KIPS
ENTRY TESTS
SERIES

PREP BOOK



BIOLOGY

MDCAT

AS PER UHS SYLLABUS

- Topic-wise UHS Complete Syllabus
- Comprehensive Course Revision
- Detailed Explanation of Topics
- Key Points, Tables, Flow Sheets & Diagrams
- Easy to Remember; Points to Ponder

A Kitab Dost Publication

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KIPS
ENTRY TESTS
SERIES

PREP BOOK
BIOLOGY
MDCAT

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»Dedication

"The Teacher of the Universe"

(Peace be upon Him)

With whose existence *and*

by having the charity of His knowledge

the cosmos got illuminated with the light of

insight and wisdom *and* the journey of human

enlightenment was made possible.

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TOPIC-1
10 MCQs

CELL BIOLOGY

LEARNING OUTCOMES

A) Compare and contrast the structure of typical animal and plant cell.
B) Compare and contrast the structure of prokaryotic cell with eukaryotic cell.
C) Explain the basics of Fluid Mosaic Model of Cell Membrane and define the terms:
   (i) Diffusion
   (ii) Facilitated diffusion
   (iii) Active transport
   (iv) Passive transport
   (v) Endocytosis
   (vi) Exocytosis
D) Outline the structure and function of the following organelles:
   (i) Ribosomes
   (ii) Cytoskeleton
   (iii) Centrioles
   (iv) Endoplasmic Reticulum
   (v) Golgi Apparatus
   (vi) Lysosome
   (vii) Peroxisome
   (viii) Glyoxysome
   (ix) Mitochondria
   (x) Nucleus

vip Table

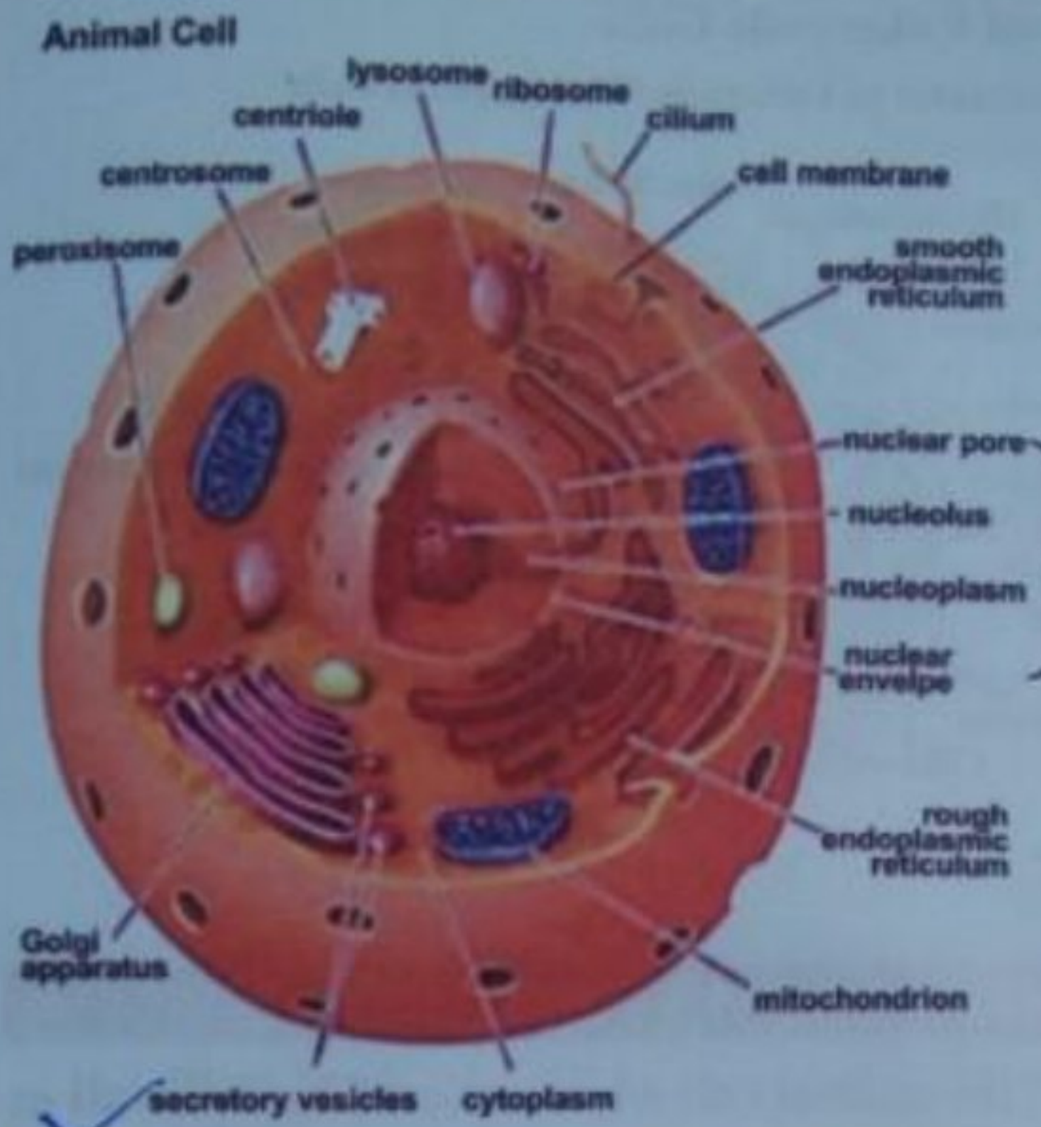
A) COMPARISON OF PLANT AND ANIMAL CELL

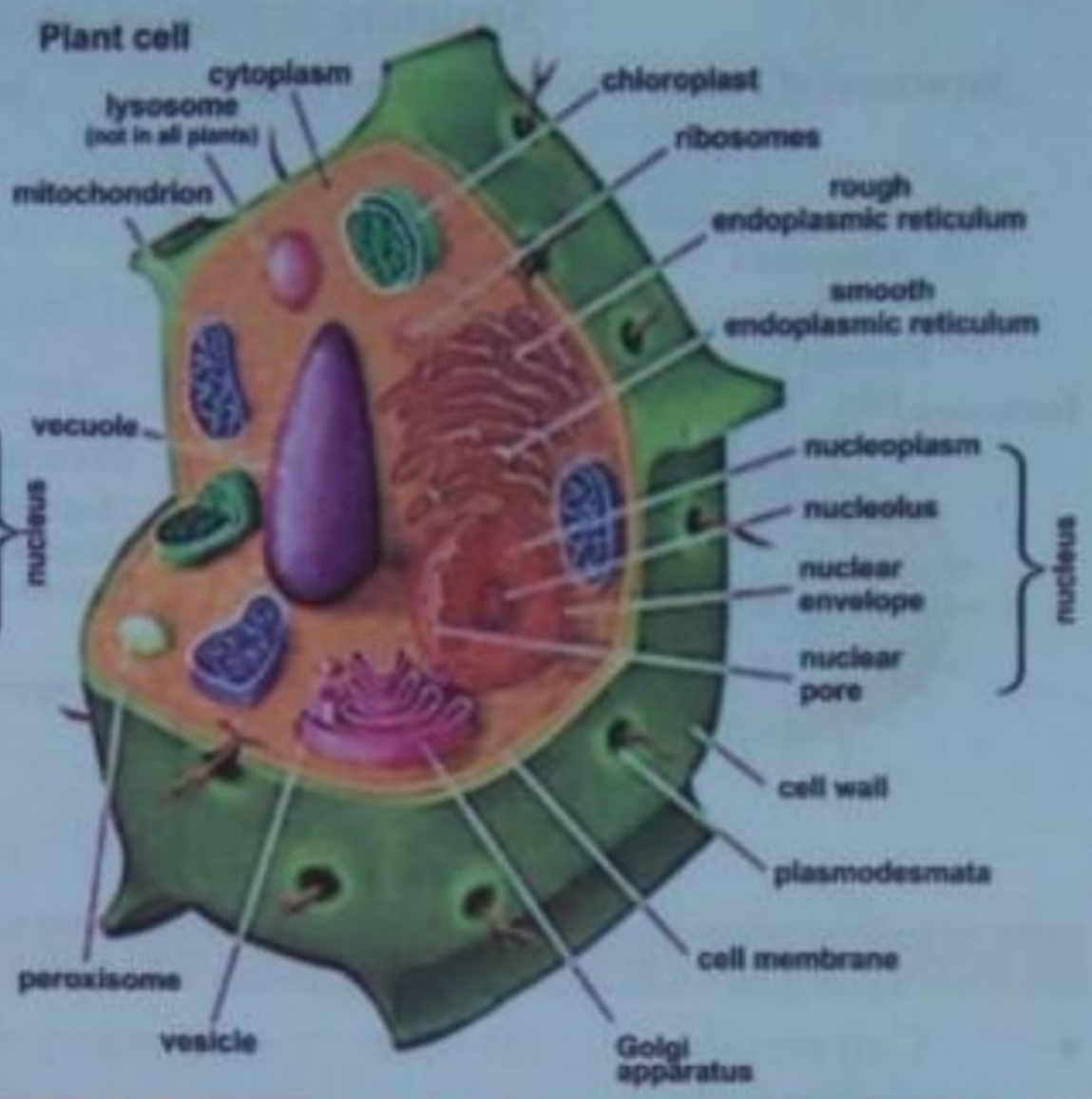
Features	Animal cell	Plant cell
Cell wall	×	✓
Plastids	×	✓
Glyoxysomes	×	✓
Centrosome (centrioles)	✓	×
Mitotic Apparatus	Spindles + Asters	Spindles Only
Cytokinesis	Inwards	Outwards
Lysosomes	✓	×
Flagella	✓	×
Phagocytosis	✓	×
Nucleus	Central	Peripheral
Vacuoles	Small	Large
Storage Products	Glycogen	Starch

POINT 70
PONDER

How flagella of prokaryotic & eukaryotic cell are different from each other?

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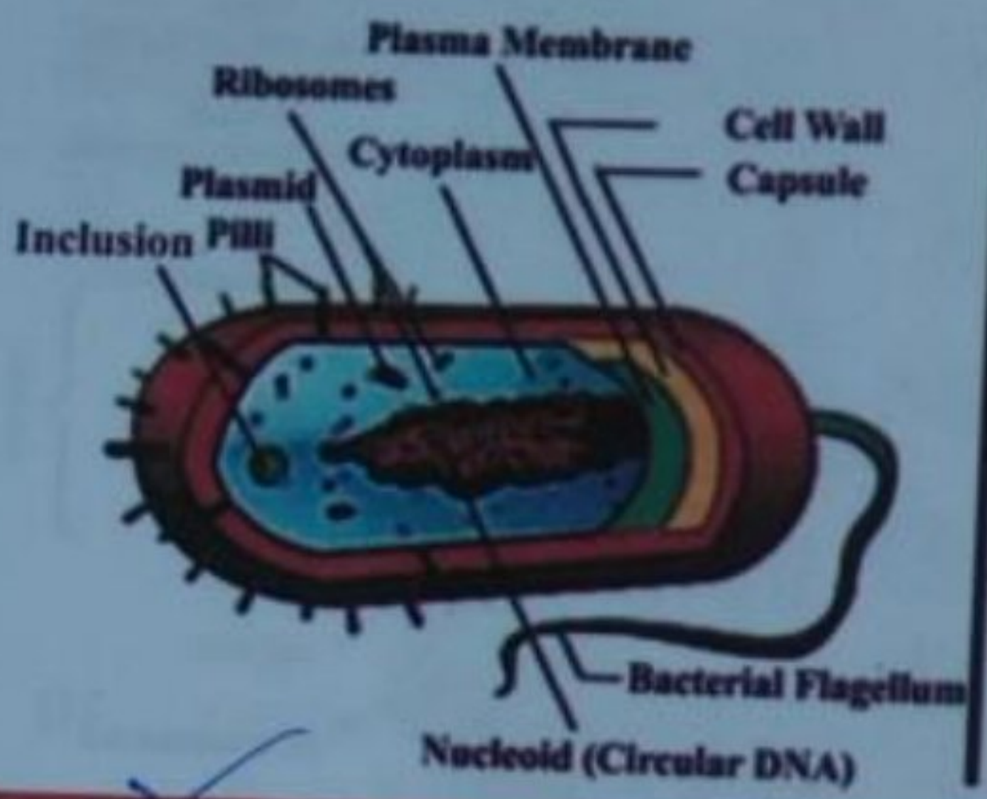
B) COMPARISON OF PROKARYOTIC AND EUKARYOTIC CELL

Differences	Prokaryotic cell	Eukaryotic cell
Well Defined Nucleus	Absent	Present
DNA	Submerged in cytoplasm	Present in nucleus
Type of DNA	Circular DNA as nucleoid	Linear DNA in nucleus
Membrane-Bounded Organelles	Absent	Present
Ribosomes	Small, 70S ribosomes (50S+30S)	Large, 80S ribosomes (60S+40S)
Cytoskeleton	Absent	Present
Cell Wall	Peptidoglycan/ Murein/ Sacculus	Cellulose/ Chitin
Cell Membrane	Sterols absent	Sterols present
Cell Division	Binary fission.	Mitosis/ Meiosis
Histones	Absent	Present
Composition of Flagella	Flagellin Protein	Tubulin Protein
Example	Bacterial cell, Cells of blue green algae	Plant and animal cells

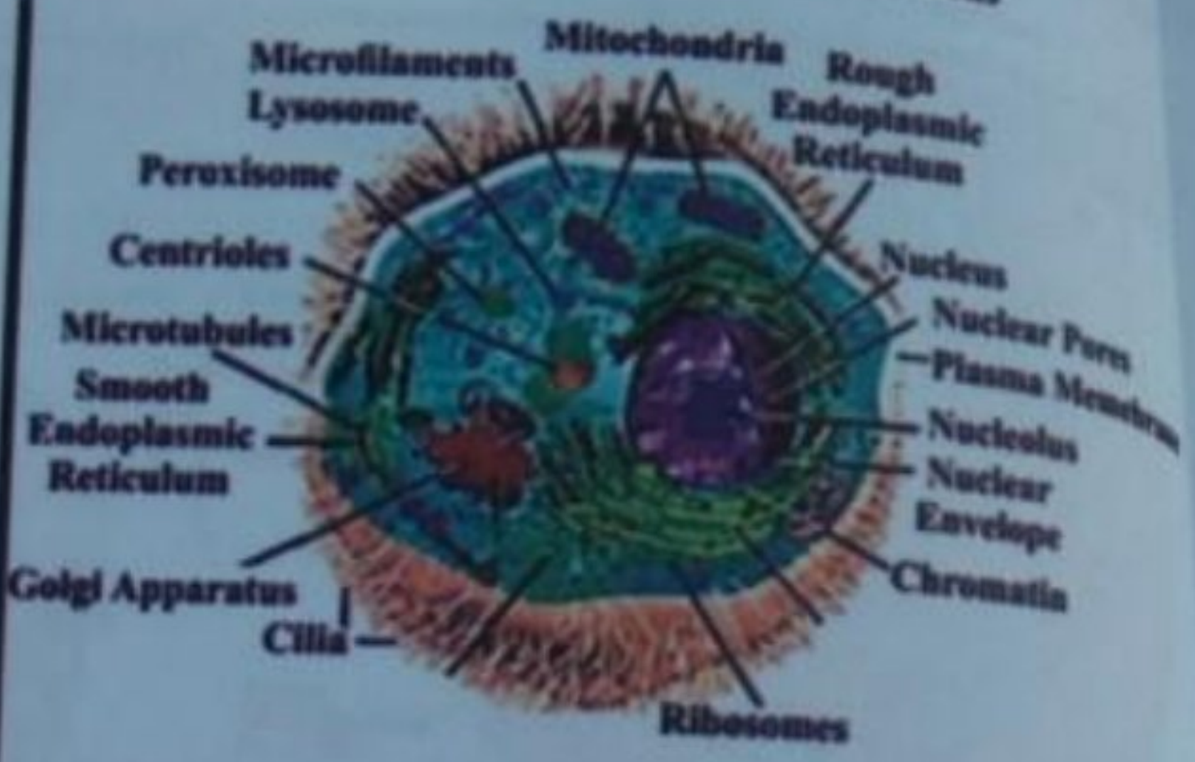
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Structure of Prokaryotic and Eukaryotic Cells

Structures of Prokaryotic (Bacterium) Cells



Structures of Eukarytic (Mammalian) Cells

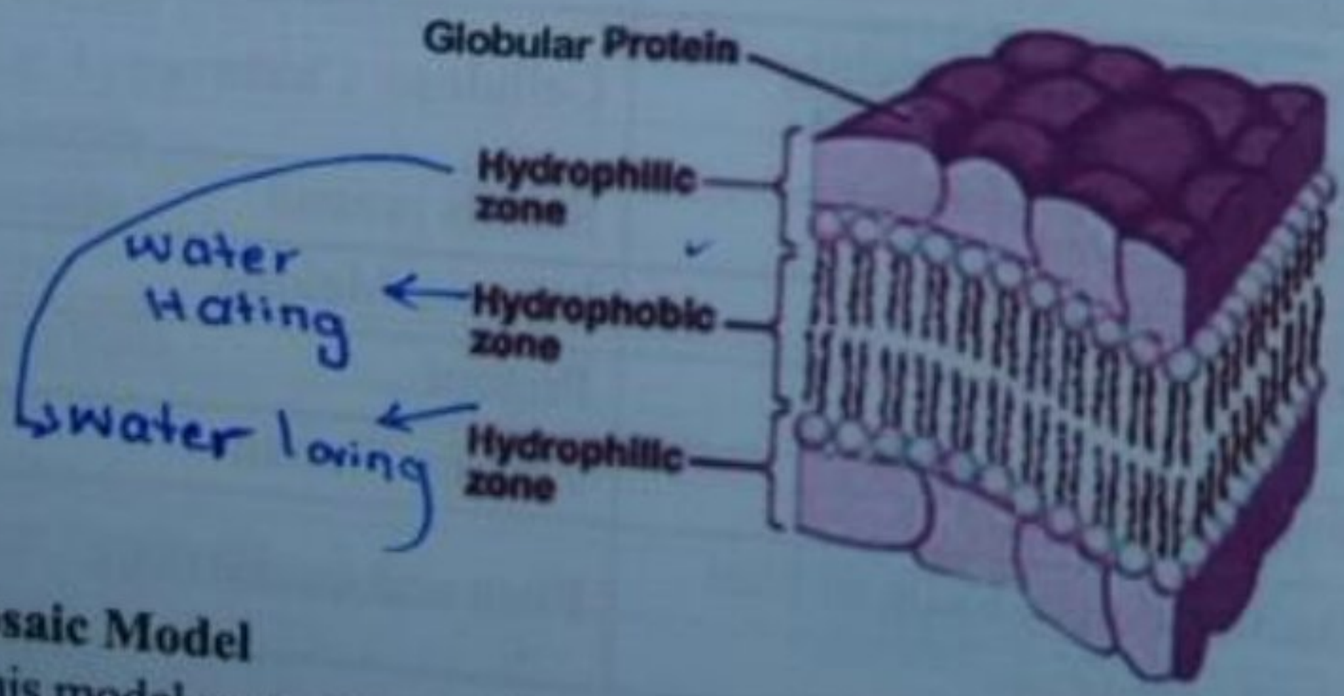


C) FLUID MOSAIC MODEL OF PLASMA MEMBRANE

- Cell membrane is the outer most boundary of the animal cell while covered by cell wall in a plant cell.
- Plasma membrane is about 7 nm thick.
- Chemically composed of:
  Proteins (60- 80 %)
  Lipids (20- 40 %)
  Small amount of carbohydrates in form of glycolipids and glycoproteins.

Unit Membrane Model

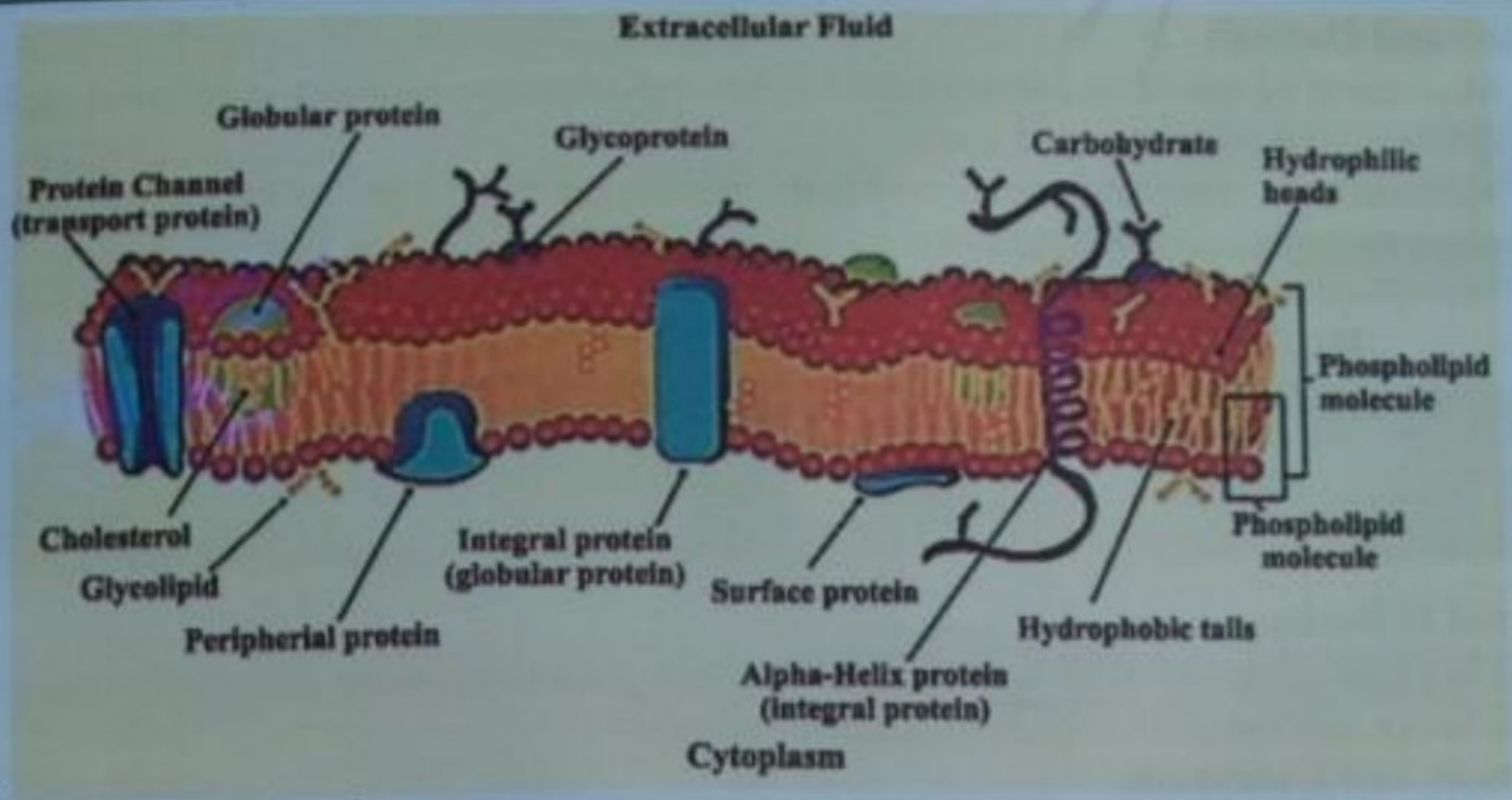
- This model was presented by J. David Robertson in 1959.
- According to Unit Membrane model, the cell membrane is composed of lipid bilayer (Phospholipids) sandwiched between inner and outer layer of proteins.
- This structure has hydrophobic component i.e. central non- polar part of phospholipid molecules and a hydrophilic part i.e., outer polar component of phospholipids + globular proteins covering both sides.



Fluid Mosaic Model

- This model was proposed by S.J. Singer and G.L. Nicolson in 1972.
- According to fluid mosaic model, protein layers are not continuous and are not confined to the surface of the membrane but are embedded in lipid layers in a mosaic manner. These protein molecules may function as a gateway (charged pore) for the transport of materials.
- This model at present is the *most accepted one*.

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Role of Different Molecules

- ***Phospholipids*** form lipid bilayer.
- ***Cholesterol*** helps to stabilize this lipid bilayer.
- ***Channel proteins*** allow a particular molecule or ion to cross the plasma membrane freely.
- ***Carrier proteins*** selectively interact with a specific molecule or ion so that it can cross the plasma membrane.
- ***Glycoproteins and glycolipids*** are found on cell surface and help in recognition.

POINT TO PONDER

What do you know about role of following in plasma membrane?
(1) Phospholipids (2) Cholesterol (3) Carbohydrates

POINT TO PONDER

What is difference between carrier & channel proteins?

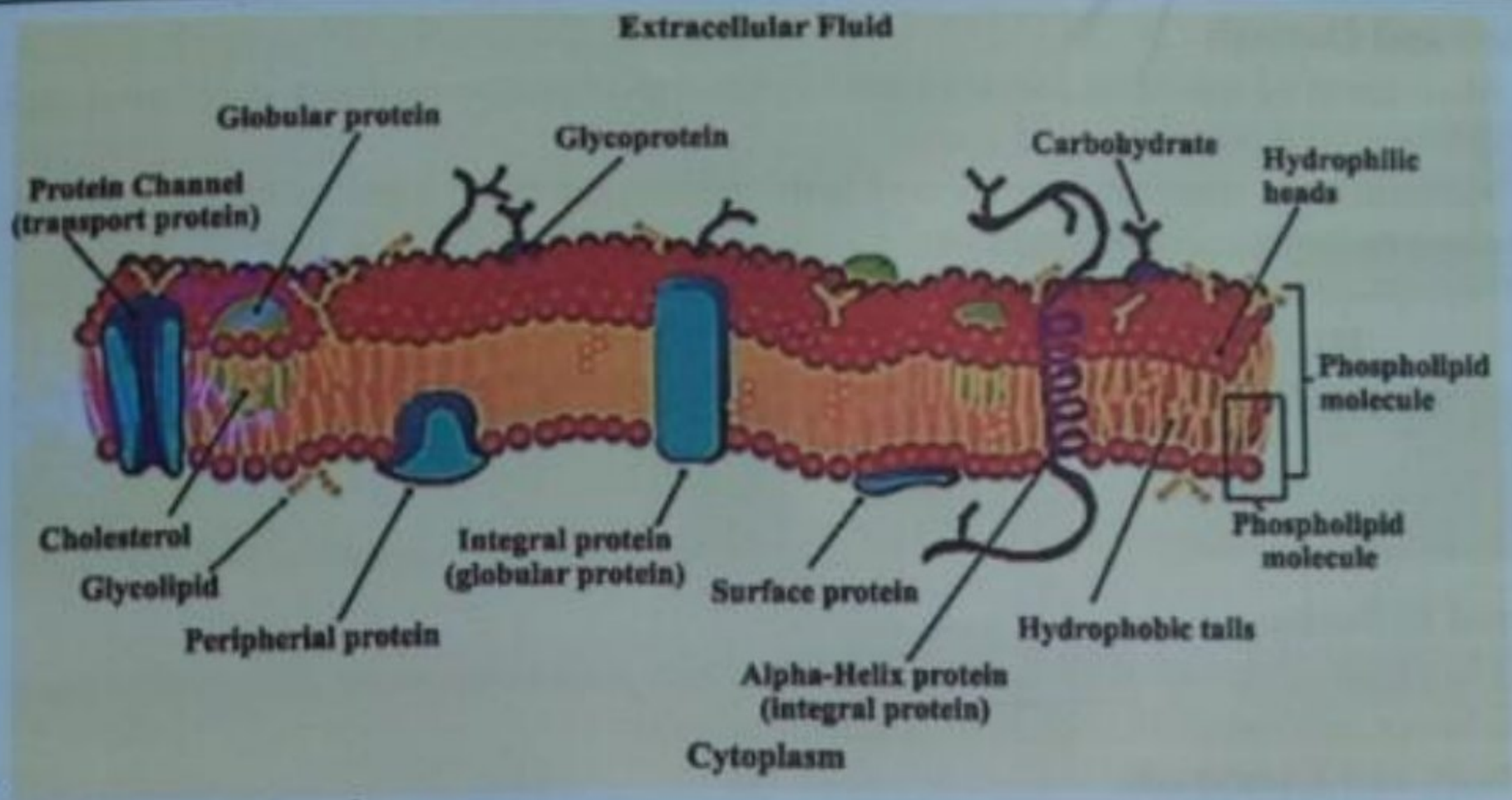
TRANSPORT MECHANISM ACROSS PLASMA MEMBRANE

- Cell membrane is a ***differentially permeable*** or ***selectively permeable membrane***, allowing only the selective substances to pass through it.
- ***Lipid soluble*** substances pass through cell membrane more easily than others.
- Many ***small*** gas molecules, water, glucose etc. being neutral can easily cross.
- ***Ions*** being charged particles have some difficulty in crossing.

Passive & Active Transport

Passive transport	Active transport
High Conc. → Low Conc.	Low Conc. → High Conc.
Along the concentration gradient	Against the concentration gradient
Downhill movement	Uphill movement
Without use of cell energy (ATP)	With use of cell energy (ATP)

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Diffusion and Osmosis

- Movement of solute molecules from higher concentration to lower concentration is called diffusion e.g. movement of gases.
- Movement of water molecules across the membrane from higher water potential to lower water potential is called osmosis.

POINT TO PONDER

What is difference between osmosis and diffusion?

POINT TO PONDER

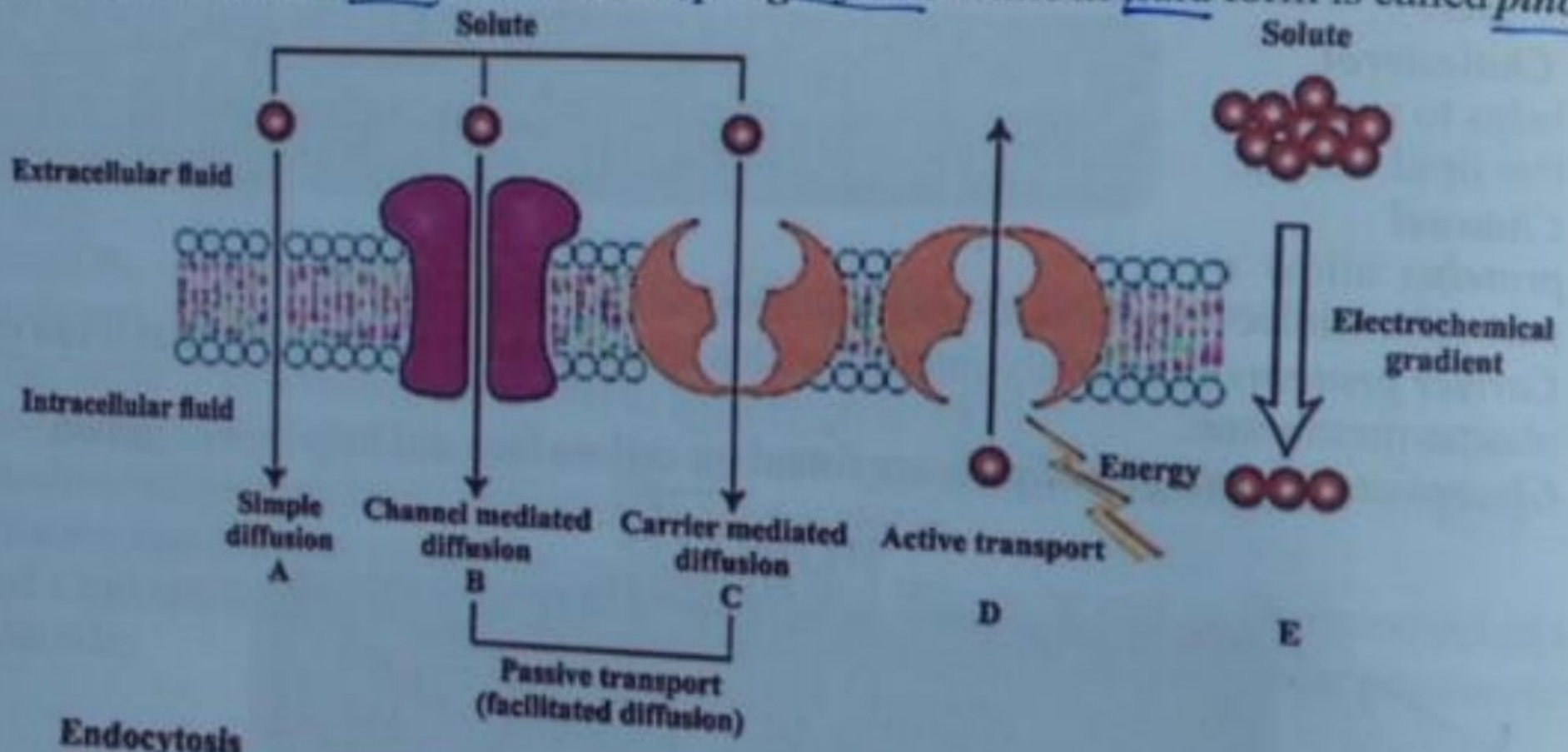
What are different types of active transport? Can you give example of each type?

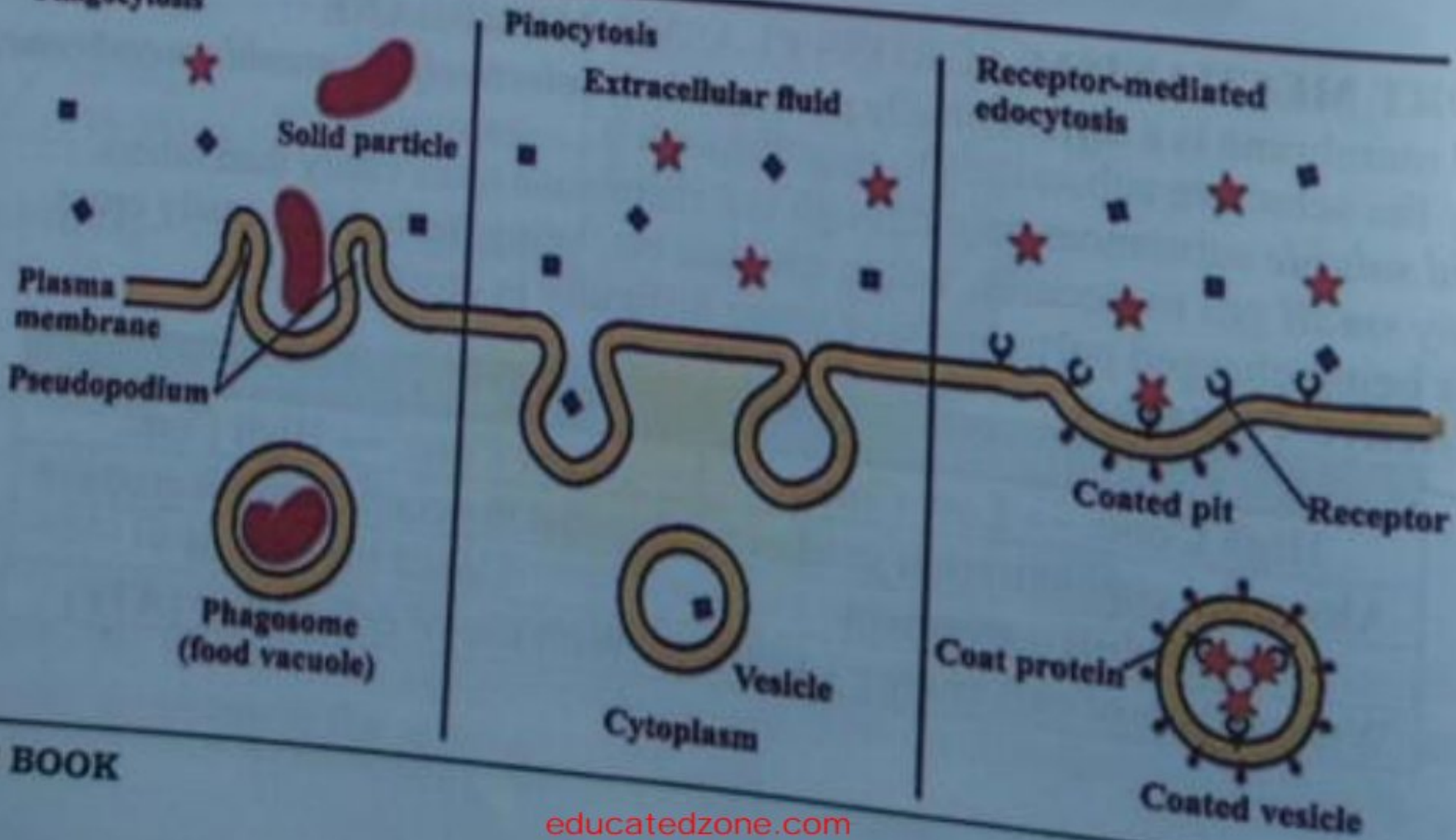
Facilitated Diffusion

- It is a type of carrier mediated transport in which molecules move from higher concentration to lower concentration with help of carrier proteins.

Endocytosis and Exocytosis

- Intake of materials along the infoldings of cell membrane in the form of vacuole is called endocytosis.
- Intake of material in solid form is called *phagocytosis* while in fluid form is called *pinocytosis*.





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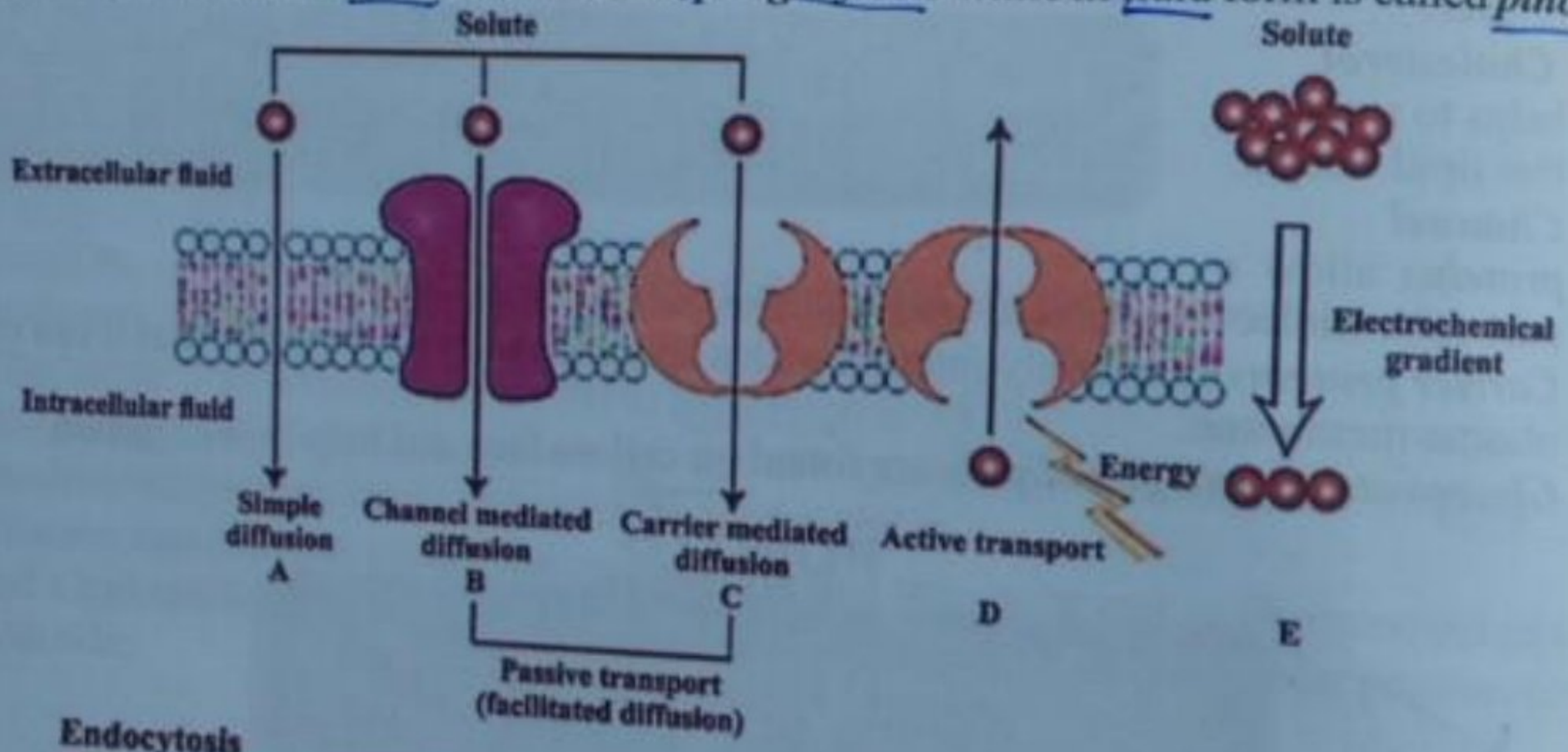
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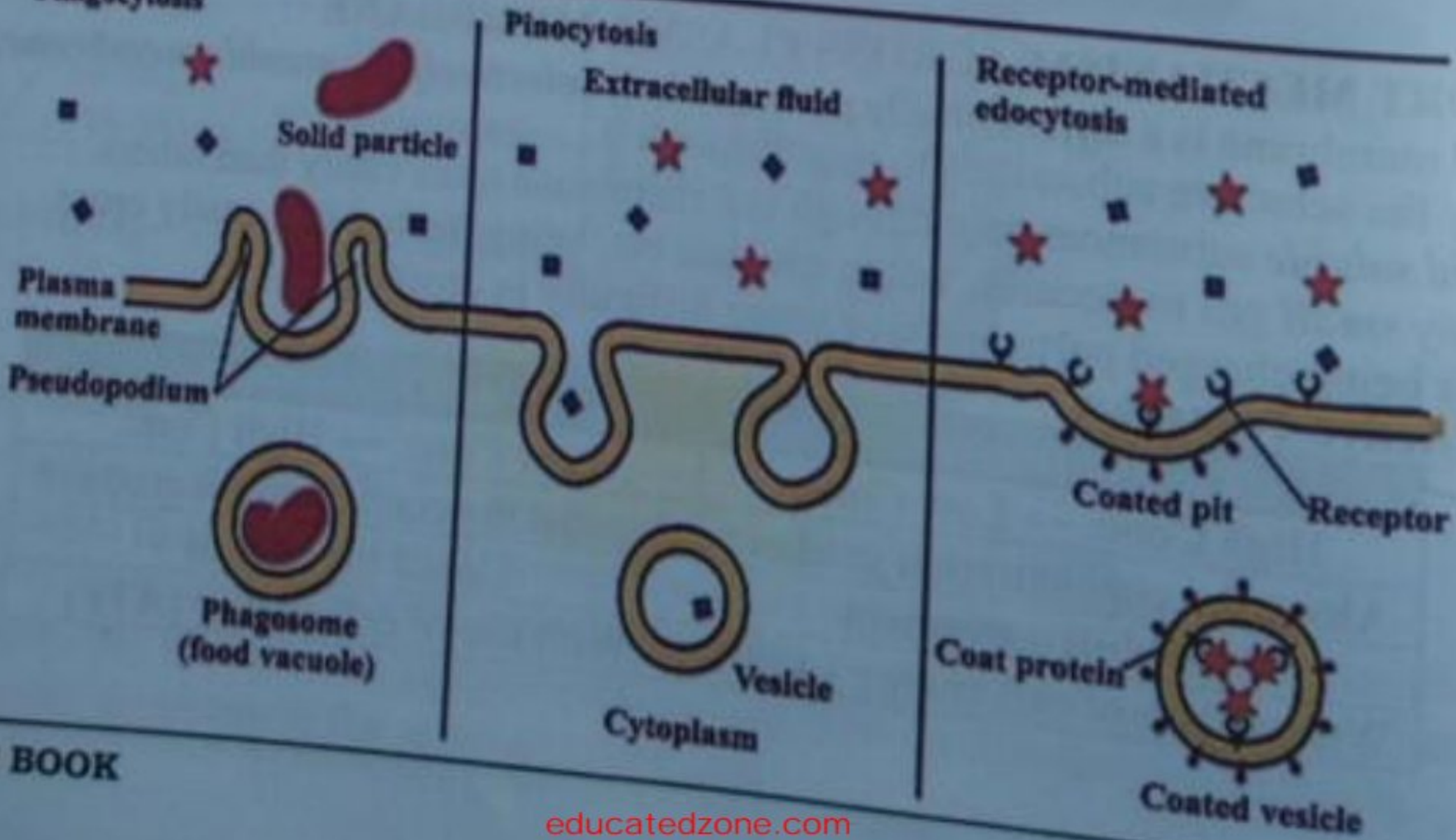
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Some Other Functions of Plasma Membrane

- In neurons (nerve cell), the cell membrane transmits nerve impulses.

D) STRUCTURE AND FUNCTION OF CELL ORGANELLES

Classification of Organelles

Non-membranous	Single membranous	Double membranous
Ribosomes	Endoplasmic Reticulum	Mitochondria
Centrioles	Golgi Apparatus	Nucleus
Cytoskeleton	Lysosomes	
	Peroxisomes	
	Glyoxysomes	

Discovery of Organelles

Organelles	Discovery
Ribosomes	George Emil Palade
Centrioles	Edouard Van Beneden
Cytoskeleton	Nikolai K. Koltsov
Endoplasmic Reticulum	Keith R. Porter, Albert Claude, Brody Meskers and Ernest F. Fullam
Golgi Apparatus	Camillo Golgi
Lysosomes	De Duve
Peroxisomes	De Duve
Glyoxysomes	Harry Beevers
Mitochondria	Richard Altmann
Nucleus	Robert Brown

1. RIBOSOMES

Chemical Composition

- Ribosomes are ***ribonucleo- proteins***.
- Ribosomes consists of ***RNA*** and ***proteins*** in almost equal proportion.

Assembly of Ribosomes

- Ribosomes are assembled in the ***nucleolus***.
- From nucleolus they are transported to the cytoplasm through nuclear pores.

Form & Physical Structure

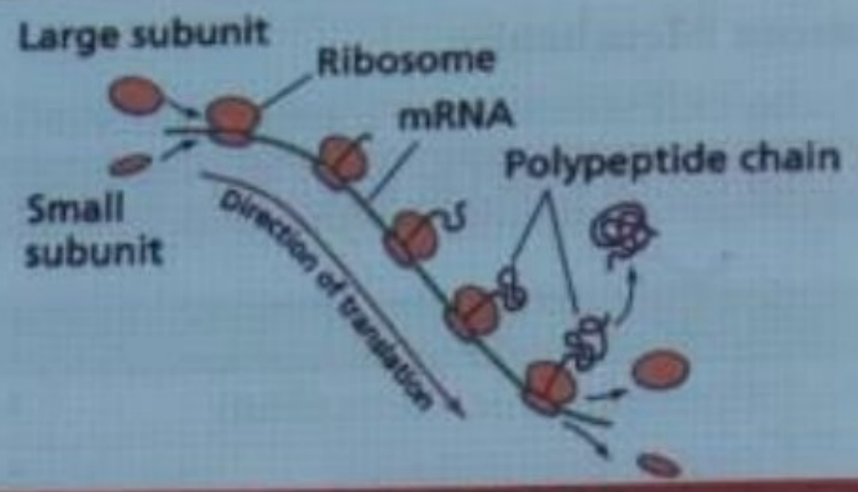
- They exist in two forms, either dispersed in the cytoplasm or attached with rough endoplasmic reticulum (RER) as tiny granules.
- Ribosomes consist of ***two subunits***: larger subunit & smaller subunit.
- Attachment of both subunits is controlled by ***Mg^{2+} ions***.
- Ribosomes are attached to 5' end of mRNA through smaller subunits.

	Ribosome	Larger subunit	Smaller subunit
Prokaryotic Ribosome	Small, 70S	50S	30S
Eukaryotic Ribosome	Large, 80S	60S	40S

Functions

- Ribosomes are the factory for protein synthesis.
- A group of ribosomes attached to mRNA is known as ***polysome or polyribosome***.

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2. CENTRIOLES

- They are ***present*** in animal cells, cells of microorganisms, fungi like protists and in lower plants.
- They are ***absent*** in higher plants and fungi.
- They usually occur in pairs at ***right angle*** to each other near one pole of nucleus.

Structure

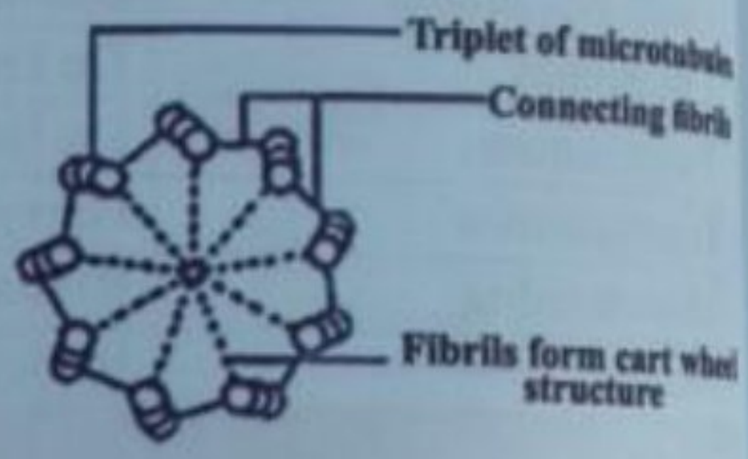
- Each centriole is made up of ***9 triplets*** of microtubules.
- Each triplet is further composed of ***3 tubules***.
- Total number of tubules in a centriole is 27.
- Centrioles/ microtubules are made up of ***tubulin protein***.



Centrioles in a pair in an animal cell



Arrangement of microtubles



Cart wheel structure of a centriole

Functions

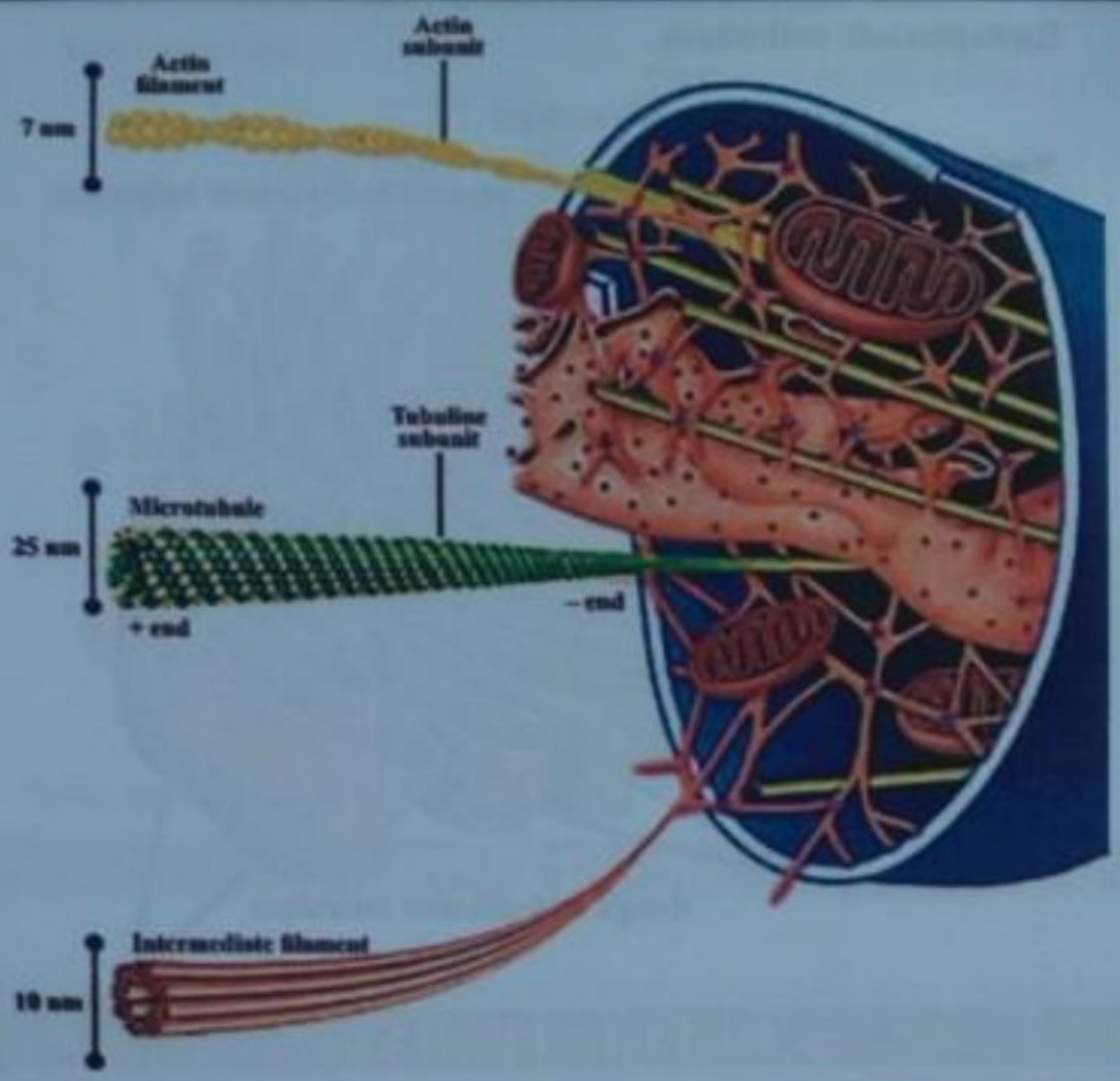
- Just before cell division, centrioles duplicate and each pair migrate to opposite poles giving rise to spindle fibers.
- Centrioles play important role in ***location of furrowing*** during cell division.
- Centrioles also give rise to ***cilia***.

3. CYTOSKELETON

- Cytosol contains cytoskeletal fabric formed of microtubules, microfilaments and intermediate filaments.
- These are distributed from nucleus to plasma membrane.

Type	Diameter	Proteins	Function
Microfilaments/ Actin Filaments	7 nm	Actin, Tropomyosin, Troponin	Internal cell motion, Cyclosis, Cytoplasmic streaming movement, Amoeboid movement
Microtubules	25 nm	Tubulin	Centriole, Basal bodies, Cilia, Flagella, Spindles
Intermediate Filaments	8-10 nm	Vimentin	Maintenance of cell shape

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4. ENDOPLASMIC RETICULUM

- Network of interconnected channels extending and often continues with cell membrane to the nuclear membrane is called endoplasmic reticulum.
- They vary in appearance from cell to cell.
- ***Cisternae*** are spherical or tubular membranes which separate the material present in these channels from that of cytoplasmic material.

Types and Functions

A) Rough E.R

- One with ribosomes attached to its external surface.
- Contain cisternae sacs.
- Directly connected with outer nuclear membrane.
- Ribosomes are attached on cisternal surface.
- RER is involved in the ***synthesis of proteins***. After synthesis, they are either stored in the cytoplasm or transported out of the cell through these channels.

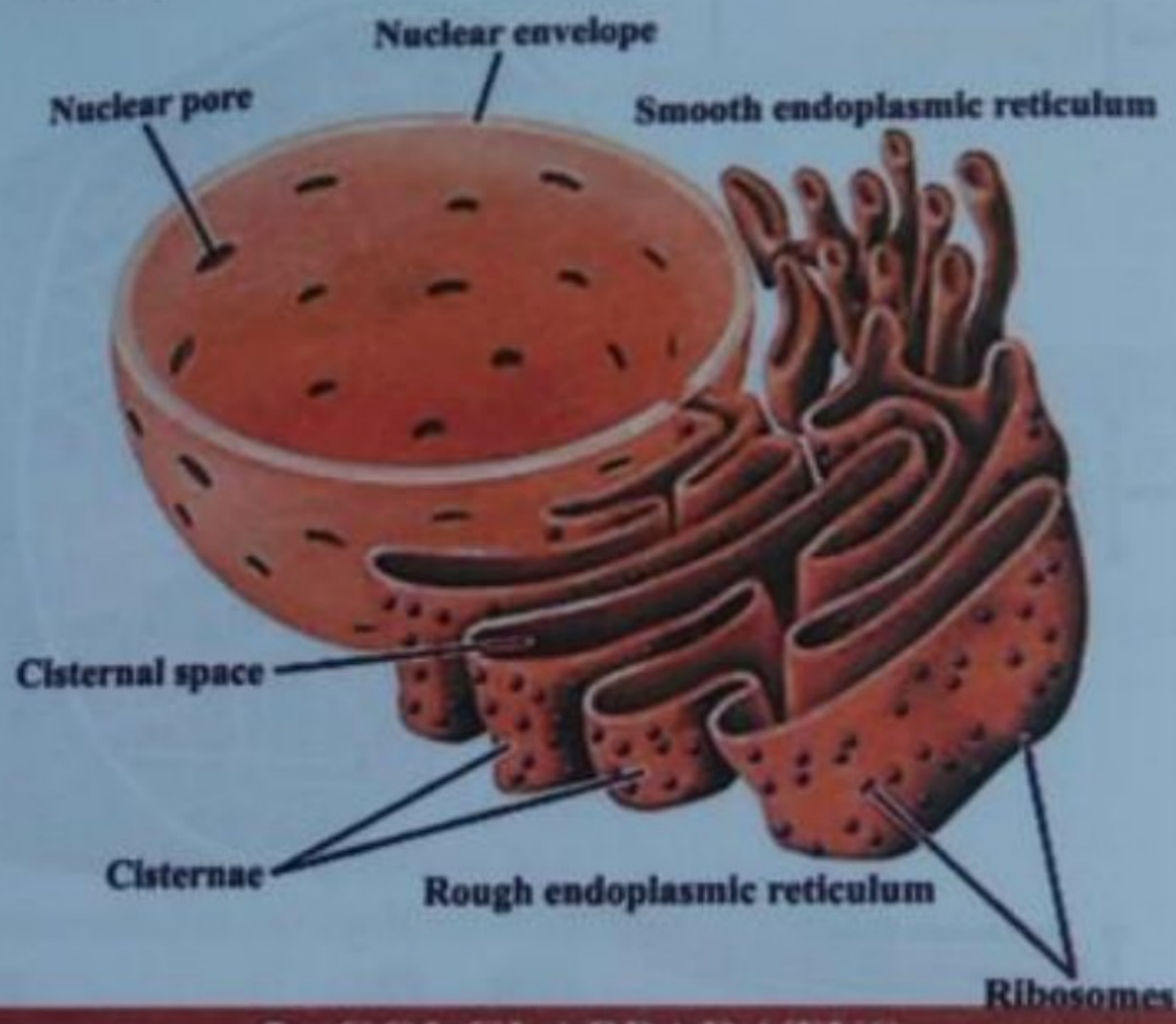
B) Smooth E.R

- One without ribosomes.
- Contain cisternae tubules.
- Helps in ***metabolism*** of various types of molecules particularly lipids.
- Helps in ***detoxifying*** harmful drugs.
- SER is also responsible for the ***transmission of impulses*** e.g. in muscles cells and nerve cells.
- Formation of Golgi vesicles.

General Functions of ER

- They provide ***mechanical support*** to the cell, so that its shape is maintained
- They are also involved in ***transport*** of materials from one part of the cell to the other.

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5. GOLGI APPARATUS

Introduction

- Single cisterna sac is called ***Golgi Body***.
- Stack of cisternae sacs is called ***Golgi Apparatus***.
- Stack of cisternae sacs with associated vesicles is called ***Golgi Complex***.
- Golgi apparatus in plants is called ***Dictyosomes*** which are used in construction of cell wall.

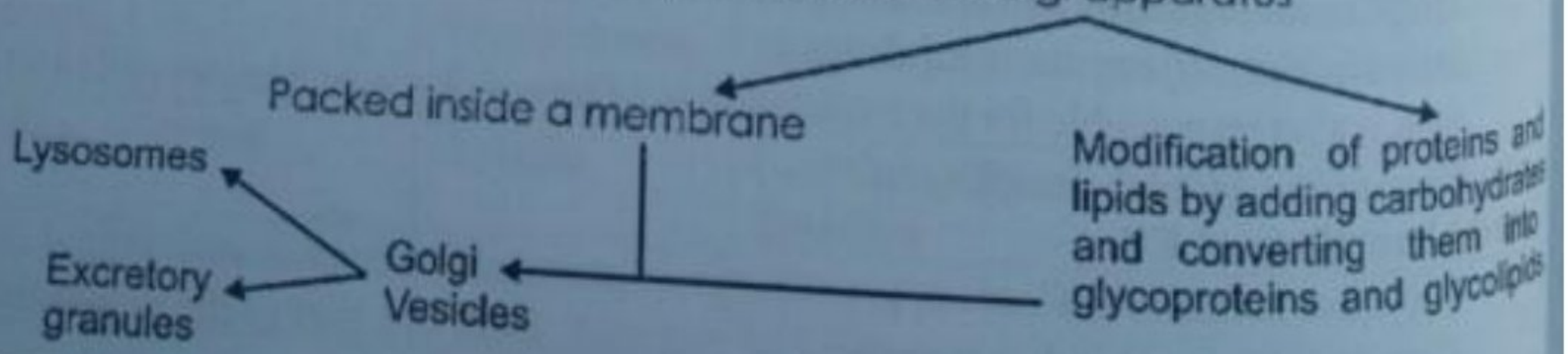
Structure

- Golgi apparatus is a stack of flattened, membrane bound sacs called cisternae.
- Golgi complex is a complex system of interconnected tubules around the central stacks. The cisternae together with associated vesicles are called Golgi complex.
- Golgi apparatus has two faces i.e. forming face and maturing face.
- ***Forming face*** is outer also called as cis face. Vesicles that bud off from smooth endoplasmic reticulum are fused together to form cisternae of Golgi apparatus at forming face.
- ***Maturing face*** is inner also called as trans face.
- ***Secretory granules***/ Golgi vesicles are pinched off from maturing surface.

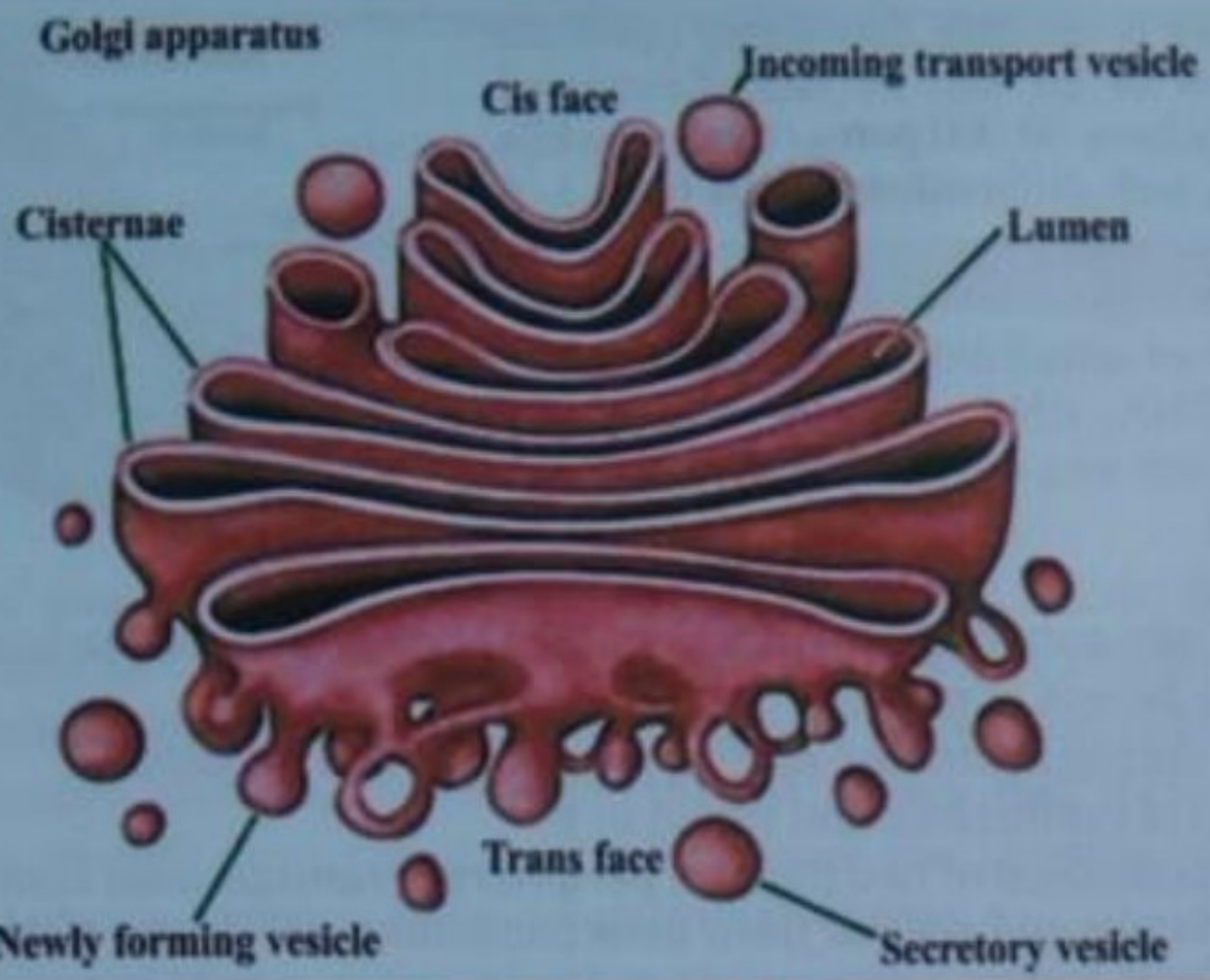
Functions

- They are concerned with the ***cell secretion***.
- They are involved in ***modification of molecules***. Most important modifications are addition of carbohydrates into proteins and lipids and formation of glycoproteins and glycolipids.
- During cytokinesis in plant cells, these are involved in formation of ***phragmoplast***.

Ribosomes → Endoplasmic reticulum → Transport vesicles → Golgi apparatus



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6. NUCLEUS

Introduction

- It is the most prominent and most important part of the cell, also called as brain of cell.
- They are visible only in non- dividing cells.
- In animal cell they are ***central*** in position with exception of skeletal muscle fiber.
- In plant cells they are pushed to ***periphery*** due to the presence of large vacuole.
- They may be irregular or spherical in ***shape***.
- A cell containing single nucleus is called ***mononucleate***, two as ***binucleate*** and with more than two as ***multinucleate***.

POINT TO PONDER

What is difference between binucleate and dikaryotic?

POINT TO PONDER

Can you give examples of anucleate, uninucleate, binucleate and multinucleate cells in human body?

Structure

- Nucleus is composed of nuclear membrane, nucleoli, nucleoplasm and chromosomes or chromatin network.

A) Nuclear Membrane

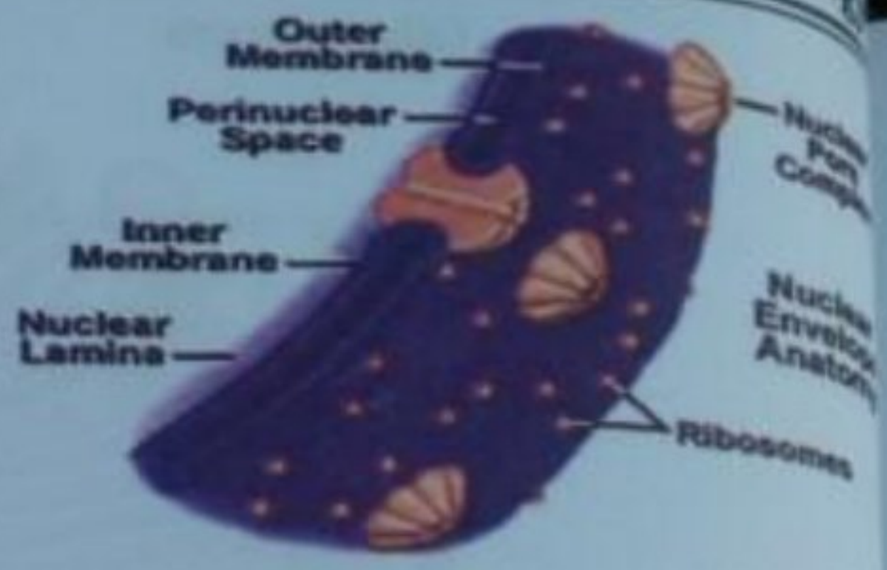
- Nuclear membrane also called as nuclear envelope separates the nuclear material from the cytoplasm.
- It is a ***double layered*** structure. Outer layer continuous with the endoplasmic reticulum and the inner one encloses the nuclear contents.
- These membranes have same structure as per fluid mosaic model.

B) Nuclear Pores

- Nuclear pores result from the fusion of outer and inner membranes. They are composed of specialized transport proteins called ***nucleoporins***.
- They act as a ***gateway*** for the exchange of materials with the cytoplasm.

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- Their ***number*** is variable depending upon the differentiation of the cell i.e. undifferentiated cells like eggs have 30,000 pores / nucleus while erythrocytes, well differentiated cells have 3- 4 pores/nucleus.



C) Nucleoplasm

- It is transparent semifluid ground substance.
- It contains DNA, RNA, proteins, Mg^{+2} ions, free nucleotides and enzymes (DNA & RNA polymerase).

D) Nucleolus

- Nucleolus is non-membranous, darkly stained body within the nucleus.
- Nucleoli may be one or more.
- They appear during interphase & disappear during cell division.
- RNA (rRNA) is synthesized and stored in it.
- Nucleolus is composed of two regions: ***peripheral granular area*** containing precursors fo ribosomal subunits and ***central fibril area*** containing rRNA and rDNA.
- It is the factory for ribosome synthesis.

POINT PONDER 70

If rRNA is synthesized in nucleolus then what is location of mRNA & tRNA synthesis?

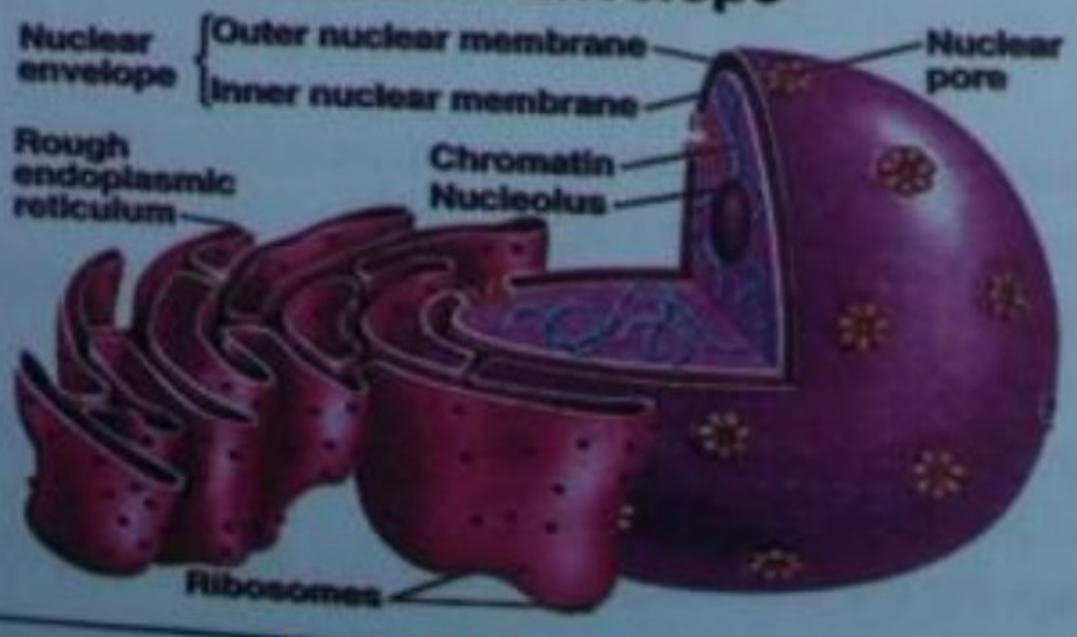
E) Chromatin & Chromosome

- Each chromosome is a thread like structure resulting from organization of chromatin material during cell division.
- Chemically chromosomes are composed of ***DNA and protein***.
- Under compound microscope they appear to be made of arms (chromatids) and centromere, the place where spindle fibers are attached during cell division.
- ***Centromere*** (primary constriction) is the place on the chromosome and ***Kinetochore*** is place on centromere where spindle fibers are attached during cell division.

Chromosome Number In Different Species

Species	Diploid (2n)	Haploid (n)	Species	Diploid (2n)	Haploid (n)
Man	46	23	Frog	26	13
Chimpanzee	48	24	Drosophila	8	4
Onion	16	8	Potato	48	24
Garden Pea	14	7	Pigeon	80	40

Nuclear Envelope



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Functions

- It controls all the metabolic activities of cell.
- It has all the genetic information in a cell.

7. MITOCHONDRIA

Introduction

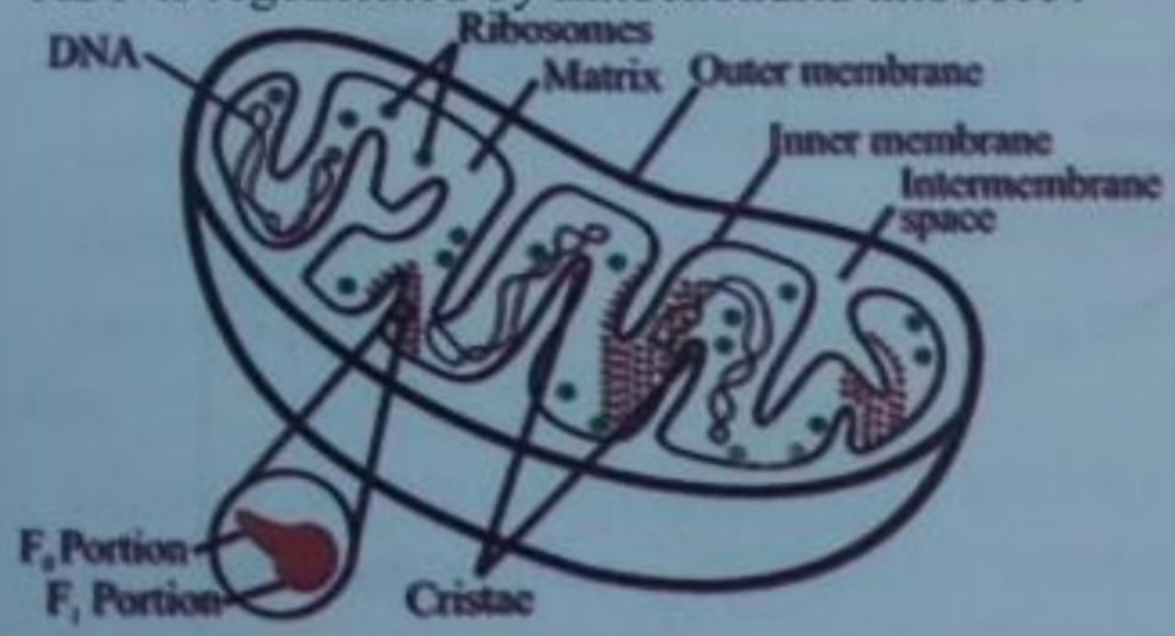
- They are also called ***power house*** of the cell.
- They are ***self-replicating*** organelles.

Structure

- Their ***size and number*** vary depending on the physiological activity of the cell.
- They also contain ***DNA and ribosome***; thus, some proteins may also be synthesized in them.
- When seen under compound microscope they appear as vesicles, rods, filaments.
- When seen under electron microscope, then it shows that they are bound by two membranes, a smooth outer membrane and an inner one forming infoldings ***(cristae)*** in mitochondrial matrix and they show complex morphology.
- The inner surface of cristae in the mitochondrial matrix contains small knob like structure called ***F_1 particles.***
- ***Mitochondrial matrix*** contains enzymes, co- enzymes and organic and inorganic salts.

Functions

- They manufacture and supply ***energy*** to the cell.
- Enzymes in mitochondrial matrix help in metabolic processes like Krebs cycle, aerobic respiration, and fatty acid metabolism. These processes extract energy from the organic food and convert them into ATP, an energy rich compound, which provides energy to the cell on demand.
- ADP is regenerated by mitochondria into ATP.



POINT TO PONDER

What is the role of mitochondria in RBCs?

POINT TO PONDER

What you know about F1 particles?

8. LYSOSOMES

Introduction

- Lysosomes (Lyso = Splitting: Soma = Body) are cytoplasmic organelles which are found in most eukaryotic cells and are different from others due to their morphology.
- These were isolated as a separate component for the first time by De Duve in 1949.

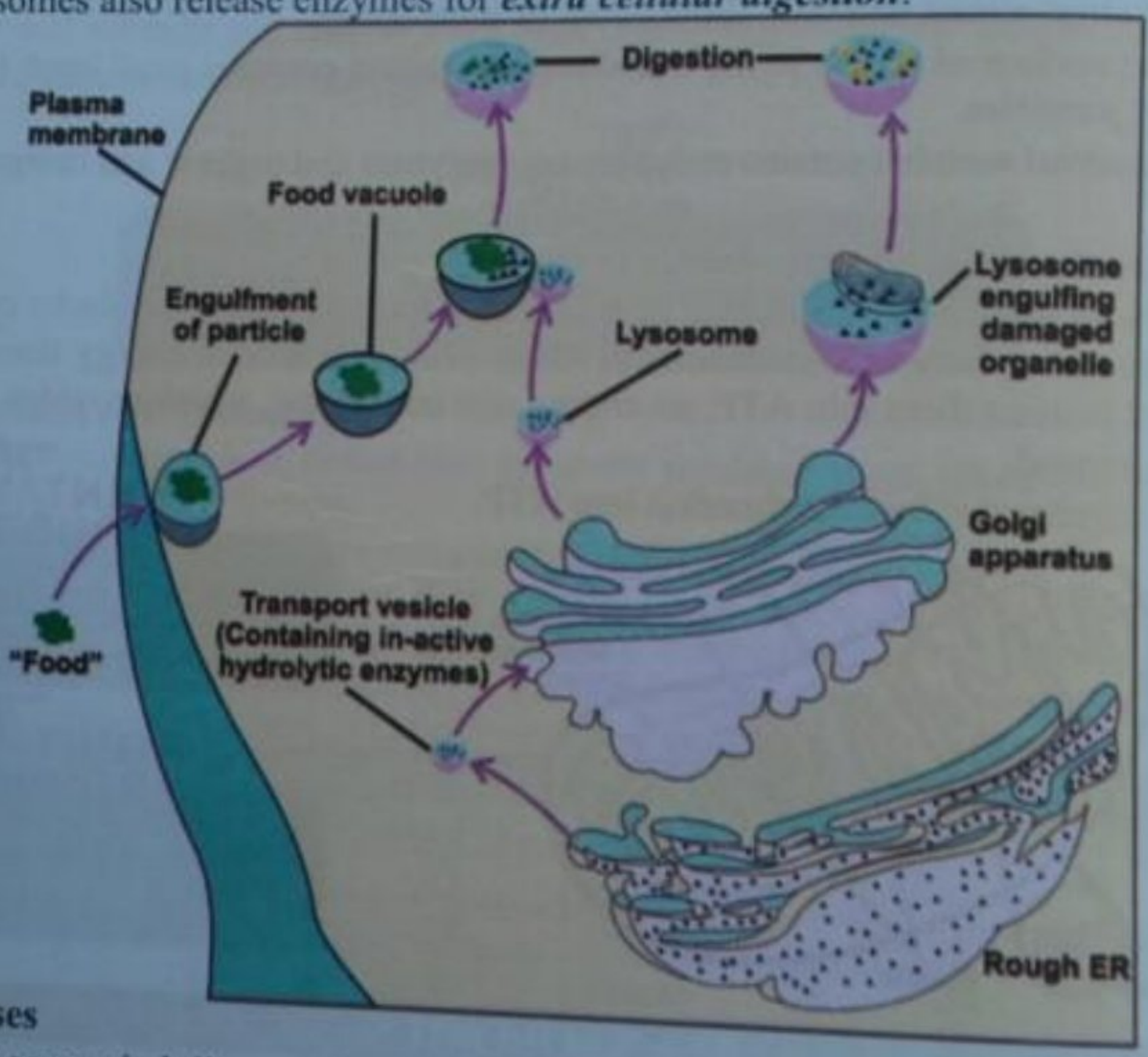
Structure

- Bound by a ***single membrane*** and are simple sacs (vesicles) rich in ***acid phosphatase*** and several other digestive or ***hydrolytic enzymes***.
- These enzymes are synthesized on RER and are further processed in the Golgi apparatus. The processed enzymes are budded off as Golgi vesicles and are called ***primary Lysosomes.***

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Functions

- Any foreign object that gains entry into the cell is immediately engulfed by the lysosomes and completely broken into simple digestible pieces. This process is known as ***phagocytosis.***
- The ingested food of cell is stored in vesicles, called food vacuoles. Once a lysosome has fused with food vacuole, the resulting structure is called secondary lysosome. Digested products are absorbed by cytoplasm while remaining wastes containing vesicle is now called contractile vacuole. This is called ***intracellular digestion***.
- They are also involved in the ***autophagy***. During this process some old, worn out parts of cells, such as mitochondria are digested. Such lysosomes are called autophagosome. Such process also occurs during starvation.
- Their enzymes can also result in ***degeneration of cell***, as may occur during some developmental processes. This type of cell death is called autolysis. Removal of tadpole tail during metamorphosis is an example of lysosomal activity.
- Lysosomes also release enzymes for ***extra cellular digestion***.



Storage Diseases

- Several congenital diseases have been found to be due to accumulation within the cell of substances such as glycogen or glycolipids. These are called storage diseases. 20 such diseases have been discovered so far.
- These diseases are produced by a mutation that effect one of the lysosomal enzymes involved in the catabolism.
- In ***glycogenosis type II disease***, the liver and muscle appear to be filled with glycogen within membrane bound organelles. In this disease, an enzyme that degrades glycogen to glucose, is absent.
- ***Tay-Sach's disease*** is because of absence of an enzyme that is involved in the catabolism of lipids. Accumulation of lipids in brain cells leads to mental retardation and even death

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9. PEROXISOMES

Introduction

- De Duve and co-workers isolated in 1965 particles from liver cells. In animals, they are most common in liver and kidney cells.
- They have also been found in protozoa, yeast and many cell types of higher plants.
- The name peroxisome was apsppplied because this organelle is specifically involved in the formation and decomposition of H_2O_2 in the cell.

Structure

- These are single membrane enclosed cytoplasmic organelles found both in animal and plant cells.
- They originate from endoplasmic reticulum.
- They are approximately 0.5 μm in diameter.
- They are rich in oxidative enzymes, such as peroxidase, catalase, glycolic acid oxidase and some other enzymes.
- Catalases are involved in breakdown of hydrogen peroxide into water and oxy n.

Functions

- They are involved in formation and decomposition of hydrogen peroxide.

10.GLYOXISOMES

Introduction

- Plants contain an organelle, which in addition to glycolic acid oxidase and catalase, also possess a number of enzymes that are not found in animal cells. This organelle is called Glyoxysomes.
- Glyoxysomes are present only during a short period in the germination of the ***lipid-rich seed*** and is absent in lipid-poor seed such as pea.

Function

- Glyoxysomes are the most abundant in plant seedlings, which rely upon stored fatty acids to provide them with the energy and the material to begin the formation of a new plant.
- One of the primary activities in these germinating seedlings is the conversion of stored fatty acids to carbohydrates, through ***Glyoxylate cycle***, the enzymes of which are located in the Glyoxysomes.
- In seeds rich in lipids such as castor bean and soya-beans, Glyoxysomes are the sites for breakdown of fatty acids to succinate.

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TOPIC-2 10 MCQs BIOLOGICAL MOLECULES

LEARNING OUTCOMES

(1) Define the terms: monomer, polymer, macromolecules, discuss Carbohydrates: Monosaccharides, Oligosaccharides, Polysaccharides (starch, glycogen, and cellulose).
(2) Explain the structure of amino acids and peptide bond formation.
(3) Explain the structure of primary, secondary, tertiary, quaternary proteins and their importance
(4) Describe Lipids: Acylglycerols, Waxes, Phospholipids, Terpenoids and their functions.
(5) Describe the structure of DNA as hereditary material along its composition and functions.
(6) Give the structure and types of RNA (mRNA, rRNA, tRNA) and their function in the cell.
(7) Define enzyme and describe its characteristics.
(8) Define the following terms: Coenzyme, Co-factor, Activator, Prosthetic group, Apoenzyme and Holoenzyme.
(9) Explain the mode / mechanism of enzyme action.
(10) Explain the effects of temperature, pH, enzyme concentration and substrate concentration on the rate of enzyme catalyzed reaction.
(11) Explain the effects of reversible and irreversible, competitive and noncompetitive inhibitors on the rate of enzyme activity.

1. TERMS

Macromolecule

A macromolecule is high molecular weight compound more or equal to 10,000 and usually water insoluble e.g. starch.

Polymer

Such a macromolecule that is made from many repeating units is called polymer e.g. glycogen.

Monomer

Basic repeating unit of a polymer is called monomer e.g. isoprenoid (C_5H_8) unit in terpenoids.

Interconversion of these molecules will be carried out by condensation and hydrolysis. Condensation is also called dehydration synthesis if water molecule is removed.

Biological Molecules	Essential Elements	Non-Essential Elements
Carbohydrates	C, H, O	N
Proteins	C, H, O, N	S
Lipids	C, H, O	N, P
Nucleic Acids	C, H, O, N, P	-

2. CARBOHYDRATES

- Literal meaning "hydrated carbons".
- They are composed of C, H, and O. Mostly hydrogen and oxygen are found in same ratio as in water (2:1).
- ***Chemically*** they are ***defined*** as "polyhydroxy aldehydes or ketones or complex substances which on hydrolysis yield polyhydroxy aldehyde or ketone subunits."
- Their ***general formula*** is $C_x (H_2O)_y$.
- Simple carbohydrates are the main ***source of energy*** in cell.

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POINT PONDER 70

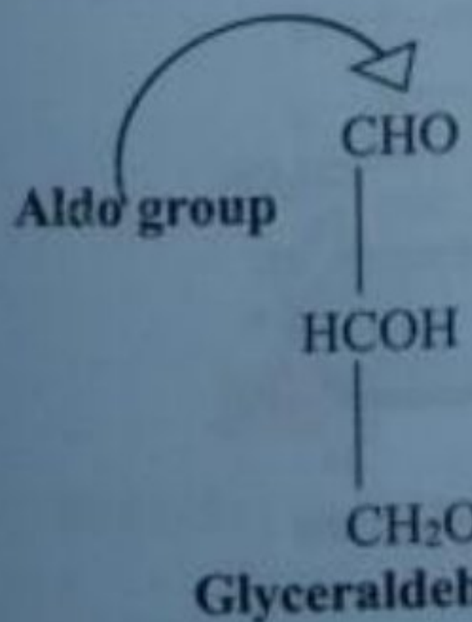
What is difference between polymerization and condensation?

- Some carbohydrates are the main ***constituents of cell walls*** in plants and microorganisms.
- ***Examples*** are cellulose in wood, cotton and paper, starches present in cereals, root tubers, cane sugar and milk sugar.
- Their ***main sources are*** green plants, which produce them by photosynthesis. Even all the other compounds of plants are synthesized from carbohydrates.
- Carbohydrates combine with proteins and lipids to form ***glycoprotein & glycolipids*** respectively.

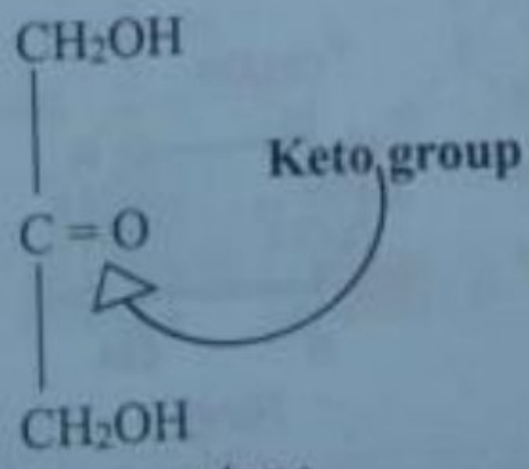
Major Groups of Carbohydrates

Feature	Monosaccharides	Oligosaccharides	Polysaccharides
Common Name	Simple sugars	Complex sugars	Most complex sugars (Branched or unbranched)
Taste	Sweet	Less sweet	Tasteless
Solubility in water	Easily soluble in water	Less soluble in water	Sparingly soluble in hot water
Hydrolysis	Can't be hydrolyzed into simpler sugar	Can be hydrolyzed	Can be hydrolyzed
General Formula	$(CH_2O)_n$/ $C_nH_{2n}O_n$/ $C_n(H_2O)_n$	$C_n(H_2O)_{n-1}$ (for disaccharides)	$Cx(H_2O)y$
Classification	• On base of number of carbon atoms e.g. trioses (3C), tetroses (4C), pentoses (5C) etc. • On base of functional group e.g. aldo and keto sugars.	On base of monosaccharides released during hydrolysis e.g. disaccharides, trisaccharides etc.	On base of structural complexity & relation e.g. starch, glycogen, cellulose, dextrin, agar, pectin and chitin.
No. of sugar units	• One	Two – Ten	$10 \leq 1000$ or above

Monosaccharides



Glyceraldehyde



Dihydroxyacetone

- In nature monosaccharide with ***3 – 7 C atoms*** are found.
- All carbon atoms except one have hydroxyl group. This exception is carbon of aldehyde or ketone group.

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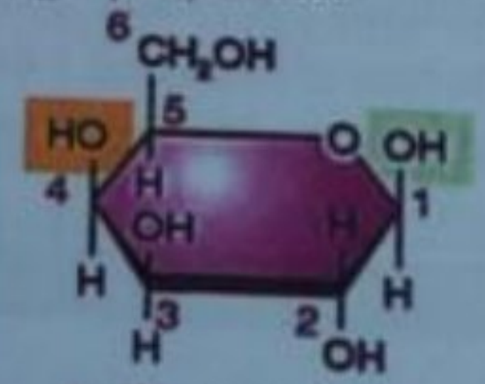
Atoms	Type	Formula	Aldo Form	Keto Form	Role
3 C	Trioses	$C_3H_6O_3$	Glyceraldehyde	Dihydroxyacetone	Intermediates in photosynthesis & respiration
4 C	Tetroses	$C_4H_8O_4$	Erythrose	Erythrulose	Intermediates in photosynthesis in bacteria
5 C	Pentoses	$C_5H_{10}O_5$	Ribose	Ribulose	Ribose (Aldo) form in RNA Ribulose (Keto) in photosynthesis
6 C	Hexoses	$C_6H_{12}O_6$	Glucose	Fructose	Energy source, Polymer formation
7 C	Heptose	$C_7H_{14}O_7$	Glucoheptose	Sedoheptulose	Intermediates in photosynthesis in bacteria

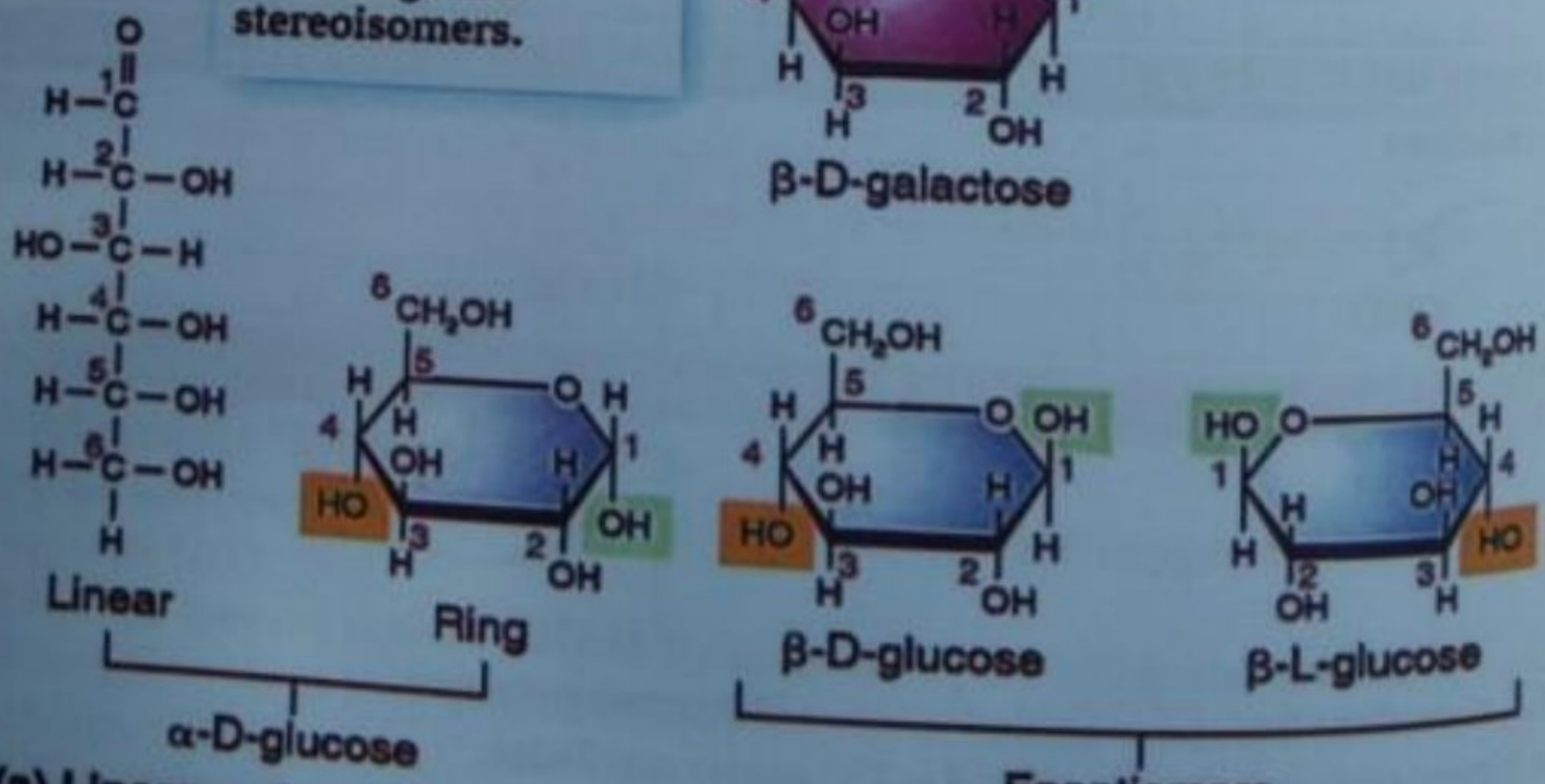
- Most monosaccharide (pentoses & hexoses) form a ***ring structure*** in solution.
- Furanose is 5 cornered ring while pyranose is 6 cornered ring.
- These rings are heterocyclic having oxygen at one corner and carbon at other corners.
- Each pentose and hexose exist in either α or β forms depending upon position of H a OH groups at C1. If OH group is found downward at C1, it is called α sugar and if O group is present upward on C1 then it is known as β sugar.

Glucose

- Naturally produced in green plants which take carbon dioxide from air and H_2O from soil to synthes glucose.
- Synthesis of ***10g of glucose*** requires ***717.6 Kcal*** of solar energy, which in turn is stored glucose molecule and becomes available in all organisms when it is oxidized in the bo
- Our ***blood*** contains ***0.08%*** glucose.
- Starch, cellulose, and glycogen yield glucose on complete hydrolysis.
- Free form of glucose is present in figs, grapes, dates.

These four molecules with rings are stereoisomers.





(a) Linear and ring structures of α-D-glucose

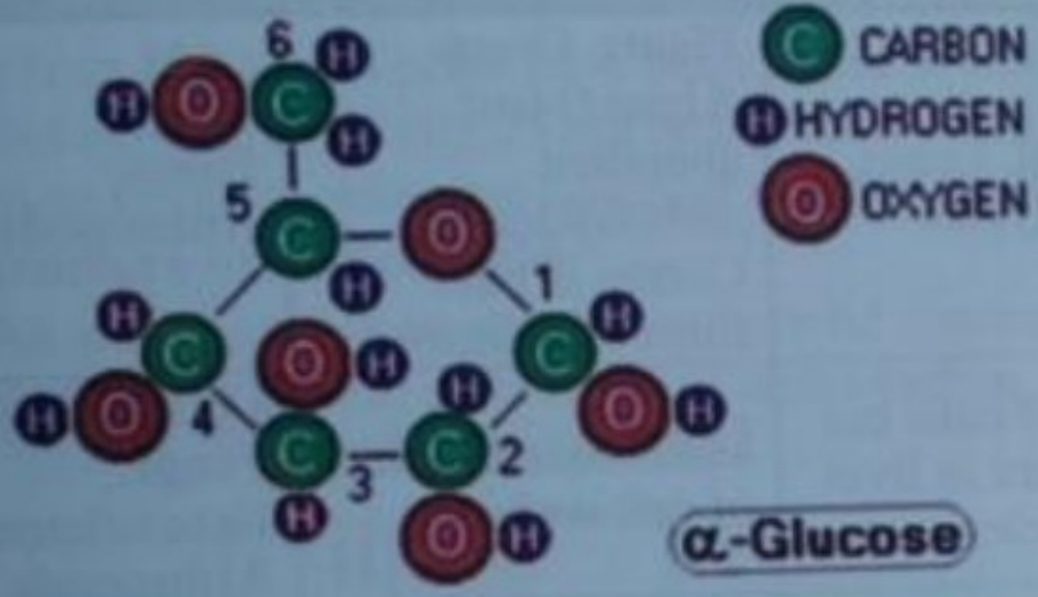
(b) Isomers of glucose

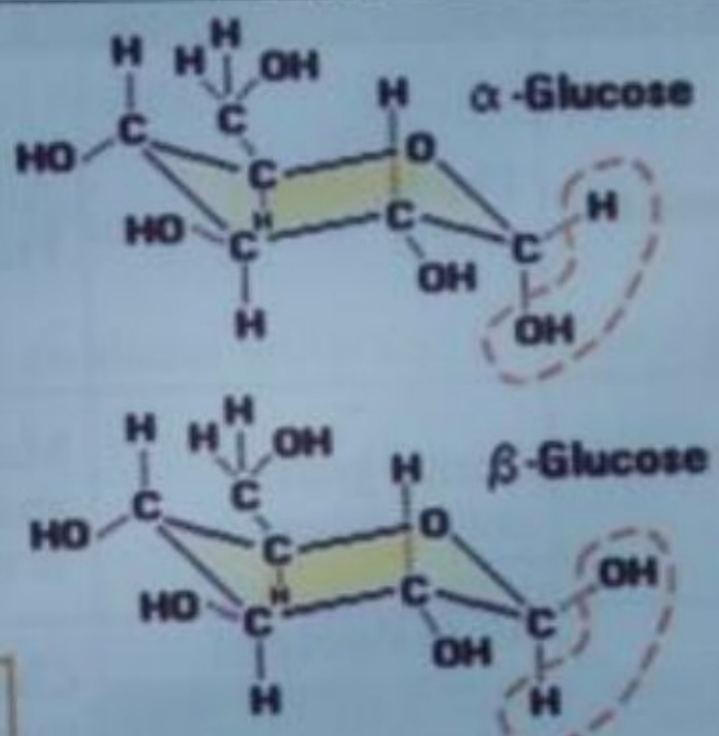
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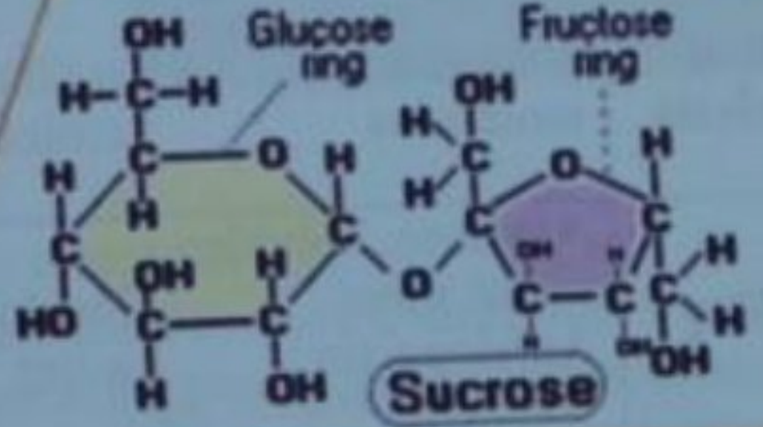
Oligosaccharides

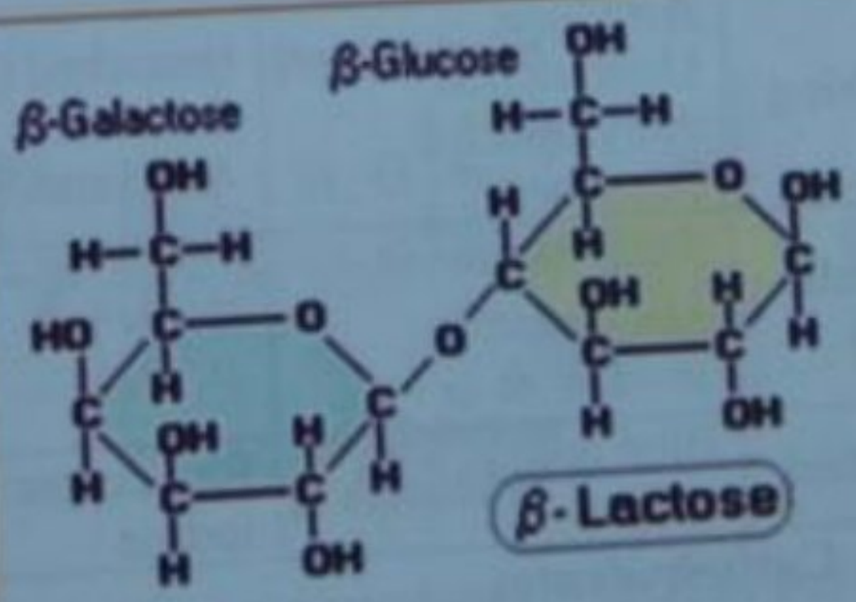
- Those oligosaccharides which yield two monosaccharide on hydrolysis are called ***disaccharides*** and those yielding three are called ***trisaccharides.***
- The covalent bond between two monosaccharides is called ***glycosidic bond.***
- ***Maltose, sucrose, and lactose*** all are disaccharides. Their general formula is $C_{12}H_{22}O_{11}$.

Disaccharide	Source & Common Name	Components	Glycosidic Bond
Maltose	Intermediate, Fruits (Malt Sugar)	Glucose + Glucose	1,4 glycosidic linkage
Sucrose	Sugar Cane (Cane Sugar)	Glucose + Fructose	1,2 glycosidic linkage
Lactose	Milk (Milk Sugar)	Galactose +Glucose	1,4 glycosidic linkage









Reducing & Non-Reducing Sugars

- Sugars which give positive result on Benedict or Fehling test are called reducing sugars. These act as reducing agents. They have free aldehyde or free ketone group. All monosaccharides, lactose and maltose are reducing sugars. Ketoses must first tautomerize to aldoses before they act as reducing sugars.

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POINT TO PONDER

Why fructose is reducing sugar while it contains ketone group?

Polysaccharides

- They are formed by several monosaccharide units linked by glycosidic bonds.
- They act as structural components, food and energy stores.
- Starches, glycogen, cellulose, dextrin, agar, pectin and chitin all are polysaccharides.

