thin. This is combined with **prostaglandins** being secreted which causes constriction of the spiral arteries, reducing oxygen supply which causes the endometrial tissue in the functional layer to die, signaling the onset of menses, which will be the first day of the next cycle.

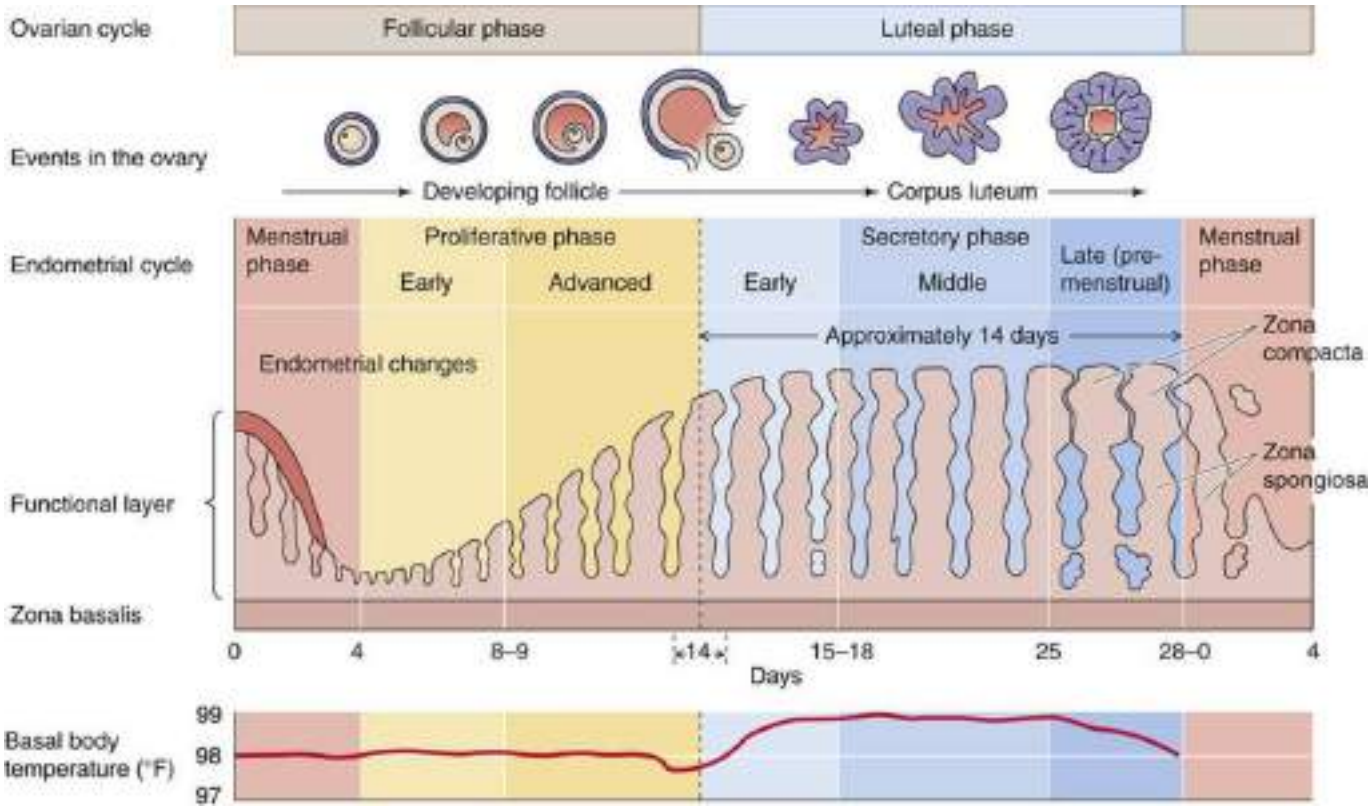


Figure 23.11 This images show the phases of the ovarian cycle (top panel), illustrating the developmental stages of the ovarian follicle, and the remnant of the follicle after ovulation, the corpus luteum. It also displays the specific stages of the endometrial or uterine cycle (middle panel), highlighting the physical changes in the inner lining of the uterus. Lastly, it shows the changes in body temperature of the female (lower panel) that occur immediately prior to ovulation, which is a small transient dip, followed by small (about 1° F) but lengthy elevation in body temperature until the start of the menstrual cycle.

Other Hormones in the Reproductive Cycle

Inhibin Hormones

The protein hormone **inhibin** is produced in the ovaries and the testes. There are actually two types of inhibin, **inhibin A** and **inhibin B**. They are secreted by **Sertoli cells** in the testis of men, and **granulosa cells**

in the ovaries of women. As the name implies, it **inhibits** the synthesis and secretion of follicle-stimulating hormone (**FSH**) and reduces the release of gonadotropin-releasing hormone (GnRH) from the hypothalamus. Inhibin A is secreted mostly by the corpus luteum and **inhibits the secretion of FSH** secretion during the luteal to follicular phase. Inhibin B controls FSH secretion via a negative feedback mechanism associated with maturation of follicles in the ovaries.

Both inhibin A and B have several functions in the male and female body, with levels in women being linked to the menstrual cycle and playing a role in fetal development. As seen in the graph in **Fig. 23.12** below, in the female ovarian cycle inhibin A is low in the early **follicular phase** and rises at **ovulation** to maximum levels in the mid-luteal phase. And in almost an exact contrast, inhibin B levels increase early in the **follicular phase** to reach a peak with the onset of the mid-follicular phase decline in FSH levels. As with other endocrine hormones, the levels of these hormones can be influenced by other hormones. Fertility testing can include an assessment of levels of Inhibin (A and B) along with other hormones in the body to learn more about the reasons for infertility.

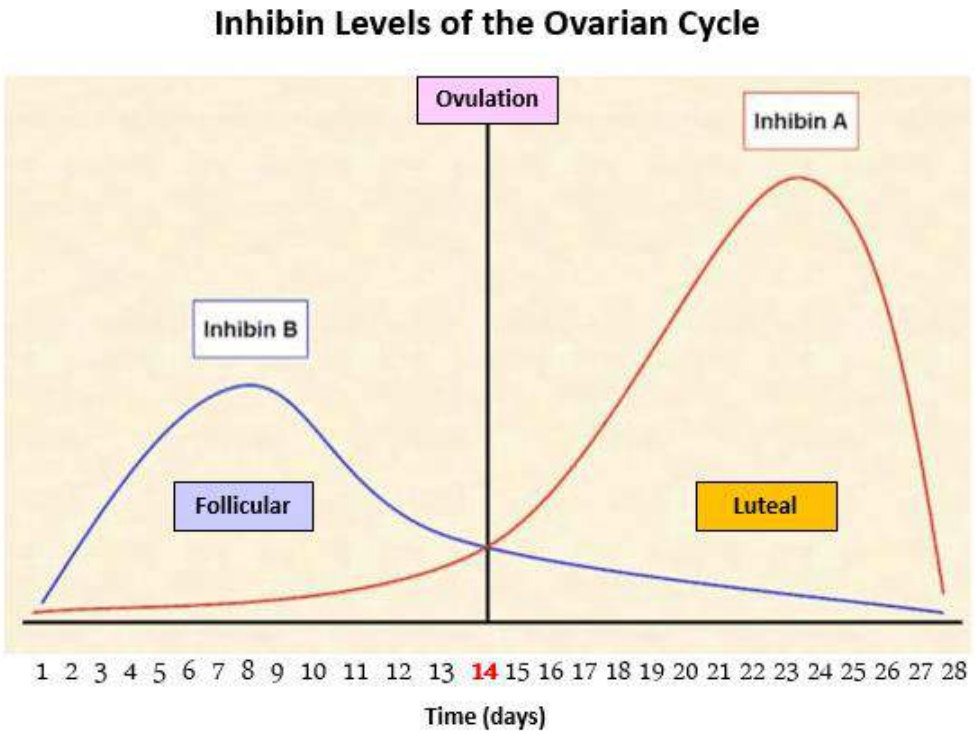


Figure 23.12 The levels of both inhibin A and inhibin B are shown during the ovarian cycle. In viewing the cycle in two parts, before and after ovulation, it is seen that inhibin A is very low for most of follicular phase, but after ovulation, it begins to rise steeply and peaks in the mid-luteal phase (which is toward the end of the entire cycle). In contrast, inhibin B levels are high early in the follicular phase reaching its peak at essentially mid-follicular phase, it then declines and remains low throughout the luteal phase.

Activin Hormone

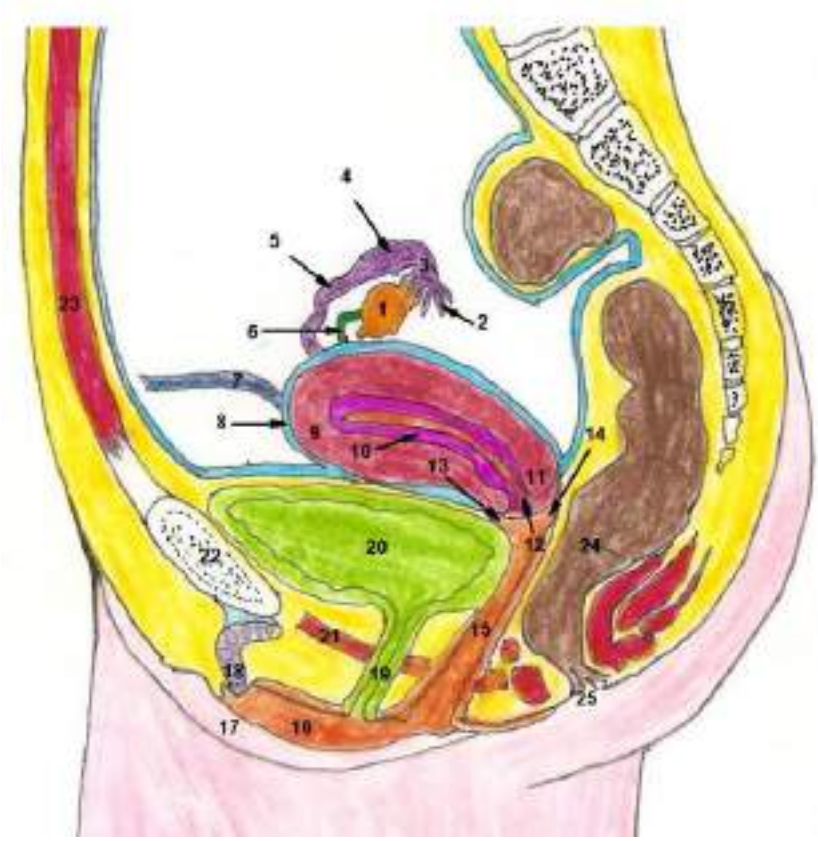
Another hormone, **activin**, has an action opposite to that of inhibin. This means that activin directly **stimulates FSH** synthesis and release from the anterior pituitary gland. The levels of inhibin and activin can fluctuate in both men and women in response to a number of cues, which can include changes in hormone levels that are triggered by natural biological processes, environmental pressures, and other factors. Activin is produced in the gonads, pituitary gland, placenta, and other organs.

In the ovarian follicle, activin **increases follicle stimulating hormone** (FSH) binding, and FSH-induced **aromatization**, this is an enzymatic process that promotes the conversion of an **androgen** into **estrogen**. It also participates in androgen synthesis enhancing **luteinizing hormone** (LH) action in the ovary and testis. In the male, activin enhances spermatogenesis.

External Female Genitals

The external female reproductive structures are referred to collectively as the **vulva**. The **mons pubis** is a pad of fat that is located at the anterior over the pubic bone. After puberty, it becomes covered in pubic hair. The **labia majora** (labia = "lips"; majora = "larger") are folds of hair-covered skin that begin just posterior to the mons pubis. The thinner and more pigmented **labia minora** (labia = "lips"; minora = "smaller") extend medially to the labia majora. Although they naturally vary in shape and size from woman to woman, the labia minora serve to protect the female urethra and the entrance to the female reproductive tract.

The superior anterior portions of the labia minora come together to encircle the **clitoris** (or glans clitoris), an organ that originates from the same tissue as the glans penis and has an abundance of nerves that make it important in sexual sensation and orgasm. The **hymen** is a thin membrane that sometimes partially covers the entrance to the vagina. An intact hymen cannot be used as an indication of "virginity"; even at birth, this is only a partial membrane, as menstrual fluid and other secretions must be able to exit the body, regardless of penile–vaginal intercourse. The vaginal opening is located between the opening of the urethra from the bladder and the anus. It is flanked by outlets to the **Bartholin's glands** (or greater vestibular glands).



The Female Reproductive Structures

1. Ovary
2. Fimbriae
3. Uterine (Fallopian) tube
4. Infundibulum
5. Ampulla
6. Ovarian ligament
7. Round ligament
8. Perimetrium layer (serous membrane)
9. Myometrium layer (of Fundus)
10. Endometrium layer
11. Cervix
12. External os (opening) of cervix
13. Anterior fornix
14. Posterior fornix
15. Vagina
16. Labia majora
17. Labia minora
18. Clitoris
19. Urethral orifice
20. Bladder
21. Urogenital diaphragm
22. Pubic symphysis
23. Rectus abdominis
24. Rectum
25. Anus

Figure 23.13 This is a mid-sagittal section of the female reproductive system. The structure key to the right starts at the ovary and follows the journey of the oocyte to the uterus and through the vagina. Also included are structures that provide a good frame of reference for the arrangements of internal structures.

The Secondary Characteristics of the Female Reproductive System

The Vagina

The **vaginal canal** or **vagina** is a muscular canal that invaginates from the external usually about 3 to 6 inches (6.5 to 15 cm) in length, see the mid-sagittal diagram in **Fig. 23.13** above. This passageway serves as the entrance to the female reproductive tract. It also serves as the exit from the uterus of blood and cellular debris during menses, and as the exit for the baby during childbirth. The vaginal canal leads directly into the most inferior portion of the uterus, the **cervix**.

The outer walls of the anterior and posterior vagina are formed into longitudinal columns or ridges, and the superior portion of the vagina creates a series of arches called the vaginal fornices (plural of fornix) where the canal meets the protruding uterine cervix. The tissue of the walls of the vagina are lined with an outer fibrous adventitia; a middle layer of smooth muscle; and an inner mucous membrane with transverse folds called **rugae**. Together, the middle and inner layers allow the expansion of the vagina to accommodate intercourse and childbirth. The thin, perforated **hymen** can partially surround the opening to the vaginal orifice. The hymen can be ruptured with strenuous physical exercise, penile-vaginal intercourse, and childbirth. The Bartholin's glands and the lesser vestibular glands (located near the clitoris) secrete mucus, which keeps the vestibular area moist.

The Normal Flora and Conditions of the Vaginal Canal

The vagina is home to a normal population of microorganisms that help to protect this region against imbalances that cause infection and abnormal bacterial or yeast growth, as other organisms can enter the opening of vagina. In a healthy woman, the most predominant type of vaginal bacteria is from the genus ***Lactobacillus***. This family is a highly beneficial bacterial flora which secretes lactic acid, and thus protects the vagina by maintaining an **acidic pH** (below **4.5**). Potential pathogens are less likely to survive in these acidic conditions.

Lactic acid, in combination with other **vaginal secretions**, makes the vagina a self-cleansing organ. In this way, the practice of douching or washing out the vagina with fluids and harsh synthetic chemicals can actually significantly disrupt the normal balance of healthy microorganisms within this region and tend to increase a woman's risk for infections and irritation. Indeed, the American College of Obstetricians and Gynecologists recommend that women do not douche, and that they allow the vagina to maintain its normal healthy population of protective microbial flora as it normally does.

The Breasts and Mammary Glands

The breasts and mammary glands are considered accessory organs of the female reproductive system. The fully developed mammary glands have a distinct role in nourishment and bonding between the mother and the baby. They are located on the chest in very close proximity to the beating heart and also close to the mother's face. The function of the breasts is to supply nutrient rich milk to an infant in a process called **lactation**. The external features of the breast include a nipple surrounded by a pigmented **areola**, whose coloration may deepen during pregnancy. The areola is typically circular and can vary in size from 25 to 100 mm in diameter. The areolar region is characterized by small, raised areolar glands that secrete lubricating fluid during lactation to protect the nipple from chafing and becoming sore. When a baby nurses, or draws milk from the breast, the entire areolar region is taken into the mouth.