Classes of Polysaccharides

Feature	Starch	Glycogen (Animal Starch)	Cellulose	Chitin
Organism	Plants, Green Algae	Animal, Fungi, Prokaryotes	Plants, Green Algae (Most abundant carbohydrate). Cotton is pure form of cellulose.	Fungi, Arthropods
Location	Fruits, grains, seeds, tubers.	Most of cells but abundant in liver & muscles.	Main constituent of cell walls.	Cell wall in Fungi, Exoskeleton in Arthropods
Main function	Main source of carbohydrates for animals.	Chief storage form in animals.	Main constituent of cell wall of plants.	Protection
Result of hydrolysis	α-Glucose molecules	α-Glucose molecules	β-Glucose molecules (α-amylase in our gut cannot digest)	N-acetyl β-glucosamine
Solubility	Amylose: Soluble in hot water Amylopectin: Insoluble	Insoluble in water	Highly insoluble in water	Insoluble
Branching	Amylose: Unbranched Amylopectin: Branched	Branched (More than Amylopectin)	Unbranched	Unbranched
Glycosidic linkage	Amylose: $\alpha-1,4$ Amylopectin: $\alpha-1,4$ & $\alpha-1,6$	$\alpha-1,4$ & $\alpha-1,6$	$\beta-1,4$	$\beta-1,4$
Iodine test	Blue colour with iodine	Red colour with iodine	No colour change on iodine test	No colour change on iodine test

Tests for Carbohydrates

- Benedict or Fehling test to detect reducing & Non-reducing sugars.
- Iodine test to detect different types of polysaccharides.

POINT TO PONDER

What are dextrins?

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3. PROTEINS

- They are the ***most abundant organic compounds*** found in cells and comprising over 50% of their total dry weight.
- Proteins are polymers of amino acids, the compounds containing ***C, N, O, and H***.
- A protein may consist of a single polypeptide or more than one.

Example	Major Functions
Enzymes	Catalyse chemical reactions and control whole metabolism of cell.
Hormones	Regulate metabolic processes.
Transport proteins	Carrier protein that transports O_2 (Hb), lipids, metal ions etc.
Antibodies	Defend the body against pathogens.
Clotting proteins	Prevent loss of blood after injury.
Mitotic apparatus	Helps in movement of chromosomes during anaphase of cell division.

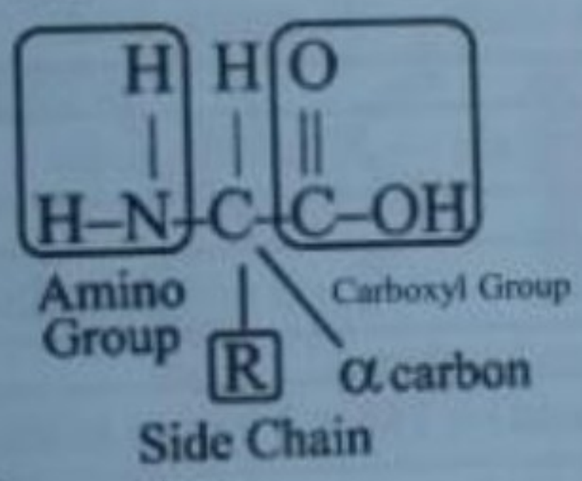
Amino Acids

- About ***170*** amino acids have been found in cells and tissues.
- Out of 170 types only ***25*** are constituents of proteins.
- Most of the proteins are however made of ***20*** types of amino acids.

Basic Structure of Amino Acid

- An amino acid is an organic compound containing an amino group and a carboxyl group, attached to central carbon called alpha carbon.

A Typical Amino Acid

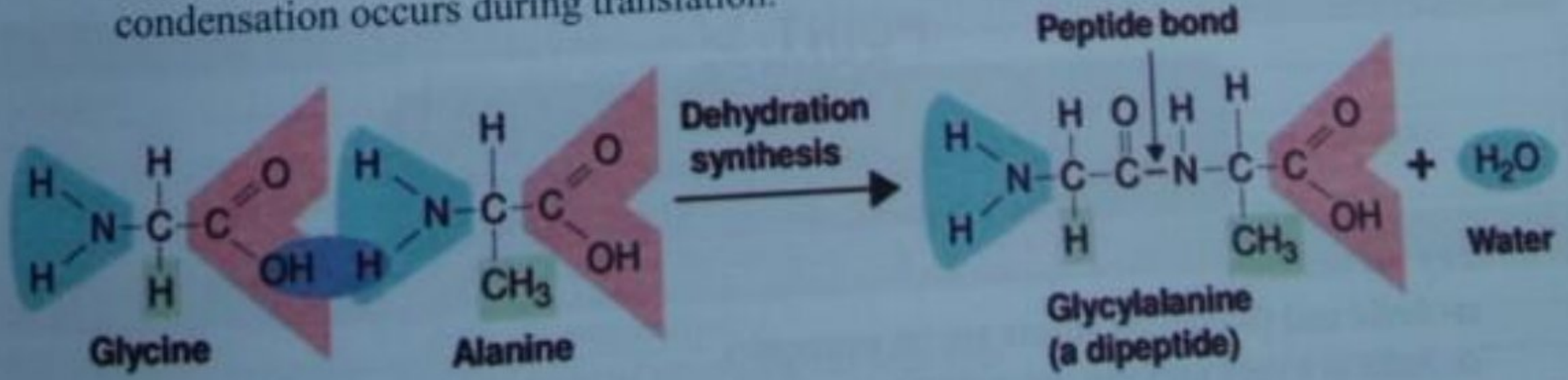


POINT TO PONDER

What are essential & non-essential amino acids?

Peptide Bond Formation

- Amino acids link together to form a polypeptide molecule.
- Two amino acids combine together via a peptide bond to form a dipeptide, e.g., Alanine and Glycine form ***glycylalanine***. Similarly tri, tetra and pentapeptides can be formed. This condensation occurs during translation.



- In this figure -OH of carboxyl group of one amino acid combines with H of amino group of another amino acid releasing water and forming C-N link called *peptide bond*.

Structure of Proteins

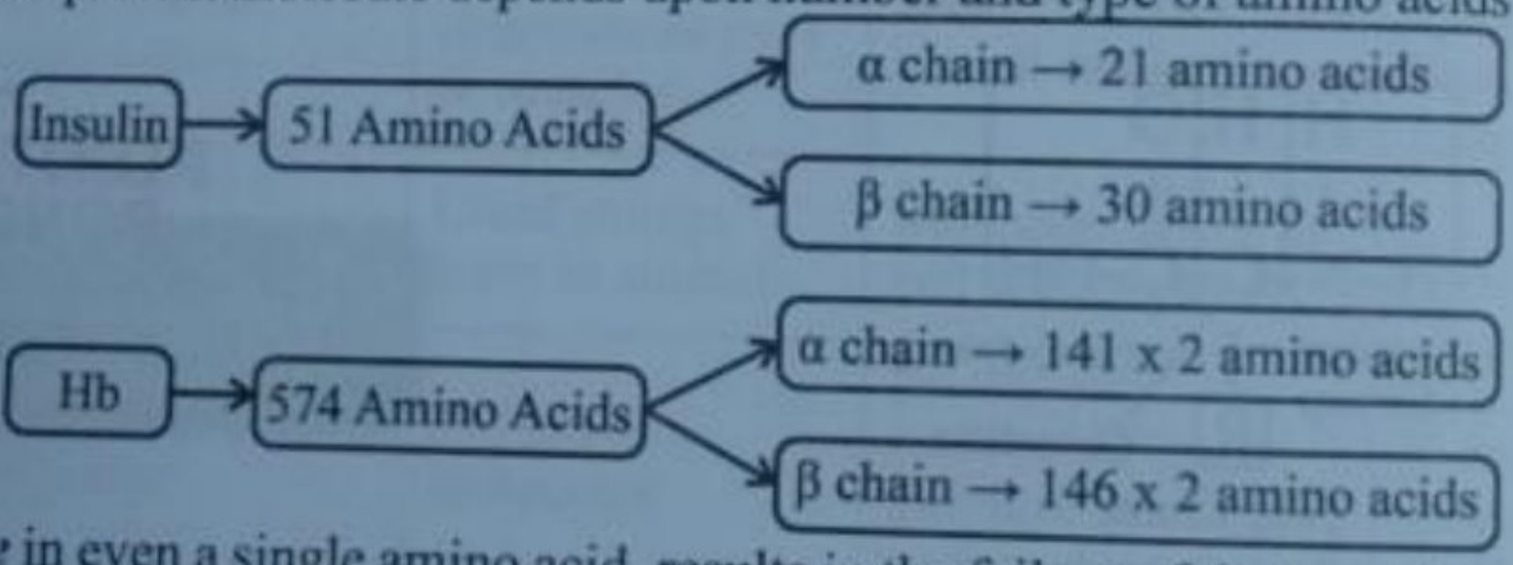
There are four levels of organization of protein molecules.

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Feature	Primary	Secondary	Tertiary	Quaternary
Information	Number & sequence of amino acids in protein molecule.	Structural conformation (form or shape) e.g. coil or helix	Bending & folding and forming globular shape.	Aggregation held together by hydrophobic interactions.
Bonds	Peptide bond Disulphide bridges	Hydrogen	Ionic, Hydrogen, Disulphide (-s-s-)	Hydrogen, Ionic bonds, Hydrophobic interactions
Example	Insulin, Hb	Alpha helix (α-helix), β pleated sheet	Single chain of Hb	Hb molecule

Primary Structure

- ***F. Sanger*** was the first scientist who determined the sequence of amino acids in a prote molecule.
- The ***sequence of amino acids*** in a protein molecule is determined by the order nucleotides in the DNA.
- It is shown by all proteins at the time of their synthesis on ribosome surface.
- The ***size*** of protein molecule depends upon number and type of amino acids comprising it



- A ***change*** in even a single amino acid, results in the failure of that protein, which may ev lead to death, e.g., replacement of glutamic acid by valine in Hb molecule results formation of HbS, which fails to carry oxygen, the characteristic of sickle cell anem ultimately leading to death.

POINT TO PONDER

Can you explain, how many genes are required for one molecule of Hb?

Secondary Structure

- ***α- helix*** and β- pleated sheets are its ***examples***.
- ***α- helix*** is a very uniform geometric structure with **3.6 amino acids** in each turn of the hel
- ***B-pleated sheet*** is formed by the folding back of the polypeptide.

Tertiary Structure

In aqueous environment, the most stable tertiary conformation is that in which hydrophobic am acids are buried inside while the hydrophilic amino acids are on the surface of molecule.

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Quaternary Structure

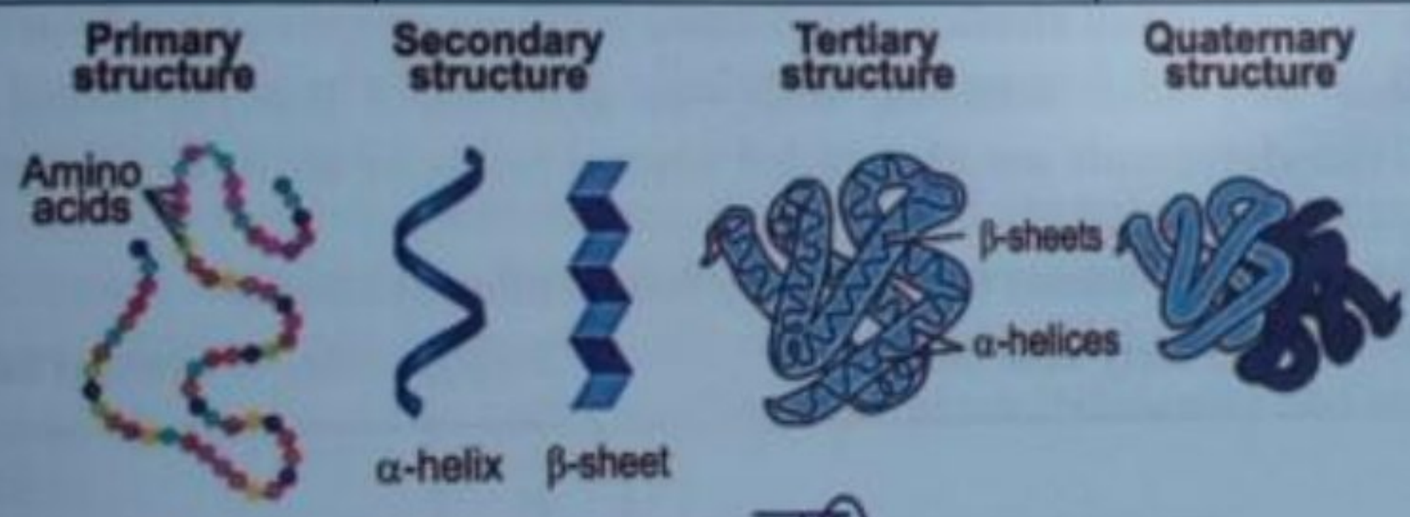
Polypeptide tertiary chains are aggregated and held together by hydrophobic interactions.

POINT TO PONDER

Which type of bond is always present in all types of proteins?

Classification of Proteins

Feature	Fibrous Protein	Globular Protein
Shape	Fibrils form	Spherical or ellipsoidal
Structural organization	Secondary	Tertiary
Solubility in aqueous media	Insoluble in aqueous media	Soluble
Crystal Nature	Non-crystalline	Crystallized
Elasticity	Elastic in nature	Inelastic
Role	Structural	Functional
Stability	Stable	Unstable
Examples	Silk fibers, myosin, fibrin, keratin	Enzymes, antibodies, hormones, hemoglobin.



POINT TO PONDER

Why fibrous are more stable than globular proteins while they are at low structural level?

Important Structural Proteins	
Collagen	Bone and cartilage matrix
Elastin	Elasticity to tendon and ligaments
Keratin	Protective coverings e.g. hair, nails, quills, feathers, horns and beaks
Histone	Chromosome

Important Functional Proteins	
Enzymes	Control metabolism
Hormones	Regulation of physiological activities
Antibodies	Immunity
Haemoglobin	Transport of Gases
Fibrinogen	Blood Clotting
Ovalbumin	Storage of amino acids in eggs
Casein	Storage of amino acids in milk

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UHS Topic-2

4. LIPIDS

- Lipids are a heterogenous group of compounds related to fatty acids.
- They are ***insoluble in water*** but ***soluble in organic solvents*** like ether, alcohol, chloroform and benzenes.
- Their hydrophobic nature makes them best suited to be a ***structural component of*** cell ***membranes***.
- Lipids store ***double the amount of energy*** as compared to same amount of carbohydrates because of high proportion of C-H bonds and very low proportion of oxygen.
- May act as ***insulating layer*** e.g., waxes in exoskeleton of insects, and cutin which is an additional protective layer on the cuticle of epidermis of some plant organs. e.g. leaves, fruits, seeds.

ACYLGLYCEROLS

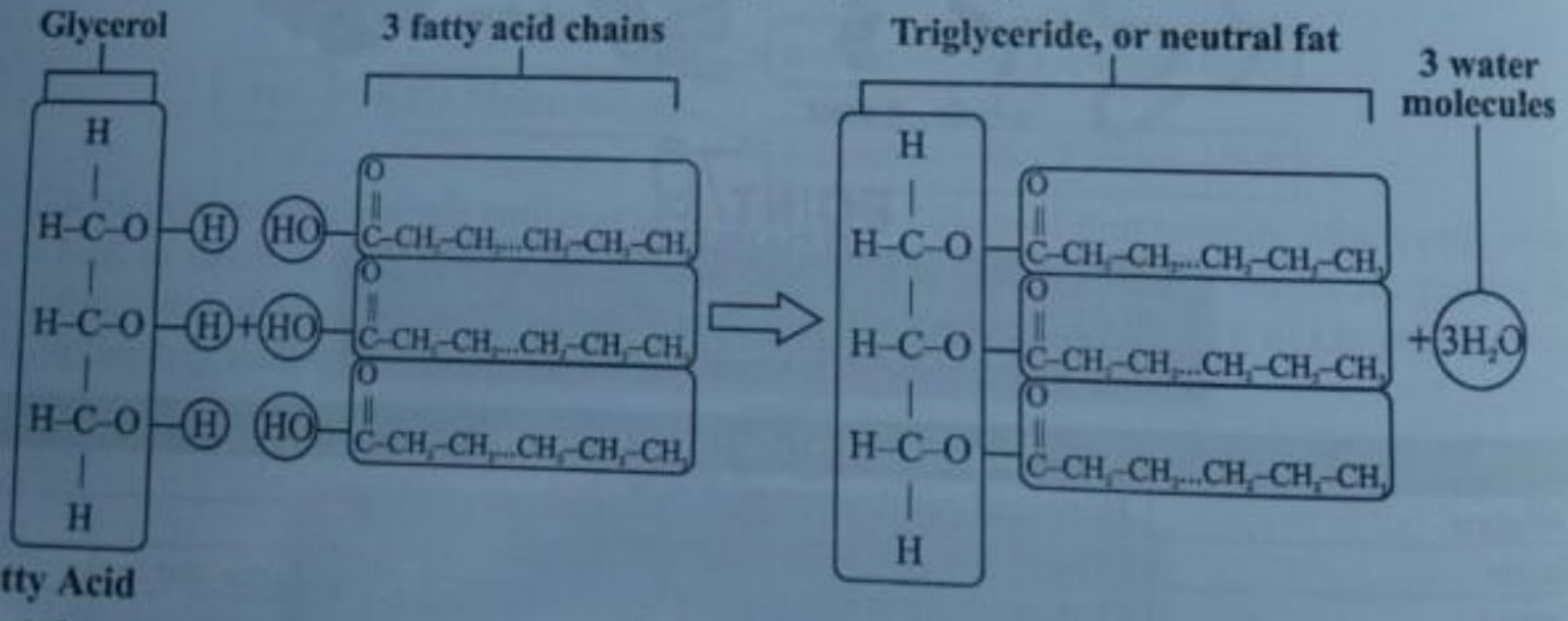
- These are esters of glycerol and fatty acids.
- An ester is the compound produced as the result of a chemical reaction of an alcohol with acid and a water molecule is released. Such a reaction is called esterification.

$$\text{Fatty Acid} + \text{Glycerol} \xrightarrow{\text{Esterification}} \text{Acylglycerol} + H_2O$$

$$C_2H_5OH + HOOCCH_3 \longrightarrow C_2H_5OCOCH_3 + H_2O$$

- Glycerol is a trihydroxy alcohol which contains three carbons, each bearing an OH group.
- When three fatty acids combine with one glycerol, a triacylglycerol (triglyceride) is formed. Triacylglycerols are also called neutral lipids as all three OH groups of glycerol are occupied by fatty acids.

Three fatty acid chains are bound to glycerol by dehydration synthesis.



- A fatty acid is an organic compound containing one carboxylic acid group attached to a hydrocarbon. where R is hydrocarbon tail.
- Fatty Acids contain even number of carbon atoms (2-30). Each fatty acid is represented as R-COOH.
- Solubility of fatty acids in organic solvents, hydrophobic nature and melting points depend upon number of carbon atoms and number of double bonds.
- Fatty acids are either saturated or unsaturated.
- Specific gravity 0.8.

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Saturated Fatty Acid	Unsaturated Fatty Acid
No double bonds between carbon atoms	Upto six double bonds
Straight chain	Ringed /Branched
Solid at room temperature	Liquid at room temperature
Fats	Oils
Animals	Plants
	More useful for living things.

Fatty acid	Type	No. of C	Source	Melting Point
Acetic acid	Saturated	2	Vinegar	16.6°C
Butyric acid	Saturated	4	Butter	-8°C
Palmitic acid	Saturated	16	Palm tree	63.1°C
Oleic acid	Mono-unsaturated	18	Olives	4°C

WAXES

- Waxes are highly hydrophobic compounds.
- There are two types of waxes:

A) **Natural waxes** are simple lipids.

- These are typically esters of long chain fatty acids and long chain alcohols.
- Examples are bee's wax (found in honeycomb), lanolin (obtained from sheep wool), cutin (on leaf surface of plants) and suberin (found in cell walls in endodermis of plant roots).
- They act as ***protective coating*** on the fruits and leaves and thus protect them from water loss and abrasive damage.
- They also provide ***water barrier*** for insects, birds and animals such as sheep.

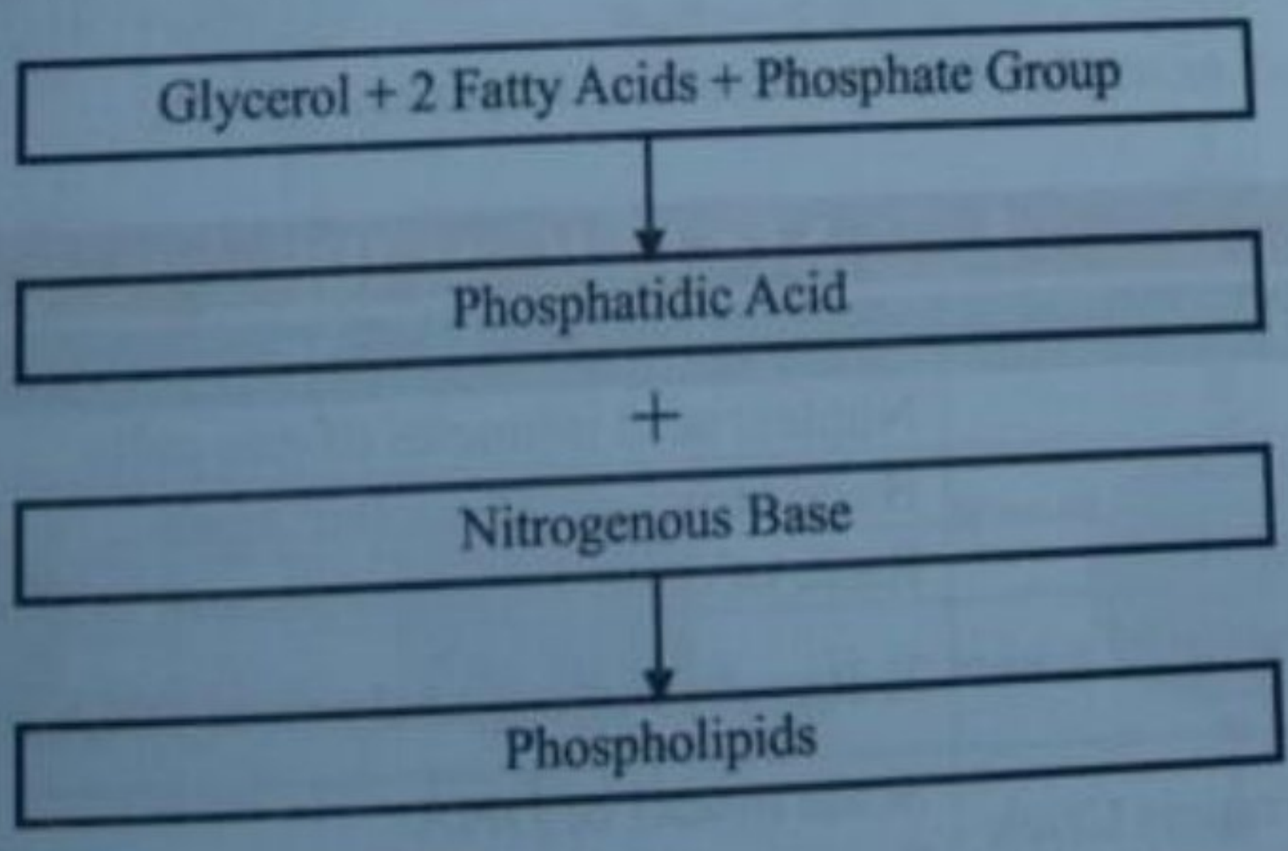
B) **Synthetic waxes** are generally derived from petroleum or polythene.

- These consist of mixtures of long chain alkanes, alcohols, aldehydes, ketones and fatty acids.
- Paraffin wax which is used to make candles, wax paper, lubricants and sealing materials.

PHOSPHOLIPIDS

Composition

- They are the derivatives of ***phosphatidic acid*** by addition of one of the nitrogenous base.
- One end of phospholipid molecule (head), containing the phosphate group and nitrogenous compound is polar and hydrophilic.
- Other end (tail) containing the fatty acid side chains is non-polar and hydrophobic.



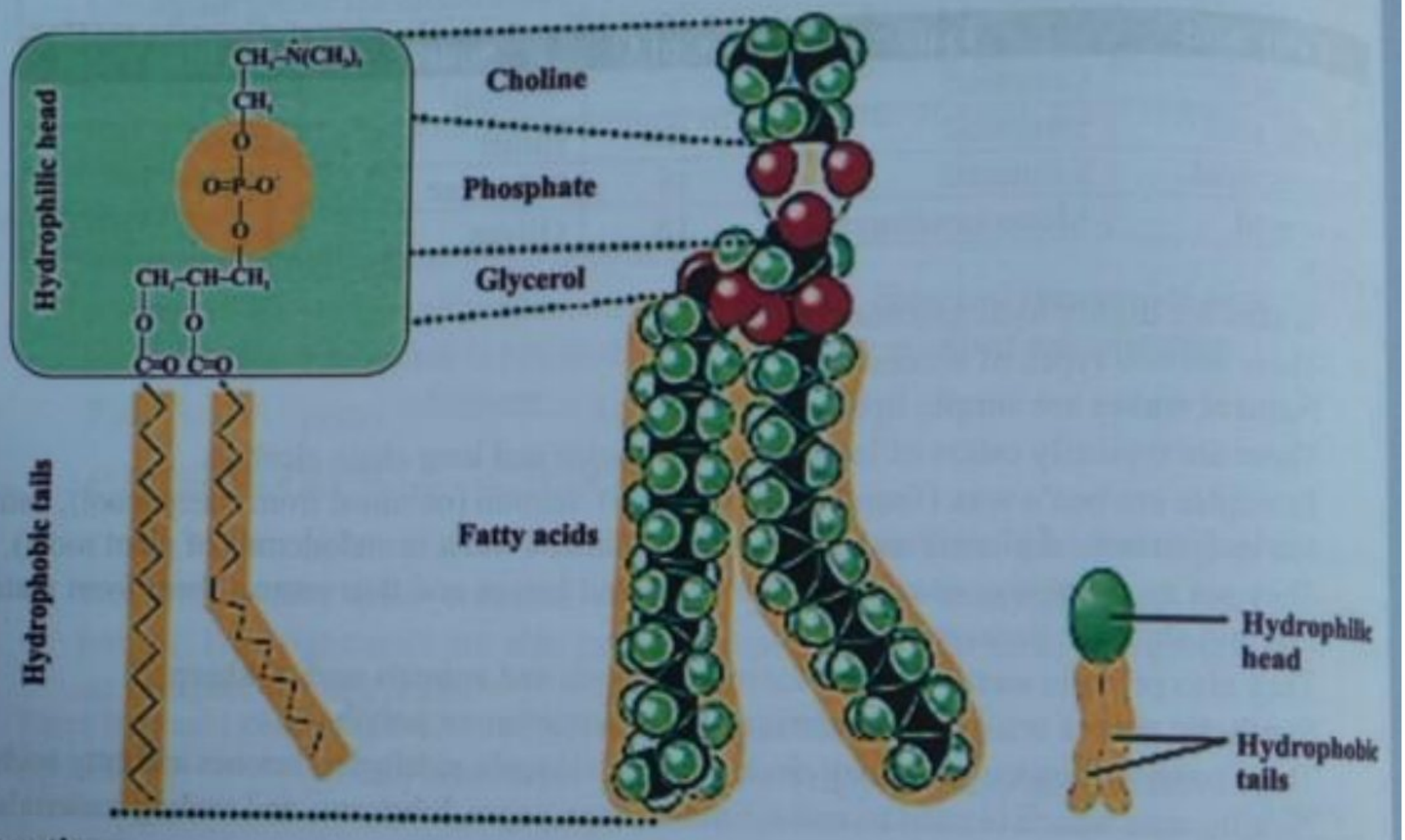
Example

- ***Phophatidylcholine*** is one of its commonest examples also called ***lecithin.***

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POINT PONDER 70

What are amphipathic substances?



Function

- They are frequently associated with ***biological membranes*** and form lipid bilayer.

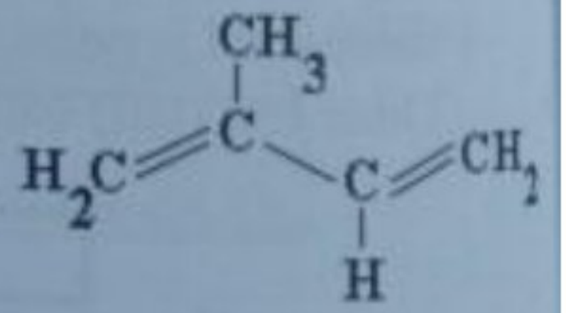
TERPENOIDS/ TERPENES

Composition

- They are made of simple repeating units called ***isoprenoid units***.
- This unit condenses in different ways to form many compounds.

Examples

- Some common examples are carotenoids, terpenes, rubber, steroids etc.



5. NUCLEIC ACIDS

Scientist	Discovery
F. Miescher	Nucleic acid in nuclei of pus cells
P.A.Levene	Basic structure of nucleic acids
Erwin Chargaff	Ratio of different bases present in DNA molecule
Maurice Wilkins & Rosalind Franklin	X-Ray diffraction analysis of DNA
James D. Watson & Francis Crick	Scale model of DNA Semiconservative replication of DNA

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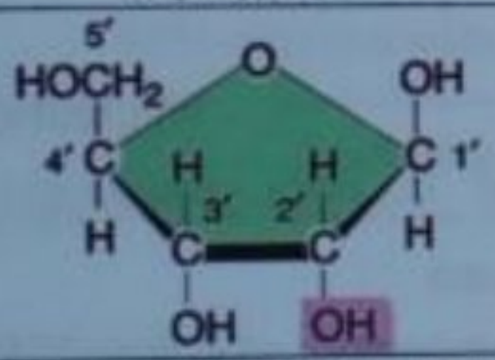
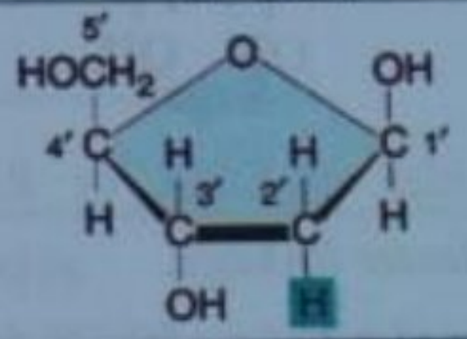
Frederich Griffith	Transformation, First evidence of DNA as hereditary material
Avery, MacLeod & McCarty	DNA as transforming principle
Alfred Hershey & Martha Chase	Confirmative evidence of DNA as hereditary material
Meselson & Stahl	Confirmation of semi-conservation replication of DNA
Marshal Nirenberg, Philip Leder and Har Gobind Khorana	Testing of 64 codons
Okazaki	Okazaki fragments during DNA replication

- Nucleic acid was first isolated in 1870 by ***F. Miescher*** from nuclei of pus cells (White blood cells).
- They are called nucleic acid, since they were first isolated from nuclei and are acidic in nature.
- Nucleic acids are polymers of nucleotides.
- There are two types of nucleic acid: DNA and RNA. Both are linear unbranched polymers.

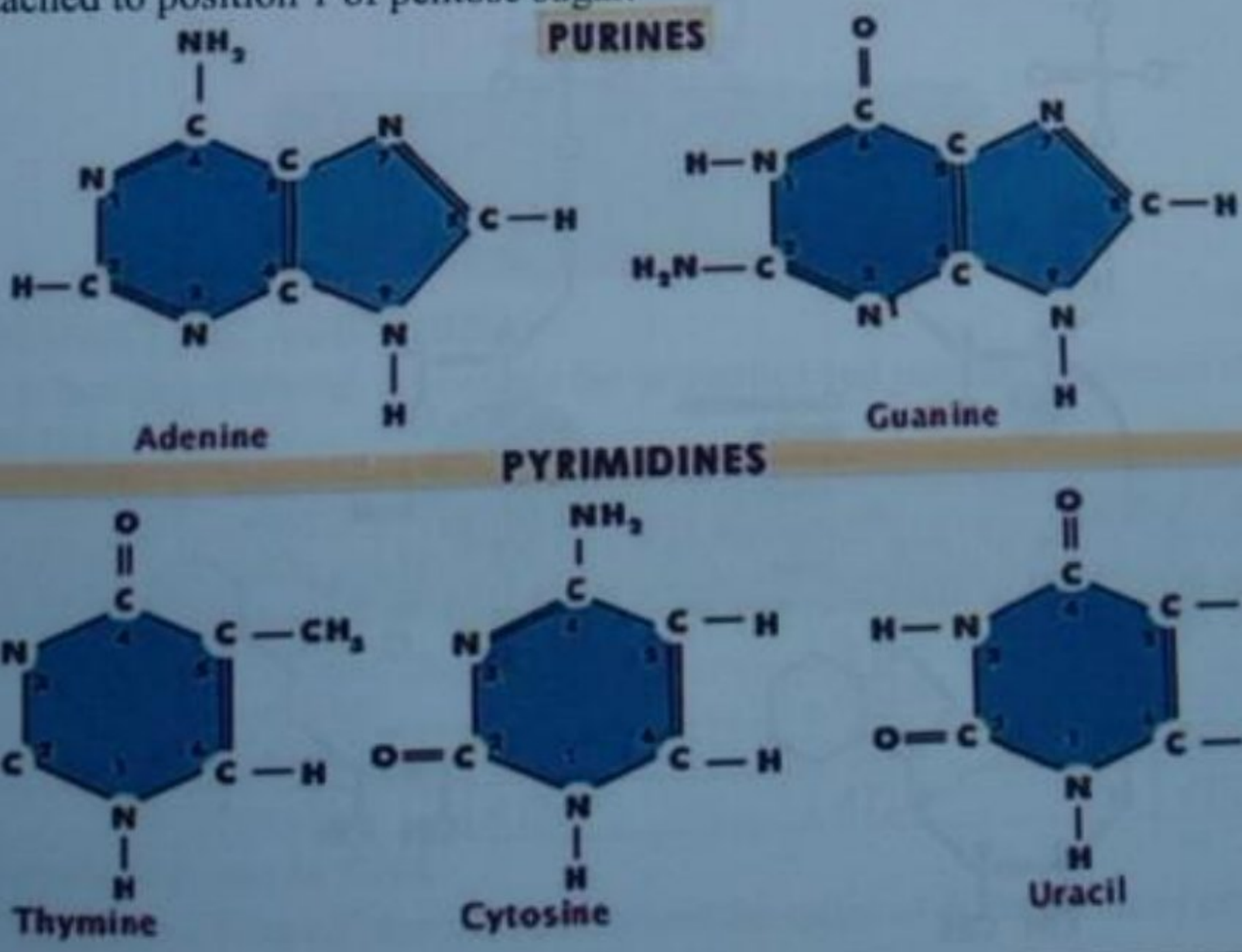
Composition of Nucleotide

- Each nucleotide is made of 3 components:

1. A 5-carbon monosaccharide (a pentose sugar). It is ribose in ribonucleotide and deoxyribose in deoxyribonucleotide.

Ribose	Deoxyribose
$C_5H_{10}O_5$	$C_5H_{10}O_4$
	

2. A nitrogen containing base. Nitrogenous bases are of two types, single ringed pyrimidines (C, T & U) and double ringed purines (A & G). In a typical nucleotide, nitrogenous base is attached to position 1 of pentose sugar.

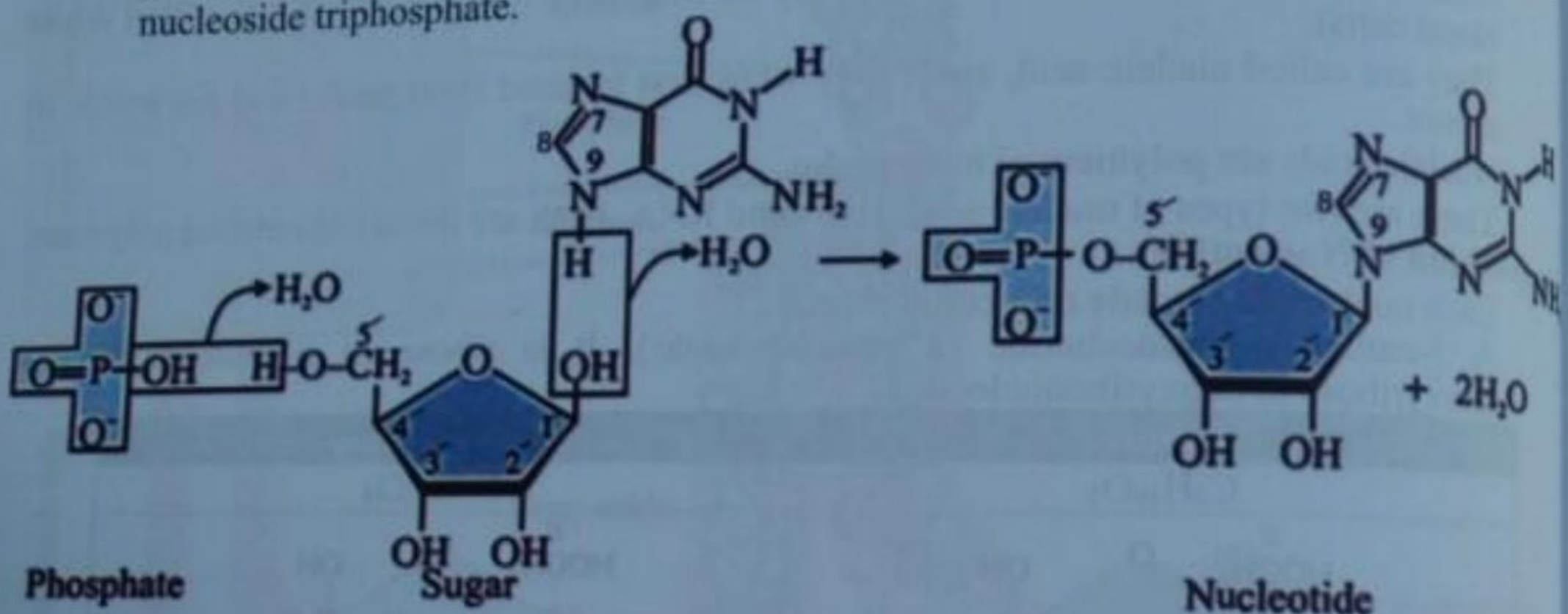


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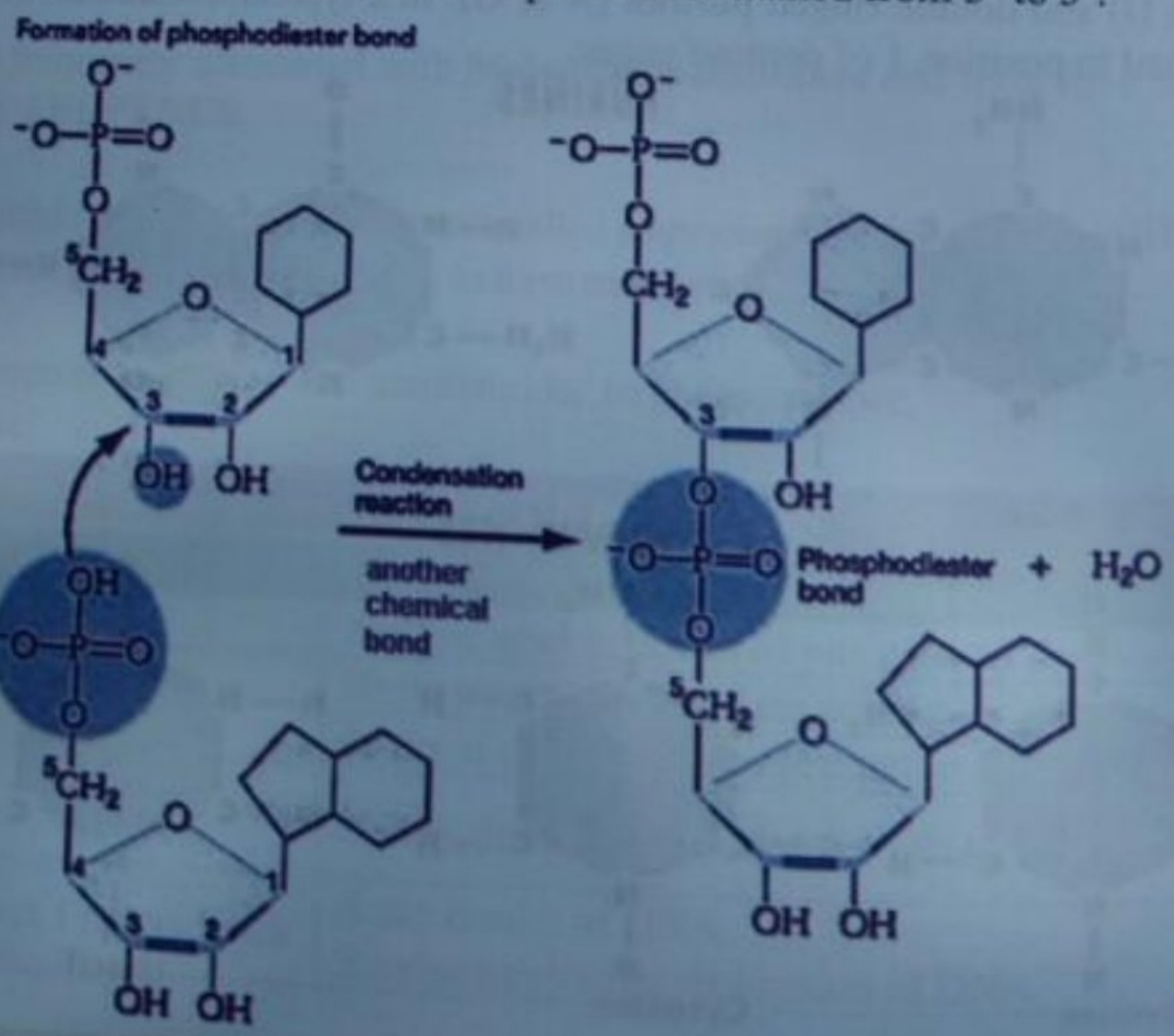
3. A phosphoric acid (H_3PO_4). It has ability to develop ester linkage with OH group of pentose sugar. It is attached to carbon at position 5 of pentose sugar. Phosphoric acid provides acidic properties to nucleic acid.

Formation of Nucleotide

- Base + Sugar → Nucleoside
- Nucleoside + Phosphoric acid → Nucleotide
- A nucleotide with one phosphoric acid is called nucleoside monophosphate, with two phosphoric acids is called nucleoside diphosphate and with three phosphoric acids is called nucleoside triphosphate.



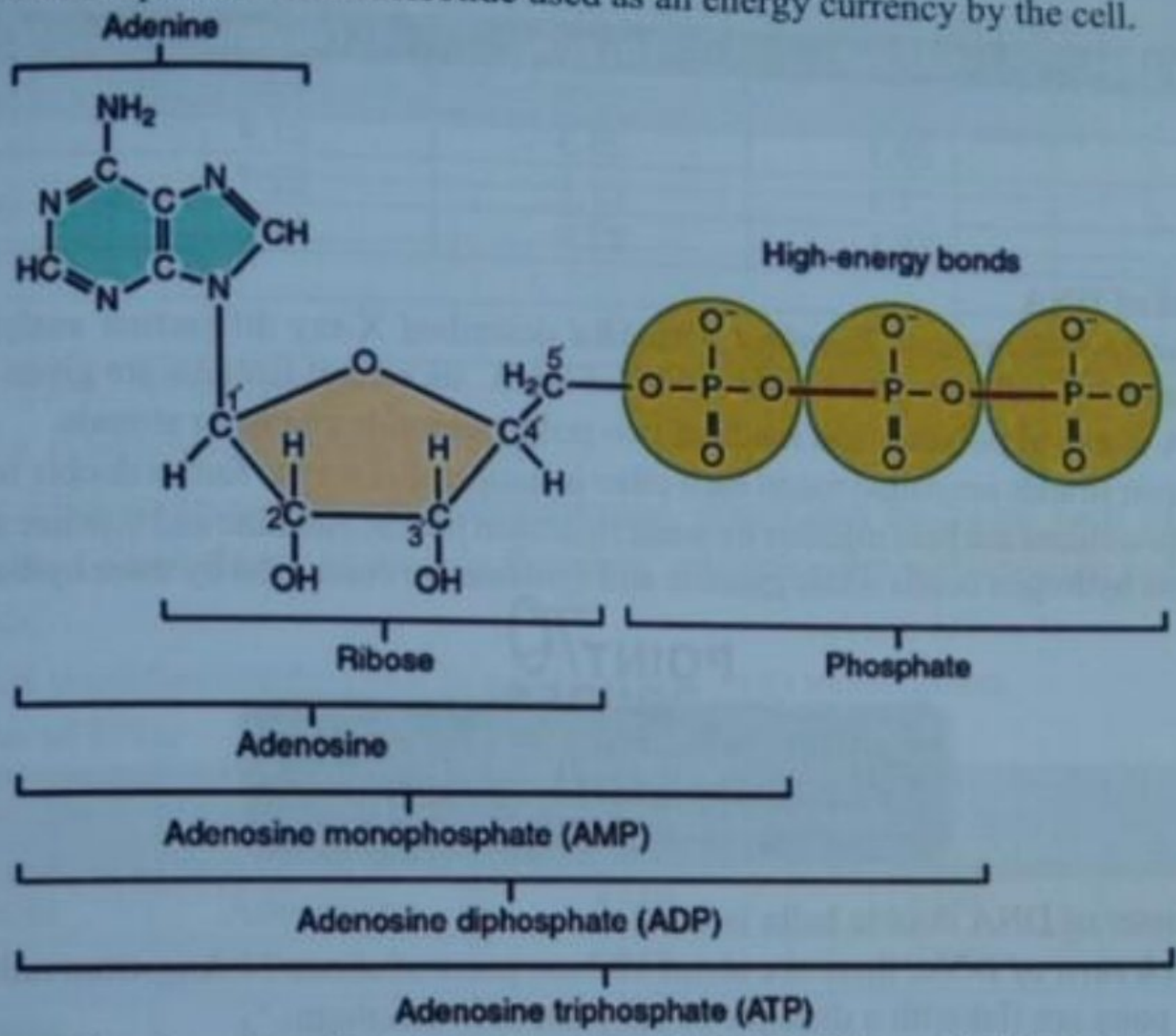
- 2 nucleotides in DNA or RNA are connected through condensation reaction by ***phosphodiester linkage.***
- Polynucleotides have a free 5' phosphate group at one end and a free 3' hydroxyl group at the other end. By convention, these sequences are named from 5' to 3'.



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Important Examples of Nucleotides

- *ATP* is an imported mononucleotide used as an energy currency by the cell.



- NAD (Nicotinamide Adenine Dinucleotide), NADP and FAD (Flavin Adenine Dinucleotide) are important dinucleotides and important co-enzyme in several oxidation-reduction reactions in the cell.

POINT TO PONDER

Do you know which vitamin is involved in formation of NAD?

DEOXYRIBONUCLEIC ACIDS (DNA)

- DNA is heredity material. It controls the properties and potential activities of a cell.

Nucleotide of DNA

Nitrogenous Base	Nucleoside (Deoxyribose + Base)	Nucleotides (Nucleoside + Phosphoric Acid)		
Adenine	d-Adenosine	dAMP	dADP	dATP
Guanine	d-Guanosine	dGMP	dGDP	dGTP
Cytosine	d-Cytidine	dCMP	dCDP	dCTP
Thymine	d-Thymidine	dTMP	dTDP	dTTP

Relative Amounts of Bases in DNA

- In 1951, ***Erwin Chargaff*** provided data about the ratios of different bases present in a DNA molecule.

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- This data suggested that adenine and thymine are equal in ratio and so are guanine & cytosine.
- Similarly total purines and total pyrimidines are in 1:1 in any DNA molecule.

Source of DNA	Adenine	Thymine	Guanine	Cytosine
Man	30.9	29.4	19.9	19.8
Sheep	29.3	28.3	21.4	21.0
Wheat	27.3	27.1	22.7	22.8
Yeast	31.3	32.9	18.7	17.1

Scale Model of DNA

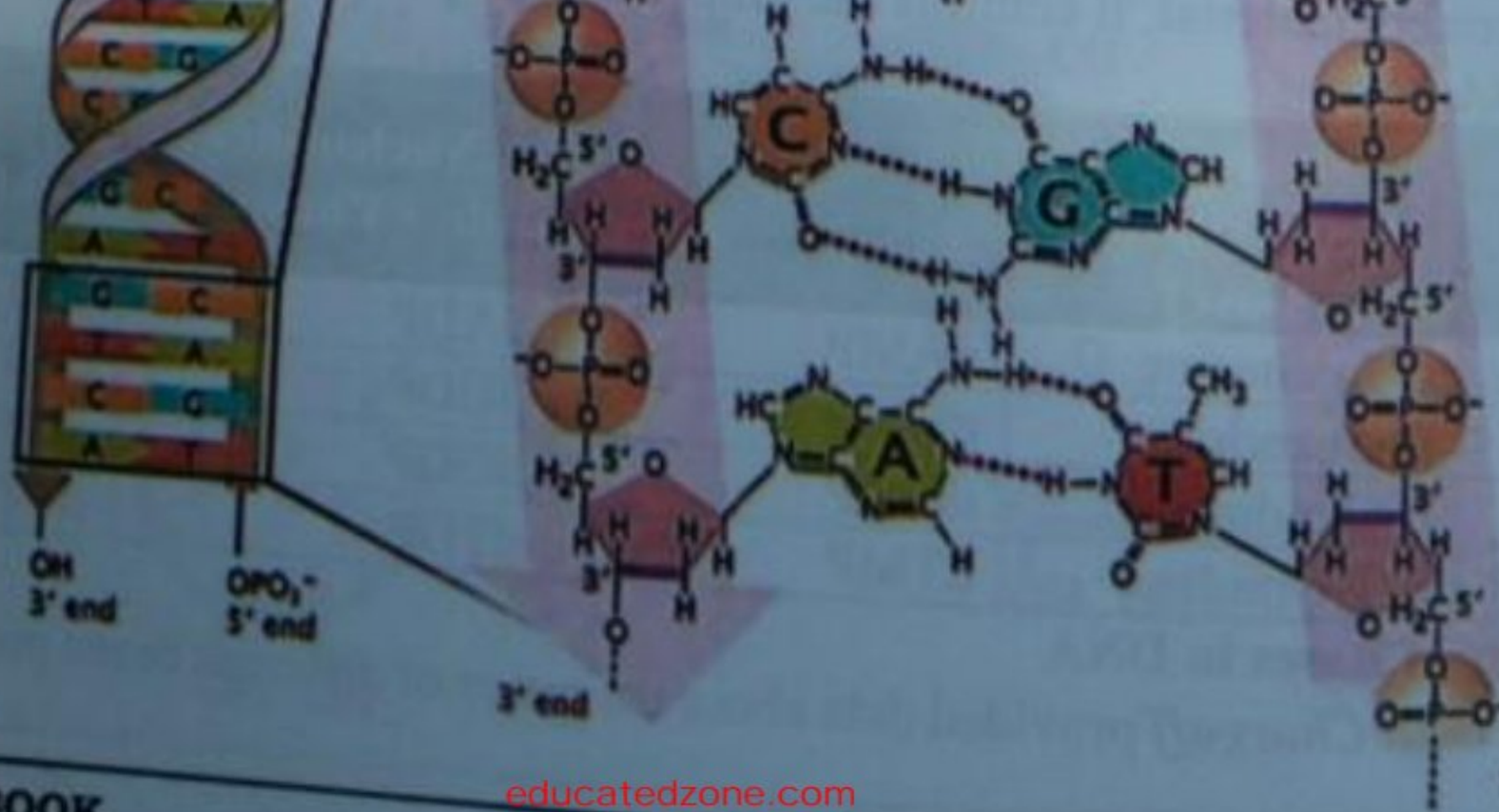
Maurice Wilkins and Rosalind Franklin described X-ray diffraction analysis of DNA. Watson & Crick presented scale model of DNA. Its salient features are given below:

- DNA is a dual polymer and made of two polynucleotide chains or strands.
- The two strands are coiled round each other in antiparallel way to form a double helix (duplex).
- The two chains are held together by weak hydrogen bonds. Adenine and thymine are connected by two hydrogen bonds while guanine and cytosine are connected by three hydrogen bonds.

POINT TO PONDER

Which elements participate in formation of hydrogen bonds in DNA?

- Diameter of DNA double helix is 2nm.
- In ***each turn of DNA***, there are about 10 base pairs of about 34 Angstrom units.
- Base pairs are flat with a distance of 0.34 nm between them.



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Amount of DNA in Somatic and Germ Cells

Type of Cell	Amount of DNA/Nucleus in Picogram in Chicken	Amount of DNA/Nucleus in Picogram in Carp
Red Blood Cells	2.3	3.3
Liver Cells	2.4	3.3
Kidney Cells	2.4	3.3
Sperm Cells	1.3	1.6

RIBONUCLEIC ACID (RNA)

- RNA is polymer of ribonucleotides.
- The RNA molecule occurs as single strand, which may be folded back on itself to give double helical characteristics. In this case, cytosine pairs with guanine and adenine with uracil.
- RNA is synthesized by DNA in a process known as transcription.

Nucleotides of RNA

Nitrogenous Base	Nucleoside (Ribose + Base)	Nucleotides (Nucleoside + Phosphoric Acid)		
Adenine	Adenosine	AMP	ADP	ATP
Guanine	Guanosine	GMP	GDP	GTP
Cytosine	Cytidine	CMP	CDP	CTP
Uracil	Uridine	UMP	UDP	UTP

Types of RNA

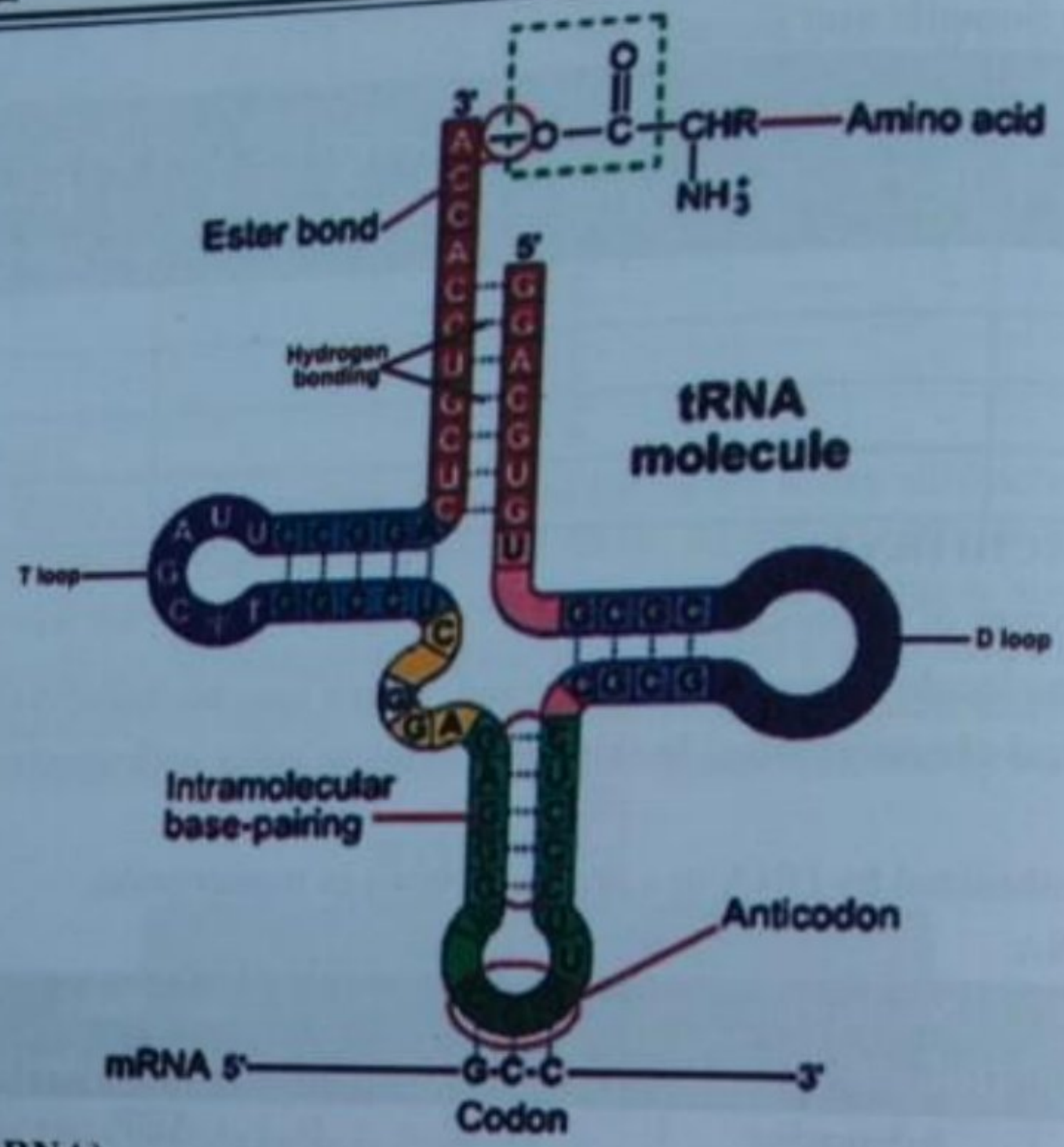
Messenger RNA (mRNA)

- It takes the genetic message from the nucleus to ribosome in the cytoplasm, where amino acids are arranged to form a specific protein molecule.
- It consists of a single strand of variable length.
- Its length depends upon the size of the gene as well as the protein for which it is taking the message. For example, for a molecule of 1000 amino acids, mRNA will have the length of 3000 nucleotides.
- Actually every three nucleotides in mRNA encode a specific amino acid, such triplets of nucleotides along the length of mRNA are called codons of genetic codes.

Transfer RNA (tRNA)

- It is smallest in size.
- It is a single stranded molecule but it shows a duplex appearance at its some regions.
- It transfers amino acid molecules to the site where peptide chains are being synthesized.
- There is one specific tRNA for each amino acid. So, there are at least 20 kinds of tRNA molecules. tRNA picks amino acids and transfers them to ribosomes.
- Human cells contain about 45 different kinds of tRNA molecules.

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Ribosomal RNA (rRNA)

- It is the major portion of RNA in the cell.
- It is transcribed by the genes present on the DNA of several chromosomes.
- These have the largest size among the RNA.
- It acts as a machinery for the synthesis of proteins.
- It is strongly associated with the ribosomal proteins where 40 – 50 % of it is present.

Feature	mRNA	tRNA	rRNA
Function	Takes message from DNA to ribosomes	Transfers amino acids to ribosomes	Formation of ribosomes
Length	Single strand of variable length	Length of 75-90 nucleotides	Double helix with constant length
Percentage	3-4%	10-20%	80%

DIFFERENCE BETWEEN DNA AND RNA

Feature	DNA	RNA
Nucleotides	Deoxyribonucleotides	Ribonucleotides
Pentose Sugar	Deoxyribose	Ribose
Nitrogenous Bases	A, G, C, T	A, G, C, U
Physical Structure	Double stranded	Single stranded
Location	Chromosome, nuclei, mitochondria and chloroplasts	Nucleolus, ribosomes, cytosol, mitochondria, chloroplast
Amount	Constant in each cell of species	Variable from cell to cell
Role	Heredity	Protein synthesis

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6. ENZYMES

ENZYME – COMPOSITION & CHARACTERISTICS

Enzymes are biological molecules (proteins) which catalyze a biochemical reaction and remain unchanged after completion of reaction. Enzymes are organic catalyst. Without enzymes reactions are possible but they would proceed at very low speed.

Composition

- Enzymes are globular proteins made of one or more polypeptide chains having tertiary conformation.
- This protein part is made up of hundreds of amino acids. These enzymes have tertiary or quaternary structure.
- Most of the amino acids maintain its globular shape while few are involved in catalysis.
- Active site is a charge bearing cavity of enzyme having two regions i.e. binding site and catalytic site. Shape of the active site is designed according to the substrate.
- Binding site is involved in recognition and binding of substrate with enzyme.
- Catalytic site is involved in transformation of enzyme-substrate complex into enzyme and product.

Cofactor

- Non-protein part of enzyme that is required for its proper functioning is called ***co-factor***.
- Cofactor acts as bridge between enzyme and substrate. It also acts as source of chemical energy for catalysis.
- Such an inorganic cofactor that is detachable is called activator e.g. metal ions like Fe^{++}, Mg^{++}, Cu^{++}, Zn^{++} etc.
- If a cofactor organic and is loosely attached to the protein part, it known as ***coenzyme***. Coenzymes are the derivatives of vitamins. For example, ATP, NAD^{+} and FAD^{+} are common coenzymes.
- If a cofactor or non-protein part is covalently bound to the protein part, it is called a ***prosthetic group***. It is permanently attached to enzyme. For example, cytochrome is prosthetic group of cytochrome oxidase.
- An activated enzyme consisting of polypeptide chain and a cofactor is known as ***holoenzyme***.
- An enzyme with its coenzyme or prosthetic group has been removed is called ***apoenzyme***.

Characteristics

- Enzymes are biological molecules (proteins) which catalyze a biochemical reaction and remain unchanged after completion of reaction.
- All enzymes are globular proteins, having specific chemical composition due to their component amino acids and specific shape.
- Even small amount of them can tremendously increase the efficacy of a biochemical reaction.
- They are specific for each type of a reaction or group of related reactions.
- Their presence does not affect the nature or properties of end products.
- They lower the activation energy of the reactants.

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- They are sensitive to even a minor change in pH, temperature and substrate concentration.
- They require aqueous media for their activity.
- Some may require co- factor for their proper functioning.
- Some enzymes are potentially damaging, if they are manufactured in their active form.

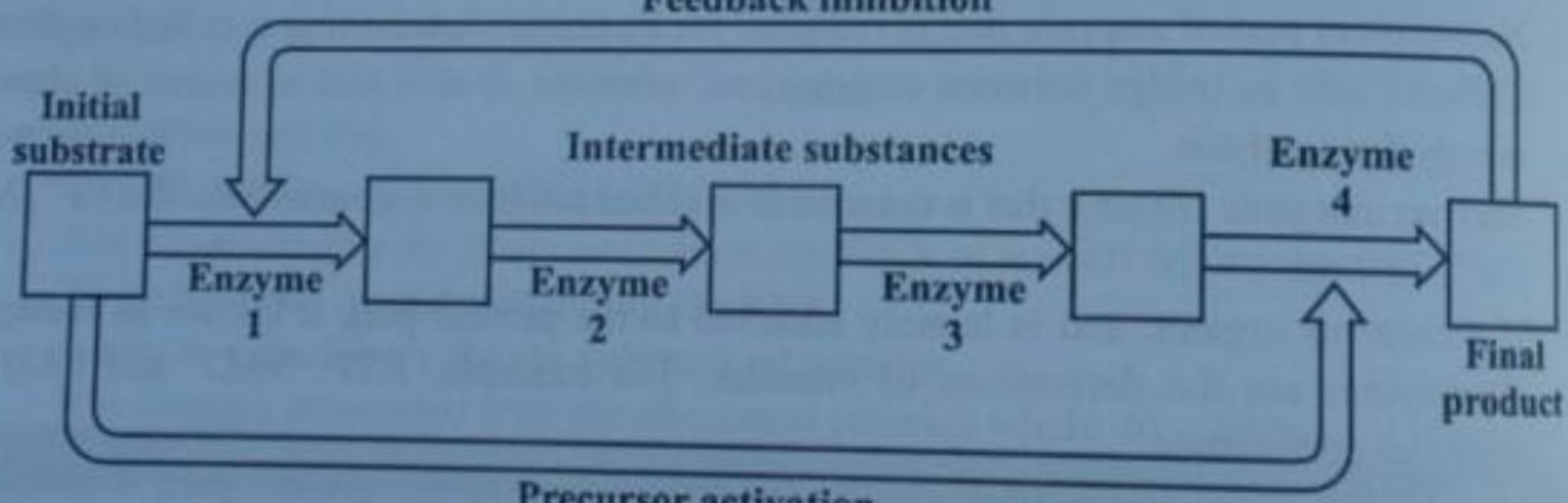
MECHANISM OF ENZYME ACTION

Mechanism

- $E+S \rightleftharpoons ES\ Complex \rightleftharpoons EP\ Complex \rightleftharpoons E+P$
- The active site of an enzyme is a three-dimensional cavity bearing a specific charge by which the enzyme reacts with its substrate.
- The active site is made of two definite regions i.e. binding site & a catalytic site.
- Binding site helps the enzyme in the recognition and binding of the proper substrate to produce an ES complex.
- Activated catalytic site catalyzes the transformation of the substrate into product (s).
- Formation of ES complex activates the catalytic site.

Precursor Activation & Feedback Inhibition

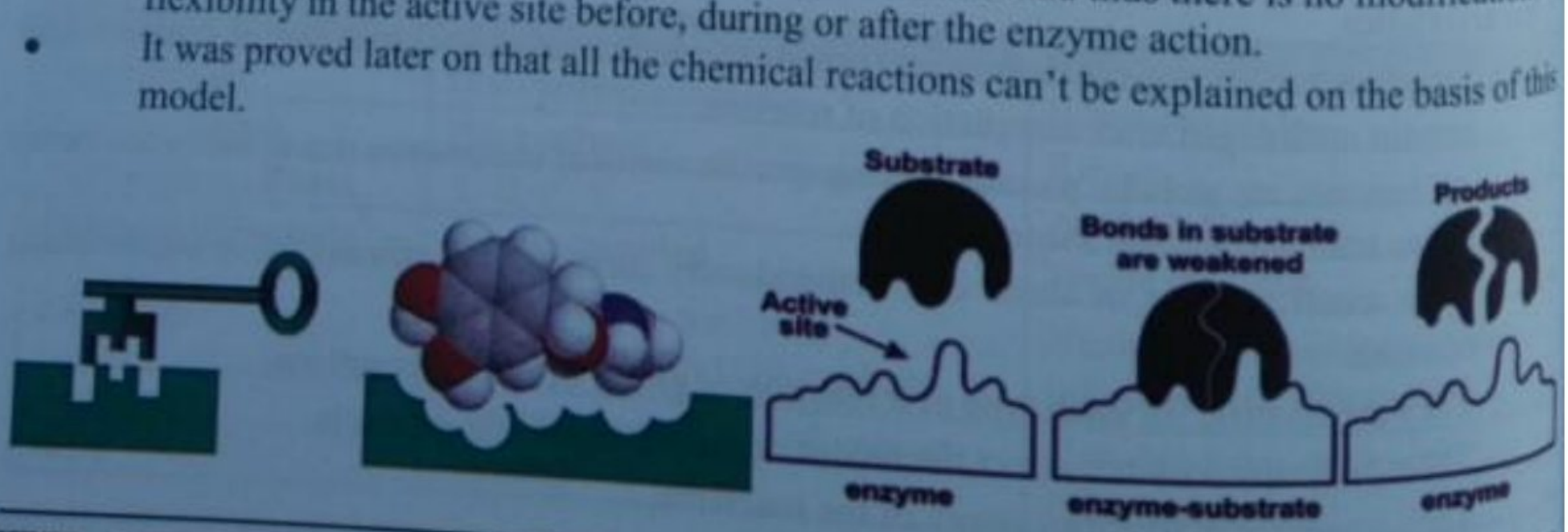
- Increase in concentration of substrate can cause increase in rate of reaction. This activation is called precursor activation.
- Similarly, activity of enzymes in a cell can be regulated by its products. When the activity of an enzyme is inhibited by its own product, it is called feedback inhibition or end product inhibition.



Models

Lock & Key Model

- Emil Fischer (1890) proposed Lock and Key model.
- As one specific key can open a specific lock, in the same manner a specific enzyme can transform a specific substrate into product (s).
- According to this model active site is a rigid structure and thus there is no modification or flexibility in the active site before, during or after the enzyme action.
- It was proved later on that all the chemical reactions can't be explained on the basis of this model.



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Induce Fit Model

- Koshland (1959) proposed Induce Fit Model.
- It is the modified form of Lock and Key model.
- It states that when a substrate combines with an enzyme, it induces changes in the enzyme structure. This change in the structure allows enzyme to carry out its catalytic activity more effectively.
- Enzymes which follow induce fit mechanism are called ***regulatory*** or ***allosteric enzymes***.

FACTORS AFFECTING ENZYME ACTION

Enzyme Concentration

- Rate of reaction is directly proportional to amount of enzyme present, which in turn determines the number of available active sites for that particular catalytic reaction.
- If substrate concentration is unlimited and amount of an enzyme is increased by two-fold the reaction rate will be doubled.
- However, after a certain limiting concentration, the rate of the reaction will no longer depend upon this increase.

Substrate Concentration

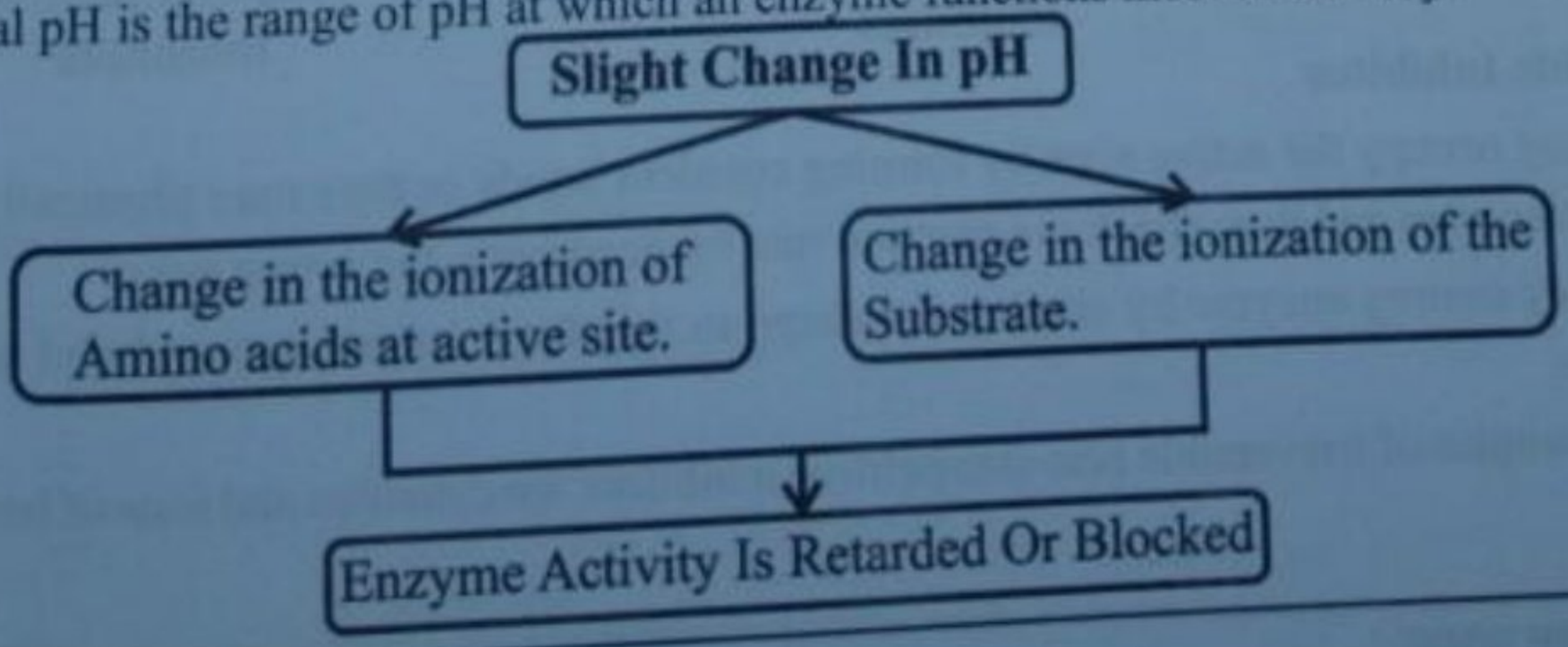
- The rate of an enzyme-controlled reaction is directly proportional to the substrate concentration provided that active sites on the enzyme are available.
- At higher concentration of enzyme, increase in substrate concentration increases reaction velocity. Reaction reaches to maximum at equilibrium state.
- When all active sites are occupied by substrate and no more available, this state is called state of saturation.

Temperature

- Heating increases molecular motions. Thus, the molecules of substrate and enzyme move more quickly, so probability of reactions to occur is increased.
- Heat provides activation energy and kinetic energy.
- The rate of an enzyme-controlled reaction increases with an increase in temperature upto certain limits. Increase of 10°C in temperature doubles the rate of reaction.
- Optimum temperature is the temperature at which an enzyme works at its maximum rate e.g., for enzymes of our body 37°C is the optimum temperature.
- Increase in temperature above optimum value increases the vibrations of atoms in enzyme. If vibrations become too violent, globular structure essential for enzyme activity is lost and the enzyme is said to be denatured.
- If temperature is reduced to near or below freezing point, enzymes are inactivated.

pH Value

- Optimal pH is the range of pH at which an enzyme functions most effectively.

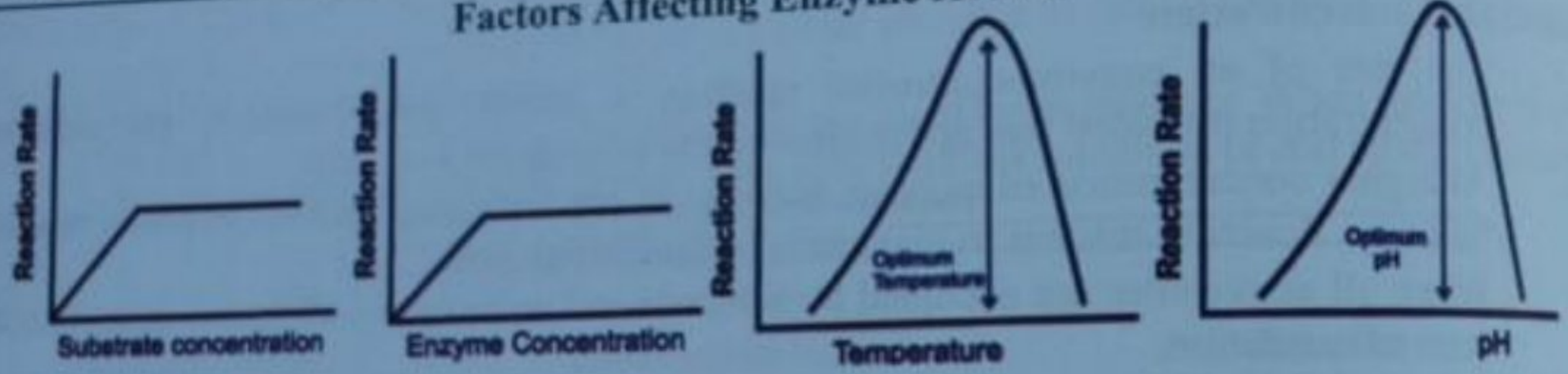


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- Extreme changes in pH cause the bonds in the enzyme to break, resulting in the enzyme denaturation.

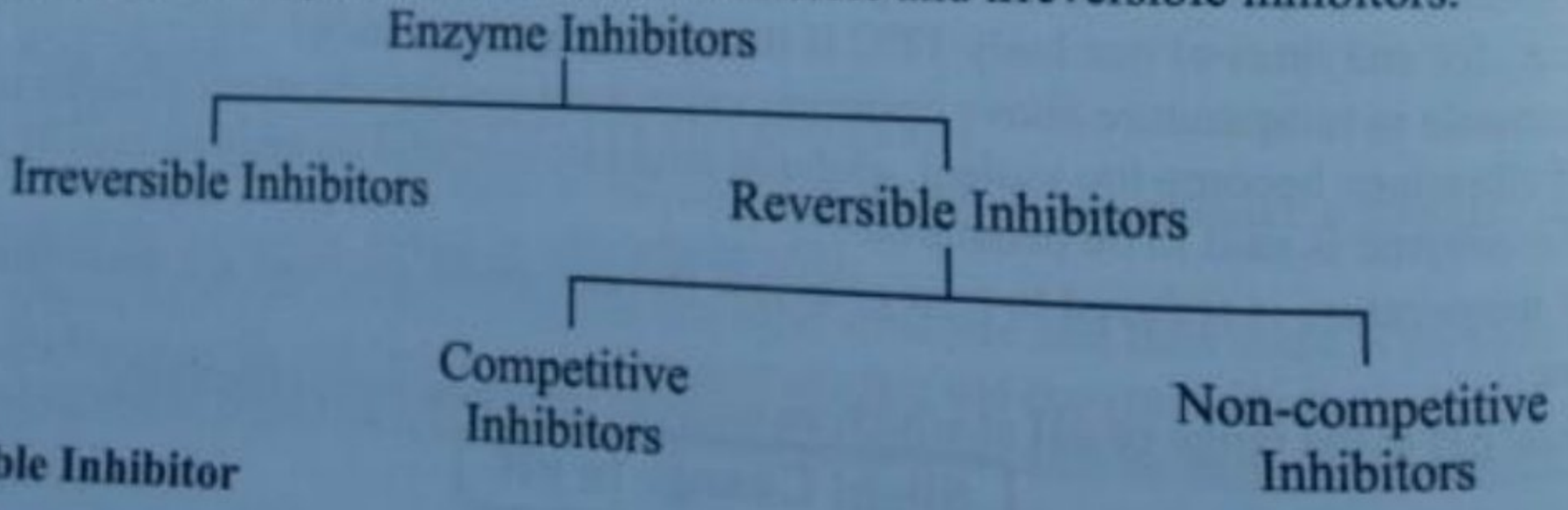
Enzyme	Function	pH Value
Pepsin	Digestion of proteins	2.00
Sucrase	Hydrolysis of sucrose	4.50
Enterokinase	Activation of trypsinogen	5.50
Salivary Amylase	Digestion of carbohydrate	6.80
Catalase	Decomposition of hydrogen peroxide	7.60
Chymotrypsin	Involved in proteolysis	7.00-8.00
Pancreatic lipase	Hydrolysis of fats	9.00
Arginase	Catalysis of arginine into urea	9.70

Factors Affecting Enzyme Action



INHIBITORS

- An inhibitor is a chemical substance which can react (in place of substrate) with the enzyme but is not transformed into product/s and thus blocks the active site temporarily or permanently.
- Examples include cyanide, antibiotics, anti-metabolites and some drugs.
- They are of two types of inhibitors i.e. reversible and irreversible inhibitors.



Irreversible Inhibitor

- They occupy the active sites by forming covalent bonds or they may physically block the active sites and they check the reaction rate by occupying the active sites.
- They destroy enzyme by altering the shape so that the substrate cannot bond to the active site.
- Examples of irreversible non-competitive inhibitors are cyanides and ions of heavy metals.

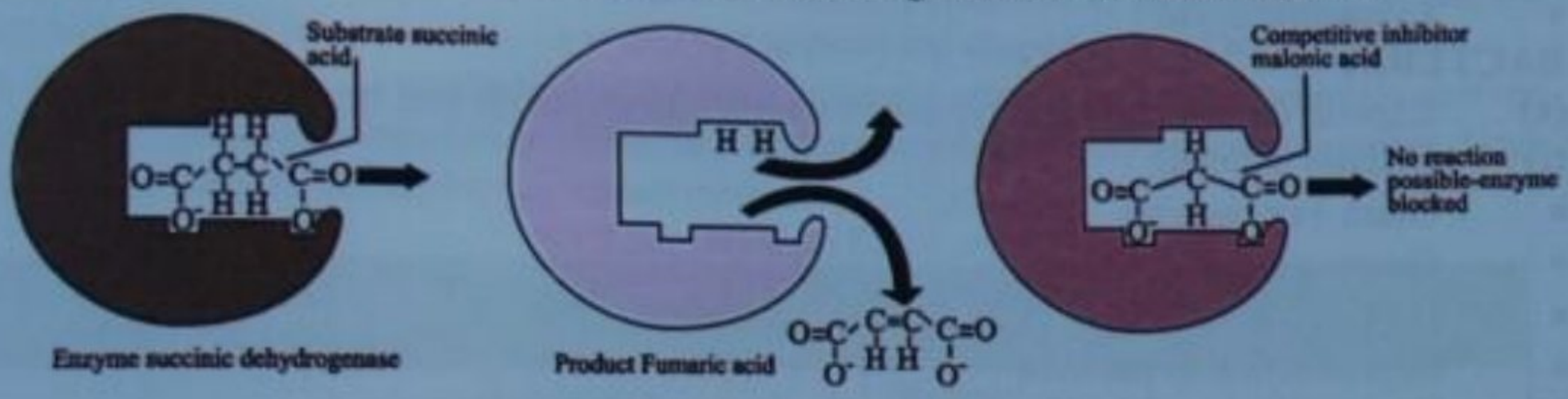
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Reversible Inhibitors

- They form weak linkages with the enzyme.
- Their effect can be neutralized, completely or partly by increase in the concentration of the substrate.
- There are two types of reversible inhibitors i.e. competitive and non-competitive.

Competitive Inhibitors

- Competitive inhibitors are structurally similar to the substrate, hence can bind to the active site but can't activate the catalytic site, thus no products are formed.
- Competitive inhibition is usually temporary.
- Level of inhibition depends upon relative concentrations of substrate and inhibitor.
- This type of inhibition can be reversed by increasing concentration of substrate.



Non-Competitive Inhibitor

- Non- competitive inhibitors bind with the enzyme at the site other than active site. The other binding site of enzyme is called allosteric site.
- Structure of enzyme is altered so that even if a genuine substrate binds the active site, catalysis fails to take place.
- Feedback inhibition is an example of reversible non-competitive inhibition.

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TOPIC-3
05 MCQs

MICROBIOLOGY

LEARNING OUTCOMES

VIRUSES

(a) Have the knowledge of discovery and structure of Viruses.

(b) Discuss viral diseases (hepatitis, measles and mumps, polio, herpes) in humans with signs, symptoms and cure.

(c) Explain the mechanism of action of Retroviruses and describe Acquired Immunodeficiency Syndrome (AIDS).

(d) Describe the life cycle of Bacteriophage including:

- Lytic cycle
- Lysogenic cycle

BACTERIA

(e) Explain the structure and types of bacteria (cocci, bacilli and spiral).

(f) Discuss in detail:

- Gram +ve bacteria
- Gram –ve bacteria
- Nutrition in bacteria
- Reproduction in bacteria

(g) Discuss the control of bacteria by physical and chemical methods.

FUNGI

(h) Define fungi.

(i) Describe the life cycle of fungus (*Rhizopus*).

(j) Discuss useful and harmful fungi to mankind.

(k) Describe the structure and reproduction in fungi.

VIRUSES

- The word "Virus" was generally referred to as a poison associated with disease and death.
- The word "virus" is derived from Latin word ***venome*** meaning poisonous fluid.
- Viruses can be defined as "non-cellular infectious entities which contain either RNA or DNA normally encased in proteinaceous coat"
- They reproduce only in living cells, so are always obligate intracellular parasites.
- ***Prions*** are infectious particles made only of proteins and cause mysterious brain infection in man and mad cow infection in cow (without RNA and DNA)
- ***Viroids*** are small particles of RNA and lack protein coat. The cause diseases in both plants and animals.

DISCOVERY OF VIRUSES

Scientist	Year	Achievement
Edward Jenner	1796	1st vaccine against small pox (viral disease)
Charles Chamberland	1884	Filterable nature of rabies viruses
Ivanowski	1892	Filterable nature of TMV
W.M.Stanley	1935	Isolation, purification and crystallization of TMV
Twort & D'Herelle	1915, 1917	Discovery of bacteriophages

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STRUCTURE OF VIRUSES

- A complete, mature and infectious particle is known as ***virion.***
- Primarily, it can be divided into two parts i.e. core and coat.

Central Core

- The core is inner part of virion which consists of viral genome and various proteins (enzymes).
- Genome is the genetic material which is either DNA or RNA.

Outer Coat

- The coat is the outer covering of viral particle which consists of capsid and envelope.
- ***Capsid*** is made up of protein subunits known as ***capsomeres.*** The number of capsomeres is specific to a particular kind of virus.
- 162 capsomeres are present in capsid of herpes virus and 252 in the capsid of adenovirus.
- There are two forms of symmetry in virus capsid i.e. ***cubical or helical***. When the capsomeres are arranged in 20 triangles, it is called icosahedral (polyhedral or spherical). When the capsomeres are arranged in a hollow coil that appears rod shaped, it is called helical.
- A few viruses have an additional lipoprotein envelope around the capsid which is derived from the cell surface membrane of the host and also contain virally encoded proteins. Non-enveloped viruses are known as ***naked viruses.***

VIRAL DISEASES

Disease	Virus	Source of Transmission	Symptoms	Immunization
Herpes Simplex (Oral herpes)	Herpes simplex type 1 virus (DNA enveloped virus)	Oral secretions or physical contact with sores or by objects (Toothbrushes, utensils)	Blisters/ Vascular lesions in epithelial layers of ectodermal tissue. Most commonly in mouth, lips, and at other skin sites.	Antiviral drugs/ Avoid contact
Measles	RNA enveloped virus (Paramyxovirus)	Coughing & Sneezing	Fever, runny nose, cough, red eyes, red flat rashes on skin	Auto-immunity, Vaccination
Mumps	RNA enveloped virus (Paramyxovirus)	Coughing & sneezing	Fever, muscle pain, headache, painful swelling of parotid glands,	Auto-immunity, Vaccination
Poliomyelitis	Polio virus/ Enterovirus	Oro-fecal route	Damage to motor neurons	Vaccination / Physiotherapy

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	(RNA non-enveloped virus, in spherical capsid). Smallest known virus		of spinal cord & leading to paralysis of limbs	
Hepatitis A (Infectious)	Picornavirus (RNA non-enveloped virus)	Oro-fecal route	Acute infection (nausea, vomiting, diarrhea, jaundice, fever, anorexia)	Vaccination/ Good hygiene
Hepatitis B (Serum)	Hepa-DNA-viruses (DNA enveloped virus)	Blood, Sexual contact, Mother to new born	Acute (vomiting, yellowish skin, tiredness, dark urine, abdominal pain) & chronic (liver cirrhosis & liver cancer)	Vaccination/ Alpha interferons/ Screening of blood
Hepatitis C (Infusion)	Flavivirus (RNA enveloped virus)	Blood	Chronic (ocassionally fever, dark urine, abdominal pain, yellow skin) with cirrhosis & liver cancer.	No Vaccination/ Alpha interferon & Ribavirin/ Screening of blood
Hepatitis D	Viroid	Blood or serum	Same as hepatitis B	Same as hepatitis B
Hepatitis E	RNA non-enveloped virus	Oro-fecal route	Acute infection (Nausea, vomiting, diarrhea, jaundice)	Good hygiene
AIDS	RNA enveloped virus (HIV)	Blood/ Sexual contact	Opportunistic infections, Swollen lymph nodes	Vaccination NOT available

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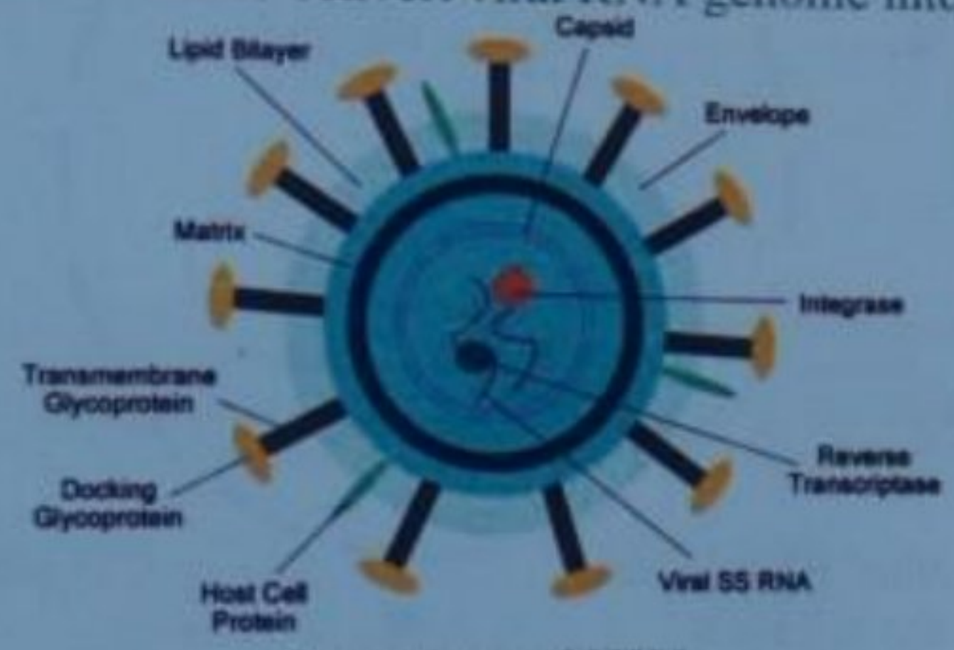
RETROVIRUSES AND AIDS

RETROVIRUS

- Retroviruses are associated with tumor production in animals like fowl, rodents and cats.
- They are ***spherical***, ***100nm*** in diameter, ***enveloped*** by host plasma membrane, contains single stranded RNA.
- Human immunodeficiency virus ***(HIV)*** which causes acquired immunodeficiency syndrome (AIDS) is a retrovirus.
- May be ***non- specific*** in their action but usually infect those cells containing specific receptors.
- ***Reverse transcriptase*** is a special enzyme which can convert single stranded RNA genome into double stranded viral DNA, which not only infect the host cell but also incorporate into host genome as a provirus that can pass on to progeny cells. In this way normal cells become cancer cells.

HUMAN IMMUNODEFICIENCY VIRUS (HIV)

- It is an RNA enveloped virus.
- HIV is spherical with conical capsid.
- The outer covering is a lipoprotein envelope.
- The viral core contains two single strands of RNA and enzymes needed for HIV replication, such as reverse transcriptase.
- Reverse transcriptase is used to convert viral RNA genome into viral DNA genome.



Structure of HIV

Host Specificity

- Primary hosts of HIV are helper T lymphocytes (CD4 cells).
- In addition, macrophages and certain brain cells may also be affected.

Mode of Transmission

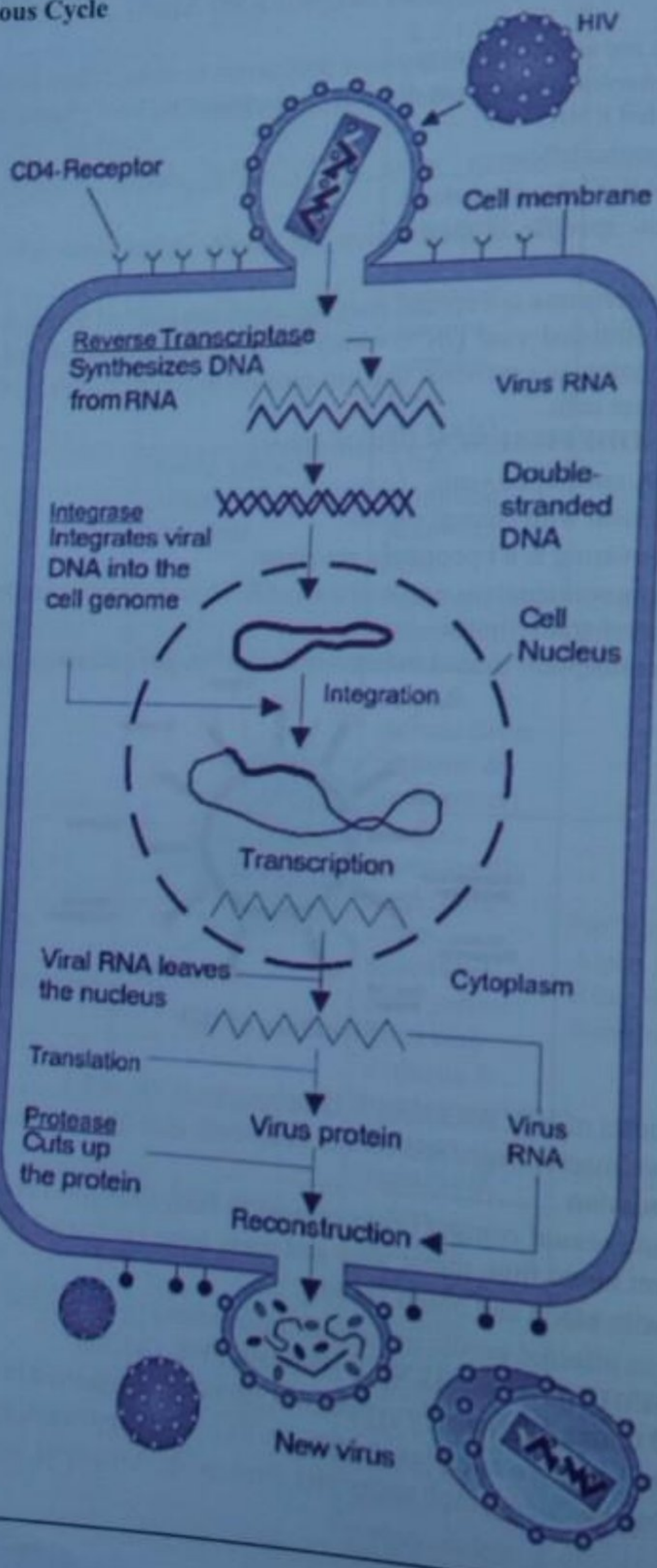
- By intimate ***sexual contact*** (virus present in body secretions and blood, which gets entry in recipient blood from minor wear and tears, more common in homosexuals).
- Contact with blood and breast feeding.
- ***Prick*** of an infected needle or surgical instruments (problem for health care providers).

ACQUIRED IMMUNODEFICIENCY SYNDROME (AIDS)

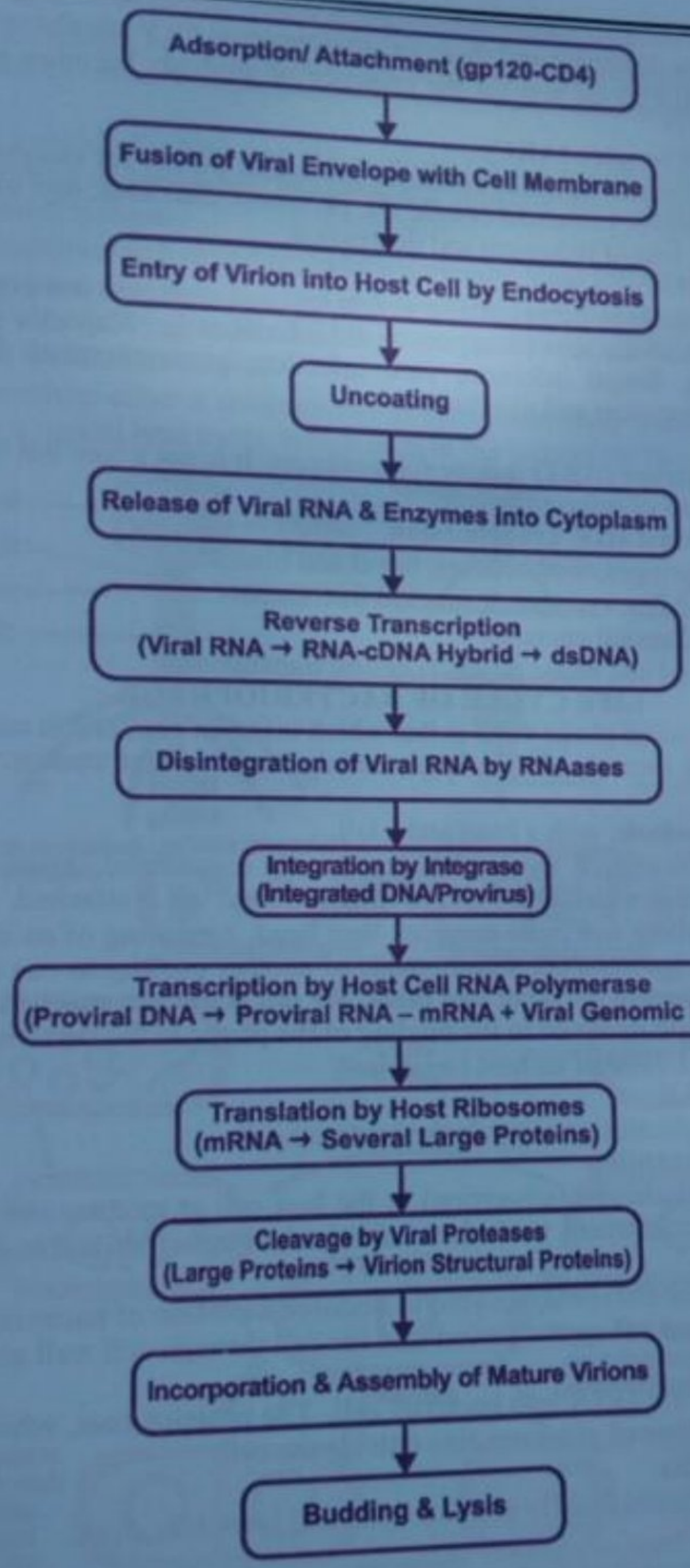
Acquired immunodeficiency syndrome (AIDS) ***first reported*** in young homosexual males, having one or more complex symptoms like severe pneumonia, vascular cancer, sudden weight loss, swollen lymph nodes and immune deficiency or decreased immune functions.

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Life Cycle/ Infectious Cycle



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Symptoms of AIDS

An HIV infection can be divided into 3 stages:

(i) **Asymptomatic Carrier**

- Fever, chills, aches (continued pain), swollen lymph glands and itchy rashes.

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- These symptoms disappear and there are no symptoms for 9 months or longer.
- The standard HIV blood test for the presence of antibody becomes positive during this stage.

(ii) AIDS Related Complex (ARC)

- Swollen lymph glands in neck, armpit or groin that persist for months. Other symptoms include night sweats, persistent cough, flu, persistent diarrhoea, loss of memory, inability to think clearly, loss of judgment and depression.

(iii) Full Blown AIDS

- It is the final stage. In it there is severe weight loss and weakness due to persistent diarrhoea and usually one of the several opportunistic infections i.e. Kaposi's sarcoma (cancer lesion on skin), fungal infection, viral infection, gastrointestinal disease, respiratory disease, nervous system and eye diseases).

Treatment of AIDS

Antiretroviral therapy (ART) is done for treatment. It is not a cure but it controls virus and increases life span of infected people.

Control Measures Against HIV Transmission

- Avoid sharing syringes, toothbrushes, towel and blades.
- Use of sterile needles, syringes & surgical instruments.
- Avoid prohibited sexual contacts.
- Screening of blood and blood products before transfusion.

LIFE CYCLE OF BACTERIOPHAGE

So far the best studied phage virus is that which infect *E. coli*, and is called T phage (T for type), and among them T_2 and T_4 phages mainly used in phage studies.

STRUCTURE OF T4

- *T_4* resembles a ***tadpole***, with a head and a tail.
- Its ***head*** is an elongated pyramidal, hexagonal, icosahedral, prism shaped structure containing double stranded DNA and to which straight tail is attached.
- ***Phage Tail*** is hollow and more complex than head, consisting of an inner proteinaceous core, enclosed in a contractile sheath, made of another protein, to one end of which there is neck or ***collar*** and to the other ***end plate***. ***Six tail fibers*** are attached with the end/ base plate. Tail fibers are involved in the binding of the phage to the bacterial cell.
- Phage volume is ***1/1000*** of its host i.e., *E. coli.*

STEPS OF LIFE CYCLE

Bacteriophage replicates only inside the bacterial cell.

(1) Attachment/ Adsorption

First step is the attachment (adsorption) to the host cell at receptor site on the cell wall of bacterium. During attachment, weak chemical union between virion and receptor site takes place.

(2) Penetration

The tail releases the enzyme lysozyme to dissolve a portion of bacterial ***cell wall.*** The tail sheath contracts and tail core is forced into the cell through cell wall and cell membrane.

(3) Injection

It is injection of viral DNA into bacterial cell. The proteins coat, which forms the phage head and tail structure of virus remains outside the cell.

(4) Replication Process

Two types of cycles are usually seen i.e. lytic and lysogenic cycle.

Lytic Cycle

(1) Viral DNA takes control of the host's biosynthetic machinery.
(2) It induces the host cell to synthesize necessary viral components (DNA & Proteins) and starts multiplying.
(3) About 25 minutes after initial infection, approximately 200 new bacteriophages are formed
(4) Bacterial cell bursts i.e. it undergoes lysis.

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(5) Newly formed phages are released to infect the bacteria and another cycle begins.
(6) The phage which causes lysis of host cell is called lytic/ virulent phage.

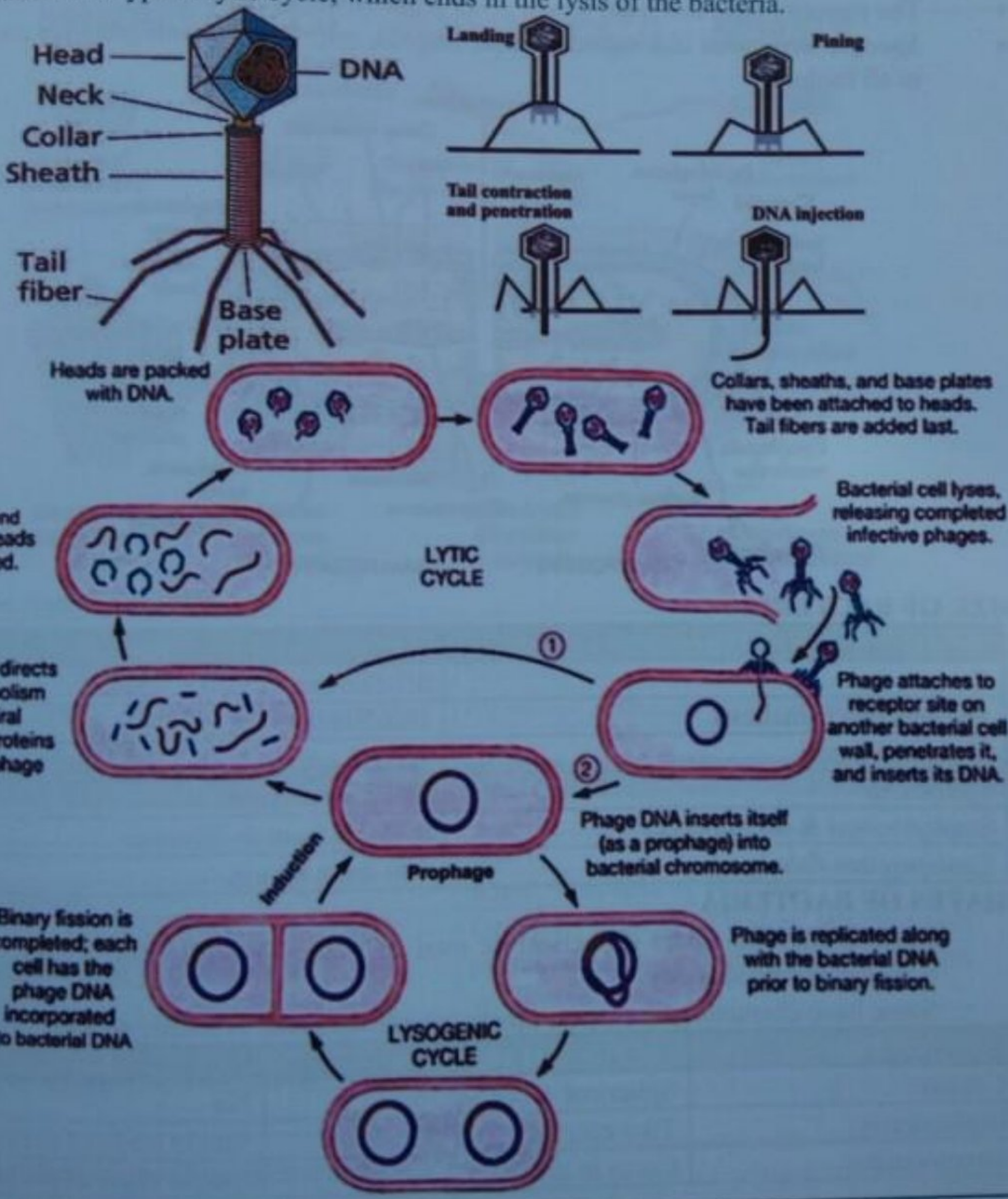
Lysogenic Cycle

(1) Viral DNA, instead of taking over the control of host's machinery, becomes incorporated into the bacterial chromosome. Phage in this dormant state is called prophage and this process is called lysogeny.