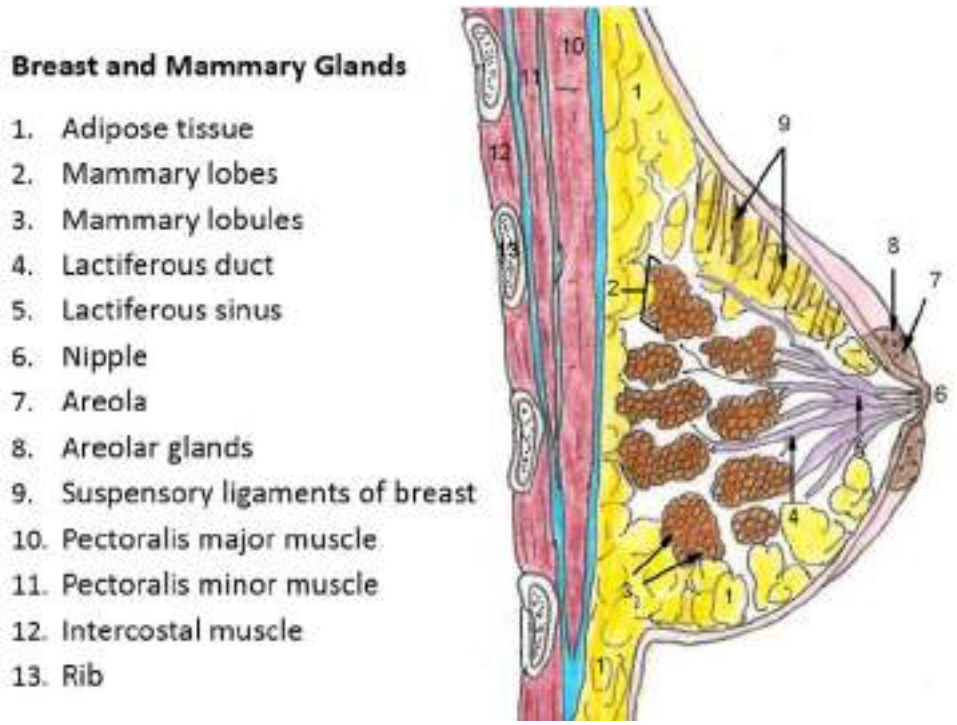


Figure 23.14 This is a mid-sagittal section of the female reproductive system. The structure key to the right starts at the ovary and follows the journey of the oocyte to the uterus and through the vagina. Also included are structures that provide a good frame of reference for the arrangements of internal structures.

In terms of navigating through the breast, the milk itself exits the breast through the nipple via 15 to 20 **lactiferous ducts** that open on the surface of the nipple, see **Fig. 23.14** above. These lactiferous ducts each extend to a **lactiferous sinus** that connects to a glandular lobe within the breast itself that contains groups of milk-secreting cells in clusters called **alveoli**. The clusters can change in size depending on the amount of milk in the alveolar lumen. Once milk is made in the alveoli, stimulated myoepithelial cells that surround the alveoli contract to push the milk to the lactiferous sinuses. From here, the baby can draw milk through the lactiferous ducts by suckling. The lobes themselves are surrounded by fat tissue, which determines the size of the breast; breast size differs between individuals and does not affect the amount of milk produced. Supporting the breasts are multiple bands of connective tissue called **suspensory ligaments** that connect the breast tissue to the dermis of the overlying skin.

During the normal hormonal fluctuations in the menstrual cycle, breast tissue responds to changing levels of estrogen and progesterone, which can lead to swelling and breast tenderness in some individuals, especially during the secretory phase. If pregnancy occurs, the increase in hormones leads to further development of the mammary tissue and enlargement of the breasts.

Breast Feeding and Breastmilk

During breastfeeding, the **letdown reflex** is a trigger that causes the release of breastmilk and allows it to flow. This reflex occurs when tactile stimulation of the nipple-areolar complex occurs when a baby begins to suckle. Nerves send afferent signals to the hypothalamus, triggering the release of **oxytocin**, which stimulates milk ejection or letdown reflex.

Breastmilk is produced by the **mammary glands**, which are modified sweat glands. This milk from a healthy mother is the best possible source of nutrients for a developing baby. Though there are numerous

scientific experiments that prove breast milk is far superior for babies than any formula, should we really need this 'proof'? Hopefully, as we understand more about the human body, issues like knowing breast milk is better for babies will become obvious and self-evident.

As the breast starts to empty, the fat globules begin to dislodge and move down the ducts (let-down facilitates this process). So the further into the feed, the higher the fat content of the milk, as more and more fat globules are forced out. The end result is that the milk gradually increases in fat as the feeding progresses, as described below in the difference between foremilk and hindmilk.

Breast milk is complex containing many subtle elements such as hormones and the perfect ratio of proteins, sugars (mostly from lactose), lipids (fats) and the vitamins and mineral needed to help your baby grow and develop. Breast also contains many other substances that protect your baby from many illnesses.

Figure 23.15 Shows the three types of breastmilk produced by mothers. Colostrum is extremely nutrient-rich and high in fats with production starting during pregnancy wherein it is the first breastmilk for the newborn baby up to 3 or 4 days after birth. After the colostrum is finished, foremilk is what the baby drinks at the beginning of a feeding and is mostly water with other nutrients. This is followed by hindmilk which is highly fatty and provides an abundance of nutrients for the baby.

Colostrum is a type of breastmilk that the breast begins to produce during pregnancy, and is the first breastmilk released by the mammary glands after birth. Its composition is very think and nutrient-rich to ensure the newborn baby has everything it needs, see **Fig 23.15** above for a compassion of the different stages of breastmilk. The colostrum changes to breastmilk within about two to four days after birth. There are then sort of two types of breastmilk, foremilk and hindmilk, but more accurately these terms describe the variations in the milk at the beginning and end of a breastfeeding session. **Foremilk** is what the baby drinks at the beginning of a feeding and is usually more watery, though it still contains many fatty nutrients and slightly higher in lactose (milk sugar) levels. This is followed by a gradual transition to **hindmilk**, which also has lactose but is much higher in fats and other growth promoting nutrients, including vitamins A and E. It is the hindmilk that satiates the baby's hunger.

Here are the main benefits of breastfeeding for both baby and mother:

- Breastmilk is the perfect nutrition for a baby.
- Creates the best digestion for baby
- Provides immense health protection for both baby and mother.
- Stimulates brain and nervous systems development.
- This food sources is almost always ready and portable.
- Numerous health and wellness benefits for mothers.
- This practice builds a special bond between mother and child.
- The advantages continue as the baby grows.

Succinctly, breastmilk is the best milk. The nutrients in breastmilk are unmatched by any other first food your baby can receive and the practice yields enormous benefits.

Further Sexual Development Occurs at Puberty

Ahhh puberty. Puberty is the stage of development at which individuals become **sexually mature**, ultimately what this means is that they are now able to reproduce. Regardless of the sex, either male or female, the general outcomes of puberty are similar in terms of the hormonal control of the process, in that the central issue is preparing the sex cells or gametes, the oocyte and the sperm. The onset of puberty may vary in terms of age, however the sequence of events and the changes that occur are very predictable for male and female adolescents.