(2) Bacterium continues to live and reproduce normally. Viral DNA being the part of bacterial chromosome passes to each daughter cell in all successive generations.

(3) Sometimes, viral DNA gets detached from the host's chromosome and lytic cycle starts. This process is called induction.

(4) Induction involves either a ***spontaneous or environmentally induced***. This results in the initiation of a typical lytic cycle, which ends in the lysis of the bacteria.



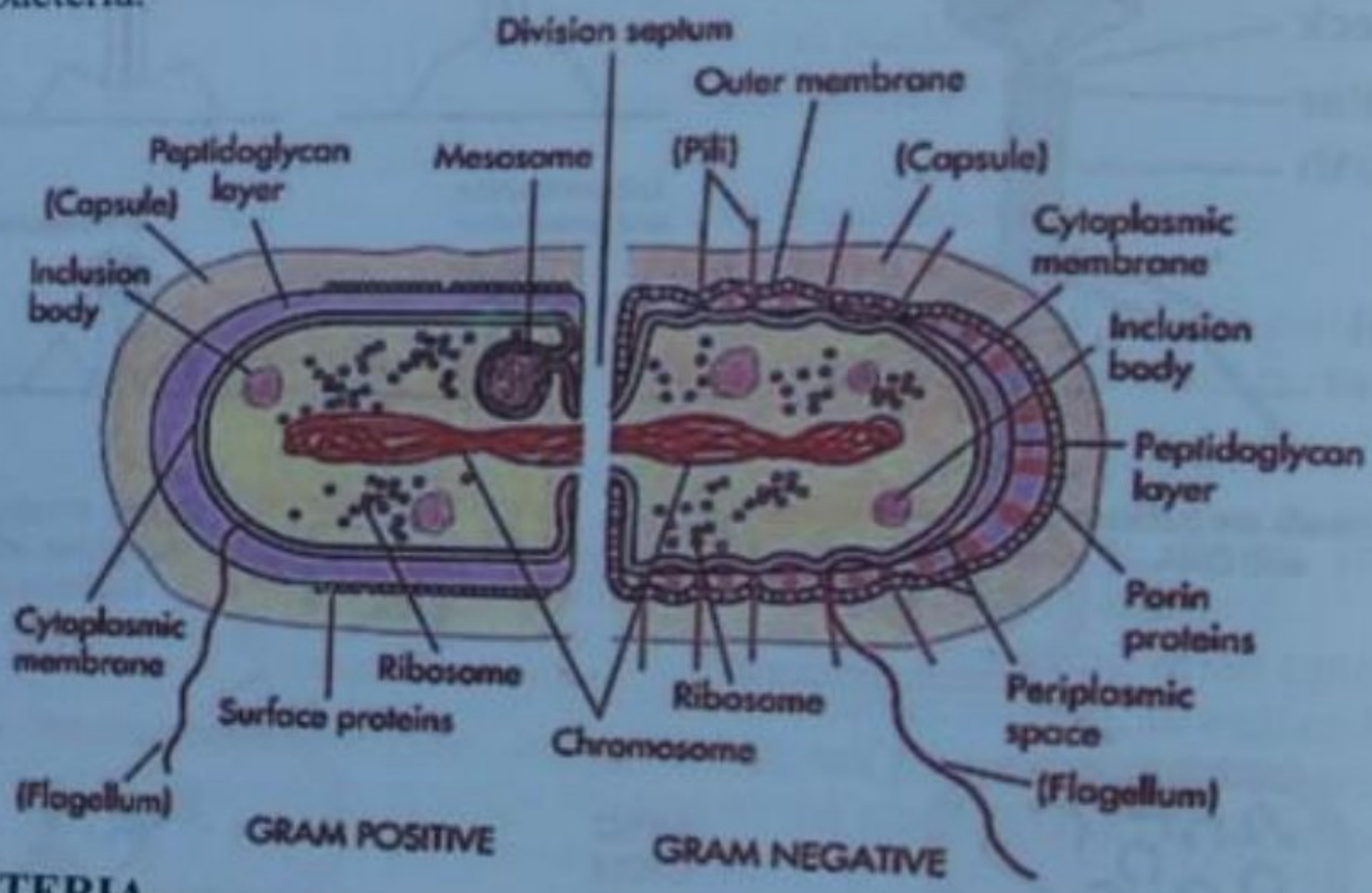
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Feature	Lytic Cycle	Lysogenic Cycle
Virus	Lytic or virulent phage	Lysogenic or temperate phage
Bacterium	Non-resistant	Resistant
Relationship	Master – Slave relation	Host – Guest relation
Effects	Infectious cycle	Non-infectious cycle
Viral DNA	Takes Control	Integrated
Bacterial DNA	Destroyed	Remains intact

BACTERIA

STRUCTURE & TYPES OF BACTERIA

- All bacterial cells invariably have a cell membrane, cytoplasm, ribosomes and chromatin bodies.
- The majority have ***cell wall***, which gives shape to the bacterial cell.
- ***Specific structures*** like capsule, slime, flagella, pili, fimbriae and granules are not found in all bacteria.



SIZE OF BACTERIA

Type	Size
Range	0.1-600 µm
Mycoplasma (Smallest)	100-200 nm
Escherichia coli	1.1-1.5 µm (width), 2.0-6.0 µm (length)
Spirochete	500 µm in length
Staphylococci & Streptococci	0.75-1.25 µm in diameter
Epulopiscium fishelsoni	600 µm x 80 µm

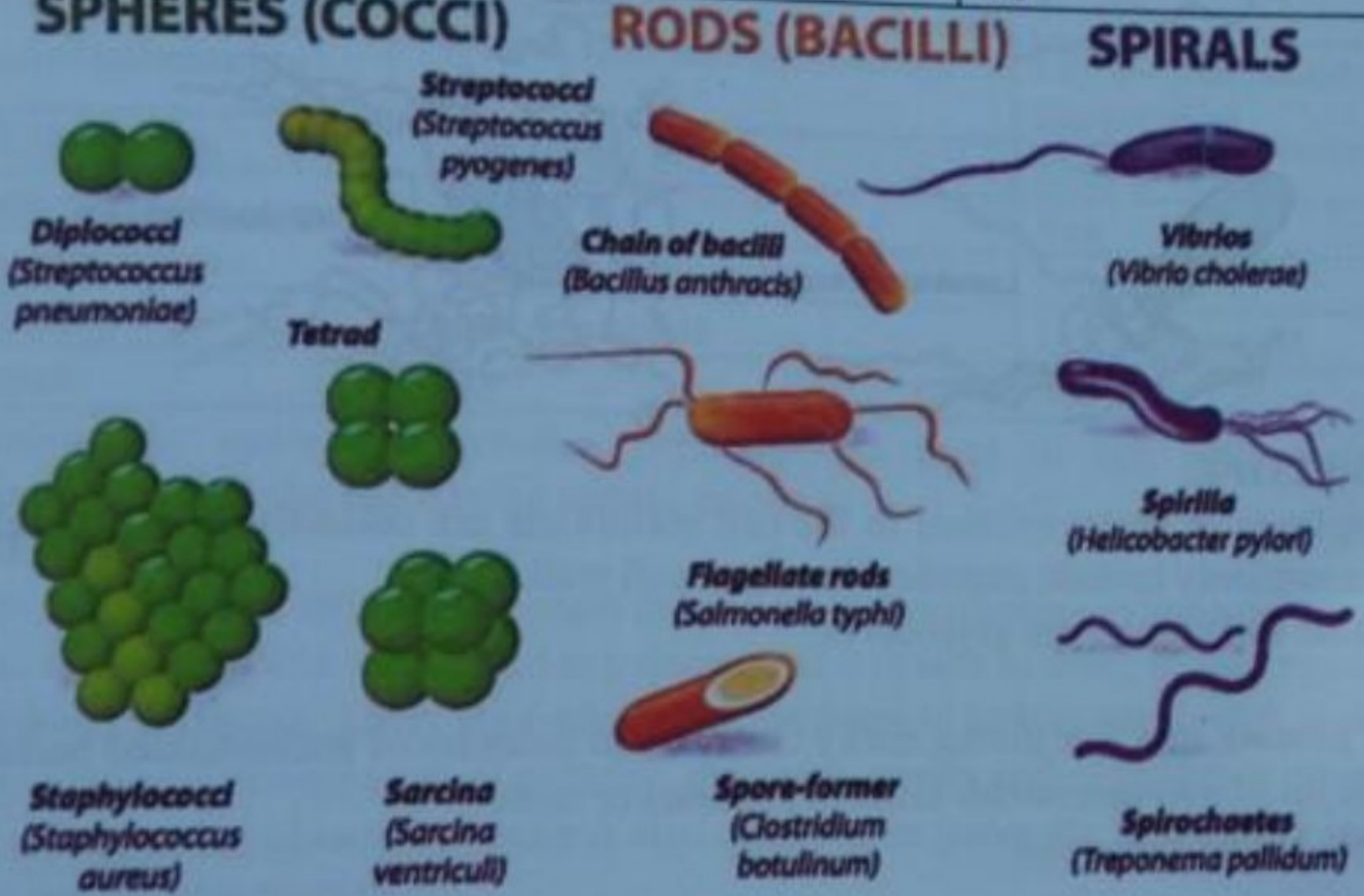
SHAPES OF BACTERIA

- Bacteria may be ***Cocci*** (Spherical or oval in shape), ***Bacilli*** (Rod shaped) and *Spiro* (Curved/ spring shaped).
- Some have characteristic shapes; others are ***pleomorphic*** (variable shape).

Type	Arrangement	Division
Coccus	Spherical	No
Diplococcus	Two cocci	Single plane of division
Streptococcus	Cocci in chain	Single plane of division

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Staphylococcus	Irregular arrangement	Random planes
Tetrad	Group of four	Two planes of division
Sarcina	Group of eight	Three planes of division
Bacillus	Rod shaped	No
Diplobacillus	Two bacilli	Single plane of division
Streptobacillus	Chain of bacilli	Single plane of division
Coccobacilli	Rod shaped with spherical ends	No
Spirals	Spirally coiled	No
Vibrio	Comma shaped	No
Spirillum	Thick, rigid spiral	No
Spirochete	Thin, flexible spiral	No



Some Important Examples

Cocci	*Diplococcus pneumoniae, Staphylococcus aureus, Neisseria meningitidis*
Bacilli	*Escherichia coli, Bacillus subtilis, Pseudomonas*
Spirals	*Vibrio cholera, Hyphomicrobium, Treponema pallidum, Spirrilum minus*

FLAGELLA & PILI

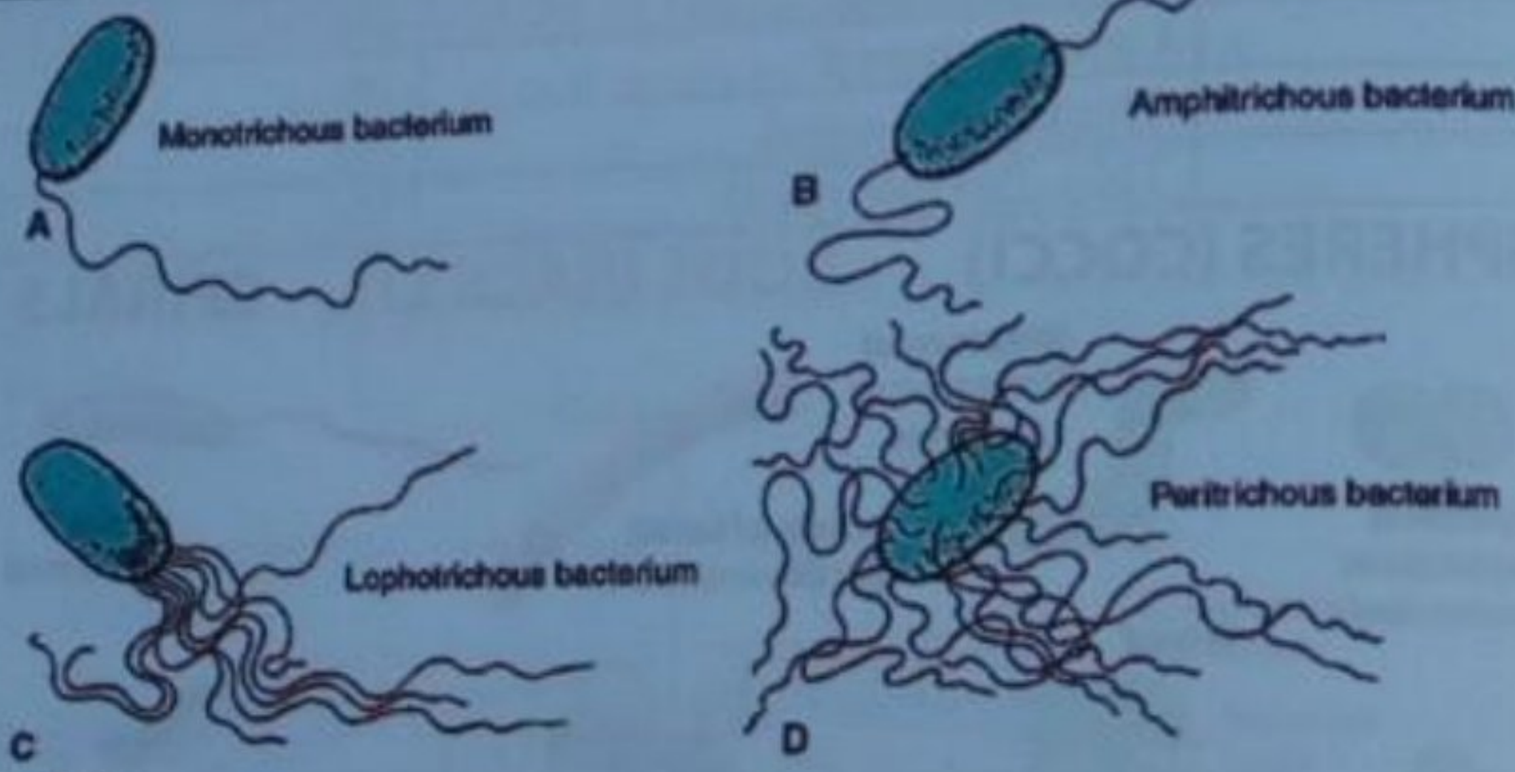
Flagella	Pili/ Fimbrae
Thin	Thick
Long	Short
Flexible, Helical	Rigid, Non-helical, Hollow
Originate from basal bodies, attached with plasma membrane & pass out through cell wall.	Originate from basal bodies, attached with plasma membrane & pass out through cell wall.
Made of flagellin protein	Made of pilin protein
Present in all except cocci. Cocci rarely have flagella.	True pili present in Gram negative bacteria
Help in locomotion/ motility/ chemotaxis.	Involved in attachment with host or with other bacterium for conjugation (Sex/F pili)

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Classification on Base of Flagella

Type	Flagella
Atrichous	No flagella
Monotrichous	Single flagellum at one end
Amphitrichous	Single flagella at both ends
Lophotrichous	Tuft of flagella at one pole
Peritrichous	Bacterium equally surrounded by flagella



CELL ENVELOPE

- Complexes of layers external to the cell membrane are collectively called cell envelope and commonly include capsule, slime and cell wall.
- Capsule and slime form glycocalyx.

Capsule

- A ***thick, gummy*** structure giving sticky character to colonies of encapsulated bacteria.
- It is made up of ***polysaccharide*** units or ***proteins*** or both.
- It is tightly bound to the cell.

Slime

- ***Loose soluble*** shield of macromolecules outside capsule is called slime capsule.
- It can be removed from cell easily.
- Slime provides greater ***pathogenicity*** to bacteria.
- It protects them from ***phagocytosis***.

Cell Wall

- A rigid structure between extracellular substances and cytoplasmic membrane.
- Cell wall is only ***absent in Mycoplasma***.
- It is composed of a macromolecule called ***peptidoglycan*** consisting of long glycan chains cross linked with peptide fragments.
- ***Sugar, teichoic acid, lipoproteins and lipopolysaccharides*** are also present which are linked with peptidoglycans.
- Teichoic acid fibers protrude outside the peptidoglycan.
- Cell wall of ***archaeobacteria*** does not contain peptidoglycan; rather contain proteins, glycoproteins and polysaccharides.
- It determines the ***shape of bacteria***.
- It ***protects*** the cell from ***osmotic lysis***.

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- It provides ***identity to different bacteria***, depending upon their staining characteristics i.e., Gram positive and Gram negative bacteria.

Characteristics	Gram-Positive	Gram-Negative
Stain	Primary dye (Crystal violet & Gram's iodine)	Secondary dye (Safranin)
Staining character	Purple	Pink
Number of major layers	1	2
Peptidoglycan	50% of dry weight	10% of dry weight
Lipids	1-4%	11-12%
Additional substances	Teichoic acid and lipoteichoic acid	Lipopolysaccharides, lipoproteins
Overall thickness	Thick 20-80 nm	Thin 8-11 nm
Outer membrane	No	Yes
Periplasmic space	Present in some	Present in all
Permeability	More permeable	Less permeable
Resistance	Less	More

- Periplasmic space lies between peptidoglycan layer of cell wall and cytoplasmic membrane. It is the site having certain enzymes.

CELL MEMBRANE

- It is thin, flexible structure beneath the cell wall, surrounding cytoplasm.
- It is very delicate in nature and any damage to it results in death of the organism.
- Bacterial membrane differs from eukaryotic membrane in ***lacking sterols*** such as cholesterol.
- It is involved in ***transport*** of proteins, nutrients, sugars and electrons or other metabolites.
- The plasma membrane of bacteria also contains ***enzymes for respiratory metabolism*** **i.e.** site for cellular respiration.

CYTOPLASMIC MATRIX

- A ***gel like*** substance present between the plasma membrane and the nucleoid.
- Plasma membrane and everything present within it is called ***protoplast***.
- Cytoplasmic matrix lack membrane bounded organelles & cytoskeleton however chromatin/ nuclear body, ribosomes, mesosomes, granules and nucleoid are present in it.

NUCLEOID

- Bacteria like other prokaryotic cells lack definite membrane bounded nucleus and chromosomes.
- Nucleoid is a single, circular, double stranded DNA molecule, aggregates as an irregular shaped dense area in the centre of bacterial cell.
- It is visible in the light microscope after staining with Feulgen dye.
- Other names for nucleoid are nuclear body, chromatin body and nuclear area.
- Extremely long molecule of DNA that is tightly folded to fit inside the cell component is chromatin body.
- Bacteria have a single chromosome, thus they are ***haploid***.
- *Escherichia coli* closed circle chromosome measures approximately 1,4000 um.

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PLASMID

- Circular, double stranded DNA molecules, ***self-replicating*** but not essential for the bacterial growth and metabolism
- Contains genes of ***drug resistance, heavy metal resistance, disease, and insect resistance***
- Plasmids are important vectors in modern genetic engineering techniques.

RIBOSOMES

- They are composed of ***RNA and proteins***.
- May be loosely attached to the cell membrane or plasma membrane.
- ***Smaller*** than eukaryotic ribosome.

MESOSOMES

- Formed by ***invagination of cell membrane*** in to the cytoplasm.
- Involved in DNA replication, cell division, export of exo-cellular enzymes and also contain respiratory enzymes.

STORAGE BODIES AND GRANULES

- Store ***extra nutrients*** like glycogen, sulphur, fat and phosphate.
- Also store ***waste material*** like alcohol, lactic acid, and acetic acid.

SPORES

- These are ***metabolically dormant*** bodies, resistant to adverse physical environmental conditions such as light, high temperature, desiccation, pH and chemical agents.
- They may be ***exospore*** (external to vegetative cell) or ***endospore*** (inside vegetative cell/ inside cell wall).
- Endospore are more resistant structures and can survive for years.
- They ***germinate*** to form vegetative cell under favorable conditions.
- They normally develop at ***end stage of growth*** of bacteria.

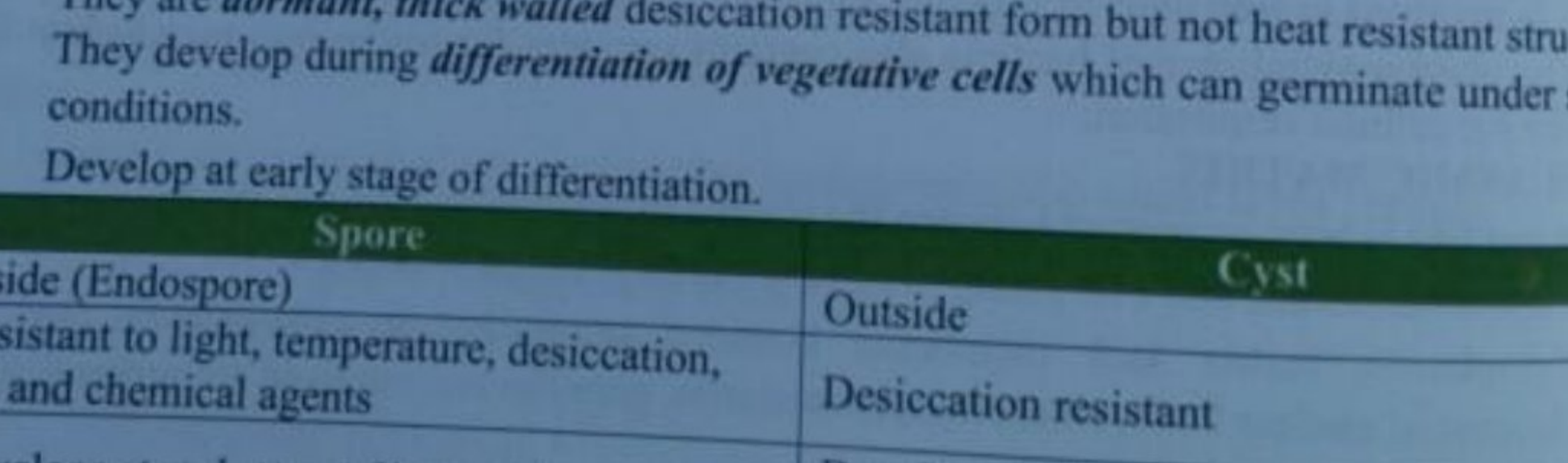
CYSTS

- They are ***dormant, thick walled*** desiccation resistant form but not heat resistant structures.
- They develop during ***differentiation of vegetative cells*** which can germinate under suitable conditions.
- Develop at early stage of differentiation.

Spore	Cyst
Inside (Endospore)	Outside
Resistant to light, temperature, desiccation, pH and chemical agents	Desiccation resistant
Develops at end stage of bacterial growth	Develops during differentiation of bacterial cell.

NUTRITION IN BACTERIA

NUTRITION OF BACTERIA



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A) Heterotrophic Bacteria

Those bacteria which cannot synthesize their organic compounds from simple inorganic substances are called ***heterotrophic bacteria***.

(1) Saprophytic Bacteria

- ***Saprophytic bacteria*** get their food from dead organic matter present in soil in the form of humus.
- Humus is the material resulting from partial decay of plants and animals.
- Saprotrophic bacteria have an ***extensive enzyme system*** that break down the complex substances of humus to simple compounds.
- Examples are *Pseudomonas, Azotobacter*.

(2) Parasitic Bacteria

- Those bacteria which are fully dependent upon their host for nutrition are ***parasitic bacteria***.
- These are also called as pathogenic bacteria as they cause disease in their host.
- Examples are *Mycobacterium tuberculosis*, *Streptococcus pneumoniae* etc.

B) Autotrophic Bacteria

Those bacteria which can synthesize their organic compounds from simple inorganic substances are called ***autotrophic bacteria***.

(1) Photosynthetic Bacteria

- ***Photosynthetic bacteria*** carry out photosynthesis.
- They contain chlorophyll which differs from chlorophyll of green plants, dispersed in the cytoplasm and thus is different from that present in cells of green plants.
- They use H_2S instead of water and thats why release sulphur instead of oxygen.
- $CO_2 + 2H_2S \xrightarrow[\text{Chlorophyll}]{\text{Light}} (CH_2O)_n + H_2O + 2S$
- ***Examples*** of photosynthetic bacteria are green sulphur bacteria, purple sulphur bacteria, purple non- sulphur bacteria etc.

(2) Chemosynthetic Bacteria

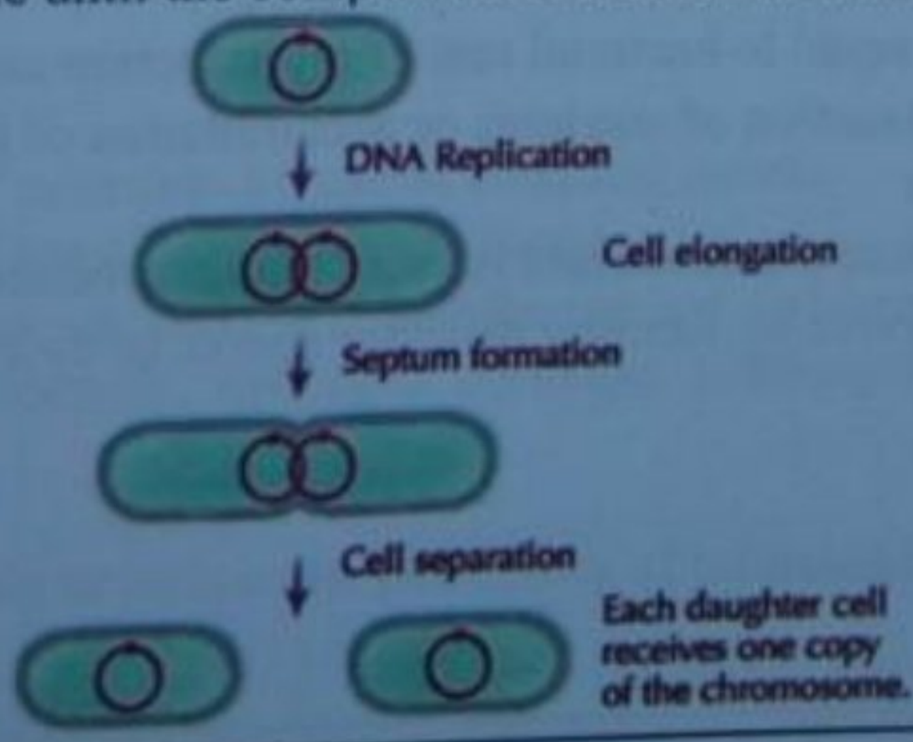
- ***Chemosynthetic bacteria*** oxidize inorganic compounds like ammonia, nitrates, nitrites, sulphur or ferrous ions and trap the energy thus released for their synthetic reactions.
- Examples are nitrifying bacteria.

GROWTH & REPRODUCTION IN BACTERIA

REPRODUCTION

Asexual Reproduction

- Bacteria lack mitosis.
- Bacteria increase in number by an asexual means of reproduction, called ***binary fission***.
- Parent Cell Enlargement → Chromosome Duplication/ DNA Replication & Distribution → Cell Membrane Invagination → Inward Growth of Cell Wall → Division of Cell into Two Daughter Cells
- The interval of time until the completion of next division is known as ***generation time***.



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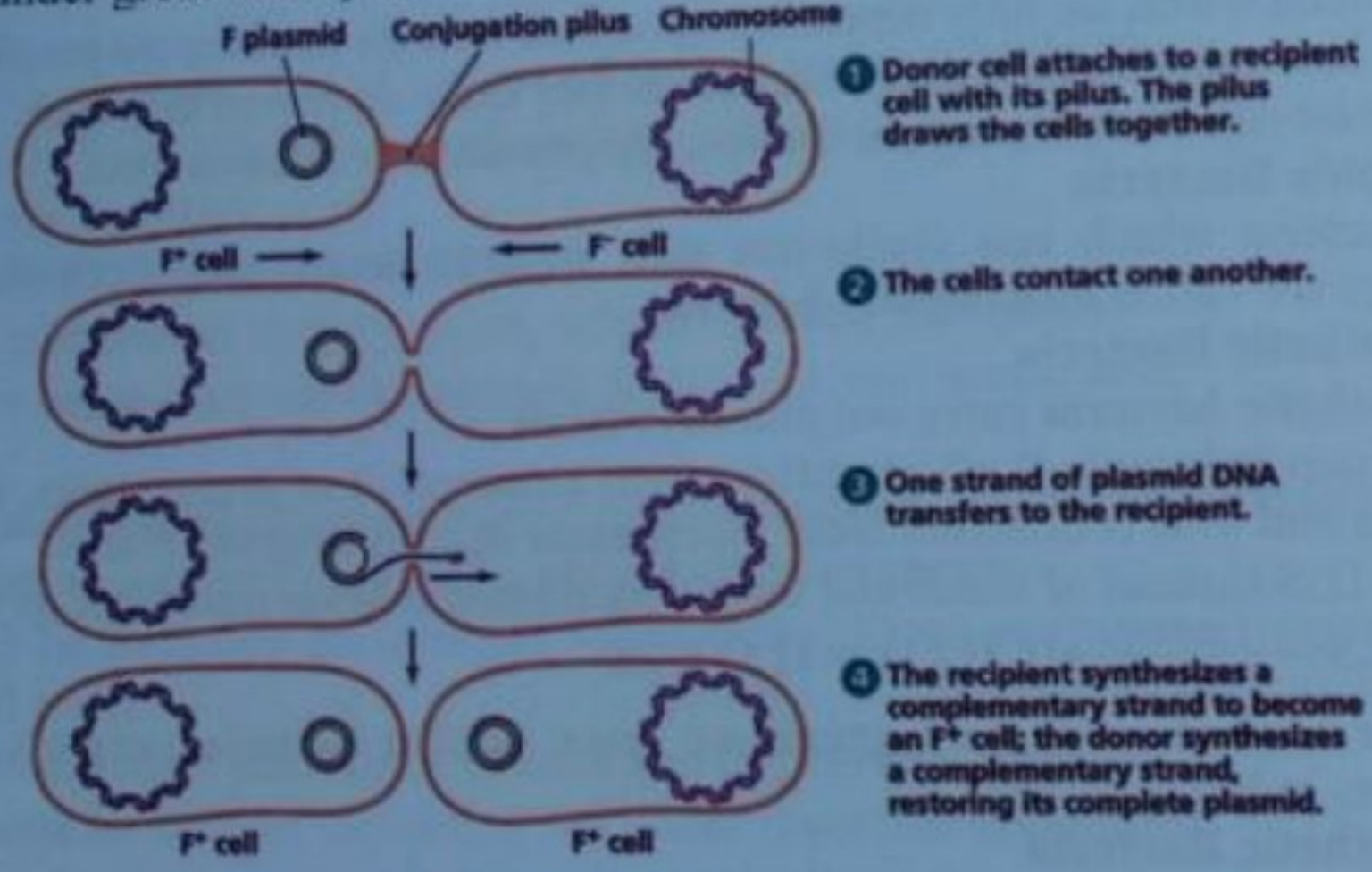
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Sexual Reproduction

Bacteria lack traditional sexual reproduction because there is no formation of gametes and zygote. Instead it involves genetic recombination. It occurs in three ways; conjugation, transduction and transformation.

Conjugation

- Some bacteria transfer genetic material from a donor bacterium to a recipient bacterium during a process called conjugation.
- During conjugation, bacteria use specialized sex pili to transfer genetic material.
- Bacterial plasmids are exchanged during conjugation.
- Conjugation produces new genetic combinations that may allow the resulting bacteria to survive under great variety of conditions.



GROWTH

- Bacterial growth refers commonly to increase in number of bacterial cells.
- Four distinct phases are recognized in bacterial growth curve.

(1) Lag Phase

- It is the phase of no growth.
- Bacteria prepare themselves for division.

(2) Log Phase

- It is the phase of rapid growth.
- Bacteria divide at exponential rate.
- Number of cells double with each doubling time.

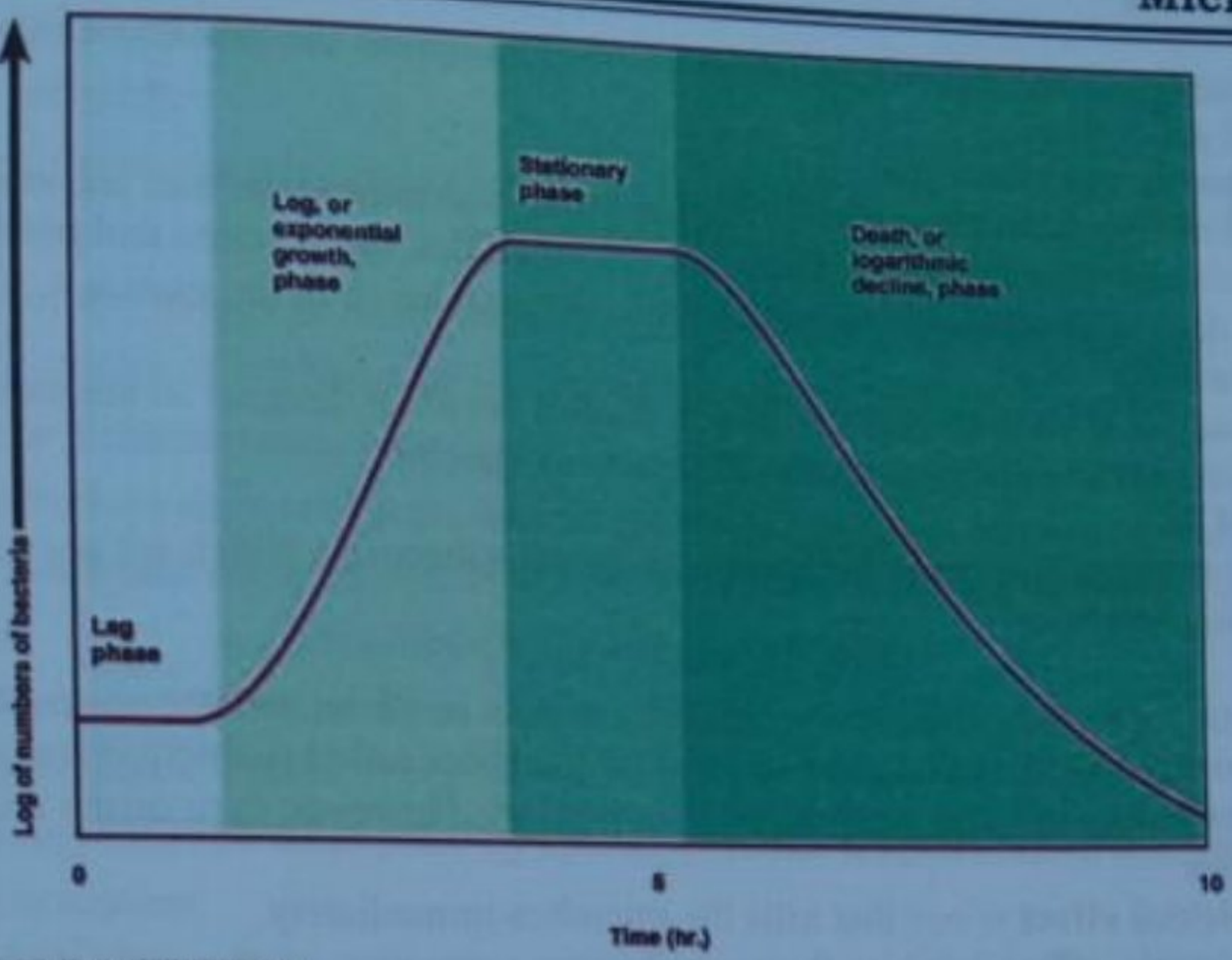
(3) Stationary Phase

- Bacterial death rate is equal to bacterial rate of reproduction and multiplication.
- This occurs due to exhaustion of nutrients or accumulation of toxic metabolites.

(4) Death/ Decline Phase

- Bacteria start dying. Here the death rate is more than reproductive rate.
- Some bacteria may survive by forming resistant spores or cysts.

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CONTROL OF BACTERIA

Bacterial control is required to prevent diseases and food spoilage.

PHYSICAL METHODS

- The process in which physical agents are used to control bacteria/microorganisms is known as **sterilization process.**
- It involves killing of all microbes.
- In physical methods, steam, dry heat, gas, filtration and radiations are used to control bacteria.

(1) Use of Heat

- Both dry heat and moist heat are effective.
- Moist heat causes coagulation of proteins and kills the microbes.
- Dry heat causes oxidation of chemical constituents of microbes and kills them.

(2) Use of Radiations

- Certain electromagnetic radiations below 300 nm are effective in killing of microorganisms.
- Gamma rays are in general used for the sterilization process.

(3) Membrane Filters

- Heat sensitive compounds like antibiotics, seras etc can be sterilized by means of membrane filters.

CHEMICAL METHODS

(1) Disinfection

- It involves killing of microbes by use of chemical agents.
- It involves killing of most but not all life forms.
- The important chemicals used for disinfection are oxidizing and reducing agents. For example halogens, phenols, hydrogen peroxide, potassium permanganate, alcohol and formaldehyde etc.

(2) Antisepsis

- Procedure to eliminate or reduce the possibility of infection is called antisepsis.

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- Chemical substances used on living tissues that inhibit the growth of microorganism are called antiseptics.

(3) Chemotherapeutic Agents

- Chemotherapeutic agents and antibiotics work with natural defense and stop the growth of bacteria and other microbes. These are sulfonamides, tetracycline and penicillin.
- They destroy or inhibit the growth of microorganisms in living tissues.

(4) Vaccination

- Vaccination is an important method to control bacterial diseases in humans.
- Pasteur used attenuated cultures of bacteria as vaccine.

ANTIBIOTICS

Antibiotics are the chemotherapeutic chemical substances which are used in treatment of infectious diseases.

Synthesis

- Antibiotics are synthesized and secreted by certain bacteria, actinomycetes (Spore forming Gram positive bacteria that grow to form long tubules called filaments) and fungi.
- Some antibiotics are also synthesized in laboratory. However, their origin are living cells.

Mode of Action

- **Microbicidal effect** is one that kills the microbes immediately.
- **Microbistatic effect** inhibits the reproductive capacities of the cells and maintains the microbial population at constant size.
- Damage by antibiotics can result in malfunctioning of cell wall, cell membrane, cytoplasmic enzymes or nucleic acids.

Misuse of Antibiotics

- Widespread problem is drug resistance against microorganisms. This results in an increased resistance against disease treatments.
- Misused antibiotics can interact with the human metabolism and in severe cases can cause death of human beings.

Antibiotic	Side Effects
Penicillin	Allergic reactions
Streptomycin	Effects auditory nerve causing deafness.
Tetracycline	Permanent discoloration of teeth in young children.

FUNGI

STRUCTURE OF FUNGI

- Fungi are eukaryotes, non-motile absorptive heterotrophs.
- The body of the fungus is called **mycelium,** consists of long, slender, branched tubular thread like filaments called **hyphae.**
- Hyphae may be septate or non-septate. ***Septate hyphae*** are divided by cross-walls called ***septa*** into individual cells containing one or more nuclei.
- Septa of many septate hyphae have a pore through which cytoplasm flows from cell to cell.
- ***Non-septate hyphae*** lack septa and are not divided into individual cells; instead these are in the form of an elongated multinucleated large cell. Such hyphae are called ***coenocytic hyphae***, in which the cytoplasm moves effectively, distributing the materials throughout. These are always multinucleate.
- Hyphae may be packed together and organized to form complex reproductive structures such as mushroom, puff balls, morels etc.
- Yeast are non-hyphal and unicellular fungi.

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- Chitin in their cell wall is more resistant to decay than are cellulose and lignin which make up plant cell wall.
- All fungal nuclei are haploid except for transient diploid zygote that forms during sexual reproduction.
- All parts of the fungus growing through the substrate are metabolically active. Extensive spreading system of hyphae provides enormous surface area for absorption.
- They show a characteristic type of mitosis, called nuclear mitosis. During nuclear mitosis, nuclear envelope does not break; instead the mitotic spindles form within the nucleus and nuclear membrane constricts between the two clusters of daughter chromosomes.

REPRODUCTION IN FUNGI

Fungi can reproduce asexually as well as sexually.

ASEXUAL REPRODUCTION

Asexual reproduction takes place by **spores, conidia, fragmentation and budding.**

(1) Spore Formation

- Spores are common mean of reproduction in fungi.
- **Spores** are produced inside the reproductive structures called **sporangia,** which are cut off from the hyphae by complete septa.
- Spores may be produced by sexual or asexual process.
- These are haploid, non-motile and not needing water for their dispersal.
- These are small in size, produced in very large number and dispersed by wind to great distances.
- Spores may also be dispersed by insects and many other small animals and by rain splashes.

(2) Conidia Formation

- **Conidia** are non-motile, asexual spores which are cut off at the end of modified hyphae called **conidiophores,** and not inside the sporangia, usually in chains or clusters.
- They may be produced in large number, can survive for weeks and cause rapid colonization of new food.

(3) Fragmentation

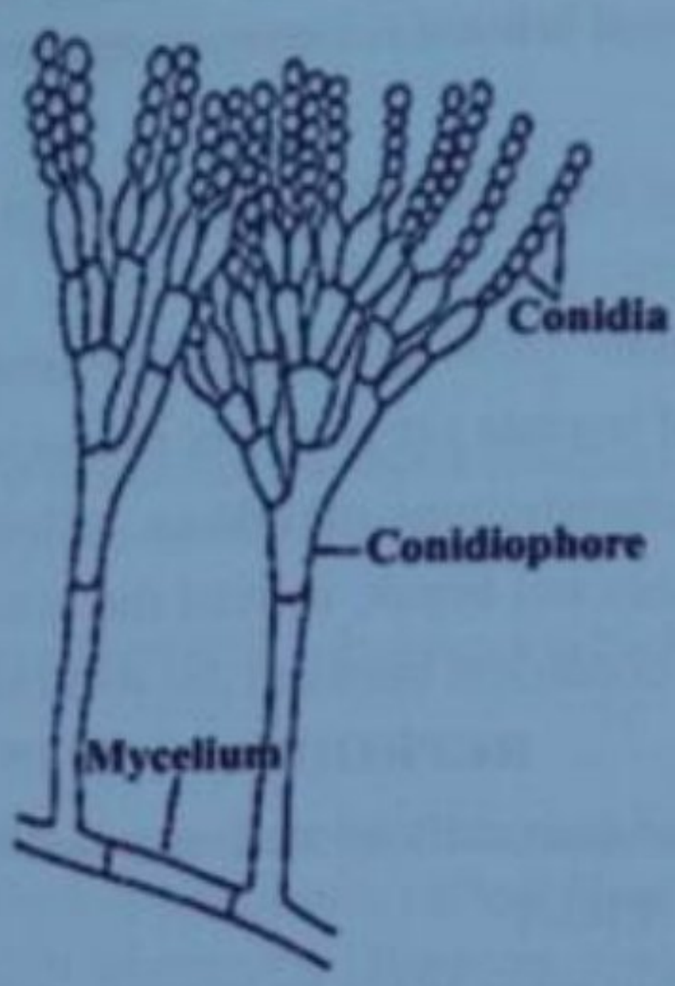
- **Fragmentation** is simple breaking of mycelium of some hyphal fungi, each broken fragment giving rise to a new mycelium.

(4) Budding

- Unicellular yeasts reproduce by **budding.**
- It is an asymmetric division in which tiny outgrowth or bud is produced which may separate and grow.
- Yeast may divide by simple, relatively equal cell division.

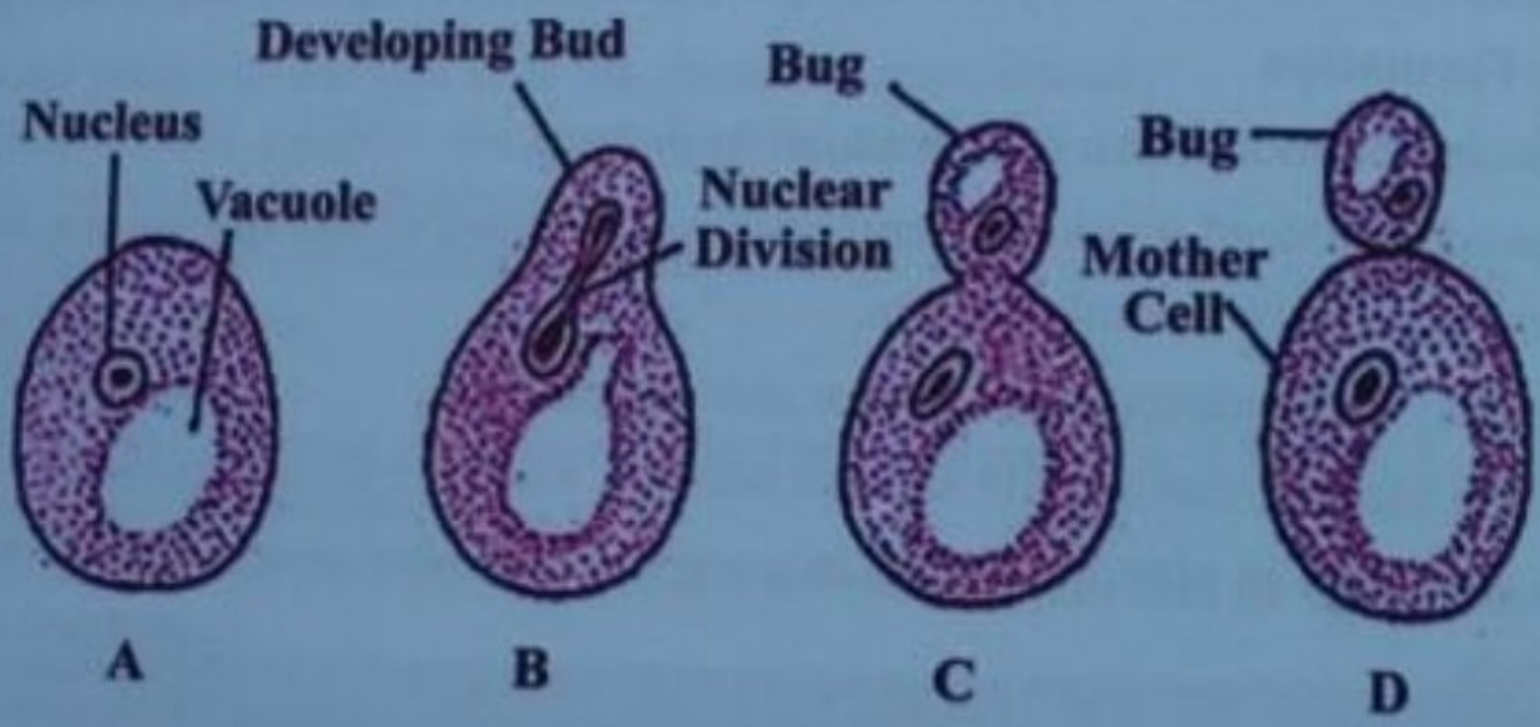
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Spore formation in fungi





Fragmentation in fungi

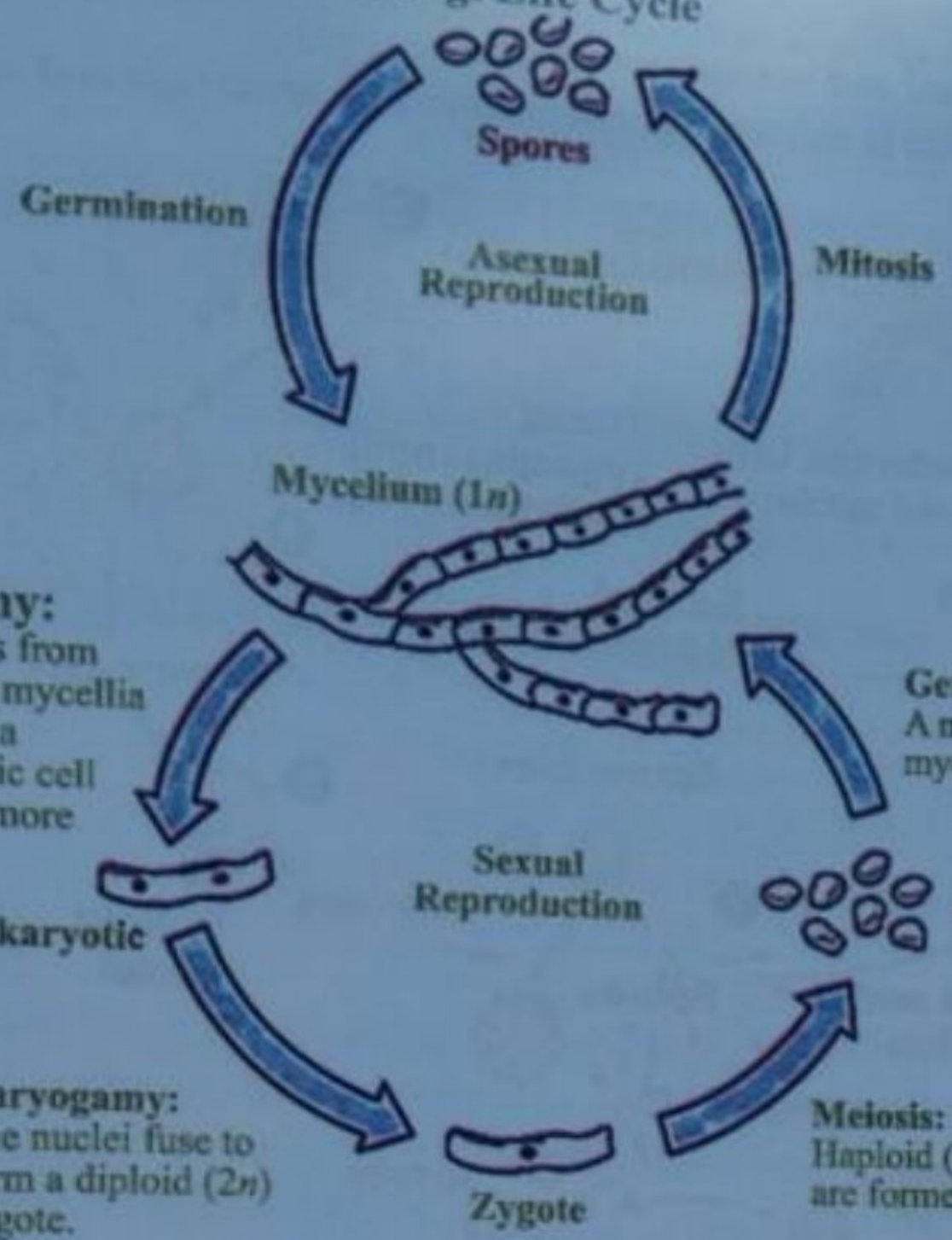


Budding in yeast

SEXUAL REPRODUCTION

- Details of **sexual reproduction** vary in different groups of fungi, but fusion of haploid nuclei and meiosis are common to all.
- During sexual reproduction in fungi, hyphae of two genetically different but compatible mating types come together, their cytoplasm fuse followed by nuclear fusion.
- **Karyogamy** is the fusion of nuclei while **plasmogamy** is the fusion of cytoplasm.
- In Basidiomycetes and Ascomycetes, karyogamy does not take place immediately after plasmogamy; instead the two genetic types of haploid nuclei from two individuals may coexist and divide in the same hyphae for most of the life of the fungus. Such hyphae having 2 different genetic types are called dikaryotic or heterokaryotic hyphae.
- Different groups of fungi produce different types of haploid sexual spores, such as basidiospores and ascospores, subsequent upon meiosis in zygote.
- These spores may be produced by their characteristic structure/ fruiting bodies such as basidia/ basidiocarp and asci/ ascocarp.

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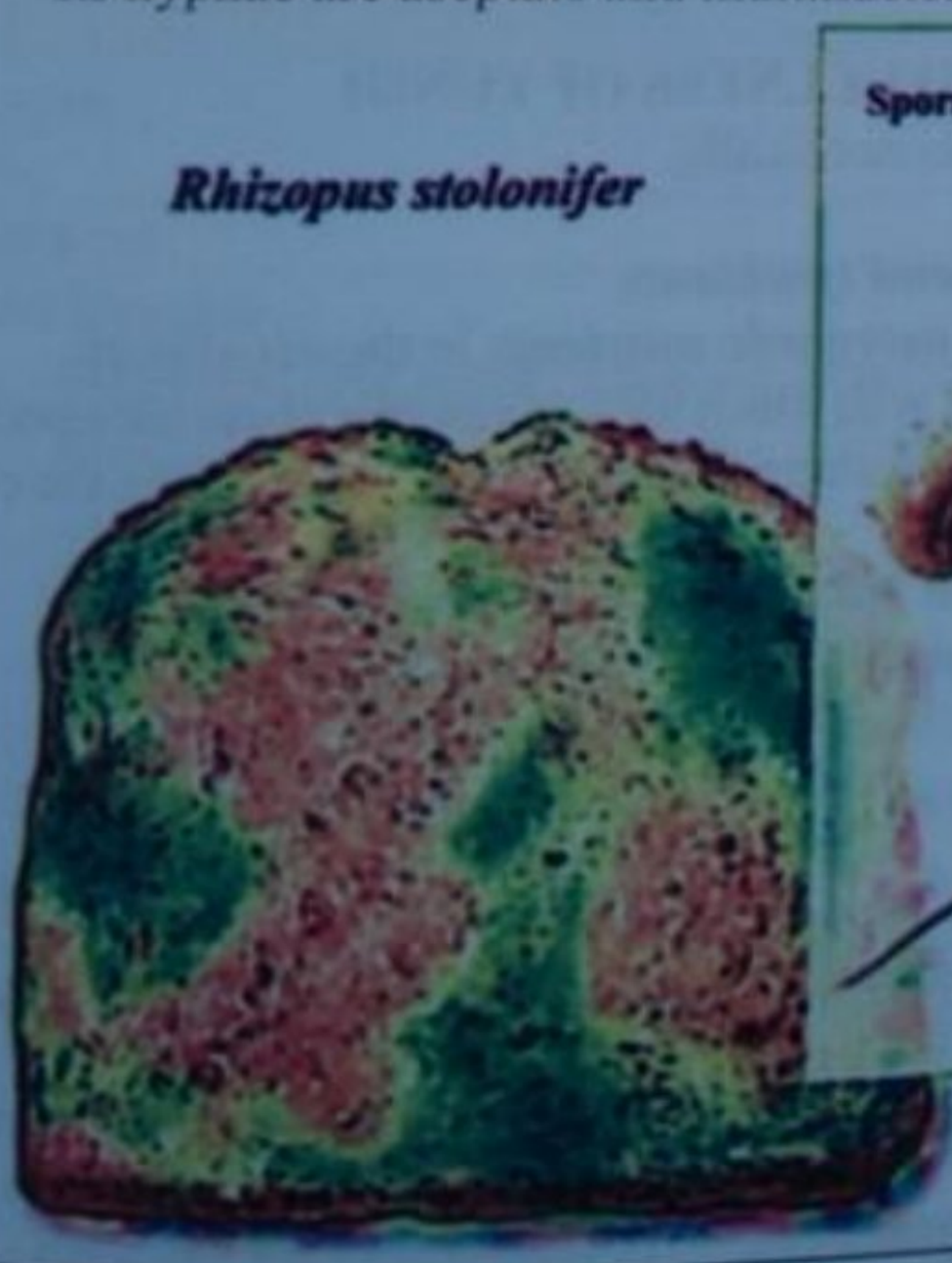


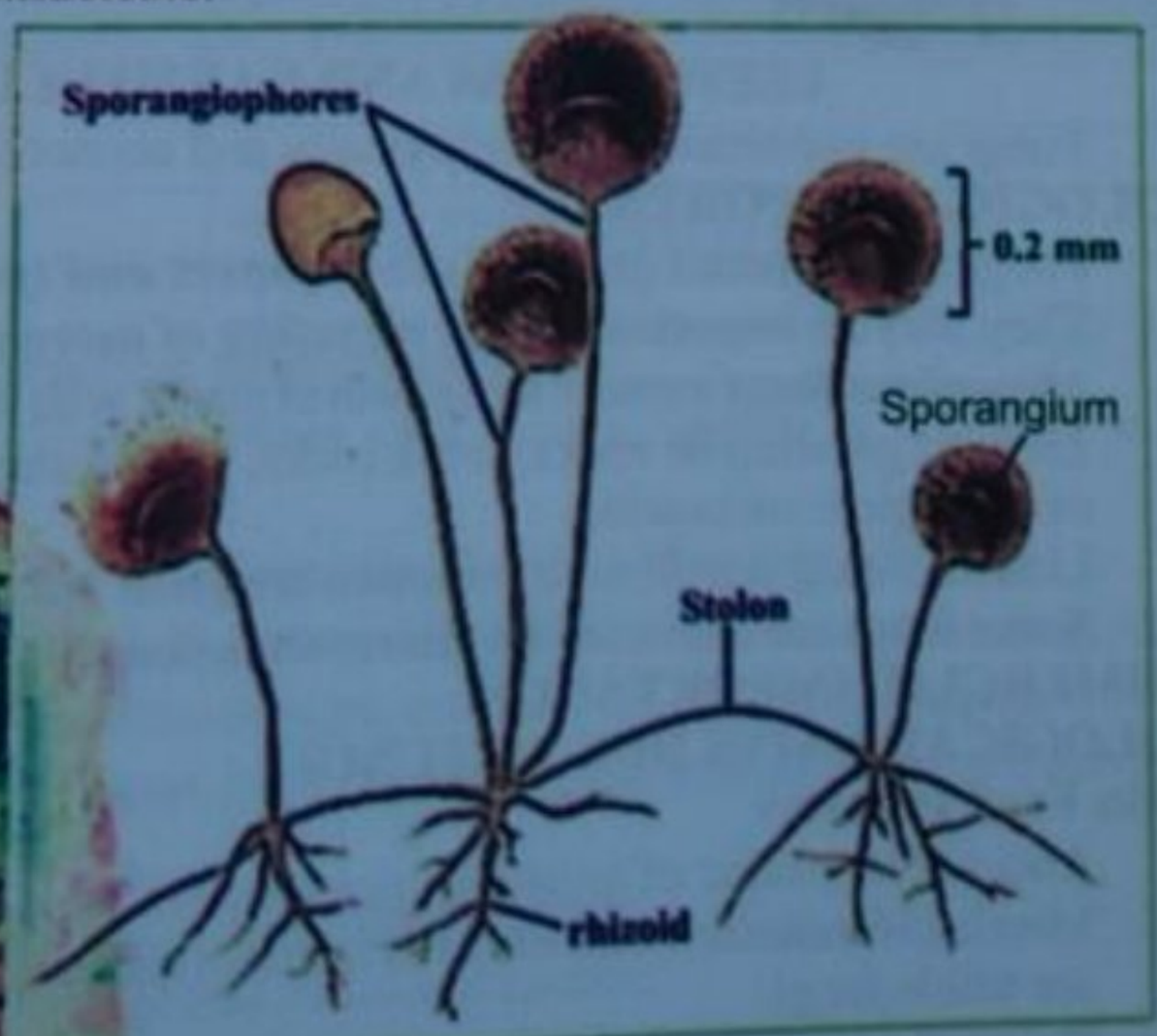
LIFE CYCLE OF RHIZOPUS

Rhizopus

- It is an example of zygomycete (conjugating fungi).
- It is a saprotroph, commonly grows on bread so called as black bread mold.
- Its hyphae are aseptate and multinucleate.

Rhizopus stolonifer

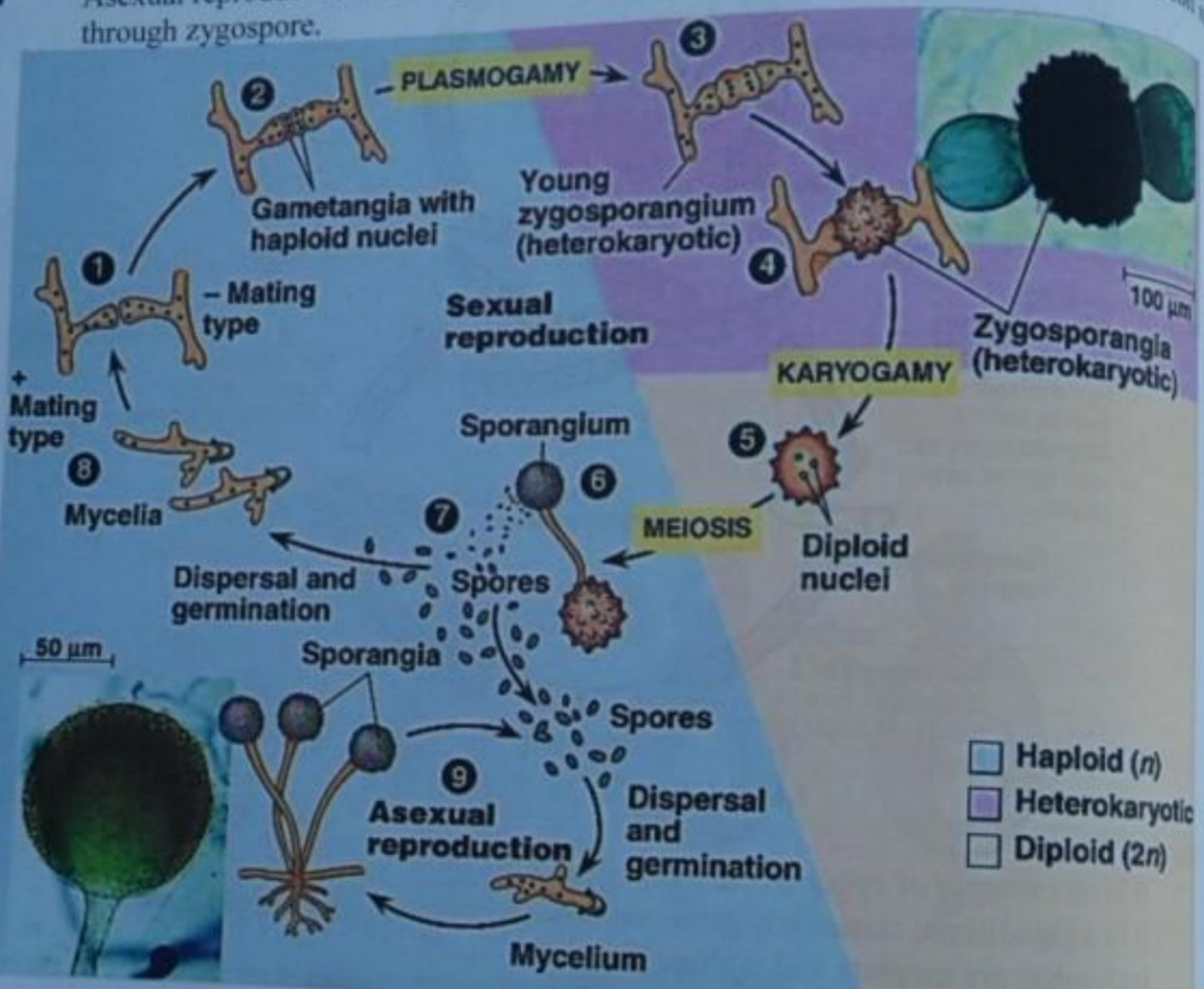




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Life Cycle

- It shows both asexual and sexual reproduction.
- Asexual reproduction is through spores produced in sporangia and sexual reproduction is through zygospore.



USEFULLNESS AND HARMFULLNESS OF FUNGI

Fungi are important both ecologically and economically.

ECOLOGICAL IMPORTANCE

- Fungi are important group of ***decomposers and symbionts***.
- They play an important role in ***recycling of inorganic nutrients*** in the ecosystem.
- ***Mycorrhizal fungi*** improve the growth of plants, with which 95% of vascular plants are associated.
- ***Lichens*** growing on rocks, break rocks, setting stage for other organisms during the course of ecological succession.
- Lichens being sensitive to pollution are ***good bio indicators*** of air quality.
- Some fungi are also used for ***bioremediation***.

COMMERCIAL IMPORTANCE

ECOLOGICAL GAINS DUE TO FUNGI

Role in Food Industry

- About 200 species of mushrooms are edible e.g. *Agaricus* sp.
- Morels (***Morchella esculenta***) and truffles (underground fruiting bodies of some ascomycetes) are edible fungi.
- Poisonous mushrooms are called toadstools e.g. death cap/death angel (*Amanita*) and Jack O' lantern mushroom.
- Reindeer moss (lichen) is used as food for reindeers.

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Example	Role
Mushrooms	Edible
Morels	Edible
Truffles	Edible
Saccharomyces cerevisiae	Fermentation to get bread and liquor.
Penicillium	Flavour, aroma and characteristic colour to some cheese.
Aspergillus	Fermentation of soya bean to get soya sauce and soya paste. Production of citric acid.

Role in Drug Industry

- Penicillin is first antibiotic, which was discovered by A. Fleming in *Penicillium notatum* (fungus).

Drug	Role
Penicillin	Antibiotic
Lovastatin	Lowers blood cholesterol
Cyclosporine	Prevent transplant rejection/ Immunosuppressive drug
Griseofulvin	Inhibit fungal growth/ Antifungal
Ergotine	Relieve headache (Migrain)

Role in Research

- ***Yeast*** were the first eukaryotes to be used by genetic engineers.
- First functional ***artificial chromosome*** was made in *Saccharomyces cervisiae*.
- Pink bread mold ***Neurospora*** (Pink bread mold) has been used in genetic research.

ECOLOGICAL LOSSES DUE TO FUNGI

Plant Diseases

Fungal Disease	Affected Plant
Powdery mildews	Grapes, rose, wheat
Ergot	Rye
Red rot	Sugarcane
Wilt	Potato
Root rot	Cotton
Scab	Apple
Brown rot	Peaches, Plums, Apricot & Cherries

Human Diseases

- ***Ringworm and athlete's foot*** are superficial fungal infections.
- ***Histoplasmosis*** is caused by inhaling spores of a fungus, which is common in soil contaminated with bird's feces.
- ***Candidasis or candidosis*** is oral or vaginal thrush caused by *Candida albicans*.
- *Aspergillus fumigatus* causes ***aspergillosis*** in persons with defective immune system (e.g. AIDS).
- Some strains of *Aspergillus* produce carcinogenic mycotoxins, called ***aflatoxins***.
- ***Ergotism*** is caused by eating bread made from purple ergot-contaminated rye flour.

Spoilage

- ***15-50%*** of world's fruit is lost each year due to fungal attack.
- ***Wood-rotting fungi*** destroy living trees and structural timber.
- ***Bracket/shelf fungi*** cause lot of damage to stored cut lumber as well as stands of timber of living trees.
- Pink yeast ***Rhodotorula*** grows on shower curtains and other moist surfaces.

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TOPIC-4
02 MCQs

KINGDOM ANIMALIA

LEARNING OUTCOMES

(a) Define the following terms: Coelomates, Acoelomates, Pseudocoelomates, Radiata, Bilateria

(b) Describe the medical importance of following phyla:

(i) Platyhelminthes (*Taenia solium*, *Fasciola hepatica*)

(ii) Aschelminthes (*Ascaris lumbricoides*, *Enterobius vermicularis*, *Ancylostoma duodenale*)

(iii) Annelida (*Hirudo medicinalis*)

(iv) Arthropoda (mosquito, lice, Tse-tse fly, common housefly)

(v) Mollusca (snail)

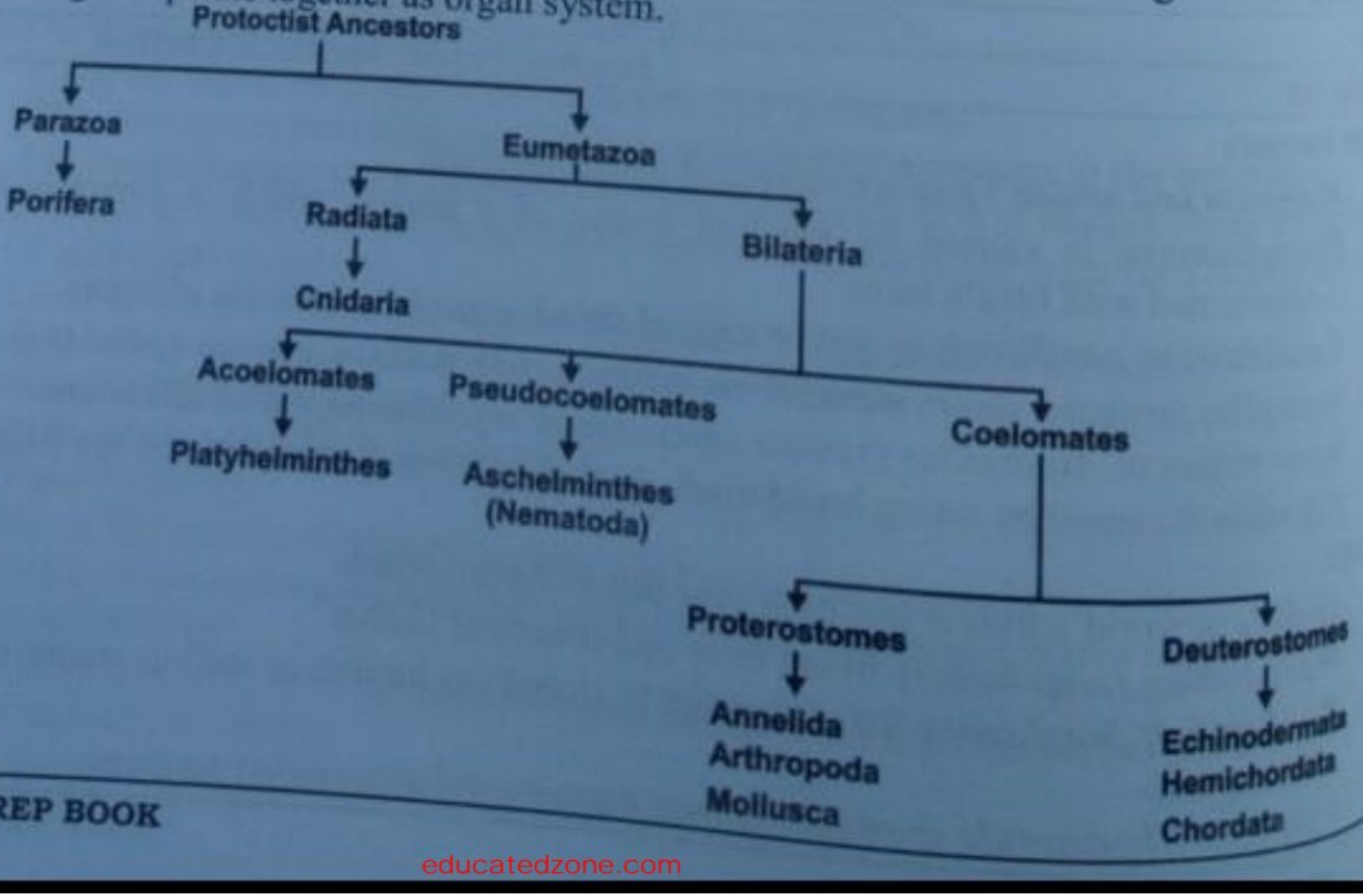
1. TERMS

Kingdom Animalia

- The name animalia is derived from Latin word anima meaning breath or soul.
- All the animals are multicellular heterotrophs and usually acquire food by ingestion followed by digestion.

COMPLEXITY IN KINGDOM ANIMALIA

- Simplest of the animals belong to subkingdom ***Parazoa***. These animals lack tissues organized into organs and have indeterminate shape and are asymmetrical. Phylum porifera is included in parazoa.
- They have cellular grade of organization.
- The subkingdom ***Eumetazoa*** includes animals of other phyla which have symmetry and organization.
- In eumetazoa, similar cells are grouped together into a highly coordinated unit called tissue. The tissues are assembled into larger functional units called organs. Different organs operate together as organ system.



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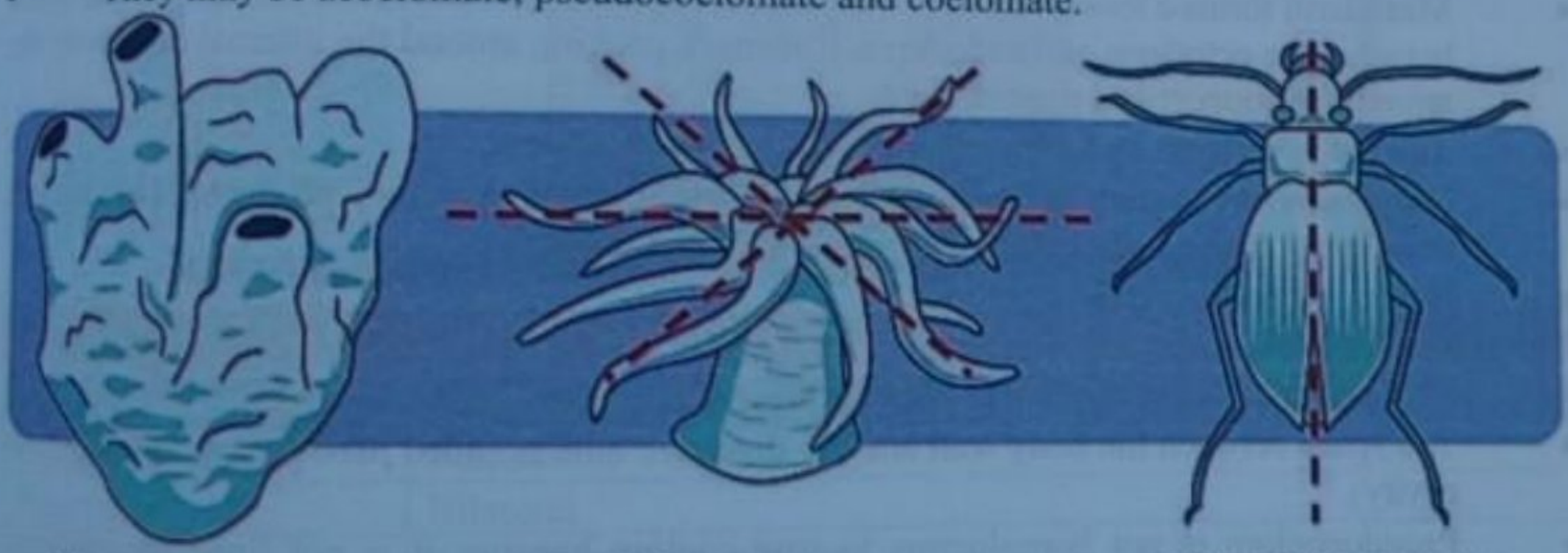
Classification on Base of Symmetry

Grade Radiata

- All the animals in grade radiata are diploblastic.
- It contains animals with radial symmetry.
- This is a condition or organization in which parts of the body are arranged around a central axis in such a way that any plane passing through the central axis divides the animal in halves that are almost mirror images of each other.
- Radial symmetry is considered an adaptation for a sessile life.
- Cnidarian (coelenterates) are placed in this group.
- The cylindrical body of a sea anemone can be cut in two equal halves vertically in any plane.

Grade Bilateria

- The animal can be divided into two equal parts by an imaginary line only in one plane.
- They have clearly defined right & left sides, anterior or head and posterior or tail ends and dorsal or back and ventral or front surfaces.
- The animals belonging to Phylum Platyhelminthes to Chordata are included in this group.
- Animals belonging to phylum Echinodermata have developed bilateral symmetry in their larval forms and adult echinoderms have secondarily developed radial symmetry, due to their special mode of life.
- All the animals included in grade bilateria are triploblastic.
- They may be acoelomate, pseudocoelomate and coelomate.



No symmetry (e.g. Porifera) | **Radial** symmetry (e.g. Cnidaria) | **Bilateral** symmetry (e.g. Arthropoda)

Classification on Base of Body Organization

Diploblastic Organization

- Diploblastic animals belong to division ***radiata***.
- These animals have tissue level of organization.
- The body of these animals consists of two layers of cells, ***ectoderm*** and ***endoderm***.
- There is ***jelly like mesenchyme*** or ***mesoglea*** which in most cases is non-cellular.
- Diploblastic animals show lesser degree of specialization and they do not form specialized organs.
- There is no special transport system in these animals. Most substances are distributed within their body by the process of diffusion.
- There is no central nervous system in these animals. A neuron net is present.

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UHS Topic-4

- There is only one cavity in the body called ***gastrovascular cavity*** or ***coelenteron*** which has only mouth which serves for the entry of food and water and also for the removal of wastes along with water. This is known as ***sac like digestive system.***
- They reproduce both asexually and sexually.
- Diploblastic animals are placed in phylum ***Cnidaria.***

Triploblastic Organization

- These animals have ***bilateral symmetry.***
- The body of these animals is made from three layers ***ectoderm, mesoderm*** and ***endoderm.***
- After embryonic development these layers in most triploblastic animals are not distinct as separate layers of cells but are represented by the structures formed from them.
- The cells of these animals show greater degree of specialization. These have specialized organs and organ systems.
- The systems such as integumentary and nervous system develop from ectoderm.
- Mesoderm gives rise to muscular, skeletal and reproductive systems.
- Endoderm forms the lining of digestive tract and glands of digestive system such as liver.
- Triploblastic animals may be acoelomate, pseudocoelomate or coelomate.

Acoelomates

- This group includes phylum ***platyhelminthes.***
- There is ***no body cavity*** or ***coelom.***
- Mesoderm forms a loose, cellular tissue ***mesenchyma*** or ***parenchyma*** which fills the space between the ectoderm and endoderm. It forms a packing around the internal organs of the animals to support and protect them.
- The gut is ***sac-type*** and there is no special transport system.
- Only excretory system is developed for the transport of excretory products. This system consists of ***flame cells***, excretory ducts and excretory pores.
- Nervous system is well developed.

Pseudocoelomates

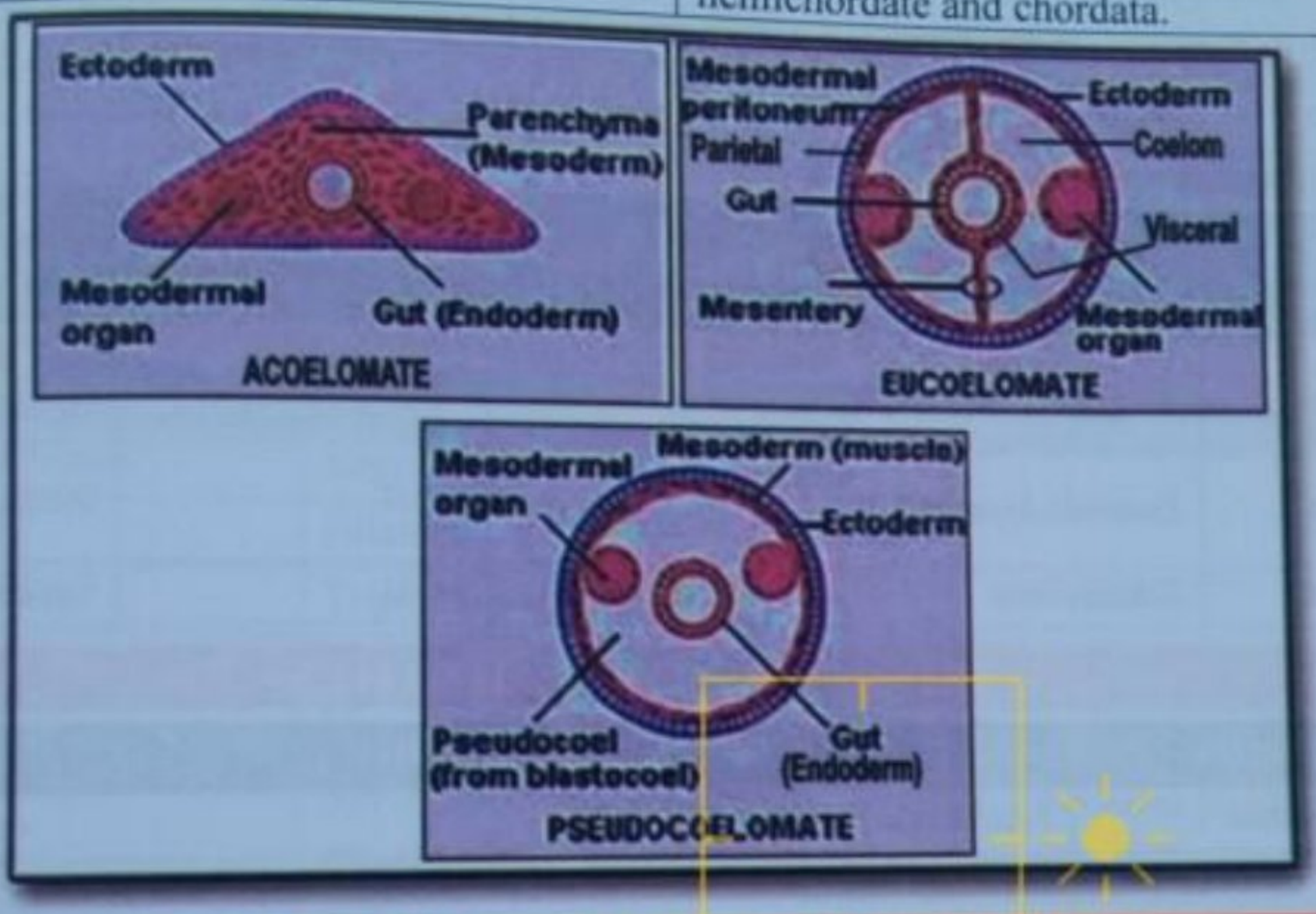
- This group includes phylum ***aschelminthes.***
- The space between the body wall and the digestive tube is called ***pseudocoelom*** (false body cavity).
- Pseudocoelom is not homologous to true coelom because it is not lined by coelomic epithelium.
- It has no relation with the reproductive and excretory organs.
- It develops from the blastocoel of the embryo and is bound externally by the muscles and internally by the cuticle of intestine.

Coelomates

- ***Coelom*** is cavity present between the body wall and the alimentary canal and is lined by mesoderm.
- The mesoderm splits into outer parietal layer which underlines the body wall and the visceral layer which covers the alimentary canal and the cavity between them is the true coelom. It is filled with fluid called ***coelomic fluid.***
- This group includes animals from ***annelids*** to ***chordates.***
- In coelomates, gut attains more complexity and neuro-sensory system is well developed along with excretory system, circulatory system, respiratory and reproductive system.
- Coelomates are further divided into two groups proterostomes and deuterostomes.

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Series Proterostomia	Series Deuterostomia
Cleavage is spiral and determinate.	Cleavage is radial and indeterminate.
Blastopore gives rise to mouth.	Blastopore forms anus.
Coelom is formed by splitting of mesoderm (Schizocoelous).	Coelom is developed from archenteron (Enterocoelous).
Mesoderm is derived from cells on anterior lip of blastopore.	Mesoderm is derived from wall of developing gut (archenteron).
It includes phylum annelida, mollusca and arthropoda.	It includes phylum echinodermata, hemichordate and chordata.



2. PHYLUM PLATYHELMINTHES

Characters	Details
Common Name	Flatworms
Symmetry	Bilateral
Organization	Triploblastic Acoelomate
Body	Unsegmented, dorsoventrally compressed
Mode of Life	Mostly endoparasites, Few Free Living
Examples	*Taenia solium* (Tapeworm), *Fasciola hepatica* (Liver fluke), *Schistosoma* (Blood fluke), *Dugesia* (Planaria)
Digestive System	Branching Sac-Like, Poorly Developed in Parasites, Absent in Tape worm
Excretory System	Protonephridia, Flame Cells
Nervous System	Centralized
Respiratory System	Absent
Circulatory System	Absent
Locomotion	Cilia in free living forms
Reproduction	Asexual (Fission), Sexual (Hermaphrodite)

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UHS Topic-4

Parasitic Adaptations in Platyhelminthes

Characters	Details
Epidermis	Absent, Resistant Cuticle Present
Adhesive Organs	Suckers, Hooks
Muscular System	Degenerated
Nervous System	Degenerated
Digestive System	Simplified
Reproductive System	Complicated, Large number of ova
Life Cycle	Two hosts

Important Parasites of Platyhelminthes

Common Name	Scientific Name	Primary Host	Secondary Host	Adhesive Organ
Tape Worm	*Taenia solium*	Human (Small Intestine)	Pig or Cattle	Sucker (P. Hog) Hooks (S. Hog)
Liver Fluke	*Fasciola hepatica*	Sheep, Human (Bile Duct)	Snail	Sucker
Blood Fluke	*Schistosoma*	Human (Blood)	Snail	Sucker

3. PHYLUM ASCHELMINTHES

Characters	Details
Common Name	Nematode, Round Worm
Symmetry	Bilateral
Organization	Triploblastic, Pseudocoelomate
Body	Unsegmented
Mode of Life	Mostly Endoparasites
Examples	*Ascaris lumbricoides* (Giant Roundworm), *Rhabditis*, *Enterobius vermicularis* (Pinworm), *Ancylostoma duodenale* (Hookworm)
Digestive System	Tube-Like, Tube Within Tube
Excretory System	2 Longitudinal Excretory Canals, Protonephridia, Nephridiopore
Nervous System	Centralized, Pharyngeal Nerve Ring, 4 Longitudinal Nerve Cords
Respiratory System	Absent
Circulatory System	Absent
Locomotion	4 Bands of Longitudinal Muscles
Reproduction	Sexual (Unisexual)

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Important Parasites of Aschelminthes

Common Name	Scientific Name	Host & Location	Disease
Giant Round Worm	*Ascaris lumbricoides*	Human (Small Intestine, Blood, Heart, Lungs)	Bloody sputum, cough, fever, abdominal discomfort, intestinal ulcer
Pin Worm	*Enterobius vermicularis*	Human (Large Intestine)	Itching of anus, inflammation of mucous membrane, insomnia, loss of appetite
Hook Worm	*Ancylostoma duodenale*	Human (Small Intestine)	Anemia, physical and mental retardation

4. PHYLUM ANNELIDA

Characters	Details
Common Name	Segmented Worms
Symmetry	Bilateral
Organization	Triploblastic, Coelomate
Body	Metamerical Segmentation
Mode of Life	Worms, Free Living, Ectoparasites
Examples	*Neries*, *Stylaria*, *Lumbricus terrestris*, *Pheretima posthuma* (Earthworm), *Hirudo medicinalis* (Leech)
Digestive System	Tube-Like
Excretory System	Metanephridia
Nervous System	Centralized, Brain, Double Ventral Longitudinal Nerve Cord
Respiratory System	Absent
Circulatory System	Closed Blood Circulatory System
Locomotion	Circular & Longitudinal Muscles, Hydrostatic Skeleton, Setae
Reproduction	Sexual (Hermaphrodite, Unisexual)

Importance of Leech

- They have chitinous jaws for making a puncture in the skin of the host.
- They have an anticoagulant secretion which is passed into the wound that allow smooth flow of blood.

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5. PHYLUM ARTHROPODA

Characters	Details
Common Name	Joint Footed Animals
Symmetry	Bilateral
Organization	Triploblastic, Haemocoel
Body	Segmented
Mode of Life	Variable
Examples	Largest group insects
Digestive System	Tube-Like
Excretory System	Malpighian Tubules
Nervous System	Centralized
Respiratory System	Gills, Book Lungs, Tracheal System (Spiracles)
Circulatory System	Open with Haemolymph
Locomotion	Legs, Wings
Reproduction	Sexual (Unisexual), Metamorphosis

Economic Importance of Insects

Examples	Significance
Female *Anopheles*	Transmits *Plasmodium* that causes malaria in man.
Tse-tse Fly	Transmits *Trypanosoma* that causes sleeping sickness
Common Housefly	Transmits Cholera, Typhoid, Hepatitis etc.
Insect larvae	Damage fruits and crops
Honey bee	Source of Honey & Wax
Silk Worm	Source of Silk
Insects	Predator of other harmful insects
Insect Larvae	Source of food for fish

6. PHYLUM MOLLUSCA

Characters	Details
Common Name	Soft-Bodied Animals, Shelled Animals
Symmetry	Bilateral
Organization	Triploblastic, Coelomate
Body	3 Segments, Mantle
Mode of Life	Free Living
Examples	Giant squid, *Helix aspersa* (Garden snail), *Limax* (the slug), *Mytilus* (marine mussel), *Ostrea* (oyster), *Loligo* (squid), *Sepia* (cuttlefish), Octopus
Digestive System	Tube-Like
Excretory System	Paired Nephridia
Nervous System	Centralized, 3 Pairs of Interconnected Ganglia
Respiratory System	Gills
Circulatory System	Open Circulatory System except for Cephalopoda, Haemocyanin
Locomotion	Ventral Muscular Foot
Reproduction	Sexual (Unisexual), Trochophore Larva

Importance of Snail

- Body is asymmetrical covered by single piece of shell.
- Mantle cavity is converted into lungs.

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TOPIC-5a
04 MCQs

DIGESTIVE SYSTEM

LEARNING OUTCOMES

Describe the anatomy of digestive system and specify the digestion in:

(a) Oral cavity (Role of saliva and enzymes)
(b) Pharynx (Swallowing)
(c) Oesophagus (Peristalsis, anti-peristalsis)
(d) Stomach (Chemical and mechanical digestion)
(e) Small intestine (Duodenum, Jejunum, Ileum)
(f) Large intestine (Caecum, Colon, Rectum)
(g) Discuss disorders related to nutrition (Obesity, Anorexia Nervosa).

DIGESTION

- Process by which large, complex non-diffusible substances are converted into small, simple and diffusible forms is called digestion.
- Digestion that occurs with help of enzymes is called chemical digestion.
- Digestion that occurs without enzymes is called mechanical digestion e.g. mastication.
- Digestion that occurs inside the cell (food vacuole) is called intracellular digestion e.g. digestion in amoeba.
- Digestion that occurs outside the cell (in digestive cavity) is called extracellular digestion e.g. digestion in stomach.

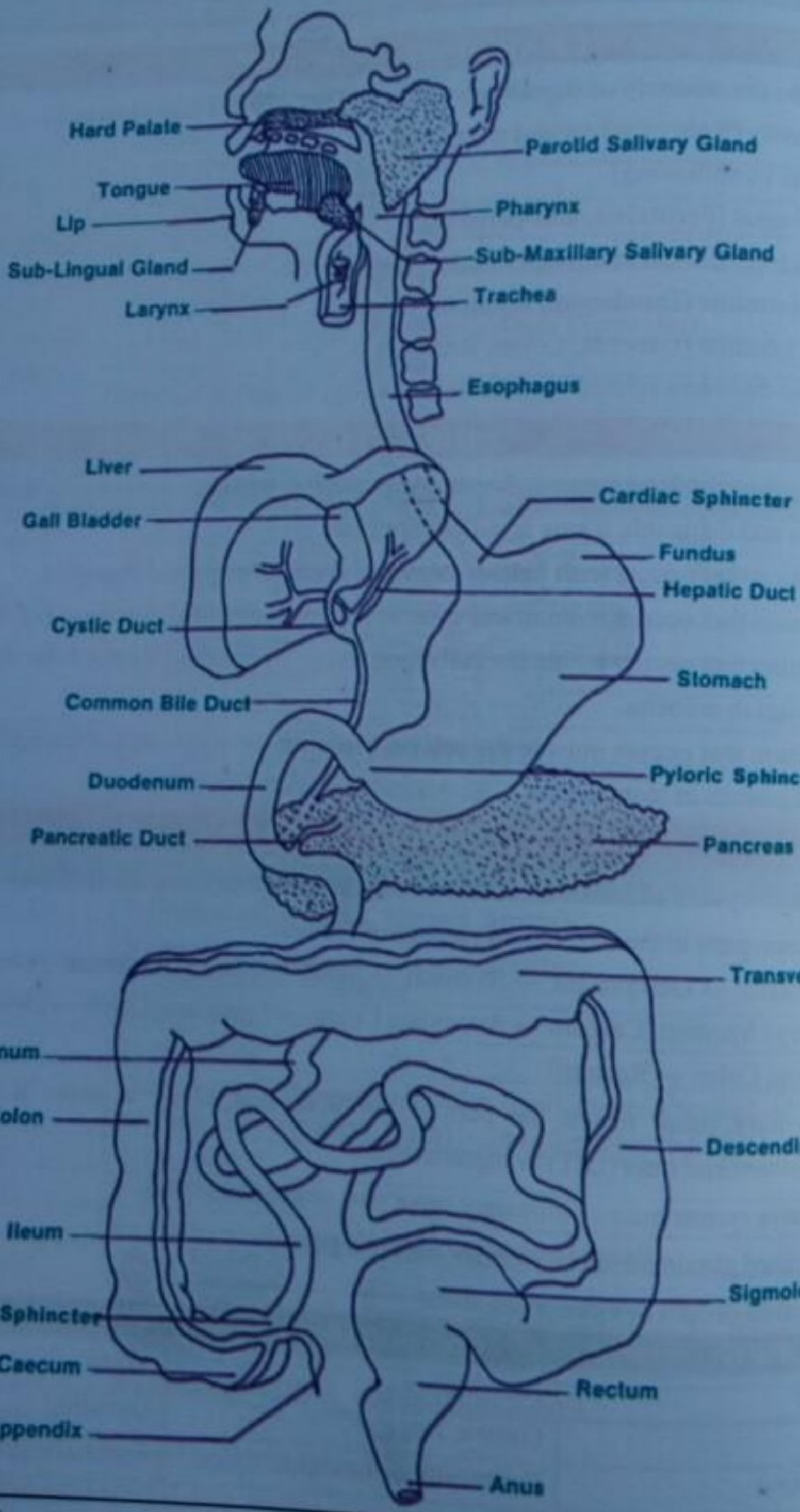
DIGESTIVE SYSTEM

- Digestive system of a man consists of structures extending from mouth to anus (tube like)
- The main parts in the direction of passage of food are:
  Oral cavity → Oesophagus → Stomach → Small Intestine (Duodenum → Jejunum → Ileum) → Large Intestine (Caecum → Ascending Colon → Transverse Colon → Descending Colon → Sigmoid Colon → Rectum)
- ***Alimentary canal*** means the part of gut from oral cavity to anus. It is also called as ***gastrointestinal tract*** (GIT) or digestive tract.
- ***Digestive system*** means alimentary canal plus associated glands.
- Associated glands are salivary glands, liver and pancreas.
- Digestion occurs at three main sites:

Parts	Chemical Digestion	Mechanical Digestion
Oral Cavity	Amylase	Teeth
Stomach	Gastric Juice	Grinding
Small intestine	Pancreatic & Intestinal Juice	Emulsification

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HUMAN DIGESTIVE SYSTEM



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DIGESTION IN ORAL CAVITY

Oral Cavity

It is the site for entrance of food in alimentary canal.

Overall Functions of Oral Cavity

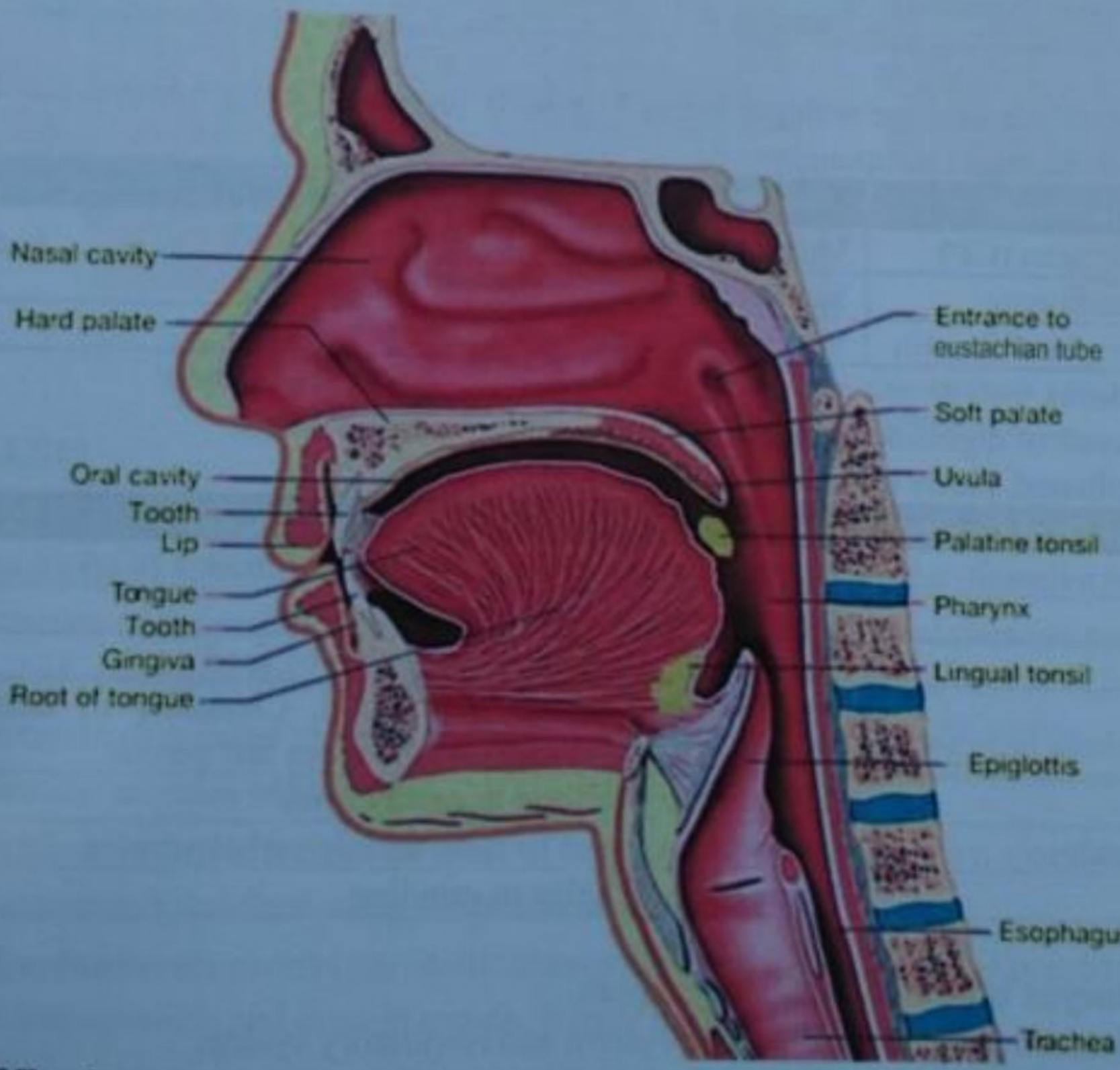
It performs four important functions:

- Selection of Food
- Grinding or Mastication
- Lubrication
- Digestion

Structures Associated with Oral Cavity

Oral cavity is bounded by:

- Palate
- Tongue
- Teeth
- Cheeks



Selection of Food

- When food enters in oral cavity, it is tasted, smelled and felt.
- Oral cavity is aided in selection by the senses of smell and sight.
- Tongue being sensory and muscular organ plays the most important role in the selection of food through its taste buds.

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UHS Topic-5a

Grinding or Mastication

- Food is ground by means of molar teeth.
- This grinding is useful because:

(a) Oesophagus allows relatively small pieces to pass through.
(b) Small pieces have much more surface for enzymes to attack.

Lubrication & Digestion

These are main functions of oral cavity accomplished by saliva. Saliva is secreted by three pairs of salivary glands:

Salivary Glands

- Three pairs of salivary glands are:

Glands	Location	Secretions	Opening of Ducts
Parotid glands (Largest)	In front of ears	Saliva with amylase	Posterior part of oral cavity
Submandibular/ Sumaxillary glands	Behind jaws	Saliva with amylase & mucus	Floor of oral cavity
Sublingual glands (Smallest)	Below tongue	Saliva with mucus only	Floor of oral cavity

Saliva

- Fresh saliva is alkaline with pH nearly 8, quickly loses carbon dioxide and gets to pH 6.
- It has three major components:

Components	Role
Water and Mucus (GP)	Moisten and lubricate food
Sodium bicarbonate	Stabilizes pH and is slightly antiseptic
Salivary Amylase/ Ptyalin	Starch/ Glycogen → Maltose

End Result Bolus

- End result of digestion in mouth is small oval lump called ***bolus***.
- It is softened, partly digested slimy food mass.

Anatomy of Oral Cavity	Physiology of Oral Cavity
Teeth	Mastication/ Mechanical digestion of food
Lips	Communication, Hold food in position
Jaws	Mastication/ Mechanical digestion of food
Tongue	Manipulation of food, hold food, Cleansing of teeth, Taste, Communication, Swallowing, mucus and serous
Soft Palate	Prevents entry of food in nasal cavity
Salivary Glands	Chemical digestion of food mainly carbohydrates
Hard Palate	Palatine bones, helps in grinding

PHARYNX

- The pharynx is a cavity behind the mouth.
- It is common passage for digestive system and respiratory system.
- It is lined by mucus.

SWALLOWING

- Transfer of bolus from buccal cavity to pharynx and then to oesophagus is called ***swallowing / deglutition***.
- Beginning of swallowing is voluntary action and then it becomes involuntary. The swallowing procedure is regulated by nerves in the medulla oblongata and pons.

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Events of Swallowing

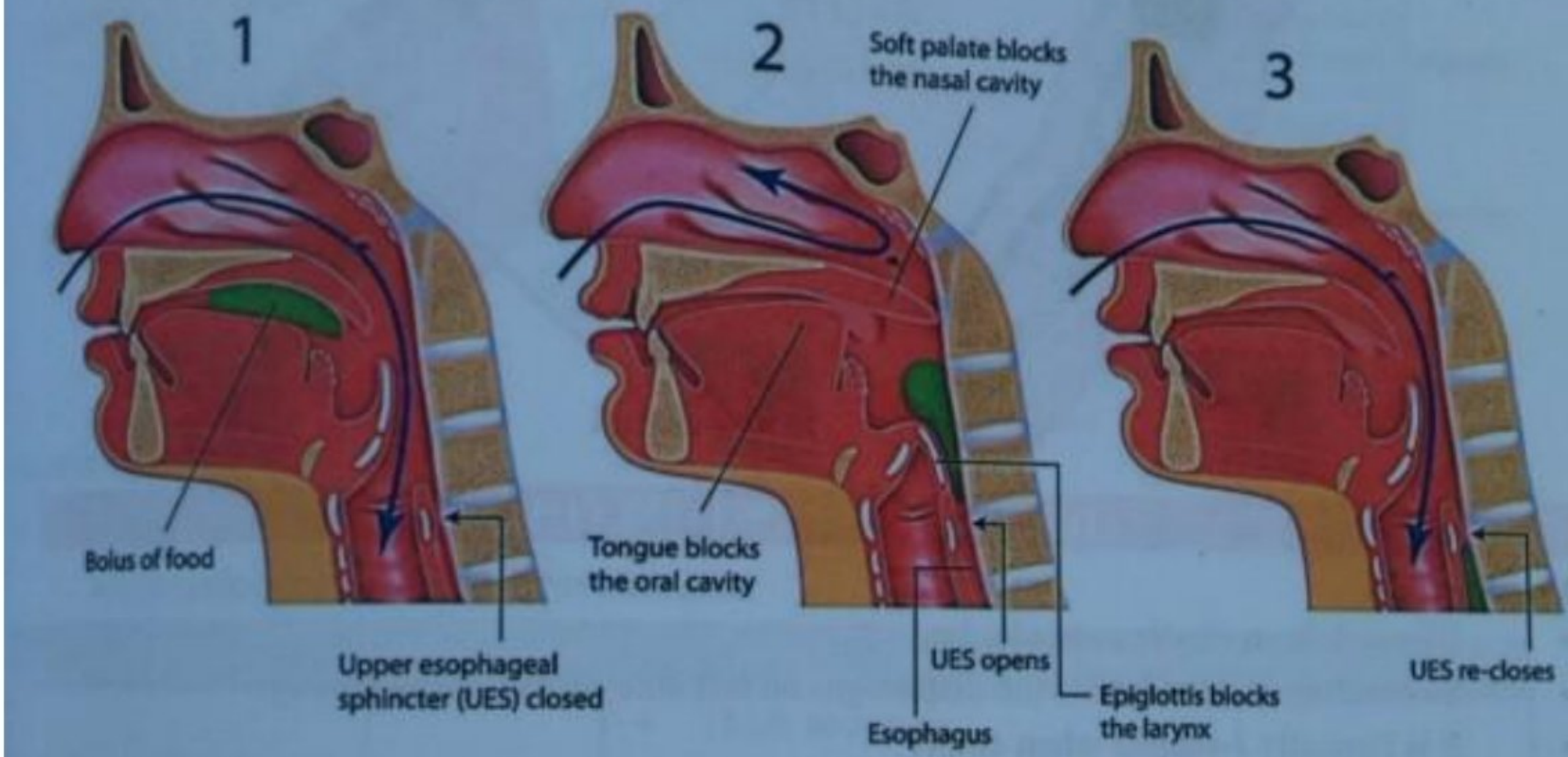
(i) Tongue moves upwards and backwards against the roof of mouth, forcing the bolus to the back of the mouth cavity.

(ii) Soft palate is pushed up by tongue which closes nasal cavity.

(iii) Tongue forces the epiglottis (flap of cartilage) into more or less horizontal in position thus closing the opening of windpipe (glottis). Epiglottis diverts the bolus toward oesophagus.

(iv) The larynx (cartilage box round the top of windpipe) moves upward under the back of tongue.

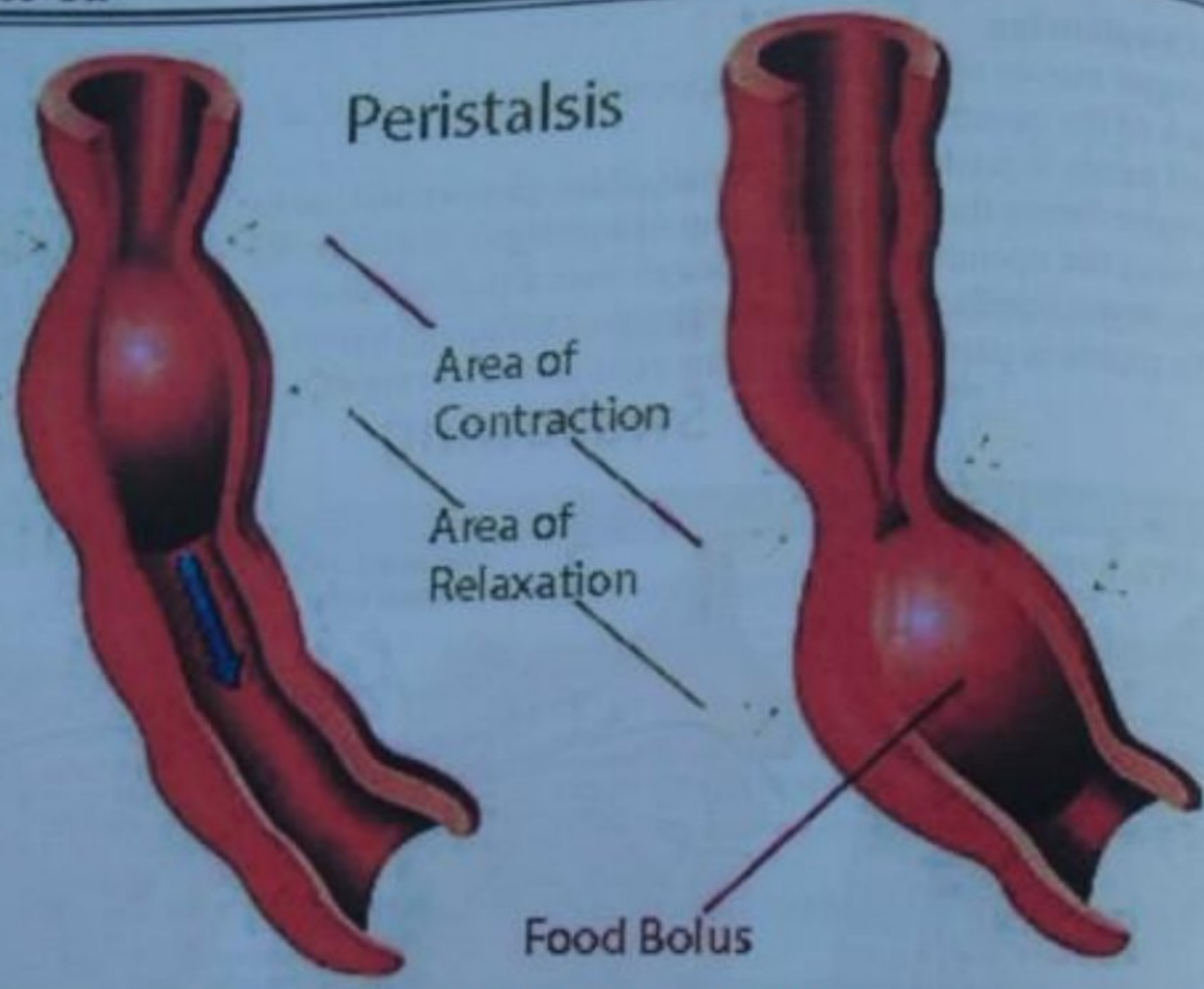
(v) The glottis is partly closed by the contraction of ring of muscles.



PERISTALSIS

- ***Peristalsis*** is characteristic movement of digestive tract due to alternate contractions and relaxations of smooth muscles by which food is pushed along the digestive tract.
- It consists of the wave of contraction of circular and longitudinal muscles preceded by the wave of relaxation thus squeezing the food down along the canal.
- Relaxation of circular muscles in front of food is followed by a wave of strong contraction of circular muscles behind food.
- Peristalsis starts just behind the mass of food, from the buccal cavity, along the oesophagus to the stomach and then along the whole alimentary canal.
- ***Antiperistalsis*** are reverse peristaltic movements due to which food is passed from intestine back into stomach and even in mouth. It may lead to vomiting.
- Hunger contractions are peristaltic contractions caused by low blood glucose level. These create an uncomfortable sensation often called ***hunger pangs***.
- Hunger pangs usually begin 12-24 hours after the previous meal.
- ***Gravity*** assist the movement of material through the oesophagus, especially when liquids are swallowed.

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DIGESTION IN STOMACH

Introduction

- Stomach is an elastic muscular bag.
- Stomach is situated below the diaphragm on left side of abdominal cavity.
- It is typically J-shaped when empty.

ANATOMY OF STOMACH

Parts

- First part of stomach where oesophagus empties its contents into stomach is called ***cardiac region***.
- At the junction between esophagus and the stomach, there is a special ring of muscles called ***cardiac sphincter.*** It is also called as lower oesophageal sphincter (LES). When the sphincter muscles contract, the entrance to the stomach closes and prevents backward movement of food. It opens when a wave of peristalsis coming down the esophagus reaches it.
- Point where stomach joins duodenum is called ***pyloric sphincter***. Stomach empties into the duodenum through the relaxed pyloric sphincter.

Layers

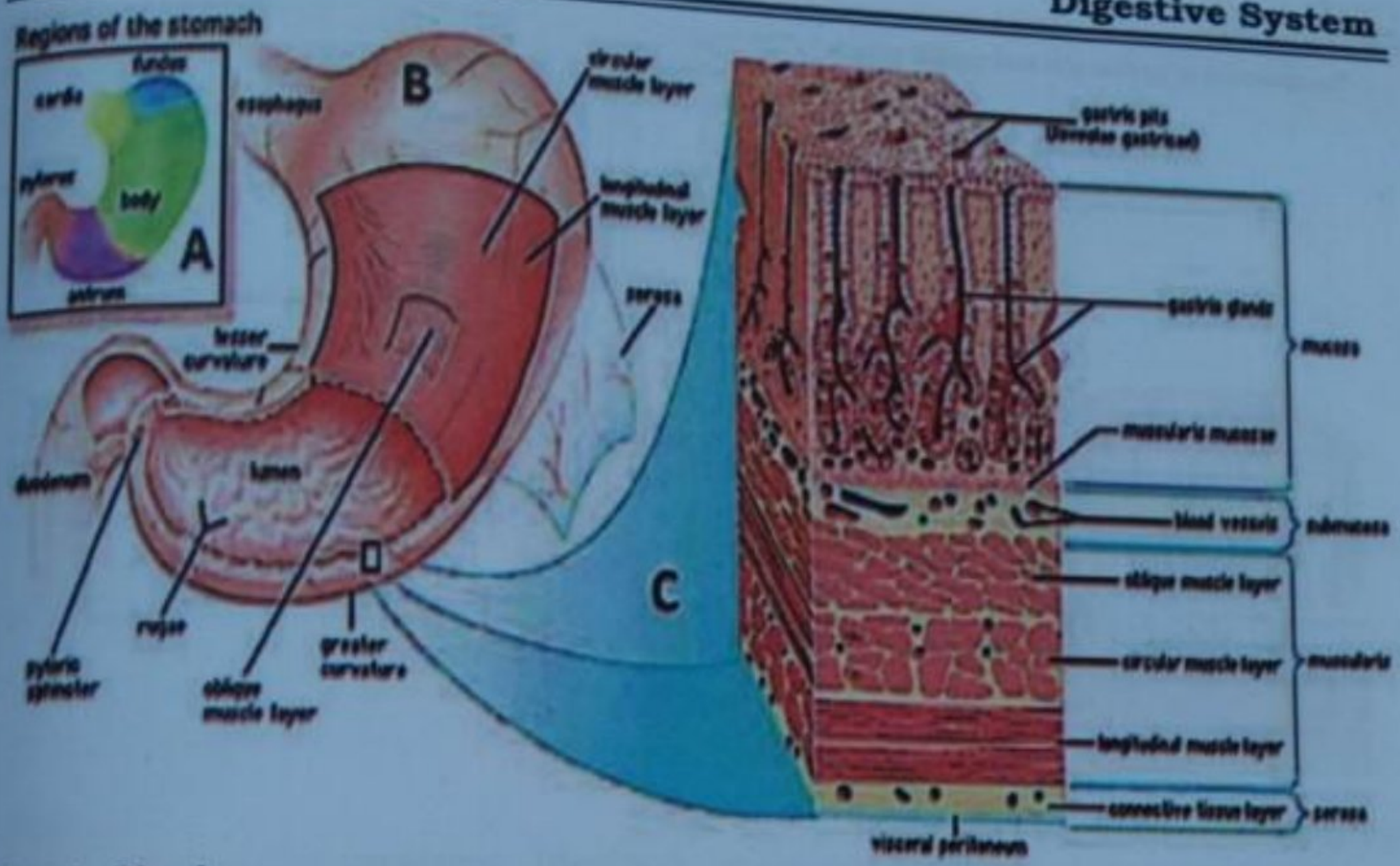
- Stomach wall is composed of three principal layers i.e.

(i) Outer layer of connective tissue called ***serosa*** or ***adventitia***.

(ii) Middle layer of smooth muscles called ***muscularis externa*** alongwith submucosa. This muscular layer has innermost oblique muscles, middle circular and outer longitudinal muscles.

(iii) Inner layer (***mucosa***) of connective tissue with many glands.

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Gastric Glands

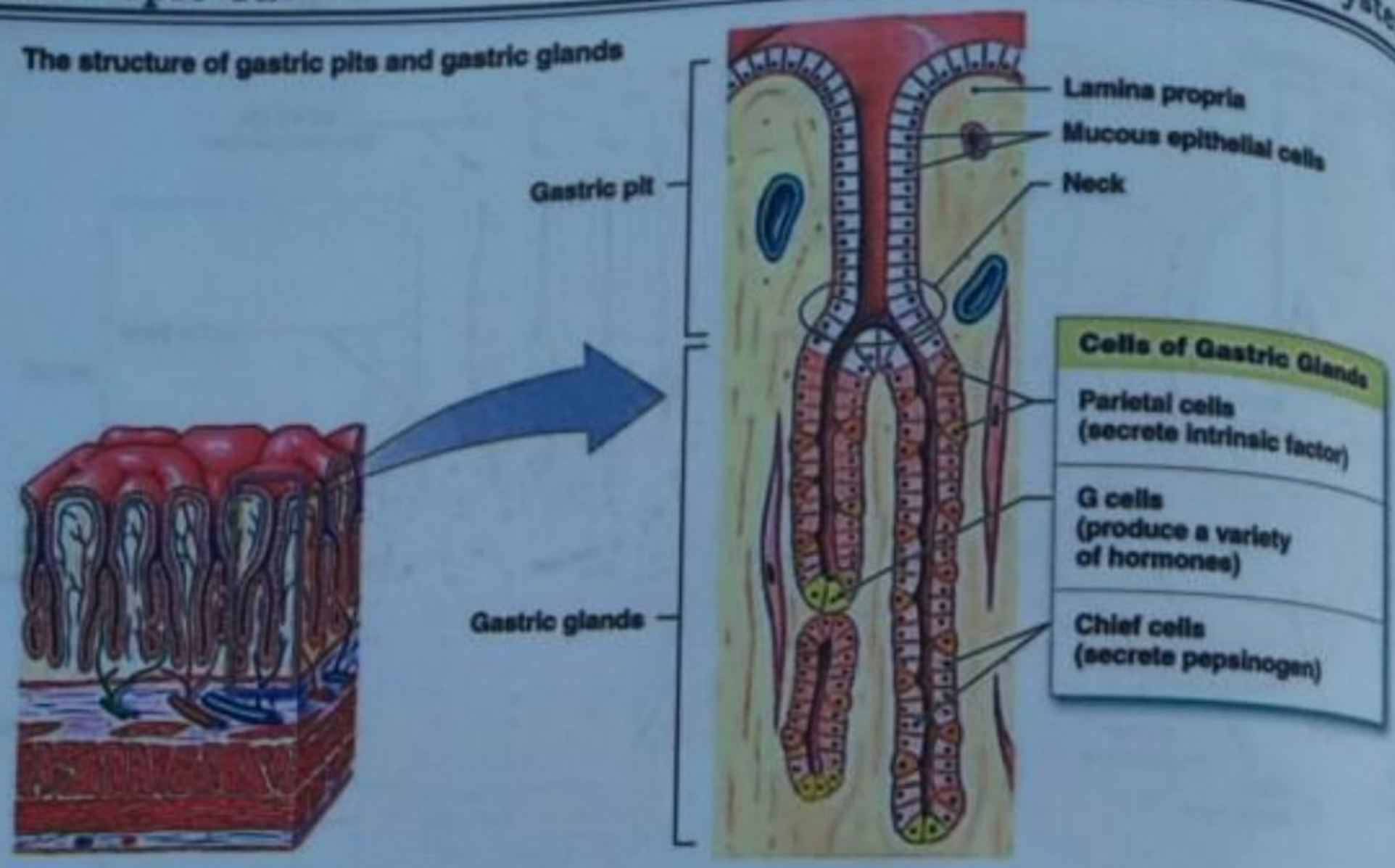
- Stomach has both ***exocrine*** and ***endocrine glands***. Exocrine glands secrete gastric juice while endocrine secrete gastrin hormone.

Cells	Secretions	Functions
Mucous cells	Mucus	• Thick secretion • Covers inside of stomach • Protects stomach wall
Parietal/Oxyntic cells	HCl	• Maintains pH from 2-3 • Provide acidic medium for enzymes • Softens food & kills microorganisms • Converts inactive pepsinogen into pepsin • Inactivates salivary amylase • Low pH denatures many proteins
Zymogen/ Chief/ Principal cells	Pepsinogen	Hydrolyzes proteins into peptones and polypeptides.
G cells/ Endocrine cells	Gastrin	Stimulates gastric juice production, secretion & stomach motility

- Pepsinogen $\xrightarrow[\text{Pepsin}]{\text{HCl}}$ Pepsin
- Proteins $\xrightarrow{\text{Pepsin}}$ Polypeptides & Peptones

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The structure of gastric pits and gastric glands



Regulation of Gastric Juice Production

- Both nervous and hormonal mechanisms regulate gastric secretions.
- Gastric juice secretion is regulated by small, sight and quality of food.
- Main hormones that regulate gastric secretions are gastrin and secretin.
- If more protein is present in food, it stimulates production of gastrin hormone from gastric endocrine lining of pyloric region of stomach.
- More protein → More gastrin → More gastric juice

PHYSIOLOGY OF STOMACH

1. **Food Storage**
- It stores food from meals for some time, making discontinuous feeding possible.

2. **Digestion of Food**
- It partly digests protein food.
- Stomach shows both chemical and mechanical digestion. Mechanical digestion is carried out by middle muscular layer and is called ***churning***. While chemical digestion is carried out by gastric glands.
- Muscular walls thoroughly mix up the food with gastric juice.
- End result of digestion in stomach is formation of semi-solid mass called ***chyme*** (semi solid

3. **Absorption**
- Some absorption also occurs at stomach.

4. **Defense/ Immunity**
- Mucous membrane and HCl act as barriers against germs.

POINT TO PONDER

Smooth muscles are present throughout alimentary canal then why churning occurs only in stomach?

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DIGESTION IN SMALL INTESTINE

- It is the longest part of alimentary canal.
- There are three parts of small intestine i.e. duodenum, jejunum and ileum.
- Duodenum is first & the shortest part of small intestine and is about 20-25 cm long.
- Jejunum is second part with length of about 2.4 m ($2/5^{th}$ of small intestine)
- Ileum is the third and the longest part with length of 3.6 m ($3/5^{th}$ of small intestine).
- Small intestine has role to complete digestion and absorb digested products.

DUODENUM

- Duodenum receives secretions from liver and pancreas.
- Duodenum also has its own secretions.
- It acts both as exocrine and endocrine gland.
- Exocrine function of duodenum is secretion of intestinal juice and endocrine function is release of secretin and small amount of gastrin hormone.
- ***Secretin*** is hormone produced by the action of acidic food on internal mucosa of duodenum. It inhibits production of gastric secretions and promotes production of secretions of liver and pancreas.
- Chyme after neutralization by secretions from liver, pancreas and duodenum is called ***chyle*** (liquid).

Pancreas

- Pancreas is also a large ***dual gland***.
- Pancreatic juice is produced by exocrine part of pancreas, which is poured in duodenum by pancreatic duct.
- Endocrine part of pancreas produces hormones insulin and glucagon.

Components of Pancreatic Juice

Component	Role
Amylase (amylopsin)	Carbohydrate digesting enzyme (Starch/Glycogen → Maltose)
Lipase	Fat digesting enzyme (Fats → Fatty acids + Glycerol)
Trypsin	Protein digesting enzyme (Proteins → Polypeptides + Peptones)
Chymotrypsin	Protein digesting enzyme (Proteins → Polypeptides + Peptones)
Sodium bicarbonate	Neutralizes chyme, provides alkaline medium

- Trypsin is secreted as inactive trypsinogen, which is activated by enterokinase, an enzyme secreted by the lining of duodenum.
- Chymotrypsin is secreted as inactive chymotrypsinogen, which is activated by trypsin.

Liver

- Bile is produced in liver, stored in gall bladder, acts in small intestine.
- Bile is transported from liver to gall bladder then to small intestine through bile duct.
- Bile is green, watery fluid containing salts and ***no enzyme***.
- Green colour of bile is due to bile pigments produced due to breakdown of hemoglobin.

POINT TO PONDER

How the common bile duct is formed?

POINT TO PONDER

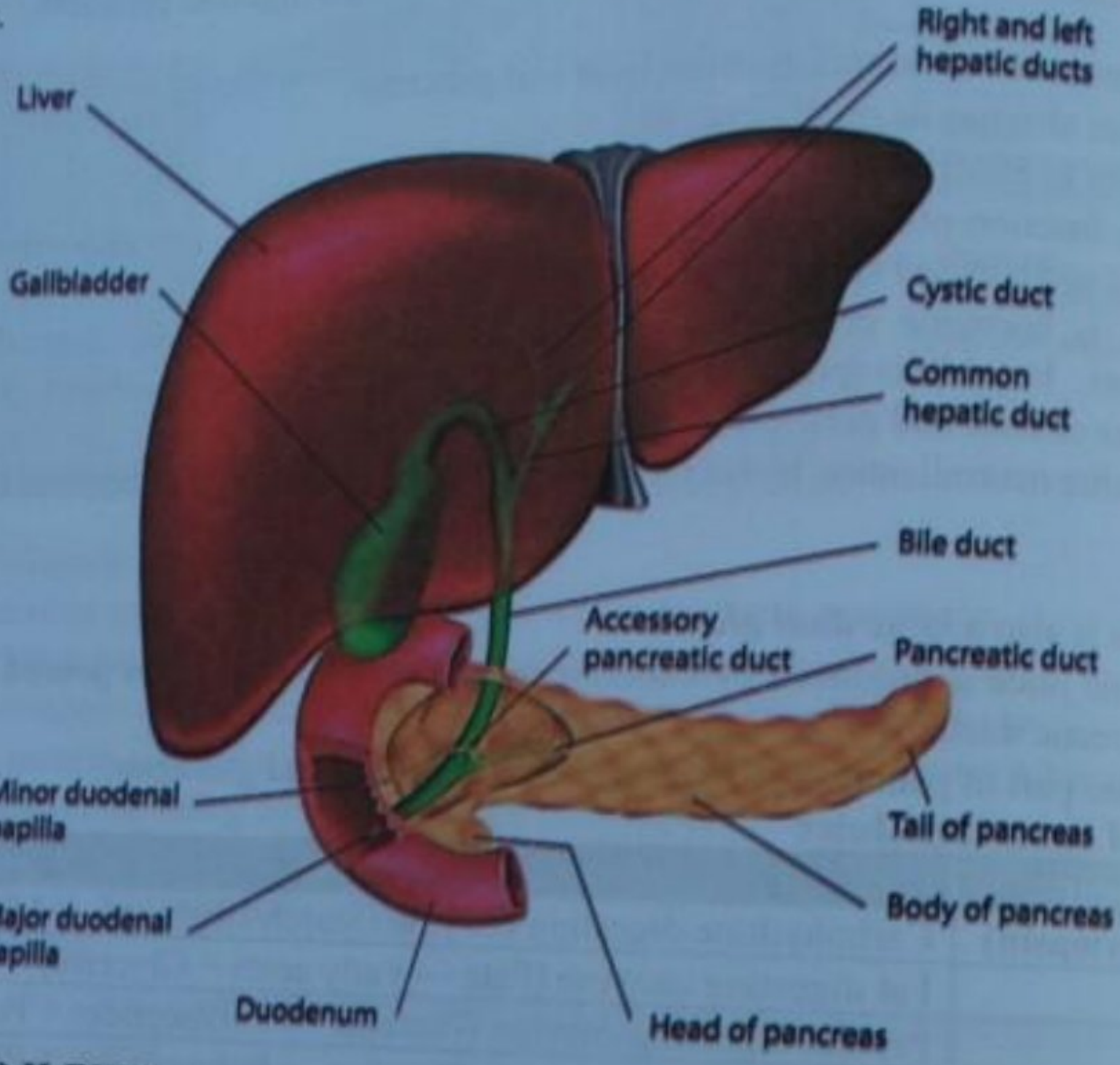
What will happen to digestion if gall bladder is removed due to gall stones?

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- Bile salts emulsify fats i.e. converts it into small globules.
- These small globules are easily digested by water soluble lipase.
- Accumulation of bile pigments in blood causes *jaundice*.
- Cholesterol secreted by liver may precipitate in the gall bladder to produce ***gall stones***, which may block the release of bile.

POINT PONDER 70

What is difference between chyme and chyle?



JEJUNUM AND ILEUM

- Jejunum and ileum are involved in complete digestion of food.

Enzymes of Intestinal Lining

Enzymes	Substrates	Products
Amino peptidase	Polypeptides	Dipeptides
Erypsin	Dipeptides	Amino acids
Lipase	Fats	Fatty acids & glycerol
Maltase	Maltose	Glucose
Lactase	Lactose	Glucose & galactose

Absorption of Food

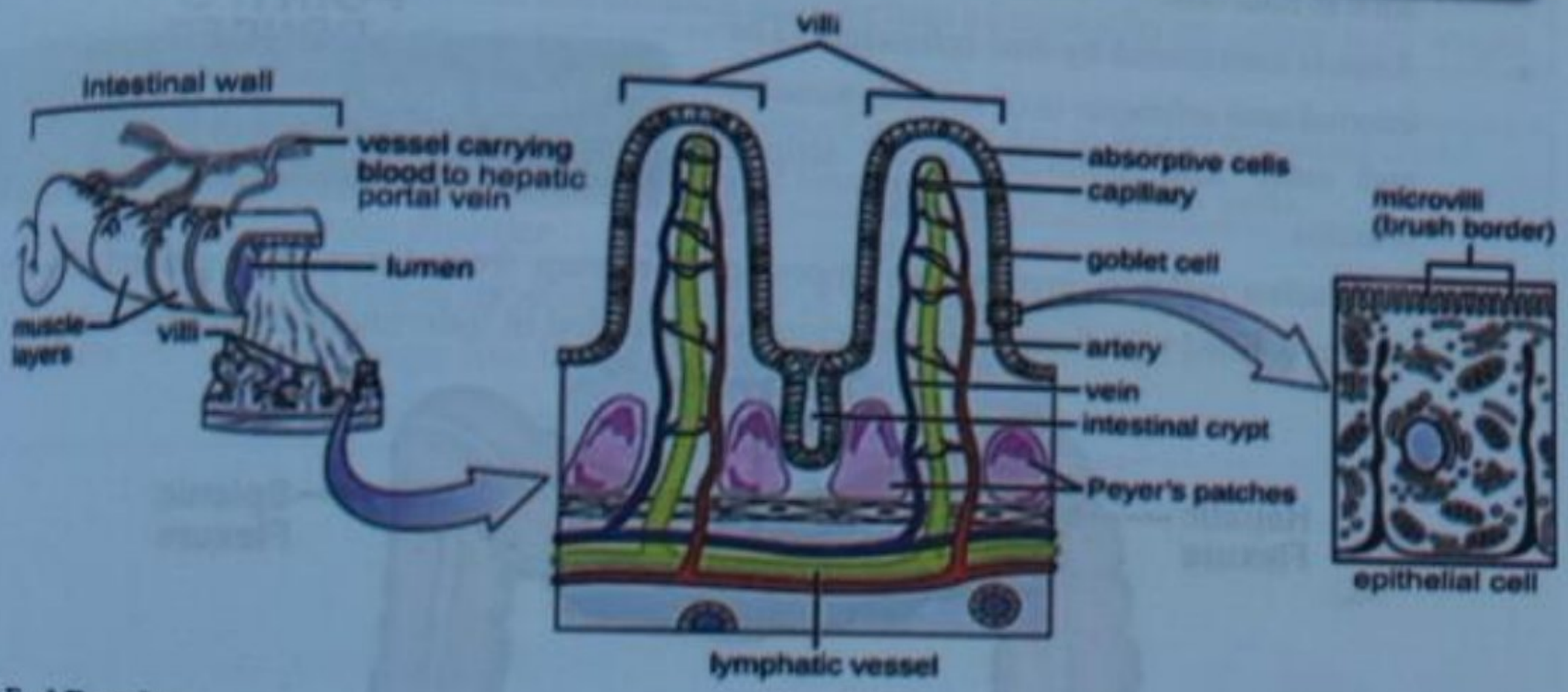
- Internal surface of ileum has many folds, which exhibits velvety appearance due to the presence of numerous finger-like outgrowths called ***villi***.
- Each villus has outer covering of epithelial cells, blood capillaries and ***lacteals***.
- Epithelial cells of villi have countless, closely packed cylindrical processes, ***microvilli***.
- The total area of absorption becomes incredibly large due to the infoldings, villi and microvilli.

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- The end products of starch and glycogen, which is glucose, and the end product of proteins (amino acids) are absorbed into blood capillaries of villi by diffusion or active transport. Some of the fatty acids and glycerol (end products of lipid breakdown) are also absorbed into blood stream.
- A large proportion of fatty acids and glycerol enter the epithelial cells of villi, where they recombine into fats. These fats alongwith proteins enter into the lacteals and are transported in form of lipoproteins droplets (***chylomicrons***) through lymph vessels. These pass into blood stream via thoracic lymph duct. The lipoproteins are hydrolysed by blood plasma enzyme and enter body cells, where they may be used in respiration or stored as fat in the liver, muscles or under the skin.

POINT TO PONDER

What do you know about Lactose intolerance?



End Result

- After absorption, the intestinal contents are pushed along the alimentary canal by normal peristaltic activity.
- At the end of ileum, there is an ***ileocolic/ileocecal sphincter*** that transfers residues to large intestine.

LARGE INTESTINE

- Large intestine is last part of alimentary canal.
- It is divided into caecum, colon and rectum.

Caecum

- ***Caecum*** is a blind sac that projects from the large intestine between ileum and colon.
- Finger-like appendix arises from the blind end of caecum. Inflammation of appendix is called ***appendicitis***.

Colon

- ***Colon*** is longest part of large intestine. It is further divided into ascending, transverse, descending and sigmoid colon.
- The material that pass from small intestine to large intestine contain a large amount of water, dissolved salts and undigested material.

POINT TO PONDER

What happens if vitamin K is not produced in large intestine?

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UHS Topic-5a

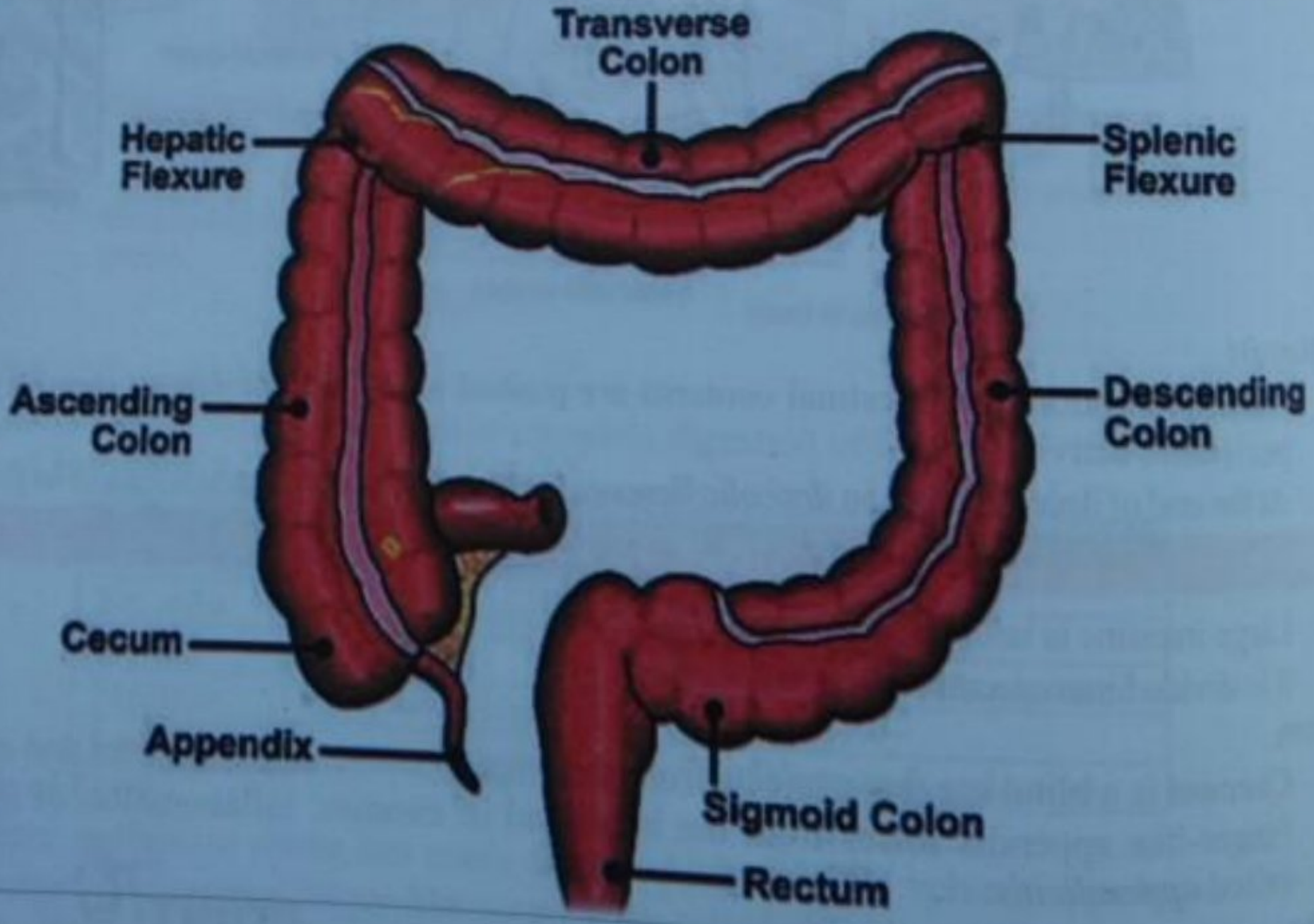
- Large intestine is involved in absorption of water and salts while undigested material is rejected as feces.
- The fecal matter contains a large number of bacteria, plant fibers, sloughed off mucosal cells, mucus, cholesterol, bile pigments and water.
- Less absorption leads to ***diarrhoea*** and then dehydration. If this condition is unchecked, it leads to dehydration and even death. Excessive absorption of water leads to ***constipation***.
- Large intestine also harbors a large population of useful bacteria (mutualistic relation) that synthesize some vitamins especially vitamin K, which are absorbed in blood.

Rectum

- It is the last part of large intestine where feces are temporarily stored and rejected through anus at intervals.
- Anus is surrounded by two sphincters. The internal anal sphincter is of smooth muscles and outer anal sphincter is of striped muscles.
- ***Defecation reflex*** is involved in emptying of rectum from feces. It is generated when rectum is filled with feces. It is consciously controlled in individuals other than infants.

POINT TO PONDER

Name the vestigial part in human digestive system?



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DISORDERS RELATED TO NUTRITION

OBESITY

Definition	It is the term employed when a person has abnormal amount of fat on the body.
Causes	• Overeating fatty food • Hormonal imbalance
Mechanism	• Certain cells accumulate fat drops in their cytoplasm which increase in number and size to form one large globule in the middle of cell. • Group of these fat cells form adipose tissue. • There is fat stored in adipose tissue in the abdomen around the kidneys and under the skin.
Effects	An obese person is more likely to suffer from high blood pressure, heart disease, diabetes mellitus and stomach disorder than a person who has normal body weight.

ANOREXIA NERVOSA

Definition	This term is employed to the loss of appetite due to fear of becoming obese. It is common in human females between the age of 12 -21 years.
Causes	Neurotic disorder
Effects	• Loss of appetite due to fear of becoming obese. • Weight loss to dangerous level. • Breakdown of essential proteins of body.

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TOPIC-5b
04 MCQs

GAS EXCHANGE

LEARNING OUTCOMES

(a) Understand the anatomy of respiratory system (Nostrils, Trachea and Lungs), functions of cartilage, cilia and goblet cells.
(b) Explain the mechanism of breathing (Inspiration and Expiration).
(c) Know how blood carries oxygen and carbon dioxide between lungs and body tissues.
(d) Discuss structure and role of respiratory pigments e.g. (Haemoglobin, Myoglobin).
(e) Discuss the respiratory disorders with causes and symptoms (Tuberculosis, Emphysema and Lung Cancer).

ANATOMY OF HUMAN RESPIRATORY SYSTEM

Human respiratory system includes:

1. Air Passage Way
2. Lungs

AIR PASSAGE WAY

- It is passage way by which air enters or leaves the lungs.
- It consists of following components in sequence:
  Nostrils → Nasal Cavities → Pharynx → Larynx → Trachea → Bronchi → Terminal Bronchioles → Respiratory Bronchioles → Alveolar Ducts → Alveolar Sacs

Components	Anatomy	Physiology
Nostrils (2)	• Bone & cartilage • Hair • Mucous membrane	• Filtration of larger particles. • Moistening • Warming
Nasal Cavities (2)	• Each cavity subdivided into 3 passage ways. • Ciliated epithelium • Mucous membrane	• Filtration • Moistening • Warming
Pharynx/ Throat	• Muscular passage • Mucous membrane	• Channelizes air to larynx
Larynx/ Voice box	• Cartilaginous box • Glottis • Epiglottis • Vocal cords	• Air passage way • Voice production
Trachea/ Windpipe (1) (ventral to oesophagus)	• C-shaped cartilage rings • Ciliated epithelium • Mucous cells/ Goblet cells	• Air passage way • Filtration • Moistening
Primary Bronchi (2)	• C-shaped cartilage rings • Ciliated epithelium • Mucous cells	• Air passage way • Filtration • Moistening
Secondary & Tertiary Bronchi	• Irregular cartilage plates • Ciliated epithelium • Mucous cells	• Air passage way • Filtration • Moistening

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Terminal Bronchioles	• Diameter of 1 mm or less • No cartilage • Ciliated epithelium • Mucous cells	• Air passage way • Filtration • Moistening
Respiratory Bronchioles	• No cartilage • No Ciliated epithelium • Mucous cells	Gaseous exchange with blood
Alveolar Ducts & Alveolar Sacs	• Single layered surrounded by blood capillaries • Lined by surfactant	Gaseous exchange with blood

POINT TO PONDER

What is role of cilia in trachea?

- Epiglottis is cartilaginous lid having a muscularly controlled, hinge-like action.
- Vocal cords are two thin edged stretched fibrous bands. These are larger in male so male have low pitched voice.
- Cartilage in air passage way prevents collapse.
- Bronchioles are made up of mainly circular smooth muscles. Change in diameter is possible through bronchioles.
- Air sac is the functional unit of lungs.

Components	Cartilage	Ciliated epithelium with goblet cells	Smooth muscles	Elastic fibers
Trachea	✓	✓	✓	✓
Bronchi	✓	✓	✓	✓
Terminal Bronchiole	×	✓	✓	✓
Respiratory Bronchiole	×	×	✓	✓
Alveolar Duct	×	×	✓	✓
Alveolar Sac	×	×	✓	✓

LUNGS

- They are closed sacs that are connected to the outside by the way of trachea and nostrils or mouth.
- The right and left lungs are slightly unequal in size.
- Lungs are spongy because of presence of millions of alveoli.
- Lungs are placed in the chest cavity.
- Chest cavity is bounded by ribs and intercostal muscles on the sides.
- The floor of the chest is called diaphragm. Diaphragm is a sheet of skeletal muscles.
- Lungs are covered by a double layered thin membranous sac called ***pleura***.

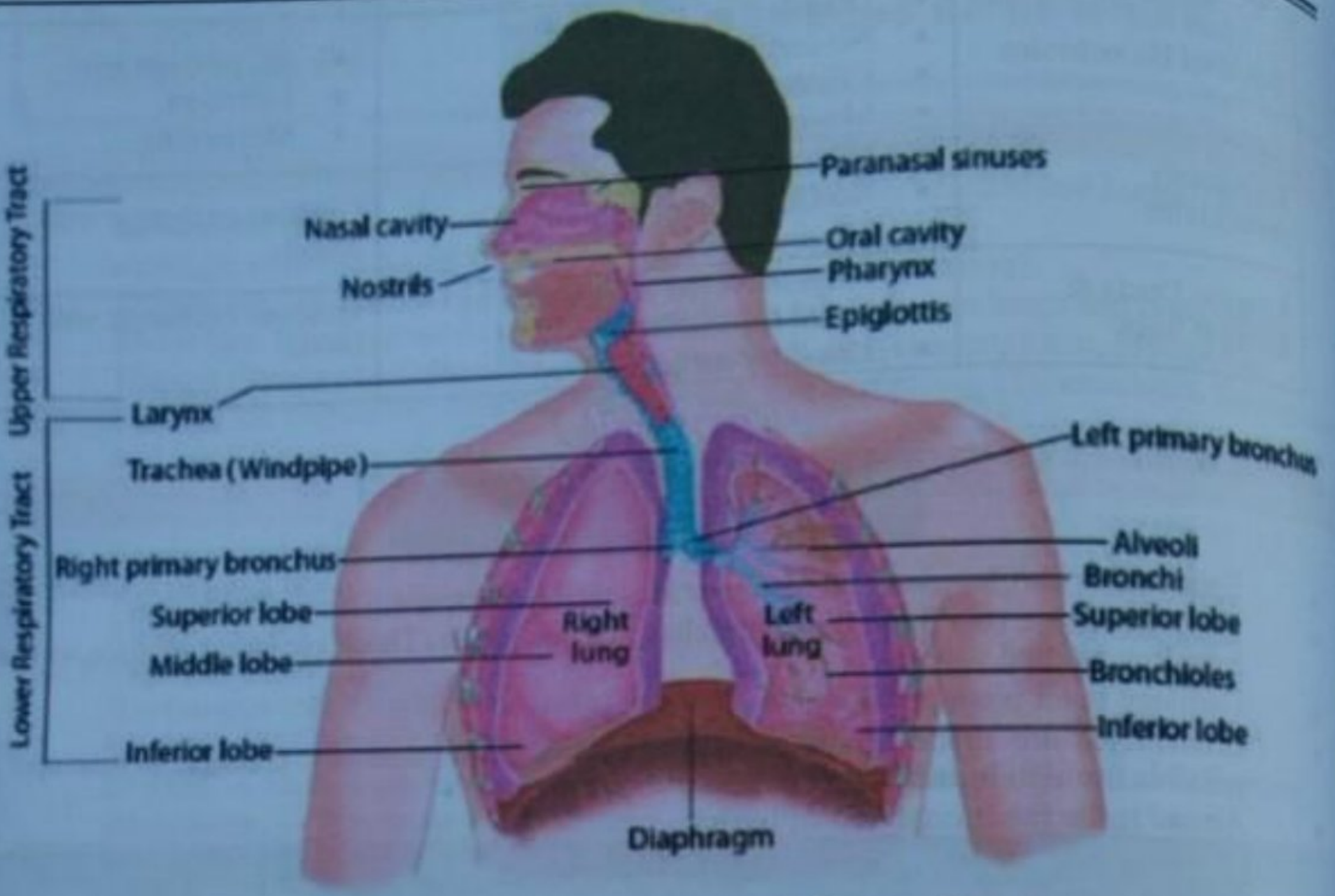
POINT TO PONDER

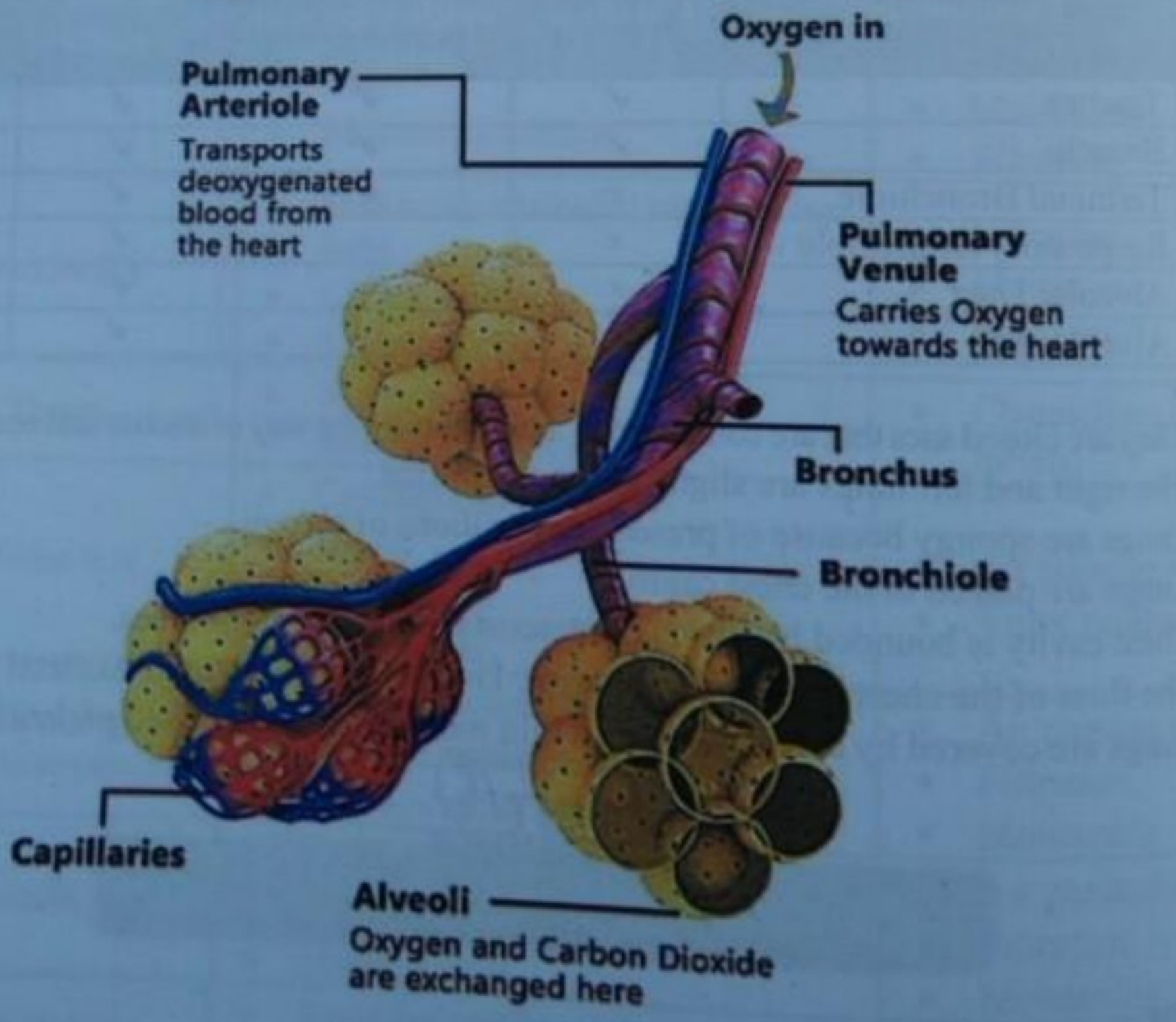
Is there any difference between right and left lung?

Surfactant

- Mixture of lipoproteins secreted by alveolar epithelium
- Forms a layer over the surface of the fluid within the alveoli to reduce surface tension
- In premature infants, respiratory distress syndrome is common due to its deficiency

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BREATHING

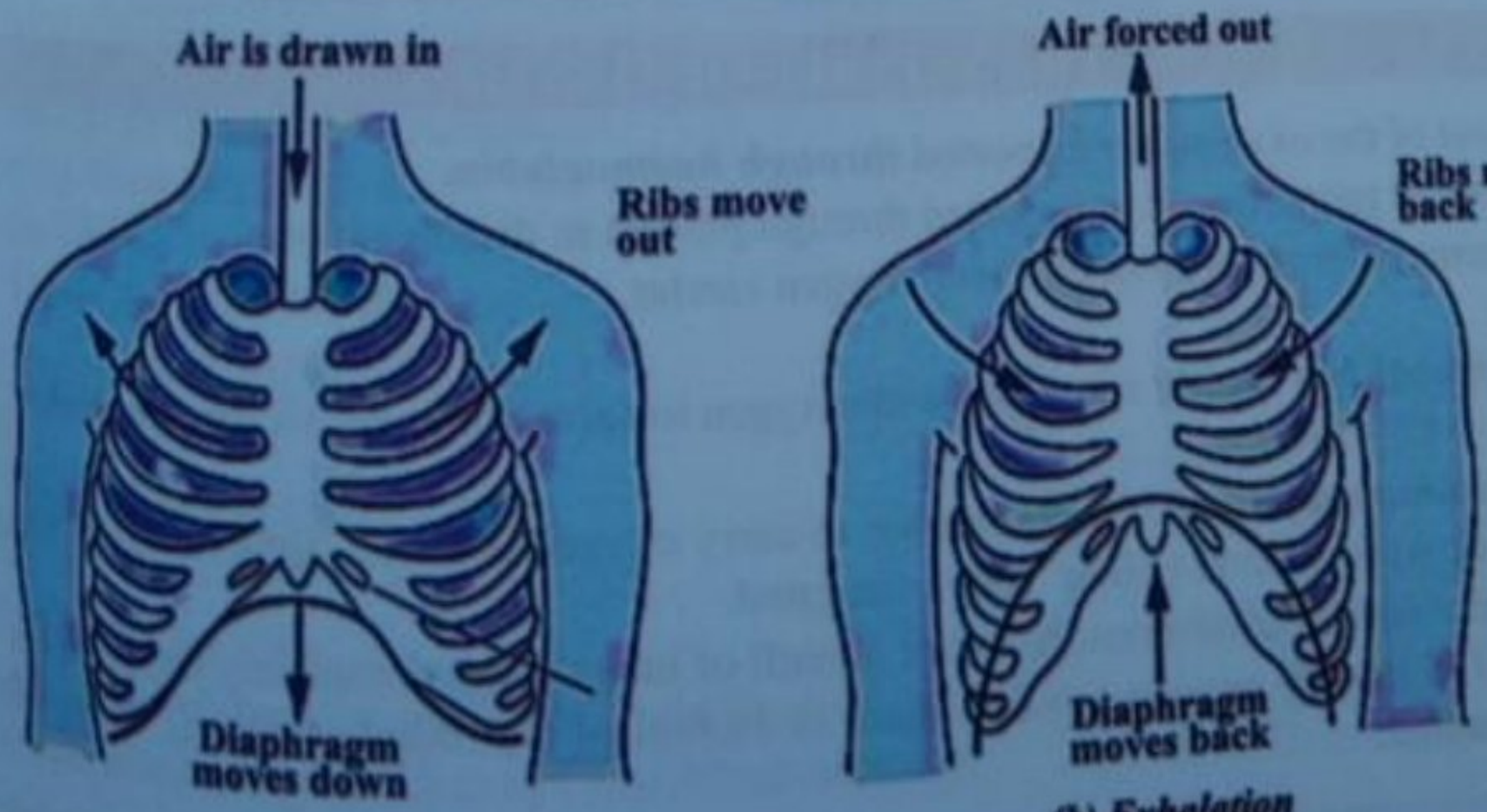
- Breathing is a process by which fresh air containing oxygen is pumped into the lungs and air with more carbon dioxide is pumped out of lungs.
- It has both voluntary and involuntary control.
- It is a mechanical process consisting of two phases, inspiration & expiration.
- During rest, normal breathing rate is 15-20 breaths/min in humans and it can increase to 30/min during exercise.

Phases of Breathing

Feature	Inspiration	Expiration
Another name	Inhalation	Exhalation
Basic Mechanism	Passive expansion of lungs	Passive contraction of lungs
Nature	Active process involving muscle contraction	Passive process involving elastic recoil
Definition	Taking in of air into the lungs	Removal of air low in O_2 and high in CO_2 from lungs outside body
Diaphragm	Contracts Moves down Becomes less dome-like	Relaxes Moves up Become more dome-like
Rib muscles	Contract	Relax
Rib cage	Moves upward, forward & outward	Moves downward, inward & backward
Overall Change in Volume	Increases	Decreases
Changes in Pressure	Decreases	Increases
Air moves	Into lungs	Out of lungs

POINT TO PONDER

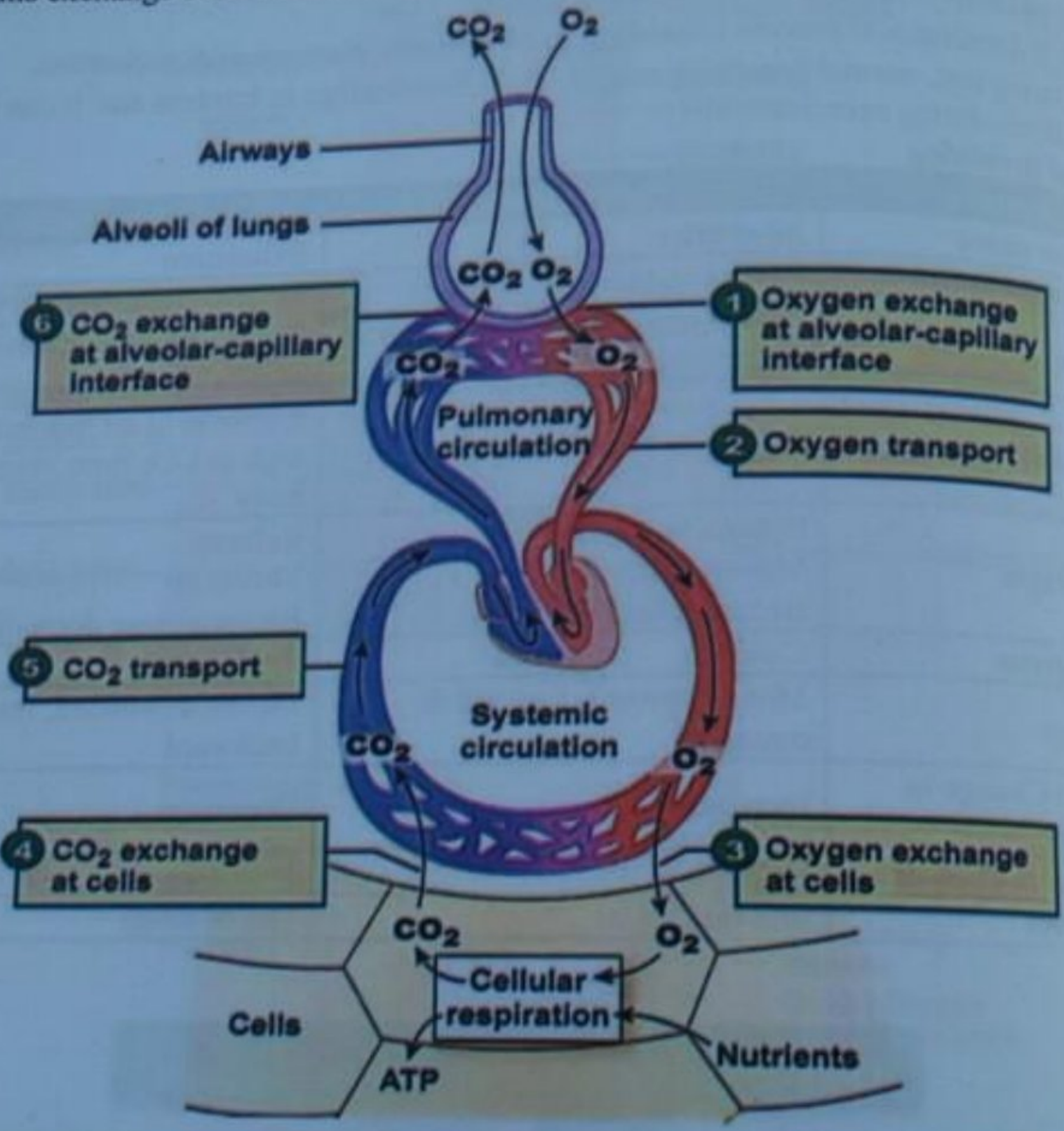
Why breathing rate is more in children than adults?



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TRANSPORT OF GASES

- Gaseous exchange follows principles of diffusion.
- This exchange occurs due to difference in partial pressure of gases.



TRANSPORT OF OXYGEN

- Most of the oxygen is transported ***through haemoglobin.***
- A small proportion is transported through plasma in dissolved form.
- Haemoglobin acts as an efficient oxygen carrier.

At Lungs

- Haemoglobin readily combines with oxygen to form bright red oxyhaemoglobin.
- $Hb + O_2 \rightarrow HbO_2$
- ***Maximum capacity*** of haemoglobin to carry oxygen is about 20ml/100ml of blood at sea level. At this blood will be 100% saturated.
- Under normal conditions, blood of alveoli of lungs is not completely oxygenated.
- ***At 115 mmHg*** oxygen tension, there is 19.6ml of O_2/100ml of blood, where Hb is 98% saturated.

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At Aerobic Tissue

- Oxyhaemoglobin is unstable and splits into the normal purple red haemoglobin and oxygen in the condition of low oxygen concentration and low pressure.
- Carbonic anhydrase enzyme present in RBC facilitates this activity.
- $HbO_2 \xrightarrow{\text{Carbonic Anhydrase}} Hb + O_2$
- ***Oxyhaemoglobin*** is unstable at pressure below 60 mmHg.
- Every 100ml of blood gives 5ml O_2 to aerobic tissue.

Factors Affecting O_2 Holding Capacity of Hb

1. **Carbon Dioxide**

- When carbon dioxide pressure increases, the oxygen tension decreases, the capacity to hold oxygen becomes less.
- Increased carbon dioxide tension favours the greater liberation of oxygen from the blood to the tissue.

2. **Temperature**

- Rise in temperature causes a decrease in oxygen carrying capacity of blood.
- For example, in increased muscular activity.

3. **pH**

- With decrease in pH of blood, amount of oxygen bound to haemoglobin also declines.
- Decreased pH results from increase in hydrogen ions. Hydrogen ions combine with the protein part of hemoglobin molecules causing a decrease in its ability to bind oxygen.

TRANSPORT OF CARBON DIOXIDE

- Carbon dioxide is more soluble than oxygen.
- CO_2 produced in Cell → Dissolved in Tissue Fluid → Passes to Plasma of Blood
- CO2 is much more important than oxygen as a regulator of normal alveolar ventilation (breathing).

Ways of Transport of CO_2

20%	Carboxyhemoglobin/ Carbaminohaemoglobin
5%	Plasma Proteins
70%	Bicarbonate ions combined with sodium in plasma.
5%	Dissolved in Plasma
Small Amount	By corpuscles combined with potassium

- Carboxyhaemoglobin/Carbaminohaemoglobin is formed when carbon dioxide combines with amino group of haemoglobin.

Transport as Bicarbonate Ions

At Aerobic Tissue

- $CO_2 + H_2O \xrightarrow{\text{Carbonic Anhydrase}} H_2CO_3$
- $H_2CO_3 \rightarrow H^+ + HCO_3^-$

At Lungs

- $HCO_3^- + H^+ \rightarrow H_2CO_3$
- $H_2CO_3 \xrightarrow{\text{Carbonic Anhydrase}} CO_2 + H_2O$

Capacity of Blood for CO_2

- ***Arterial blood*** contains about 50ml of CO_2/100ml of blood.
- ***Venous blood*** contains 54ml of CO_2/100ml of blood.

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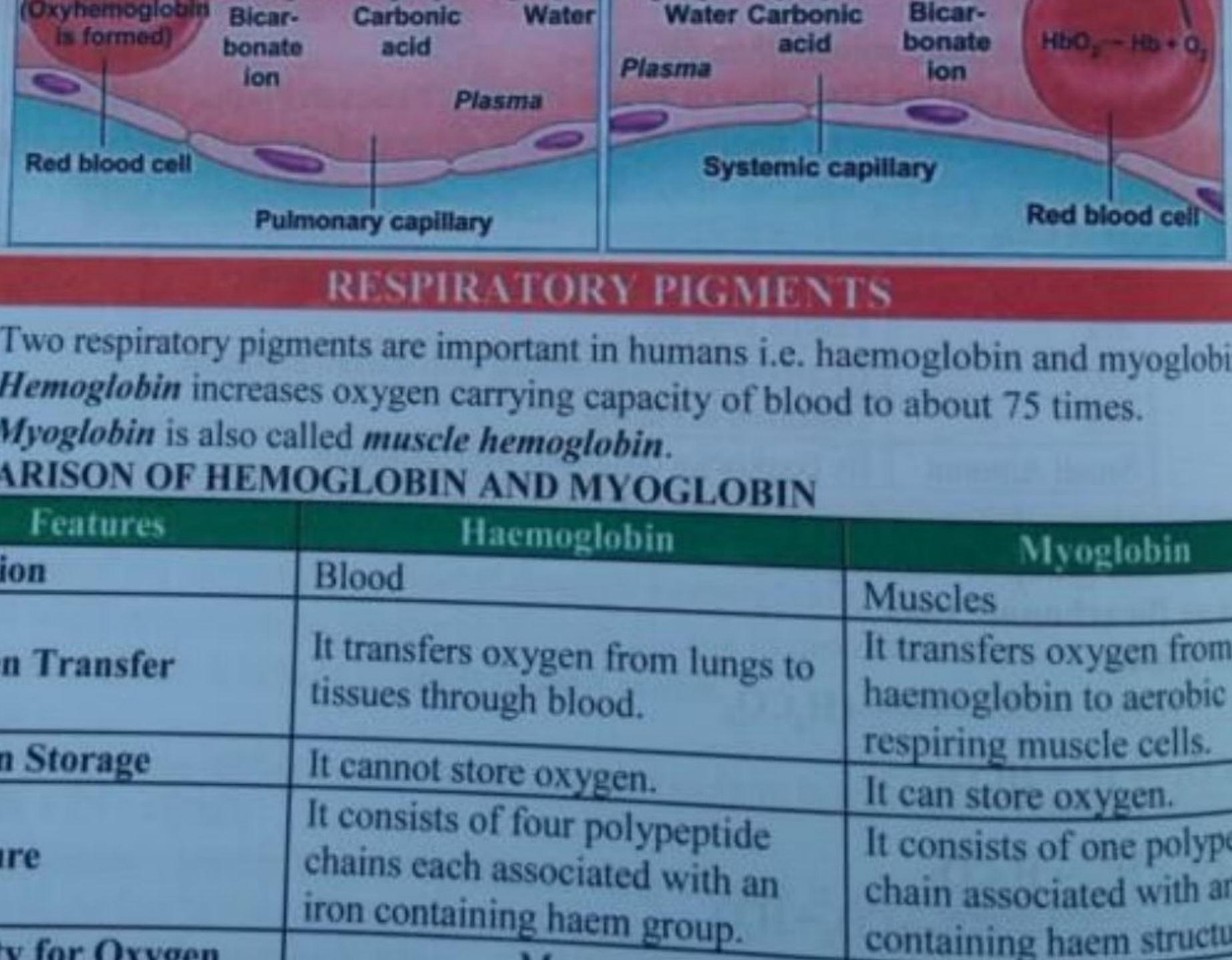
- Each 100ml of blood takes 4ml of carbon dioxide as it passes through the tissues and given 4ml of CO_2 as it passes through lungs.

POINT TO PONDER

What happens to Hb when CO binds with it?

POINT TO PONDER

With which parts of Hb, H^+, O_2, CO_2 & CO combine?



RESPIRATORY PIGMENTS

- Two respiratory pigments are important in humans i.e. haemoglobin and myoglobin.
- ***Hemoglobin*** increases oxygen carrying capacity of blood to about 75 times.
- ***Myoglobin*** is also called ***muscle hemoglobin***.

COMPARISON OF HEMOGLOBIN AND MYOGLOBIN

Features	Haemoglobin	Myoglobin
Location	Blood	Muscles
Oxygen Transfer	It transfers oxygen from lungs to tissues through blood.	It transfers oxygen from haemoglobin to aerobic respiring muscle cells.
Oxygen Storage	It cannot store oxygen.	It can store oxygen.
Structure	It consists of four polypeptide chains each associated with an iron containing haem group.	It consists of one polypeptide chain associated with an iron containing haem structure.
Capacity for Oxygen	More	Less
Affinity with Oxygen	Less	More
O_2 molecules Bound	4	1

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RESPIRATORY DISORDERS

Features	Tuberculosis	Emphysema	Cancer
Disease	Infectious disorder of respiratory system	Breakdown of alveoli	Lung malignant tumor of potentially unlimited growth
Cause	*Mycobacterium tuberculosis* (air-born droplets) Malnutrition Poor living conditions	Smoking	Smoking (90%) Other pollutants
Pathogenesis	Contagious disease Lung damage Cough & fever	• Smoke chemicals → Weaken walls of alveoli • Irritants → Smokers cough → Bursting of weak alveoli → ↓ Absorptive area → ↓ Gaseous exchange → Breathlessness & exhaustion • Inflammation of bronchioles → Obstruction → ↑ airway resistance	Malignant tumor Local expansion by invasion and systemic by metastasis Occlusion of respiratory passage
Treatment	Medicine	Quitting smoking, Bronchodilator, Antibiotics	Chemotherapy & radiotherapy

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TOPIC-5c
04 MCQs

TRANSPORTATION

LEARNING OUTCOMES

(i) Describe the structure of Heart (external and internal structure), difference in left and right chamber of heart, SA node and AV node.
(ii) Describe the Cardiac Cycle, ECG and Blood pressure (systolic and diastolic).
(iii) Explain structure of blood vessels (Arteries, Veins, Capillaries) and arterial disorder (atherosclerosis).
(iv) Describe Blood and its composition; plasma and blood cells (red blood cells, white blood cells and platelets)
(v) Discuss the following circulatory disorders with symptoms and causes: Thrombosis, Embolism, Myocardial infarction, Cerebral Infarction.
(vi) Understand components of lymphatic System: Lymph, Lymph Vessels, Lymph Nodes

HEART

Introduction

- The human heart is located in the chest cavity between lungs slightly left of the sternum.
- The heart contracts automatically with rhythmicity, under the control of the autonomic nervous system.

Pericardium

- The heart is enclosed in a double membranous sac – the pericardial cavity, which contains the pericardial fluid.
- ***Pericardium*** protects the heart, prevents it from over extension.
- ***Pericardial fluid*** reduces friction during contraction.

POINT TO PONDER

Can you name the arteries arising from arch of aorta?

Heart Walls

- The wall of the heart is composed of three layers: Epicardium, Myocardium and Endocardium.
- ***Epicardium*** is a thin serous membrane.
- ***Myocardium*** of heart is made up of special type of muscles, the cardiac muscles. Their arrangement and mechanism of contraction is essentially same as skeletal muscles except that they are branched cells. Successive cells are separated by junctions called ***intercalated discs***.
- Endocardium consists of simple squamous epithelium over a layer of connective tissue.

Heart Chambers

- There are four chambers of heart: two upper thin walled atria and two lower thick-walled ventricles.
- Right atrium receives blood from superior and inferior vena cava and the coronary sinus. The left atrium receives the four pulmonary veins.
- Atria pump blood to ventricles. Atria open into the ventricles through atrioventricular apertures.
- Right ventricle pumps deoxygenated blood to lungs through pulmonary arteries while left ventricle pumps blood to all organs except lungs through aorta.

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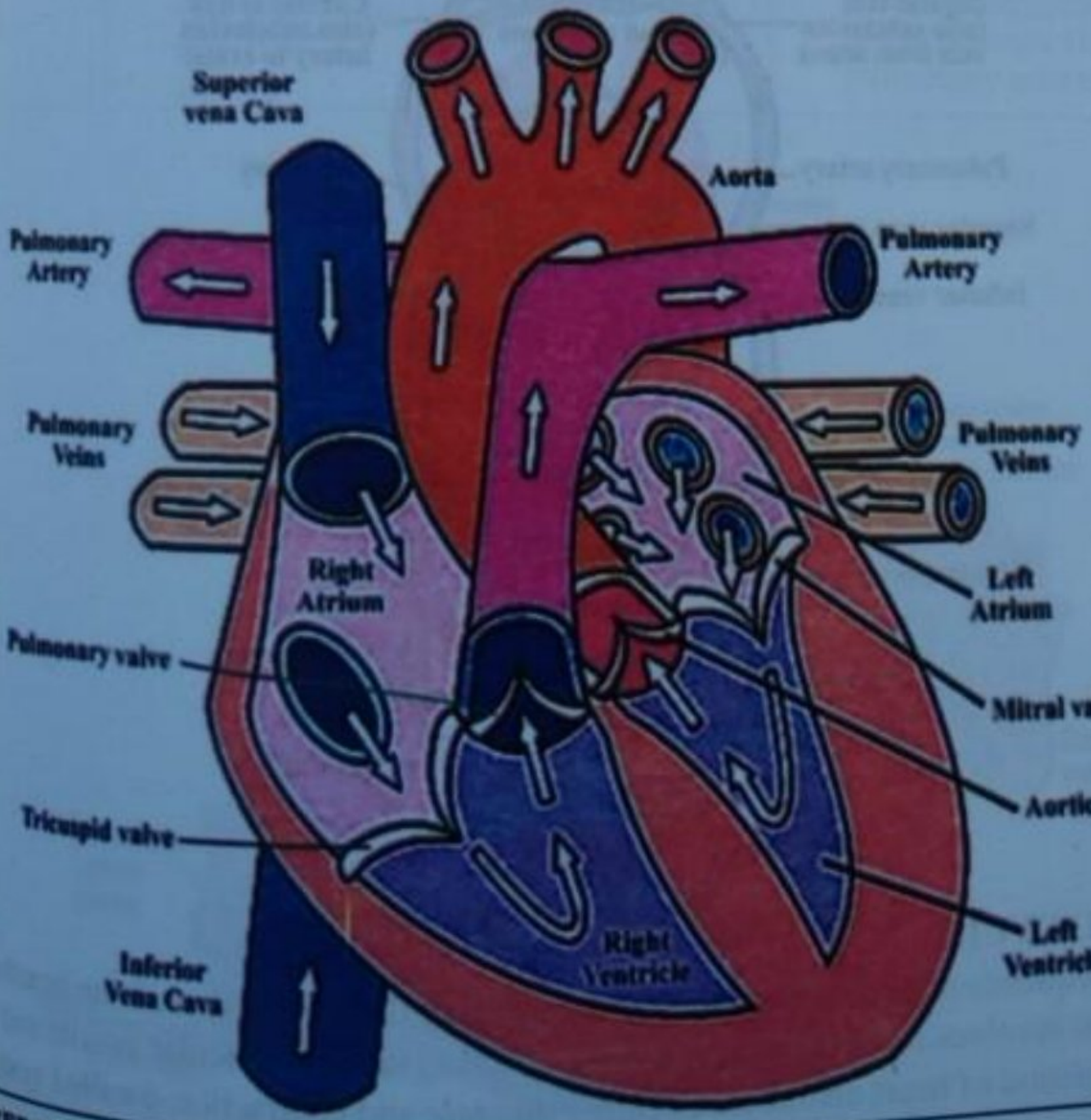
- Right side is concerned with deoxygenated blood and left side with oxygenated blood.
- Complete separation of deoxygenated and oxygenated blood is maintained by formation of ***septa*** (interatrial and interventricular).
- Atria are separated from each other by interatrial septum and ventricles by interventricular septum.
- The wall of left ventricle is thicker (3 times) than that of right ventricle.

Heart Valves

- ***Tricuspid***/ Right AV valve (3 flaps) valve is present between right atrium and right ventricle.
- ***Bicuspid*** valve/ Left AV valve/ Mitral valve (2 flaps) is present between left atrium and left ventricle.
- These flaps are attached with fibrous cords called ***chordae tendinae***, to the ***papillary muscles*** which are extensions of the wall of the ventricles. Papillary muscles contract when the ventricles contract and prevent the valves from opening into the atria by pulling on the chordae tendinae attached to the valve cusps.
- ***Semilunar valves*** are present at base of aorta and pulmonary trunk. Each valve consists of three pockets like semilunar cusps.

POINT TO PONDER

Why gap junctions are present in heart muscles?



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Blood Circulation Through Heart

- Heart functions as a double pump and is responsible for pulmonary and systemic circulation.

Pulmonary Circulation

Deoxygenated Blood

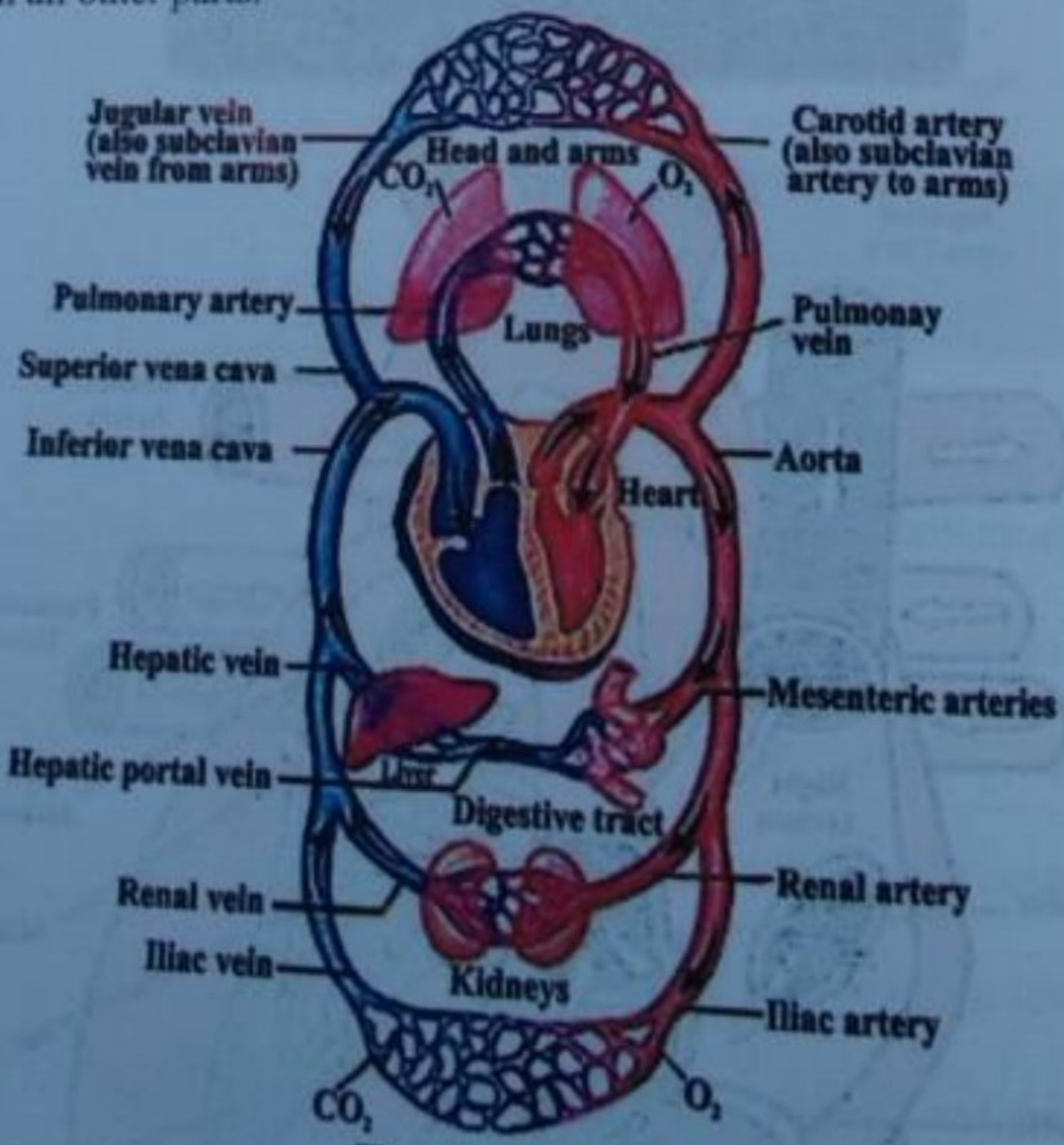
Vena cavae (Deoxygenated Blood) → Right Atrium → Right Ventricle → Pulmonary Trunk → Right & Left Pulmonary Arteries → Lungs

Oxygenated Blood

Lungs → Pulmonary Veins (Oxygenated Blood) → Left Atrium → Left Ventricle → Systemic /Aortic Circulation

Systemic Circulation

- At the ***base of aorta***, first pair of arteries, the coronary arteries arise and supply blood to heart.
- Three branches arise from ***arch of aorta*** that supply blood to head, shoulders and arms.
- The aorta descends down in the chest cavity. It gives many branches to the chest wall.
- In abdominal region, it supplies to different parts of alimentary canal, kidneys and lower abdomen.
- At the end of abdomen, aorta bifurcates into iliac arteries which supply blood to legs.
- ***Superior vena cava*** collects blood from head, shoulder and arms, while ***inferior vena cava*** from all other parts.



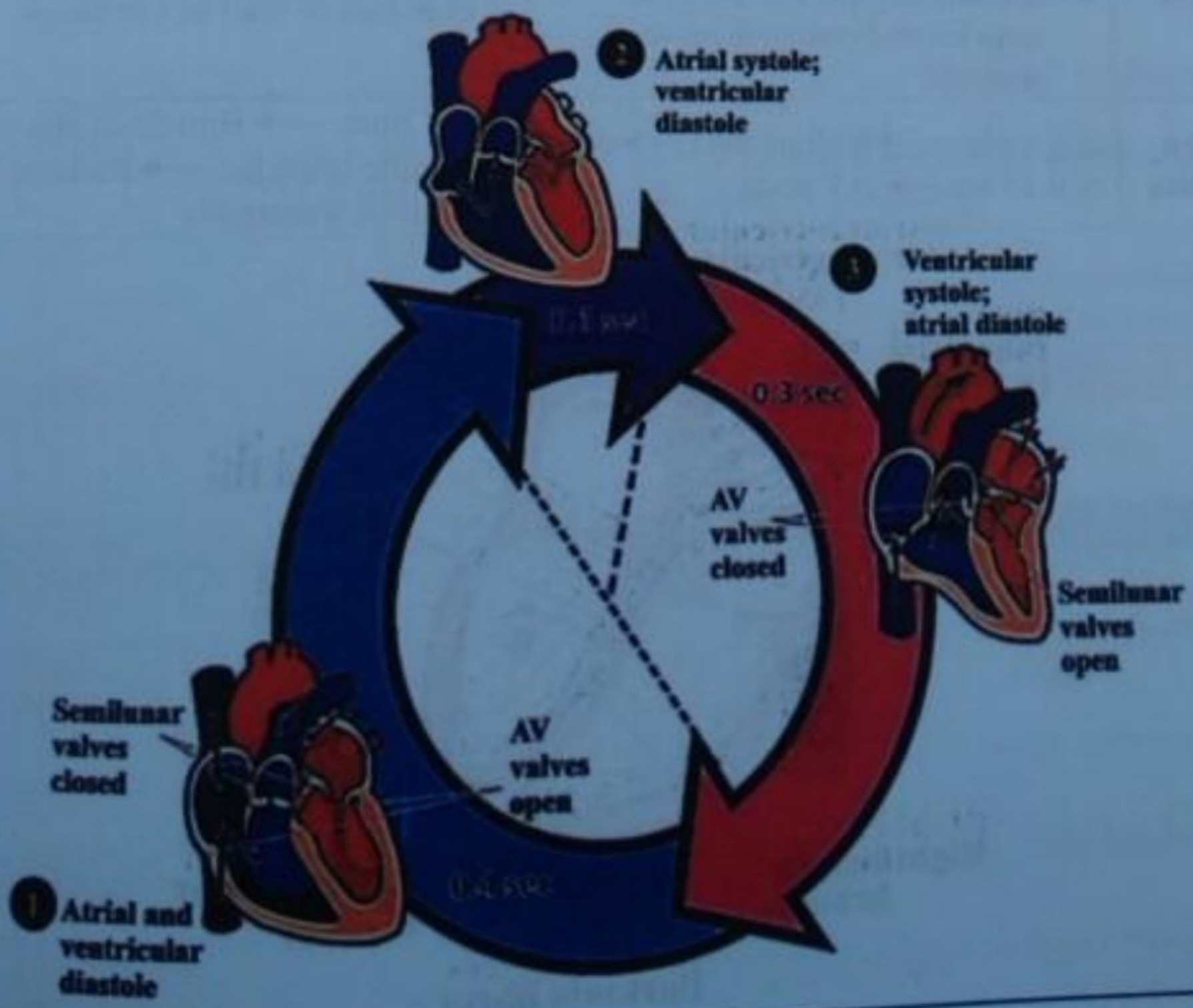
THE CARDIAC CYCLE

- It is the sequence of events which take place during the completion of one heartbeat.
- Heart beat involves three distinct stages i.e. atrial systole, ventricular systole and diastole.
- Relaxed period of heart chambers is called ***diastole*** and contraction is called *systole*.

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- One complete ***heartbeat*** consists of one systole and one diastole and lasts for about 0.8 seconds. In one's life, heart contracts about 2.5 billion times, without stopping.

Phase	Valves	Events in Atria	Events in Ventricles	Duration
Diastole (Relaxation)	• AV valves open • SL valves closed	• Atria relaxed • Deoxygenated blood enters right atrium by vena cava • Oxygenated blood enters left atrium by pulmonary veins	• Ventricles relaxed • Deoxygenated blood enters right ventricle through right atrium • Oxygenated blood enters left ventricle through left atrium.	0.4 seconds
Atrial Systole	• AV valves open • SL valves closed	Muscles of atria contract and pump blood to ventricles	Ventricles are relaxed and receive blood from atria.	0.1 sec
Ventricular systole	• AV valves close (LUBB sound) • SL valves open at the beginning • SL valves close at the end of systole (DUBB sound)	Atria are relaxed during this phase	• Both ventricles contract • Left ventricle pumps oxygenated blood via aorta to all parts of body • Right ventricle pumps deoxygenated blood to lungs via pulmonary arteries	0.3 secs approx.

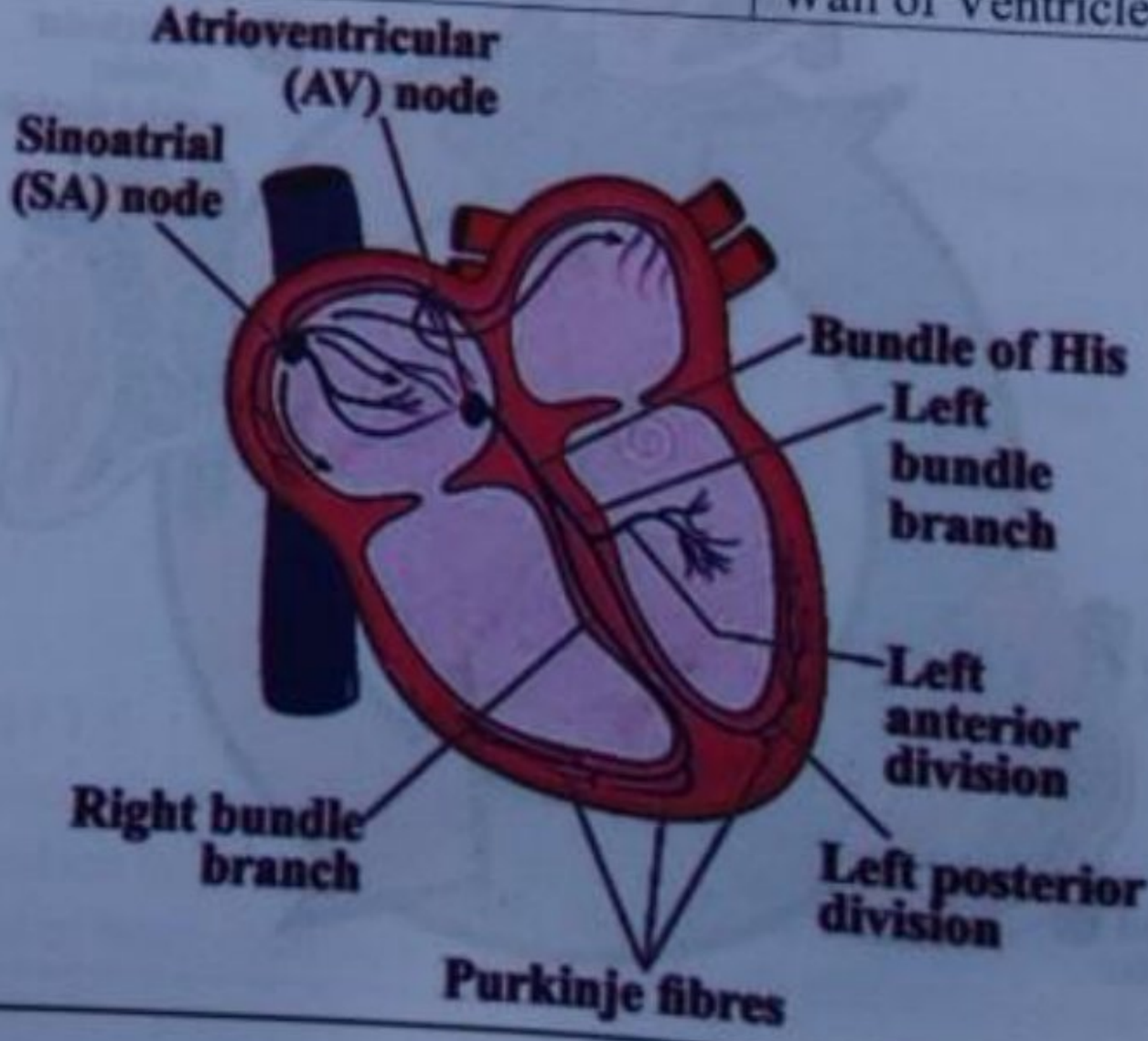


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MECHANISM OF HEART EXCITATION AND CONTRACTION

- Heartbeat starts when the sino-atrial node (***pacemaker*** at the upper end of right atrium) sends out electrical impulses to the atrial muscles, thus causing both atria to contract.
- The ***sino-atrial node*** consists of small number of diffusely oriented cardiac fibres, possessing few myofibrils and few nerve endings from the autonomic nervous system. It has been developed from sinus venosus.
- Impulses from the SA node travel to the musculature of the atrium and to atrioventricular node (AV).
- There is a delay of approximately 0.15 seconds in conductance from the S-A node to A-V node, permitting atrial systole to be completed before ventricular systole begins.
- From AV node, AV bundle of muscle fibers propagate the regulatory impulses via excitable fibers in the interventricular septum to the myocardium of the ventricles.
- ***Pacemaker*** is responsible for initiating the impulses, which trigger the heartbeat rate.
- ANS → SA Node → Atrial Musculature + AV Node (Internodal fibers)
- AV Node → Bundle of His → Right & Left Bundle Branches → Purkinje Fibers → Ventricular Musculature

Property	SA Node	AV node
Location	Upper end of right atrium	Junction of right atrium and right ventricle
Structure	• Diffusely oriented cardiac fibers • Few myofibrils • Few nerve endings from autonomic nervous system	• Diffusely oriented cardiac fibers • Few myofibrils • Few nerve endings from autonomic nervous system
Function	• Initiates heart-beat by generating electrical impulses • It sends impulses to the atrial muscles and causes them to contract.	It acts as relay and transfers the impulses to wall of ventricles
Direction of impulse	S.A node ⟶ Wall of atria ⟶ delay of 0.15 sec ⟶ AV node	AV node ⟶ Bundle of His ⟶ Bundle branches ⟶ Purkinje fibers ⟶ Wall of Ventricles

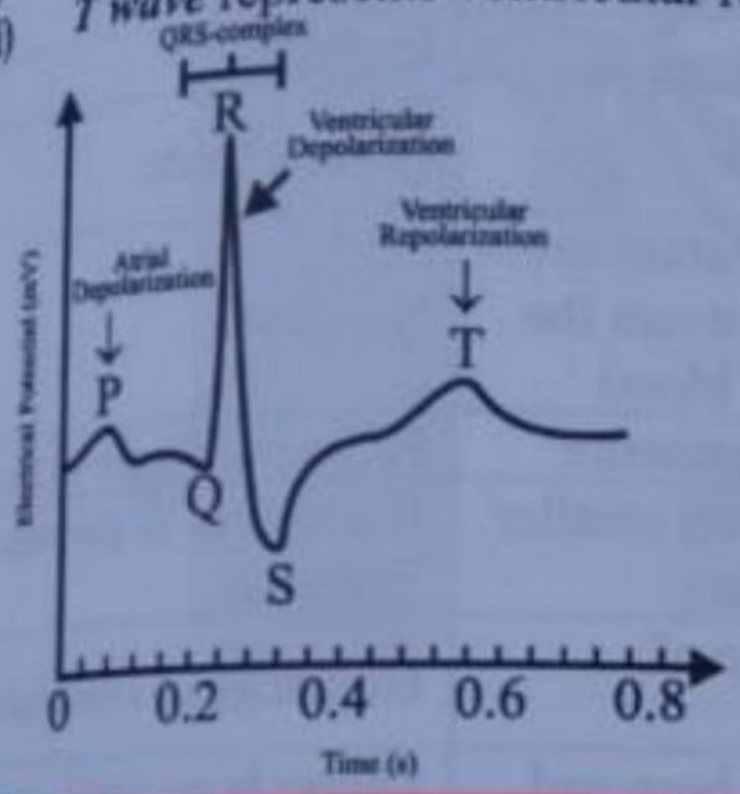


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ELECTROCARDIOGRAM

- As the cardiac impulses pass through heart, these also spread into surrounding tissues. Electrodes are placed on opposite sides of the heart and electrical potentials generated by these currents can be recorded.
- This recording is called ***electrocardiogram*** which is taken by ECG machine.
- It helps to diagnose the abnormalities in the rhythmicity and conduction system of the heart.
- In an ECG:

(i) ***P wave*** represents atrial contraction.
(ii) ***QRS complex*** represents ventricular contraction.
(iii) ***T wave*** represents ventricular relaxation.



POINT TO PONDER

How ECG can be used as diagnostic test?

BLOOD PRESSURE

- "It is the measure of force with which blood pushes up per unit area against the walls of blood vessels".
- It is measured in mmHg.
- It is the force that keeps blood flowing from the heart to all the capillary networks in the body.
- The blood pressure is generated by the contraction of ventricles. This is called ***systolic pressure***.
- When the ventricles relax, the atrial pressure is lowest and is called ***diastolic pressure***.
- Blood pressure consistently decreases in the following pathway:
  Aorta → Arteries → Capillaries → Veins → Vena cava
- The normal systolic blood pressure is ***120 mm Hg*** which is during ventricular systole.
- The normal diastolic blood pressure is ***75-85 mm Hg*** which is during diastole of the heart.

BLOOD VESSELS

- Blood vessels are involved in the transportation of circulatory fluid (blood). They are three types of blood vessels i.e. Arteries, Veins and Capillaries

Feature	Arteries	Veins	Capillaries
Direction of Blood Flow	They transport blood away from heart to various parts of body	They collect blood from various parts of body and transport it towards heart	They link arteries with veins
Type of Blood	All carry oxygenated blood except pulmonary arteries	All carry deoxygenated blood except pulmonary veins	They have mixed blood

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Structure	• Three layers • Outer: Connective tissue + Elastic fibers • Middle: Circular smooth muscles + Elastic fibers • Inner: Endothelium	• Three layers • Outer: Connective Tissue • Middle: Circular smooth muscles + Thin elastic membrane • Inner: Endothelium	Only one cell thick endothelium
Elasticity	Elastic	Less elastic	Inelastic
Pulsatile Nature	Pulsatile	Non-pulsatile	Non-pulsatile
Valves	No valves except at the base of aorta & pulmonary trunk	Semilunar Valves are present to prevent the backflow of blood	No valves
Blood Pressure	High blood pressure	Low blood pressure	Falling pressure in these
Rate of Blood Flow	Rapid blood flow 400-500 mm/sec	Increases from smaller to larger veins	Blood flow is slowest 1mm/sec
Exchange of Material	No exchange of materials	No exchange of materials	Exchange of materials
Bore & Thickness	Have smaller bore and thick walls	Have larger bore and thin walls	Larger bore; wall one cell in thickness

Some Other Features

Arteries

- Contraction of circular smooth muscles of arteries and arterioles is under control of nervous system and endocrine system.
- When stimulated the muscles contract, constricting the arterioles (vasoconstriction) thus reducing the flow of blood in them and vice versa.

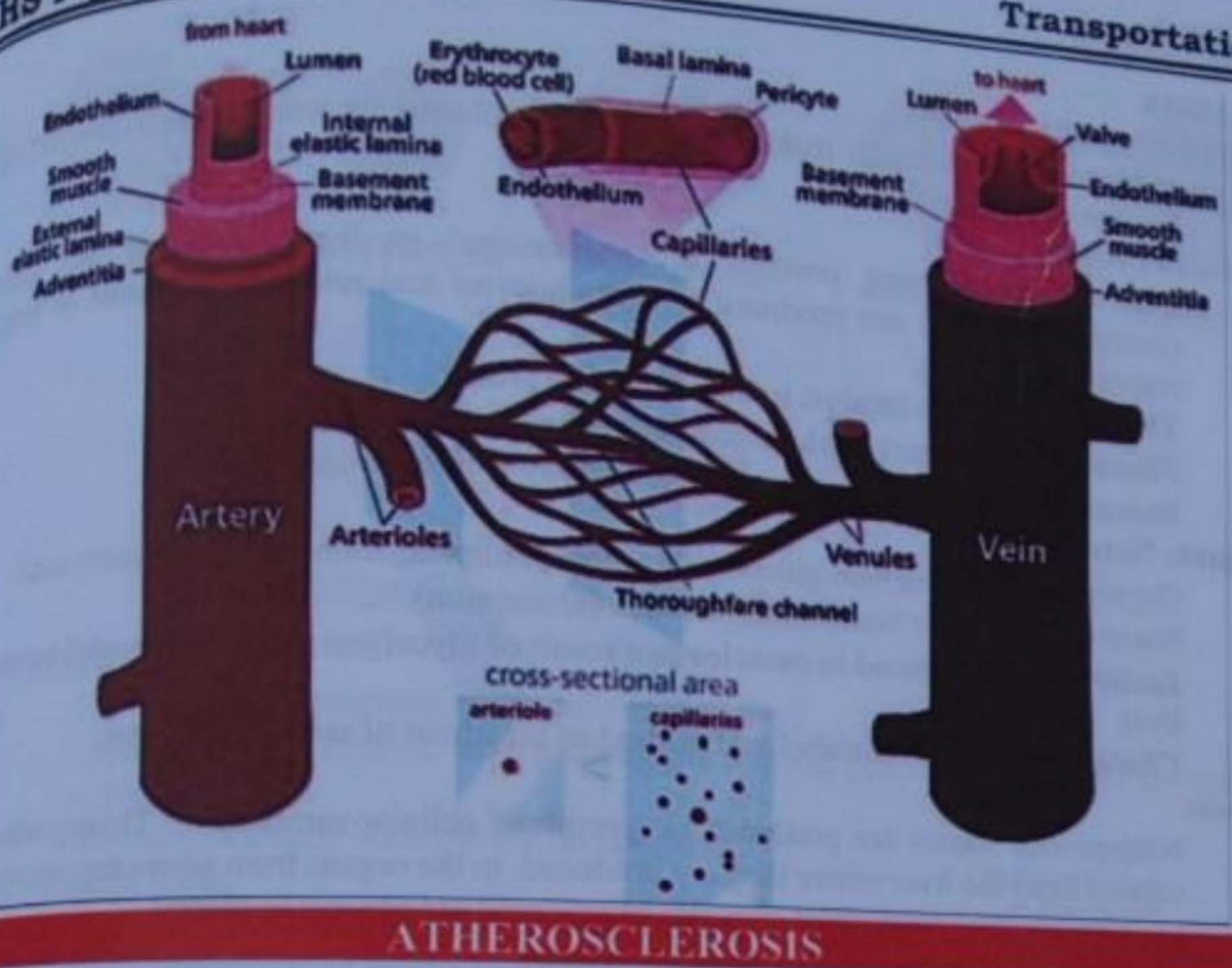
Veins

- In veins, muscle contraction also assists (squash blood vessels) in blood flow re towards heart alongwith valves.
- Portal veins carry blood to any organ other than the heart. For example, hepatic portal carries blood from intestine to liver.

Capillaries

- In liver, every cell is in direct contact with capillary.
- The diameter of a capillary can be altered by nervous stimulation, which tends to them and by chemicals, such as histamine, which dilate them.
- The change in diameter is brought about by change in shape of cells.
- The pre-capillary sphincters also regulate the amount of blood flowing in capillaries.
- Exchange of materials between blood and cells occurs through with extracellular fl involves diffusion, active transport and endocytosis.

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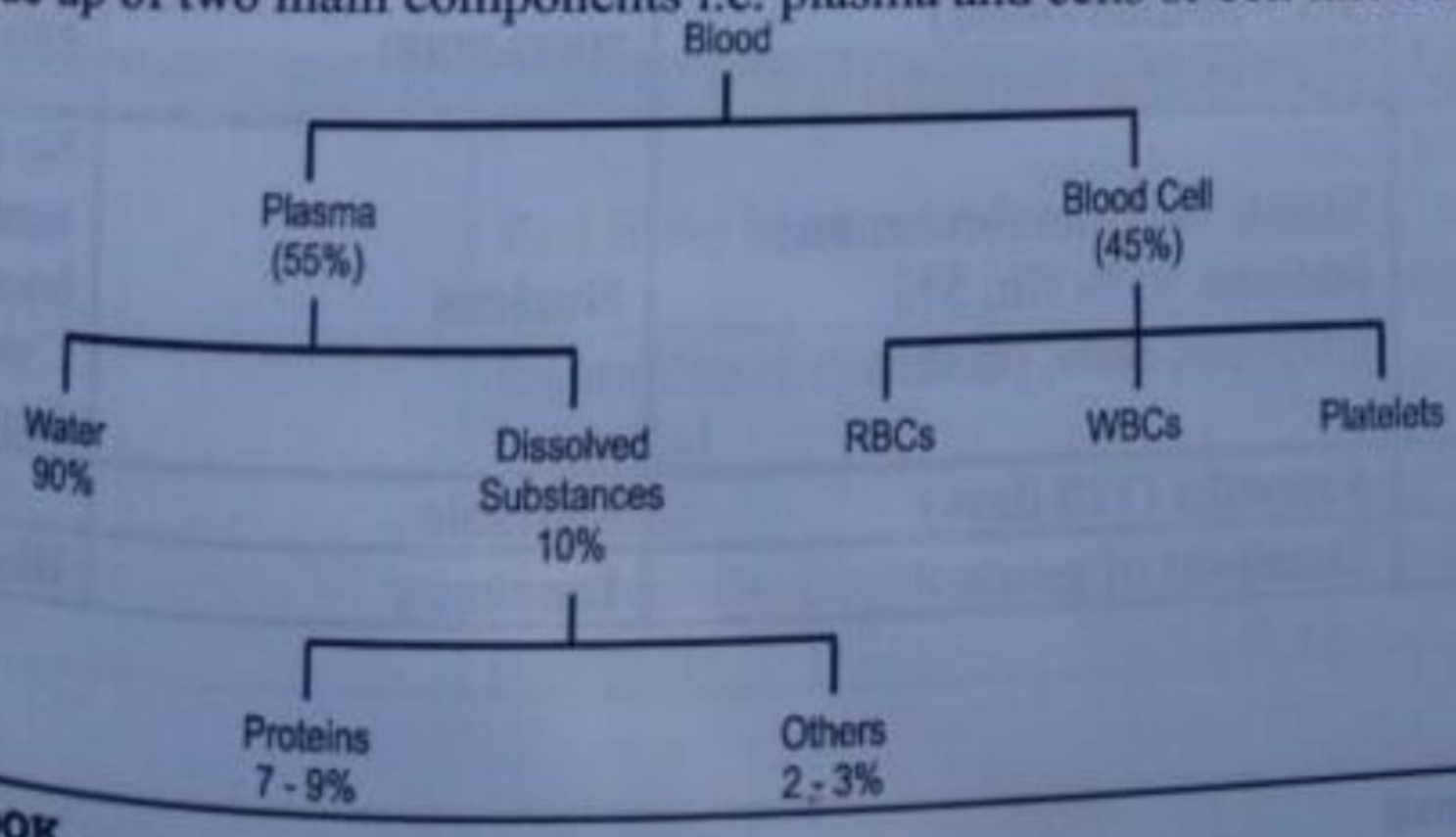


ATHEROSCLEROSIS

- It is actually coexisting atheroma and arteriosclerosis.
- ***Atheroma*** is the deposition of hard yellow plaque of lipoid material in the inner most layer of arteries which may be due to the high level of cholesterol in the blood.
- ***Arteriosclerosis*** is a degenerative arterial change associated with advancing age and it is a thickening of the middle layers of arteries and is associated with some sort of atheroma.
- ***Atherosclerosis*** causes narrowing and hardening of arteries and increases the risk of thrombus formation which can be fatal if occurs in brain and heart.
- ***Atherosclerosis*** is a major condition leading to heart attack.

BLOOD

- The weight of blood in our body is about $1/12^{th}$ of our body.
- The normal ***pH*** of blood is 7.4.
- It is made up of two main components i.e. plasma and cells or cell like bodies.



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PLASMA

Inorganic or Mineral Ions

- Inorganic ions and salts make up 0.9% of the plasma by weight. More than 2/3 of this amount is sodium chloride.

Plasma Proteins

- Most of the plasma proteins are synthesized in liver. Some of the globulins (immunoglobulins) are produced by lymphocytes and released in plasma or lymph in response to antigen.
- ***Thrombin*** acts as a catalyst in blood clotting process.
- ***Fibrinogen*** takes part in blood clotting process.
- ***Immunoglobulins*** play important role in body's defense against disease.

Organic Nutrients

- Organic nutrients include glucose, fats, phospholipids, amino acids and lactic acid.
- Some of them enter blood from intestine (absorption).
- ***Lactic acid*** is produced in muscles as a result of glycolysis and is transported by blood to liver.
- ***Cholesterol*** is either metabolized or used as precursor of steroid hormones.

Others

- Nitrogenous wastes are produced as a result of cellular metabolism. These products are carried from the liver where they are produced, to the organs from where they are removed i.e. kidneys. Urea and small amounts of uric acid are present in plasma.
- Hormones and gases are also found in plasma.

Types of Blood Cells

Feature	RBCs	WBCs	Platelets
Name	Erythrocytes	Leucocytes	Thrombocytes
Colour	Red	Colourless	Colourless
Formation	• Liver & spleen (embryonic life) • Red bone marrow of sternum, ribs, vertebrae (adult life)	Red bone marrow & lymphatic tissue	Red bone marrow
Size	8μm	Larger than RBC	Smaller than RBC
Shape	Biconcave	Polymorphic	Plate like
Number per mm^3 of blood	5-5.5 million (male) 4-4.5 million (female)	7000-8000	250,000
Structure	Elastic cell membrane, no nucleus, 95% Hb, 5% enzymes, salts, proteins	Nucleus	No nucleus, membrane bounded Cytoplasmic fragments of cells
Life span	4 months (120 days)	Variable	-
Function	Transport of gases	Immunity	Blood clotting

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Monocyte



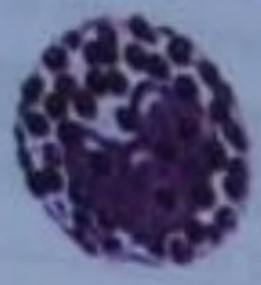
Lymphocyte



Neutrophil



Eosinophil



Basophil



Macrophage



Erythrocyte



Platelets

Red Blood Cells

- These are most numerous of the cells in the blood.
- These cells when formed, have nucleus, but it is lost before they enter the circulatory fluid or blood.
- The red blood cells once mature do not divide.