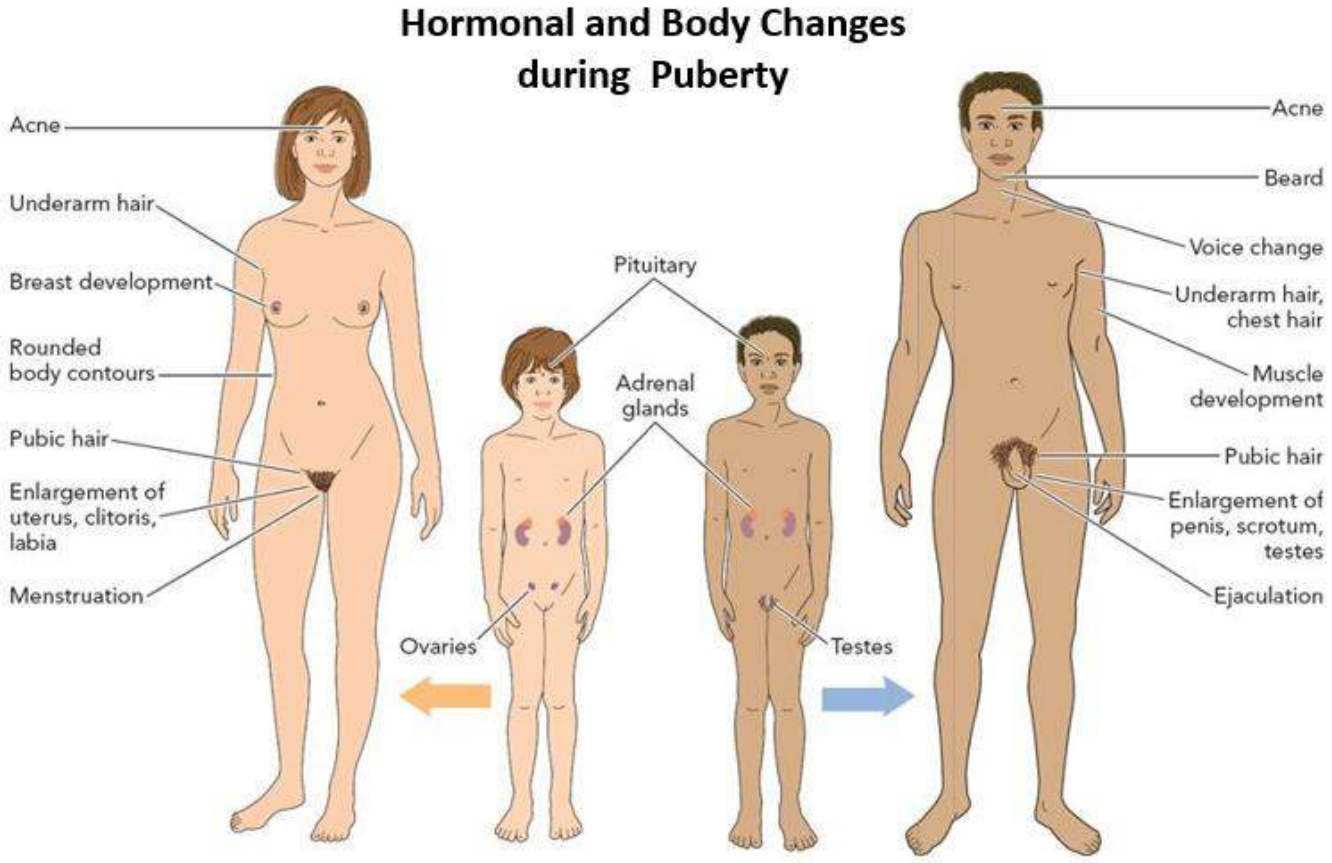


Figure 23.16 During puberty many bodily changes begin to occur. Female genitals and uterus enlarge, breasts develop and enlarge with characteristic fat deposits for women on hips and thighs and menstruation (periods) begins. In males, the penis, testes and scrotum get larger. Males also experience enlarged larynx (Adam's apple) producing voice changes (deeper), broad shoulder 'triangle' body shape, body hair distribution, and facial hair.

It is quite a symphony of hormones that facilitates this stage of development. The concerted release of hormones from the hypothalamus **gonadotropic releasing hormone** (**GnRH**), the anterior pituitary **luteinizing hormone** (**LH**) and **follicular stimulating hormone** (**FSH**), and the gonads (either testosterone or estrogen) are responsible for the maturation of the reproductive systems and the development of **secondary sexual characteristics**, which are the often visible physical changes that occur which serve auxiliary roles in reproduction.

The first changes begin sooner than some may realize. At around the age of eight or nine the production of LH becomes detectable (see **Fig. 23.16**). The release of LH occurs primarily at night during sleep and precedes the physical changes of puberty by several years. In pre-pubertal children, the sensitivity of the negative feedback system in the hypothalamus and pituitary is very high. This means that very low

concentrations of androgens or estrogens will negatively feed back onto the hypothalamus and pituitary, keeping the production of GnRH, LH, and FSH low.

Two important changes in sensitivity occur as an individual approaches puberty. First, there is a decrease of sensitivity in the hypothalamus and the anterior pituitary to the usual negative feedback mechanism, such that it takes increasingly larger concentrations of sex steroid hormones to stop the production of LH and FSH. The second change is an increased sensitivity of the gonads to the FSH and LH signals, meaning the **gonads of adults are more responsive to gonadotropins than are the gonads of children**. Due to these two changes, the levels of **LH** and **FSH** steadily, slowly increase and lead to the **enlargement and maturation of the gonads**, which in turn leads to secretion of higher levels of **sex hormones** and the initiation of **spermatogenesis** (development of sperm) and **folliculogenesis** (development of eggs).

Males

The physical changes of puberty for a boy usually start with enlargement of the testicles and sprouting of pubic hair, followed by a growth spurt between ages 10 and 16, this is typically 1 to 2 years later than when girls start puberty. A male's arms, legs, hands, and feet also grow faster than the rest of his body (see **Fig. 23.16** above as a reference). The first real physical sign of the beginning of puberty for boys is the growth of the testes, which is followed by growth and pigmentation of the scrotum and growth of the penis. The next step is the growth of hair, including armpit, pubic, chest, and facial hair. Testosterone stimulates the growth of the **larynx** (Adam's apple) and thickening and lengthening of the vocal folds, which causes the voice to drop in pitch. The first fertile ejaculations typically appear at approximately 15 years of age, but this age can vary widely across individual boys. Unlike the early growth spurt observed in females, the male growth spurt occurs toward the **end** of puberty, at approximately age 11 to 13, and a boy's height can increase as much as 4 inches a year. In some males, pubertal development can continue through the early 20s.

Females

Girls usually begin puberty between the ages of 8 and 13 years old. Typically the first change that is visible is the development of the breast tissue. This is followed by the growth of axillary and pubic hair. A growth spurt normally starts at approximately age 9 to 11, and may last two years or more. During this time, a girl's height can increase 3 inches a year. The next step in puberty is menarche, the start of menstruation. There are continued changes including vaginal discharge and expansion and further development of the pelvis, creating wider hips for child bearing, and also the female fat distribution patterns, especially on the hips, thighs (see **Fig. 23.16** above as a reference).

Factors Effecting the Onset of Puberty

Multiple factors can affect the age of onset of puberty, including genetics, environment, and psychological stress. One of the more important influences may be nutrition; historical data demonstrate the effect of better and more consistent nutrition on the age of menarche in girls in the United States, which decreased from an average age of approximately 17 years of age in 1860 to the current age of approximately 12.75 years in 1960, as it remains today. Some studies indicate a link between puberty onset and the amount of stored fat in an individual. This effect is more pronounced in girls, but has been documented in both sexes. Body fat, corresponding with secretion of the hormone leptin by adipose cells, appears to have a strong role in determining menarche (the first period for girls). This may reflect to some extent the high metabolic costs of gestation and lactation. In girls who are lean and highly active, such as gymnasts, there is often a delay in the onset of puberty.

Secondary Sexual Characteristics

Men and women are physically different and that is a great thing because it is accurate and can be seen, and one of the most obvious systems that exemplify how very different men and women are is the reproductive system. The key to the physical differences that exist and can be defined and measured between men and women are the **sex hormone concentrations differences** between the sexes. An important aspect of these hormone differences is that they contribute to the development and function of **secondary sexual characteristics**. This can be seen in **Figure 23.16** above and in **Table 23.1** below.

Table 23.1 Comparison of Male and Female Secondary Sexual Characteristics.

Development of the Secondary Sexual Characteristics	
Male	**Female**
Increased larynx size (Adam's apple) and deepening of the voice.	Deposition of fat, predominantly in breasts, hips and thighs.
Broader Shoulder to Hip ratio (Triangle)	Broader Hip to Shoulder to ratio (Pare)
Increased muscular development.	Breast development.
Growth of facial, axillary, and pubic hair, and increased growth of body hair.	Broadening of the pelvis and growth of axillary and pubic hair.

The Q angle, also known as quadriceps angle, is defined as **the angle formed between the quadriceps muscles and the patella tendon**. The Q angle has become accepted as an important factor in assessing knee joint function and determining knee health in individuals suffering from an anterior knee pain

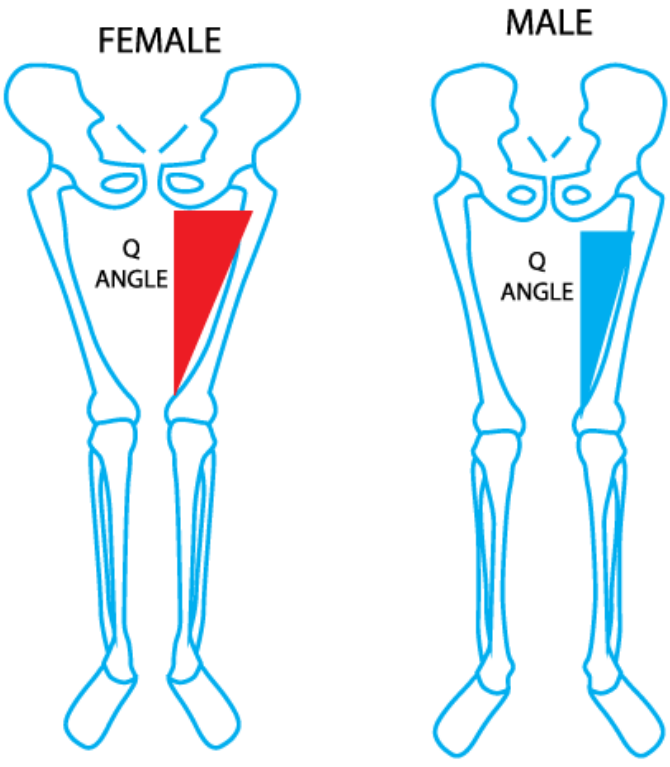


Figure 23.17 Shows the differences in female and male quadriceps or Q angle, which is formed between the quadriceps muscles and the patella tendon. The female Q angle is much larger than in males.