White Blood Cells

- There are five different types of WBCs which can be distinguished on the basis of the shape of the nucleus and density of granules in the cytoplasm.
- They can be grouped into two main types, ***granulocytes*** and ***agranulocytes***.
- ***Monocytes*** stay in blood for 10-20 hours then enter tissues and become tissue macrophages.
- ***Lymphocytes*** have life spans of months or even years; but this depends on the body's need for these cells.
- ***Monocytes*** and ***neutrophils*** travel through capillaries and feed on bacterial invaders or other foreign cells, including cancer cells.
- ***Macrophages*** and ***neutrophils*** typically die in a process and their dead bodies accumulate and contribute to the white substance called pus, seen at infection sites.

POINT TO PONDER

Enlist organelles present in RBCs

Main Categories of WBC

Feature	Granulocytes	Agranulocytes
Formation	Red Bone Marrow	Bone Marrow & Lymphoid tissue (Lymph nodes, spleen, tonsils, adenoids, thymus)
Nucleus	Incompletely divided/ Spherical	Spherical to lobed
Cytoplasm	Granular	Agranular
Examples	Neutrophils, Eosinophils, Basophils	Monocytes, Lymphocytes (B & T)

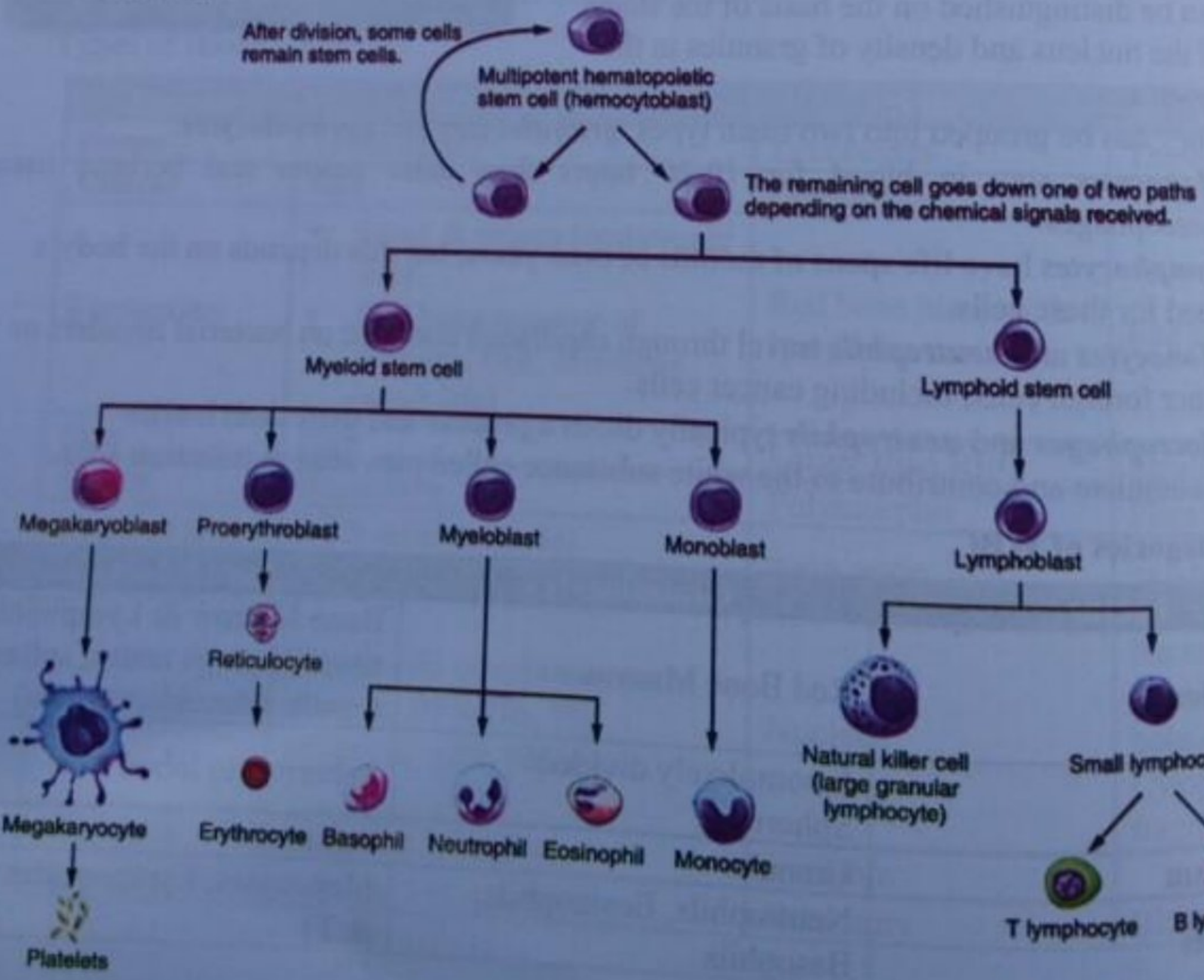
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Subcategories of WBCs

Feature	Neutrophils	Eosinophils	Basophils	Monocytes	Lymphocytes
Size in relation of RBC	Twice	Twice	Twice	Twice to thrice	Slightly larger
Nucleus	2-5 lobed	Bilobed	Bilobed	Round to lobed	Round, nearly filling cell
%age	62%	2%	< 1%	3%	32%
Function	Destruction of small particles by phagocytosis	Inactivate inflammation producing substances & attack parasites	Release heparin to prevent blood clots & histamine to cause inflammation	Destroy large particles by phagocyto-sis	Immune response by producing antibodies

Platelets

- These are not cells but are fragments of large cells called ***megakaryocytes***.
- Platelets help in conversion of fibrinogen, a soluble plasma protein, into soluble form, fibrin. The fibrin threads enmesh RBCs and other platelets in the area of damaged tissue, ultimately forming a ***blood clot***.
- The ***clot*** serves as temporary seal to prevent bleeding until the damaged tissue can be repaired.



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FUNCTIONS OF BLOOD

1. **Maintenance of Osmotic Balance**
- Plasma proteins maintain colloid osmotic pressure of blood.
- 75% role is played by albumins, 25% by globulins and almost none by fibrinogen.

2. **Transportation**
- Blood helps to transport nutrients, water, salts and waste products.
- Hormones are transported by blood from the endocrine tissues to the target cells.
- Gases (O_2 and CO_2) are transported by blood.

3. **Homeostasis**
- Blood acts as a buffer to maintain the acid-base balance i.e. concentration of H^+ and OH^- ions in the body.
- Blood helps in maintaining the body temperature, concentration of water and salts, thus helps in homeostasis.
- Blood helps the body in maintaining the internal environment, by producing heparin, histamine and also by maintaining the amounts of chemicals.

Defense/ Immunity

Blood helps in body defenses against disease. Neutrophils and monocytes engulf and destroy invading microorganisms e.g. bacteria.
- Blood provides immunity by the lymphocytes.
- Blood produces interferons and antitoxins which are proteins and protect our body from nucleic acids and toxins of invading organisms.

5. **Blood Clotting**
- It helps in blood clotting process and seals the wounds that stop entry of pathogens into the body.

6. **Exchange of Materials**
- Walls of capillaries help in exchange of materials between blood and body tissue through blood capillaries via interstitial fluid.

POINT TO PONDER

Name one coagulant & one anticoagulant agent?

CIRCULATORY DISORDERS

Disorders	Definition	Cause/Risk Factors	Effects
Thrombosis	Thrombus is a solid mass or plug of blood clot in a blood vessel and can completely or partially block blood vessel.	• Irritation or infection of lining of blood vessels. • Reduced rate of blood flow due to long periods of inactivity • Pneumonia and tuberculosis, emphysema	• Blockage of artery. • Cerebral infarction or myocardial infarction.
Embolism	When thrombus is dislodged to other location in circulatory system it is called as embolus	• Hypertension • Atherosclerosis • High blood cholesterol • Thrombus	• Blockage of artery. • Cerebral infarction or myocardial infarction.

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Myocardial Infarction	Necrosis or damage to the portion of heart muscles, a condition known as myocardial infarction	• Thrombus, embolus, atheroma. • Fatty food (cholesterol rich) • Obesity • Hypertension • Smoking	• Sharp pain in the chest • Shortness of breath • Pain in the jaw and upper arm • Sweating • Arrhythmias & ventricular fibrillation
Cerebral Infarction	Blockage or narrowing of arteries supplying blood and oxygen to the brain can cause necrosis and damage, a condition called cerebral infarction	• Thrombus, embolus, atheroma. • Fatty food (cholesterol rich) • Obesity • Hypertension • Smoking	Symptoms depend on the part of brain affected.

LYMPHATIC SYSTEM

INTRODUCTION

- This system is responsible for the ***transport and returning of material*** from the tissues of the body to the blood.
- It ***comprises of*** lymph capillaries, lymph vessels, lymphoid masses, lymph nodes, and lymph

COMPONENTS OF LYMPHATIC SYSTEM

Lymph

- ***Lymph*** is the fluid which flows in the system.
- The ***lymph vessels*** empty in veins; so lymph is a fluid in transit between interstitial fluid and the blood.
- The ***intercellular spaces*** in the walls of lymph vessels are larger than those of the capillaries of blood vascular system.
- In an average person, about three litres more fluid leaves the blood capillaries that is re-absorbed by them each day.
- After a fatty meal, the fat globules may make up 1% of the lymph.



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Lymph Vessels

- *Lacteals* are the branches of lymph capillaries inside villi of intestine.
- *Lymph capillaries* are blind ended structures.
- Largest lymph vessel is thoracic duct.
- Lymph vessels which carry lymph towards lymph nodes are called *afferent lymph vessels*.
- Lymph vessels which carry lymph away from lymph nodes are called *efferent lymph vessels*.

Lymph Nodes

- Masses of connective tissue where lymphocytes are present are called *lymph nodes*.
- Lymph nodes are present in neck region, axilla and groin of humans.
- Several afferent lymph vessels enter a lymph node, which is drained by single efferent lymph vessel.
- Lymph nodes act as filter for lymph as do spleen for blood.

FLOW OF LYMPH

- Direction of flow of lymph is:
  Lymph Capillaries → Smaller Lymph Vessels → Larger Lymph Vessels → Thoracic Duct → Subclavian Vein
- The flow of lymph is maintained by:
  (i) Activity of skeletal muscles
  (ii) Movement of viscera
  (iii) Breathing movements
  (iv) Semilunar valves that prevent backward flow

FUNCTIONS OF LYMPHATIC SYSTEM

- Return of excess extracellular fluid and proteins to the blood.
- Absorption of large fat globules by lacteals of villi.
- Play important role in the defense system of the body. Lymphocytes and macrophages present inside lymph nodes kill bacteria and viruses.

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TOPIC-5d
05 MCQs

HOMEOSTASIS

LEARNING OUTCOMES

(i) Understand the terms homeostasis, internal and external stimuli, receptors, central control, coordination system, effectors and negative feedback.

(ii) Describe the structure of kidney and its functions, structure of nephron with associated blood vessels, ultrafiltration, reabsorption and formation of urine.

(iii) Explain the terms osmoregulation and thermoregulation.

(iv) Explain types of kidney problems (Kidney stones and Renal failure) and cures (Lithotripsy, Kidney transplant and Dialysis-peritoneal and hemodialysis).

BASIC TERMS

Homeostasis

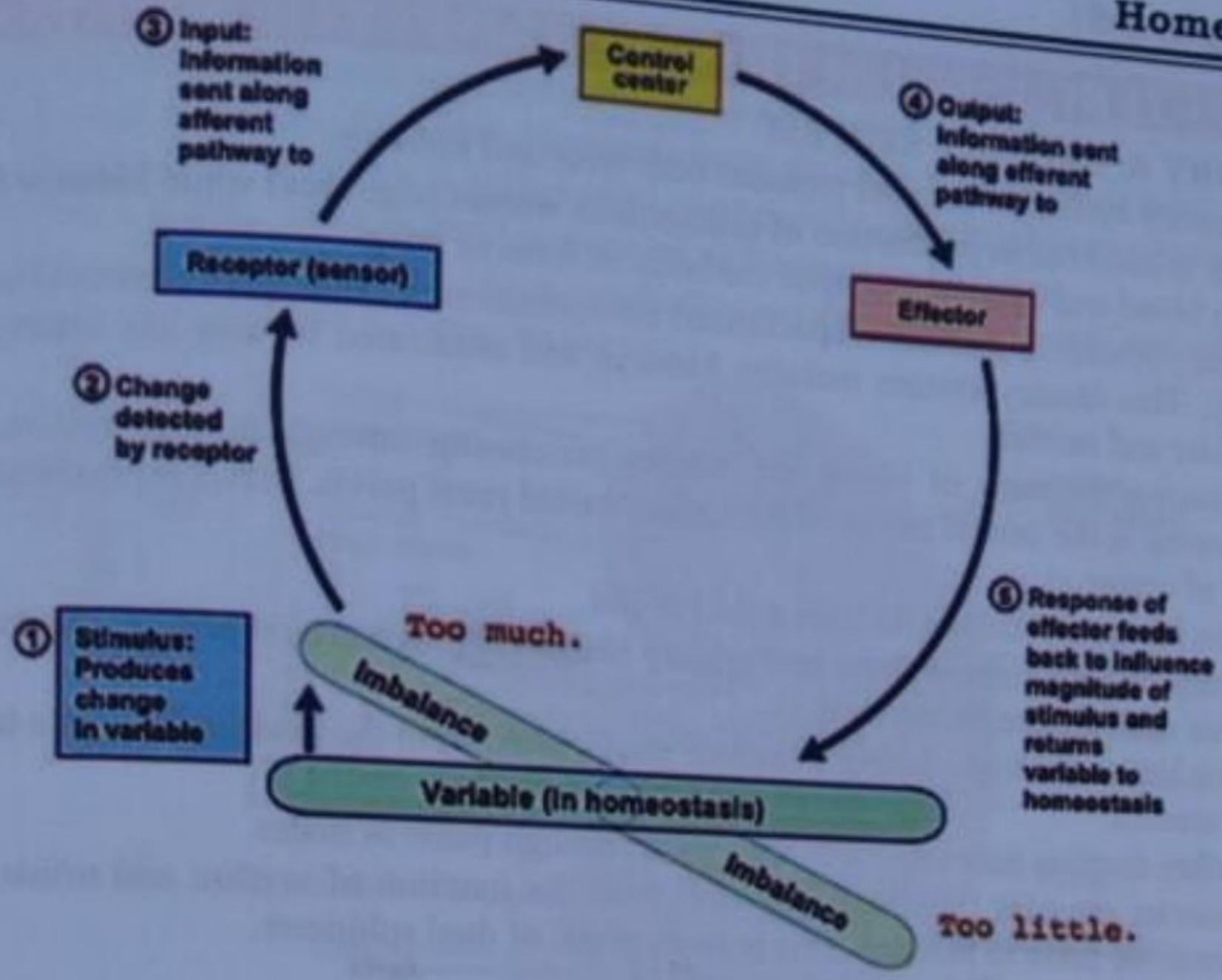
- The protection of internal environment from the harms of fluctuations in external environment is termed as homeostasis.
- The homeostasis keeps the internal fluctuations in a narrow range.
- Most susceptible components of internal environment that may be affected by fluctuations in external environments are water, solutes and temperature.

Control & Coordination

- The coordination makes possible the integration of functions essential to organismic behaviour.
- Coordination is must for any organism to survive. In the unicellular organisms, coordination exists between various cellular processes. In multicellular organisms, although there is division of labour among cells, yet every cell can respond to changes in its immediate vicinity.
- Control and coordinating systems in living organisms are either nervous system or hormones or both.
- External environment may show changes within broad range.
- Intracellular and extracellular internal environments also keep fluctuating but in narrow range. Here, in addition to solute and water various essential metabolites, hormones etc. are kept in required range. This control is brought about by control system.
- Living control system has three components i.e. receptor, control center and effector.

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Homeostasis



Stimulus

- Any change in internal or external environment is called stimulus.
- Change in temperature of atmosphere and light are examples of external stimuli.
- Change in solute or water concentration in blood are examples of internal stimuli.

Receptors

- These are the structures which detect change in external or internal environment.
- The receptors may be cells (e.g. rod and cone cells of eye), neuron endings (e.g. Pacinian corpuscles) and organs (e.g. nose, ear).
- Receptors are also classified on base of type of stimuli e.g. chemoreceptors, mechanoreceptors, thermoreceptors etc.

Control Centre

- It integrates data from receptor with data stored as set point.
- Control centre of most of the activities of humans is brain.

Effectors

- These are the structures which respond to stimulus.
- Effectors are either muscles or glands. Muscles show response by contraction while glands through secretions.

Feedback Mechanism

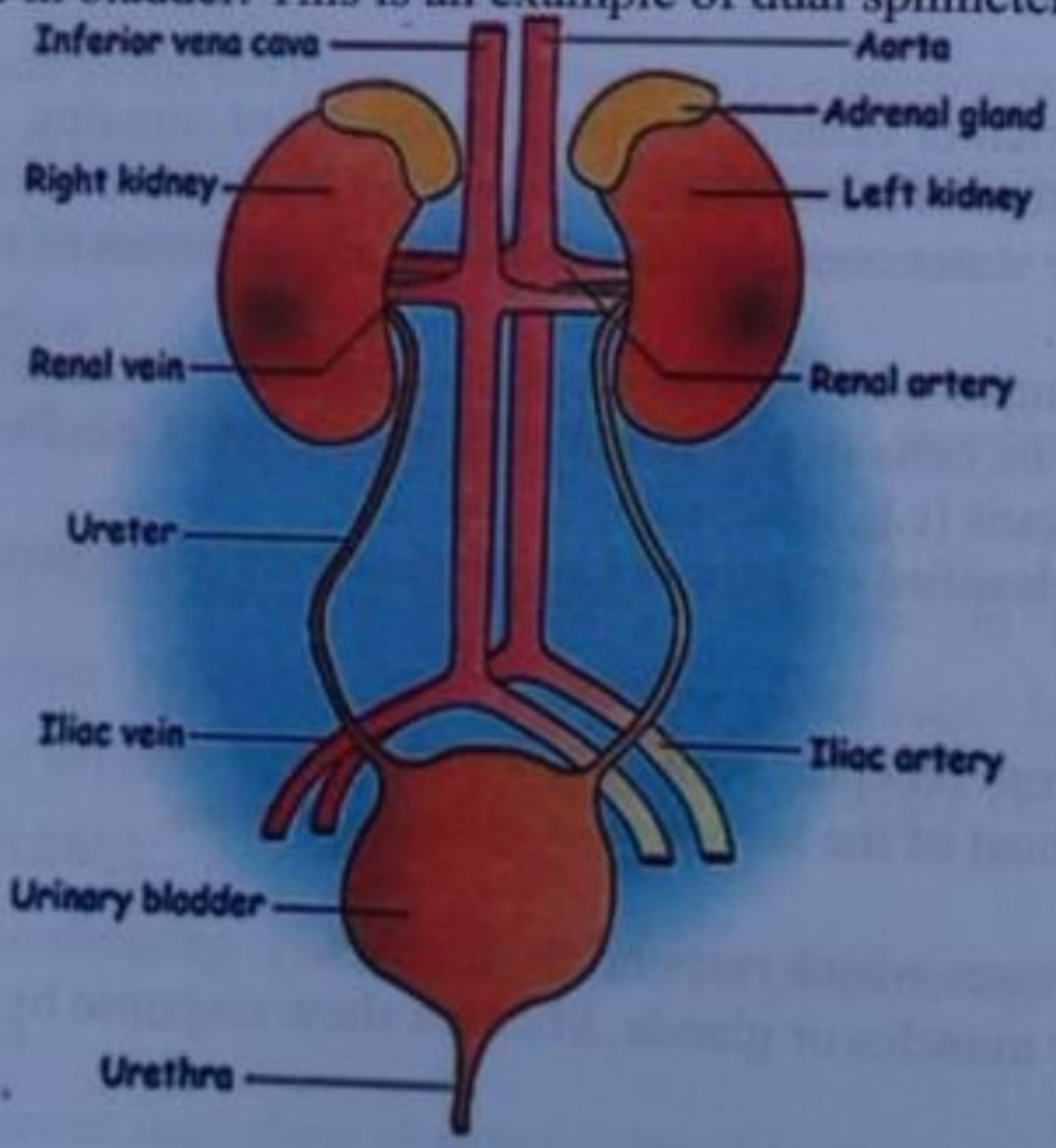
- Feedback mechanism is a type of interaction in which a controlling mechanism is itself controlled by the products of reactions it is controlling.
- For proper body functions, two opposing systems are needed, if there are accelerators, there must be inhibitors.
- Negative feedback is an inverse response to change in environment e.g. increase in body temperature will stimulate that system which lowers body temperature.
- Positive feedback involves a change in some variable that triggers mechanisms that amplify rather than reverse the change e.g. labour contractions during child birth.

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STRUCTURE AND FUNCTIONS OF KIDNEY IN HOMEOSTASIS

EXCRETORY & URINARY SYSTEM

- Excretory system of humans includes both liver and kidneys.
- Liver is involved in production of nitrogenous wastes (e.g. urea) while kidneys filter urea from blood and remove it outside the body in form of urine.
- Urinary system in humans is specialized for formation of urine and its removal outside the body. This urinary system includes kidneys and associated tubules like ureters, urinary bladder and urethra.
- Following filtration of blood and further processing through tubular system, urine is collected in the central cavity of the kidney called renal pelvis. Pelvis is proximal enlarged end of ureter.
- Urine leaves the kidney through a duct ureter.
- Ureters of both kidneys drain into urinary bladder through uretral orifice. Urinary bladder stores urine before its removal.
- Urine leaves the body during urination/ micturition, from the bladder through a tube called the urethra.
- Urethra empties near vagina in females or through penis in males.
- Sphincter muscles (Urethral sphincter) near the junction of urethra and urinary bladder control the urine in bladder. This is an example of dual sphincter.



KIDNEYS

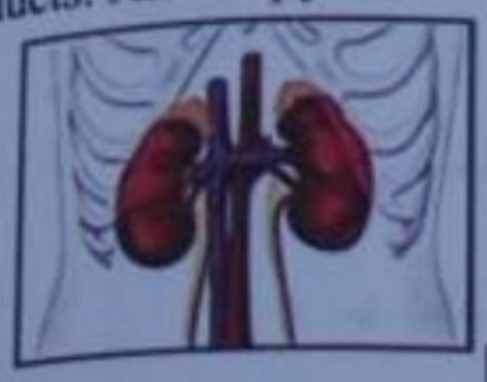
Introduction

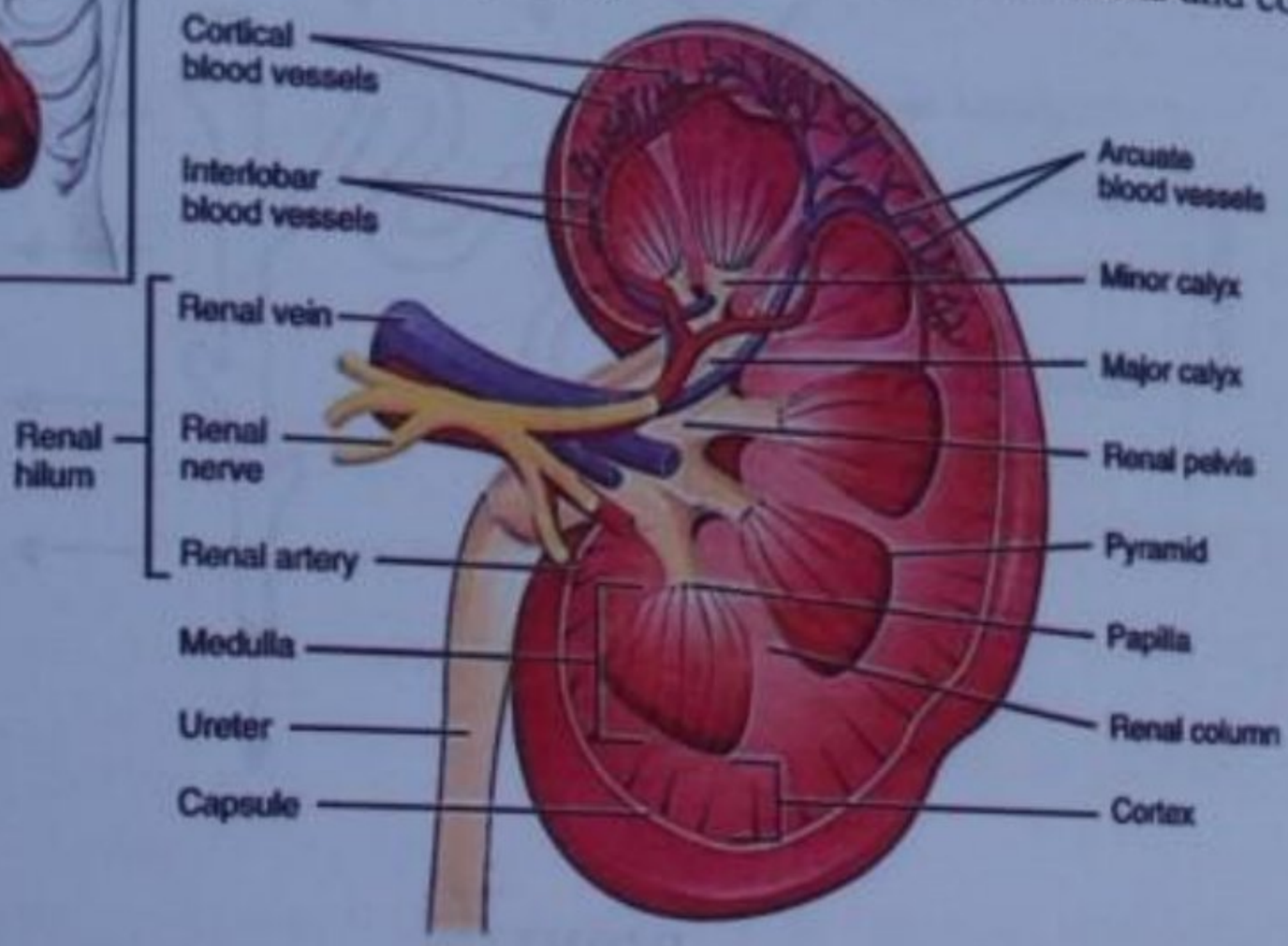
- Humans have two kidneys placed in abdominal cavity, on both sides of vertebral column and attached with dorsal abdominal wall.
- Right kidney is slightly lower in position than left kidney due to longer right lobe of liver.
- A pair of kidneys consists of millions of functional units called nephrons or urinary tubules.
- Kidneys are not only the major excretory organs of humans but also act as an osmoregulator.
- Kidneys account for just less than *1 %* of the body weight, while they receive *20%* of blood supplied with each cardiac output.

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Morphology

- Kidneys are bean shaped with inner concave and outer convex walls.
- Middle portion of kidneys by which all vessels enter, or leave is called renal hilus.
- Outer darker portion of kidney is called renal cortex while inner brighter portion is called renal medulla. Cortex contains renal corpuscles and convoluted tubules.
- Renal pyramids are conical parts of renal medulla containing blood vessels and collecting ducts. All the pyramids project into the pelvis.





Functions

- Kidneys are involved in filtration of wastes from blood, formation of urine and its removal outside the body through tubular system.
- Kidneys act as osmoregulatory organs and maintain solute and water level in blood and body.
- Kidneys also help to regulate blood volume and blood pressure.
- Kidneys also release a stimulus (erythropoietin) for production of RBCs.

NEPHRONS

- Basic structural and functional unit of a kidney is called ***nephron***.
- These are also called as urinary tubules.
- Each nephron is composed of renal corpuscle and renal tubule.

Types

- Nephrons are of two types i.e. cortical and juxtamedullary.
- Those nephrons that are present along the border of cortex and medulla, with tubular system looping deep in inner medulla are called juxtamedullary nephrons.
- The nephrons arranged along the cortex are called cortical nephrons.
- ***Juxtamedullary nephrons*** play important role in production of concentrated urine.

POINT TO PONDER

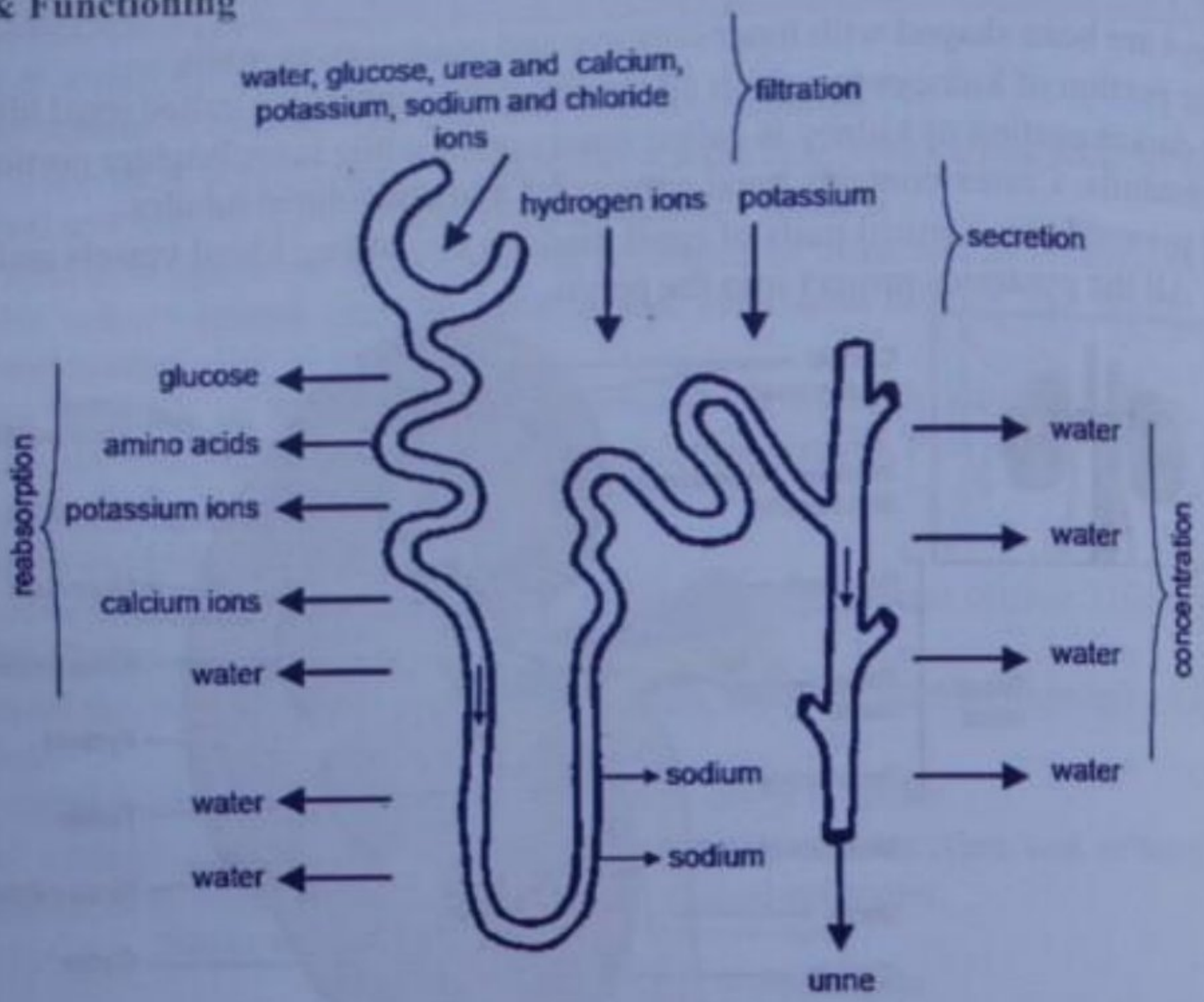
Why left kidney is slightly lower than other in position & why?

POINT TO PONDER

How do the skin & lungs contribute in excretion?

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Structure & Functioning



POINT TO PONDER

Which organ in human body receives maximum blood supply?

Component	Anatomical Features	Physiological Features
Bowman's capsule	• Cup shaped • Blind end	Pressure Filtration
Glomerulus	• Cluster of blood capillaries inside Bowman's capsule • Porous walls • High blood pressure • Receives blood from afferent arterioles.	Pressure Filtration
Peritubular network	• Network of capillaries around tubular part • Receives blood from efferent arterioles • Vasa recta is additional loop in Juxtamedullary nephrons	Selective Reabsorption

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		Homeostasis
Proximal convoluted part	• 1st convoluted part	• Selective Reabsorption • Maximum Reabsorption
Loop of Henle	• Descending/ Thin limb (Permeable to water) • Ascending/ Thick limb (Permeable to Na^+ ions)	• Selective Reabsorption • Counter Current Multiplier • Site of action of aldosterone • Tubular Secretion (Ascending Limb)
Distal convoluted part	2nd convoluted part	• Selective secretion
Collecting tubules	Changeable permeability for water	Reabsorption of water under action of ADH

Mechanism of Urine Formation

Urine formation involves following steps:

1. **Pressure Filtration/ Ultrafiltration**
- Blood passing through glomerulus is filtered into Bowman's capsule.
- Glomerulus walls are porous and the fraction of blood pressure reaching here provides the filtration pressure.
- The filtrate appearing in Bowman's capsule is called as glomerular filtrate, which contains various useful substances such as glucose, amino acids, salts etc.
- Composition of glomerular filtrate is same as plasma minus plasma proteins.

2. **Selective Reabsorption**
- It occurs at the tubular part of nephrons.
- Most of the useful constituents of glomerular filtrate (80%) are reabsorbed in proximal tubules and when filtrate leaves proximal tubules, it mostly contains nitrogenous wastes.
- Glucose, amino acids, vitamins and hormones are 100% reabsorbed while sodium chloride and water are 80% reabsorbed.

3. **Tubular Secretion**
- The tubular epithelium also secretes substances into the lumen.
- This secretion is very selective and is mainly of hydrogen ions to balance pH/ acid base balance of blood and filtrate.

CONCENTRATION OF URINE

- In restricted supply of water, the conservation of water is the principal function of the body. This is done by concentration of filtrate by counter current and hormonal mechanisms.
  Less H_2O/ Hyperosmotic Body Fluid → More ADH → More Reabsorption of H_2O → Less amount of concentrated urine.
- In the sufficient or excess supply of water, reabsorption of water from the filtrate is reduced, specifically due to inhibition of release of ADH in the presence of hypoosmotic body fluids. The reduction in reabsorption causes large volume of diluted urine.
  More H_2O/ Hypoosmotic Body Fluids → Less ADH → Less Reabsorption of H_2O → More amount of diluted urine
- Mammalian kidney including humans is adapted to conserve water by over 99.5% reabsorption of glomerular filtrate.

Factors for Concentration

1. **Structural Adaptation**
Juxtamedullary nephrons and vasa recta are structural adaptations for concentration of urine.

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2. **Hypertonic Environment of Medulla**
The interstitial fluid of kidney is gradually concentrated from cortical to medullary part. The inner medulla is highly concentrated due to presence of urea and counter current multiplier.

3. **Counter Current Multiplier**
Counter current multiplier causes gradual osmotic outflow of water from the filtrate back to kidney as it passes downward in the descending loop of Henle. Ascending loop of Henle does not allow outflow of water from its filtrate, instead actively transports Na ions into kidney interstitium to sustain its high concentration.

4. **Hormonal Control**
- The active uptake of sodium in the ascending limb or thick loop of Henle is promoted by the action of aldosterone, the hormone secreted from adrenal cortex.
- ADH released from posterior pituitary lobe acts to actively transport water from filtrate in collecting tubules back to kidney.

POINT TO PONDER
Why the colour of urine is yellow?

POINT TO PONDER
What is literal meaning of ADH?

OSMOREGULATION

- The mechanism of regulation, generally between organism and its environment, of solute and the gain and loss of water is osmoregulation.
- Water is solvent of the solutes in the cell. Each cell has been adapted to defined quantity of water in relation to salts in it to perform its functions.

Water Relations to Cells

1. **Hypotonic Environment**
- Diluted solutions compared to the cell concentration is designated as hypotonic environment.
- The hypotonic environment osmotically causes entry of water into the cell and renders the cell solutions diluted which is needed to be regulated.
- The plant cells become turgid while animal cells may be ruptured.

2. **Hypertonic Environment**
- The more concentrated external environment is termed as hypertonic environment.
- The hypertonic environment renders cell solutions concentrated and shrinks the cell due to loss of water which is needed to be regulated.

3. **Isotonic Environment**
- Environment that resembles to internal solution is called isotonic environment.
- There is no need of osmoregulation in such case. Such animals are called osmoconformers.



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THERMOREGULATION

Maintenance of internal temperature within a tolerable range is designated as thermoregulation.

- Animals are classified into three groups on the base of thermoregulation i.e. ectotherm, endotherm and heterotherm.
- Animals that generate their own heat through heat production as by product during metabolism are endotherms e.g. humans, birds, some fishes and flying insects.
- Animals which produce metabolic heat at low level (that is also exchanged with the environment quickly) and absorb heat from surroundings are called ectotherm e.g. most invertebrates, fish, amphibians and reptiles.
- Animals which are capable of varying degrees of endothermic heat production but generally do not regulate their body temperature within a narrow range are heterotherms e.g. bats, humming bird etc.

Thermoregulatory Adaptations in Animals

Adaptation	Examples
Structural Adaptations	• Changes in sub-dermal fatty layer insulation. • Pelage • Sweat glands • Lungs modification for panting
Physiological Adaptations	• Regulation of blood flow to skin (Vasodilation, Vasoconstriction). • Activation of muscles for thermogenesis • Plumage fluffing • Activation of sweat glands for evaporative cooling
Behavioural Adaptations	• Change in habitat • Change in body posture

THERMOREGULATION IN MAMMALS/ HUMANS

Regulatory Strategies

- Mammals including humans maintain their body temperature within a narrow range of about 36-38°C (36.1-37.8°C).
- Humans are endotherm.
- Hypothalamus is thermoregulatory centre in humans.

Strategies in Cold Temperature

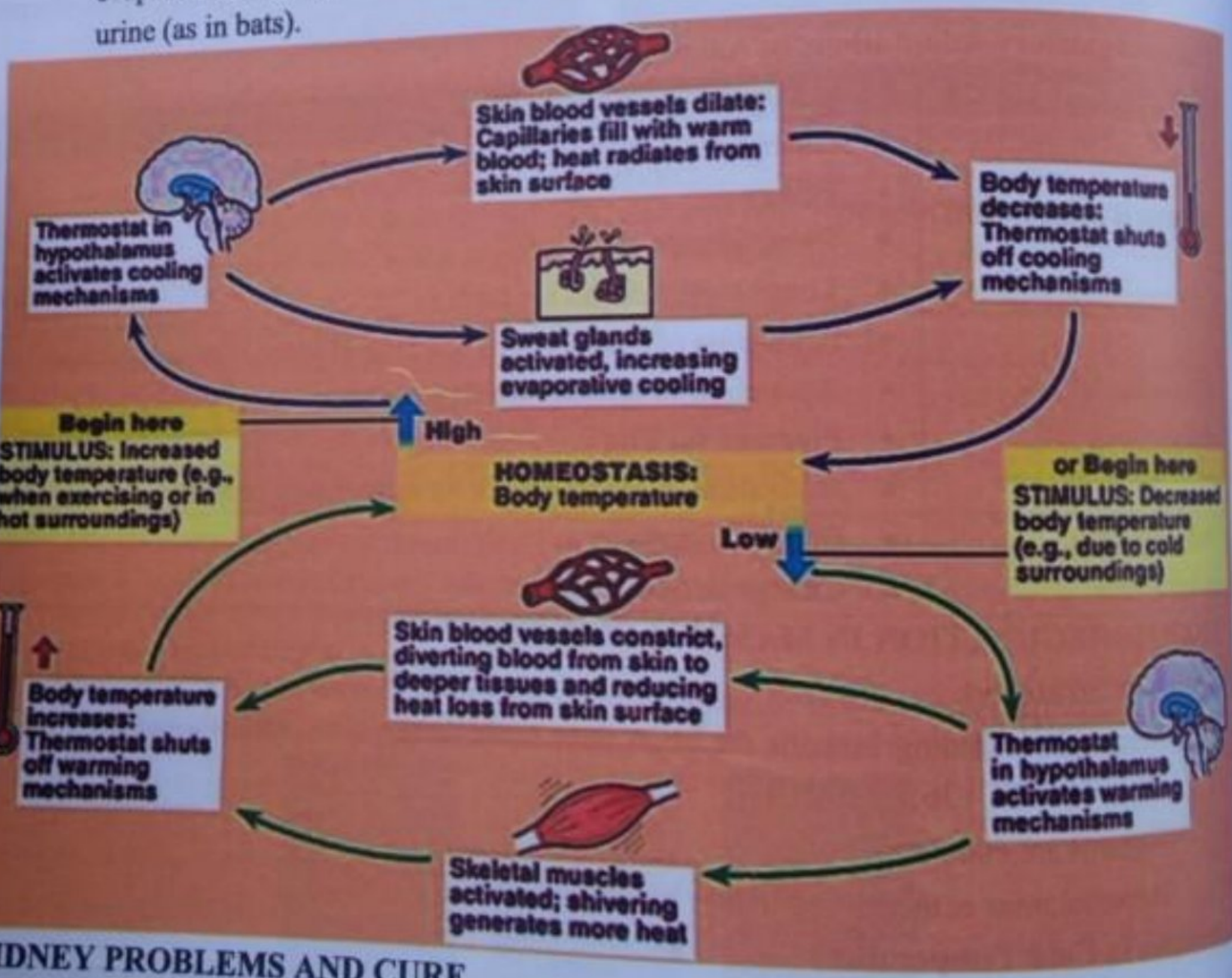
- The rate of heat production is increased by increased muscle contraction by movements or shivering so called shivering thermogenesis.
- Hormones trigger the heat production as do thyroid hormones and are termed as non-shivering thermogenesis.
- Some mammals have brown fat, which is specialized for rapid heat production.
- Vasoconstriction occurs at skin which reduces rate of blood flow and also heat loss.
- Vasodilation occurs at trunk where most of the vital organs are located.

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- Sweat glands are inhibited.
- Erection of hair in humans and raising of fur in others maintains body heat by trapping air and increasing insulation.
- Humans mostly rely on a layer of fat beneath skin acting as insulating layer. Similarly marine mammals like whales and seals inhabit much colder water and have a thick layer of insulating fat called blubber just under the skin.

Strategies in Warm Temperature

- Vasodilation occurs at skin which increases rate of blood flow and more heat loss.
- Heat dissipation occurs either through evaporation, radiation, conduction or convection.
- Sweat glands are activated which promote evaporative cooling. In some mammals, this evaporative cooling occurs in the respiratory tract (panting in dogs) or through saliva and urine (as in bats).



KIDNEY PROBLEMS AND CURE

KIDNEY STONES

- Stone formation in kidney and urinary bladder, results in obstruction to flow of urine, increases susceptibility to infection and thus eventually leads to kidney failure.

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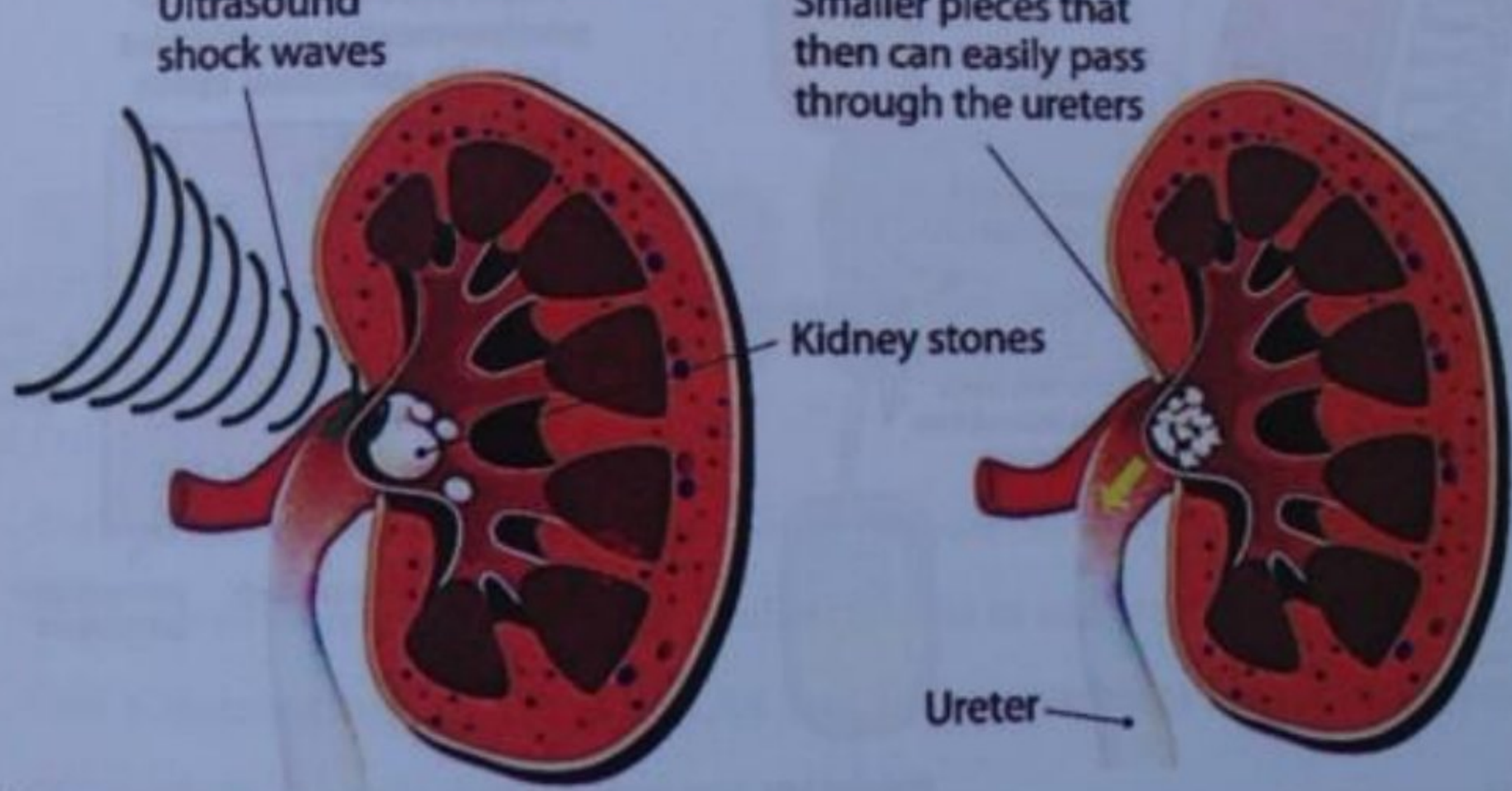
Types of Stones

Different types of kidney stones are as follows:

Type of Stone	%Age	Cause
Calcium oxalate	70%	• Higher level of oxalates in blood. • Increased use of tomatoes and green leafy vegetables.
Calcium phosphate	15%	• Hypercalcemia (high level of Ca^{2+} in the blood) • Hyperparathyroidism
Uric acid	10%	• Increased uric acid level in blood • High protein intake in food

Cure

- Lithotripsy is used for non-surgical removal of smaller kidney stones.
- ***Extracorporeal shock wave lithotripsy*** **(ESWL)** is the one opted for small kidney stones. This is a minimal invasive surgery, in which kidney, pelvic or ureteric stones are broken down by bombarding ultrasounds or X- rays on them without giving any cut.
- Smaller stone pieces are flushed through ureter and then through urethra out of the body.
- ***Renal surgery*** is done for larger stones which can't be broken by lithotripsy technique. Direct surgical exposure and removal of stone is done.



RENAL FAILURE

- Failure of all the kidney functions i.e., excretory, osmoregulatory, hormonal (secretion of erythropoietin) and metabolic function is called renal failure.
- Nephrons are destroyed particularly at glomerular part, leading to accumulation of urea, other waste materials, bone weakening and anemia.

Causes

- Acute renal failure can occur due to blood clot or cholesterol deposits. Certain chemotherapy drugs, antibiotics and toxins such as alcohol, heavy metals and cocaine can also cause kidney failure.

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- Most common causes of chronic renal failure are diabetes and hypertension. Other causes include long-term daily use of anti-inflammatory drugs and other analgesic medicines.

Cure

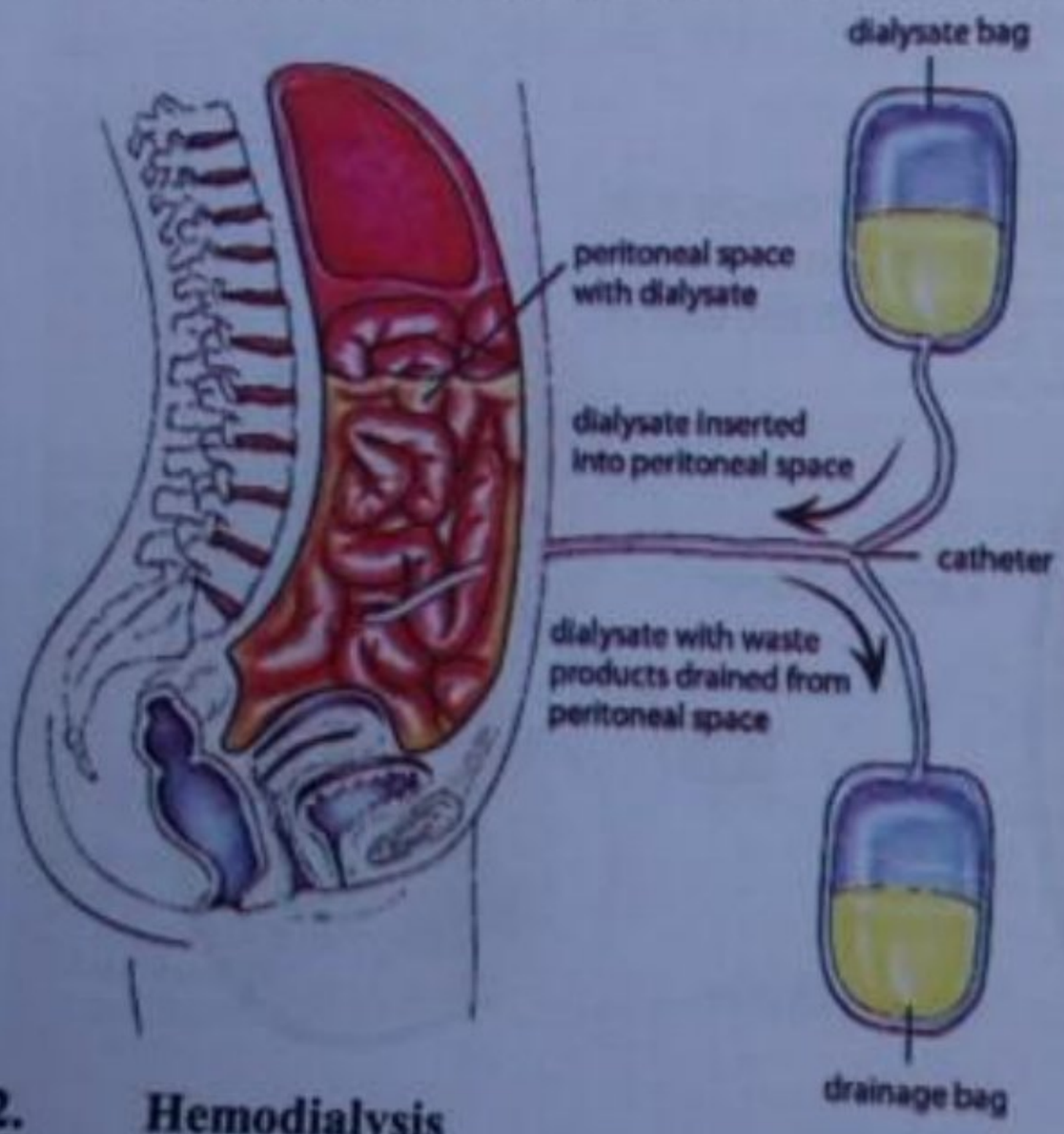
It is either dialysis or kidney transplantation.

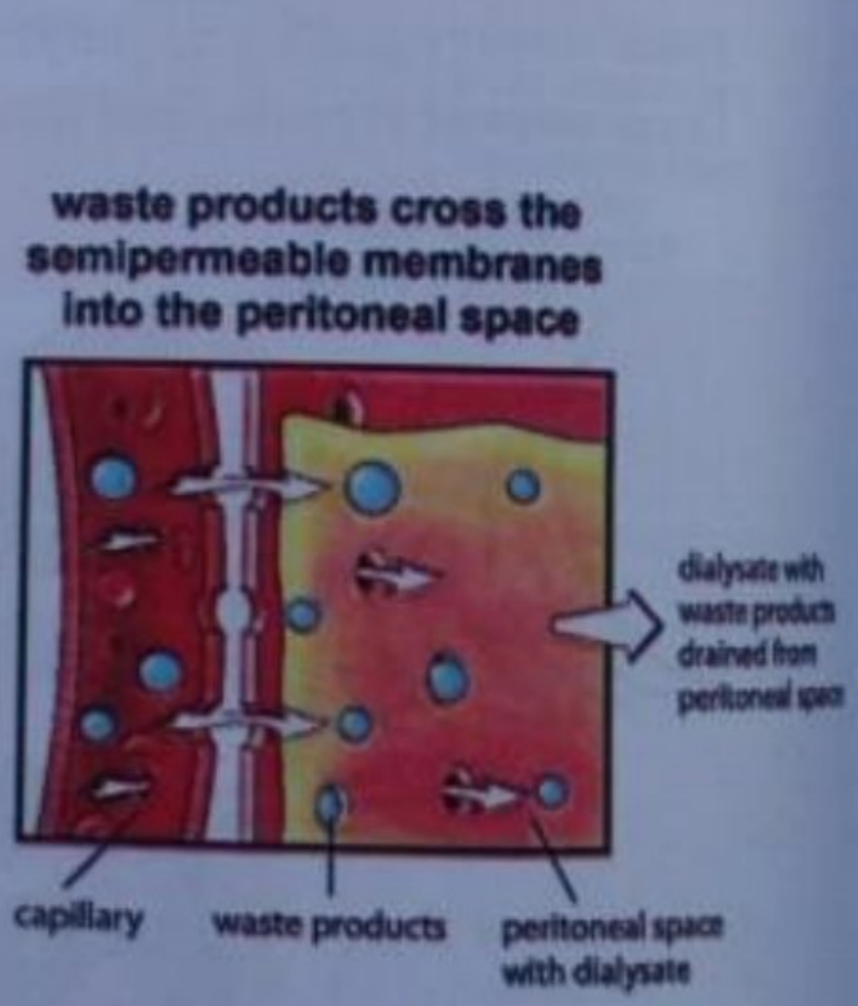
Dialysis

- The process of artificially removing nitrogenous wastes is called dialysis.
- The waste materials e.g. urea from the blood, either by pass kidneys through an artificial kidney (dialysis machine) or filtering it within the abdomen.
- Dialysis is of two types i.e. peritoneal dialysis and hemodialysis.

1. **Peritoneal Dialysis**

- ***Peritoneal dialysis*** uses the peritoneum (inner lining of abdomen) to filter the blood present in peritoneal blood vessels.
- Peritoneal cavity is filled with dialyzing solution. Waste materials having high concentration in blood are filtered through peritoneum into the peritoneal cavity containing dialyzing solution, which is removed afterwards.

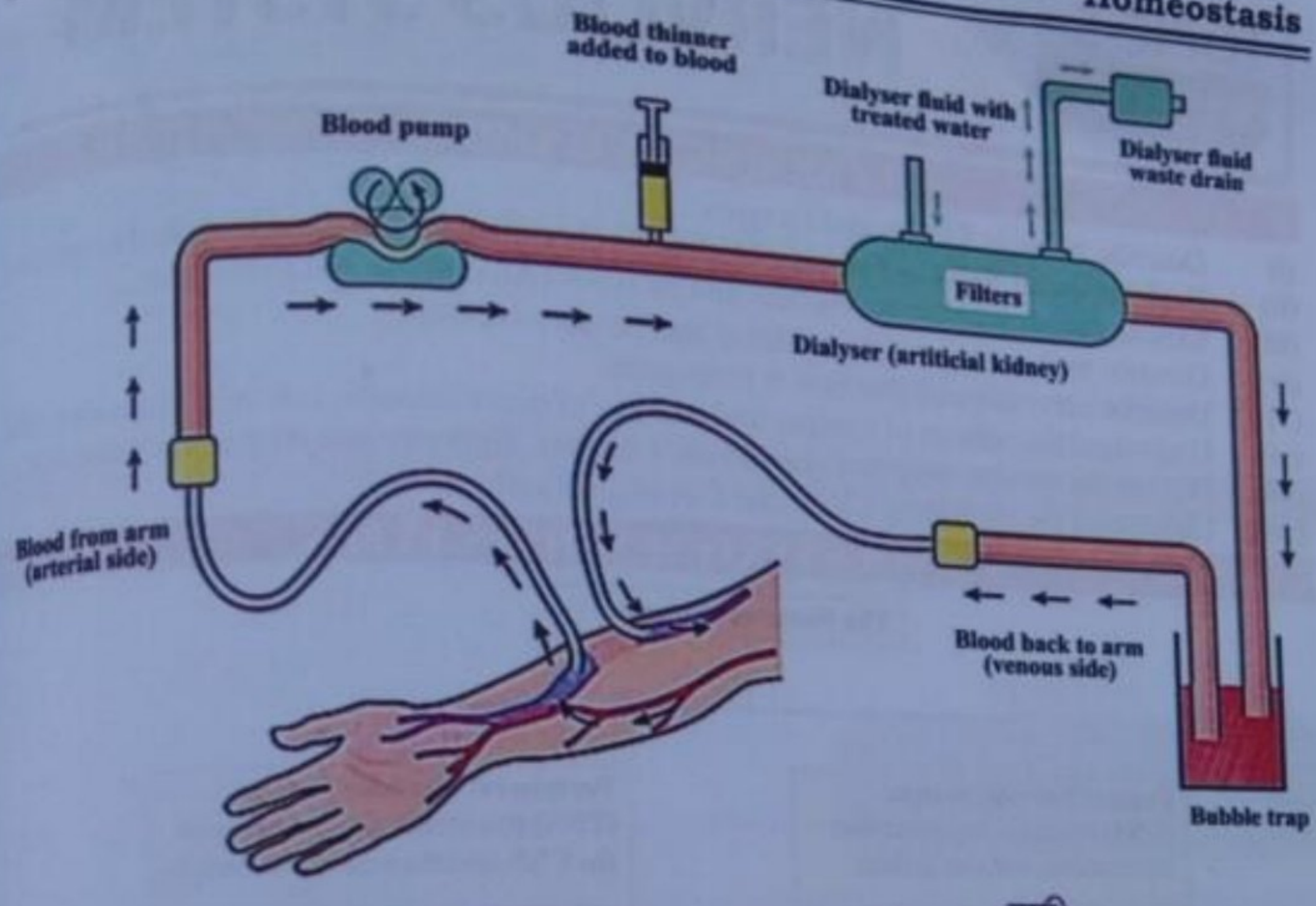




2. **Hemodialysis**

- Hemodialysis means cleaning the blood.
- Waste material in blood is filtered by passing it through a machine which contains a dialyzer also called ***artificial kidney.***
- It is made of two spaces separated by a thin membrane. Blood flows inside the membrane in one direction and dialyzing fluid outside the membrane in another direction.

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POINT TO PONDER

Why kidney failure causes Anemia & high blood pressure?

POINT TO PONDER

Differentiate between
(a) Micturation (b) Egestion
(c) Excretion

Renal Transplant

- It is considered permanent treatment. Since dialysis can only be done on temporary basis.
- Mostly opted in severe renal failure, called uremia or end-stage renal disease.
- Only a matched kidney (blood/HLAs and tissue matching) can be transplanted in an individual. So it needs donor-recipient matching.

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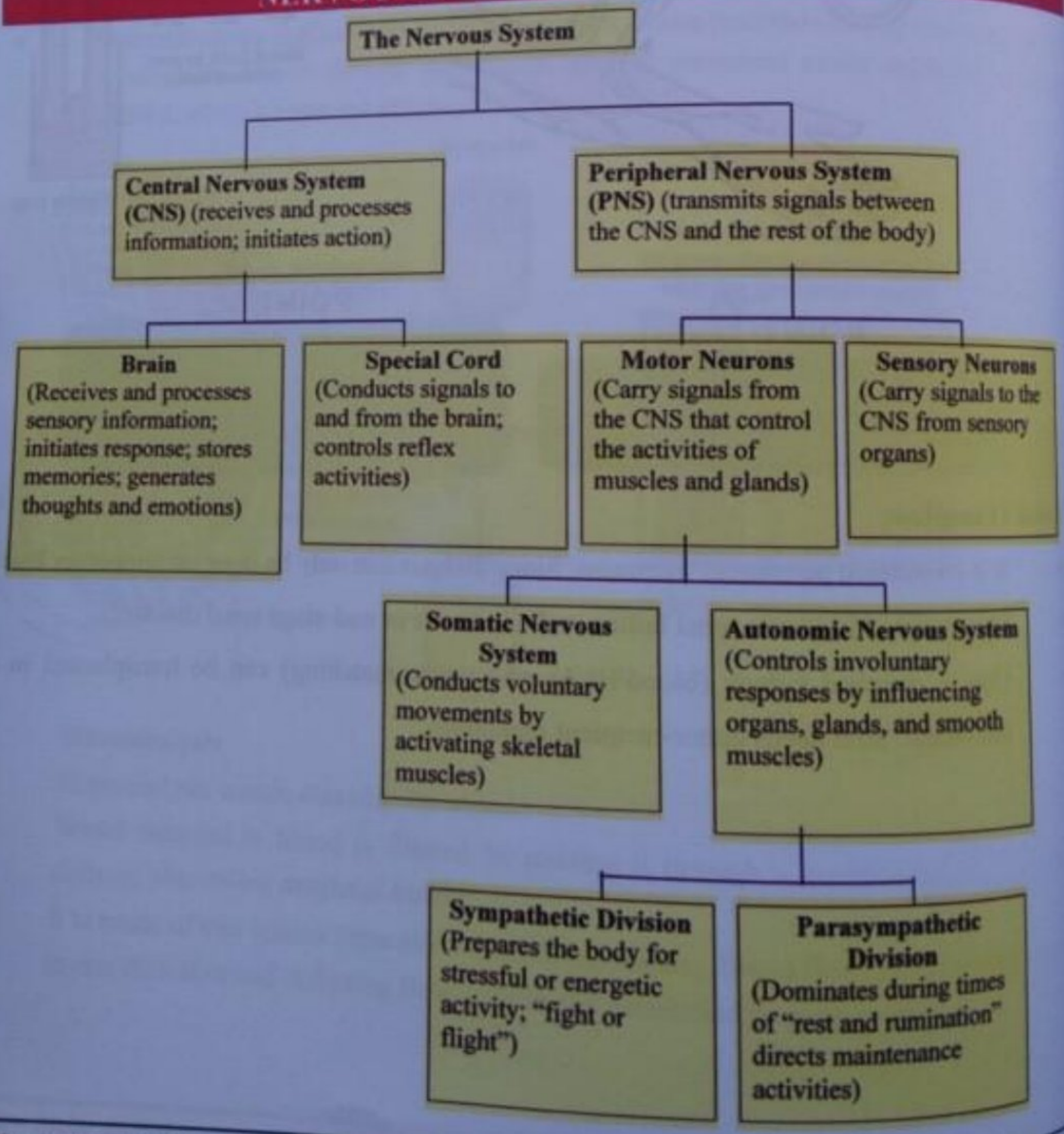
TOPIC-5e
04 MCQs

NERVOUS SYSTEM

LEARNING OUTCOMES

(i) Describe Nervous System and its types.
(ii) Explain Central Nervous System including forebrain, mid brain, hind brain and spinal cord.
(iii) Explain Peripheral Nervous System and its types (Autonomic and Sympathetic).
(iv) Describe neurons (Associative, Motor and Sensory Neurons).
(v) Describe nerve impulse and how it propagates.
(vi) Understand the concept of synapse and passage of nerve impulse, role of neurotransmitters.
(vii) Discuss the nervous disorders (Parkinson's disease, Epilepsy and Alzheimer's disease).
(viii) Understand the Biological Clock and Circadian Rhythms.

NERVOUS SYSTEM AND ITS TYPES



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EVOLUTION OF NERVOUS SYSTEM

Feature	Diffused Type	Centralized Type
Brain	×	✓
Specialized Neurons	×	✓
Ganglia	✓	✓
Sense Organs	×	✓
Nerves	×	✓
Direction of Stimulus	Non-Directional	Directional
Phylum	Cnidaria	Platyhelminthes to Chordata
Example	Hydra	Planaria

CENTRAL NERVOUS SYSTEM

- The central nervous system consists of brain and spinal cord
- Both brain and spinal cord are hollow. The spinal cord has central canal and brain has many cavities (ventricles).
- Both are protected in three ways.

(i) Cranium, which is part of skull, protects the brain and neural arches of vertebrae of vertebral column protect the spinal cord.

(ii) The brain and spinal cord are also protected by three layers of meninges.

POINT TO PONDER

Write names of 3 layers of meninges and their sequence.

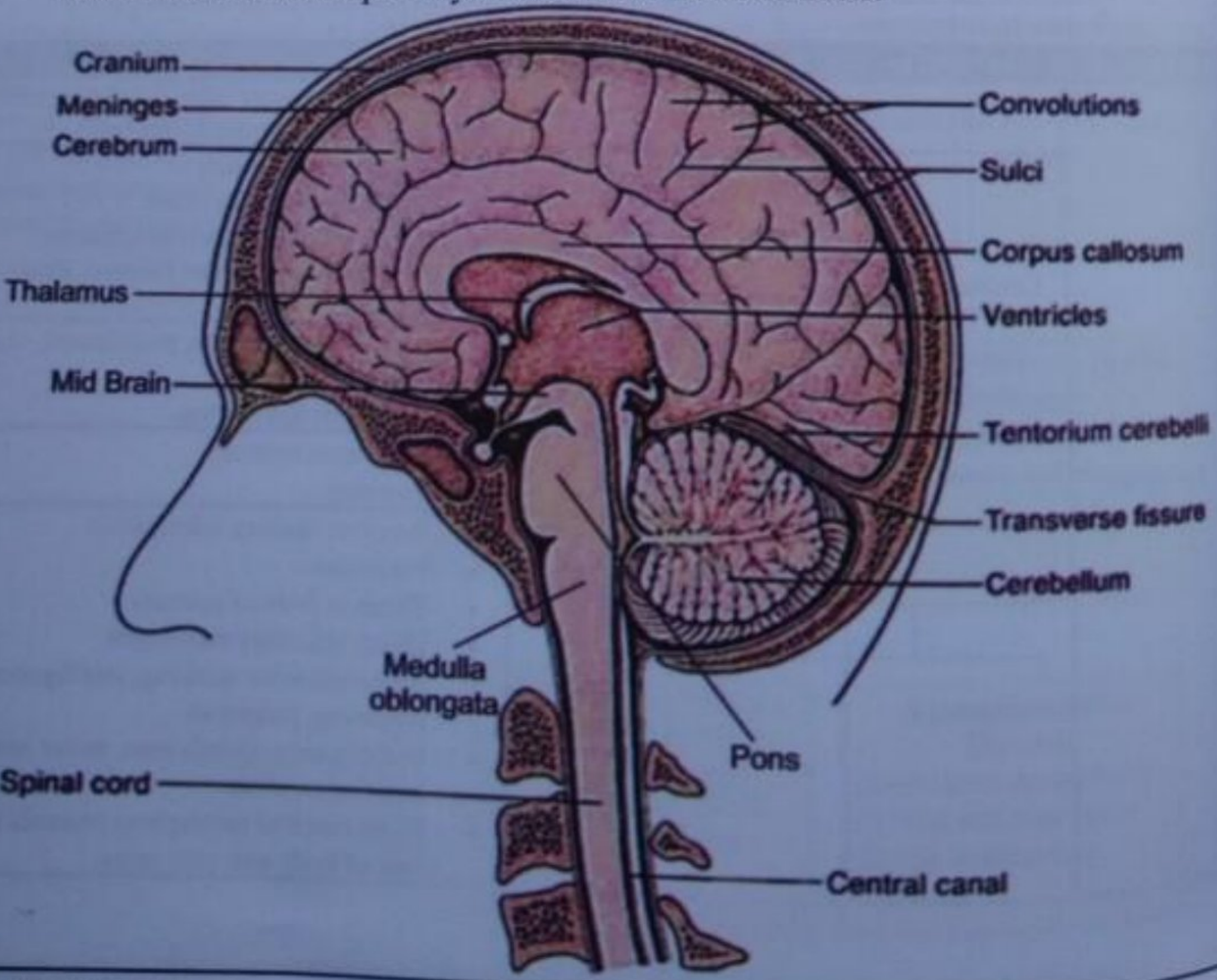
(iii) CSF bathes the neurons of brain and spinal cord and cushions against the bumps and jolts. Its composition is similar to blood plasma. It is found in cavities of brain and spinal cord and between meninges.

Parts	Sub-Parts	Anatomical Features	Physiological Features
Forebrain	Thalamus	Relay centre	Relay between sensory input from eyes, ears, skin etc to limbic system & cerebrum.
	Limbic system (Arc between thalamus & cerebrum)	Hypothalamus	• Hormone production • Major coordinating center • Controls body temperature, hunger, menstrual cycle, water balance, sleep-wake cycle.
		Amygdala (cluster of neurons)	• Sensation of pleasure, punishment, sexual arousal • Feeling of fear & rage
		Hippocampus	• Long-term memory • Learning
	Cerebrum	• Largest part • Two halves (cerebral hemispheres) • Corpus callosum (band of axons) • Outer cerebral cortex forming convolutions	• Receives sensory information • Processes it • Stores in form of memory • Direct voluntary movement • Responsible for thinking, intelligence, reasoning, judgment. • Sensory area, speech area, motor area, association areas • Right cerebral hemisphere controls left side of body and vice versa.

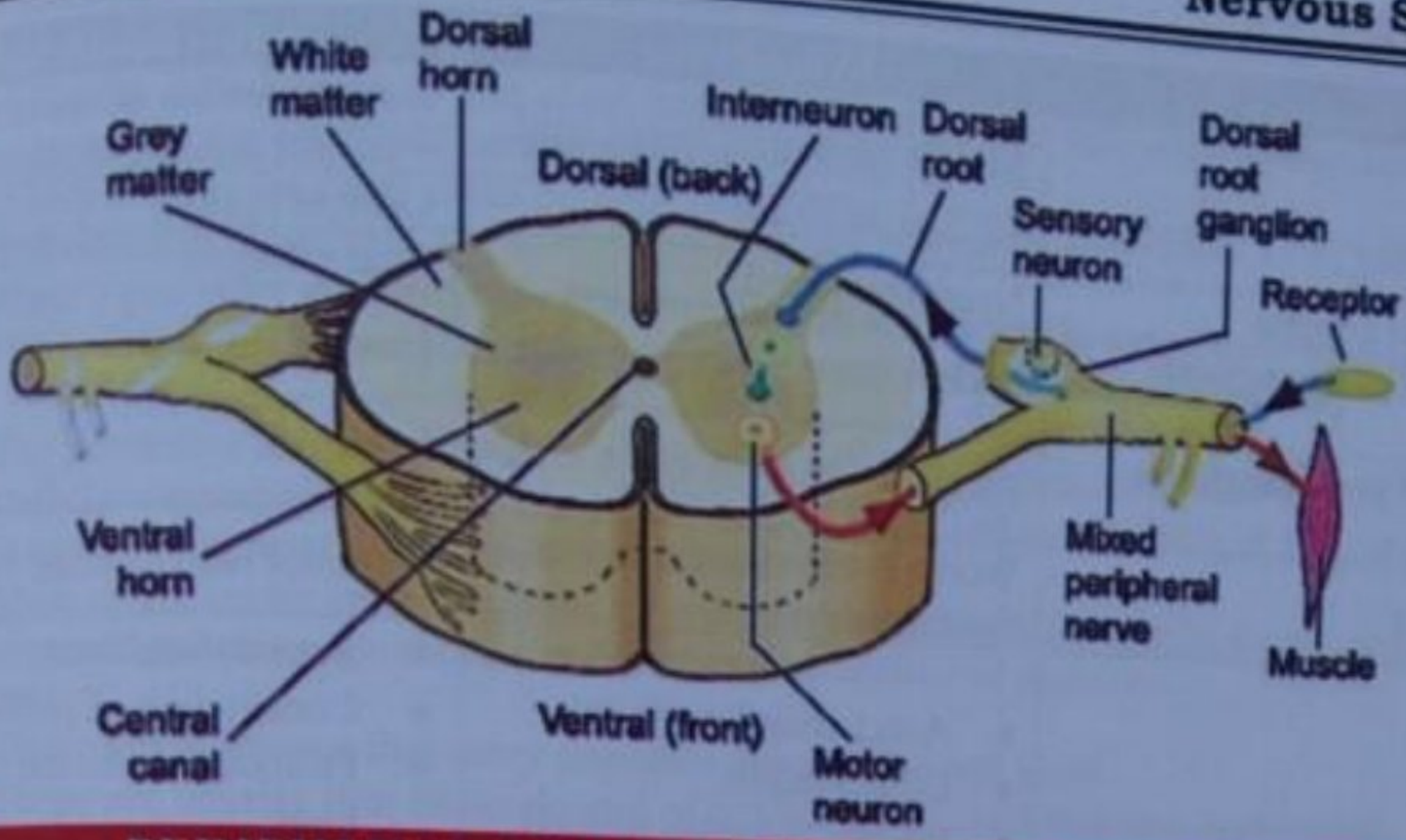
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Midbrain (reduced in human)	Reticular formation		• Relay center connecting hindbrain with forebrain • Screening input information • Contains auditory relay station,
Hindbrain	Pons		• Influence transition between sleep & wakefulness • Controls rate & pattern of breathing
	Medulla		Controls autonomic functions e.g. • Breathing • Heart rate • Blood pressure • Swallowing
	Cerebellum (best developed in birds)	2nd largest part 2 cerebellar hemispheres connected by vermis.	• Coordinates voluntary movements • Guides smooth & accurate motions • Maintains body position • Learning & memory storage for behaviours.
Spinal Cord		• Oval shaped hollow cylinder • Runs throughout vertebral column • Inner butterfly shaped gray matter • Central canal • Outer white matter	• Centre for many reflexes • Pathway for conduction of impulses to and from different parts of body and brain.

- Gray matter consists of cell bodies and non-myelinated nerve fibers or tracts.
- White matter is made up of myelinated nerve fibers or tracts.



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PERIPHERAL NERVOUS SYSTEM & ITS TYPES

- It consists of sensory neurons and motor neurons, which may form ganglia and the nerves.
- ***Ganglia*** are concentrations of cell bodies of neurons. Ganglia often interconnect with other ganglia to form a complex system called plexus.
- The ***nerves*** are the bundles of axons or dendrites, bounded by connective tissue.

POINT PONDER 70

Can you explain the role of vagus nerve?

Classification of Nerves

Functional Classification

- They may be sensory, motor or mixed nerves depending upon the direction of impulse they conduct.
- Mixed nerves contain both sensory and motor neurons.

Regional Classification

- Nerves which arise or lead to brain are called cerebral or cranial nerves. There are 12 pairs of cranial nerves in humans. Some of these are sensory, some motor and some are mixed. All these supply to only head except for vagus nerve which extends even upto abdomen.
- Nerves that arise or lead to spinal cord are called spinal nerves. There are 31 pairs of spinal nerves (8 cervical, 12 thoracic, 5 lumbar, 5 sacral and 1 coccygeal) and all are mixed nerves.

Classification of PNS

- Motor neurons form ***somatic nervous system***, which controls voluntary movements, which are under conscious control of the body, involving skeletal muscles.
- The motor neurons from ***autonomic nervous system*** which control involuntary responses are divided into the sympathetic and parasympathetic nervous system.

Autonomic Nervous System

- It controls involuntary responses by influencing organs, glands and smooth muscles.
- It is classified into sympathetic and parasympathetic divisions.

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Features	Sympathetic	Parasympathetic
Origin	Middle portion of spinal cord	Bottom portion of spinal cord + cranial nerves (vagus nerves)
	Thoracic region	Lumbar region
Position of ganglia	Near spinal cord	Near effectors
Length of pre-ganglionic fibers	Short	Long
Length of post-ganglionic fibers	Long	Short
Functions	Works in emergency, fear and fight situations	Promotes relaxed state
Actions	• Accelerates heartbeat • Dilates pupils • Inhibits digestion of food • Rise in blood pressure	• Retards heartbeat • Constriction of pupils • Promotes digestion of food • Lowering of blood pressure

POINT TO PONDER

What is difference in length of pre and post-ganglionic fibers in divisions of ANS?

POINT TO PONDER

How do you relate neurotransmitter with divisions of ANS?

NEURONS

- It is the basic structural and functional unit of nervous system.
- Neurons can generate and conduct nerve impulses which travel across synapses and pass from receptors to effectors, bringing about nervous coordination.

POINT TO PONDER

Why neurons are excitable?

- Neuroglia cells mostly present in higher animals, playing important role in nutrition of neurons and their protection by myelin sheath.
- They constitute nearly half of the nervous system.
- Neurons once matured do not divide any further. However, they exhibit limited regenerative capabilities, only if neural cell body is intact.

Structure of Neuron

A typical neuron consists of:

(1) Cell body

(2) Dendrites

(3) Axons.

POINT TO PONDER

Why neurons are unable to divide?

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Cell Body

- It is also called soma, is the chief nutritional part of the cell, and synthesizes materials necessary for growth and maintenance of neuron.
- It contains nucleus and other cellular organelles, like E.R, ribosomes, G.A, mitochondria embedded in cytoplasm.
- ***Nissl's granules*** are group of ribosomes which are present in association with R.E.R.
- If it is intact, the neuron can regenerate its axonal and dendrital components.

Axons

- The processes carrying impulses away from cell body are called axons.
- Cellular organelles like mitochondria, microtubules and neurofibrils, R.E.R. and G.A are present throughout the axoplasm of the neuron.
- Most of the axons are surrounded by protective sheaths called myelin sheath, important for neuronal nutrition, protection and proper propagation of impulses.

Dendrites

- These are processes that carry impulses towards the cell body.
- These are usually thin fibres devoid of Schwann cells and thus non-myelinated.
- They unlike axon give a spiny look.

Myelin Sheath

- Neurons are surrounded by a layer, of fatty substance, called myelin sheath.
- It acts as insulator and gives white appearance.
- It is secreted by Schwann cells in peripheral nervous system.

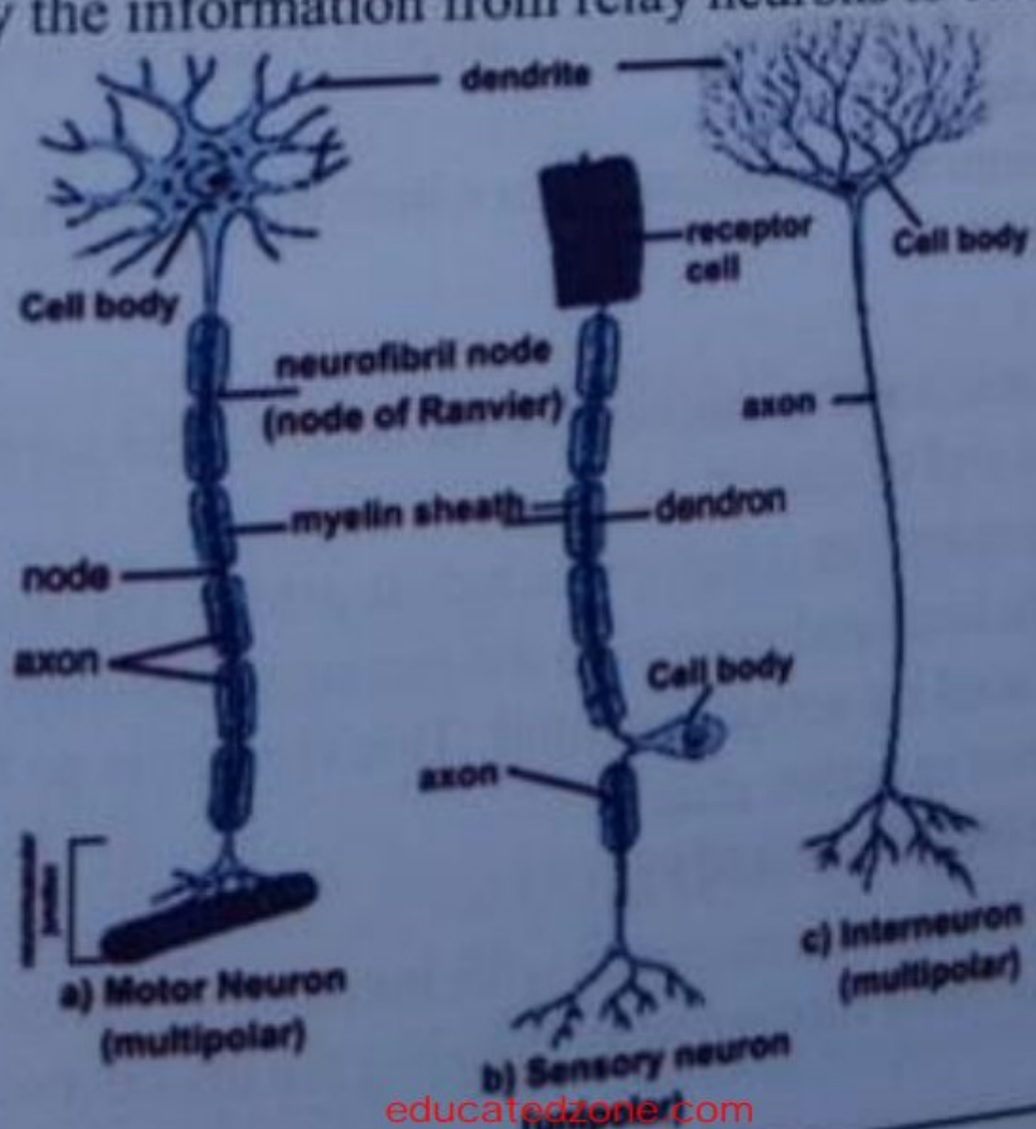
Types of Neurons

There are three main types of neurons:

1. **Sensory Neurons**
- ***Sensory neurons*** carry sensory information from receptors to associative neurons present in CNS.
- The dendrite endings of some sensory neurons also acts as receptors.
- They usually have single long dendrite called Dendron. It is structurally and functionally similar to axon.

2. **Associative Neurons**
- Associative (intermediate/ relay) neurons are present in CNS and connect sensory and motor neurons.
- They are involved in processing and interpretation of information coming from receptors.

3. **Motor Neurons**
- Motor neurons carry the information from relay neurons to effectors.



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NERVE IMPULSE

Definition

Nerve impulse is a wave of electrochemical changes, which travels along the length of neurons involving movement of ions across the membrane and chemical reactions.

Membrane Potential

- Electrical potential is the measure of the capacity to do electric work.
- The electrical potential that exists across a cell membrane is called membrane potential.

A) Resting Membrane Potential

- Potential difference across the membrane when neuron is in non-conducting state is called resting membrane potential (RMP).
- Neuron in this state is in polarized form.
- A typical neuron at rest is more positive electrically outside than inside the cell membrane.
- Its value for a typical neuron is -70 mV.

B) Active Membrane Potential/ Action Potential

- Potential difference across the membrane when neuron is in conducting state is called active membrane potential (AMP).
- It is in form of nerve impulse. During this state, inner membrane surface becomes more positive than outside.
- Its value is +50 mV.

Ions Involved

- Sodium and potassium ions are most important in nerve cell and surrounding fluid.
- Sodium ions are tenfold higher in concentration outside than inside the membrane surface.
- Potassium ions are twenty times more concentrated inside than outside.
- The large negative organic ions (such as proteins, organic acids etc.) are much more inside the membrane than outside. This makes the inside of neuron membrane more negative.

Channels Involved

- The cell membrane is virtually impermeable to all ions except K^+ so some K^+ leak out of the cell. The loss of these positive ions from neuron by diffusion accounts for more negative charges inside than outside.
- All the neurons have very active sodium and potassium pumps located in their cell membranes. Driven by the splitting of ATP, these pumps transport 3 Na+ out and 2 K+ into the cell, against their concentration gradient.
- Cell membrane has sodium and potassium gates which when open allow movement of ions along the concentration gradient.

Initiation of Nerve Impulse

- Under normal conditions, a nerve impulse is initiated by an appropriate stimulus (threshold stimulus) applied at one end of neuron.
- Minimum intensity of stimulus that is required to initiate a nerve impulse is called ***threshold stimulus***.
- It results in a remarkable localized change in the resting membrane potential. It disappears for a brief instant and is replaced by action potential. This change is so brief (for a millisecond) that only a portion of neuron is in active state.

Conduction of Nerve Impulse (RMP → AMP)

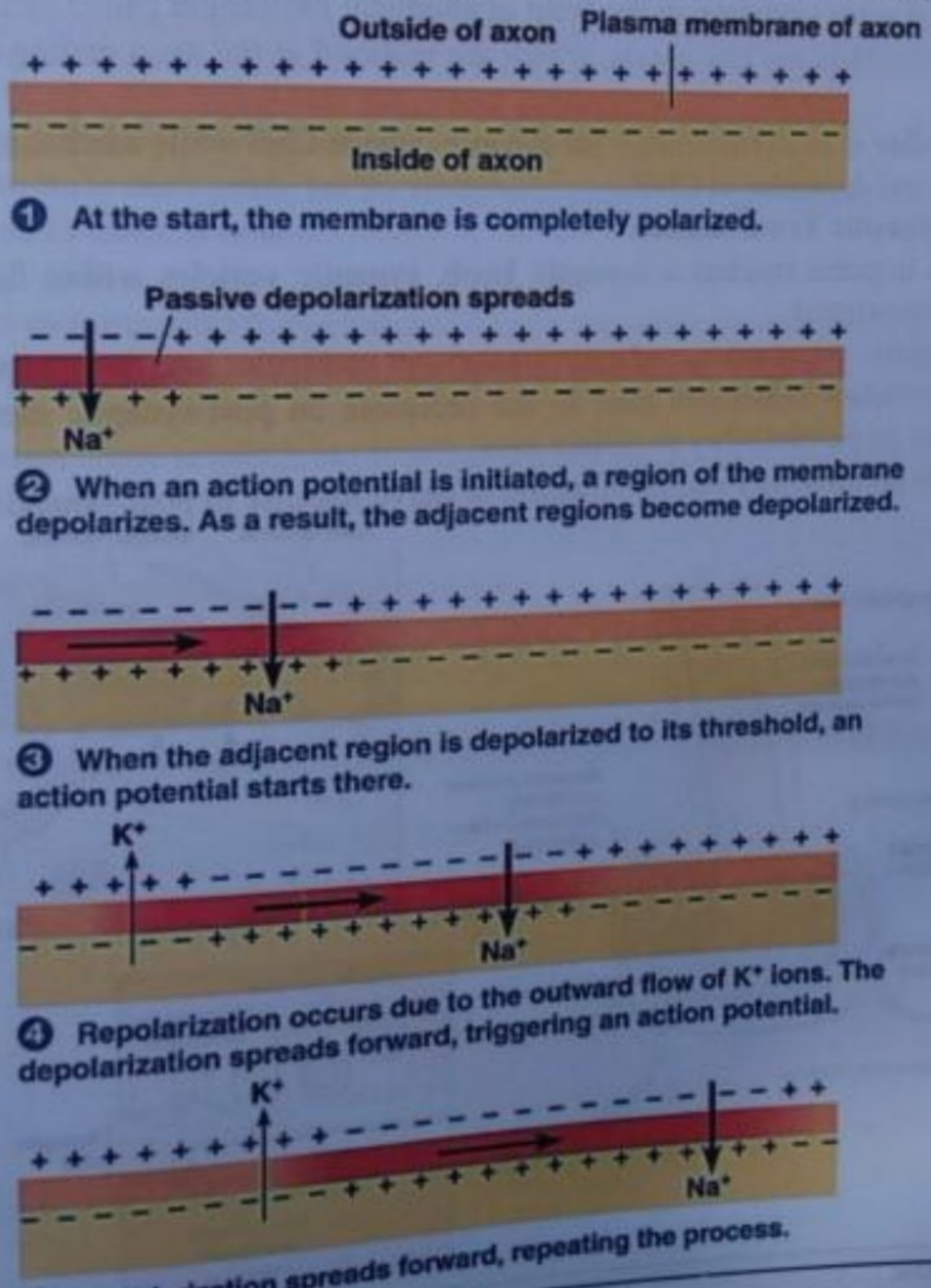
- The passage of nerve impulse is associated with increase in permeability of Na+ ions moving inwards upsetting the potential momentarily, making the inside more positive than outside.

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- This increased permeability is due to opening of sodium gates. When these gates open, sodium ions rush into the neuron by diffusion. Some K^+ move out.
- The inner side of the cell membrane has excess of positive ions and outer surface becomes more negative.
- During active membrane potential, the neuron conducts the impulse in the form of nerve impulse.
- These changes occur along the length of neuron till the impulse reaches synapse.
- Soon after the passage of impulse, the resting membrane potential is restored by the movement of a small number of ions especially K^+ moving out. This neuron is now ready to conduct another impulse.

Repolarization of Neuron (AMP → RMP)

- It is the restoration of resting membrane potential, after the wave of depolarization has passed.
- Results from closure of Na+ gates and opening of K+ gates, without flux of K+ ions, causing repolarization
- Na^+/ K^+ pump restore the original ionic gradient and thus the resting potential.
- The whole process of depolarization and repolarization takes about 2- 3 millisecond



❶ At the start, the membrane is completely polarized.

❷ When an action potential is initiated, a region of the membrane depolarizes. As a result, the adjacent regions become depolarized.

❸ When the adjacent region is depolarized to its threshold, an action potential starts there.

❹ Repolarization occurs due to the outward flow of K^+ ions. The depolarization spreads forward, triggering an action potential.

❺ Depolarization spreads forward, repeating the process.

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Speed of Nerve Impulse

- Normal speed in humans is 100 m/s but can reach upto 120 m/s.
- The nerve impulse is conducted from node to node in jumping manner. This kind of jumping nerve impulse is called ***saltatory impulse***.

POINT TO PONDER

How can you differentiate between pumps & gates in neuron?

SYNAPSES

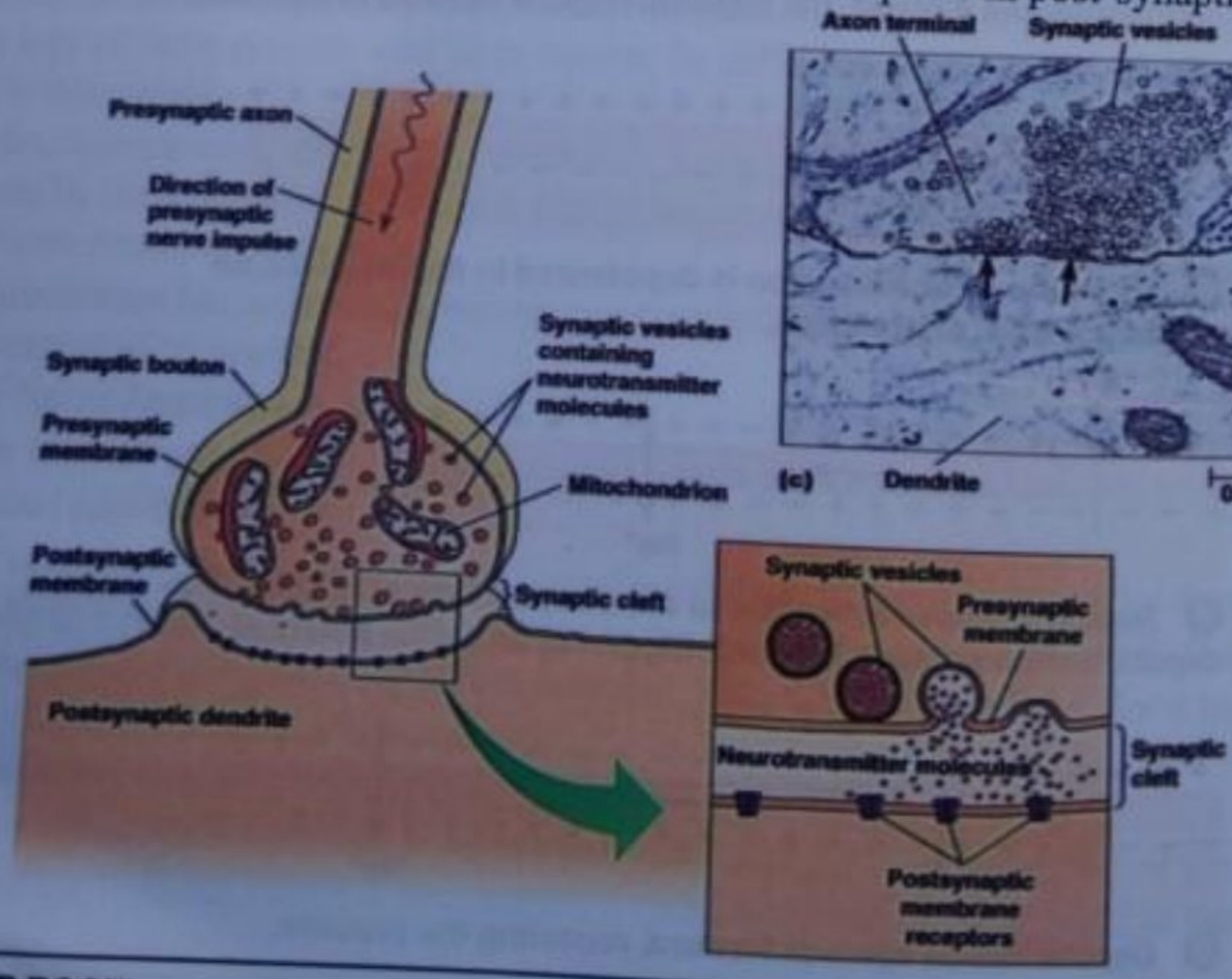
- Cytoplasmic gaps between consecutive neurons are called ***synapse***.
- A single neuron may form synapses with many incoming fibres of different neurons.
- A single nerve impulse does not necessarily get across the synapse. It may take two or three impulses arriving in rapid succession or perhaps simultaneously from two or more fibers to start an impulse in the next neuron.

Neurotransmitters

- The action potential cannot jump from one neuron to the next in line, rather the message is transmitted across synapse in the form of chemical messenger called neurotransmitters.
- Neurotransmitters are chemicals, which are released at the axon ending of the neurons at synapse.
- ***Acetylcholine*** is neurotransmitter for synapse outside CNS while adrenalin, nor-epinephrine, serotonin and dopamine in CNS.

Mechanism of Synaptic Transmission

- When an impulse reaches a synaptic knob, synaptic vesicles within fuse with the pre-synaptic membrane.
- These vesicles cause release of neurotransmitter molecules into the synaptic cleft.
- Neurotransmitter molecules bind to the receptors on post-synaptic membrane, causing changes in its permeability to certain ions.
- Change in permeability causes initiation of nerve impulse in post-synaptic neuron.



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NERVOUS DISORDERS

Feature	Parkinson's Disease	Epilepsy	Alzheimer's Disease
Definition	It is a nervous disorder, characterized by involuntary tremors, diminished motor power and rigidity.	It is a convulsive disorder of nerves characterized by abrupt transient symptoms of motor, sensory, psychic or autonomic nature, frequently associated with changes in consciousness.	It is characterized by decline in brain function.
Onset	Late age disease (50's or 60's) & Progressive	Before 30 years of age Organic disease after 30 years	Late age disease & progressive
Cause	Cell death in brain area that produces dopamine that may be due to head trauma	No known cause. Emotional disturbance, alcohol etc are aggravating factors	Genetic predisposition, High levels of aluminium
Treatment	L-dopa, Use of GDNF	EEG for diagnosis, Anti-convulsive drugs for therapy	Non-curable

BIOLOGICAL CLOCK & CIRCADIAN RHYTHMS

- In living things, the behaviour activities occur at regular intervals which are called biorhythms or biological rhythms.
- The rhythms are in one's genes, but the environment influences the rhythms to some extent.
- Basic period of clock is innate.

Types

- Biorhythms showing periodicity of about 24 hours are called ***circadian or diurnal rhythms***.
- Biorhythms showing periodicity of 365 days or 1 year are called ***circannual rhythms***.

Mechanism

- The organisms come across environmental changes that are cyclical in nature such as days, tides and seasons etc.
- Many organisms maintain internal rhythm or clock to predict onset of the periodic changes and to keep them prepared for these changes.
- Biorhythms may be the result of the following:

(1) There may be direct response to various changes in the external (exogenous) stimuli.

(2) There may be an internal (endogenous) rhythm that progresses the organism's behaviour in synchronicity with the exogenous temporal period, particularly a 24 hour or a 365 day period.

(3) The synchronization mechanism may be a combination of both or 1 and 2.

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TOPIC-5f
04 MCQs

REPRODUCTION

LEARNING OUTCOMES

(i) Explain the structure and function of reproductive system in male.
(ii) Explain the structure and function of reproductive system in female.
(iii) Describe menstrual cycle with its stages.
(iv) Explain the stages of gametogenesis (Spermatogenesis and Oogenesis).
(v) Discuss the following Sexually Transmitted Diseases (STD's) with their causative agents, symptoms and cure: Gonorrhea, Syphilis, AIDS.

MALE REPRODUCTIVE SYSTEM

Gonads

- Male gonads consist of a ***pair of testes***, which lie outside the body, in sac-like scrotum.
- Each testis consists of a highly complex duct system called seminiferous tubules, in which repeated division by the cells of the germinal epithelium produces spermatogonia.
- Seminiferous tubules also contain ***sertoli cells/ nurse cells***, which provide liquid medium, protection and nourishment to sperms while they are in the tubules. These cells also secrete inhibin hormone which serves to control the spermatogenesis at normal rate.
- ***Interstitial cells/ leydig cells*** are present between the seminiferous tubules and secrete testosterone essential for production of sperms and development of male secondary sexual characteristics during puberty.
- Both germinal epithelial cells and sertoli cells are under the control of FSH while interstitial cells are under the control of ICSH.

External Genitilia

- ***Penis*** is copulatory organ and external genitalia, which is used to transfer sperm into female reproductive tract.

Duct System

- ***Seminiferous tubules*** are the sites for spermatogenesis.
- ***Epididymis*** is the proximal highly convoluted portion of vas deferens where maturation of sperms is completed, they become motile and are stored.
- ***Vas deferens*** (sperm duct) is the main duct of male reproductive tract.
- Part of vas deferens that receives secretions from seminal vesicles is called ***ejaculatory duct***.
- ***Urethra*** in male is also called as urinogenital duct because it transfers both urine and semen outside the body.

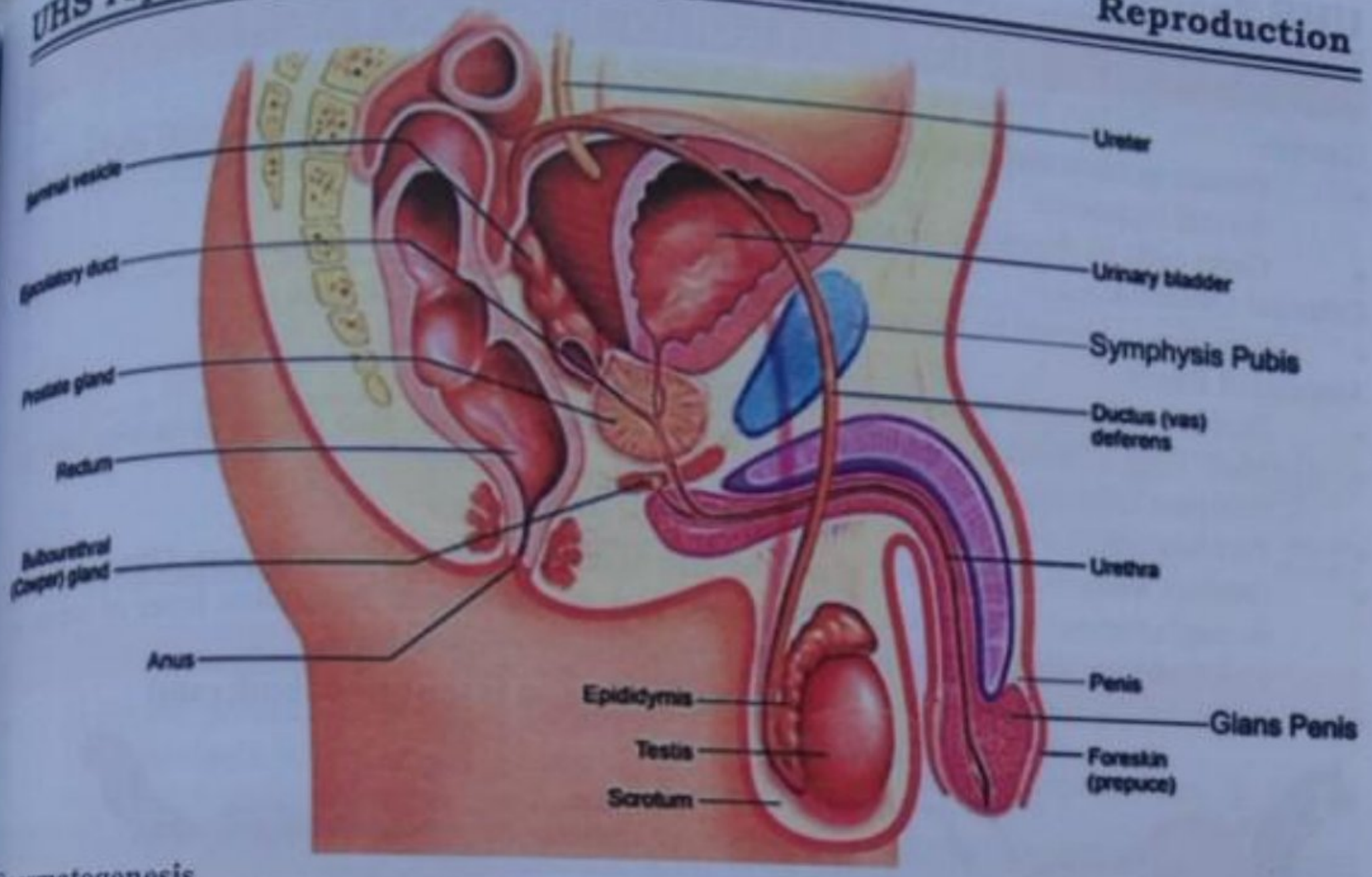
Glands

- Testes are endocrine glands which are paired and produce male sex hormones, most important of which is testosterone.
- Seminal vesicles, prostate and bulbourethral/ Cowper's glands are exocrine glands.

POINT TO PONDER

What is function of Seminal vesicles and Prostate gland?

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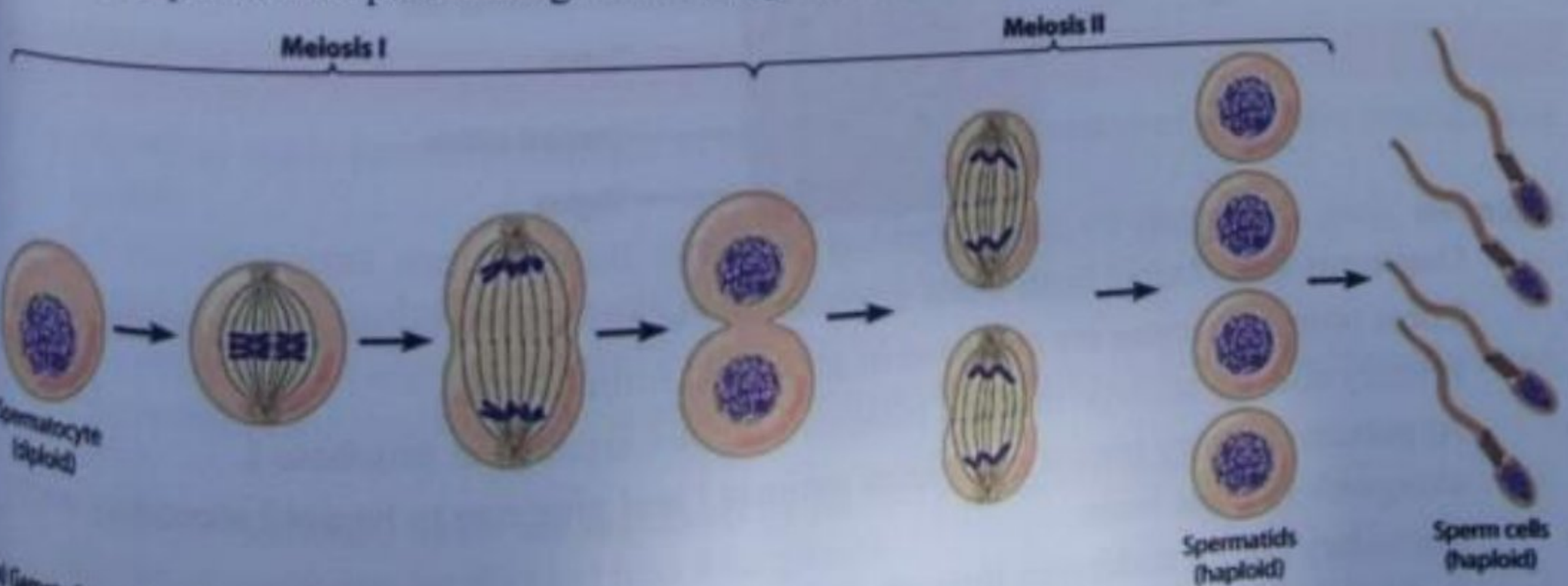


Spermatogenesis

- Spermatogonia increase in size and differentiate into primary spermatocytes which undergo meiotic division to form secondary spermatocytes and spermatids.
- Eventually spermatids differentiate into mature sperms.
- The sperms are then transferred to the main duct of the male reproductive tract, the vas deferens, which forms highly convoluted epididymis.
- The sperms then pass through the urinogenital duct and are discharged out.

POINT TO PONDER

What is average duration of sperm production in man?



(a) Gamete formation in the male

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FEMALE REPRODUCTIVE SYSTEM

Gonads

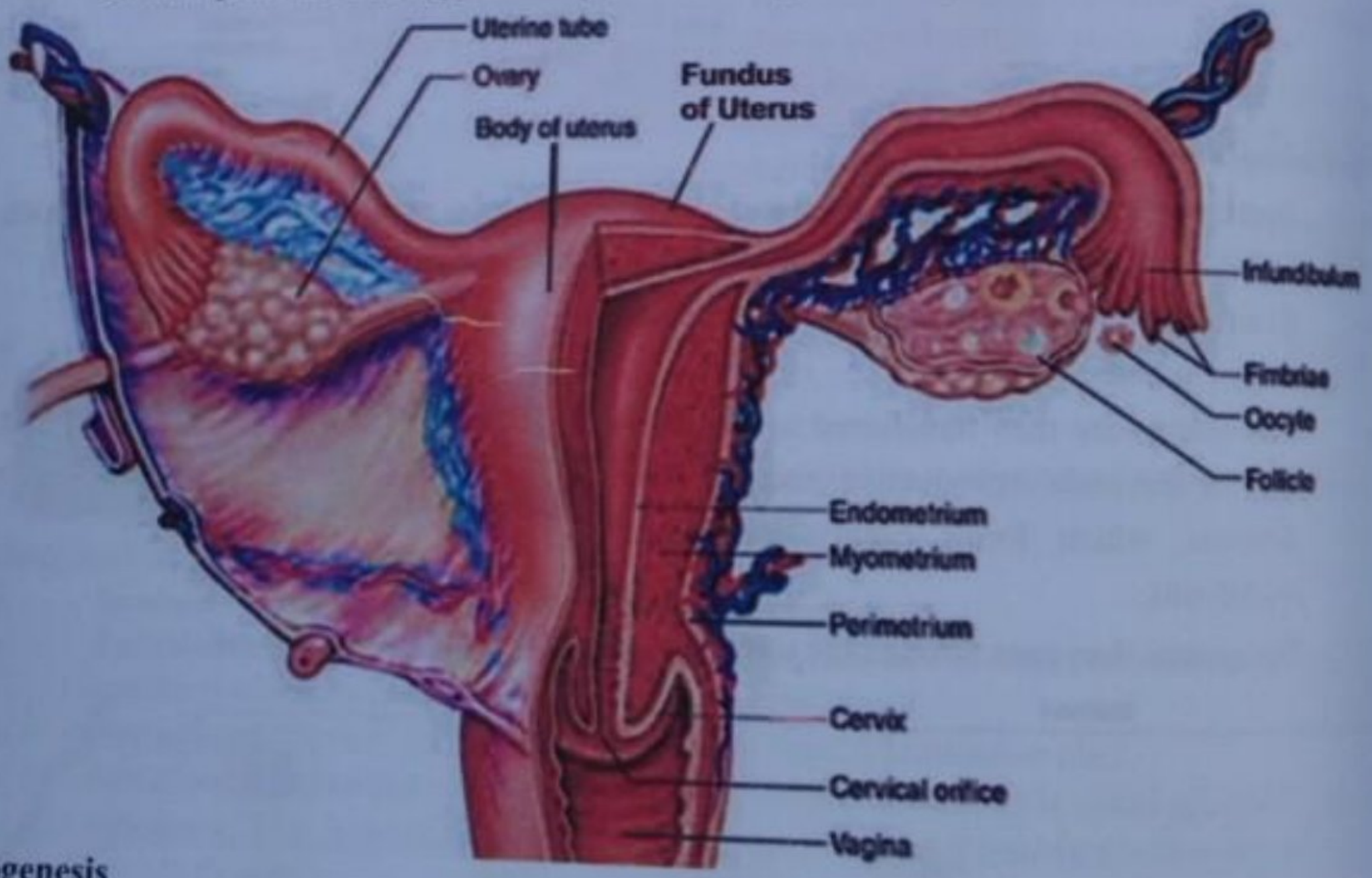
- Female gonads are ovaries which lie within the body cavity of the female and held by several ligaments.
- Germ cells in the ovary produce many oogonia.

External Genitilia

- Structures external to ***vagina*** constitute external genitalia in female.

Associated Ducts

- Discharge of ovum from ovary is called ***ovulation***.
- Main duct of female reproductive tract is oviduct that is also called as uterine tube or fallopian tube.
- Fertilization of ovum occurs in ***proximal part of oviduct.***
- Oviduct leads to uterus. It is about the size and shape of an inverted pear. Uterus has role in implantation/ conception, placentation and development. Innermost layer of uterus is endometrium, middle myometrium and outermost is perimetrium.
- Uterus opens into the vagina through cervix. Vagina is the part of birth canal.

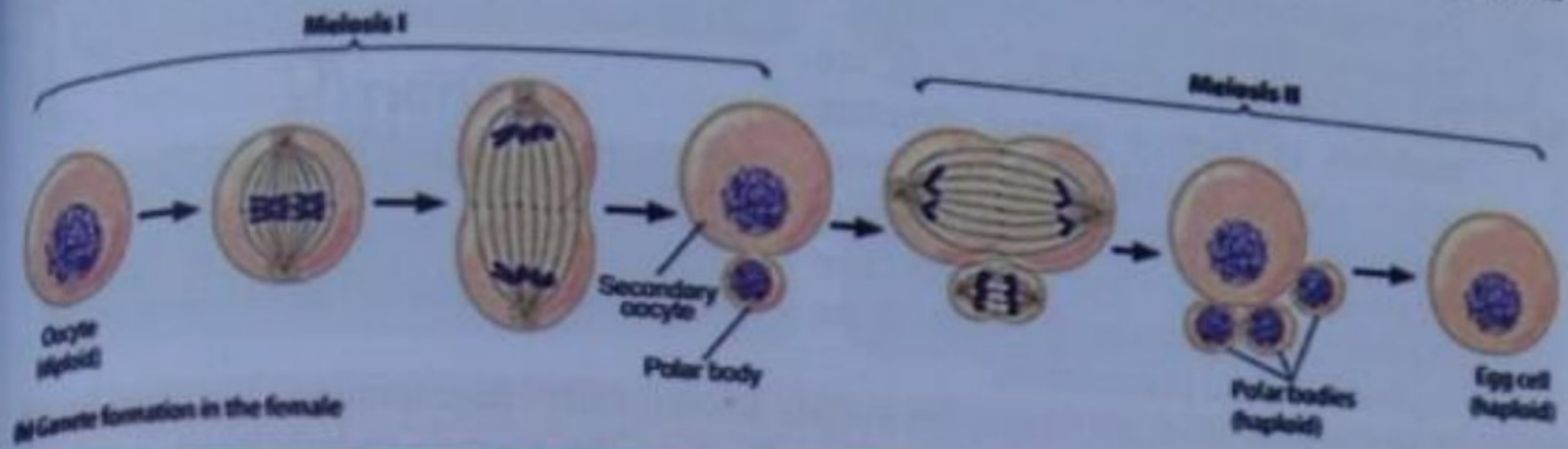


Oogenesis

- Oogenesis starts before birth when oogonia divide mitotically to produce primary oocytes.
- These primary oocytes are enclosed in groups of follicle cells.
- Primary oocytes undergo through meiosis I but are arrested at prophase I.
- At puberty, primary oocyte completes meiosis I and give rise to haploid secondary oocyte alongwith 1st polar body.
- Secondary oocyte undergoes through meiosis II but arrested in Metaphase II. It is released in this stage from ovary and does not proceed further until fertilized.

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- If fertilization occurs, then secondary oocyte divides to form ovum and 2nd polar body.
- In human female only one ovum is usually discharged from the ovary at one time, this phenomenon is called ovulation.



(a) Gamete formation in the female

FEMALE REPRODUCTIVE CYCLE

- In female, production of egg is a cyclic activity as compared to male.
- Oestrous cycle is reproductive cycle in all mammalian female except humans. In human female, it is called menstrual cycle.

Feature	Oestrous Cycle	Menstrual Cycle
Occurrence	All mammals except human	Human female
Release of Oestrogen	At low level	At higher level
Preparation of Uterus	Partial for conception	Fully for conception
If fertilization does not occur	Resorption of endometrium	Destruction and discharge (Menstrual flow)
	Egg is conserved	Egg is released
Ovulation	Requires physical stimulus of mating	Under hormonal control

POINT PONDER 70

Which hormone acts on myometrium?

MENSTRUAL CYCLE

- Menstrual cycle involves changes in the structure and function of the whole reproductive system.
- 1st ovulation and menstruation occur at puberty. Start of menstrual cycle is called menarche. Its complete stop or end is called menopause.
- It is completed in approximately 28 days.
- The events of the menstrual cycle involve the ovaries (ovarian cycle) and the uterus (uterine cycle).
- Events of menstrual cycle are regulated by pituitary gonadotrophins.
- Menstrual cycle can be divided into four phases.

Phases & Events of Menstrual Cycle

(i) Pituitary gland on the onset of puberty, releases FSH which stimulates the development of several primary follicles. Only one of these follicles continues to grow with its primary oocyte while the rest breakdown by a degenerative process known as *follicle atresia*.

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(ii) Ovary under influence of FSH produces estrogen.

(iii) Estrogen, on one hand, stimulates the endometrium and vascularizes it. On the other hand, it inhibits secretion of FSH.

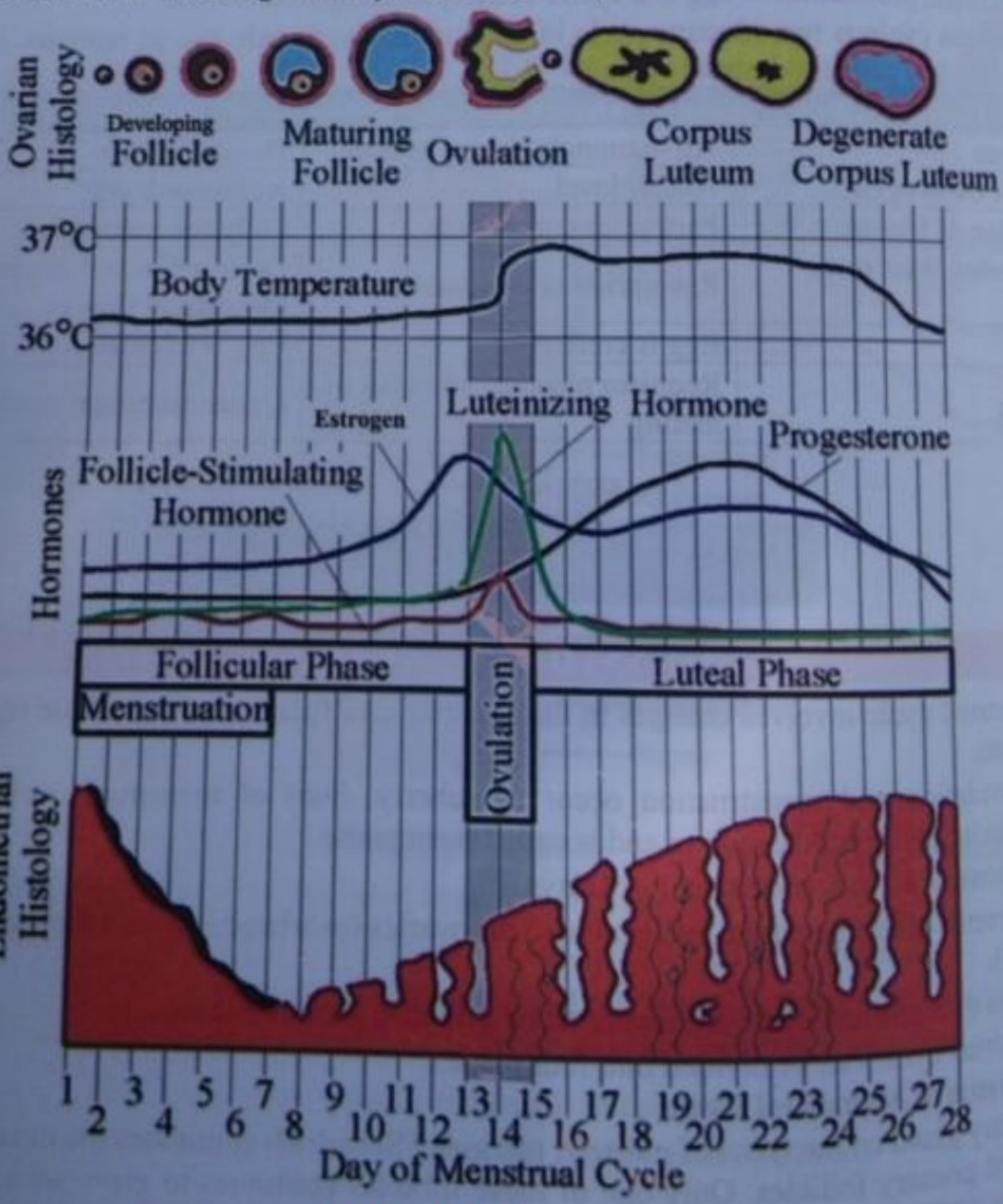
(iv) Decrease of FSH and increase of estrogen, causes the pituitary gland to secrete LH which induces ovulation.

(v) The follicle cells, after release of egg, are modified to form a special structure called corpus luteum. This yellowish glandular structure starts secreting progesterone, which develops endometrium and makes it receptive for implantation and placentation.

POINT TO PONDER

What is average life of sperm and egg after release?

(vi) If fertilization does not occur, the corpus luteum starts degenerating. The progesterone secretion diminishes and its supporting effect on the spongy endometrium is reduced, which suffers a breakdown. This causes the discharge of blood and cell debris known as menstruation. This stage usually lasts for 3-7 days.



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POINT TO PONDER

Can you differentiate between
(a) Fetus (b) Embryo (c) Zygote

POINT TO PONDER

Name the stages at which oocytes is arrested during meiosis?

POINT TO PONDER

What are Ulcers? Name some diseases that can cause Ulcers.

POINT TO PONDER

How many eggs are produced by a female in her life?

SEXUALLY TRANSMITTED DISEASES

Feature	Gonorrhea	Syphilis	Genital Herpes	AIDS
Causative Agent	Gram positive bacteria	Spirochaete	Virus	Virus
Cause	*Neisseria gonorrhoeae*	*Treponema pallidum*	Herpes simplex type II	HIV
Main parts Affected	Mucous membrane of urinogenital tract, eye infection to baby.	Damage to reproductive organs, eyes, bones, joints, CNS, heart, skin.	Infection of genitilia, genital soreness & ulcers, damage to eyes & CNS in infants.	Destruction of immune system
Source of Transmission	Sexual contact	Sexual contact	Sexual contact	Sexual contact
Treatment	Antibiotics	Antibiotics	Anti-viral	Anti-viral

POINT TO PONDER

Can you differentiate between HSV type I & HSV type II?

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TOPIC-5g
05 MCQs

SUPPORT AND MOVEMENT

LEARNING OUTCOMES

(1) Human skeleton:
(i) Define and explain terminologies: Bone, Cartilage, Tendon, and Ligament.
(ii) Describe Axial & Appendicular Skeleton.
(iii) Describe Joints and their types (fibrous, cartilaginous, synovial, pivot and multistage).
(2) Muscular system:
(i) Compare the types of muscles (smooth, cardiac and skeletal).
(ii) Explain structure and function of skeletal muscle.
(iii) Explain the concept and working of sarcomere, ultrastructure of myofilaments, sliding filament model.
(iv) Understand the sources of energy for muscle contraction.
(v) Describe Muscle Fatigue, Tetany, and Cramp with their causes.

BASIC TERMINOLOGIES

BONE

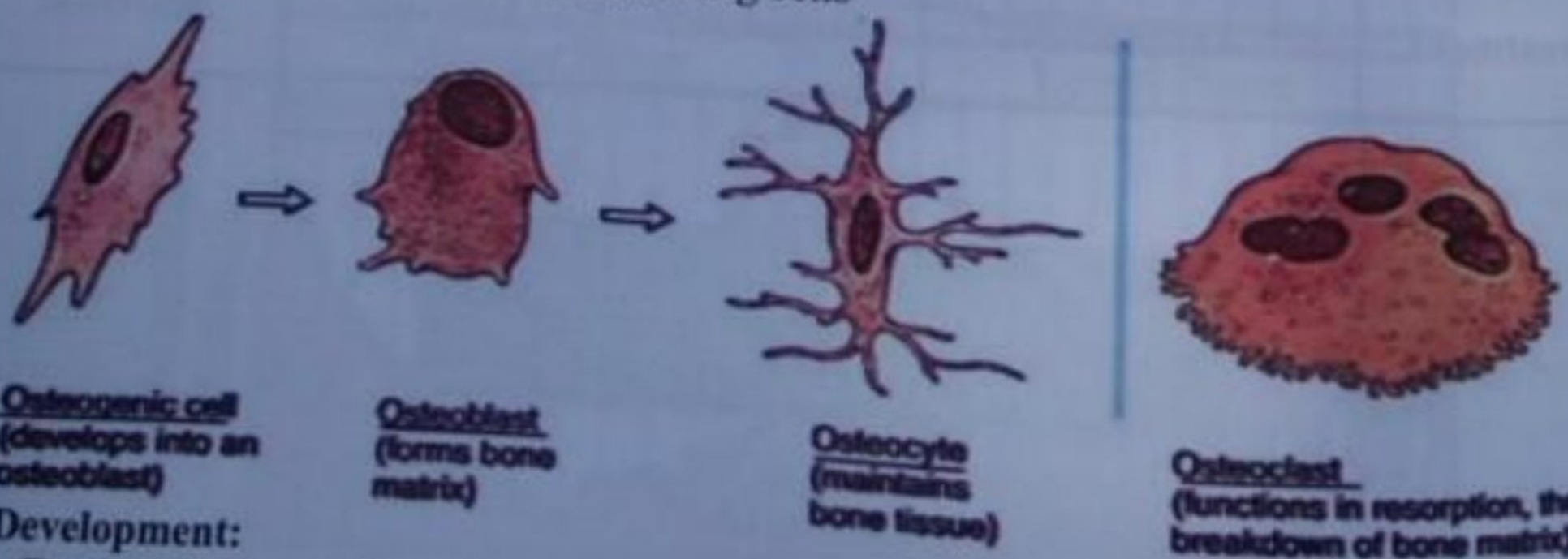
- It is the most rigid form of connective tissue and forms endoskeleton of humans.
- The collagen fibers of bones are hardened by calcium phosphate deposition.

Types of Bone

Feature	Compact Bone	Spongy Bone
Nature	Dense and strong	Light and highly porous
Blood supply	Less	More
Function	Attachment site for muscles	Contains bone marrow and involved in blood cell production.
Example	Outer portion of long bones	Inner portion of long bones

Bone Cells:

- ***Osteoblasts:*** Bone forming cells
- ***Osteocytes:*** Mature bone cells
- ***Osteoclasts:*** Bone dissolving cells



Bone Development:

Bone replaces cartilage in early development.
Osteoclasts invade and dissolve the cartilage → Osteoblasts then replace it with bone → Matrix is hardened by calcium phosphate deposition → Osteoblasts are gradually entrapped within it (now called Osteocytes).

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CARTILAGE

- It is softer connective tissue than bone.
- It has no blood supply and gets nutrients by diffusion.
- Living cells of cartilage are called chondrocytes.
- Collagen matrix is secreted by chondrocytes.

Types of Cartilage

1. **Hyaline Cartilage**
   - Most abundant type in human body
   - Found at the movable joints
2. **Elastic Cartilage**
   - Matrix containing bundles of collagen fibres
   - Forms external ear/ pinnae and the epiglottis
3. **Fibrocartilage**
   - Annulus fibrosus of vertebral disc is an example.

Feature	Bone	Cartilage
Cells	Mature cells are osteocytes	Mature cells are chondrocytes
Strengthening Material	Inorganic salts	No
Reshaping	✓	×
Blood Supply	✓	×
Healing	✓	×

TENDON & LIGAMENT

Feature	Tendon	Ligament
Nature	Inelastic connective tissue	Elastic connective tissue
Function	Attaches muscle to bone	Holds bones at joints

HUMAN AXIAL & APPENDICULAR SKELETON

- Human skeleton is mainly bony. There are about 350 bones in infant and 206 in adult.
- Human skeleton is generally divided into two parts: axial skeleton (80 bones) and appendicular skeleton (126 bones).
- Axial skeleton provides basic framework of body and consists of skull, vertebrae and ribs.
- Appendicular skeleton is associated with extremities and consists of pectoral girdle with forelimbs and pelvic girdle with hind limbs.
- Primary function of skull is protection of brain.
- Vertebral column provides protection to spinal cord. It has four curvatures.

POINT TO PONDER

Which types of skeletons are present in human?

Major part	Subparts	Bones
Axial Skeleton		
Skull (22)	Cranium (8)	• Paired (2): Parietal & Temporal • Unpaired (4): Frontal, Occipital, Sphenoid, Ethmoid.
	Face (14)	• Paired (6): Maxilla, Zygomatic, Nasal, Lacrimal, Palatine, Inferior Concha. • Unpaired (2): Mandible, Vomer
Vertebral Column	Cervical	7 vertebrae, neck region, first two atlas and axis

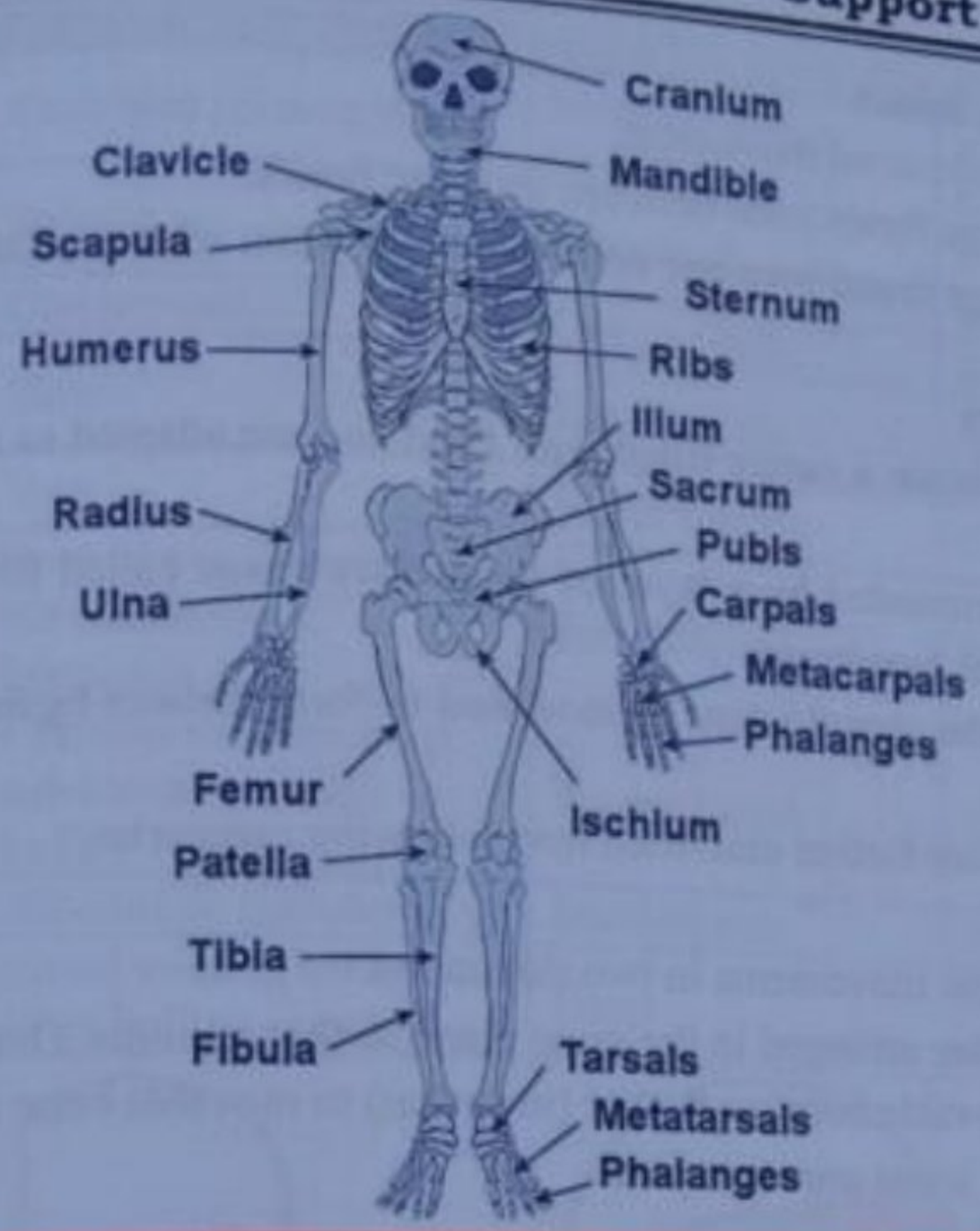
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(33 vertebrae)	Thoracic	12 vertebrae
	Lumbar	5 vertebrae
	Pelvic	9 vertebrae, anterior 5 join to form sacrum & posterior 4 join to form coccyx (tail bone).
Rib cage and sternum (Chest bone)	12 pairs of ribs	• 12 pairs articulate with thoracic vertebrae posteriorly. • 7 pairs connect anteriorly with sternum directly (True ribs) • 3 pairs connect with sternum through costal cartilages (False ribs). • 2 pairs are of floating ribs (since they don't attach to the sternum).

Appendicular Skeleton	
Pectoral Girdles (4)	• Scapula (Shoulder blade) • Clavicle (Collar bone/ Beauty bone) connects scapula with sternum.
Fore limb (30x2)	• 1 Humerus (Upper arm) • 1 Radius and 1 ulna (Forearm) • 8 carpals (Wrist) • 5 metacarpals (Palm) • 14 phalanges (Fingers/ Digits)
Pelvic Girdle (2)	• 2 coxal (hip) bones • Each having ilium, ischium and pubis
Hind limb (30x2)	• 1 Femur (Upper leg) • 1 tibia and 1 fibula (Lower leg) • 7 tarsals (Heel) • 5 Meta-tarsals (Sole) • 14 Phalanges (Digits/ Toes) • 1 Patella (Knee cap)

Joints of Axial Skeleton		
Joint	Type	Formation
Shoulder Joint	Ball & Socket Joint	Head of humerus & glenoid cavity of scapula
Elbow Joint	Hinge Joint	Distal end of humerus and proximal ends of ulna
Wrist Joint	Multistage Joint	Distal ends of radius & ulna and carpals
Hip Joint	Ball & Socket Joint	Head of femur & acetabulum of hip bone
Knee Joint	Hinge Joint	Distal end of femur and proximal ends of tibia
Ankle Joint	Multistage Joint	Distal ends of tibia & fibula & tarsals

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JOINTS

- Joints are formed where bones meet.
- They not only hold our skeleton together but also give it mobility.

CLASSIFICATION OF JOINTS

On Base of Amount of Movement

(1) Immovable Joints

- These joints do not allow any movement.
- Fibrous joints are immovable joints.
- Sutures (Joints of skull) are examples.

(2) Slightly Moveable Joints

- These joints allow slight movements.
- Cartilaginous joints of vertebral column are examples.

(3) Freely Movable Joints

- These joints allow free movements.
- Synovial joints are examples of freely moveable joints.

On Base of Structure

(1) **Fibrous Joints**

- These joints held together by short fibres embedded in connective tissue.
- These joints are immovable.
- Examples of fibrous joints are joints between skull bones and joints between teeth and jaws.

POINT TO PONDER

Calculate total number of bones in human Adult.

POINT TO PONDER

Do you know the common names of following bones?

(a) Clavicle (b) Coccyx (c) Scapula
(d) Carpals (e) Tarsals (f) Patella

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(2) Cartilaginous Joints

- These allow little or no movement.
- Hyaline cartilage forms joint between growing bones.
- Fibrous cartilage found between vertebrae at the point where coxal bones meet in front of the pelvis.

(3) Synovial Joints

- These joints contain a cavity filled with fluid and are adapted to reduce friction between moving joint.
- The joint is surrounded by a layer of connective tissue called fibrous capsule and inner layer of synovial membrane.
- Some parts of the capsule may be modified to form distinct ligament, holding the bones together.
- Synovial joints are further classified into following categories.

(i) Hinge Joint

- These joints allow movements in two directions.
- Pair of muscles are arranged in the same plane as that of joints. One end of muscle (origin) is fixed to immovable bone and other (insertion) to movable bone across the joint.
- Elbow and knee joints are examples.

(ii) Ball & Socket Joint

- These joints allow movements in several directions.
- Such joints have at least two pairs of muscles present perpendicular to each other.
- They provide maximum flexibility.
- Hip joint and shoulder joint are examples.

(iii) Pivot Joint

- These joints allow rotation within limits.
- Superior radioulnar joint and neck joint are examples.

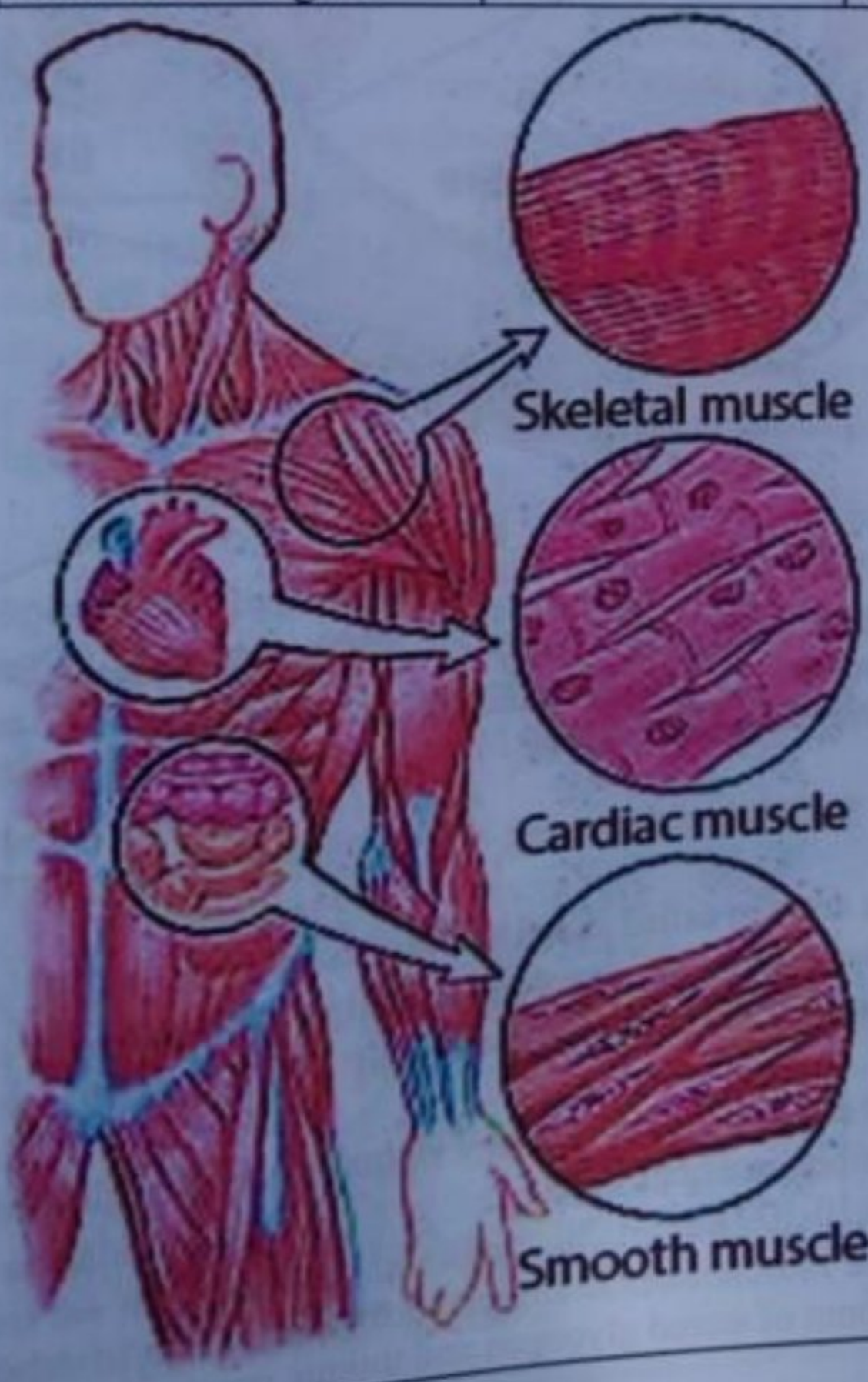


TYPES OF MUSCLES

- Earliest forms of muscles to be evolved are smooth muscles which are present throughout animal kingdom.
- Cardiac muscles and skeletal muscles are found only in vertebrates.
- Most abundant type of muscles in human body are skeletal muscles.

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Property	Smooth	Cardiac	Skeletal
Muscle appearance	Unstriped (non-striated)	Irregular stripes (striated)	Regular stripes (striated)
Cell shape	Spindle	Branched	Spindle or cylindrical
Number of nuclei	One per cell	One per cell.	Many per cell
Speed of contraction	Slow	Intermediate	Slow to rapid
Fatigue	Vary	Never fatigue	Can be fatigued
Contraction caused by	Spontaneous, stretch, nervous system, hormones	Spontaneous	Nervous system
Function	Controls movement of substances through hollow organs	Pumps blood	Moves the skeleton
Control	Autonomic (involuntary)	Involuntary	Voluntary
Location.	Blood vessels, GIT, other hollow organs	Heart	Associated with skeleton

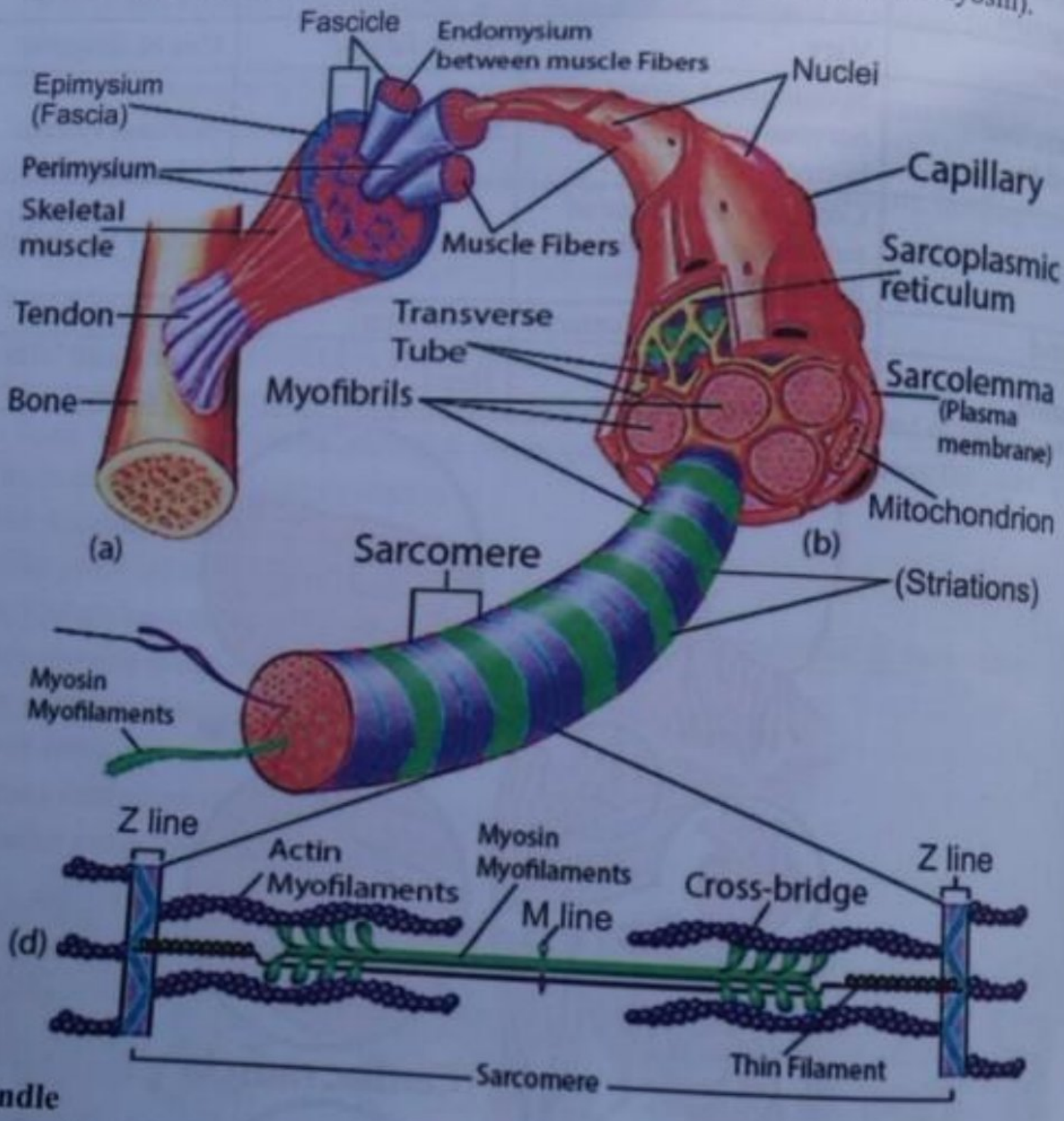


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STRUCTURE OF SKELETAL MUSCLE

- The muscles that are attached to the skeleton and are associated with the movement of bones are called skeletal muscles.
- The entire muscle is covered by a layer of connective tissue called epimysium.
- Structural scheme of a skeletal muscle is given below:

Skeletal muscles → Muscle bundles → Muscle fibers → Myofibrils → Sarcomere (smallest contractile unit of muscle fiber) → Myofilaments (Actin & Myosin).



Muscle Bundle

- Muscles bundles are also called as muscle fasciculi.
- These are bounded by a connective tissue called perimysium.
- Muscle bundles are further composed of muscle fibers or cells.

Muscle Fibers

- Each muscle fiber is a long cylindrical cell with multiple oval nuclei just beneath sarcolemma.
- Skeletal muscle fibers are huge cells.
- Their diameter is 10-100 μm.
- Sarcoplasm of the muscle fiber is similar to the cytoplasm of other cells, but it contains usually large amount of stored glycogen and unique oxygen binding protein, myoglobin.

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- Sarcoplasmic reticulum is continuous system of sarco-tubules extending throughout the sarcoplasm around each myofibril. It is like endoplasmic reticulum but devoid of ribosomes.
- Each muscle fiber further contains large number of myofibrils.

Myofibrils

- Each myofibril is 1-2 μm that run in parallel fashion and extend entire length of cell.
- Bundles of these fibrils are enclosed by the sarcolemma.
- The myofibrils consist of smaller contractile units called sarcomere.
- Myofibril has series of dark and light bands. These give cell as whole its striped appearance.

Ultrastructure of Myofilaments

- Myofilament is made up of thick and thin filament.

(i) **Thick Filament**

- Thick filament is about 16nm in diameter and is composed of myosin.
- Each myosin molecule has a tail terminating in two globular heads.
- Myosin tail consists of two long polypeptide chains coiled round each other.
- The heads are sometimes called cross bridges because they link the thick and thin myofilaments together during contraction.
- Each myosin filament is surrounded by six actin filaments on each end.

(ii) **Thin Filaments**

- Thin filaments are 7-8 nm thick and are composed of chiefly actin molecules.
- The actin molecules are arranged in two chains which twist around each other like a twisted double strand of pearls.
- Twisting around the actin chains are two strands of another protein, tropomyosin. When the muscle is at rest, the tropomyosin is disposed in such a way that it covers the sites on the actin chain where head of myosin become attached.
- The other major protein in thin filament is troponin. It is actually three polypeptide complexes, one binds to actin, another bind to tropomyosin while third binds with calcium ions.

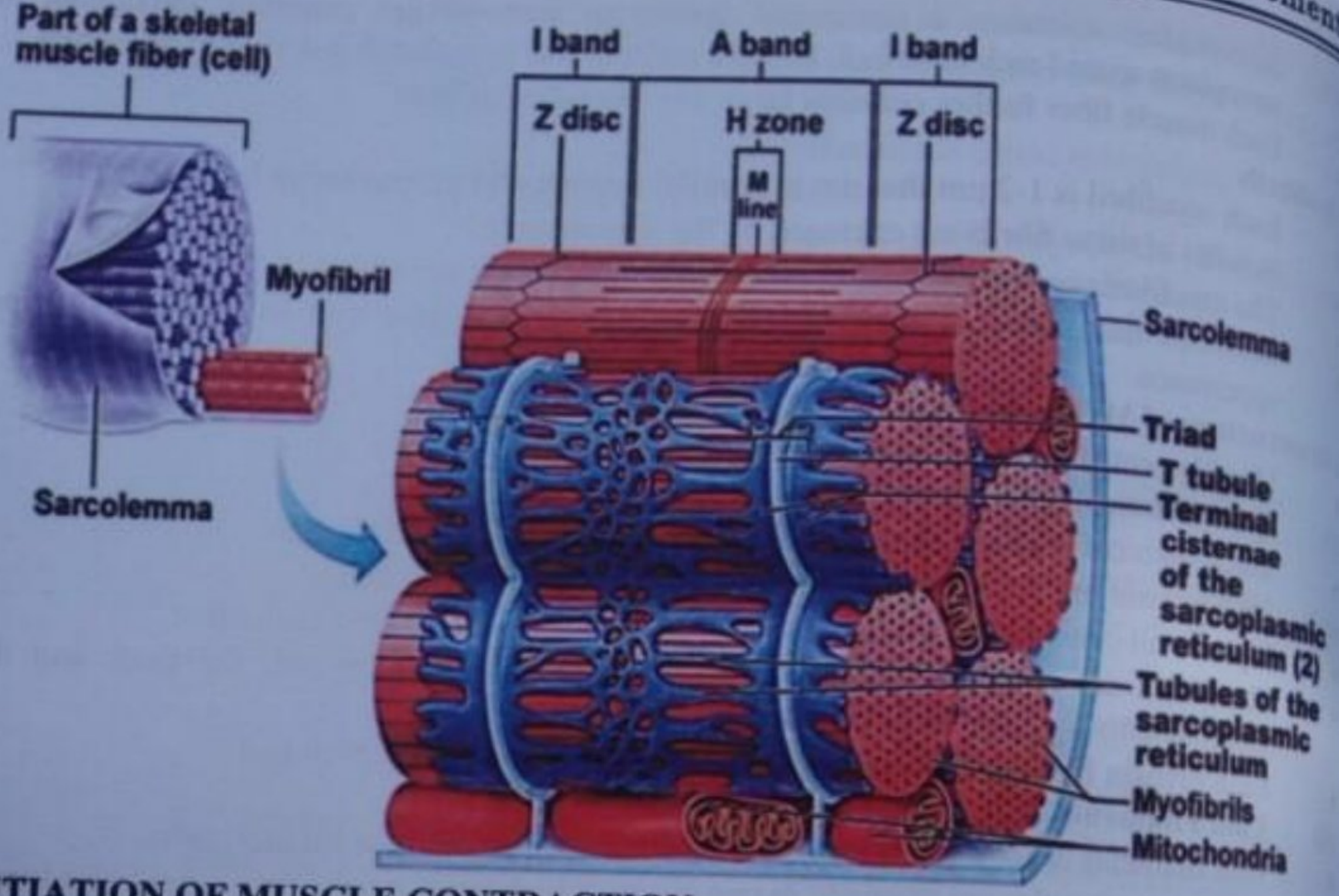
Banding Pattern

- Each dark band is called A band, because it is anisotropic i.e. it can polarize visible light.
- The light band called I band is isotropic or non-polarizing.
- Each A band has a lighter strip in its mid-section called H zone.
- The H zone is bisected by dark line called M line.
- The I bands have mid line called Z line.
- A sarcomere is the region of a myofibril between two successive Z line and is the smallest contractile unit of muscle fiber.

T-Tubule, T System & Triad

- The sarcolemma of muscle fiber cell penetrates deep into the cell to form hollow elongated tube, the transverse tubule or T tubule, the lumen of which is continuous with the extracellular fluid.
- The thousands of T tubules of each muscle cell are collectively called T system.
- It extends and encircles the myofibril at the level of Z-line or A-I junction.
- The T-tubule and the terminal portion of the adjacent envelope of sarcoplasmic reticulum form triads at regular interval along the length of the fibril.

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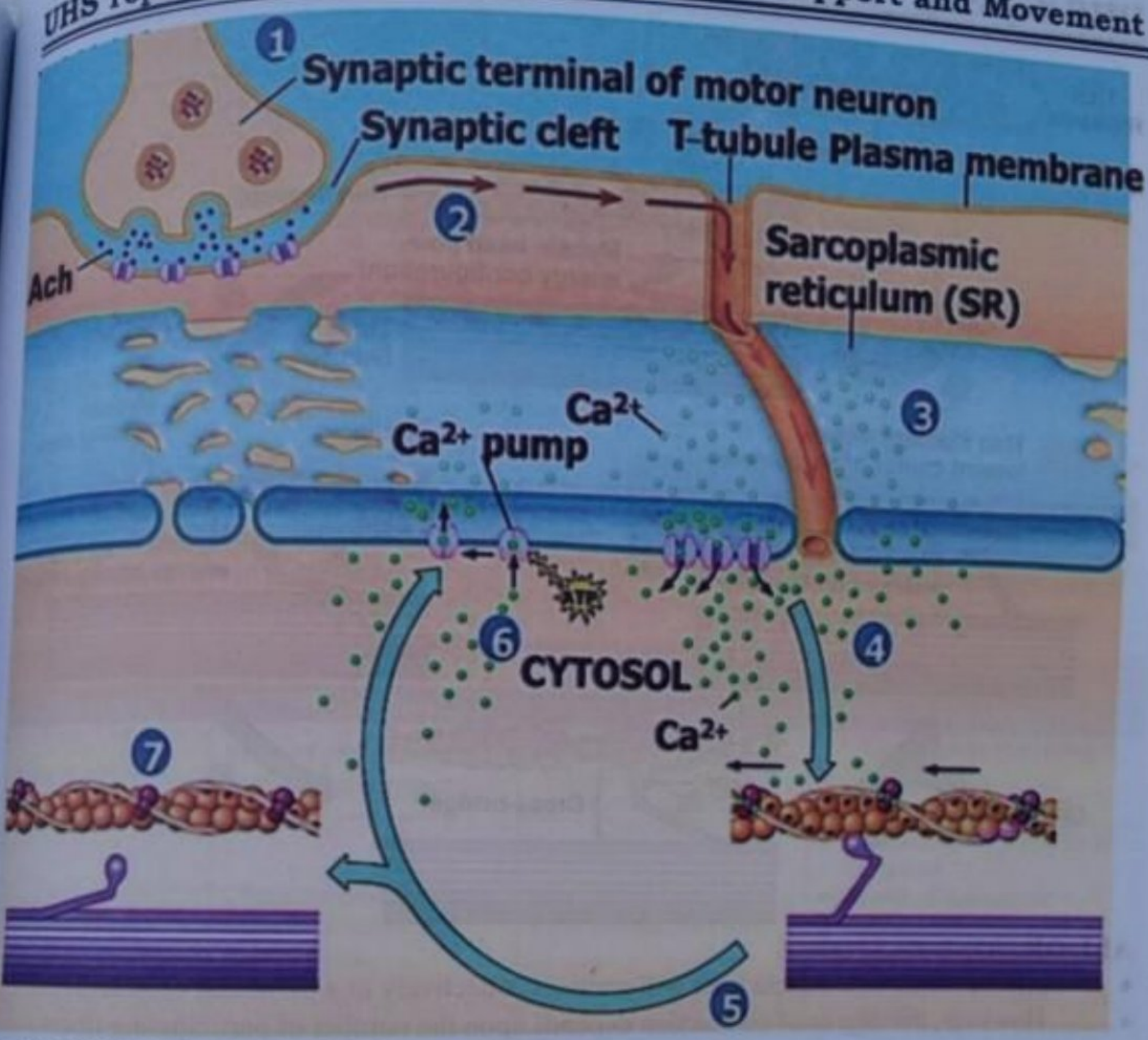
INITIATION OF MUSCLE CONTRACTION

- Muscle contraction is initiated by nerve impulse arriving at the neuromuscular junction. All the fibers innervated by a single motor neuron are a "motor unit" and contract simultaneously.
- Nerve impulse from sarcolemma penetrates into the muscle fiber through T tubule.
- Then it is carried through the T-tubule to the adjacent SR.
- The calcium gates of SR open releasing calcium in cytosol.
- Calcium ions bind with the troponin molecules of thin filaments. This has the effect of displacing the tropomyosin and exposing the binding sites for the myosin.
- Once the myosin head has become attached to the actin filament, ATP is hydrolyzed and the bridges goes to its cycle and result in muscle contraction.
- ***Rigor Mortis*** is stiffening of the body after death. Since ATP is required to break the bond between actin and myosin, which get deficient after death, thus the bridges can't be broken and the body gets stiff.

POINT TO PONDER

Name the neurotransmitter released at NMJ for muscular contraction?

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SLIDING FILAMENT MODEL

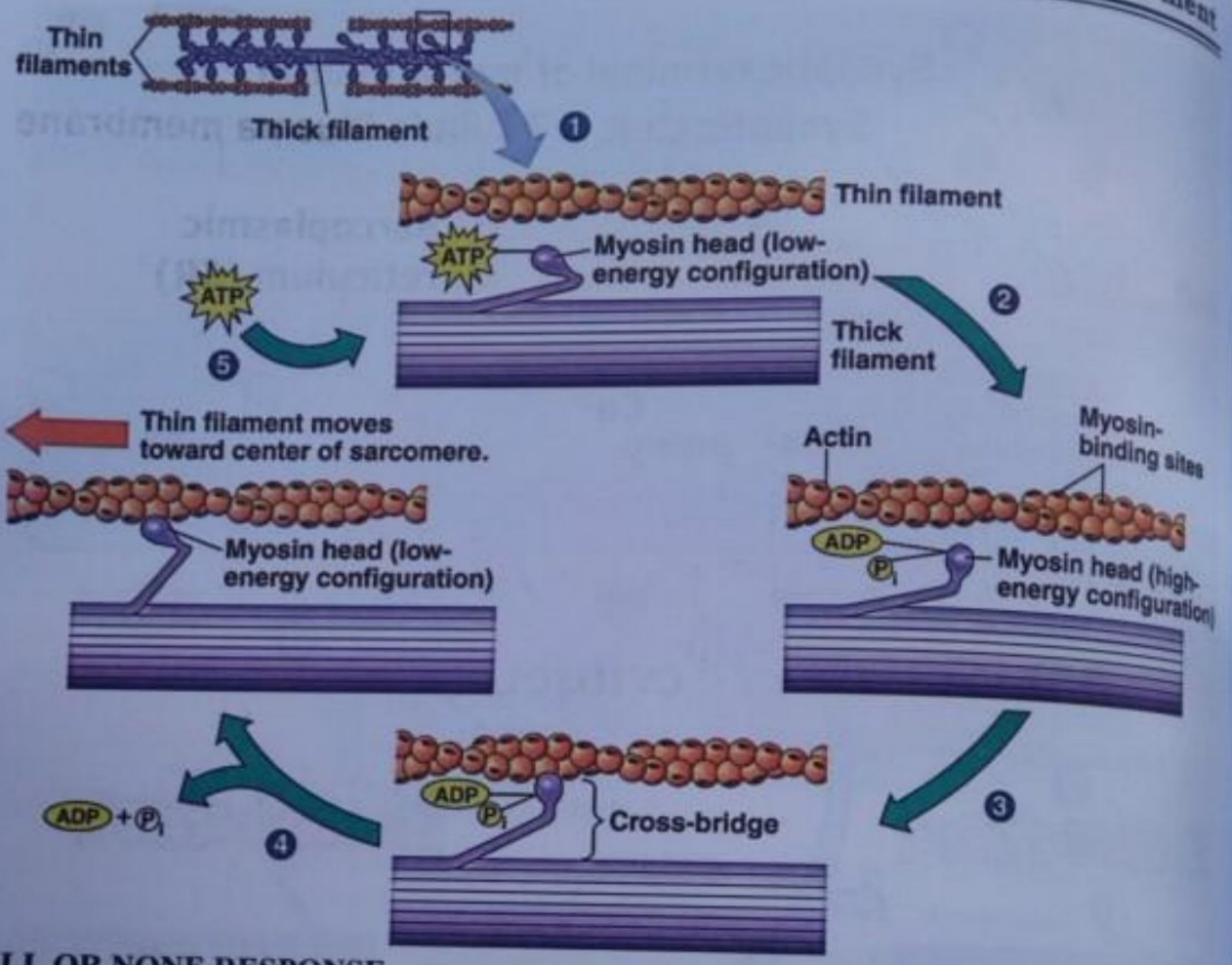
H. Huxley and A.F. Huxley suggested this model of muscle contraction. Its salient features are given below.

- When muscle fiber contracts, the thin and thick filaments undergo shifting.
- Thin filaments slide past the thick filaments.
- Actin and myosin filaments overlap to greater degree.
- The I-band reduces in length.
- Z-lines get closer.
- H zone disappears.
- Length of A band remains unchanged.
- Actin filaments come close to each other.

POINT PONDER 70

How many steps require energy during muscle contraction and relaxation?

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ALL OR NONE RESPONSE

- All the fibrils of a muscle fiber will contract collectively in a particular contraction.
- However, the degree of contraction depends upon the number of participating fibers.

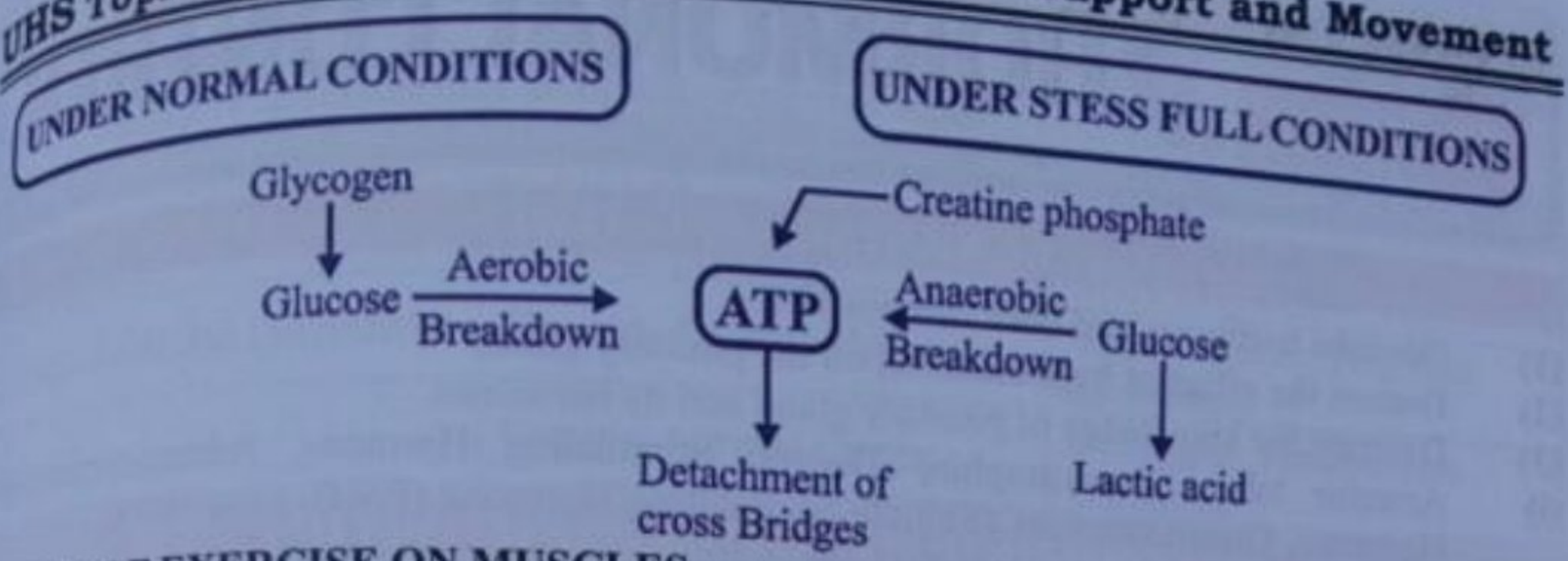
POINT TO PONDER

How can you differentiate between perimysium and endomysium?

ENERGY FOR THE MUSCLE CONTRACTION

- Energy for muscle contraction comes from ATP.
- Supply of ATP is maintained by the aerobic breakdown of glucose in muscle cell, which comes from stored glycogen in the cell.
- When more energy is required due to high metabolism, it is provided by another energy storing substance called creatine phosphate.
- Sometimes during oxygen deficiency or very high metabolic activity such as prolonged or strenuous muscular activity), ATP requirement is met by anaerobic breakdown of glucose into lactic acid. Lactic acid accumulation causes muscle fatigue. At rest, 1/5 of lactic acid is broken aerobically and its energy is used to change the remaining 4/5 lactic acid into glucose.

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EFFECT OF EXERCISE ON MUSCLES

- Increase in size of the muscle.
- Increase in its strength.
- More efficient and fatigue resistant.
- Capillaries surrounding muscle fibers and mitochondria in it increases
- Synthesize more myoglobin

POINT TO PONDER

How creatine phosphate and ATP correlate during muscle contraction?

MUSCLE FATIGUE, TETANY & CRAMP

Disorder	Definition	Cause	Effects
Muscle Fatigue	State of physiological inability to contract.	Relative deficit of ATP, Accumulation of lactic acid, Ionic imbalance	• Contracture formation • Drop in muscle pH • Muscle ache
Muscle Tetany	Characterized by muscle twitches and convulsions.	Low calcium in blood	• Increased excitability of neurons • Loss of sensations • Progresses to spasm of larynx, respiratory paralysis and ultimately death.
Muscle Cramp	Tetanic contraction of entire muscle.	Hypoglycemia, Dehydration, Electrolyte depletion, Irritability of spinal cord and nerves.	• Lasts for few second to hours, commonly at night or after exercise. • Muscles become taut or painful.
Tetanus	Acute infectious disease caused by anaerobic bacterium.	*Clostridium tetani*	• Persistent painful muscle spasm. • Begins with stiffness of jaws and neck muscles, progresses to lock jaw and spasm of trunk and limb muscles. • Fatal due to respiratory failure. • Mortality rate is 40% in developing countries.

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TOPIC-5h
04 MCQs

HORMONAL CONTROL

LEARNING OUTCOMES

(1) Describe hormones and their composition.
(2) Discuss the effect of hypothalamus on the pituitary gland.
(3) Describe the knowledge of pituitary gland and its hormones.
(i) Anterior lobe: Somatotrophin, Thyroid Stimulating Hormone, Adrenocorticotropic Hormone, Gonadotrophins (Follicle Stimulating Hormone (FSH), Luteinizing Hormone (LH), Luteotropic Hormone (LTH), Prolactin).
(ii) Posterior lobe: Vasopressin, Oxytocin.
(4) Explain the hormones of thyroid and parathyroid: T3, T4 (Thyroxin), Calcitonin, Parathormone.
(5) Discuss the adrenal gland in detail:
(i) Adrenal cortex (cortisol, corticosterone, aldosterone, androgens).
(ii) Adrenal medulla (adrenaline and nor adrenaline).
(6) Explain hormones of Islets of Langerhans i.e. Insulin, Glucagon.
(7) Describe the hormones of alimentary canal (Gastrin, Secretin).
(8) Discuss the hormones of ovaries and testes (oestrogen, progesterone, testosterone).
(9) Explain the disorders of endocrine gland i.e. diabetes mellitus, diabetes insipidus, goiter, dwarfism, gigantism.

GLANDS

- These are tissues, specialized for secretions. Glandular cells are secretory or neurosecretory cells that have abundant Golgi bodies.
- Hormones released from neurosecretory cells are called as neurosecretions e.g. ADH is neuropeptide.
- Glands can be divided into two main categories i.e. exocrine and endocrine glands.
- Endocrine system of human consists of about 20 endocrine glands.

Feature	Exocrine Glands	Endocrine Glands
Another Name	Ducted glands	Ductless glands
Secretions	Enzymes, mucus etc	Hormones
Transportation	Through ducts	Through blood
Examples	Sweat glands, Salivary glands	Adrenal glands, Pituitary gland

HORMONES

- Hormones are organic compounds of varying structural complexity.
- They are poured directly and are transported to blood to respective target tissues. The hormones affect the target cells.
- They do not initiate new biochemical reactions but produce their effects by regulating enzymatic and other chemical reactions already present.
- They may either stimulate or inhibit a function.
- Hormones may also control some long-term changes, such as rate of growth, rate of metabolic activity and sexual maturity.

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Types of Hormones

Chemically hormones may be of following four types:

Category	Gland	Hormones
Protein Polypeptides	Iselets of Langerhans	Insulin, Glucagon
	Posterior pituitary	ADH, Oxytocin
Amino Acids and Derivatives	Thyroid, Adrenal Medulla	T3, T4, Epinephrine, Nor-epinephrine
Steroid	Gonads, Adrenal Cortex	Oestrogen, Testosterone, Cortisone.

HYPOTHALAMUS & ITS HORMONES

- It is a part of forebrain. It has neurosecretory cells which produce and secrete a variety of hormones.
- It is here that many of the sensory stimuli of nervous system are converted into hormonal responses.
- It is believed that oxytocin and ADH are produced in hypothalamus and travel down the nerves to the posterior lobe of pituitary to be stored in nerve endings. They are released from posterior pituitary after receiving nerve impulses from the hypothalamus.
- Another cluster of neurons in hypothalamus produce and secrete a battery of releasing and inhibiting hormones, which are carried by the blood to the anterior pituitary. These regulate the secretion of many tropic hormones, growth hormones and prolactin manufactured by the anterior pituitary cells.

POINT TO PONDER

Elaborate the path way of communication between hypothalamus and pituitary

PITUITARY GLAND & ITS HORMONES

- In man, the pituitary gland or hypophysis cerebri is an ovoid structure about 0.5gm in the adult and is connected to brain through a short stalk (the infundibulum).
- It has three lobes viz, anterior, median and posterior.
- The anterior lobe is often referred to as the ***master gland***, because in addition to producing primary hormones it produces the tropic hormones which control the secretion of hormones in many of the other endocrine glands.

Anterior Lobe

1. Somatotrophin Hormone (STH)

- It is also called as growth hormone.
- Hypothalamus → SRF → Anterior Pituitary → STH → Growth
- Somatotrophin releasing factor (SRF) is secreted from hypothalamus throughout life.
- When growth has mostly ceased after adolescence, the hormone continues to promote protein synthesis throughout the body.

POINT TO PONDER

What do you know about?
(a) Cretinism (b) Myxoedema (c) Grave's disease

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- If produced in excess during early life, leads to ***gigantism*** or if later in life causes the abnormal development of hands, feet, jaws etc (known as ***acromegaly***).
- If there is under secretion, ***dwarfism*** results, as well as other symptoms associated with lack of thyroid and adrenal hormone.

2. Thyroid Stimulating Hormone (TSH)

- Thyroxine in Blood → Hypothalamus → TRF → Anterior Pituitary → ↑TSH → Thyroid Gland → Thyroxine
- Release of thyrotrophin releasing factor from the hypothalamus is controlled by the levels of thyroxine in the blood.
- In the presence of low levels of thyroxine, there is increasing production of TSH and vice versa.
- It is secreted throughout life but particularly reaches high levels during the periods of rapid growth and development.
- It acts directly on the cells of thyroid gland, increasing both their numbers and secretory activity.

3. Adrenocorticotrophic Hormone (ACTH)

- Steroid in Blood → Hypothalamus → CRF → Anterior Pituitary → ACTH → Adrenal Cortex → Corticosteroid
- Release of corticotrophin releasing factor from the hypothalamus is controlled by steroid levels in the blood and by direct nervous stimulation of the hypothalamus as a result of stress e.g. cold, heat, pain, fright, infections.
- Excess and deficiency results in disturbance of normal adrenal functions

4. Gonadotrophic Hormone (GH)

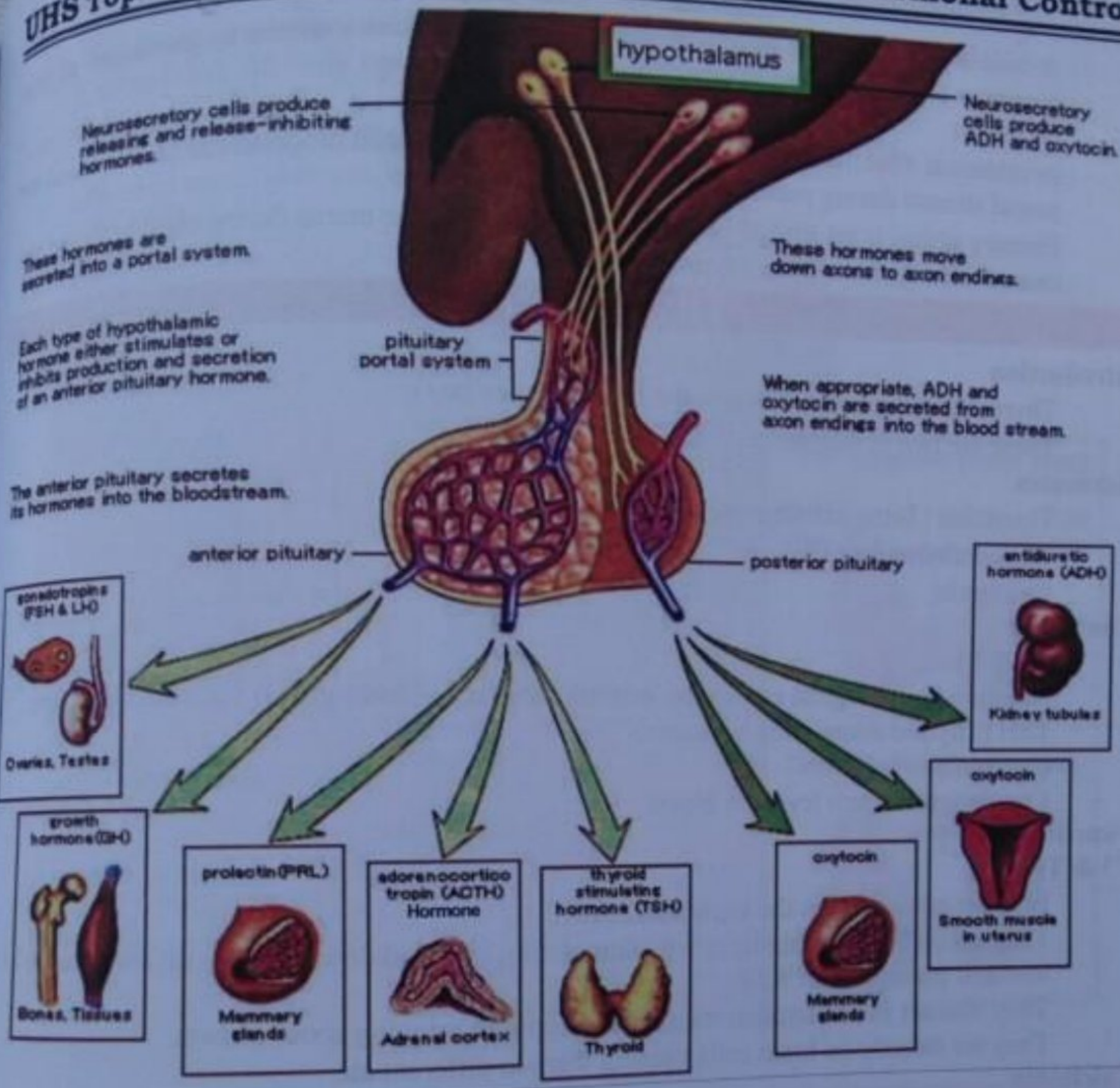
- These are follicle stimulating hormone (FSH), luteinizing hormone (LH, also called ICSH in male) and prolactin (sometimes inappropriately called luteotrophic hormone, LTH).
- FSH and LH/ICSH share a common hypothalamic releasing factor.
- Prolactin is continuously produced from the pituitary and is inhibited by prolactin inhibiting factor (PIH) from the hypothalamus.
- Prolactin stimulates milk production and acts with LH.
- FSH in females stimulates follicle development and secretion of oestrogens from the ovaries; in males it stimulates development of the germinal epithelium of testes and sperm production.
- LH works with FSH to stimulate estrogen secretion and rupture of mature follicles to release egg or ovum.
- It also causes the lutenisation of mature follicles and acts synergistically with prolactin to maintain corpus luteum (and hence the progesterone it secretes).
- ICSH in the male stimulates the interstitial cells of the testes to secrete testosterone.

POINT TO PONDER

Which hormone of Anterior Pituitary is primary?

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Hormonal Control



Median Lobe

- Median lobe secretes MSH.
- Its inhibition of secretion is controlled by hypothalamus.
- External light governs its secretion.
- More secretion in pregnancy stimulates melanocytes in skin to produce brown pigment, melanin, which darkens the skin.
- Excess MSH is secreted in Addison's disease. One of the symptoms of which is darkening of skin.

POINT TO PONDER

Can you correlate MSH and cortical hormones levels in Addison's disease?

Posterior Lobe

1. **Antidiuretic Hormone (ADH)/ Vasopressin**

- Its secretion is caused by decrease in blood pressure, blood volume and osmotic pressure of the blood which is detected by osmoreceptors in hypothalamus.
- External sensory stimuli also influence hypothalamic neurosecretory cells.
- Increased levels cause increased water reabsorption in distal parts of nephron.

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- A lack of this hormone produces ***diabetes insipidus***, characterized by production of large quantities of dilute urine and great thirst.

2. Oxytocin

- Its release is stimulated by distension of cervix, decrease in progesterone level in blood and neural stimuli during parturition and suckling.
- Primary action is on smooth muscles, particularly in the uterus during child birth and also causes milk ejection from mammary glands.

THYROID GLAND

Introduction

- Thyroid gland is located below the larynx (voice box).
- These are two in number.

Hormones

- Thyroxine (Tetra-iodothyronine/ T4)
- Tri-iodothyronine (T3)
- Calcitonin

Control

- T3 & T4
  Negative physiological control by anterior pituitary (master gland) via tropic hormone TSH (Thyroid stimulating hormone)
- Calcitonin
  Circulating calcium levels in blood

Functions

T3 & T4

- Both act essentially in the same way.
- They act on basal metabolic rate by stimulating the breakdown of glucose and release of heat and generation of ATP.
- They also act in conjunction with somatotropin in bringing about growth.
- They act directly on brain cells causing them to differentiate.

Calcitonin

It regulates blood calcium level. High Ca^{+2} ion concentrations in the blood causes stimulation of the synthesis and release of calcitonin.

Abnormalities of T3 & T4

Overproduction

- Excess thyroxine produces a condition called ***Graves' disease*** which is characterized by ***exophthalmic goiter*** and increase in the basal metabolic rate.
- This can lead to cardiac failure if prolonged.
- It is caused by production of an abnormal body protein which continuously stimulates thyroid to excessive secretion.

Under-secretion

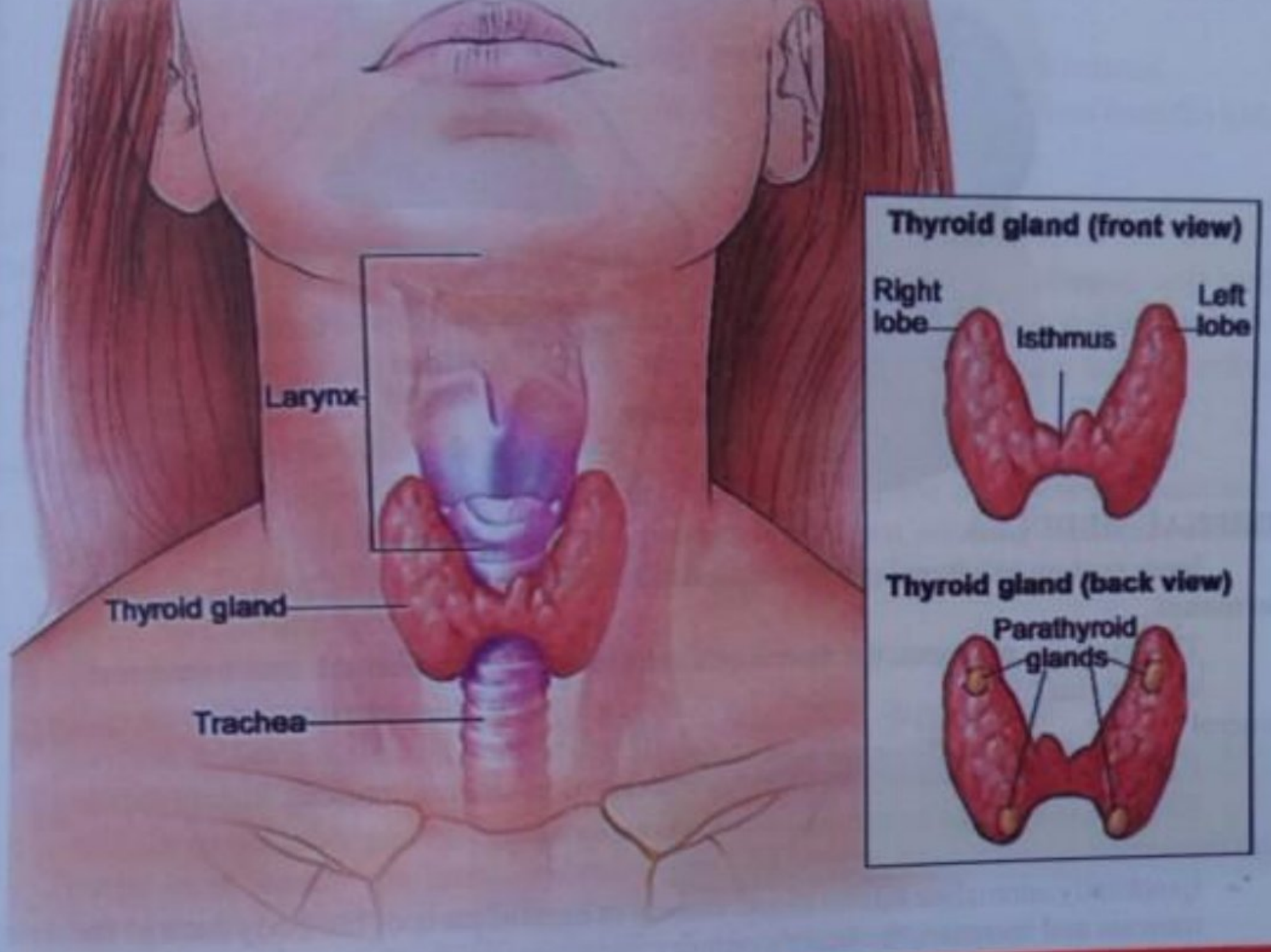
- If congenitally deficient, the lack of thyroxine causes ***cretinism***, where individuals fail to develop normally. They are small, have coarse scanty hair, thick yellowish scaly skin and are mentally retarded. They also fail to develop sexually.
- Deficiency later in life, perhaps due to iodine deficiency, produces swelling of neck (goiter) and may lead to deposition of excess fat as a result of which weight is increased.

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This condition is known as ***myxoedema***. Myxoedema is characterized by puffiness of hand and skin. All body and mental processes are retarded.

Abnormalities of Calcitonin

- Excess or deficiency leads to disturbance of calcium metabolism with its associated effects on nerve, skeleton, muscle, blood etc.



PARATHYROID GLAND

Introduction

- In man, the glands are found embedded in the posterior part of the lateral lobes of the thyroid.
- These are four in number.

Hormone

- These produce a hormone called Parathormone.

Control

- Low levels of blood Ca^{+2} ions stimulate the parathyroid directly to increase the parathormone production.
- High levels of Ca^{+2} ions suppress its release.

Abnormalities

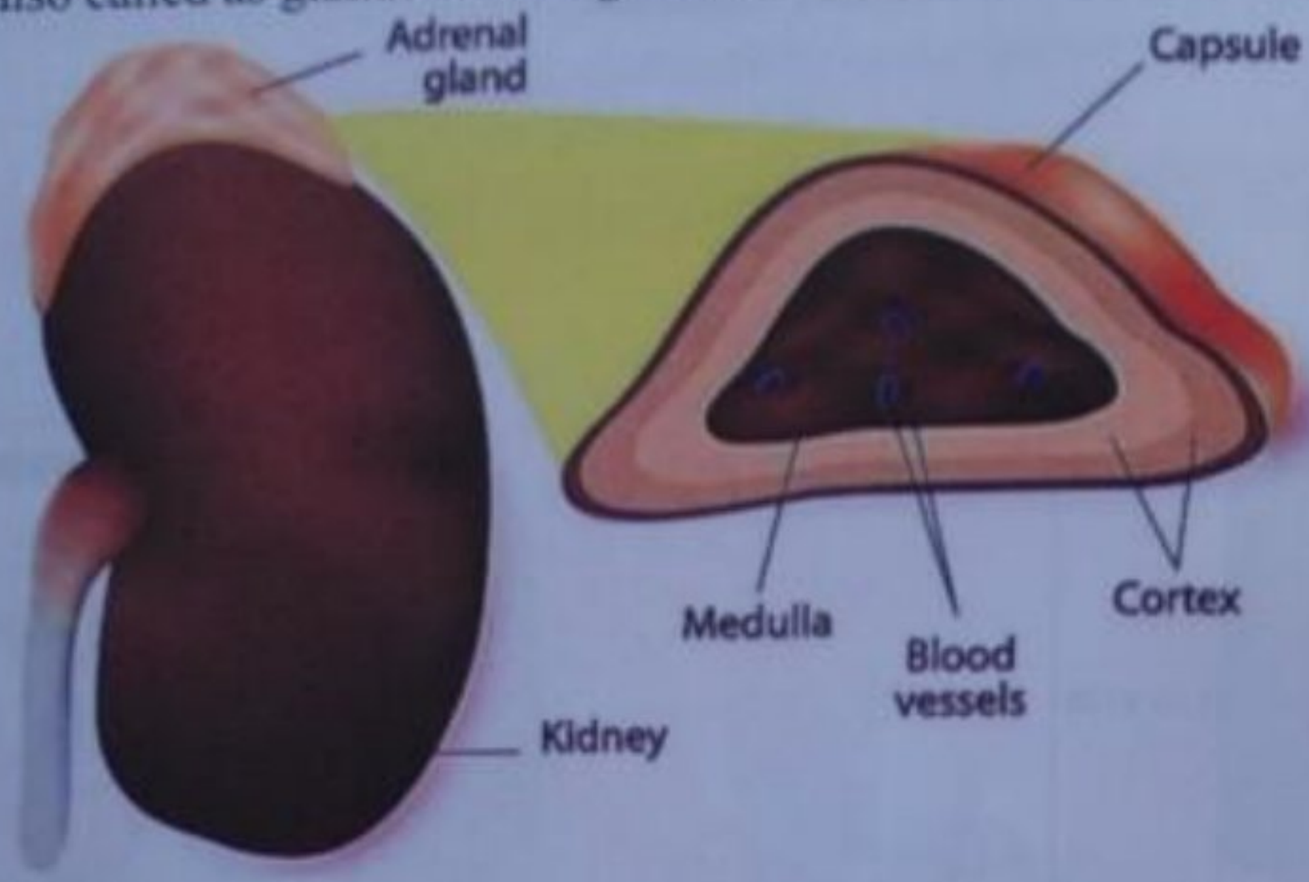
- Under-activity causes a drop in blood Ca^{+2} ions which in turn leads to muscular tetany.
- Over-activity would lead to a progressive demineralization of the bones similar to rickets, as well as to the formation of massive kidney stones.

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ADRENAL GLAND

Introduction

- A pair of adrenal gland is present, one on top of each kidney.
- These are also called as glands of emergency or supra-renal glands.



ADRENAL MEDULLA

- Inner portion of adrenal gland is called adrenal medulla.

Hormones

- The medulla produces the hormones adrenaline (epinephrine) and noradrenaline (nor-epinephrine).

Control

- Both adrenaline and nor-adrenaline are secreted in stress situations.
- They are influenced by sympathetic nervous system.

Functions

- Essentially adrenaline dilates blood vessels in certain parts of the body such as the skeletal muscles and increases the heart's output.
- Noradrenaline constricts blood vessels but again only in certain areas such as the gut.
- Effects of the two hormones are synergistic in raising blood pressure.
- Adrenaline and noradrenaline promote the release of glucose from liver glycogen and reinforce the effects of the sympathetic system.

Abnormalities

- Rarely found, but in excess, these hormones lead to abnormally high blood pressure.
- In rats whose adrenal medulla has been removed surgically, the ability to withstand any stress situation – such as cold – is markedly diminished.

ADRENAL CORTEX

- Outer portion of adrenal gland is called adrenal cortex.

Hormones

- The adrenal cortex secretes corticosteroids such as cortisol, corticosterone, aldosterone and androgenic hormones.
- Cortisol is the glucocorticoid.
- Corticosterone is both a glucocorticoid and a mineralocorticoid.
- Aldosterone is the principal mineralo-corticoid.

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Control

- Hormones of adrenal cortex are secreted under influence of ACTH from adrenal cortex.

Functions

- The adrenal cortex is active at all times but especially so following shock or stress situation or infections.
- Cortisol brings about an increase in blood glucose level mainly by its production from protein and antagonizing the action of insulin.
- Corticosterone increases blood glucose levels and regulate mineral ion balance.
- Aldosterone conserves the level of Na^+ in the body by preventing their loss from the kidney tubules.

Abnormalities

Under-secretion of Corticosteroids

- The destruction of the adrenal cortex, such as occurs in ***Addison's disease,*** will lead to general metabolic disturbance, in particular weakness of muscle action and loss of salts.
- Stress situations, such as cold, which would normally be overcome, lead to collapse and death.

Overproduction of Corticosteroids

- The reverse of this is found in Cushing's disease where too much cortical hormone is produced. Symptoms are an excessive protein breakdown resulting muscular and bone weakness. The high blood sugar disturbs the metabolism as in diabetes.

Overproduction of Androgens

- Androgens cause development of the secondary male characteristics.
- Very small amounts of androgens are secreted in both male and female by adrenal glands.
- A tumor on the inner part of the adrenal cortex in a female can cause excess androgens to be produced and thus the development of certain male characteristics. Such cases are very rare.

POINT TO PONDER

- Why both Addison's and Cushing diseases effect muscles?

ISLETS OF LANGERHANS

Introduction

- Pancreas is a dual gland that acts both as exocrine and endocrine glands.
- Endocrine portion of pancreas contains Islets of Langerhans.

Hormones

- The Islets contain large number of β cells associated with insulin production.
- The smaller number of α cells secrete glucagon.

Control

- This is under control of the pituitary trophic hormones, STH and ACTH and also respond directly to the level of blood glucose.

Functions

- In general, insulin depresses blood glucose levels, in a variety of ways which include:

(i) Increasing glycogen synthesis
(ii) Increasing cell utilization of glucose
(iii) Stimulates conversion of glucose into proteins and lipids, which in turn reduce glucose levels.
(iv) Inhibits the hydrolysis of glycogen in the liver and muscles.

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- Glucagon is essentially antagonistic to insulin and causes an increase in blood glucose levels. It does this mainly by:

(i) Promoting breakdown of glycogen to glucose in the liver and muscles.
(ii) Increasing the rate of breakdown of fats.

Abnormalities of Insulin

Under-secretion

- Failure to produce insulin leads to a condition called ***diabetes mellitus***. The symptoms of this are:

(i) High level of blood sugar.
(ii) Sugar in the urine.
(iii) A disturbance of the body's osmotic equilibrium.
(iv) Derangement of the nervous system.
(v) Toxic metabolites from fat (which need 'glucose energy' for their oxidation) also accumulate and are only lost from the kidney with valuable metal cations.
(vi) The body becomes dehydrated.

Overproduction

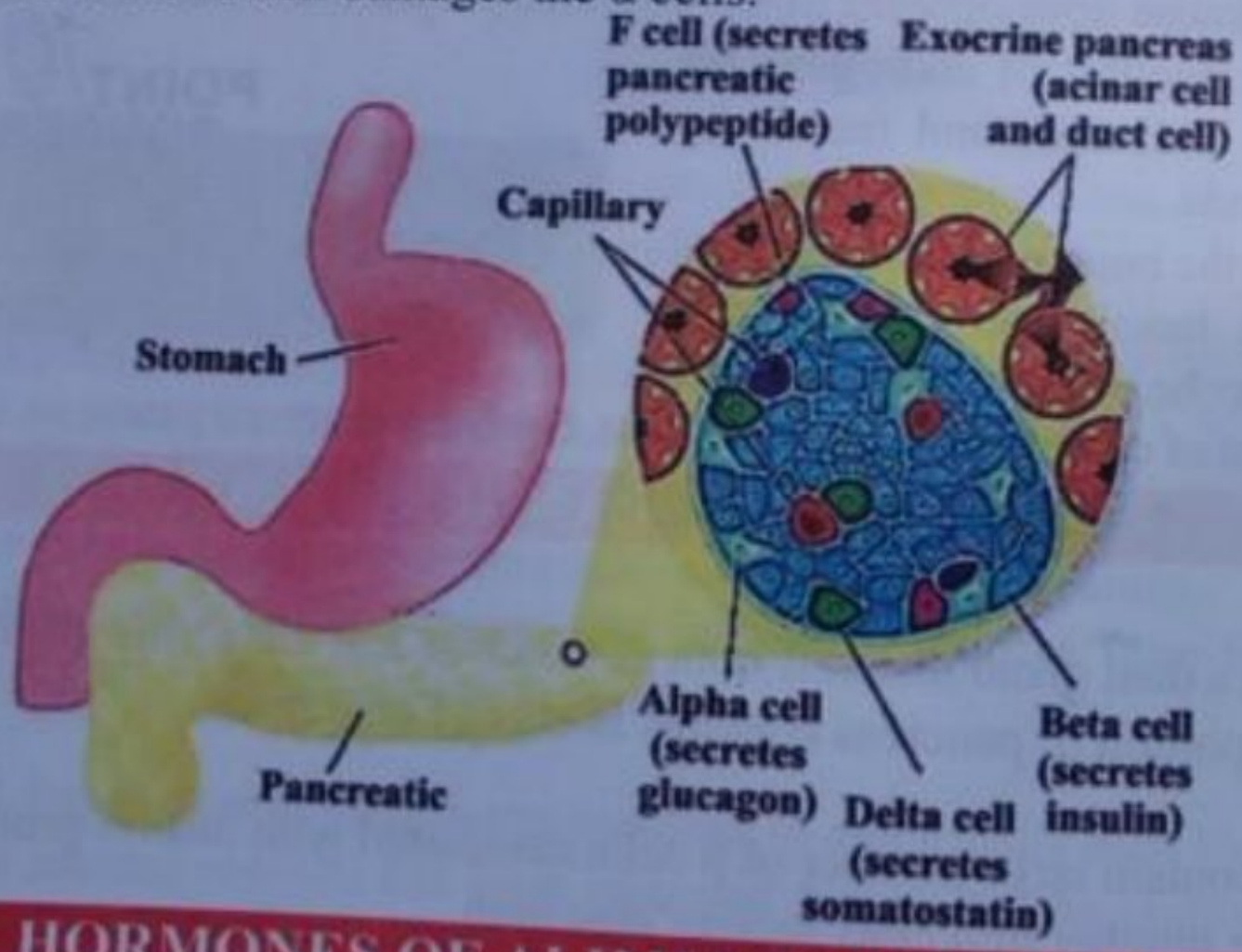
- If excess insulin is produced, the utilization of sugar is too great and its level falls in the blood (hypoglycemia) which upsets nerve and muscle functioning.

Abnormalities of Glucagon

- Glucagon abnormalities seem rare as endocrine disorders.
- Tumors on the β cells will cause excess glucagon secretions and consequently high blood glucose levels. This in turn damages the α cells.

POINT TO PONDER

How we relate insulin with type I & type II diabetes?



HORMONES OF ALIMENTARY CANAL

Gastrin

- It is the hormone produced by mucosa of the pyloric region of the stomach.
- It stimulates the secretion of gastric juice.
- It is produced under the influence of protein food in the stomach after it is partially digested.

Secretin

- It is produced from the duodenum when acid food touches its lining.
- It affects the pancreas to produce and release pancreatic juice and also affects the rate of bile production in the liver.

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HORMONES OF OVARIES & TESTES

OVARIES

Hormones

Ovaries are involved in production and secretion of female sex hormones mainly oestrogens and progesterone.

OESTROGEN

Production & Control

- Oestrogens are secreted by ripening follicles whose development has been initiated by FSH from the pituitary.
- In many species produced by interstitial cells of the ovary.

Functions

- Bring about the development of the secondary sexual characters in the female.
- Cause thickening of uterine wall.
- At a point during the oestrous or menstrual cycle, exert a positive feedback which results in a sharp rise in LH output by the pituitary.
- They also aid in healing and repair of uterine wall after menstruation.
- Under the influence of estrogen, some of the cells of uterine wall become glandular and start secreting proteinaceous secretions which are taken up by the embryo during its early stages of development.

Abnormalities

- Deficiency of the sex hormones, for one reason or another, leads in the young of failure to mature sexually and sterility in the adult.

PROGESTERONE

Production & Control

- Produced by the ruptured follicle in response to LH from the pituitary

Functions

- It inhibits further FSH secretion from the pituitary, thus preventing any more follicles from ripening.
- It also affects uterus, causing further thickening and vascularization of its wall and other areas of the female body, preparing it for maintaining the state of pregnancy.
- It suppresses ovulation that is why it is a major constituent of birth control pill.

TESTES

Hormones

- The testes consist of many coiled seminiferous tubules where the spermatozoa develop.
- Between the tubules, regions of interstitial cells produce gonadal hormones called testosterone and 17 β-hydroxytestosterone.
- After the initiation of development, the sex organs in the foetus produce them and their level rises fairly consistently until puberty.
- After puberty the supply of LH (ICSH), and therefore the level of testosterone, remains constant.

Functions

- In the foetus, it initiates the development of the sex organs.
- At puberty, it brings about development of the male secondary characteristics and promotes the sex drive.
- The castrated male fails to develop secondary sexual characteristics and his body tends more towards the form of the immature female.

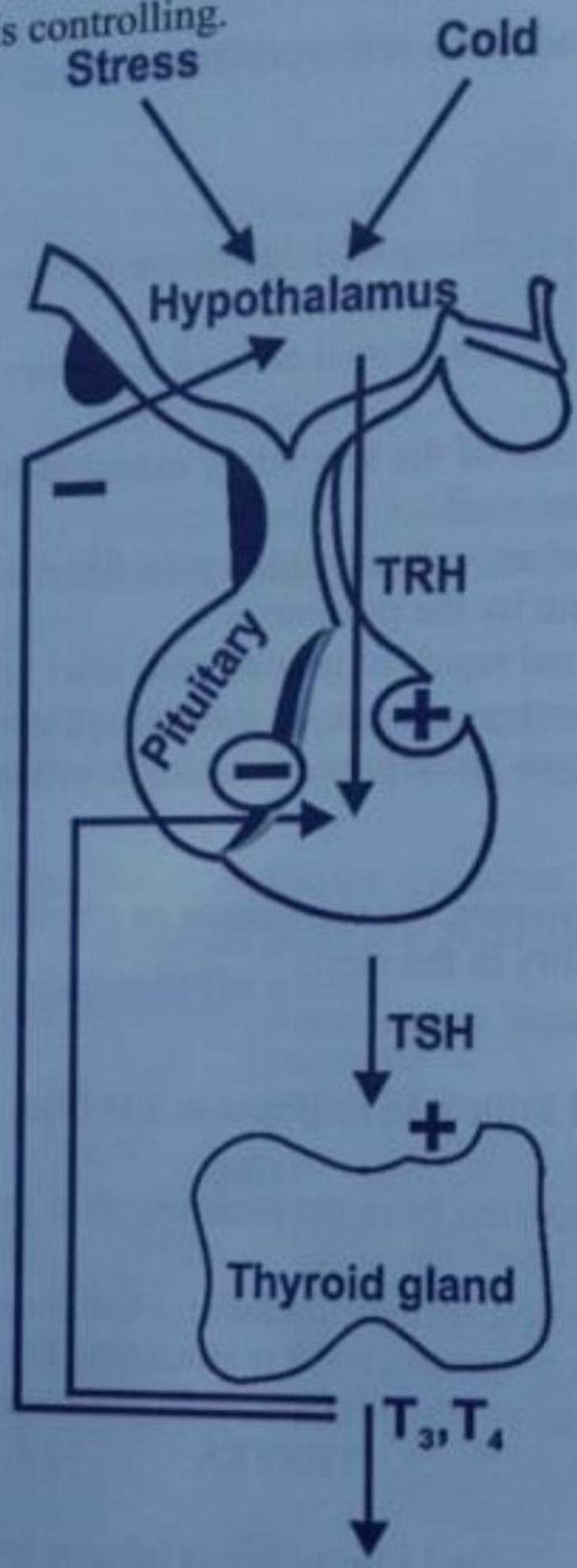
POINT TO PONDER

How castration will affect an Adult Male?

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FEEDBACK MECHANISM

- It is a type of interaction in which a controlling mechanism is itself controlled by the products of reactions it is controlling.



POINT TO PONDER

Can you differentiate between positive and negative feedback mechanism?

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TOPIC-5i
03MCQs

IMMUNITY

LEARNING OUTCOMES

(1) Define immune system and describe its components:
   (i) Antigen.
   (ii) Antibody (structure of antibody).
   (iii) Lymphocytes (B and T cells).
(2) Describe cell mediated response and humoral immune response.
(3) Discuss the types of immunity:
   (i) Active immunity.
   (ii) Passive immunity.
(4) Explain vaccination.

IMMUNITY

- The capacity to recognize the intrusion of any material foreign to the body and to mobilize cells and cell products to help remove the particular sort of foreign material with greater speed and effectiveness is called ***immunity***.
- There are three defense lines of our body. 1st defense line is provided by physical and chemical barriers, 2nd defense line by phagocytes and 3rd defense line by immune system.
- 1st & 2nd defense lines are non-specific while 3rd defense line is specific.
- Skin, mucous membrane and blood clot are physical barriers.
- HCl and lysozyme are examples of chemical barriers.
- Phagocytes and lymphocytes are example of cellular/ biological barriers.

IMMUNE SYSTEM

- Immune system forms 3rd defense line of our body.
- It is derived from mesoderm.
- It has two main components i.e. lymphocytes and antibodies.
- ***Antigen*** or immunogen is a foreign substance, often a protein which stimulates the formation of antibodies. The term ANTIGEN comes from ANTIbody GENerating substances.

LYMPHOCYTES

- Lymphocytes are examples of agranulocytes and belong to WBCs.
- There are two major types of lymphocytes i.e. T & B lymphocytes.
- T lymphocytes have been given name due to their relationship with thymus glands. Thymus has role in maturation of T lymphocytes and make them immunologically competent. T cells originate from stem cells in bone marrow. After early embryonic development, the newly forming T cells migrate to thymus gland for processing. T lymphocytes are further divided into following categories:

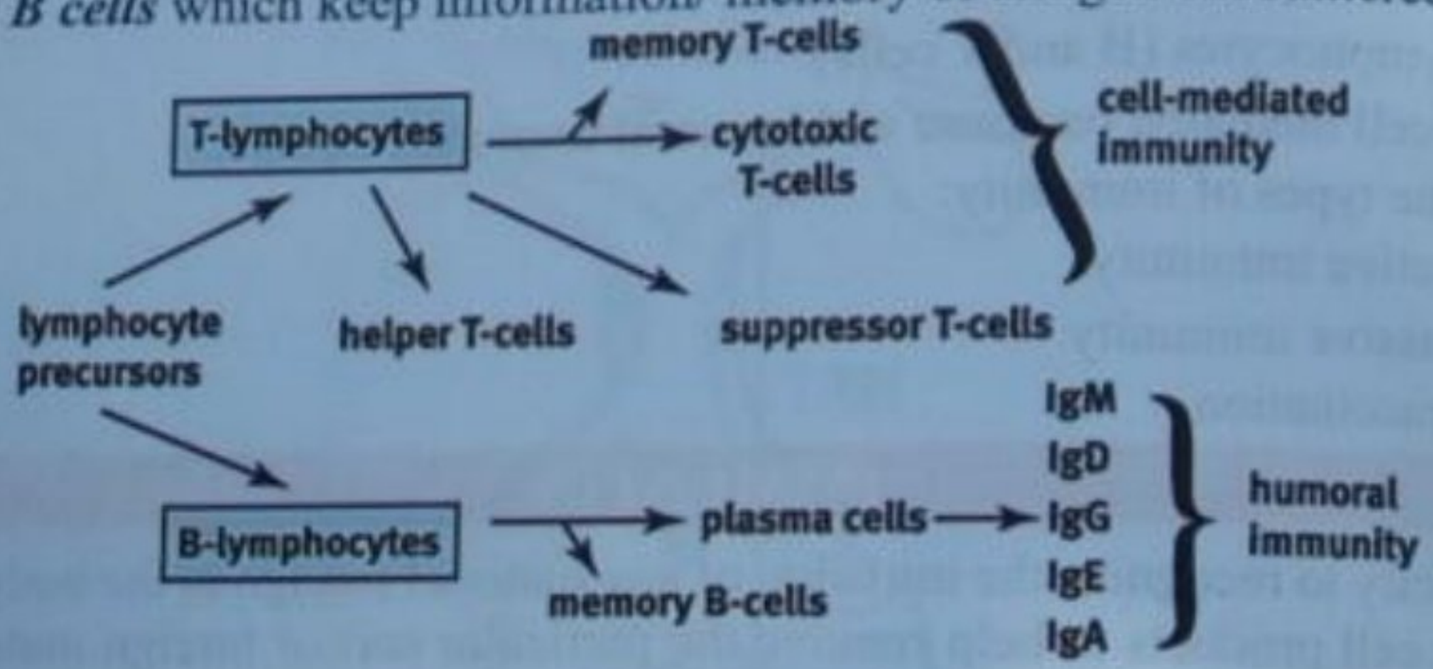
(i) ***Helper T lymphocytes*** recognize the antigen and inform other cells by releasing specific chemical substances (cytokines). Thus they help to produce immunity.
(ii) ***Suppressor T lymphocytes*** are involved in controlling immune response.
(iii) ***Cytotoxic T lymphocytes*** are involved in direct killing or destroying of antigens. For destruction, they usually depend upon lysosomes and peroxisomes.

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(iv) ***Memory T lymphocytes*** keep information/ memory of the antigen to protect body for next attack by same antigen.

- ***B lymphocytes*** have been given name due to their 1st discovery from Bursa of Fabricius, which is a lymphoid tissue in birds around cloaca. In humans, these are produced and released in mature form from bone marrow. After stimulation by antigen, they are activated and start dividing and form:

(i) ***Plasma cells clone*** which synthesize and secrete antibodies in plasma.
(ii) ***Memory B cells*** which keep information/ memory of antigen encountered.