Refer to the **Figure 23.17** to the left:

* The female pelvis is larger and broader than the male pelvis, which is taller (owing to a higher iliac crest), narrower, and more compact.
* The distance between the ischium bones is small in males. This causes the sides of the male pelvis to converge from the inlet to the outlet, whereas the sides of the female pelvis are wider apart.
* This results in the female inlet being large and oval in shape, while the male inlet is more heart shaped.
* The angle between the inferior pubic rami is acute (70 degrees) in men, but obtuse (90–100 degrees) in women. Accordingly, the angle is called the subpubic angle in men and pubic arch in women.
* The greater sciatic notch is wider in females.
* The ischial spines and tuberosities are heavier and project farther into the pelvic cavity in males.
* The male sacrum is long, narrow, straighter, and has a pronounced sacral promontory.
* The female sacrum is shorter, wider, more curved posteriorly, and has a less pronounced promontory.
* The acetabula are wider apart and face more medially in females than in males. This change in the angle of the femoral head gives the female gait its characteristic swinging of hips.

Birth Control

Birth control is how to prevent pregnancy before it begins. There are several different methods and it is extremely important for anyone considering these to know all of the consequences involved, as many options can irreparably harm the health of the person using it.

The most obvious and fail-proof method of birth control is abstinence from sexual intercourse. In terms of birth control methods that involve sexual intercourse, these can be broadly classified into three different methods. Firstly is the **barrier methods**, this prevents the sperm cells from reaching the egg. Condoms and diaphragms are examples of barrier birth control methods. Secondly are methods that **prevent ovulation** such as the birth control pill, because it prevents ovulation from occurring. Thirdly are methods that allow fertilization of the egg but **prevent implantation of zygote** (the fertilized egg) inside the uterus (womb). An example of this is the intrauterine device (IUD). No method of birth control is 100% effective in preventing pregnancy, nor do they have any real impact on sexually transmitted diseases (STDs). A woman should carefully weigh the short and long term risks and side effects with the benefits.

How Birth Control Pills Work

Birth control pills prevent pregnancy through several mechanisms, primarily by **stopping ovulation**. If no egg is released, there is nothing to be fertilized by the sperm and the woman cannot get pregnant. Most birth control pills contain **synthetic forms of estrogen and progestin**. These synthetic hormones are more potent and harsh, thus not really like the natural female hormones, and they alter a woman's normal hormone levels and prevent estrogen from peaking mid-cycle. Without the estrogen bump, the pituitary gland does not release the other hormones that normally cause the ovaries to release mature eggs.

Synthetic estrogen in the pill works to:

- Stop the pituitary gland from producing follicle stimulating hormone (FSH) and luteinizing hormone (LH) in order to prevent ovulation
- Support the uterine lining (endometrium) to prevent breakthrough bleeding mid-cycle

Synthetic progestin works to:

- Stop the pituitary gland from producing LH in order to prevent egg release
- Make the uterine lining inhospitable to a fertilized egg
- Partially limit the sperm's ability to fertilize the egg
- Thicken the cervical mucus to hinder sperm movement

Menopause

As women approach their mid-40s to mid-50s, the ovaries begin to lose their sensitivity to follicle stimulating hormone (**FSH)** and luteinizing hormone (**LH)** to an extent that the menstrual periods become less frequent and ultimately finally cease. This process is known as menopause. Interestingly, there are still eggs and potential follicles within the ovaries, however, without the stimulation of FSH and LH, they will not be able to produce a viable egg to be released. The signals the end of the potential for child bearing.

There are various symptoms associated with menopause, including hot flashes, heavy sweating, headaches, muscle pain, vaginal dryness, insomnia, depression, changes in weight (usually gain), and initial mood swings. Estrogen is involved in calcium metabolism and, without it, blood levels of calcium decrease. To replenish the blood, calcium is lost from bone, which may decrease the bone density and lead to osteoporosis.

Natural Sources of Estrogen for Menopause

During menopause women's estrogen levels decline, which can lead to the symptoms described. The most widely cited natural remedy is **soy** because it is very high in **phytoestrogens**, however there are many significant drawbacks from eating unfermented soy. Unfermented soy in and of itself, organically grown or not, contains a number of problematic components that can wreak havoc with your health, including:

Too much **phytoestrogen**, can disturb endocrine function. Thyroid **goitrogens** are in all unfermented soy and interfere with thyroid function. **Phytates** in soy bind to metal ions, preventing the absorption of minerals, including: calcium, magnesium, iron, and zinc - all of which are co-factors for optimal biochemistry in your body. **Hemagglutinin**, this is a clot-promoting substance causing clumping of red blood cell. This can disrupt blood flow and can prevent the distribution of oxygen to your tissues. **Trypsin Inhibitors** in soy such as saponins, soyatoxin, ***protease inhibitors***, and oxalates will interfere with enzymes needed to digest protein. While small occasional amounts are not likely cause problems, daily supplements may not be advisable for all.

Great sources of **estrogen** building foods are: Unfermented soy products like miso, tempeh and natto beans, flax seeds, sesame seeds, red clover, hummus, garlic and dried fruit.

Fertilization, Pregnancy and Parturition (Birth)

The female carries the developing embryo and fetus in the womb (uterus) for approximately 40 weeks after the zygote (fertilized egg cell) is created. Many have the impression that the duration of a pregnancy is 9 months, but it's actually about 10 months (40 weeks). As seen in **Fig. 23.18** below, there are three stages of prenatal development, they are: **1)** Germinal (red dashed line); **2)** Embryonic (green dashed line); and **3)** Fetal (solid red line). Prenatal development is also organized into three equal trimesters, which do not correspond with the three stages.

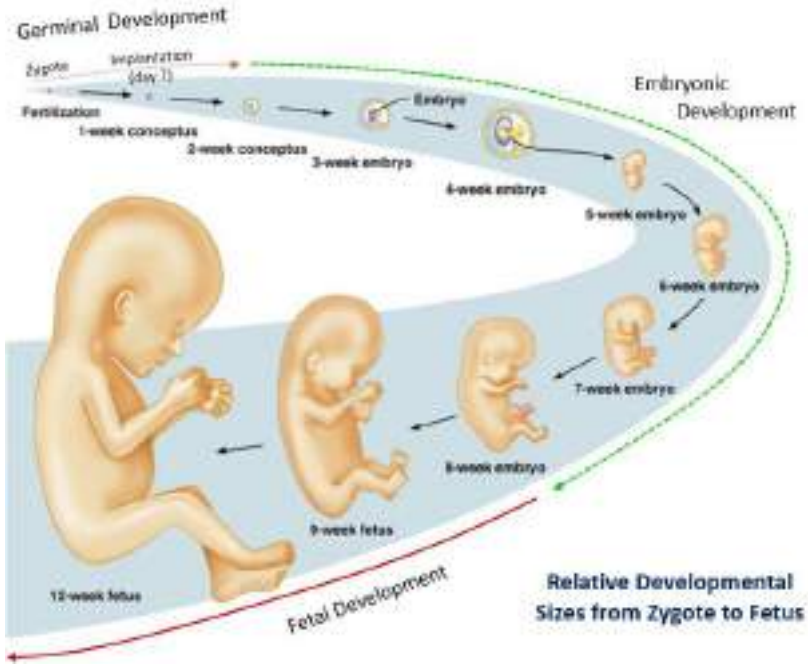


Figure 23.18 Shows the zygote which became fertilized in the uterine tube. As it continues to travels toward the uterus, the process of cell multiplication starts and continues, forming the blastula of dividing cells, then the embryo, which implants in the endometrial layer of the wall of the uterus for embryonic development from week 2 until week 8. At the ninth week post-conception, fetal development period begins, with continued rapid growth and development, culminating with partition (giving birth) after about week 40.