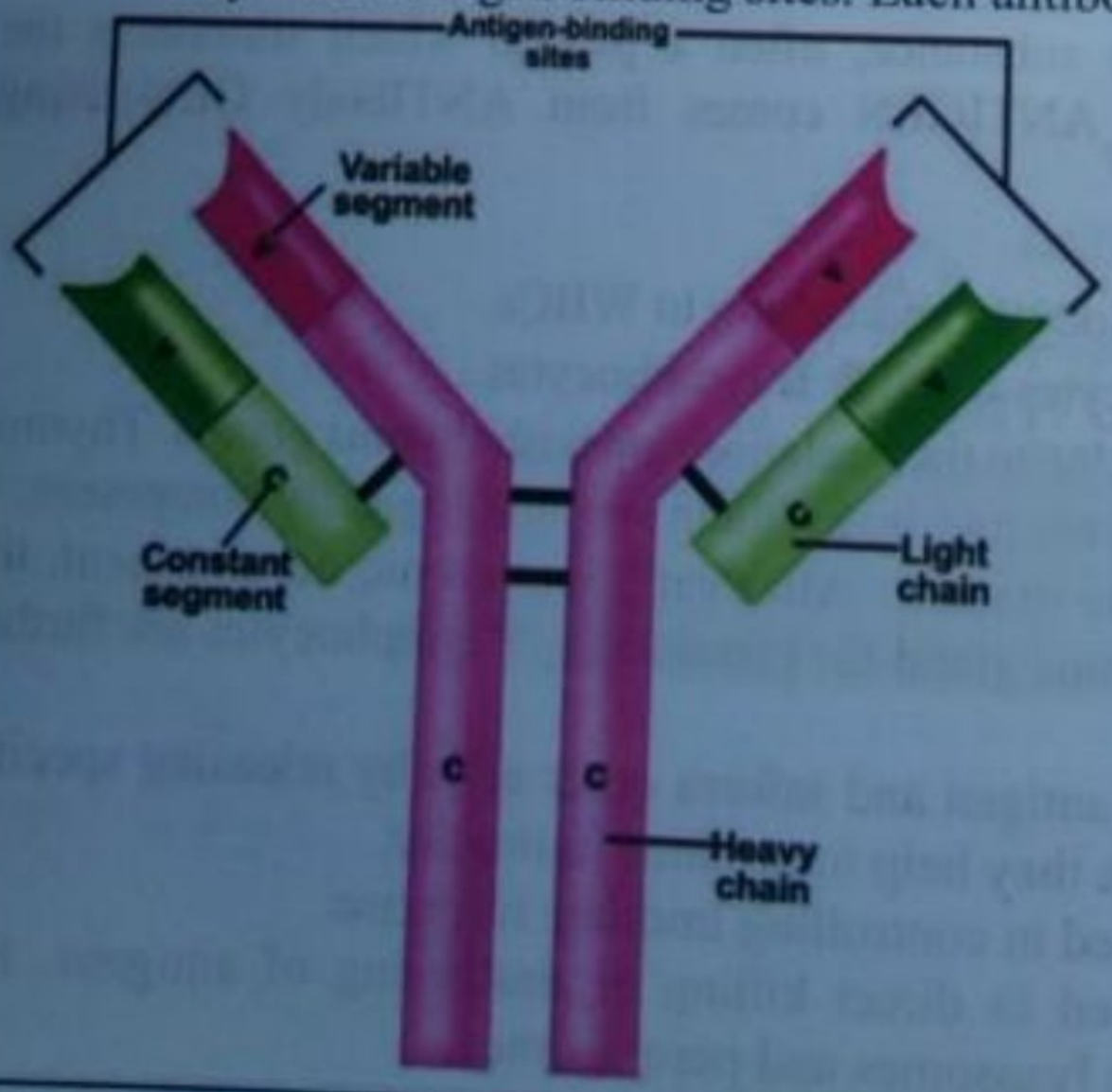


ANTIBODIES

- ***Antibodies/ Immunoglobulins*** are globular proteins, manufactured by B-lymphocytes, then secreted into the lymph and blood where they circulate freely.
- These are Y shaped molecules.
- Each antibody consists of four polypeptide chains; two heavy chains and two light chains.
- Each chain has a constant region and variable region.
- In constant region, the amino acid sequence is constant within a particular immunoglobulin class.
- Variable segment consists of different amino acid sequence in every antibody. Therefore, they act as antigen binding sites. Each antibody has two antigen binding sites.

POINT TO PONDER

What is function of constant region of antibody?



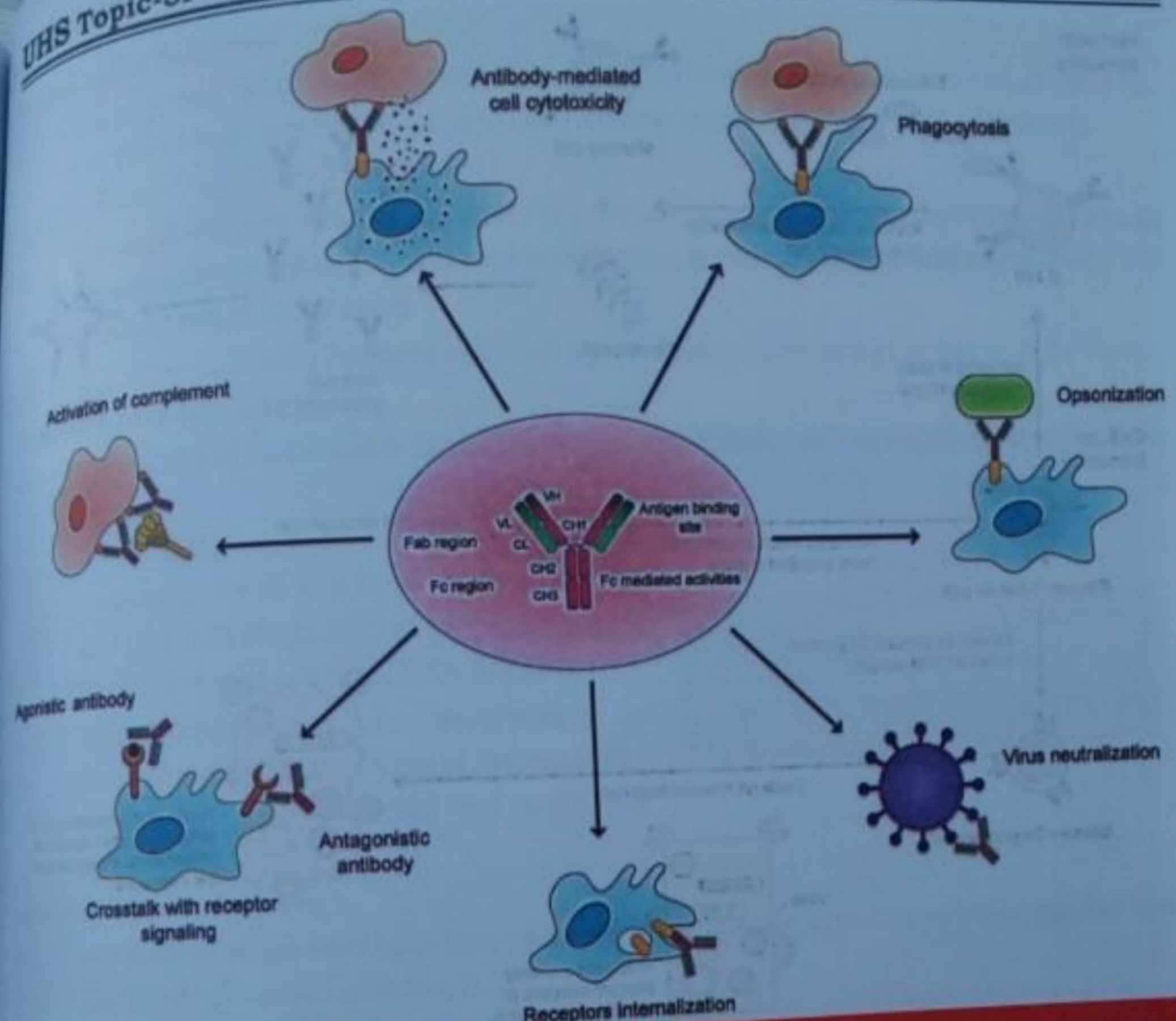
POINT TO PONDER

What do you know about different types of antibodies?

POINT TO PONDER

If a dog bites a person, what kind of immunization will be preferred to prevent Rabies?

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TYPES OF IMMUNITY

- There are two basic types of immunity: inborn or innate immunity and acquired or adaptive immunity.

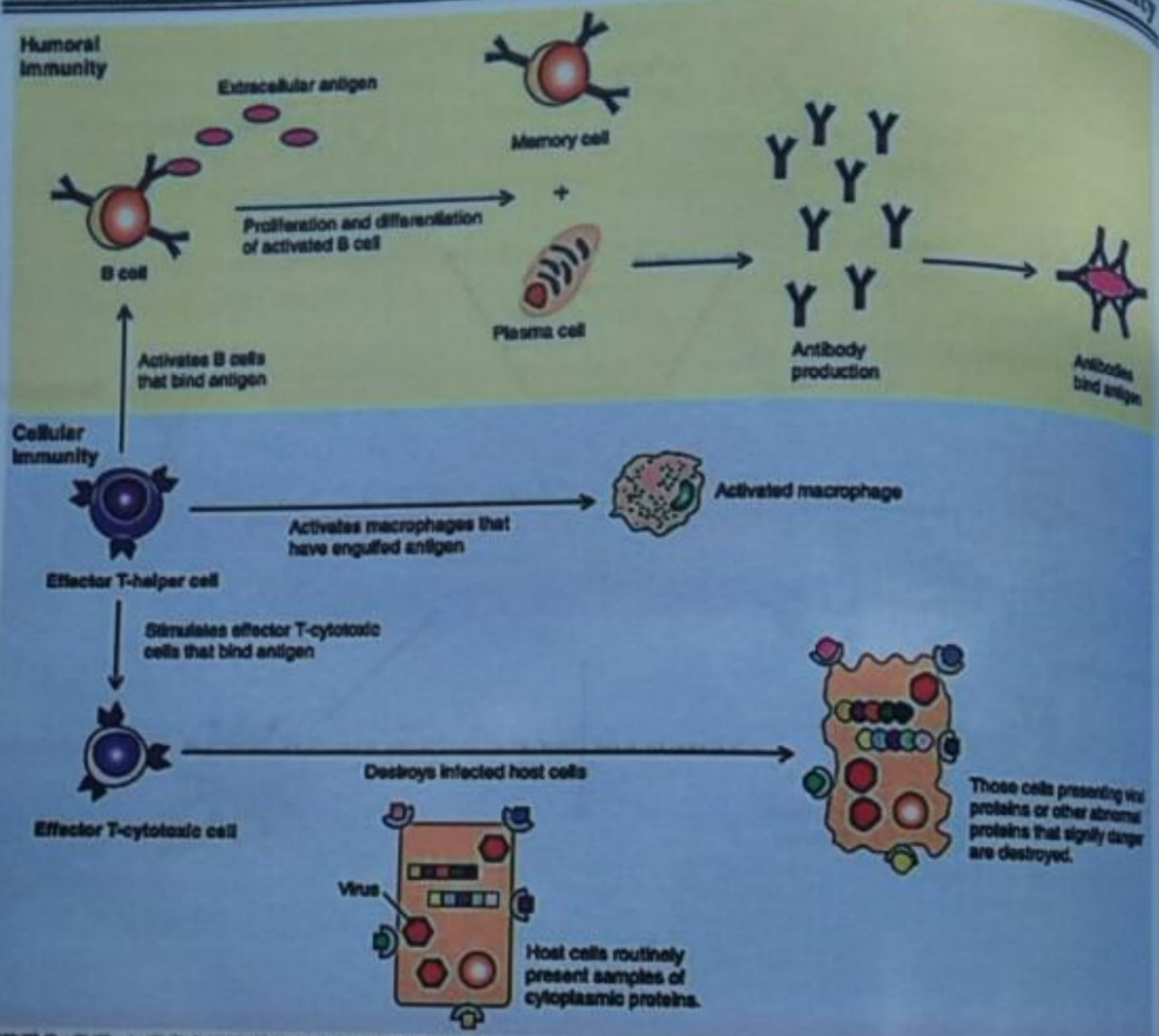
INNATE IMMUNITY

- The ability of the innate immunity to kill microorganisms is not specific.
- First and second lines of defense are part of innate immunity.

ACQUIRED IMMUNITY

- Highly specific protection is provided by innate immunity, but it takes several days for this system to become fully functional.
- There are two types of acquired immune responses i.e. cell-mediated response and antibody-mediated or humoral immune response.
- T-cells recognize antigen and then combat microorganisms and also responsible for rejection of foreign transplanted tissue if it is not properly matched. This is called ***cell mediated response***.
- B-cells recognize antigen and form plasma cell clone. These plasma cells synthesize and liberate antibodies into the blood plasma and tissue fluid. Here antibodies attach to the surfaces of bacteria and speed up their phagocytosis. Some antibodies behave as antitoxins for neutralization of toxins produces by microorganisms. This is called ***humoral immune response***.

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TYPES OF ACQUIRED IMMUNITY

- There are two types of acquired immunity:

(a) Active Immunity
(b) Passive Immunity

- The method of passive immunization is used to combat active infections of tetanus, infectious hepatitis, rabies, snakebite venom etc.
- These are further divided into natural and artificial immunity.

Feature	Active Immunity	Passive Immunity
Production of Immunity	Produced because of entry of antigen.	Produced because of entry of antibodies.
Source of Antibodies	Body is stimulated to produce antibodies.	Antibodies are introduced from other source.
Substance Entering	Antigen	Antiserum
Response	Delayed immune response	Immediate immune response
Results	Prolonged results	Short acting
Memory cell production	✓	×
Role	Preventive	Preventive & Curative

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Natural Active Immunity

- When a person is exposed to an infection (antigen) becomes ill and in most cases survives, then this immunity developed against that disease is called ***natural active immunity***.

Artificial Active Immunity (Vaccination)

- The use of vaccines, which stimulates the production of antibodies in the body, and making a person immune against the diseases or infection, is called ***artificial active immunity***. The process is called vaccination.
- This active immunity has been achieved by artificially introducing; antigens in the body.

Natural Passive Immunity

- If the source of antibodies is natural, then type of immunity will be called as natural passive immunity.
- For example, antibodies from a mother can cross the placenta and enter her fetus. In this way they provide protection for the baby until its own immune system is fully functional.
- This immunity may also be provided by colostrum, the first secretion of the mammary glands. The baby absorbs the antibodies through its gut.

POINT TO PONDER

Name at least three diseases that provide auto immune response in individuals?

Artificial Passive Immunity

- Antibodies which have been formed in one individual are extracted and then injected into the blood of another individual.
- In the case of snakebite venom, passive immunity is produced by antitoxins, so the serum is called antivenom serum.
- Similarly, specific antibodies used for combating tetanus and diphtheria are cultured and injected into humans.

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TOPIC-6
06 MCQs

BIOENERGETICS

LEARNING OUTCOMES

(1) Describe photosynthetic pigments (chlorophyll and carotenoids).
(2) Understand the concept of absorption and action spectra.
(3) Discuss light dependent stage (cyclic and non-cyclic phosphorylation).
(4) Discuss light independent stage (Calvin cycle).
(5) Describe the respiration at cellular level including:
(i) Glycolysis (with preparatory and oxidative phase), Krebs cycle (with reference to production of NADH, FADH and ATP), Electron Transport Chain with its carriers.
(ii) Anaerobic Respiration and its types (alcoholic and lactic acid fermentation).

PHOTOSYNTHETIC PIGMENTS

- Photosynthetic pigments are the substances that absorb ***visible light*** (380-750 nm wavelength).
- All the wavelengths that are absorbed by the pigments are disappeared.

CHLOROPHYLLS

- They are ***main photosynthetic pigments of plants***.
- They are ***insoluble in water*** but are ***soluble in organic solvents*** like carbon tetrachloride, alcohol etc.
- ***Chlorophyll a, b, c and d*** are found in eukaryotic photosynthetic plants and algae.
- ***Bacteriochlorophylls*** are found in photosynthetic bacteria.
- They mainly ***absorb violet-blue and orange-red wavelengths.*** Green, yellow and indigo wavelengths are least absorbed by chlorophylls and transmitted or reflected.

Structure

- A chlorophyll molecule has two parts i.e. **hydrophilic head** and a **hydrophobic hydrocarbon tail.**
- ***Hydrophilic head*** is flat, square, light absorbing complex porphyrin ring or tetrapyrrole ring structure containing magnesium as central metal ion, which is coordinated with nitrogen.
- ***Hydrophobic hydrocarbon tail*** is long, anchoring phytol ($C_{20}H_{39}$). The chlorophyll molecule is embedded in the hydrophobic core of thylakoid membrane by this tail.

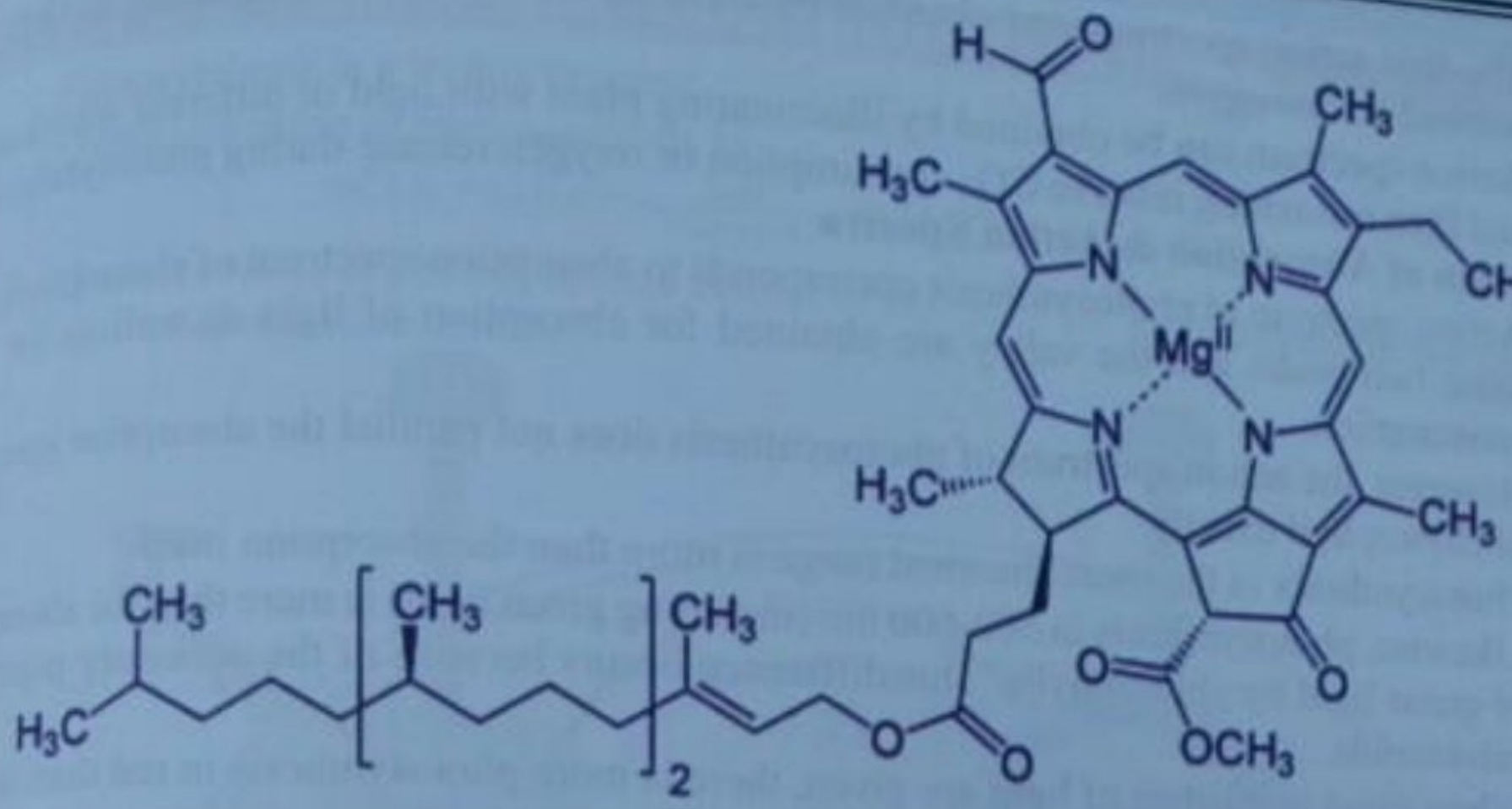
Chlorophyll a and b

- Of all the chlorophylls, chlorophyll a is the most abundant and the most important photosynthetic pigment.
- It takes part directly in the light dependent reactions.

Differences between chlorophyll a and chlorophyll b

Features	Chlorophyll a	Chlorophyll b
Molecular formula	$C_{55}H_{72}O_5N_4Mg$	$C_{55}H_{70}O_6N_4Mg$
Functional group	$-CH_3$ (methyl group)	-CHO (carbonyl group)
Occurrence	All photosynthetic organisms except photosynthetic bacteria	In association with chlorophyll a in all green plants and green algae
Forms	Differ slightly in their red absorbing peaks e.g. 670,680,690,700 nm	No such different forms
Colour	Blue - green	Yellow- green

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CAROTENOIDS-ACCESSORY PIGMENTS

- Carotenoids are yellow and red to orange pigments.
- They absorb strongly the ***blue-violet range***.
- ***Carotenoids and chlorophyll b*** are called accessory pigments, since they absorb light and transfer the energy to chlorophyll a, which then initiate the light reaction.

POINT TO PONDER

Why chlorophyll a is blue green?

Carotenoids → Chlorophyll b → Chlorophyll a

Functions

- They broaden the spectrum of light that provides energy for photosynthesis.
- Some of these may ***protect chlorophyll*** by absorbing and dissipating intense light.
- Similarly, carotenoids may ***protect human eye***.

ABSORPTION & ACTION SPECTRA

- Light is form of energy called electromagnetic energy or radiations. It behaves as waves as well as sort of particles called photons.
- The radiations most important for life are the visible light that ranges from about 380 to 750 nm wavelength.
- Only about 1% of the light falling on the leaf surface is absorbed, the rest is reflected or transmitted.

Absorption Spectrum

- Graph showing relative absorption of different wavelengths of light by different photosynthetic pigments is called absorption spectrum.
- Absorption spectrum of chlorophylls indicates that absorption is maximum in blue and red parts of the spectrum, two absorption peaks being at around 430 nm and 670 nm respectively.
- Absorption peaks of carotenoids are different from those of chlorophylls.

Action Spectrum

- Graph showing relative effectiveness of different wavelengths of light in driving photosynthesis is called action spectrum of photosynthesis.

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- The first action spectrum was obtained by German biologist T.W.Engelman in 1883. He worked on *Spirogyra*.
- Action spectrum can be obtained by illuminating plant with light of different wavelengths and then estimating relative CO_2 consumption or oxygen release during photosynthesis.

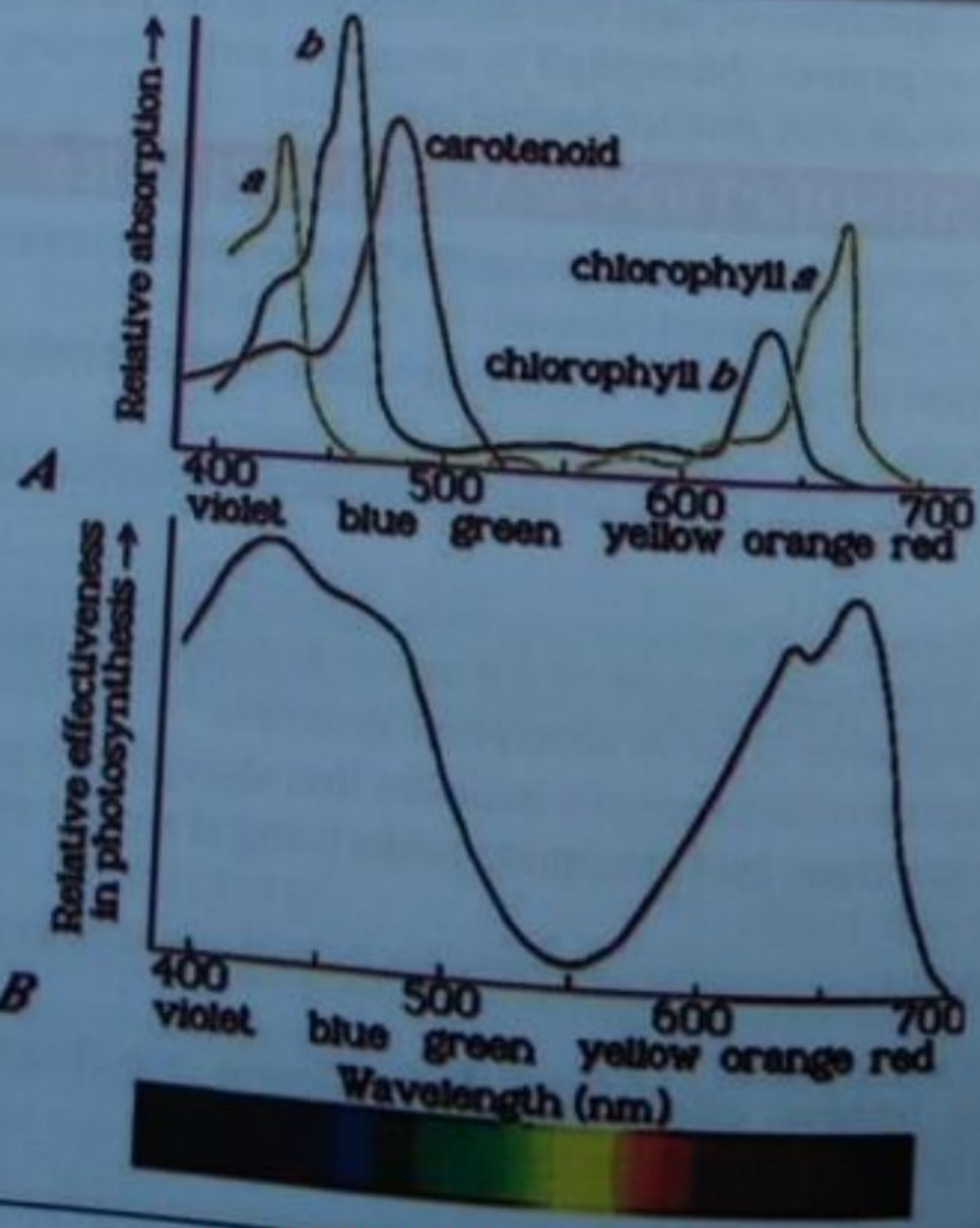
Comparison of Absorption & Action Spectra

- Action spectrum of photosynthesis corresponds to absorption spectrum of chlorophyll. The same two peaks and the valley are obtained for absorption of light as well as for CO_2 consumption.
- However, the action spectrum of photosynthesis does not parallel the absorption spectrum of chlorophyll exactly.
- Photosynthesis in the most absorbed range is more than the absorption itself.
- Likewise, photosynthesis in 500-600 nm (including green light) is more than the absorption of green light by chlorophylls. This difference occurs because of the accessory pigments, carotenoids.
- When equal intensities of light are given, there is more photosynthesis in red than in blue part of spectrum.

Feature	Absorption Spectrum	Action Spectrum
Peaks	Narrow	Broader
Valley	Broader and deep	Narrow and not deep

POINT PONDER

Most effective colour in photosynthesis is red but in action spectrum, why the highest peak is formed at violet-blue?



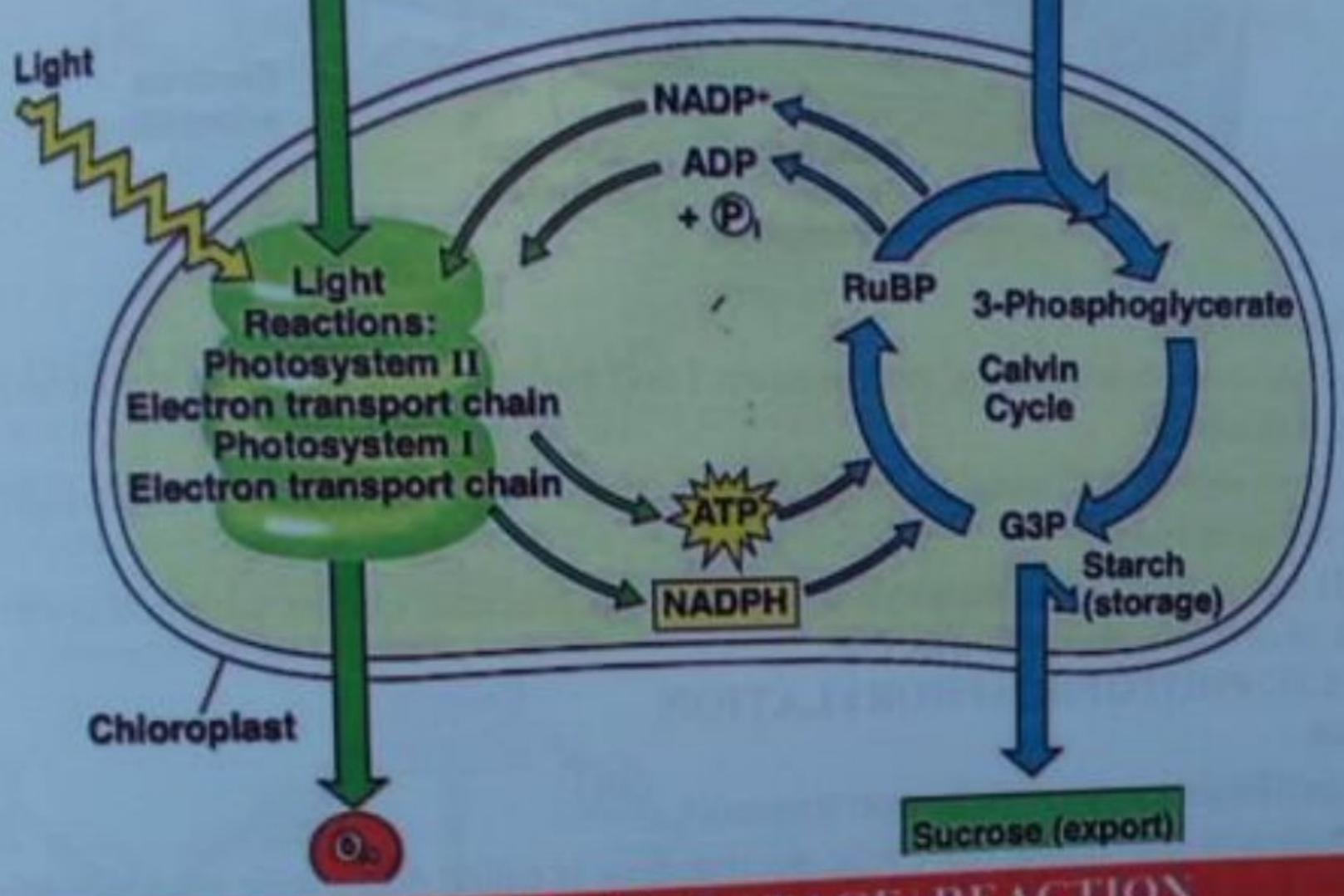
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REACTIONS OF PHOTOSYNTHESIS

- Photosynthesis is a 'redox process'.
- Overall equation of photosynthesis is:

$$6CO_2 + 12H_2O \xrightarrow[\text{Chlorophyll}]{\text{Light}} C_6H_{12}O_6 + 6O_2 + 6H_2O$$

- These reactions of photosynthesis consist of two parts i.e. light-dependent reactions and light-independent reactions.



LIGHT DEPENDENT STAGE/ REACTION

- Such types of reactions, which require light and constitute that phase of photosynthetic reaction during which light energy is absorbed by chlorophyll and other photosynthetic pigment molecules and converted into chemical energy are called light reactions.
- As a result of this energy conversion, reducing and assimilating powers in the form of $NADPH_2$ (NADPH + H^+) and ATP are formed. Both temporarily store energy and carry alongwith H to the light independent reactions.

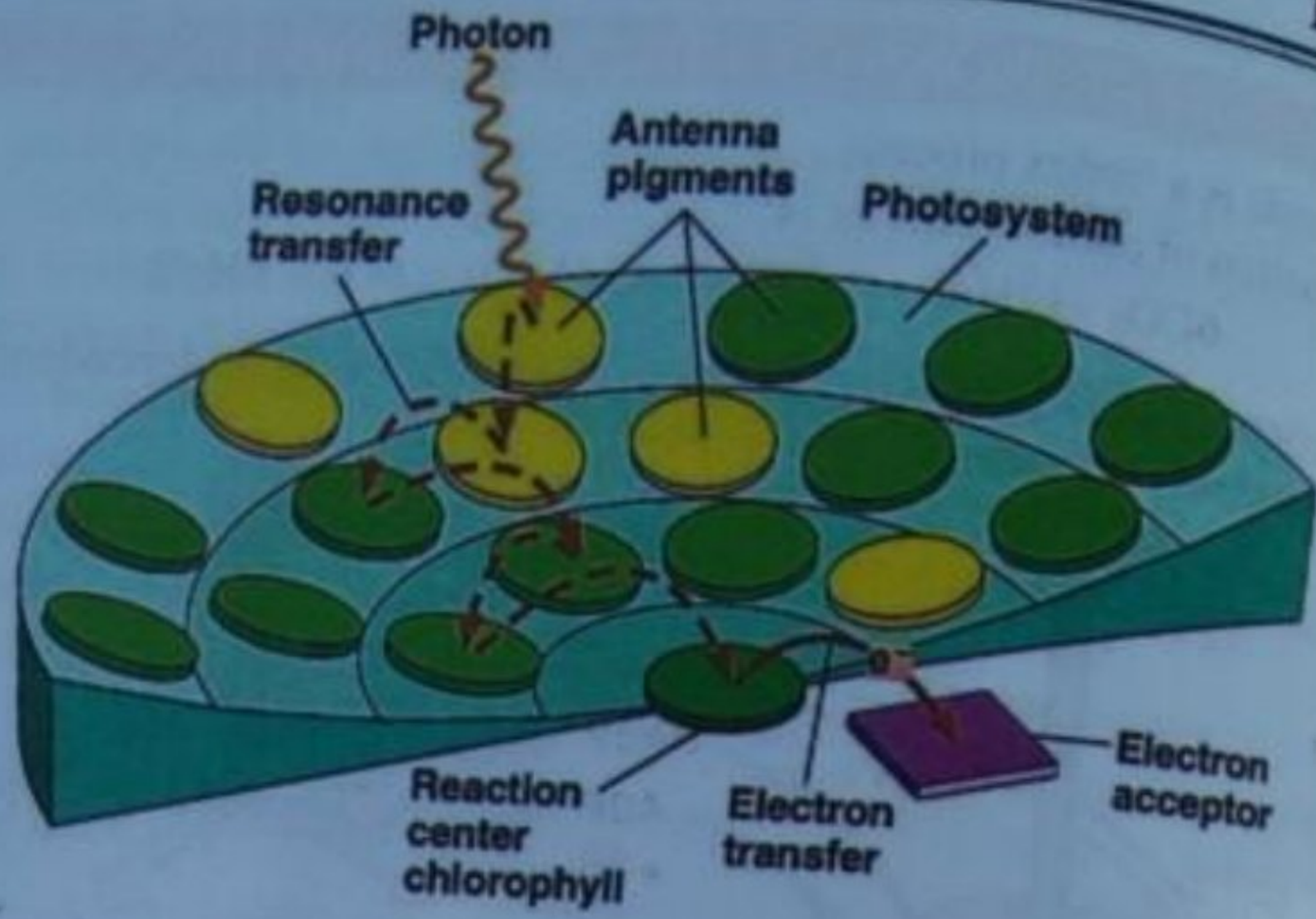
Photosystems

- Photosynthetic pigments are organized into clusters called ***photosystems***.
- Photosystem is for efficient absorption and utilization of solar energy in the thylakoid membranes.
- Each photosystem consists of two parts:

(i) ***Antenna complex*** has many chlorophyll a, b and carotenoids, which channelize energy to reaction centre.

(ii) ***Reaction centre*** is constituted by chlorophyll a along with primary electron acceptor and associated electron carriers of electron transport system. Electron transport system plays role in generation of ATP by chemiosmosis.

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Types of Photosystem

- There are two photosystems; photosystem I and photosystem II. These are named so in order of their discovery.
- **PS I** have chlorophyll a molecule in reaction centre which absorbs maximum light of 700 nm, also called as P_{700}.
- **PS II** has a form of chlorophyll a molecule in reaction centre which absorbs maximum light of 680 nm, also called as P_{680}.

NON-CYCLIC PHOTOPHOSPHORYLATION

Introduction

- It is predominant type of electron transport.
- Formation of ATP during non-cyclic electron flow is called non-cyclic photophosphorylation.
- Non-cyclic phosphorylation is also called ***Z-scheme,*** due to flow of electrons in Z-shape.

Mechanism

- Important steps of non-cyclic photophosphorylation are:

(i) Photoexcitation of electrons
(ii) Photolysis of water
(iii) Electron transport and formation of ATP through chemiosmosis
(iv) Formation of $NADPH_2$

- The oxygen produced during photolysis is the main source of replenishment of atmospheric oxygen.
- Plastoquinone (Pq), Cytochromes and Ferredoxin (Fd) are iron containing electron carriers while Plastocyanin (Pc) is copper containing electron carrier.
- One photon excites one electron.

Passage of Electrons

PS II → PEA → Pq → Cyt. Complex → Pc → PS I → PEA → Fd → $NADP^+$

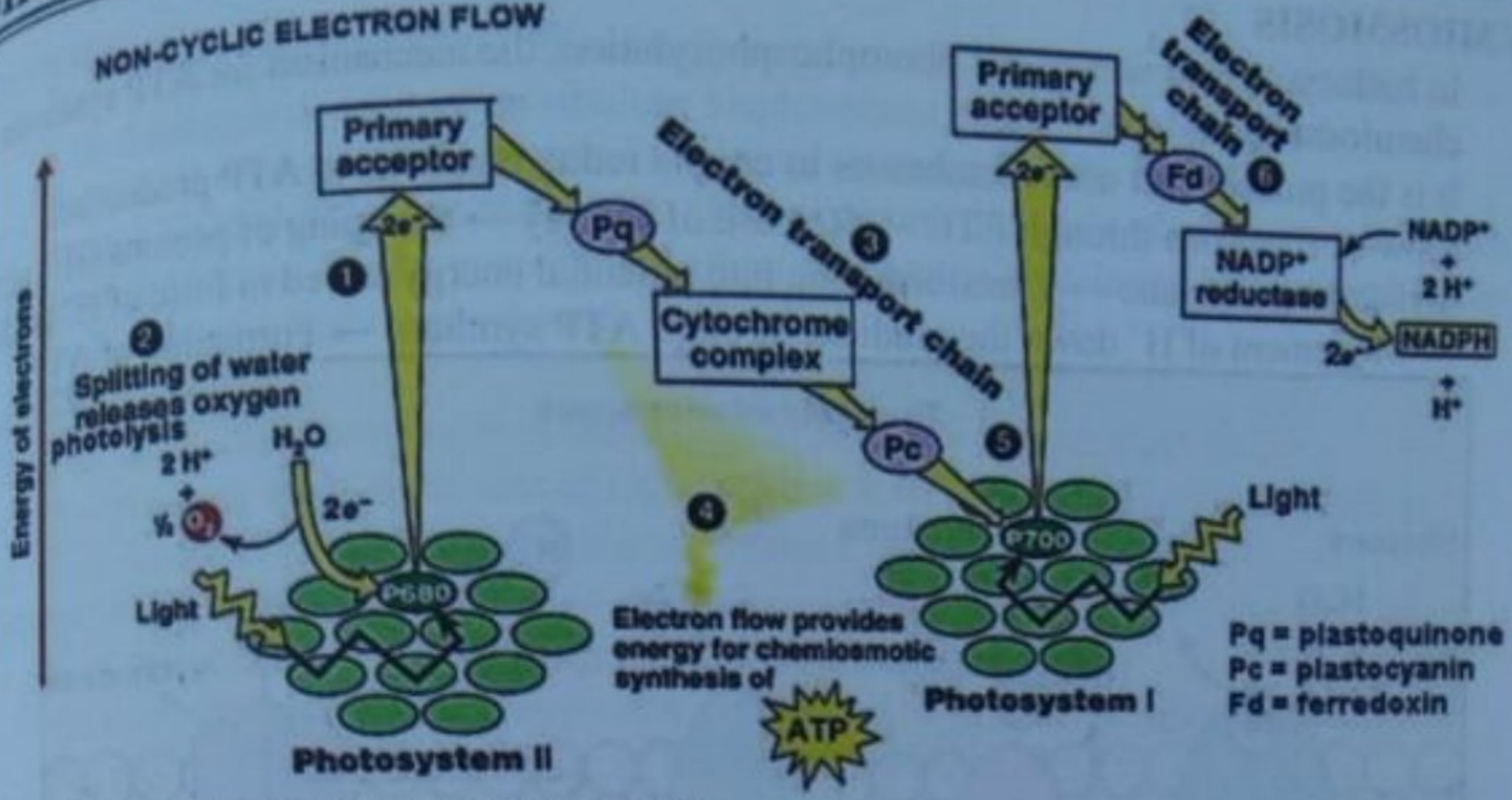
End Products of Light Reaction

- NADPH/ $NADPH_2$
- ATP
- Molecular oxygen

POINT TO PONDER

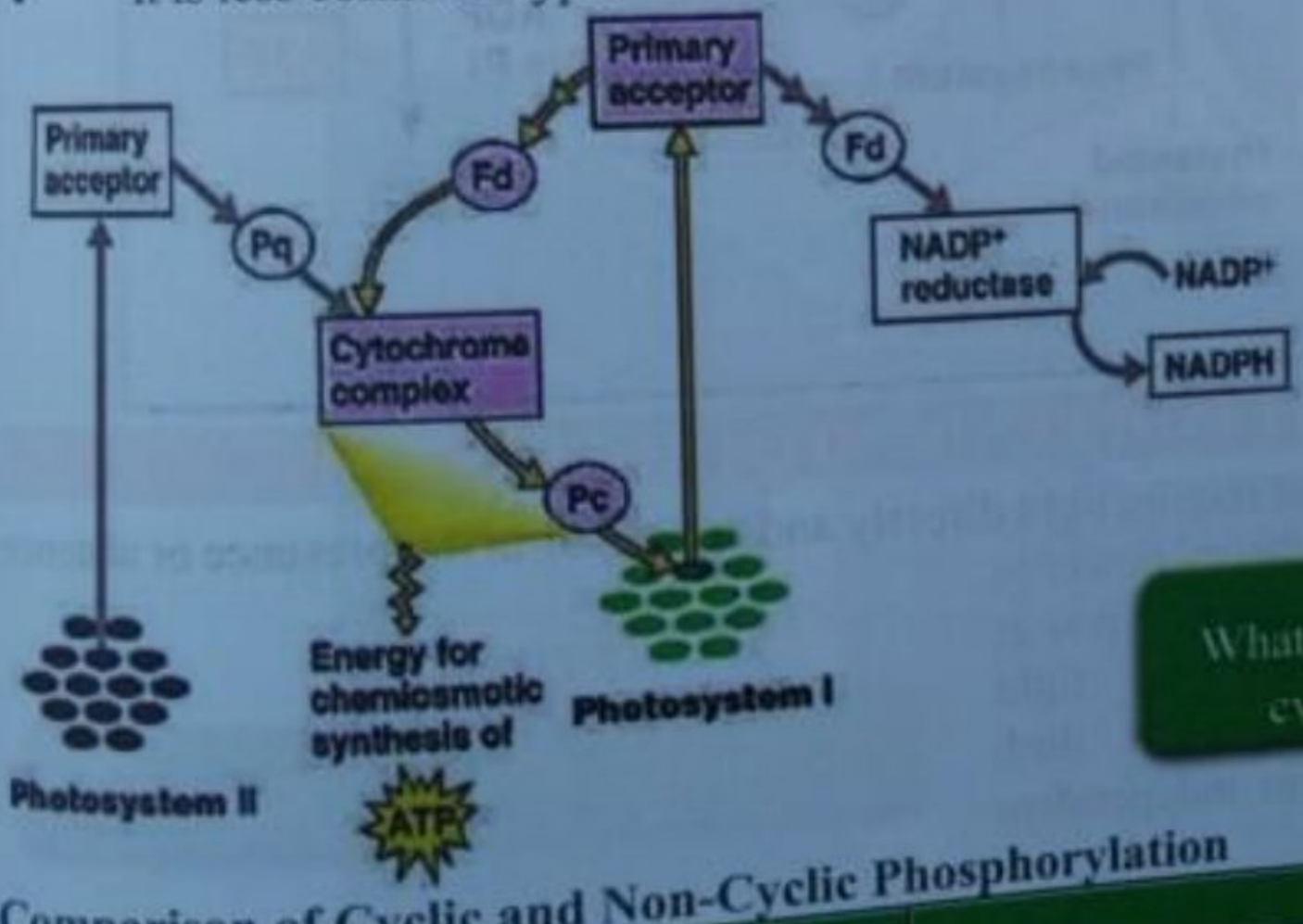
Which part of chloroplast catalyzes photolysis?

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CYCLIC PHOTOPHOSPHORYLATION

- It occurs at that time when chloroplast run low on ATP for Calvin cycle, the cycle slows down, and NADPH accumulate in chloroplast.
- This rise in NADPH may stimulate a temporary shift from non-cyclic to cyclic electron flow until ATP supply meets the demand.
- It is less common type.



POINT TO PONDER

What is the fate of electrons in non-cycle photophosphorylation?

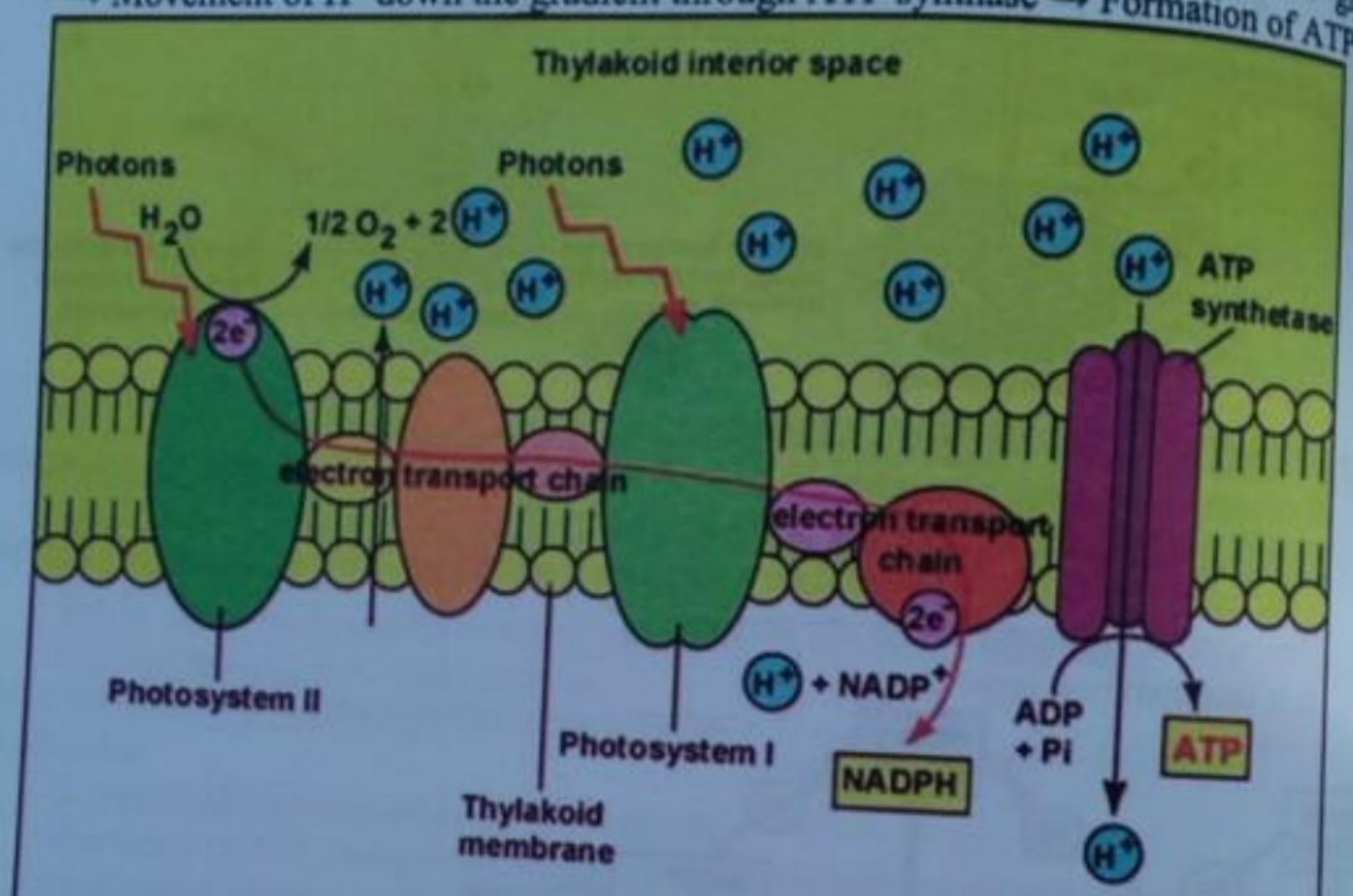
Comparison of Cyclic and Non-Cyclic Phosphorylation

Non-cyclic	Cyclic
Electrons are not reused.	Electrons are reused.
It involves both PS I and II.	It involves only PS I.
It is long pathway.	It is short circuit.
It is normal process.	It occurs when ATP are less and NADPH are more.
It generates both ATP and NADPH.	It generates only ATP.
H_2O splits	H_2O does not split
Oxygen is released.	Oxygen is not released.

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CHEMIOSMOSIS

- In both cyclic and non-cyclic photophosphorylation, the mechanism for ATP synthesis is chemiosmosis.
- It is the process that uses membranes to couple redox reactions to ATP production.
- Flow of Electrons through ETC → Release of Energy → Pumping of protons (H^+) across thylakoid membrane → Transformation into potential energy stored in form of H^+ gradient → Movement of H^+ down the gradient through ATP synthase → Formation of ATP



LIGHT INDEPENDENT STAGE

- Those reactions which do not require light directly and can occur in the presence or absence of light provided that assimilatory power in the form of ATP and reducing power $NADPH_2$, produced during the light reaction is available are called dark reactions and constitute light independent phase of photosynthesis.
- $NADPH_2$ provides energized electron and H^+ while ATP provides chemical energy for the synthesis of sugar by reducing CO_2.
- These reactions take place in stroma of chloroplast.
- The cyclic series of reactions, catalyzed by respective enzymes, by which the carbon is fixed and reduced, resulting in the synthesis of sugar during the dark reaction, is called ***Calvin Cycle.***
- It is divided into three steps:

(i) Carbon fixation
(ii) Reduction
(iii) Regeneration of CO_2 acceptor.

POINT TO PONDER

Does Rubisco involve in respiration?

POINT TO PONDER

How Rubisco acts as oxygenase and carboxylase?

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CO_2 Fixation

- Carbon fixation refers to the initial incorporation of CO_2 into organic material.
- CO_2 fixation is dependent on ribulose bisphosphate carboxylase (***Rubisco***).
- Rubisco is most abundant protein in chloroplast and on earth.
- Three CO_2 molecules are required to synthesize one molecule of carbohydrate, a triose.
- First product is highly unstable 6-carbon compound that immediately breaks into two molecules of 3-carbon compound.

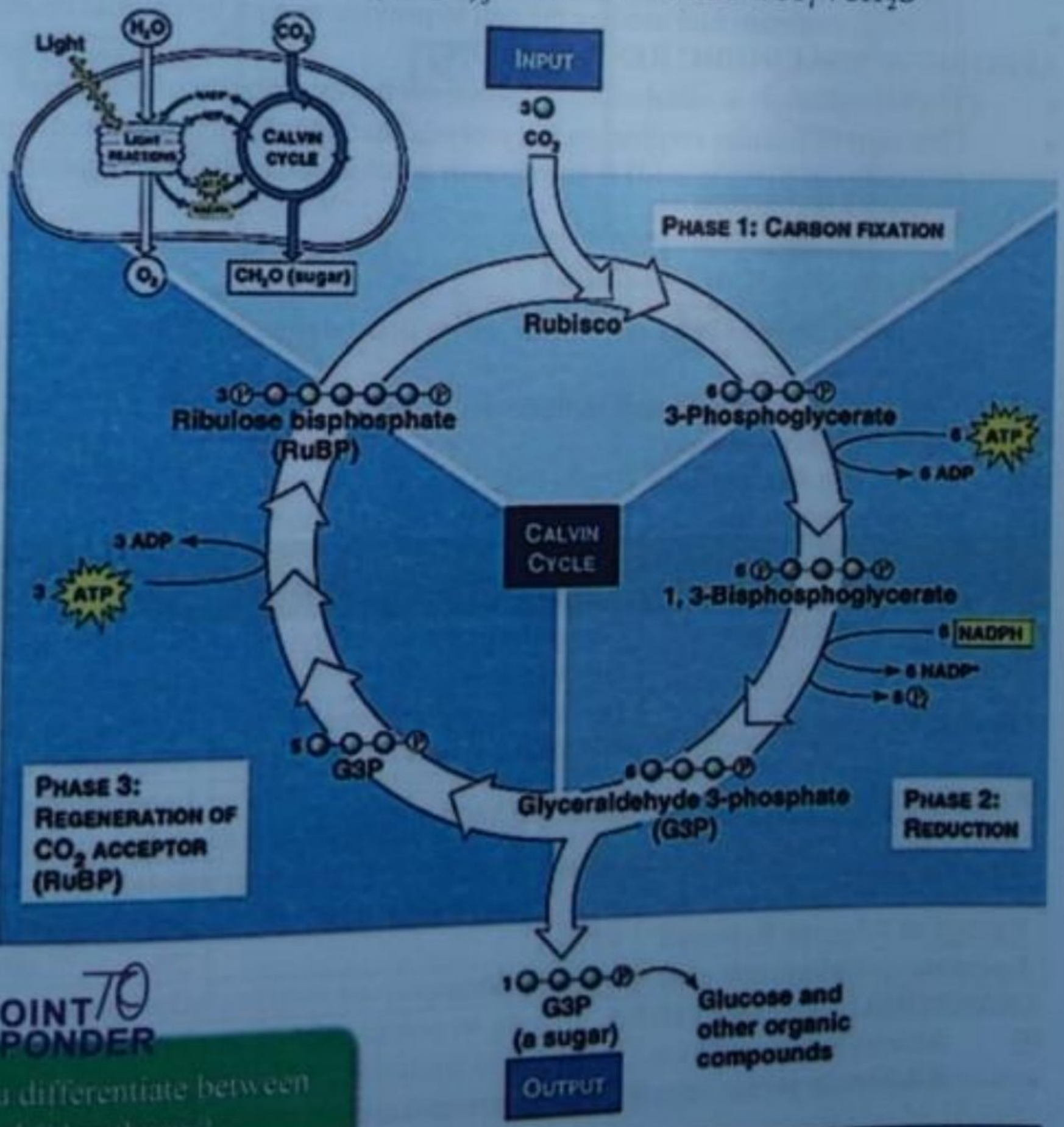
Reduction

- This reduction phase involves utilization of products of light reaction.
- Reduction of three molecules of CO_2 requires 6 ATP and 6 $NADPH_2$ molecules.
- G3P (product of Calvin cycle) is also obtained during this phase.

Regeneration of RuBP

- Five molecules of G3P are recycled into 3 molecules of RuBP.
- This conversion requires energy that is provided by ATP from light reactions.
- For regeneration of 3 molecules of RuBP, 3 ATP molecules are consumed.

$$3CO_2 + 6NADPHH^+ + 9ATP \rightarrow (CH_2O)_3 + 6NADP^+ + 9ADP + 9P_i + 3H_2O$$



POINT PONDER

How can you differentiate between C3 and C4 pathway?

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Comparison of Light and Dark Reactions

Light Reactions	Dark Reactions
Occur in grana of chloroplast.	Occur in stroma of chloroplast.
Light is required.	Light is not required.
O_2, ATP and $NADPH_2$ are the end products.	In Calvin cycle, ATP and $NADPH_2$ are used to prepare carbohydrates.
Water is used	CO_2 is used

CELLULAR RESPIRATION

- Respiration is the universal process by which organisms breakdown complex compounds containing carbon in a way that allows the cells to harvest a maximum of usable energy.
- ***External respiration*** involves exchange of respiratory gases between the organism and its environment.
- ***Cellular respiration*** is the process by which energy is made available to cells in a step by step breakdown of C-chain molecules in the cell.
- Cellular respiration is an ***oxidation*** process.
- The most common fuel used by the cell to provide energy by cellular respiration is glucose.

AEROBIC & ANAEROBIC RESPIRATION

- The way glucose is metabolized depends on the availability of oxygen.
- First step of cellular respiration (Glycolysis that splits glucose molecule into two molecules of pyruvic acid) is common in aerobic and anaerobic respiration.

$$C_6H_{12}O_6 \xrightarrow{2NAD \rightarrow 2NADH_2} 2C_3H_4O_3 + \text{Energy}$$

- The next step in cellular respiration varies depending on the type of cell and prevailing conditions.
- Cell processes pyruvic acid in three major ways:

(i) Alcoholic fermentation
(ii) Lactic acid fermentation
(iii) Aerobic respiration

Feature	Aerobic Respiration (Oxygen)	Anaerobic Respiration (Anti Oxygen)
Involvement of Oxygen	Occurs in presence of O_2	Occurs in absence of O_2
Reactants	Glucose & O_2	Glucose
Glucose Breakdown	Involves complete breakdown of glucose	Involves incomplete breakdown of glucose
End Products	CO_2, H_2O and energy	Lactic acid or Ethyl alcohol & CO_2
ATP Formed	Total: 40 ATP Net: 36 or 38 ATP	Total: 4 ATP Net: 2 ATP
Energy of Glucose Released	98%	2%
Location in Eukaryotic Cell	Mitochondria	Cytoplasm

ANAEROBIC RESPIRATION

(i) Alcoholic Fermentation

- It occurs in primitive cells and in some eukaryotic cells such as yeast.

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Pyruvic acid is broken into ethyl alcohol and CO_2

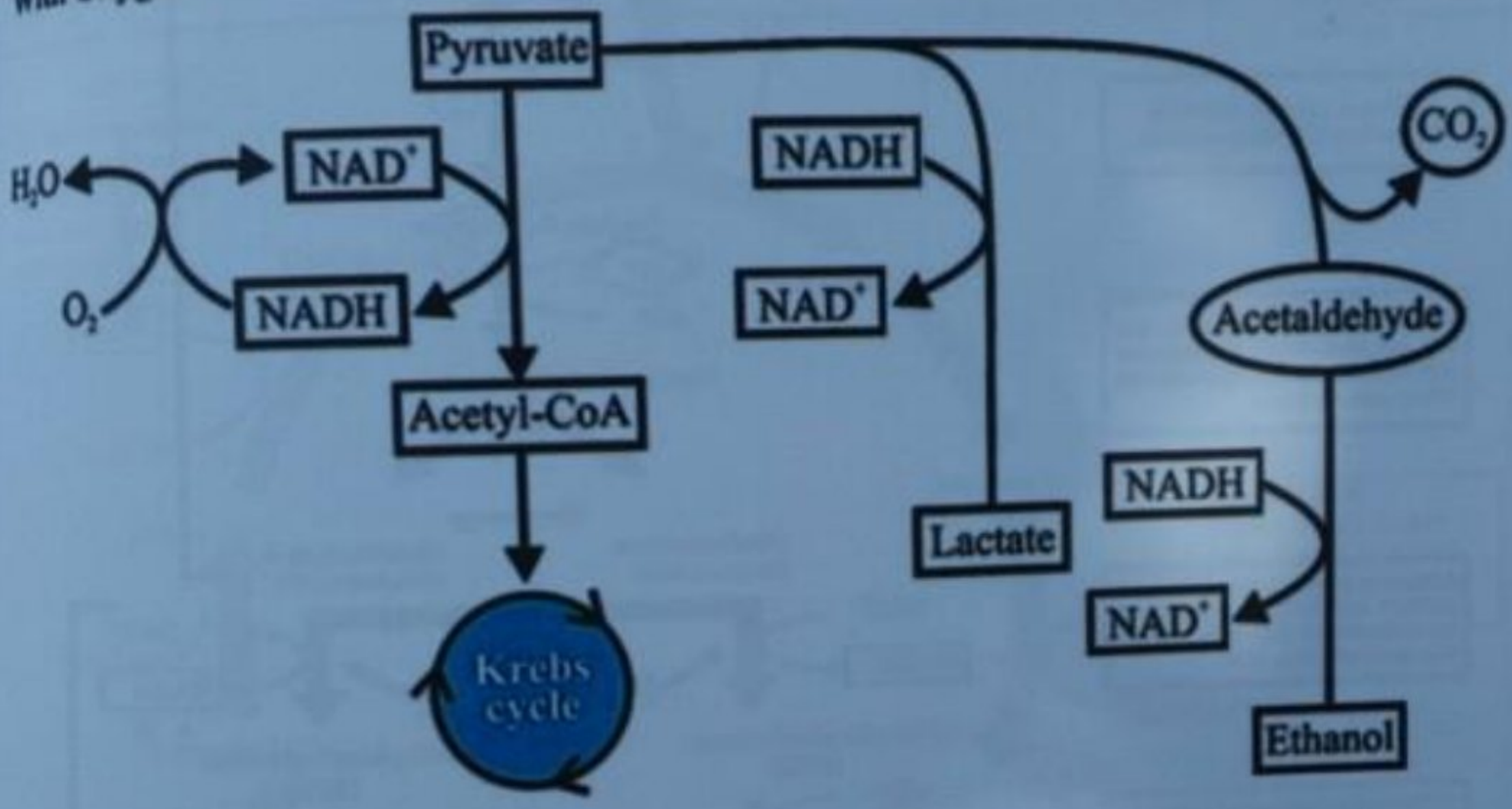
$$2(C_3H_4O_3) \xrightarrow{2NADH_2 \;\; 2NAD} 2(C_2H_5OH)+2CO_2$$

(ii) Lactic Acid Fermentation

It occurs in muscle cells of humans and other animals during extreme physical activities such as sprinting.

Pyruvic acid is metabolized in lactic acid.

$$2(C_3H_4O_3) \xrightarrow{2NADH_2 \;\; 2NAD} 2(C_3H_6O_3)$$



AEROBIC RESPIRATION

Aerobic respiration may be subdivided into four stages:

(i) Glycolysis
(ii) Pyruvic acid oxidation
(iii) Krebs cycle or citric acid cycle.
(iv) Respiratory chain.

GLYCOLYSIS

- Glycolysis is the breakdown of glucose upto the formation of pyruvic acid.
- It occurs in ***cytoplasm***.
- It takes place in the absence (***Anaerobic)*** or in the presence of O_2 (***Aerobic*** conditions).
- Enzymes, ATP, and Coenzyme NAD (nicotinamide adenine dinucleotide) are essential for glycolysis.

Phases of Glycolysis

- There are ***two phases*** of glycolysis i.e. preparatory phase and oxidative phase.
- ***Preparatory phase*** involves the conversion of glucose into one molecule of G3P and one molecule of DHAP. It utilizes two molecules of ATP.
- ***Oxidative or pay off phase*** involves conversion of G3P into pyruvate alongwith formation of 4 ATP and 2 NADH molecules.

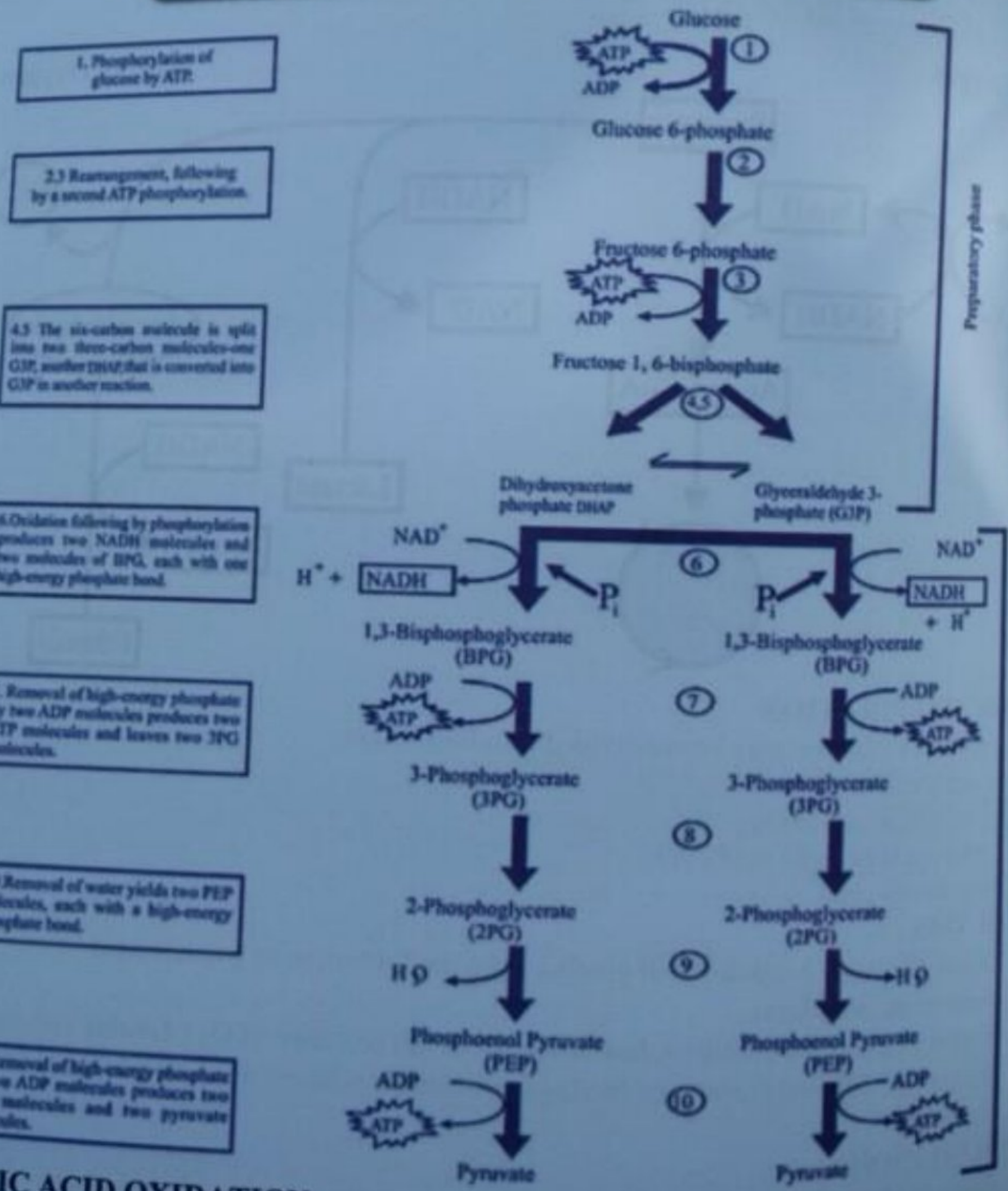
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End Products

- Total consumption of ATP during glycolysis is 2ATP.
- Total production of ATP during glycolysis is 4ATP molecules.
- Net production of energy during glycolysis is 2ATP molecules.

POINT TO PONDER

What is the role of following in Glycolysis:
(a) Decarboxylase (b) Glucokinase (c) Phosphofructokinase



PYRUVIC ACID OXIDATION

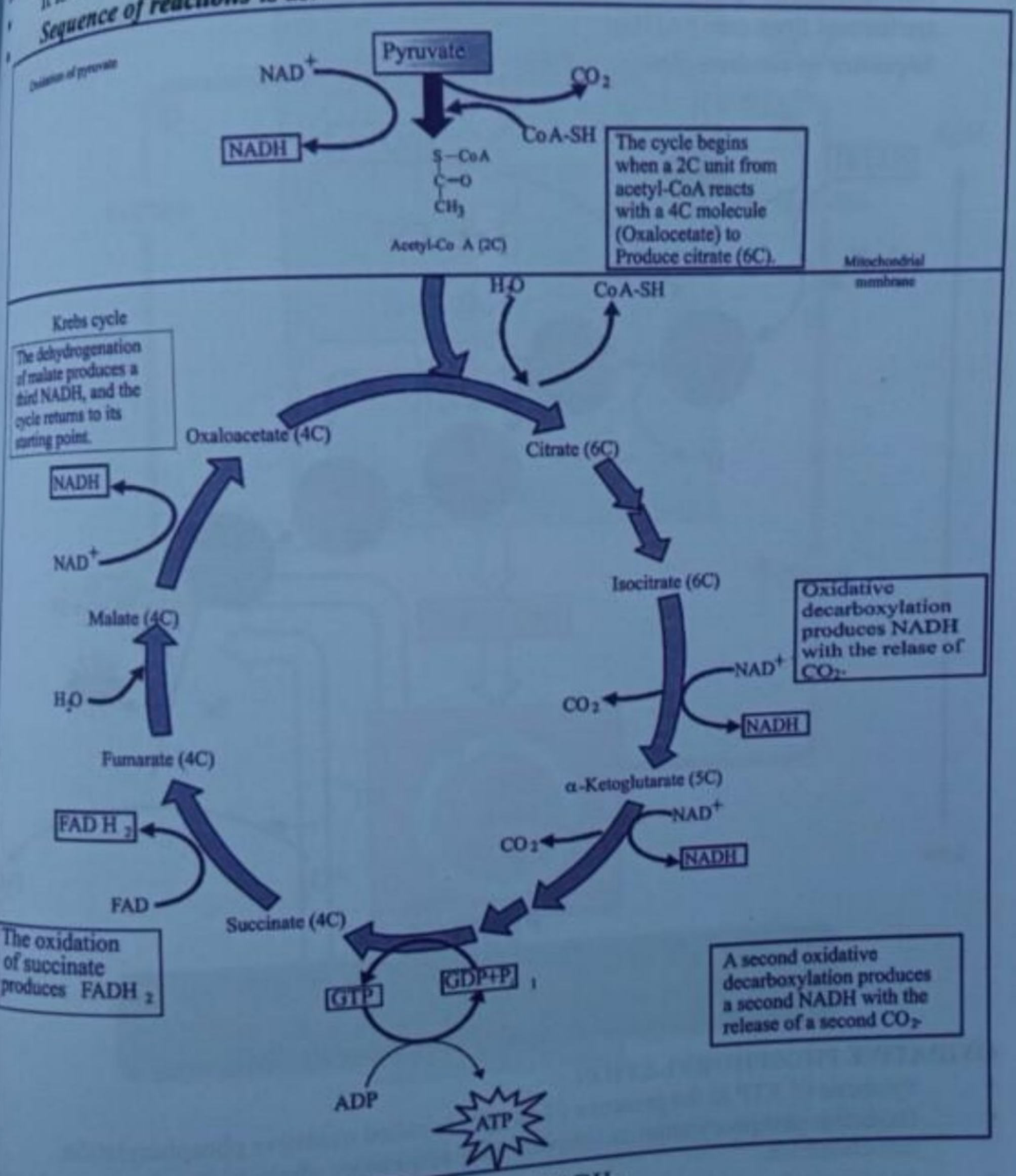
- This is also called as link reaction.
- Pyruvic acid does not enter Krebs cycle directly. It is decarboxylated and oxidized into acetic acid (2C).

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- Acetic acid on entering the mitochondrion unites with coenzyme-A (CoA) to form acetyl CoA (active acetate).

KREBS CYCLE

- It is also called ***citric acid cycle*** or Tricarboxylic acid (TCA) cycle.
- ***Sequence of reactions*** is as:



- One Krebs cycle yields 1ATP, 3NADH and 1$FADH_2$.

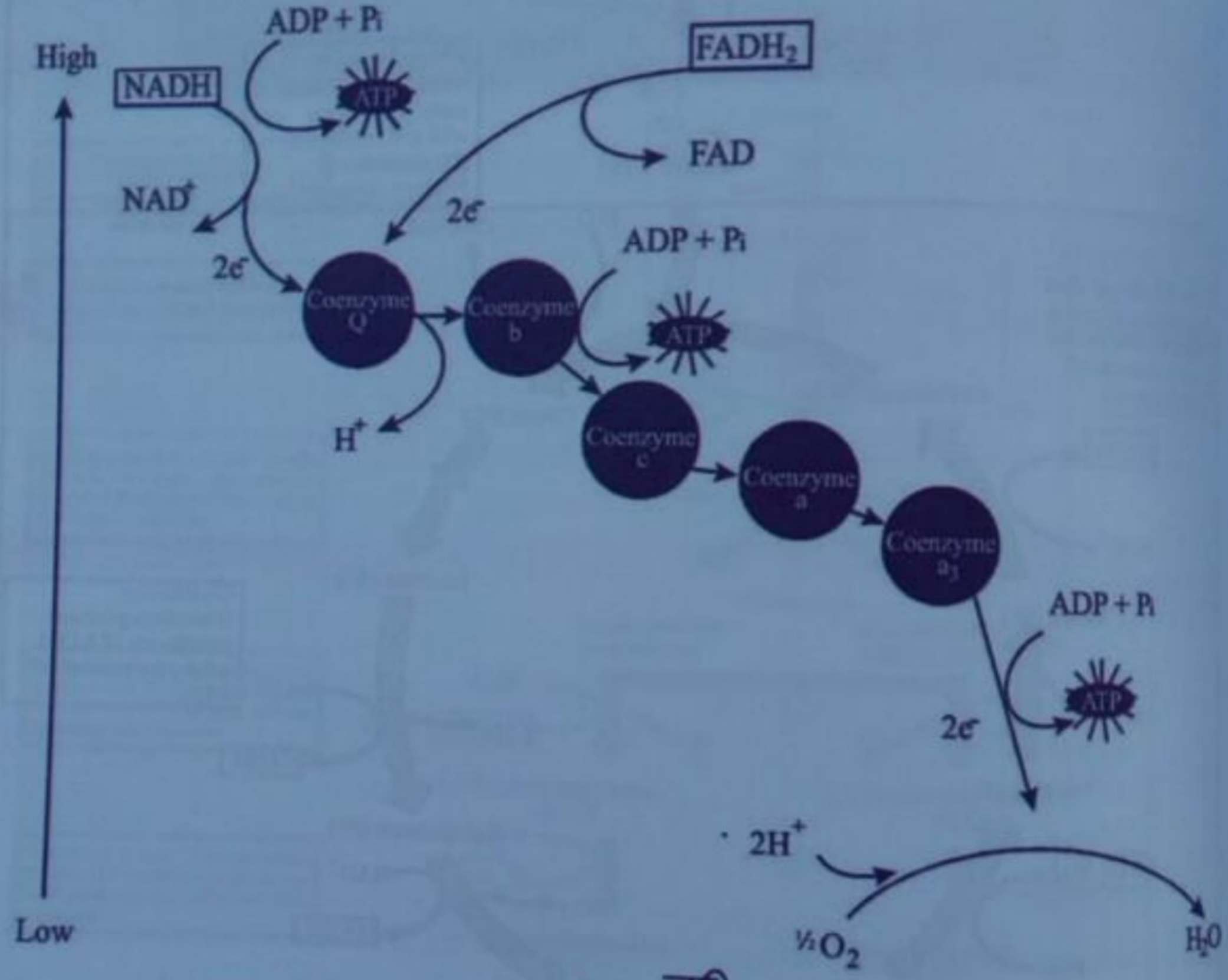
POINT PONDER

How the movement of H^+ occurs in chemiosmosis?

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ELECTRON TRANSPORT CHAIN

- A system where electrons are transported in a series of oxidation-reduction steps to react ultimately, with molecular oxygen is called ***electron transport system or respiratory chain***.
- Synthesis of ATP in the presence of O_2 is called ***oxidative phosphorylation***.
- During ***oxidative phosphorylation,*** 3 ATPs are formed from one NADH and two ATPs are formed from one $FADH_2$.
- ***Sequence of electron flow*** is as follows:



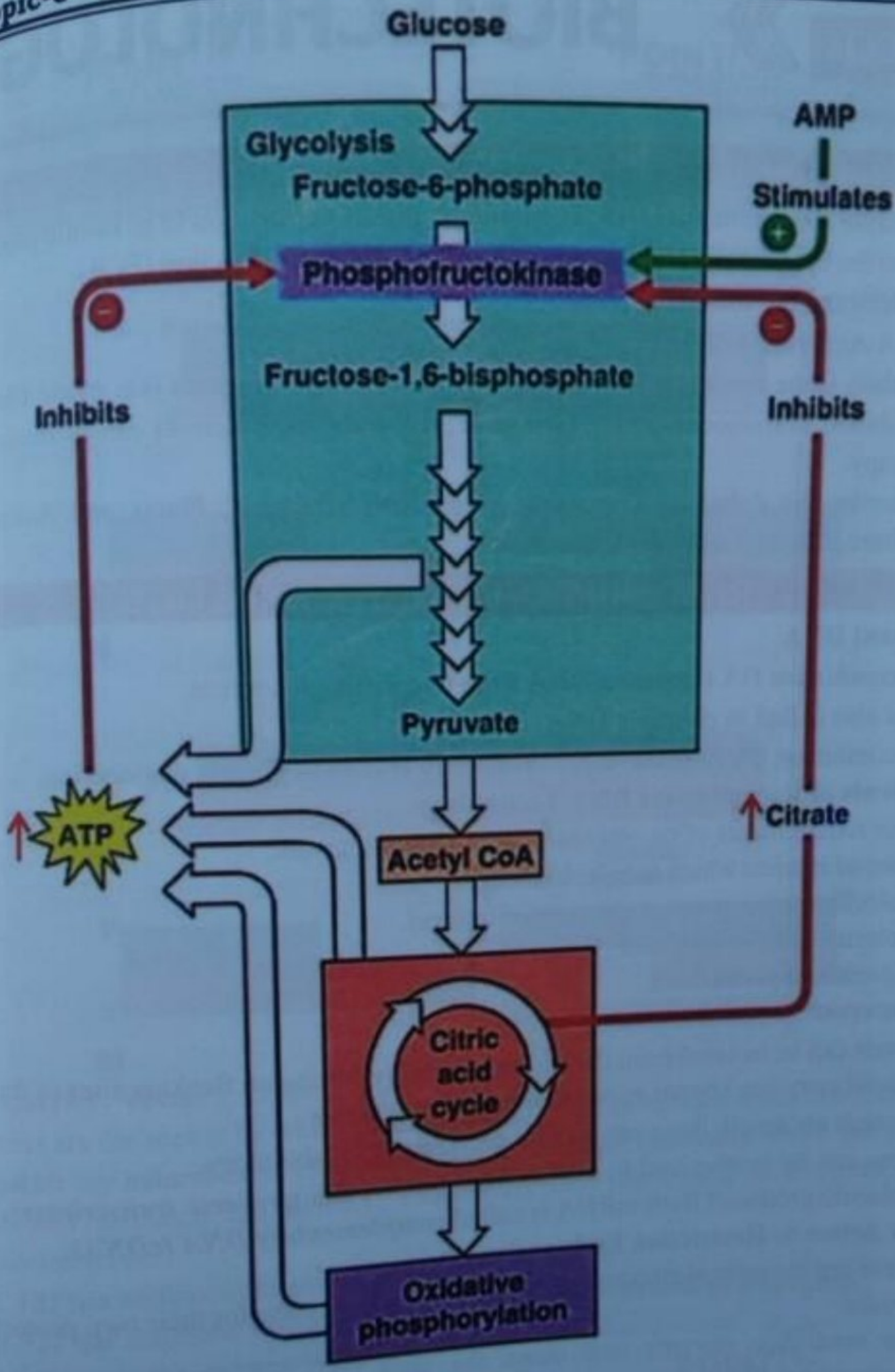
POINT PONDER 70

Is there any difference between number of ATPs produced by aerobic respiration of glucose in eukaryotes & prokaryotes?

OXIDATIVE PHOSPHORYLATION

- Synthesis of ATP in the presence of oxygen is called oxidative phosphorylation.
- Oxidative phosphorylation is coupled with respiratory chain in the inner membrane of mitochondrion.
- As compared to photosynthesis, here pumping of protons (H^+) is across the inner membrane of mitochondrion folded into cristae, between matrix of mitochondrion and mitochondrion's intermembrane space.

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TOPIC-7
05 MCQs

BIOTECHNOLOGY

LEARNING OUTCOMES

(1) Describe Recombinant DNA Technology and its application (e.g. Insulin production).
(2) Describe the principle and steps of Polymerase Chain Reaction (PCR).
(3) Understand the following terms:
DNA Analysis (Finger Printing, Gene Sequencing).
(4) Explain Gene therapy with reference to how genetic diseases (i.e. cystic fibrosis, severe combined immunodeficiency syndrome, hypercholesterolemia) can be treated with gene therapy.
(5) Describe the detail of Transgenic Organisms (Bacteria, Plants and Animals), Tissue Culture, Cloning and their applications.

RECOMBINANT DNA TECHNOLOGY

Recombinant DNA

- ***Recombinant DNA*** contains DNA from two different sources.
- It is also called as chimeric DNA.
- Recombinant DNA technology is popularly known as genetic engineering.

Requirements of Recombinant DNA Technology

Four requirements of recombinant DNA technology are:
(i) Gene of interest which is to be cloned.
(ii) Molecular scissors to cut out gene of interest.
(iii) Molecular carrier or vector
(iv) Expression system

Gene of Interest

- Genes can be isolated from the chromosomes by cutting on flanking sites of the gene using special enzymes known as ***restriction endonucleases***.
- If genes are small, these can also be synthesized in laboratory.
- Gene can be synthesized in the lab from mRNA using ***reverse transcriptase***. Such DNA molecule produced from mRNA is called ***complementary DNA (cDNA)***.

Molecular Scissors: Restriction Endonucleases

- These are the natural enzymes of bacteria, which they use for their own protection against viruses.
- The restriction enzyme cuts down the viral DNA but does not harm to bacterial chromosome. Thus, they restrict viral growth.
- First ***restriction enzyme*** was isolated by Hamilton O. Smith in 1970.
- **400** restriction enzymes are discovered, **20** are commonly used.
- ***Palindromic sequences*** are sequences of four or six nucleotides arranged symmetrically in the reverse order produced by restriction enzymes, which cut the DNA at specific sites.
- *EcoR1* is a commonly used restriction enzyme.
- The single stranded but complementary ends of the two DNA molecules are called *sticky ends*.

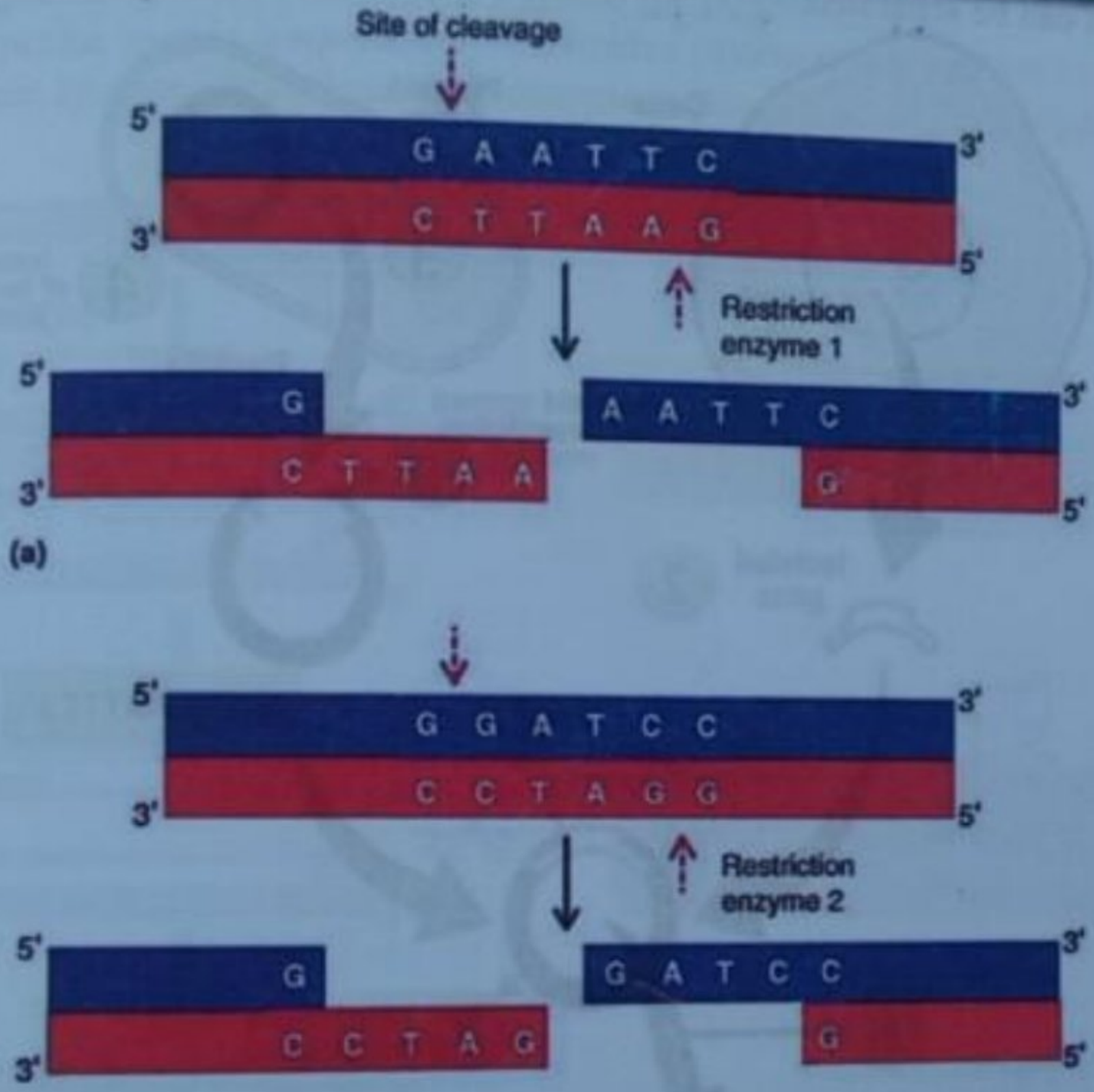
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POINT TO PONDER

Why restriction endonuclease does not act on bacterial DNA?

POINT TO PONDER

Can you differentiate between endonuclease and exonuclease?



Molecular Carrier: Vector

- Vectors are the means by which recombinant DNA is introduced into a host cell.
- *Plasmids* are natural extra chromosomal circular DNA molecules which carry genes for antibiotic resistance and fertility. These were first discovered in intestinal bacterium *Escherichia coli*.
- *pSC 101* has antibiotic resistance gene for tetracycline.
- *pBR 322* has antibiotic resistance gene for tetracycline as well as ampicillin.
- *DNA ligase* is the enzyme which seals the foreign piece of DNA into the vector.

POINT TO PONDER

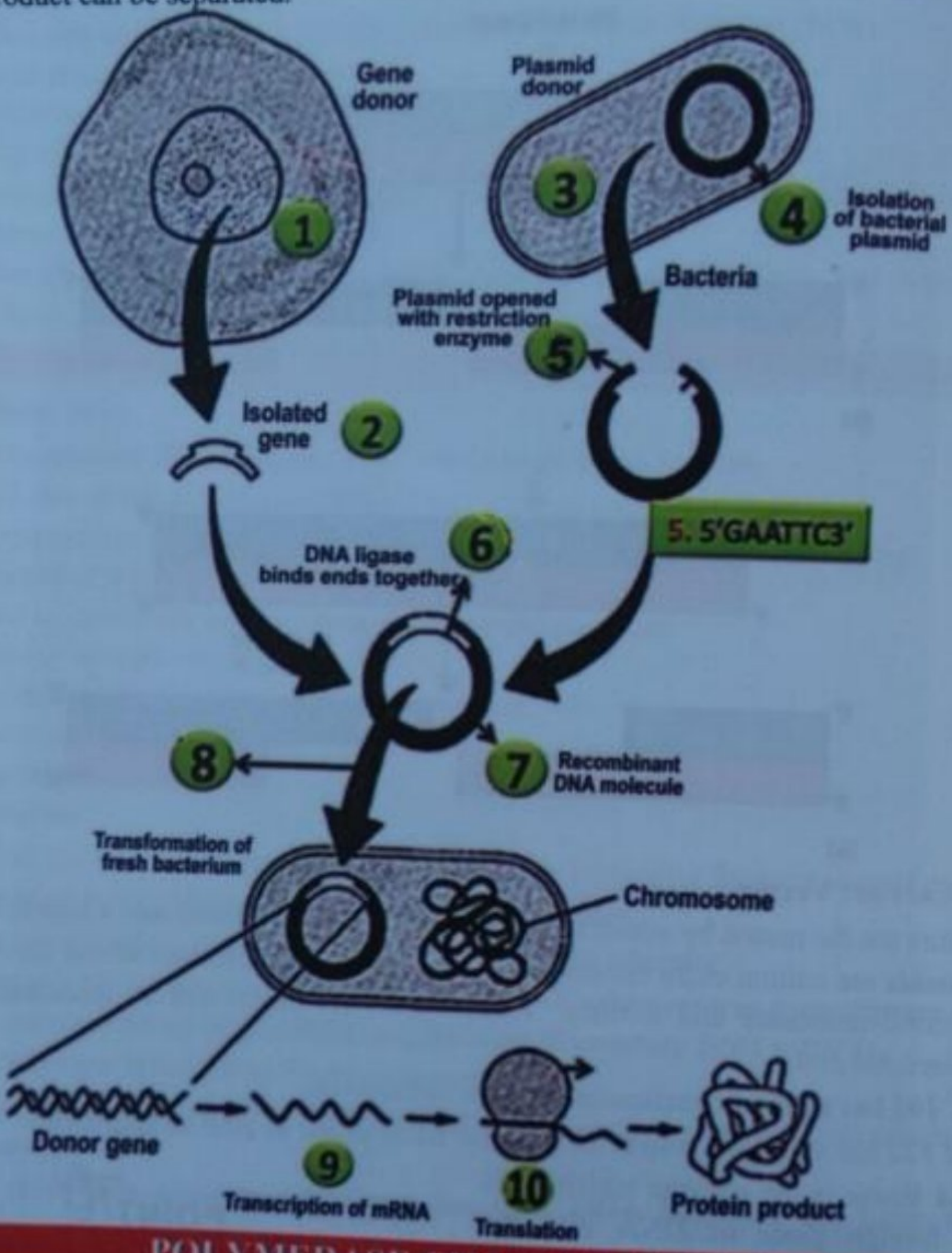
What do you know about:
(a) Conjugation (b) Transduction
(c) Transformation

Expression of the Recombinant DNA

- Bacterial cells take up recombinant plasmid if they are treated with *calcium chloride* to make them more permeable.
- *Lambda phage* (DNA of bacterial viruses) can also be used as a vector.

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- A clone can be a large number of molecules or cells or organisms that are identical to an original specimen.
- Bacterial cells after taking recombinant DNA are cloned. Each clone contains gene of interest which will express itself and make a product.
- From this bacterial clone, the cloned gene can be isolated for further analysis or protein product can be separated.



POLYMERASE CHAIN REACTION

- ***Polymerase chain reaction*** (PCR) was developed by Kary B. Mullis in 1983.
- ***PCR*** takes its name from DNA polymerase, the enzyme that carries out DNA replication process in cell.
- PCR is done in automatic PCR machine or thermocycler.
- PCR can create millions of copies of a single gene or any specific piece of DNA quickly in a test tube.

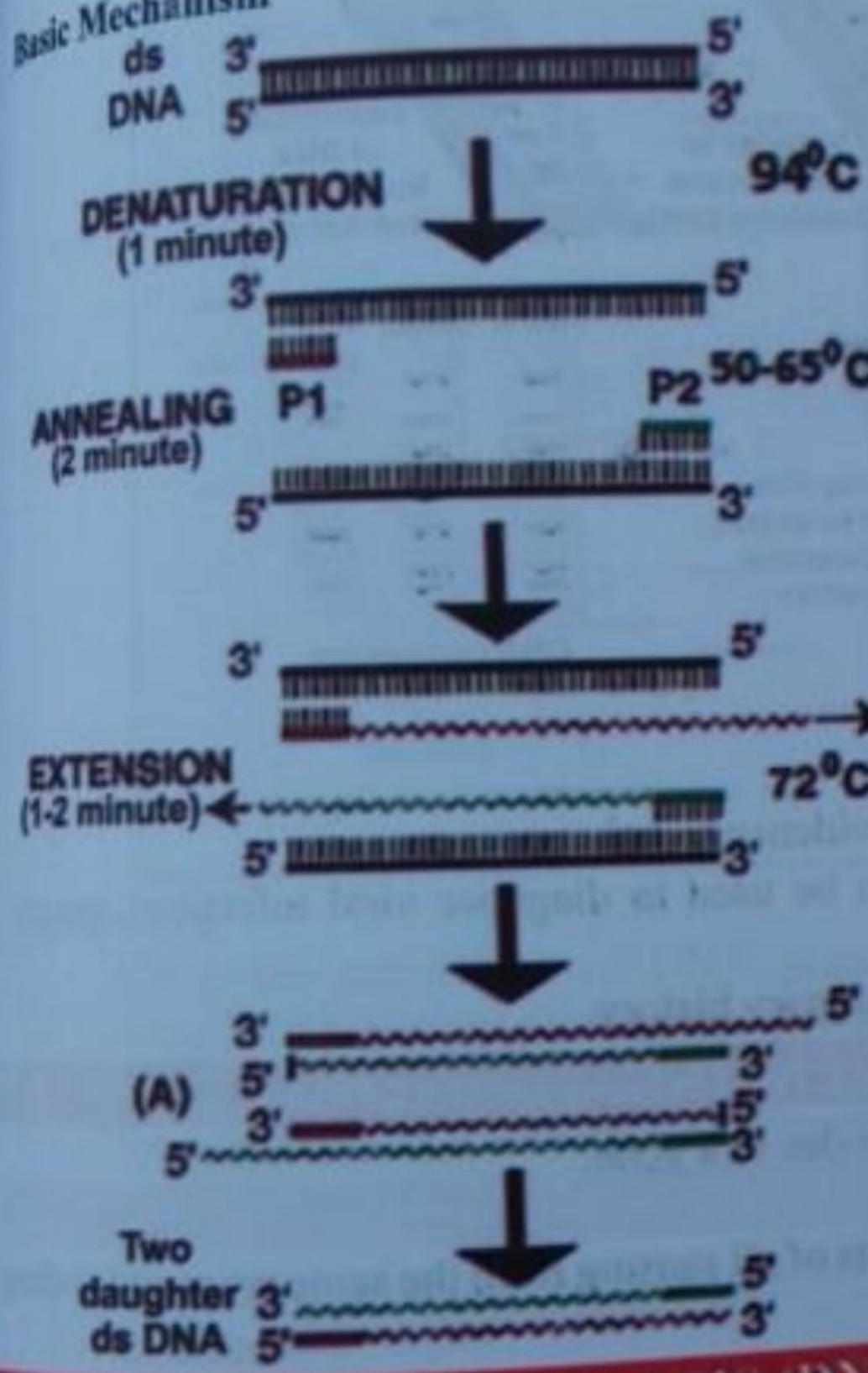
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PCR is very specific, the targeted DNA sequence can be less than one part in a million of the total DNA sample.

Main Requirements of PCR

- ***Primers*** are the sequences of about 20 bases that are complementary to the bases on either side of the target DNA. Primers are needed because DNA polymerase does not start the replication process; it only continues or extends the process.
- DNA polymerase used is ***temperature–insensitive*** (thermostable) enzyme extracted from the bacterium ***Thermus aquaticus***. This enzyme is also known as ***Taq polymerase***.

Basic Mechanism



POINT TO PONDER

What are the requirements for PCR?

POINT TO PONDER

Can you differentiate between primer used in PCR and DNA replication?

POINT TO PONDER

How the probe is used in search of certain gene in genomic library?

DNA ANALYSIS (DNA FINGERPRINTING)

It is a process by which entire genome of an individual can be analyzed.

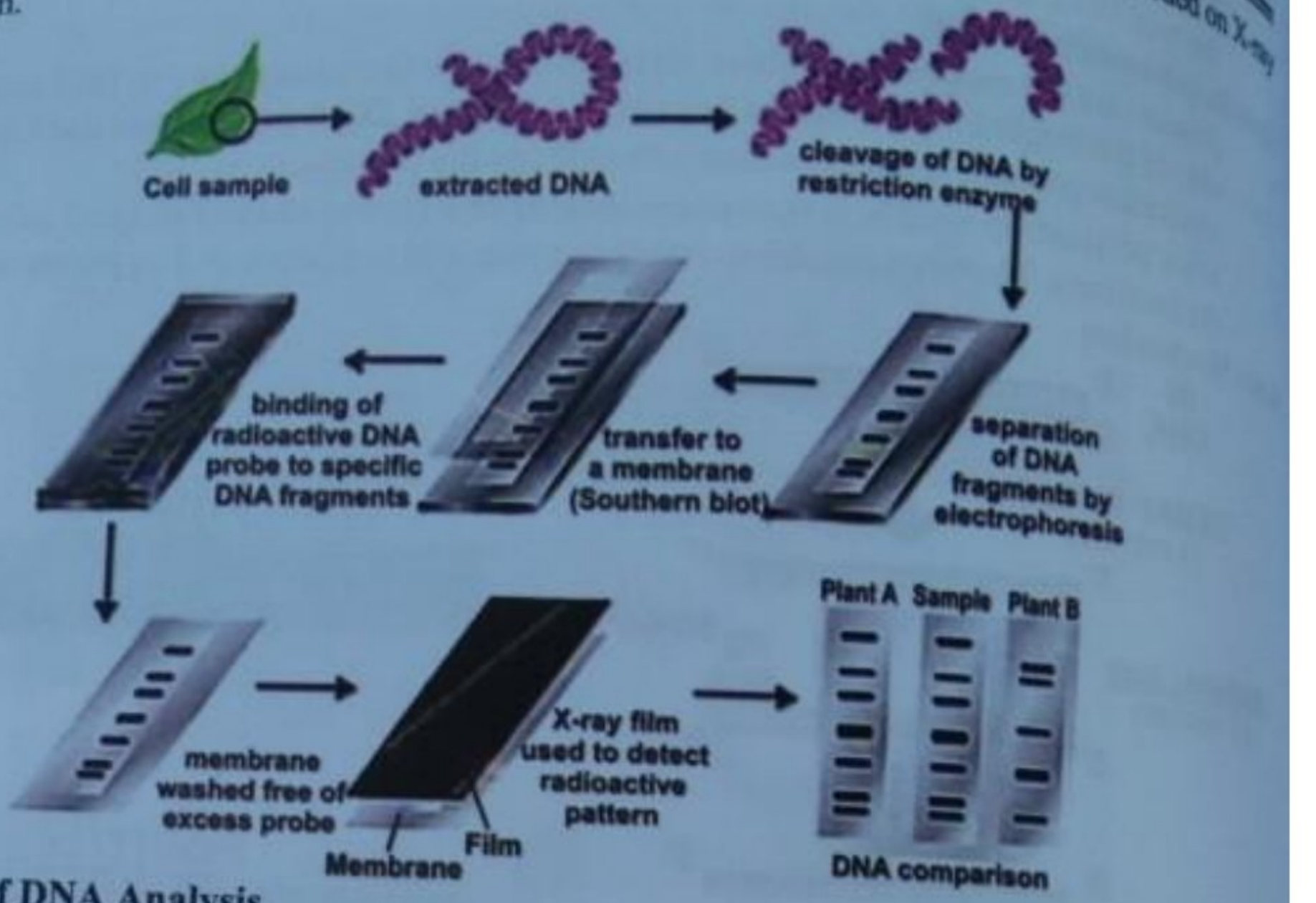
Basic Mechanism

Different steps involved in DNA analysis are as follows:

- The genome is treated with restriction enzymes, which results in a unique collection of different sized fragments. These fragments vary in length and restriction enzyme separates according to this length, which is different in different individuals. This process of existing in different lengths is called restriction fragment length polymorphism (RFLPs).
- Fragments of genome can be separated according to their lengths through a process called gel electrophoresis.
- It results in formation of a number of bands that are so close together that they appear as a smear.

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- Use of probes for genetic markers produces a distinctive pattern that can be recorded on X-ray film.



Importance of DNA Analysis

- It can be used to solve disputes of paternity.
- It is important in forensic laboratories as evidence to solve crimes.
- PCR amplification and DNA analysis can be used to diagnose viral infections, genetic disorders and cancer.
- These can also be used to determine evolutionary history.

GENE SEQUENCING

It is a technique to find sequence of nucleotides in a gene.

Main Principles of Method

- Generation of different sized DNA fragments of all starting from the same point and ending at different points.
- Separation of these different pieces of DNA on agarose gel.
- Reading of sequence from the gel.

Methods to Generate Pieces of DNA

For generation of different sized DNA fragment, two methods are generally used.

1) ***Sanger's method*** in which dideoxyribonucleoside triphosphates are used to terminate DNA synthesis at different sites.
2) ***Maxam-Gilbert method*** in which DNA threads are chemically cut into pieces of different sizes.

Separation and Reading of Gene Sequence

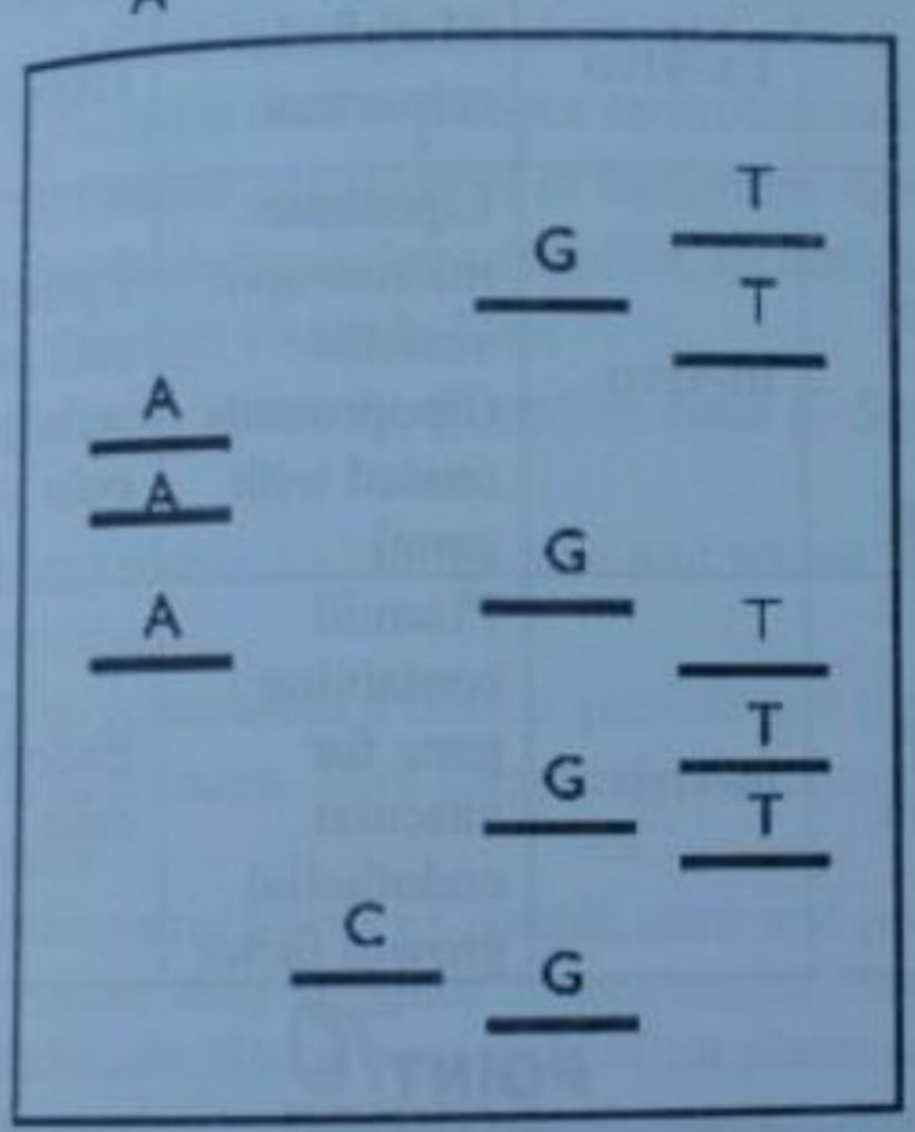
DNA sequence is now completely automated, robotic devices mix the reagents and then load, run and read the order of nucleotide bases from the gel.