From the earlier details in this chapter regarding the female ovarian and uterine cycles, we know that if fertilization does occur soon after ovulation (release of that oocyte), this will trigger the release of **human chorionic gonadotropin** (hCG) from the developing embryo, and the corpus luteum in the ovary will be maintained in order to oversee the pregnancy proceedings, allowing the corpus luteum to produce the levels of **progesterone** required to sustain the pregnancy.

Also as previously briefly mentioned, most over the counter pregnancy tests are detecting **hCG** as an indicator of implantation of a zygote. The levels of hCH are very low initially and may take a few weeks to be high enough for detection by the test of hCH in the blood. The subsequent speedy rise in hCG levels in the urine can then be tested, even prior to the missed period, which of course is a big indicator of pregnancy, but is not fool proof.

Fertilization and Pregnancy

The secondary oocyte is directed into the lumen of the uterine tube by the fringe-like fimbriae of the fallopian tube. Fertilization normally occurs in the **ampulla** of the uterine tube. Capacitated sperm contact the surrounding corona radiata cells of the oocyte. The acrosome reaction then occurs, causing proteolytic enzymes to be released from the head of the sperm. This allows the sperm to penetrate the oocyte (corona radiata and zona pellucida).

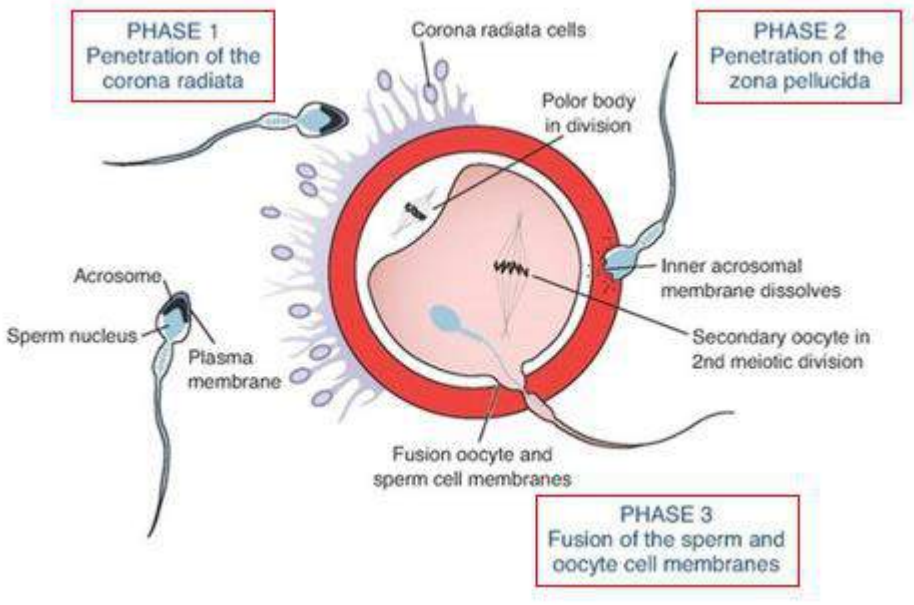


Figure 23.19 There are three phases for the sperm cell during fertilization. Phase 1 is when a sperm penetrates the corona radiate cells on the outermost layer of the egg cell. Phase 2 is when a sperm comes in contact with the zona pellucida layer of the ovum and induces changes in the membrane that block the entry of additional sperms. Thus, it ensures that only one sperm can fertilize an ovum. Phase 3 is the fusion of that sperm cell and egg cell membrane.

As seen in **Fig 23.19** above, there are three phases of activity for the sperm cell during fertilization. This can be further detailed by six stages. They are: **1)** The acrosome reaction occurs as the sperm approaches the oocyte. **2)** The corona radiata of the oocyte plays a role in chemotaxis of sperm and induction of the acrosome reaction. The sperm penetrates the epithelium of the corona radiata within a few seconds with powerful tail movements, then adheres to the zona pellucida for several minutes. **3)** The zona pellucida is penetrated after a few minutes. Sperm pass through this layer at an angle and meet the cell membrane of the oocyte tangentially. **4)** Contact of the sperm with the oocyte cell membrane releases cortical

granules that induce an excitatory potential that is responsible for initiating the zona pellucida reaction (blocking polyspermy), removing the block on metaphase II, and activating oocyte metabolism. Embryonic development is almost ready to begin. This proceeds in three steps: **a)** The sperm head dips into the microvilli on the surface of the oocyte membrane; **b)** Incorporation of sperm into the membrane; **c)** Sperm head, neck, and tail sink into the yolk sac. **5)** Fertilization causes completion of the second meiotic division, and the second polar body is expelled. **6)** The chromosomes of the sperm and oocyte (haploid sets) decondense and form the female and male pronuclei. The flagellum disintegrates in the oocyte.

Stages of Fertilization and Implantation

The first stage is when fertilization activates the oocyte, wherein the haploid egg nucleus and the haploid sperm nucleus are transformed into female and male pro-nuclei. Both pronuclei go through a phase of DNA synthesis, and their replicated chromosomes are arranged on a common spindle. The second stage is when the oocyte travels along the uterine tube toward the uterus as its cells divide within the zona pellucida. The third stage is when the **blastocyst** forms consisting of an inner cell mass (embryoblast) and an outer cell mass (trophoblast). The blastocyst hatches out of the zona pellucida, allowing it to attach to the uterine endothelium which is implantation in the uterine wall.

Fusion of Parental DNA

The very first sperm cell that comes in contact with the oocyte's plasma membrane will activate the oocyte to respond. The activation causes chemical and physiological changes in the oocyte which prevents the egg cell from being fertilized by more than one sperm cell. The cell membranes of the oocyte and sperm fuse, with the much smaller sperm cell being engulfed into the significantly larger oocyte. It is at this point when the male and female DNA of the parents fuse within the oocyte to complete the fertilization process.

Mitosis of the one cell zygote into a morula preembryo (16 cells) occurs within the oviduct. At the late morula stage (32 cells), the preembryo reaches the uterine lumen, where blastocyst development occurs. A blastocyst consists of an outer layer of trophoectoderm (trophoblast), which will become the fetal placenta, an inner cell mass (embryoblast), which will become the fetus, and a blastocele (fluid-filled cavity).

Implantation

The **blastocyst** must hatch out of the **zona pellucida** before implantation into the endometrium can occur. Trophoblast cells in the attachment zone differentiate into cytotrophoblast cells. These cells fuse together to form the syncytiotrophoblast, which is able to penetrate into the endometrium. Implantation is complete by the second week of pregnancy, marking the end of the preembryonic stage.

Stromal cells in the endometrium surround the endometrial spiral arteries and cuff them to stop the flow. This protects maternal tissues from the invading trophoblast and helps protect the fetoplacental unit from rejection by the maternal immune system.

Ectopic Pregnancy – Wrong Implantation Location

An ectopic pregnancy is when the fertilized egg cell implants in the wrong place, and that is anyplace outside the uterine cavity, usually in the fallopian tubes. If implantation occurs in the uterine tubes, it is called a '**tubal pregnancy**', and they are not viable. This is a rare condition, but it is more likely to occur in **salpingitis**, which is an inflammation of the uterine tubes. It may also occur after a tubal infection, from tubal damage due to previous ectopic pregnancies or endometriosis, or from taking what can be toxic fertility drugs in an attempt to stimulate ovulation. Other signs of ectopic pregnancy are abdominal pain,

vaginal bleeding, cramping, and faintness. There may also be an odd and seemingly disconnected pain in the tip of the shoulder. This can occur because the presence of blood in peritoneum (which is abnormal) irritates the phrenic nerve of the diaphragm passing near the shoulder area.

Treatment of ectopic pregnancy depends on what stage the ectopic pregnancy is detected. If detected early, methotrexate may be given to arrest the development of the fertilized ovum, which is then resorbed by the body. Laparoscopy may be needed to stop any bleeding into the peritoneum.

Stages of Pregnancy: The 3 Trimesters
A pregnancy is divided into trimesters:

1. The first trimester is from week 1 to the end of week 12.
2. The second trimester is from week 13 to the end of week 26.
3. The third trimester is from week 27 to the end of the pregnancy.

Figure 23.20 shows the three phases of pregnancy which are the first, second and third trimesters.

In the first trimester, the baby will grow from a fertilized egg into a moving fetus with eyes, ears, and working organs. In the second trimester, the baby's features develop and you may be able to feel your baby move. In the third trimester, the baby will grow rapidly to get ready for birth. Easy as that!

First Trimester
With the formation of the primary germ layers (ectoderm, mesoderm, and endoderm) and extraembryonic membranes (amnion, yolk sac, allantois, and chorion), the **embryonic stage** begins, which is represented as occurring from **week 3 to week 8** of development.

During the first trimester, the placenta becomes firmly established, and embryonic/fetal organ development occurs. For this and other reasons it is often considered that the first trimester is the typically the most critical with regard to the baby's development. At the early stage the mother may not be showing much outwardly, but internally the baby's major body organs and systems are commencing their genius formation. At all stages of pregnancy, and this stage especially, it is crucial to eat very good highly nutritious food with as few toxins as possible. Also equally important is to avoid unnecessary stress!

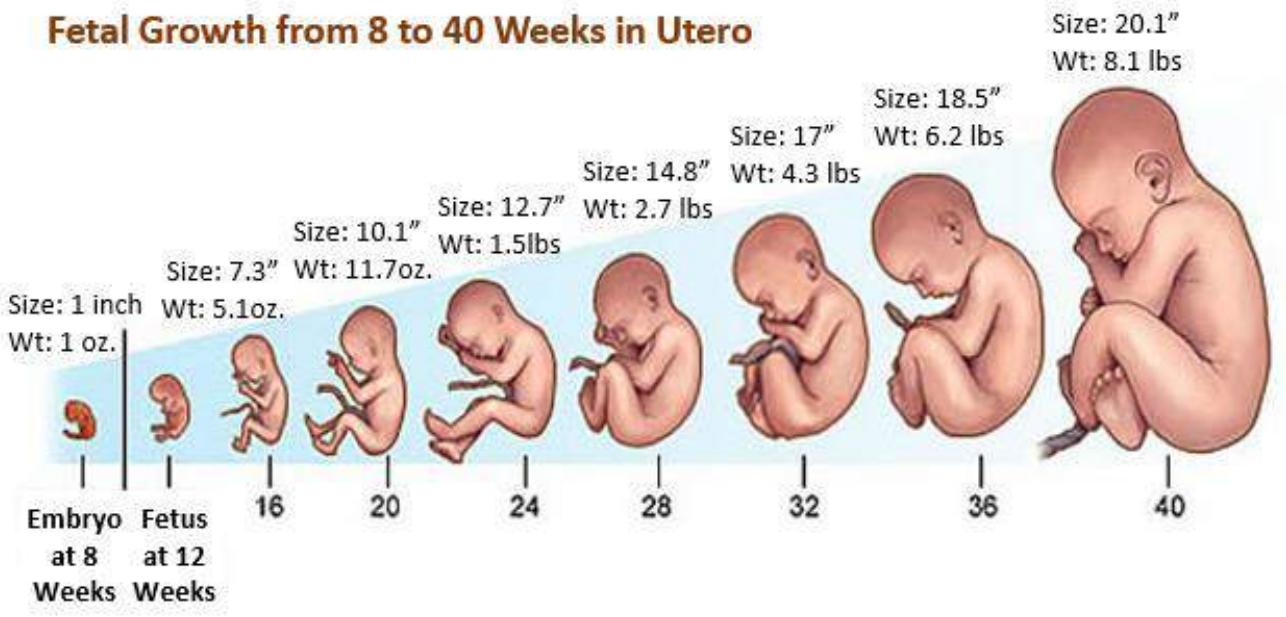


Figure 23.21 Shown here are the estimated head-to-bottom height measurements in inches (") up to 13 weeks, then head-to-toe height in inches measured at week 14 and beyond. The weight (Wt) measurements are in ounces (oz.) and pounds (lbs.) as development continues. The size and weight of a boy fetus is statistically larger than for a girl fetus, as such the values displayed are taken from an average of boy and girl measurements. It is totally normal for values of a fetus to be lower and higher than the numbers reported here.

The **corpus luteum** is the major source of progesterone (and estrogen) during the first 6 to 8 weeks of gestation. The function of the corpus luteum is stimulated by the release **human chorionic gonadotropin** hCG (from the syncytiotrophoblast). Human chorionic gonadotropin (hCG), secreted by the placenta during pregnancy, is the predominant hormone during the first trimester. It stimulates the synthesis of dehydroepiandrosterone sulfate (DHEA-S) from the fetal adrenal cortex, suppresses follicle maturation in the maternal ovaries, and maintains the production of estrogen and progesterone in the corpus luteum.

Maternal concentrations of **human placental lactogen** (hPL), **corticotropin-releasing hormone** (CRH), and **estrogen** rise sharply during the third trimester. The hPL stimulates **lactogenesis**, the production of milk by the mammary glands, after parturition. CRH concentration plays a role in the timing of parturition by increasing adrenocorticotropic hormone (ACTH) production by the fetal pituitary, which increases cortisol. It also stimulates fetal lung development.

In addition, estrogen plays a critical role in parturition by mitigating the pregnancy-sustaining effects of progesterone, and it also helps propagate uterine contractions. At about the eighth week of gestation, the trophoblast takes over the secretion of the hormones progesterone and estrogen, making the **placenta** the main source of progesterone during the remainder of the pregnancy.

Placental Abruption

Placental abruption is the separation of the placenta from the uterus. The consequences of this depend on the extent of the placental separation and the amount of blood loss. In severe abruptions, the fetus may not receive an adequate supply of oxygen, causing neurologic defects or death. The mother's life may also be at risk from shock or disseminated intravascular coagulation (DIC). DIC is a pathological activation of clotting that ultimately consumes the body's supply of clotting factors and platelets, causing bleeding from the skin, mucous membranes, and viscera. Signs of placental abruption include shock that is out of

keeping with visible vaginal blood loss, backache (if the abruption is posterior), abdominal pain, uterine tenderness, fetal distress, lack of fetal heartbeat, and DIC. Treatment also depends on the extent of the abruption. If it is a small abruption, then the mother is monitored frequently, but the pregnancy is allowed to progress. If severe, urgent delivery of the baby is necessary.

Placenta Previa

The condition of **placenta previa** when the placenta is situated low in the uterus, partially or completely covering the cervix. As the cervix begins to dilate later in pregnancy, the placenta stretches and tears, leading to painless vaginal blood loss. Shock may occur if the blood loss is severe. In contrast to placental abruption, there are usually no coagulation problems or uterine tenderness. Fetal distress is also less common, as the frank vaginal bleeding alerts the mother and health care providers to the problem before the fetus becomes distressed. Placenta previa is more common in women who have uterine damage, most common from previous cesarean sections, births, or fibroids, or if the placenta is larger than usual, for example with twins. Treatment depends on the severity, in minor cases bed rest for the mother for the remainder of the pregnancy, whereas more severe cases may warrant early delivery of the baby.

Second and Third Trimesters

In **Figure 23.21**, a clear progression of fetal growth during the second and third trimesters can be clearly seen. In the start of the second trimesters, now that the placenta has taken over progesterone synthesis, the **corpus luteum** in the ovary degenerates. Interestingly, the placenta cannot convert progesterone to estrogens because of a deficiency of the enzyme 17α-hydroxylase, therefore it need to rely on the conversion of dehydroepiandrosterone sulfate (**DHEA-S**) from the adrenal glands of both the fetus and the mother to synthesize estriol, estradiol, and estrone.

As already seen, **human placental lactogen** (**hPL**) is produced by the placenta, with its peak blood concentrations occurring in the third trimester. The hPL is very similar in structure and function to growth hormone and prolactin, and its secretion causes an increase in **lipid metabolism**, enhanced carbohydrate stimulated insulin secretion, and **increased insulin resistance** in some maternal tissues. Collectively, these alterations in maternal metabolism enhance maternal free fatty acid utilization while sparing glucose for use by the growing fetus. This is one aspect of the susceptibility of mothers acquiring **gestational diabetes** at this stage, due to the shifting of metabolism in order to ensure that any additional glucose goes to the developing baby. The hPL may also play an important role in mammary gland development.

Hormonal Synthesis in the Placenta, Mother, and Fetus

The **placenta** produces **human chorionic gonadotropin** (**hCG**) hormone, which stimulates the synthesis of steroids such as DHEA and DHEA-S, by the **fetal adrenal cortex**. The hCG also maintains the production of estrogen and progesterone in the corpus luteum until the placenta is able to produce sufficient quantities of these hormones.

In addition, the placenta must receive **cholesterol** or **androgens** from either the maternal or fetal adrenal cortex, respectively, before it can synthesize progesterone and estrogen. Progesterone is then transported to the fetal adrenal cortex, where it is converted to DHEA and DHEA-S. DHEA and DHEA-S pass to the placenta, where they are used for estrogen synthesis. **Progesterone** is converted to **testosterone** in the **testes** of the **male fetus**.

Maternal Changes during Pregnancy

The process of pregnancy is not without radical and dramatic changes in the female, both anatomically and physiologically. In other words it's not all fun, and can be very taxing on the body. Most of the changes are definable and ultimately all normal changes are tolerable.

Some of the more significant changes include **preeclampsia**, this is a type of hypertension, **proteinuria**, an excess protein filtered by the kidneys which leads to protein in the urine, and systemic **edema**, which is tissue swelling form retaining fluid in the body during pregnancy. These more radical changes can usually be seen after 20 weeks gestation. Preeclampsia can cause fetal distress, low birth weight, and pre-term birth due to lack of blood flow to the placenta. It also increases the occurrence of placental abruption.

Parturition (Birth)

During a normal pregnancy, which consists of 270 pre-determined days, the secretion of **progesterone** prevents uterine contractions by elevating the threshold for myometrial contractility. This is referred to as the **progesterone block**.

Just prior to the occurrence of child birth, or parturition, placental estrogen production is increased relative to progesterone, thereby increasing the estrogen-to-progesterone ratio. This removes the progesterone block and allows estrogen to increase the synthesis of receptors for estrogen, prostaglandins, and oxytocin on myometrial cells. This upregulation of receptors is necessary for the **increase in myometrial contractility** at parturition.

Myometrial stretching and pressure exerted on the cervix by the fetus cause a reflexive release of oxytocin from the posterior pituitary. **Oxytocin** binds to **myometrial receptors**, where it stimulates the production of uterine and placental prostaglandins, which, in turn, increase intracellular Ca^{2+} and promote myometrial contractility.

Estrogen also affects the cervix by increasing its responsiveness to **relaxin**, which is secreted by the corpus luteum and the placenta. The prostaglandins are secreted by the uterus and placenta. These hormones cause the cervix to become more vascular and change its structure. This results in **cervical dilation** and **effacement**, which is when the cervix becomes softer and shorter during labor.

The Stages of Child Birth

Stage 1. This is the period from the onset of regular contractions until the cervix is fully dilated. Contractions originate in the fundus and progress toward the cervix, forcing the head of the fetus against the cervix. The cervix starts to dilate from the effects of estrogen and **relaxin** and the mechanical force from fetal pressure. During this time the cervix becomes softer and shorter (effaces). Changes in the cervix result from physical breakdown of connective tissue of the cervix with increased water content, vascularization, and mass. The fetal membranes rupture, so the contents of the amniotic sac are lost. This enhances the effects of contraction for applying fetal pressure on the cervix.

Stage 2. This is the period from full dilation of the cervix until parturition. Uterine muscle contractions are of high frequency and high amplitude. This stage typically lasts < 1 hour but can be longer.

Stage 3. The placenta separates and is delivered. This occurs within about 10 minutes after birth and is associated with weak muscle contractions.

Lactation

During pregnancy, estrogen, growth hormone, human placental lactogen (hPL), and cortisol continue to stimulate the development of the mammary glands, which started at puberty. Progesterone converts duct epithelium to a secretory epithelium. **1)** Relaxation of the cervix: the cervix remains tightly closed during pregnancy but is stimulated to relax around the time of parturition by **relaxin**, secreted by the corpus luteum and placenta. **2)** Onset of labor: locally, prostaglandins cause contractions of the uterine muscles. Systemically, oxytocin, from the posterior pituitary gland, is released in response to cervical irritation caused by pressure from the fetal head. Oxytocin causes further prostaglandin secretion.

During the latter stages of pregnancy, estrogen acts on the anterior pituitary, causing levels of prolactin to rise. This is accompanied by a fall in prolactin-inhibiting hormone (PIH). Prolactin is the hormone after delivery that initiates **lactogenesis**, or **milk production**. Lactation does not occur during pregnancy because placental estrogen and progesterone prevent prolactin from acting on the mammary glands. However, when estrogen and progesterone are withdrawn at birth, lactation is able to occur. Suckling is a mechanical stimulus for the continuation of lactation, as it stimulates increased levels of prolactin (by inhibiting PIH) and oxytocin.

Breast Feeding (Nursing) and Pregnancy

When a mother breastfeed or naturally nurses an infant, this can be effective in preventing another pregnancy because the prolactin inhibits ovarian function in the following ways: **1)** it inhibits the hypothalamic release of gonadotropic releasing hormone (**GnRH)**; **2)** from the decreased GnRH, there is an inhibition in the release FSH and LH from the anterior pituitary; and finally, **3)** the decreased levels of FSH and LH have **inhibitory effects on ovulation**, thus reducing the releasing of viable eggs from the ovaries.

The Letdown Reflex for Breastfeeding

As discussed earlier in the chapter in the section regarding breastmilk, the letdown reflex starts the breastfeeding process. The mechanical sensory input to the spinal cord from the stimulation of the breast nipple when the baby begins to suckle ascends to the hypothalamus and posterior pituitary, causing the release of oxytocin from the posterior pituitary. **Oxytocin** stimulates smooth muscle contractions. This helps shrink the uterus to pre-pregnancy size and creates high pressure in the milk ducts, which can squirt milk into the infant's mouth. This can also contribute to leakage of milk. Mechanical stimulation of the cervix can also release oxytocin.

Infertility

The inability of a couple to conceive a baby is the basic definition of **infertility**. More formally, it is the failure to conceive after repeated attempts to become pregnant over the course of a year. It affects approximately one in five couples in the United States. More than half of couples who have not conceived after 1 year will eventually conceive. In about one-third of cases of infertility, there are problems with sperm; in about one-third, there are problems with the fallopian tubes; and in about one-sixth, there are ovulation problems. Rarely are there problems with cervical mucus. The cause of infertility is unidentified in the remainder of cases.

Many causes of infertility can be reversed with natural therapeutic remedies. The most significant practices would be to decrease the stress levels in everyday life. Also vitally important is to avoid toxins and poisons (including situations or thoughts), maintain a whole food fat-rich diet and create a healthy happy positive attitude.

Review Questions for Chapter 23: Female Reproductive System

1. What usually occurs between days 13 and 15 of the menstrual or uterine cycle?
- **a)** The lining of the uterus builds up
- **b)** Ovulation
- **c)** The lining of the uterus remains in place in preparation for the possible arrival of an embryo
- **d)** Shedding of the lining of the uterus

2. This occurs on days 1 to 5 of the menstrual cycle.
- **a)** The lining of the uterus remains in place in preparation for the possible arrival of an early embryo.
- **b)** An egg is released from the ovaries
- **c)** Shedding of the lining of the uterus
- **d)** The lining of the uterus builds up

3. The entrance to the womb is also known as theentrance.png
- **a)** cervix
- **b)** ovary
- **c)** fallopian tube
- **d)** vagina
- **e)** fimbriae

4. Which hormone is responsible for ovulation in females?
- **a)** GH
- **b)** TSH
- **c)** PRL
- **d)** ACTH
- **e)** LH

5. In a typical menstrual cycle of 28 days, what is the most likely fertile period?
- **a)** Days 5 to 10
- **b)** Days 11 to 14
- **c)** Days 14 and 15
- **d)** Days 1 to 5
- **e)** Days 26 t0 28

6. This carries the egg to the uterus.
- **a)** Wave of mucus in the fundus
- **b)** The Fallopian tube
- **c)** The vagina
- **d)** The ovaries
- **e)** The cervix

7. Fertilization takes place in what region of the female reproductive tract? The:

a) fallopian tube
b) vagina
c) cervix
d) uterus
e) endometrium

8. During the menstrual cycle, which events happens if a released egg does not become fertilized?

a) The lining of the womb wall stays built up.
b) Another egg is immediately released.
c) The lining of the womb wall builds up again.
d) The lining of the womb wall breaks down and sloughs off.

9. Comparing secondary sexual characteristics of males and females, in general females have:

a) a higher basal metabolic rate
b) lower levels of androgens than males
c) greater muscle mass
d) lower levels of estrogen than males
e) lower pitched voices than males

10. The female gonads make gametes called _____ and sex the hormones _____.

a) follicles: progesterone
b) egg cells: androgens
c) sperm: estrogen
d) egg cells: estrogen
e) egg cells: estrogen and progesterone

Answers in Appendix B