SANGER'S METHOD

- It is also called as enzymatic or dideoxy method.

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- Chain terminating nucleotides labelled with different coloured fluorescent dyes are used.
- All four synthesis reactions are performed in same tube and products are separated in a single lane of a gel.
- A detector (positioned near the bottom of the gel) reads and records the colour of fluorescent label on each band as it passes through a laser beam.
- A computer then reads and stores this nucleotide sequence.



Deduced Sequence	Fragment Size
G	19
C	20
T	21
G	22
T	23
T	24
A	25
G	26
A	27
A	28
T	29
G	30
T	31

Significance

Using this automation of DNA sequencing, genomes of many organisms have been sequenced e.g. plant chloroplast, animal mitochondria, bacteria, yeast, a nematode worm, *Drosophila*, model plant *Arabidopsis*, mouse and human. Researchers have also deduced the complete DNA sequence of a variety of human pathogens.

GENE THERAPY

- ***Gene therapy*** is the insertion of genetic material into human cells for the treatment of a disorder.
- There are two main methods for gene therapy i.e. ***Ex-vivo & In-vivo.***
- Gene therapy for cancer patients makes cancer cells more vulnerable to chemotherapy and normal cells more resistant to chemotherapy.
- During coronary artery angioplasty, a balloon catheter is sometimes used to open up a closed artery.
- It will be possible to use in-vivo therapy to cure hemophilia, diabetes, Parkinson's disease or AIDS.
- To treat hemophilia, patients could get regular doses of cells that contain normal clotting factor genes or such cells could be placed in organoids, artificial organs that can be implanted in the abdominal cavity.
- To cure Parkinson's disease, dopamine-producing cells could be grafted directly into the brain.

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Disease	Cause	Defect	Method	Vectors	Target Cells
SCID	ADA Deficiency	Immune deficiency, life threatening infections	Ex-vivo	Modified retrovirus	Bone marrow stem cells
Familial Hypercholesterolemia	Lack of receptor on liver cells for cholesterol	Fatal heart attacks	Ex-vivo	Modified retrovirus	Liver cells
Cystic Fibrosis	Trans-membrane carrier of Cl^-	Numerous infections of respiratory tract, thick mucus plug	In-vivo	Liposome-microscopic vesicles (lipoproteins coated with gene)	Epithelial cell/ mucous cells/ goblet cells
Heart Attack	Blockage of coronary artery	Necrosis of myocardium	In-vivo	Plasmid containing gene for vascular endothelial growth factor	Endothelial cells

POINT TO PONDER

What may be other options to treat coronary artery blockage?

POINT TO PONDER

What is difference between angioplasty and angiography?

TRANSGENIC ORGANISMS

Organisms that have any foreign gene inserted in them are called **transgenic organisms**.

TRANSGENIC BACTERIA

Bacteria having foreign gene are called **transgenic bacteria.**

Methods of Production & Propagation

- Recombinant DNA technology is used to produce bacteria that reproduce in large vats called **bioreactors**.

Significance

- These are used to get various biotechnology product for human use.
- Biotechnology is used to convert frost-plus to frost-minus bacteria.
- These are used to produce insect toxins in plant cells.
- Bacteria can be used in industries as biofilters.
- They are also used in biosynthesis of different chemicals e.g. phenylalanine, chemical needed to make aspartame (the dipeptide sweetner) better known as Nutrasweet.
- These bacteria are used in bioleaching.
- Bacteria are also used in cleaning up beaches after oil spills.

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TRANSGENIC PLANTS

Plants having any foreign gene are called **transgenic plants**.

Methods of Production & Propagation

Insertion of Gene through Current

A foreign **gene** isolated from any type of organism is placed in the tissue culture medium. This tissue culture contains protoplasts. High voltage electric pulses are used to create pores in the plasma membrane so that DNA enters.

Insertion of Gene through Bacterium

A plasmid is used to produce recombinant DNA. This recombinant DNA contains foreign gene. It is inserted into plasmid of bacterium ***Agrobacterium***, which normally infects the plant cells. When bacterium infects the plant, recombinant DNA is introduced into plant cells.

Insertion through Particle Gun

This method was developed by ***John C. Sanford and Theodore M. Klein*** of Cornell University in 1987.

Many plants including corn and wheat varieties have been genetically engineered by this method.

They constructed a device; particle gun that bombards a callus with DNA coated microscopic metal particles. Then genetically altered somatic embryos developed into adult plants.

Significance

- Transgenic forms of cotton, corn and potato have been made which are resistant to pests because they produce insect toxins. Soybeans have been made resistant to a common herbicide. Some corn and cotton plants are both pest and herbicide resistant.
- A weed called mouse-eared cress has been engineered to produce a ***biodegradable plastic (polyhydroxy butyrate)*** in cell granules.
- Plants are being engineered to produce human ***hormones, clotting factors*** and ***antibodies*** in their seeds. One type of antibody made by corn can deliver radioisotopes to tumor cells. Antibody produced by soybean can be used as treatment for genital herpes. Plant made antibodies are inexpensive and have little chances of contamination.
- Improvements are going in improving quality of food.

TRANSGENIC ANIMALS

Animals containing foreign DNA in their cells are called transgenic animals.

Methods of Production & Propagation

- Transgenic animals have been developed by inserting genes into the eggs of animals
- In order to get transgenic animals, ***two methods*** are used i.e. ***microinjection*** (by hand) and ***vortex mixing method***, by inserting gene into egg.
- In Vortex method the eggs are placed in an agitator with DNA and silicon-carbide needles. The needles make tiny holes through which the DNA can enter.

Significance

- ***Gene pharming*** is the use of transgenic farm animals to produce pharmaceuticals.
- Genetic engineering is done to improve quality and quantity of food obtained from animals.
- ***Urine is a preferable vehicle*** for a biotechnology product than milk because;

(1) All animals in herd urinate while only females produce milk.
(2) Animals start to urinate at birth while female do not produce milk until maturity.
(3) It is easier to extract proteins from urine than from milk.

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POINT TO PONDER

Name three human organs which show regeneration?

POINT TO PONDER

What is role of antithrombin III in surgery?

CLONING OF TRANSGENIC ANIMALS AND ITS APPLICATION

- Cloning is form of asexual reproduction and is most preferable method for getting identical copies of animals.
- Cloning of an adult vertebrate requires that all genes of an adult cells be turned on again if development is to proceed normally. It had long been thought that it is impossible.
- In 1997, scientists at Roslin Institute in Scotland produced a cloned sheep called Dolly. Since then calves and goats have been cloned.
- Different steps involved are:
  - 2n nuclei from cumulus cells (those that cling to an egg after ovulation process occurs) were taken and introduced in enucleated egg.
  - A specially prepared chemical bath was used to stimulate the eggs to divide and begin development.

TISSUE CULTURE AND ITS APPLICATIONS

- Tissue culture is the growth of a tissue in an artificial liquid culture medium, also called micropropagation.
- German botanist ***Gottlieb Haberlandt*** in 1902 said that, plant cells are totipotent.
- Cornell botanist ***F. C. Steward*** in 1958 first time grew a complete carrot plant from a tiny piece of phloem.
- Tissue culture techniques are used to produce millions of identical seedlings in a limited amount of space. Common methods used in this are following:

MERISTEM CULTURE

- In this method, meristematic cells are used.
- Meristem is virus free portion of plant.

Procedure

- Different steps involved are:

(i) A small piece of tissue, usually mesophyll tissue from a leaf, is taken and enzymes are added to digest cell wall and convert it into protoplast.

(ii) Protoplasts regenerate a new cell wall and begin to divide due to presence of auxins and cytokinins in liquid medium.

(iii) Clumps of cells are manipulated to produce somatic embryos. These somatic embryos (sometimes called artificial seeds) are encapsulated in a protective hydrated gel. Somatic embryos of tomato, celery, asparagus, lilies, begonias and African violets can be produced in millions in large tanks called bioreactors.

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(iv) A mature plant develops from each somatic embryo. Plants generated from somatic embryo vary somewhat because of mutations that arise during the production process. These are called ***somaclonal variations***.

ANTHER CULTURE

- It is a technique in which mature anthers are cultured in a medium containing vitamins and growth regulators.
- It is useful in plants that express **recessive alleles.**

Procedure

- Different steps involved are:

(i) Haploid tube cells within pollen grain divide, producing pro-embryos consisting of as many as 20-40 cells.

(ii) Pollen grains rupture releasing haploid embryos.

(iii) Haploid plant can be generated or chemical agents are added that encourages chromosomal doubling

(iv) After chromosomal doubling, resulting plants are diploid but homozygous for all their alleles.

CELL SUSPENSION CULTURE

- This technique is used to get biotechnology products within culture medium.
- It will no longer be necessary to farm plants for the purpose of acquiring the chemicals they produce.
- Cell suspension cultures of *Cinchona ledgeriana* produce quinine and *Digitalis lanata* produce digitoxin.

Procedure

- Different steps involved are:

(i) Rapidly growing cultures are cut into small pieces and shaken in a liquid nutrient medium so that single cell or small clumps of cells break off and form a suspension.

(ii) These cells produce the same chemicals as the entire plant.

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TOPIC-8
02 MCQs

ECOSYSTEM

LEARNING OUTCOMES

(1) Define succession and describe various stages of xerosere.

(2) Describe the significance of human activity on ecosystem such as Population, Deforestation, Ozone Depletion, Greenhouse Effect, Acid rain, Eutrophication and Pesticides.

(3) Describe Nitrogen cycle (ammonification, nitrification, assimilation, depletion).

(4) Define and explain Energy Flow, Trophic Levels (producers, consumers, decomposers), Productivity, Food chain, Food web.

SUCCESSION & ITS STAGES

- ***Succession*** is a change in community structure and its non-living environment over a period of time.

  Succession is a sequence of events in community structure of ecosystem over period of time.
- It is also called as community relay.
- Succession begins by a few hardy invaders called ***pioneers***.
- Diverse and relatively stable community at the end of succession is called ***climax community***.
- All the communities during succession are called as ***seral communities***.

Types of Succession

- Succession on dry land takes two major forms, primary succession and secondary succession.

Feature	Primary Succession	Secondary Succession
Definition	Such a succession where an ecosystem is forged from bare rock, sand or clear glacial pool where there is no traces of previous life.	A new ecosystem develops after an existing ecosystem is disturbed as in case of forced fire or an abandoned farm field.
Duration	As it is from scratch, so often requires thousands of years.	Due to previous community, it happens much more rapidly.

Primary Succession

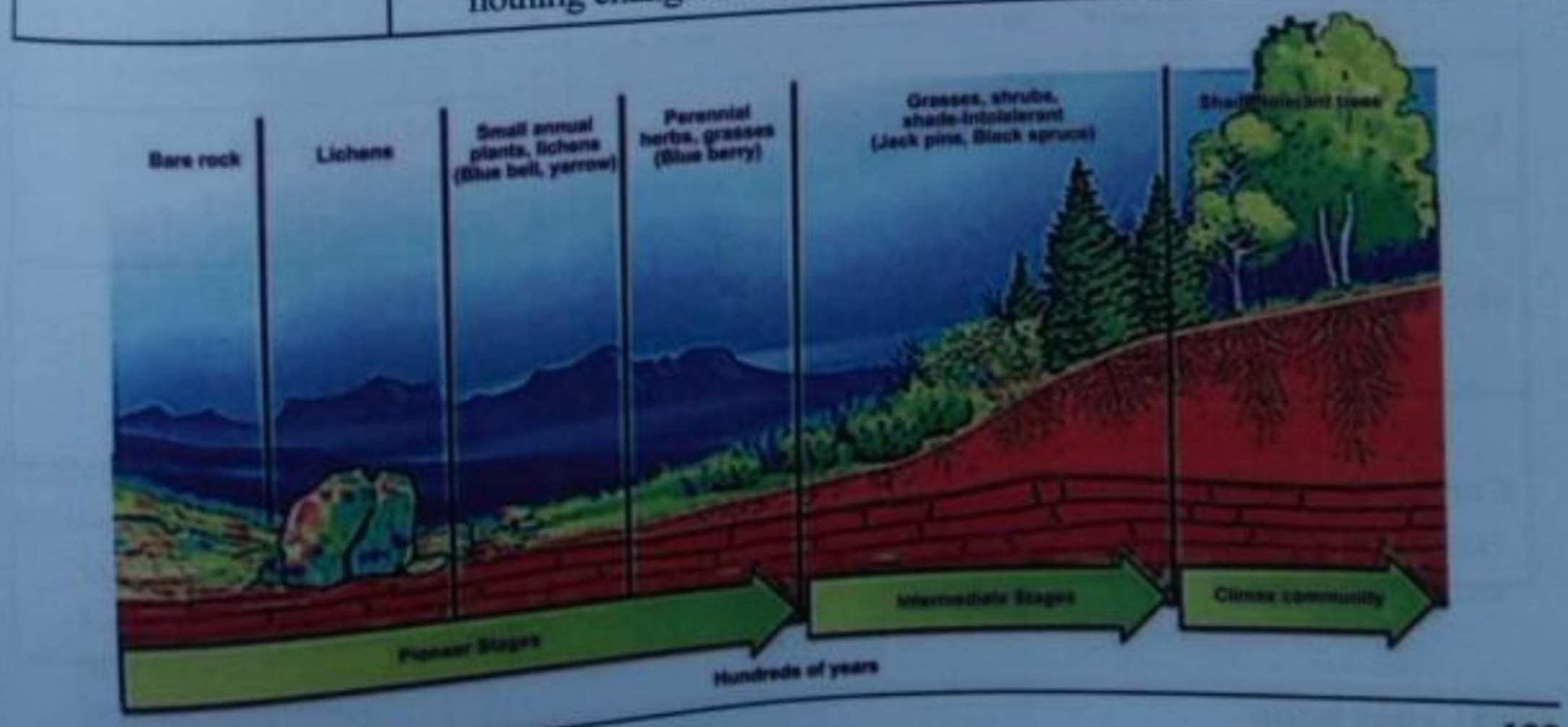
- Primary succession starting in a pond is called ***hydrosere.***
- Primary succession on a dry soil or habitat is called ***xerosere.***

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- Plants growing in xeric conditions are called ***xerophytes***, which are able to withstand prolonged periods of droughts.
- Succulent plants like cacti have water stored in large parenchyma tissue.

Stages of Xerosere

Stage	Details
Crustose lichen stage	• Crustose means crust on the substratum. • Crustose lichen can live in extreme conditions. • They absorb water during dry season. • They are quiescent or dormant, normally desiccated during dry season. e.g. *Bacidia* and *Lecanora*.
Foliage lichen stage	• Lichens are just like crumpled leaves attached at one point. • Produces shade to the crustose lichens as a result of which their growth is reduced or decreased. • Area becomes rough with more fissure and depressions develop. • Examples are *Dermatocarpon, Permellia*
Moss stage	• Examples of mosses are *Polytrichum, Tortula* etc. • They compete with lichens for water and penetrate deeper into the soil add more humus to the soil.
Herbaceous stage	• Small seedlings establish due to more availability of moisture, humus, soil for anchorage.
Shrub stage	• Shrubby plants start growing and shadowing herbaceous plants which die and add more humus to the soil.
Climax forests	• Woody plants develop due to improved soil. • They dominate and this stage in succession remains essentially same if nothing changes in the environment to upset the balance



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SIGNIFICANCE OF HUMAN ACTIVITY ON ECOSYSTEM

POPULATION

- ***Demography*** is the study of human populations and things that affect them.
- ***Population of Pakistan*** was 32.5 million in 1947. It has now increased to around 150-160 million in year 2000.
- About 20 years ago, human population was increasing at rate of 2% and was doubling every 35 years.

DEFORESTATION

- Clearance of vast areas of forest for procuring lumber, planting subsistence crops or grazing cattle is called ***deforestation***.
- The destruction of forests leaves the soil barren and it is called deforestation leading to ***desertification.***
- ***Reforestation*** is replantation of plants in the areas where they were present earlier.
- In reforestation coniferous species are important which often require bare soil to establish.
- ***Aforestation*** is establishment of new forests where no forests existed previously.
- Forests are called as ***environmental buffers*** because they break speed of wind, rain and floods.
- About half of the rain, which falls, in tropical forests comes from transpiration of these plants
- ***Biodiversity*** is total number of different species within an ecosystem and the resulting complexity of interactions among them.

ATMOSPHERIC POLLUTION

- The befouling of the air by anything that may be harmful to living organisms is air pollution.
- These harmful substances are called pollutants.

Air Pollutant	Sources	Harmful Effects
Chlorofluorocarbons	• Aerosol spray foams • Air conditioning system • Refrigerants	• Thinning of ozone layer • Greenhouse effect • Global warming
Sulphur dioxide	• Power station • Fossil fuel	• Acid rains • Breathing disorders • Lung cancer
Lead compounds	Combustion of leaded petrol or oils	• Lead poisoning • Brain damage • Forest decline
Oxides of nitrogen	Burning of fossil fuels	• Global warming • Greenhouse effect • Acid rain • Headache & cough
Carbon monoxide	• Incomplete burning of carbonate & carbon compounds • Cigarette smoke	• Headache • Brain damage • Death

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OZONE LAYER DEPLETION

Ozone

- In pure form ozone is bluish, explosive and highly poisonous gas. Ozone molecule is made up of 3 oxygen atoms (O_3).

Ozone Layer

- Ozone is layer of atmosphere extending from ***10-50 km*** above earth.
- It filters and protects us from UV rays.

Ozone Depletion

- Decline in thickness of ozone layer is called ***ozone depletion***.
- Ozone depletion is caused by increasing *chlorofluorocarbons* **(CFCs)**, which contains chlorine, fluorine and carbon.
- These are produced from air conditioners and refrigerators.
- A single chlorine atom can react with ultraviolet rays and destroys as many as one million ozone molecules.

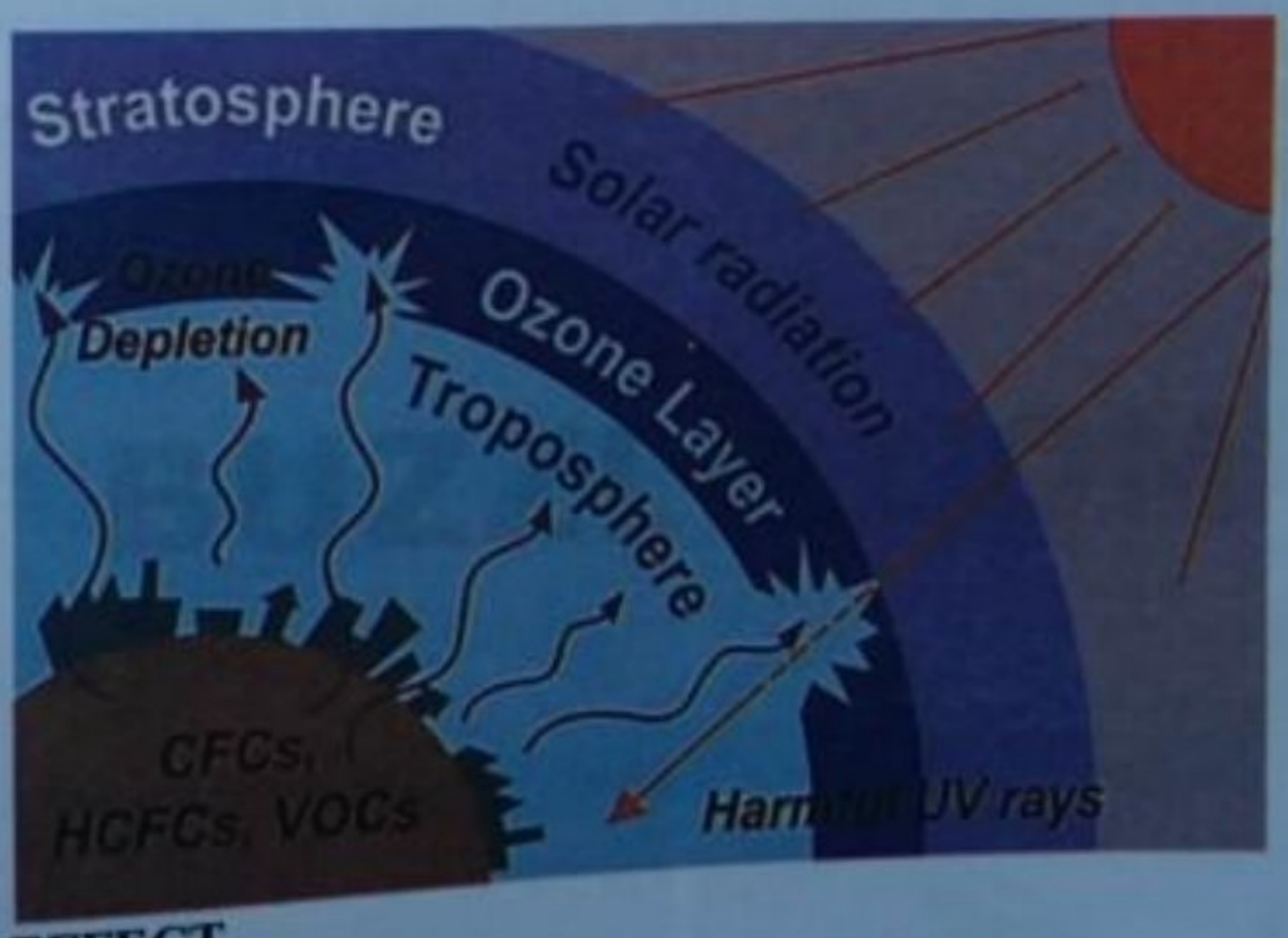
POINT TO PONDER

Why ozone layer depleted in Antractica?

- The level of ozone in the ozone layer over the ***Antarctica*** has fallen drastically and has led to a hole.

Effects of Ozone Depletion

- More ultraviolet rays from the sun are able to reach earth.
- This entry of UV rays is affecting all life on earth by increasing temperature.
- They cause skin cancers and cataract in human.
- They can also affect crops, plants, trees and even marine plankton and distort weather patterns.



GREENHOUSE EFFECT

Greenhouse

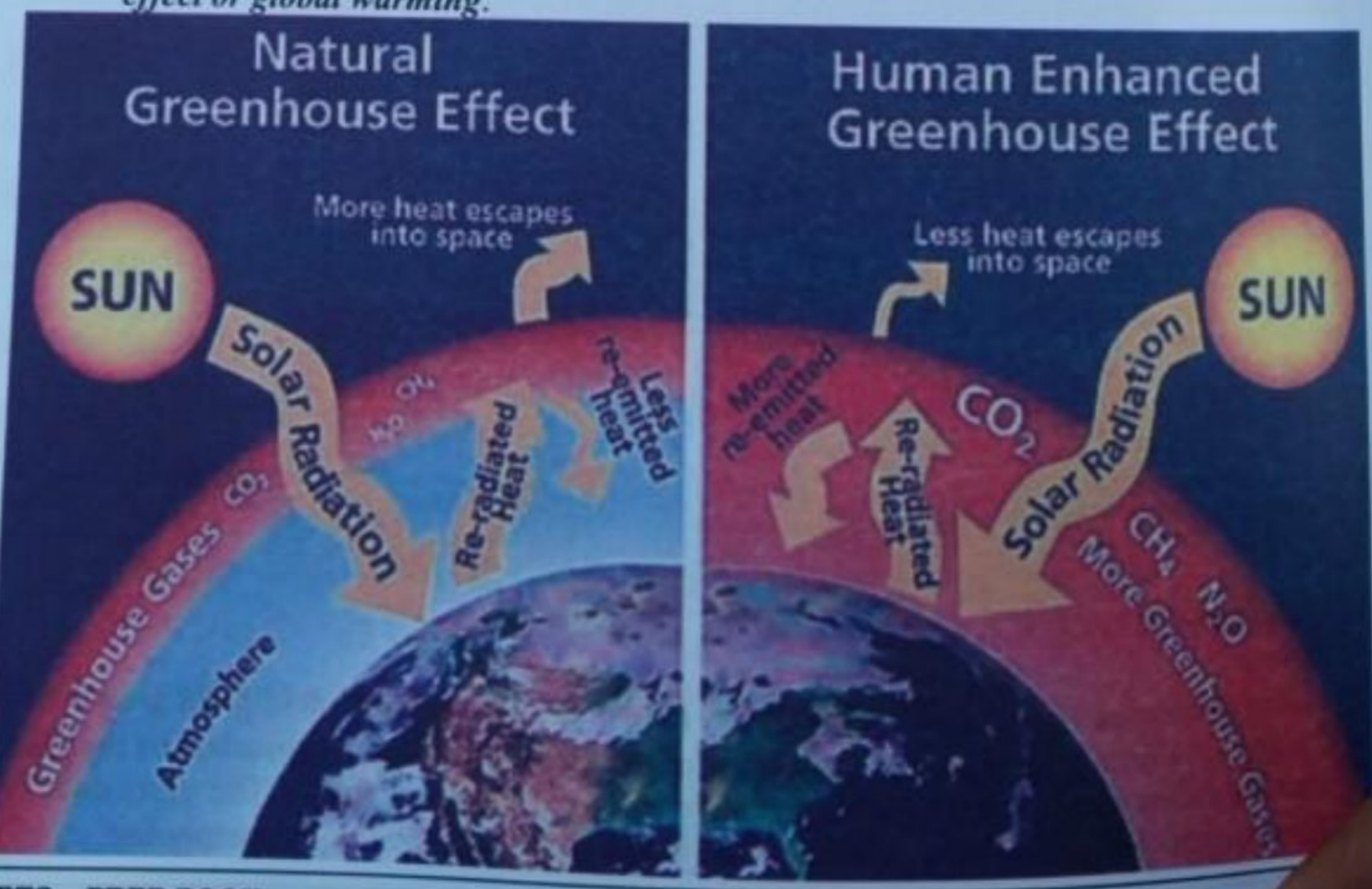
- Greenhouses are developed in area of low temperature for protection of plant growth.
- Light rays from the sun penetrate the glass of the greenhouse and are absorbed by the plants and soil and then reradiate as longer wave infra-red radiation (heat). The glass does not permit these rays to escape outside and so the heat remains within the greenhouse.

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Greenhouse Effect

- The carbon dioxide of the atmosphere behaves like glass sheet of greenhouse. It absorbs the sun energy but does not allow it to escape outside, as a result of which temperature of the atmosphere increases.
- ***Greenhouse gases*** are those, which prevent heat to escape out from them e.g. CO_2.
- Increase in earth's atmosphere due to CO_2 and retention of heat rays is called ***green house effect or global warming***.



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Causes

Causes of greenhouse effect are:

- Over urbanization
- Deforestation
- Industrialization

Effects

This global warming may lead to:

- Rapid melting of ice caps and glaciers.
- Bringing floods and changing the path of major air and ocean currents.
- Drastic effects on global weather conditions.

ACID RAIN

Process through which acids fall on earth either dissolved in rain or as microscopic dry particles is called acid rain.

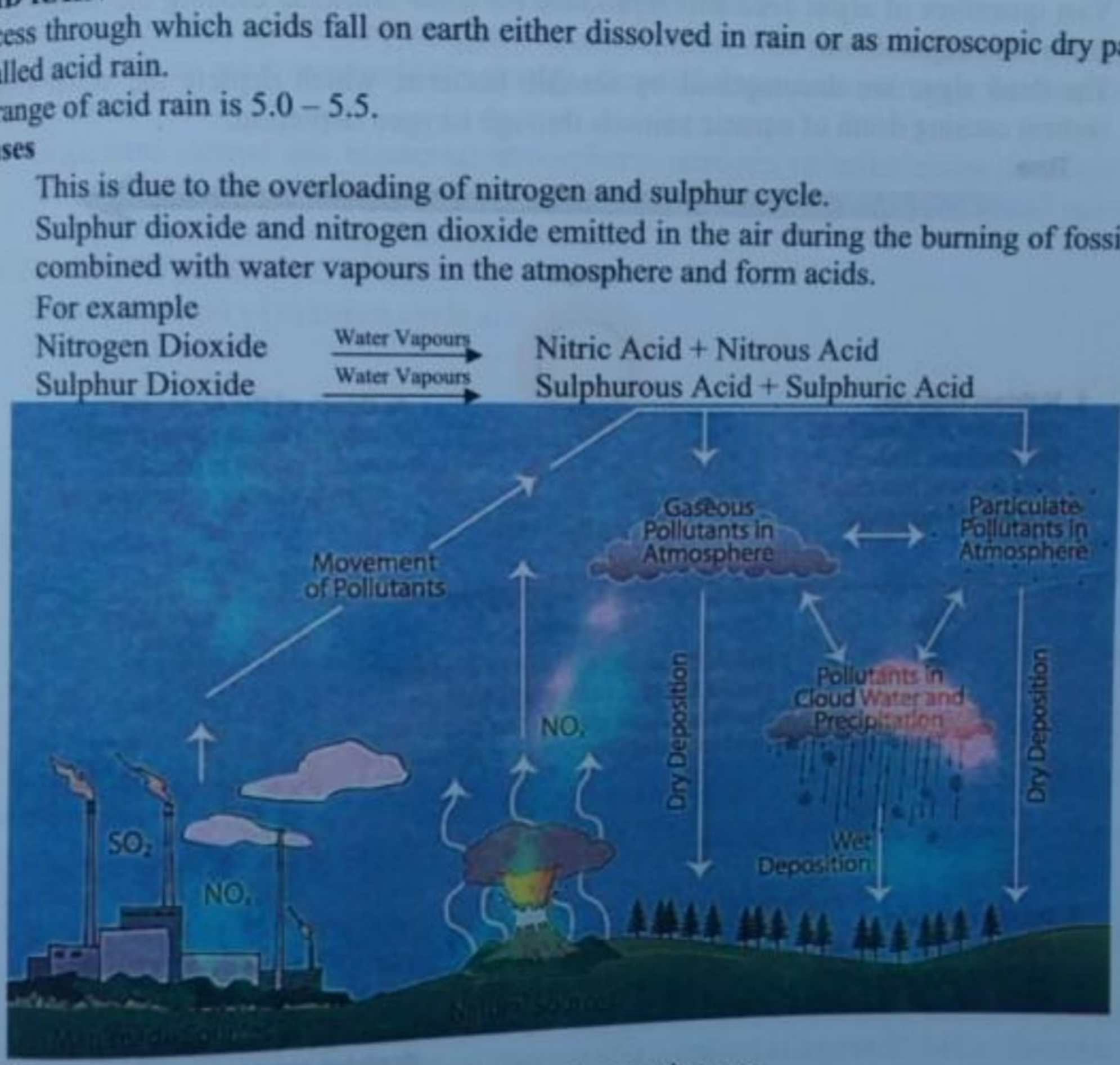
pH range of acid rain is 5.0 – 5.5.

Causes

- This is due to the overloading of nitrogen and sulphur cycle.
- Sulphur dioxide and nitrogen dioxide emitted in the air during the burning of fossil fuels combined with water vapours in the atmosphere and form acids.
- For example

Nitrogen Dioxide $\xrightarrow{\text{Water Vapours}}$ Nitric Acid + Nitrous Acid

Sulphur Dioxide $\xrightarrow{\text{Water Vapours}}$ Sulphurous Acid + Sulphuric Acid



Effects

Some of the important harmful effects of acid rains are:

- Damage to life in lakes, farms and forests.
- Washing out essential nutrients of soil such as calcium and potassium.
- Killing of decomposers and microorganisms.
- Plants poisoning, and deprivation of nutrients makes them weak and vulnerable to infection and insect attack.
- Erosion of 'Taj Mahal' due to 'stone cancer' by acid rains.

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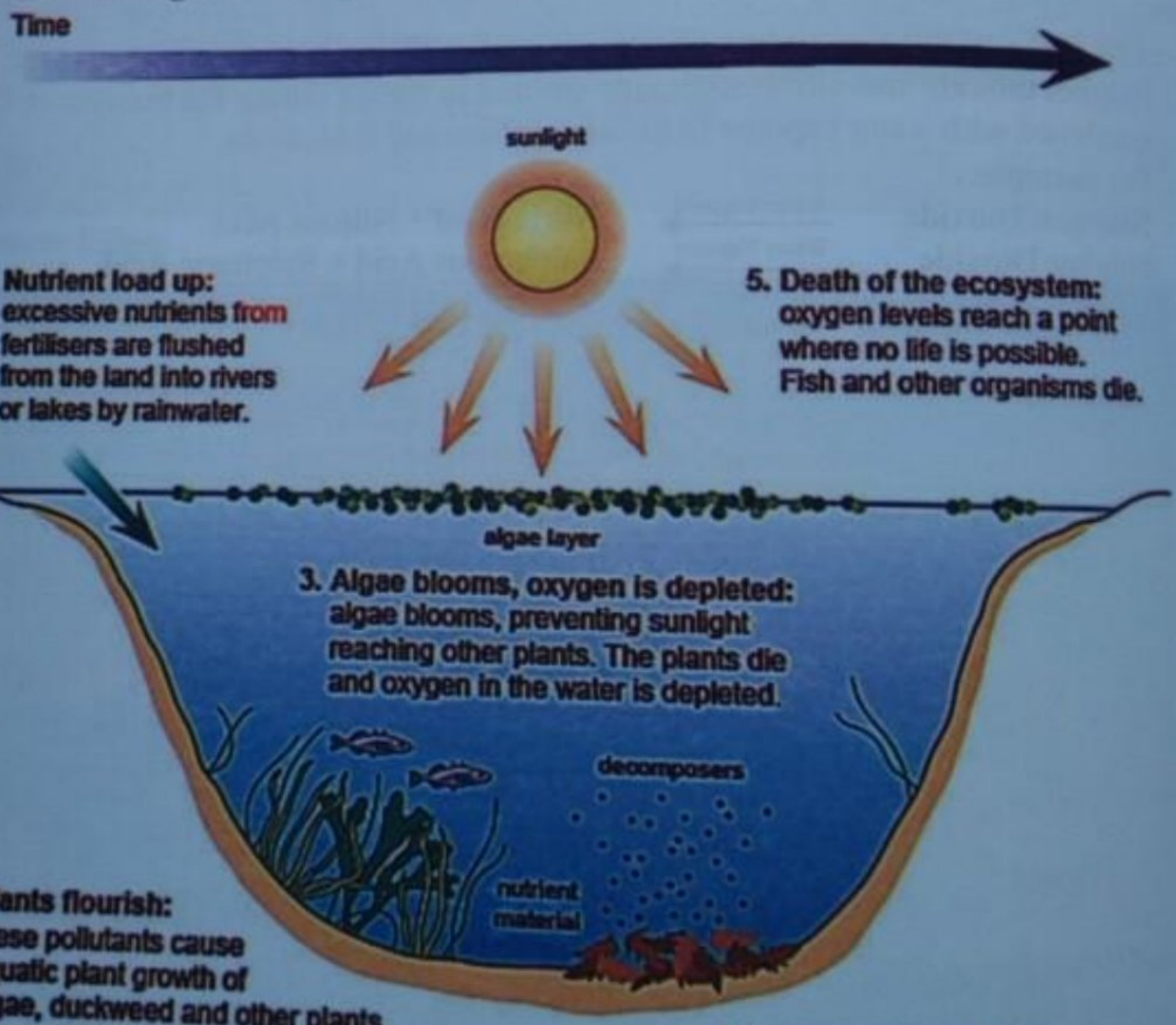
EUTROPHICATION/ ALGAL BLOOM

- It is natural process of excessive enrichment of water with nutrients by which large amount of living organic matter grows in the water.
- Human activities have speeded up this natural process of eutrophication by adding minerals and organic nutrients in larger quantities than nature would provide, as excreta, phosphates from washing powder and nitrates and phosphates from fertilizers.
- It occurs in fresh water and in sea water, both developing unpleasant color and smell.

Procedure

Different steps involved are:

- Different chemical wastes travel to water reservoirs.
- Vast quantities of algae feed and reproduce on these nutrients causing the water to turn green with algal bloom.
- The dead algae are decomposed by aerobic bacteria, which deplete the water oxygen content causing death of aquatic animals through oxygen depletion.



POINT TO PONDER

What is algal bloom?

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Assimilation

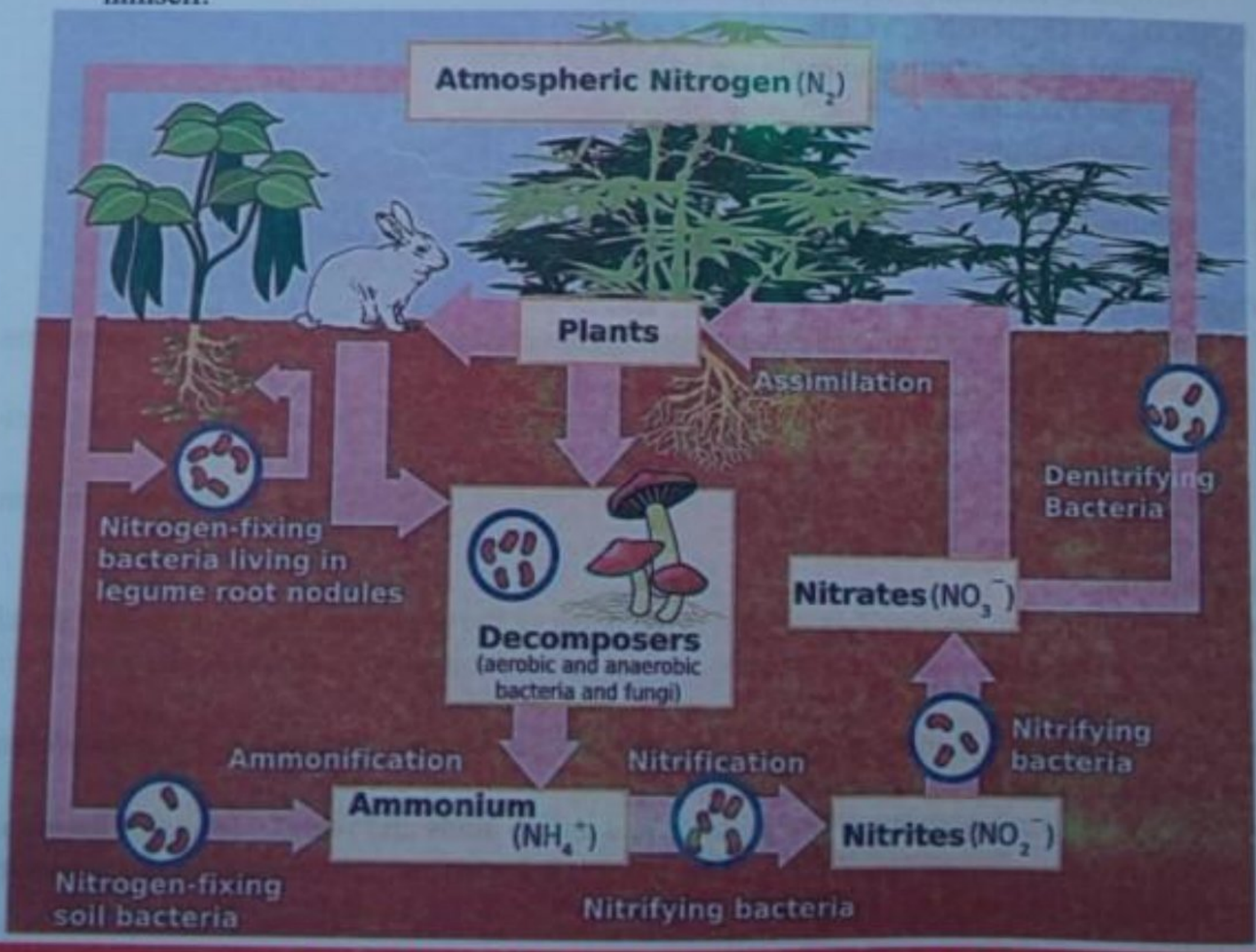
- Utilization of nitrogen inside the plant body/cells for synthesis of nitrogen containing organic compounds is called assimilation.
- Nitrate is the form through which most nitrogen moves from the soil into the roots.
- Once nitrate is within the plant cell, it is reduced back to ammonium in contrast to nitrification. This assimilation process requires energy.
- The ammonium ions thus formed are transferred to carbon-containing compounds to produce amino acids and other nitrogenous organic compounds needed by the plants.

Denitrification

- Certain soil bacteria break down nitrates in absence of oxygen, releasing nitrogen back into the atmosphere and using oxygen for their own respiration. This process is known as denitrification.
- Soil nitrates are lost from ***soil erosion***, ***fire*** and water percolating down through the soil.

Remedies of Nitrogen Depletion in Soil

Soil nitrogen resources are strengthened by the addition of nitrogen fertilizers by the man himself.



FLOW OF ENERGY IN AN ECOSYSTEM

- Energy in the form of radiant heat and light from the sun flows through an ecosystem passing through different trophic levels (links) and radiates again back into outer space.
- About 1% of the total energy from the sun is trapped by the producers in an ecosystem. The remaining 99% of solar energy is used to evaporate water, heat up soil and is then lost to outer space.

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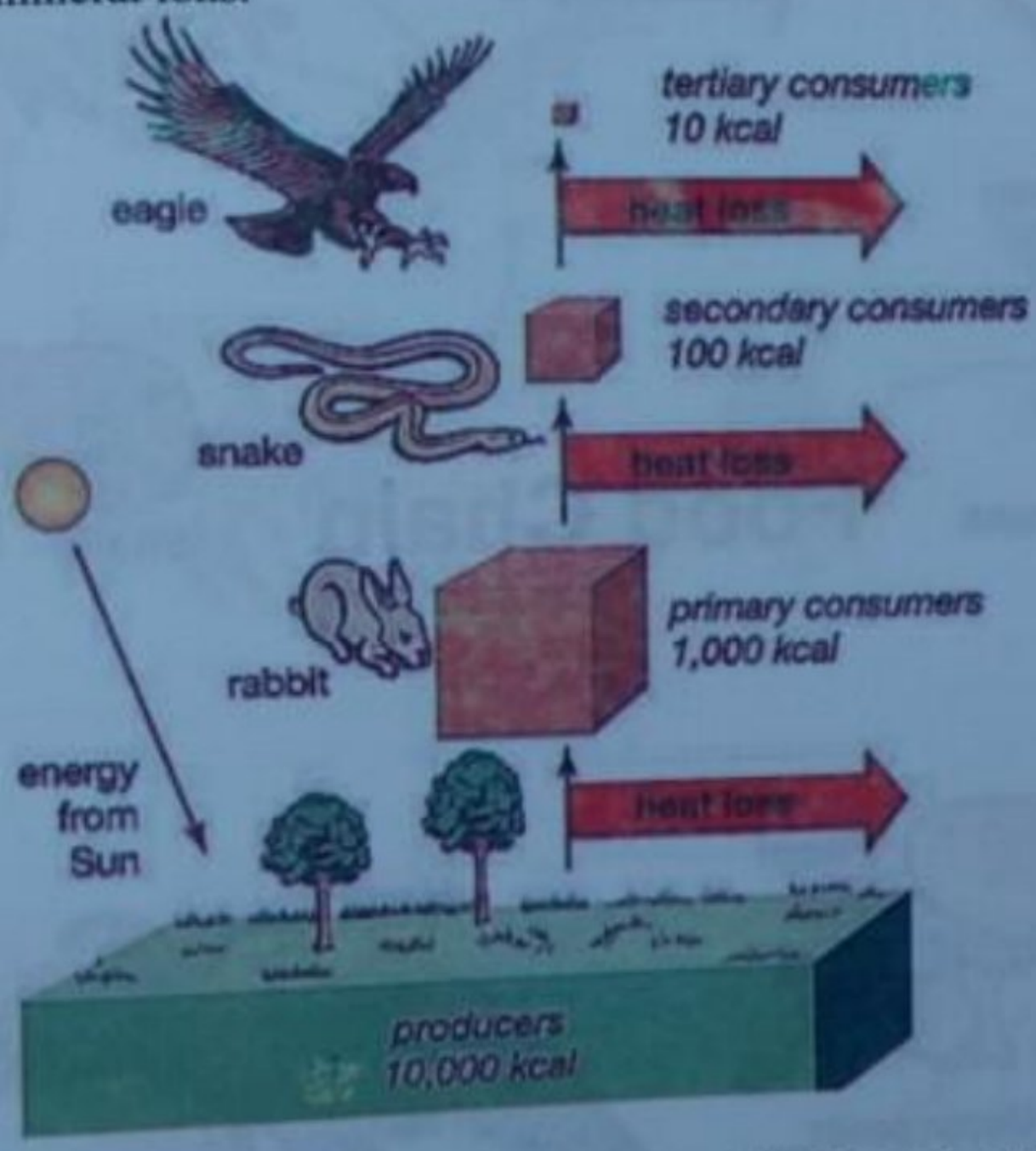
The total amount of energy fixed by plants is ***gross primary production***.

The amount of energy left after plants have met their respiratory needs is net primary production, which shows up as plant biomass. (Gross primary production minus respiratory loss = ***Net Primary Production/ Plant Biomass***.

As energy is transferred from one trophic level to the next, from producer to primary consumer, 80-90% of the original energy is lost in form of heat as byproduct of respiration and only 10-20% is available to next trophic level.

A short food chain of two or three links supports a community more efficiently than a long chain of five links where much of the original energy from the producers would never reach those organisms at higher trophic levels.

Decomposers are able to obtain energy by converting plants and animal tissues and waste into inorganic mineral ions.



PRODUCTIVITY

- Productivity can be indicated by consumption of CO_2 and evolution of O_2 during photosynthesis.
- Primary productivity is amount of energy fixed by plants per unit area and unit time.
- Its unit is Kcal/M^2/YR.
- Productivity of aquatic ecosystem is basically determined by the ***light and nutrients.***
- Light intensity and quality vary with the water depth, so the primary productivity also varies with light. The amount of nutrients also changes with season.
- In temperate grassland, rate of primary production is about 700-1500 g/m^2 annually.
- In sub humid tropical grassland, it is more than 4000 g/m^2annualy.

POINT TO PONDER

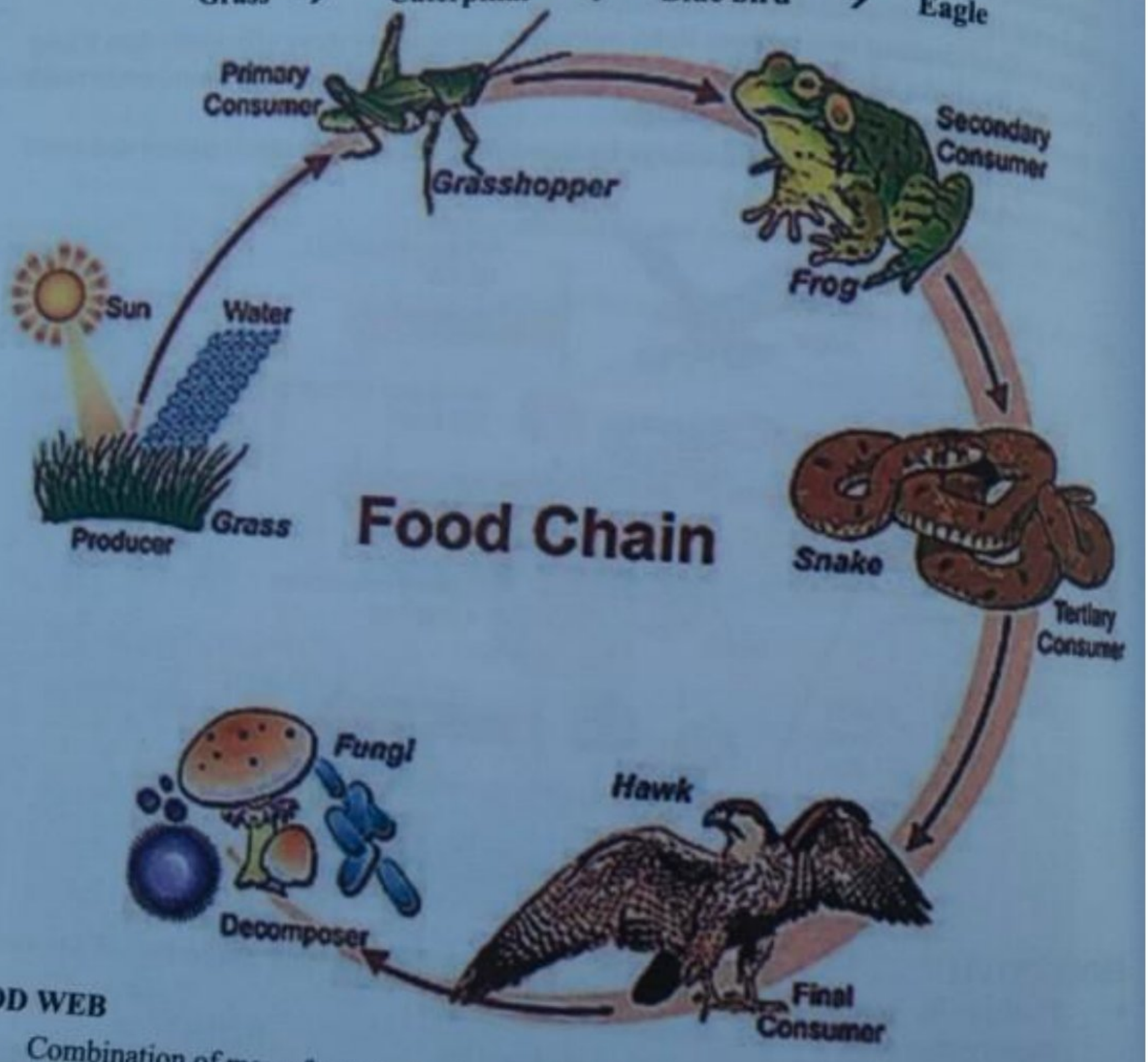
Why short food chain is more favorable than long food chain?

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FOOD CHAIN

- Linear arrangement of organisms on basis of feeding relationship is called food chain.
- All animals depend on plants for their food.
- All food chains start with producers (plants or algae).
- ***Simple food chain*:**

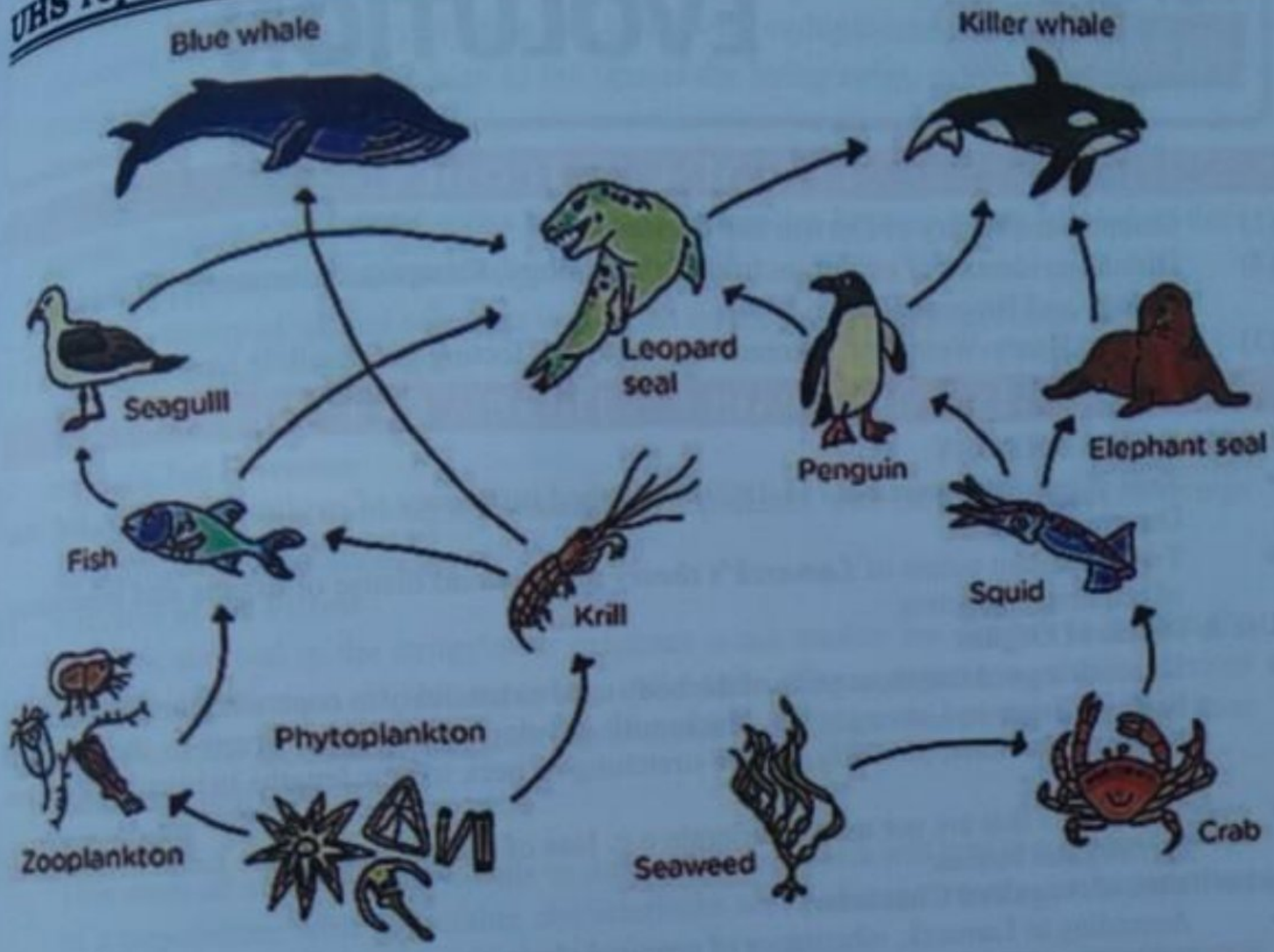
Grass → Caterpillar → Blue bird → Eagle



FOOD WEB

- Combination of many food chains is called ***food web***.
- Food webs consist of ***3-5 trophic levels***
- Different trophic levels in food web are:
  - T1: Producer
  - T2: Primary Consumer/ Herbivores
  - T3: Secondary Consumers/ Carnivores
  - T4: Tertiary Consumers/ Carnivores
- The variety of pathways in a food web helps to maintain the stability of the ecosystem.

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TOPIC-9
03 MCQs

EVOLUTION

LEARNING OUTCOMES

(1) Compare the theory of Darwin and Lamarck.
(2) Discuss evidences of evolution from Paleontology, Comparative anatomy, Molecular biology and Biogeography.
(3) Explain Hardy-Weinberg Theorem and factors affecting gene / allele frequency

DARWIN AND LAMARCK'S THEORY OF EVOLUTION

LAMARCK'S THEORY

- ***Jean Baptiste Lamarck*** (1744-1829) published his theory of evolution in 1809, the year Darwin was born.
- Two important points of ***Lamarck's theory*** are; use and disuse of organs and inheritance of acquired characters.

Use & Disuse of Organs

- Lamarck argued that those parts of the body used extensively to cope with the environment become larger and stronger e.g. blacksmith developing a bigger biceps in the arm that works the hammer. Similarly, giraffe stretching its neck to new lengths in pursuit of leaves to eat.
- Those parts that are not used deteriorate e.g. loss of legs in snakes due to their habitat of burrows and bushes.

Inheritance of Acquired Characters

- According to Lamarck, inheritance of acquired characters means that the modifications an organism acquires during its lifetime can be passed along to its offspring e.g. the long neck of giraffe, Lamarck reasoned, evolved gradually as the cumulative product of a great many generations of ancestors stretching higher and higher.

Demerits of Lamarck's Theory

It has been now known that acquired characters cannot be inherited.

POINT TO PONDER

Can you give example of any trait evolving in humans?

DARWIN'S THEORY OF NATURAL SELECTION

- Darwin observed and collected thousands of specimens of diverse faunas and floras of South America.
- His main observations were about fauna and flora of Galapagos Islands where he collected 13 types of finches.
- ***According to Darwin***, new species would arise from an ancestral form by the gradual accumulation of adaptations to different environments, separated from original habitat by geographical barriers. Over many generations, the two populations could become dissimilar enough to be designated as separate species.
- In 1844 Darwin wrote a long essay on the origin of species and natural selection, his book ***The origin of species*** was published in 1859.

Descent with Modification

- Darwin believed in ***perceived unity in life*** i.e. all organisms related through descent from some common ancestor that lived in the remote past.

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- According to Darwin, history of life is like a tree, with multiple branching and re-branching from a common trunk all the way to the tips of the living twigs, symbolic of the current diversity of organisms.

Natural Selection & Adaptation

- Darwin suggested that populations of individual species become better adapted to their local environments through natural selection.
- Darwin's theory of natural selection was based on the following observations:

(i) **Overproduction**
Production of more individuals that the environment can support.

(ii) **Struggle for Existence**
Struggle for existence among individuals of a population, with only a fraction of offsprings surviving each generation.

(iii) **Survival of the Fittest**
It means survival in the struggle for existence is not random but depends in part on the heredity constitution of the surviving individuals. Those organisms whose inherited characteristics fit them best to their environment are likely to leave more offsprings than the less fit individuals.

(iv) **Evolution**
This unequal ability of individuals to survive and reproduce will lead to a gradual change in a population, with favourable characteristics accumulating over the generations thus leading to the evolution of new species.

EVIDENCES OF EVOLUTION

BIOGEOGRAPHY

- It is the geographical distribution of species.
- It was first evidence that suggested idea of evolution to Darwin.
- According to Darwin, islands have many species of plants and animals that are endemic but closely related to species of the nearest mainland or neighboring island.
- Armadillos (armored mammals) live only in America. The evolutionary view of biogeography predicts that contemporary armadillos are modified descendants of earlier species that occupied these continents and fossil records also confirm existence of such ancestors.

POINT TO PONDER

Is evolution real?

PALAEONTOLOGY

- The succession of fossil forms is a strong evidence in favour of evolution.
- It provides a visual record in a complete series showing the evolution of an organism.
- ***Fossils*** are either the actual remains or traces of organisms that lived in ancient geological times.
- Most fossils are found in ***sedimentary rocks.***
- The oldest known fossils are of prokaryotes.

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- The chronological appearance of the different classes of vertebrate animals as shown by fossils may be presented as evolutionary arrangement:
  Fishes → Amphibians → Reptiles → Mammals + Birds

COMPARATIVE ANATOMY

- Anatomical similarities between species grouped in the same taxonomic category bring another support to the theory of the Descent with modification.
- Comparative anatomy supports that evolution is a remodeling process in which ancestral structures that functioned in one capacity become modified as they take on new functions.

Homologous Structures

- Such organs, which are functionally different but structurally similar are called homologous organs.
- Similarity in characteristics resulting from common ancestry is known as ***homology*** and such anatomical signs of evolution are called homologous structures.
- For examples, same skeletal elements make up the forelimbs of human, cats, whales, bats and all other mammals although they have different functions.
- The basic similarity of these forelimbs is the consequence of the descent of all functions.
- The flower parts of a flowering plant are homologous. They are considered to have evolved from leaves, to form sepals, petals, stamens and carpels.
- They are considered to be evolved by ***divergent evolution.***

Analogous Structures

- Such organs, which are functionally alike but structurally different, are called analogous organs.
- They are considered to be evolved by ***convergent evolution.***
- For example, wings of birds and insects are examples of convergent evolution.

Vestigial Structures

- Such organs, which are historical remnants of structures that had important functions in ancestors but are no longer essential presently are called vestigial organs.
- These are oldest homologous structures.
- For example, skeleton of whales and some snakes retain vestiges of the pelvis and leg bones of walking ancestors, vermiform appendix in carnivores, ear muscles in man etc.

MOLECULAR BIOLOGY

- The study of biochemical structures and functions of organisms at molecular level is called molecular biology.
- Evolutionary relationships among species are reflected in their **DNA and proteins,** in their genes and gene products. If two species have genes and proteins with sequences of monomers that match closely, the sequences must have been copied from a common ancestor.
- Molecular biology provides strong evidence in support of evolution as the basis for the unity and diversity of life.

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Examples

- A common genetic code brings evidence that all life is related.
- Humans and bacteria have some common proteins.
- Cytochrome c, a respiratory protein, is found in all aerobic species.

POINT TO PONDER

What are petrified fossils?

POINT TO PONDER

Do you know about:
(a) Homologous and analogous organs
(b) Divergent and convergent evolution

HARDY-WEINBERG THEOREM

- The frequencies of alleles and genotypes in a population's gene pole remain constant over the generations unless acted upon by agents other than sexual recombination.
- This theorem was presented by two scientists Hardy and Weinberg who presented it separately in 1908.
- So, shuffling of alleles due to meiosis and random fertilization has no effect on the overall genetic structure of a population.

Hardy-Weinberg Equation

$p^2 + 2pq + q^2 = 1$

- This equation is in fact binomial expansion i.e. $(p + q)^2 = p^2 + 2pq + q^2$
- This equation is used for calculating the frequencies of alleles and genotypes in populations at equilibrium.
- In a population where only two alleles occur for a gene, 'p' represents frequency of one allele and 'q' of other allele.

Examples

Consider an imaginary wild flower population.

$p = 0.8$
$q = 0.2$

Thus $p + q = 1$

- The combined frequencies of all possible alleles must account for 100% of the genes for that locus in the population.
- If there are only two alleles and we know the frequency of one, the frequency of other can be calculated.

If $p + q = 1$
Then $1 - p = q$
Or $1 - q = p$

- When gametes combine to form a zygote, then probability of genotype becomes p^2 for gene pair (suppose AA).
- In the wild flower population;

$p = 0.8$ & $p^2 = 0.64$ (Frequency for homozygous dominant AA).
$q = 0.2$ & $q^2 = 0.04$ (Frequency for homozygous recessive aa).
$2pq = 2 \times 0.8 \times 0.2 = 0.32$ (Frequency for heterozygous Aa).

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- Now if we add all these frequencies, it will be equal to 1. Consider equation;

p^2	+	2pq	+	q^2	=	1
0.64	+	0.32	+	0.04	=	1

FACTORS AFFECTING GENE FREQUENCY

Many factors can alter gene frequency and out of these five affect proportion of homozygotes and heterozygotes enough to produce significant deviation from proportion claimed by Hardy-Weinberg principle.

Mutation

- It is ultimate source of all changes.
- Single mutation alone does not change allele frequency much.

Migration

- It is a very potent agent of change.
- Migration locally acts to prevent evolutionary changes by preventing populations that exchange members from diverging from one another.
- Emigration and immigration of members of a population cause disturbance in the gene pool.

Genetic Drift

- It is change in frequency of alleles at a locus that occurs by chance.
- In small populations, such fluctuations may lead to loss of particular alleles.

Non-random Mating

- Inbreeding is its most common form.
- Individuals with certain genotypes sometimes mate with one another more commonly than expected on a random basis. This is called non-random mating.
- It does not alter allele frequency but lessens the proportion of heterozygote individuals.

Selection

- Some individuals leave behind more progeny than others, and the rate at which they do so is affected by their inherited characteristics. This is called selection.
- Selection can be natural or artificial.
- In natural selection, environment plays role, thus affecting the proportions of gene in a population.
- In artificial selection, the breeders (humans) select for the desired characters.

POINT TO PONDER

What is fixed allele?

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TOPIC-10
08 MCQs

GENETICS

LEARNING OUTCOMES

(1) Explain the terms: Gene, locus, allele, dominant, recessive, co-dominant, linkage, F1 and F2, phenotype, genotype, homozygous, heterozygous, mutation, epistasis, multiple allele, Rh factor, dominance relations, polygenic inheritance.
(2) Explain law of segregation and law of independent assortment through Punnet square, solve problems related to monohybrid, dihybrid crosses and testcross.
(3) Discuss gene linkage and sex linkage in human (haemophilia and colour blindness).
(4) Discuss hypothesis about DNA Replication, Meselson and Stahl experiment and mechanism of replication.
(5) Explain mechanism of gene expression: Transcription and Translation.
(6) Describe Genetic code and its properties.
(7) Explain sex chromosomes and discuss different systems of sex determination (XO-XX, XY-XX, ZZ-ZW).
(8) Know cell cycle and its phases.
(9) Describe events of mitosis and meiosis along with their significance.
(10) Discuss meiotic errors (Down's syndrome, Klinefelter's syndrome, Turner's syndrome).

BASIC TERMINOLOGIES

Gene

- It is the basic unit of biological information.
- Genes are actually parts of DNA comprising its basic sequence.
- It is sequence of nucleotides that specifies sequence of amino acids in a polypeptide chain.

Locus

- The position of a gene on the chromosome is called its locus.

Allele

- Genes form pairs on pairs of homologous chromosomes.
- One member of a gene pair is located on one homologue and the other member on the other homologue.
- Partners of a gene pair are called alleles.
- Each allele of a gene pair occupies the same gene locus on its respective homologue.
- Both alleles on one locus may be identical or different from each other.

Dominant

- Such an allele that masks the effect of other allele in a pair is called dominant allele and such trait is dominant.
- For example, in pea plant, round (R) is dominant over wrinkled (r).

Recessive

- Such an allele that is masked by another allele in a gene pair is called recessive allele and such trait is called recessive trait.
- For example, in pea plant, green (y) is recessive while yellow (Y) is dominant.

Phenotype

- Physical appearance of a trait is called phenotype.
- For example, round and wrinkled are phenotypes of seed shape as the shape is a trait.

Genotype

- Genotype is the genetic complement i.e. the genes in an individual for a particular trait.

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- For example, genotype of AB blood group is I^AI^B.

Homozygous

- When both alleles of a gene pair in an organism are same, the organism is homozygous for that gene pair.
- An individual with homozygous genotype is called homozygote or true breeding.
- For example, RR is genotype of homozygous round seeded pea plant.

Heterozygous

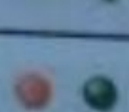
- If both alleles of a gene pair are different from each other, the organism is heterozygous for that gene pair.
- An individual with heterozygous genotype is called heterozygote or hybrid.
- For example, Rr is genotype of heterozygous round seeded pea plant.

LAW OF SEGREGATION

Selection of Pea Plant

Mendel selected pea plant (*Pisum sativum*) as experimental material due to following reasons:

- It is easy to cultivate.
- Its flowers were hermaphrodite. It was normally self-fertilizing but could be cross fertilized.
- It has short generation time.
- It has many sharply distinct traits.

Character	Contrasting traits	
Seed shape	Round/wrinkled	
Seed color	Yellow/green	
Pod shape	Full/constricted	
Pod color	Green/yellow	
Flower color	Violet/white	
Flower position	Axial/terminal	
Stem length	Tall/dwarf	

LAW OF SEGREGATION

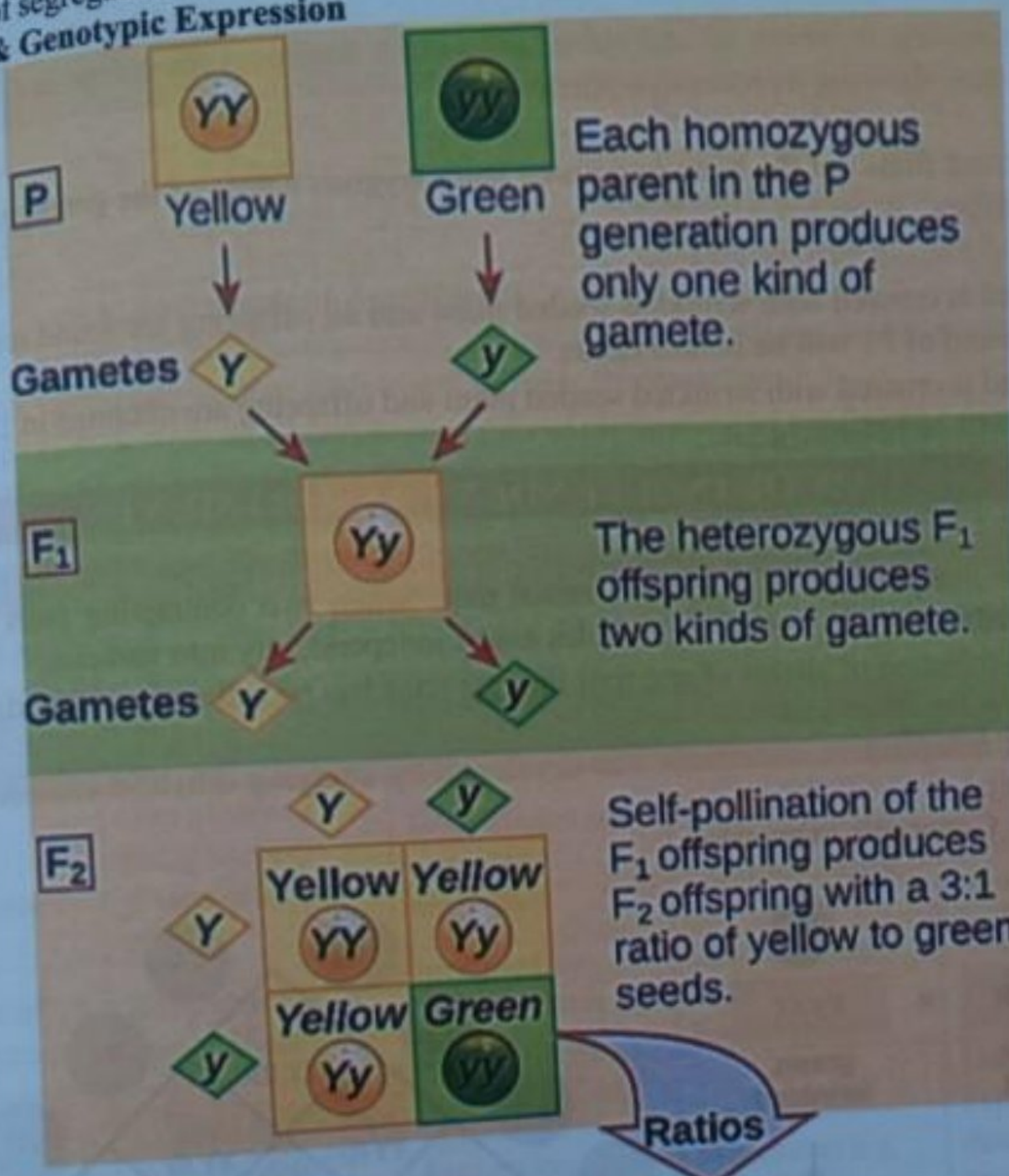
Introduction

- According to law of segregation, "the two coexisting alleles for each trait in an individual segregate (separate) from each other at meiosis, so that each gamete receives only one of the two alleles. Alleles unite again at random fertilization of gametes when zygote is formed."

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Law of segregation was developed through ***monohybrid cross*** (varying in one trait).

Phenotypic & Genotypic Expression



Phenotypes	Genotypes	Genotype ratio	Phenotype ratio
Yellow	YY	1	3
	Yy	2	
Green	yy	1	1

Results

- Yellow is dominant over green.
- Phenotype ratio of F2 generation is 3:1.
- Genotype ratio of F2 generation is 1:2:1.

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TEST CROSS

Definition

It is a mating in which an individual showing a dominant phenotype is crossed with an individual showing its recessive phenotype.

Significance

This cross finds out the homozygous or heterozygous nature of the genotype of dominant phenotypes.

Details

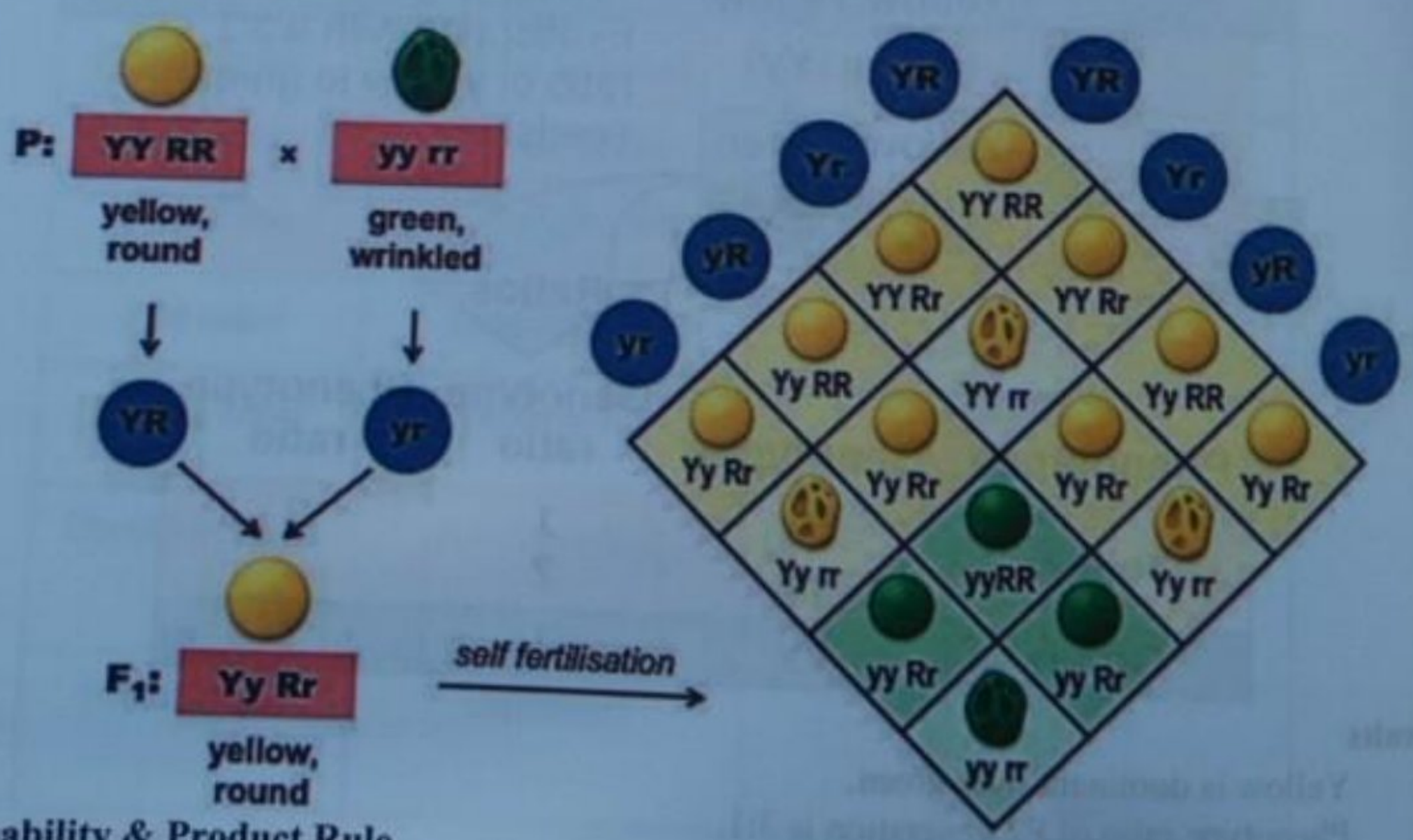
- If round is crossed with wrinkled seeded plant and all offspring are round seed producing, then round of P1 will be homozygous.
- If round is crossed with wrinkled seeded plant and offspring are obtained in 1:1 then round of P1 will be heterozygous.

LAW OF INDEPENDENT ASSORTMENT

Introduction

- Law of independent assortment is stated that "when two contrasting pairs of traits are followed in the same cross, their alleles assort independently into gametes."
- The distribution of alleles of one trait into gametes has no influence on the distribution of alleles of the other trait.
- Law of independent assortment was developed by studying dihybrid crosses (varying in two traits).

Phenotypic & Genotypic expression



Probability & Product Rule

- Probability is the chance of an event to occur e.g. in F2 offspring of a monohybrid cross the independent chance for a seed to be round is 3/4.
- "When two independent events are occurring simultaneously like in dihybrid cross, the ratio of each joint phenotypic combination can be obtained by multiplying the probabilities of individual phenotypes. It is called product rule."

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Event No.1 Seed Shape Independent Probability	Event No.2 Seed Colour Independent Probability	Both Events at a Time Seed Shape & Colour Joint Probability
Round = 3/4	Yellow = 3/4	Round Yellow = 3/4 x 3/4 = 9/16
Round = 3/4	Green = 1/4	Round Green = 3/4 x 1/4 = 3/16
Wrinkled = 1/4	Yellow = 3/4	Wrinkled Yellow = 1/4 x 3/4 = 3/16
Wrinkled = 1/4	Green = 1/4	Wrinkled Green = 1/4 x 1/4 = 1/16

Limitations of Law of Independent Assortment

- Genes are located on chromosomes at specific loci. Independent assortment of genes depends upon independent assortment of their chromosomes.
- All the genes present on a homologous pair of chromosomes are linked to each other in the form of a linkage group. These cannot assort independently.
- Those traits assort independently whose alleles are riding non-homologous chromosomes

DOMINANCE RELATIONS

- It is a physiological effect of an allele over its partner allele on the same gene locus.
- There are four types of dominance relations:

Feature	Complete Dominance	Incomplete Dominance	Co-dominance	Over Dominance
Alleles in Heterozygote	One allele completely masks effect of other.	Both alleles are expressed partially.	Both alleles are expressed fully.	One allele boosts effect of other allele.
Phenotype of Heterozygote	Resembles with one homozygote	Intermediate between both homozygotes	Distinct from both homozygotes.	Exceeds in quantity from homozygote.
Expression of Alleles	Capital letter for dominant and small letter for recessive.	Different expression e.g. R1 and R2	Different expression e.g. M and N	Different expression for dominant and recessive e.g. w+ and w.
Phenotype & genotype Ratios	Different	Same	Same	Same
Need of Test Cross	✓	×	×	×
Examples	All seven traits studied by Mendel	Flower colour in 4 O'clock plant	AB and MN blood groups	Eye colour of *Drosophila*

MULTIPLE ALLELES

- All such altered alternative forms of a gene, whose number is more than two are called multiple alleles.
- Some genes may have as many as 300 alleles.
- Any two of these multiple alleles can be present in the genome of a diploid organism, but a haploid organism or a gamete have just one of them in its genome.
- Gene mutations may produce many different alleles of a gene.

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ABO BLOOD GROUP SYSTEM

- ABO blood group is first discovered multiple allelic blood group system in man.
- This blood group system is encoded by a single polymorphic gene I on chromosome 9. It has three multiple alleles I^A, I^B and i.
- Allele I^A specifies production of antigen A, allele I^B specifies production of antigen B but allele i does not specify any antigen.
- Alleles I^A and I^B are codominant for each other while completely dominant over i.

Phenotypes & Genotypes

Phenotype	Genotype	Antigen	Antibody
A	I^AI^A, I^Ai	A	Anti-B antibody
B	I^BI^B, I^Bi	B	Anti-A antibody
AB	I^AI^B	A & B	No Antibody
O	ii	No	Anti-A antibody Anti-B antibody

- Serum containing antibodies is called ***antiserum***.

Blood Transfusion

Blood Group	Donated To	Receives From
A	A, AB	A, O
B	B, AB	B, O
AB	AB	A, B, AB, O
O	A, B, AB, O	O

Rh BLOOD GROUP SYSTEM

- Positive or negative sign of blood group refers to the presence or absence of another blood group system antigen called Rh factor.
- Rh blood group system is defined on the basis of Rh factor present on the surface of RBCs.
- Rh blood group system is encoded by three genes C, D and E which occupy two tightly linked loci.
- Alleles of gene D occupy one locus called locus D, while genes C and E alternatively occupy the other locus. The D locus is of prime importance.
- Gene D has two alleles, D and d. D is completely dominant over d.

Phenotypes & Genotypes

Phenotype	Genotype	Antigen	Antibody
Rh positive	DD, Dd	Present	Absent
Rh negative	dd	Absent	Absent

Blood Transfusion

Blood Group	Donated To	Receives From
Rh positive	Rh positive	Rh positive Rh negative
Rh negative	Rh positive Rh negative	Rh negative

EPISTASIS

- Epistasis is the interaction between different genes occupying different loci.
- When an effect caused by a gene or gene pair at one locus interferes with or hides the effect caused by another gene or gene pair at another locus, such a phenomenon of gene interaction is called epistasis.

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The expression of ABO blood type antigens by I^A or I^B gene on chromosome 9 depends upon the presence of another gene H on chromosome 19. This is called Bombay phenotype.

POLYGENIC INHERITANCE

Introduction

- Such traits which are encoded by alleles of two or more different gene pairs found at different loci, all influencing the same trait in an additive way are called polygenic traits and their genes are polygenes.
- These are also called as continuously varying traits or quantitative traits.

Features

- Each polygene has a small positive or negative effect on character.
- Polygenes supplement each other and sum of positive or negative effects of all individual polygenes produce quantitative phenotypes of a continuously varying trait.
- These traits produce a smooth bell-shaped curve.

Examples

- Kernel colour of wheat grain is determined by 3 gene pairs.
- Human skin colour is determined by 3-6 gene pairs.
- Human height and intelligence are also polygenic traits.

GENE LINKAGE

- Phenomenon of staying together of all the genes of a chromosome is called gene linkage.
- Gene linkage is a physical relationship between genes.
- A chromosome carries its linked genes en bloc in form of linkage group.
- The number of linkage groups corresponds to the number of homologous pairs of chromosomes. Man has 23 linkage groups.
- Gene linkage minimizes the chances of genetic recombination and variation among offsprings.

Examples

- Genes for colour blindness, haemophilia, gout etc form one linkage group on human X chromosome.
- Gene for sickle cell anaemia, leukemia and albinism etc form linkage group on human chromosome 11.

SEX CHROMOSOMES AND SEX DETERMINATION

SEX CHROMOSOMES

- Chromosomes which are different in male and female and have genes for determination of sex are called sex chromosomes.
- All chromosomes other than sex chromosomes are called autosomes. Autosomes do not carry any sex determining gene.

Humans as Example

- Humans have 46 chromosomes in form of 23 pairs.
- 22 pairs are of autosomes and one pair is of sex chromosomes.

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- Autosome pairs are common in both the sexes but 23rd sex chromosome pair is very different in male and female.
- A female has two similar X chromosomes in her 23rd pair but a man has an X chromosome alongwith a much shorter Y chromosome in his 23rd pair.
- The 23rd pair in man is heteromorphic. She is XX but he is XY.
- SRY is the male determining gene. It is located at the tip of short arm of Y chromosome. It is male sex switches and expressed during 6th week of pregnancy.

PATTERNS OF SEX DETERMINATION

Feature	XO-XX	XY-XX	ZZ-ZW
Examples	Grasshopper, *Protenor bug*	Human, *Drosophila*	Birds, Butterflies, Moths
Male	XO	XY	ZZ
	Heterogametic	Heterogametic	Homogametic
Female	XX	XX	ZW
	Homogametic	Homogametic	Heterogametic
Sex Determining Gamete	Sperm	Sperm	Egg
Sex Ratio	1:1	1:1	1:1

SEX LINKAGE IN HUMANS

- A trait whose gene is present on X chromosome is called ***X-linked trait***. X-linked traits are commonly referred as sex-linked traits.
- ***X-linked recessive traits*** are common in male while ***X-linked dominant traits*** are common in female.
- X-linked traits follow ***zig zag path*** while Y-linked traits are transmitted in ***straight way***.
- Genes located on Y chromosomes are called Y-linked genes and their traits are called ***Y-linked traits***.
- Such traits whose genes are located on both X & Y chromosomes are called X & Y linked or ***pseudoautosomal traits*** such genes are called X-and-Y linked genes.

HAEMOPHILIA

- It is a rare X-linked recessive trait.
- Haemophiliac's blood fails to clot properly after an injury, because it has either reduction or malfunction or complete absence of blood clotting factors.
- It is a serious heredity disease because a haemophiliac may bleed to death even from minor cuts.

Types of Haemophilia

Type	Occurrence	Factor	Genetics
A	80%	VIII	X-linked recessive
B	20%	IX	X-linked recessive
C	Less than 1%	XI	Autosomal recessive

- Haemophilia A and B are non-allelic recessive sex-linked but haemophilia C is an autosomal recessive trait (Autosome 4).
- Haemophilia A and B have more chances in male as compared to female while haemophilia C has equal chances in both male and female.

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Genetics of Haemophilia A

- A woman can suffer from haemophilia A only when she is homozygous for the recessive allele.
- A man with just one recessive allele will display the trait.
- Haemophilia A zig zag from maternal grandfather through a carrier daughter to a grandson.
- It never passes direct from father to son.
- Gene for normal is H and gene for haemophilia A is h.

Gender	Genotype	Phenotype
Female	X^HX^H	Normal
	X^HX^h	Normal but Carrier
	X^hX^h	Haemophilic
Male	X^HY	Normal
	X^hY	Haemophilic

POINT TO PONDER

Do you know how many factors are required for blood clotting? Name those which are not present in Haemophilics.

COLOUR BLINDNESS

- It is a hereditary disease in which a person cannot differentiate between different colours.
- Normal trichromatic colour vision is based on three different kinds of cone cells in the retina, each sensitive to one of the three primary colours colours, red, green or blue.
- Each type of cone cell has specific light absorbing proteins called opsins.

Genetics

- The genes for red and green opsins are on X chromosome while the gene for blue opsin is present on autosome 7.

Types of Colour Blindness

- Mutations in opsin genes cause three types of colour blindness:

(i) **Dichromacy**

- A dichromat can perceive two primary colours but is unable to perceive one whose opsins are missing due to mutation.
- It is further categorized into three following types:

Type	Blindness	Perception
Protanopia	Red blindness	Green, Blue
Deuteranopia	Green blindness	Red, Blue
Tritanopia	Blue blindness	Red, Green

(ii) **Protanomalous**

- Some people can detect red and green but with altered perception of the relative shades of these colours.
- They have abnormal but still partially functional opsins.
- They are protanomalous and deuteranomalous for red and green weakness respectively.

(iii) **Monochromacy**

- A monochromat can perceive only one colour. Monochromacy is true colour-blindness.

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- ***Blue cone monochromacy*** is an X-linked recessive trait in which red and green cone cells are absent.
- It is a common heredity disease.
- Like any sex-linked recessive traits, it also zigzags from maternal grandfather through a carrier daughter to a grandson.
- It never passes direct from father to son.
- This type of colour blindness is more common in men than women, because chances for a male to be affected by it are much more than a female.

POINT TO PONDER

Can color blindness and haemophilia be autosomal?

POINT TO PONDER

What you know about rod and cone cells?

OTHERS

- ***Testicular feminization syndrome*** is a rare X-linked recessive trait in which person has X & Y chromosomes yet tfm genes on their x-chromosome develops them physically into female.
- A ***sex-limited trait*** is limited to only one sex due to anatomical differences e.g. beard growth in human male and milk yield in cows.
- ***Sex influenced traits*** occur in both males and females, but they are more common in one sex e.g. pattern baldness. These are influenced by hormonal differences.

TRAITS AND EXAMPLES

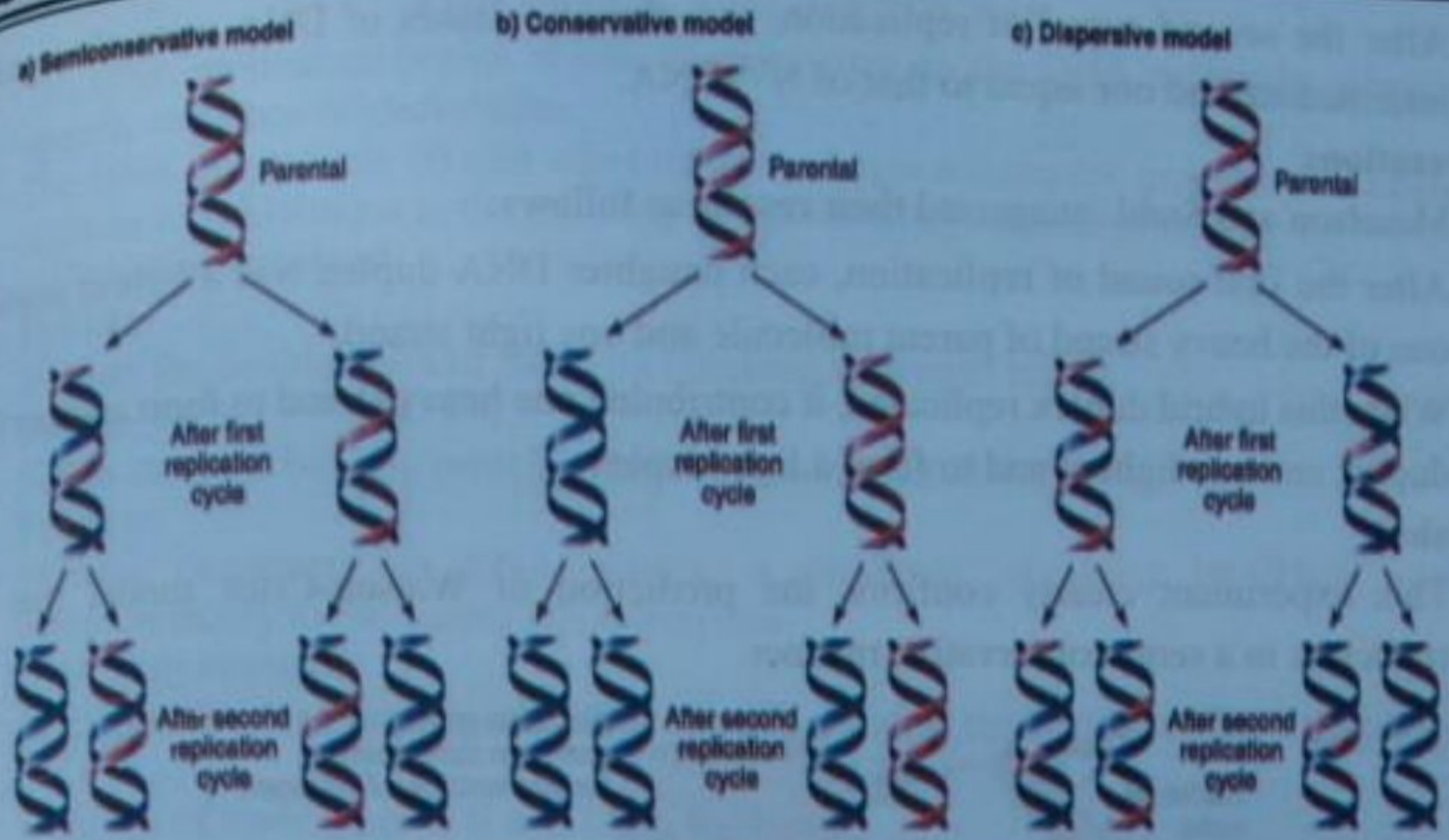
Trait	Example
X-linked recessive	Hemophilia, colorblindness, testicular feminization syndrome
X-linked dominant	Hypophosphatemic or vitamin D resistant rickets
Y- linked trait	Maleness
Pseudoautosomal trait	Bobbing in insects
Sex limited trait	Milk yield in cow, beard in man
Sex influenced trait	Baldness

DNA REPLICATION

- Semiconservative replication model was presented by Watson & Crick.
- Semi-conservative replication was confirmed by ***Meselson and Stahl***.
- In ***Semi conservative replication***, the sequence of the original duplex is conserved after one round of replication, the duplex itself is not.
- According to ***conservative model***, parental double helix would remain intact and generate DNA copies consisting of entirely new molecules.
- According to ***dispersive model***, parental DNA would become completely dispersed and each strand of all daughter molecules would be a mixture of old and new DNA.

Model	Primary Structure	Secondary Structure
Conservative Model	Conserved	Conserved
Dispersive Model	Lost	Lost
Semi-conservative Model	Conserved	Lost

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MESELSON-STAHL EXPERIMENT

- The three hypothesis of DNA replication were evaluated by Mathew Meselson and Franklin Stahl.
- They grew bacteria in a medium containing heavy isotopes of nitrogen N^{15}, which became incorporated into the bases of the bacterial DNA.

Step I

Growth of Bacteria in Artificial Medium

- They grew bacteria in a medium containing heavy isotope of nitrogen, N^{15}, which became incorporated into the bases of the bacterial DNA. After several generations, the DNA of these bacteria was denser than that of bacteria grown in a medium containing the lighter isotope of nitrogen, N^{14}.
- Then they transferred the bacteria from the N^{15} medium to the N^{14} medium and collected the DNA at various intervals.

Step II

Ultracentrifugation

- They dissolved the DNA in Cesium Chloride and then spun it at a very high speed in an ultracentrifuge. DNA strands of different densities got separated.
- Each DNA floats or sinks in the gradient until it reaches the position where its density exactly matches the density of cesium there.
- Because N^{15} strands are denser than N^{14} strands, they migrate farther down the tubes to a denser region of the cesium chloride gradient.

Observations

- The DNA collected immediately after the transfer was all dense.
- After the bacteria completed their first round of DNA replication in the N^{14} medium, the density of their DNA had decreased to a value intermediate between N^{14}-DNA and N^{15}-DNA.

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- After the second round of replication, two density classes of DNA were observed, one intermediate and one equal to that of N^{14}-DNA.

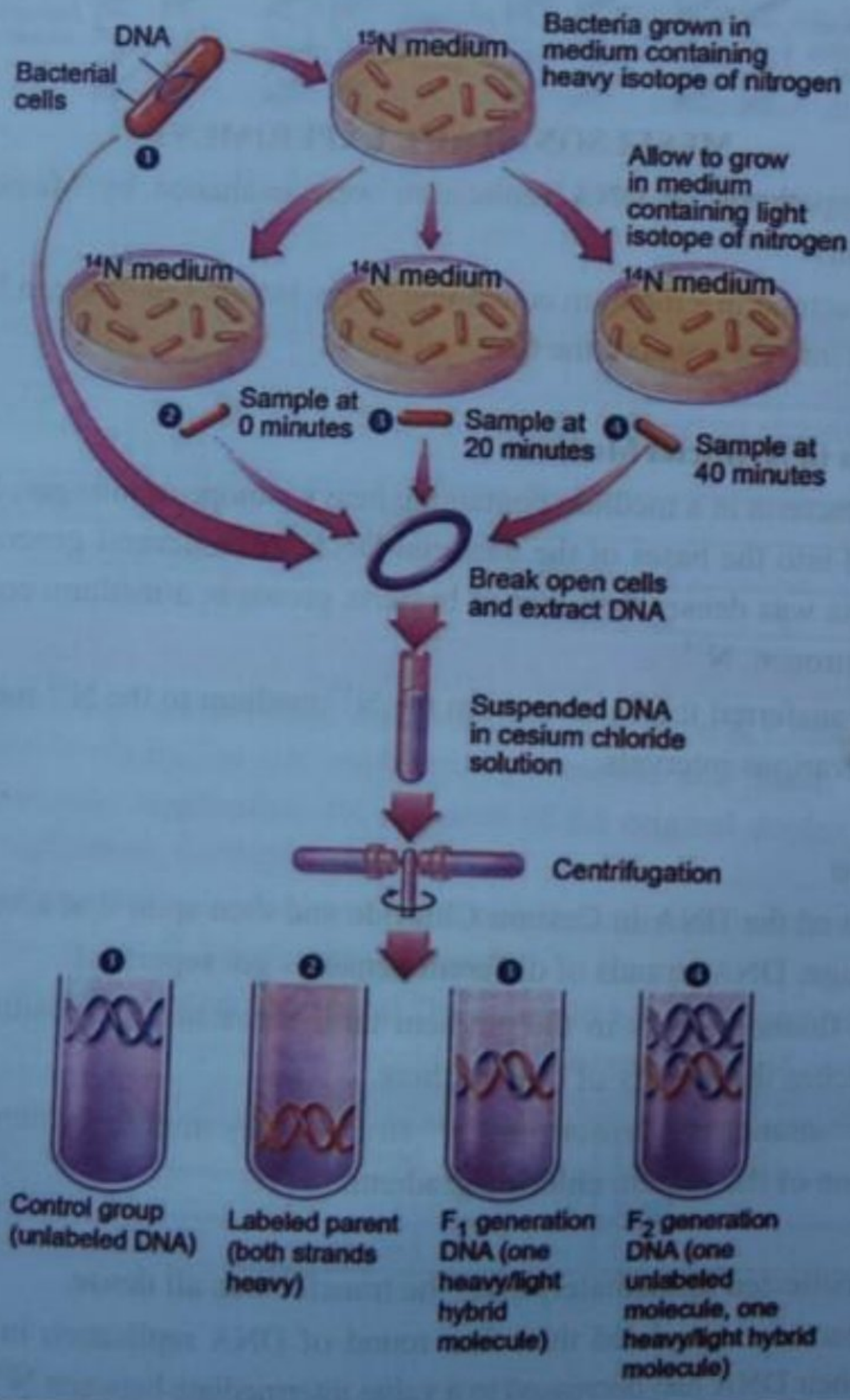
Interpretations

Meselson and Stahl interpreted their results as follows:

- After the first round of replication, each daughter DNA duplex was a hybrid possessing one of the heavy strand of parent molecule and one light strand.
- When this hybrid duplex replicated, it contributed one heavy strand to form another hybrid duplex and one light strand to form a light duplex.

Conclusion

This experiment clearly confirms the prediction of Watson-Crick model that DNA replicates in a semi-conservative manner.



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THE REPLICATION PROCESS

- The DNA replication begins at one or more sites on the DNA molecule, where there is specific sequence of nucleotides.
- The DNA polymerase III and other enzymes begin a complex process that catalyzes the addition of nucleotides to the growing complementary strands of DNA.

Enzymes/ Proteins Involved

(i) **Helicase**
- It opens the double helix of DNA by breaking hydrogen bonds.

(ii) **SSBPs**
- Single stranded binding proteins prevent recoiling of DNA.

(iii) **Primase**
- Primase constructs an RNA primer, a sequence of about 10 RNA nucleotides complementary to the parent DNA template

(iv) **DNA Polymerases**
- DNA polymerases catalyze addition of nucleotides to the complementary growing strands of DNA.
- They are of three types I, II and III in bacteria.
- The true E.coli replicating enzyme is DNA polymerase III which is 10 times larger.
- This enzyme is a dimer and catalyzes replication of one DNA strand.
- ***Rate of replication*** is 1000 nucleotides /sec.
- It can add nucleotides only to a chain of nucleotides that is already paired with the parent strands.
- DNA polymerase cannot initiate synthesis on its own.
- It can add nucleotides to the 3' end of a DNA strand so replication always proceeds from *5' → 3'* direction on a growing DNA strand.

(v) **DNA Ligase**
- It connects DNA fragments together.

Mechanism

Following steps are involved during DNA replication:

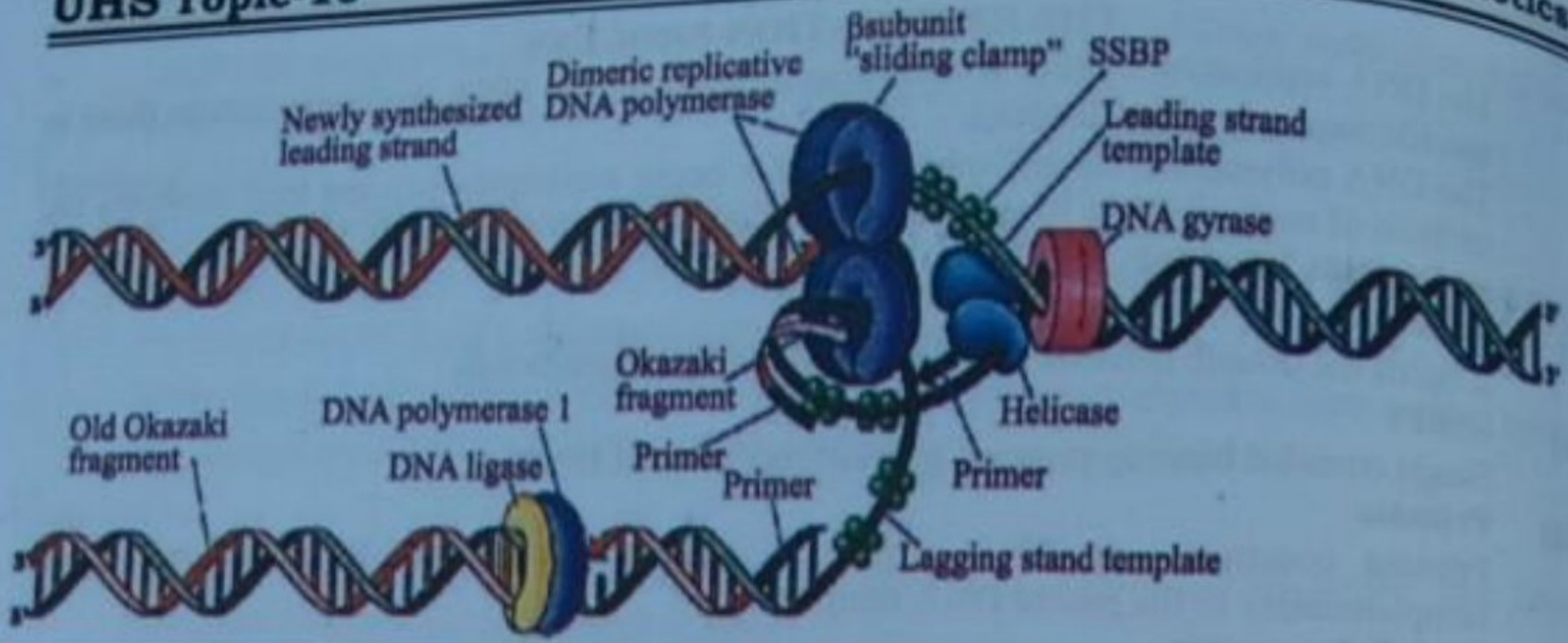
(i) Helicase opens double helix of DNA and SSBPs prevent recoiling.
(ii) Primase adds primer complementary to DNA strand.
(iii) DNA polymerase III recognizes primer and constructs new strand in 5' → 3'.
(iv) ***Leading strand***, which elongates towards the replication fork, is built up simply by adding nucleotides continuously to its growing 3' end.

- ***Lagging strand***, which elongates away from replication fork, is synthesized discontinuously as a series of short segments that are later connected.
- These segments called ***Okazaki fragments*** are 100-200 nucleotides long in eukaryotes and 1000-2000 nucleotides long in prokaryotes. Each segment is synthesized in 5' → 3', beginning at the replication fork and moving away from it.
- When the polymerase reaches the 5' end of the lagging strand, ***DNA ligase*** connects these Okazaki fragments.
- The DNA is further unwound, new RNA primers are constructed and DNA polymerase III then jumps ahead 1000-2000 nucleotides (towards the replication fork) to construct another fragment.

POINT TO PONDER

Can you explain the role of DNA polymerase I and DNA polymerase II?

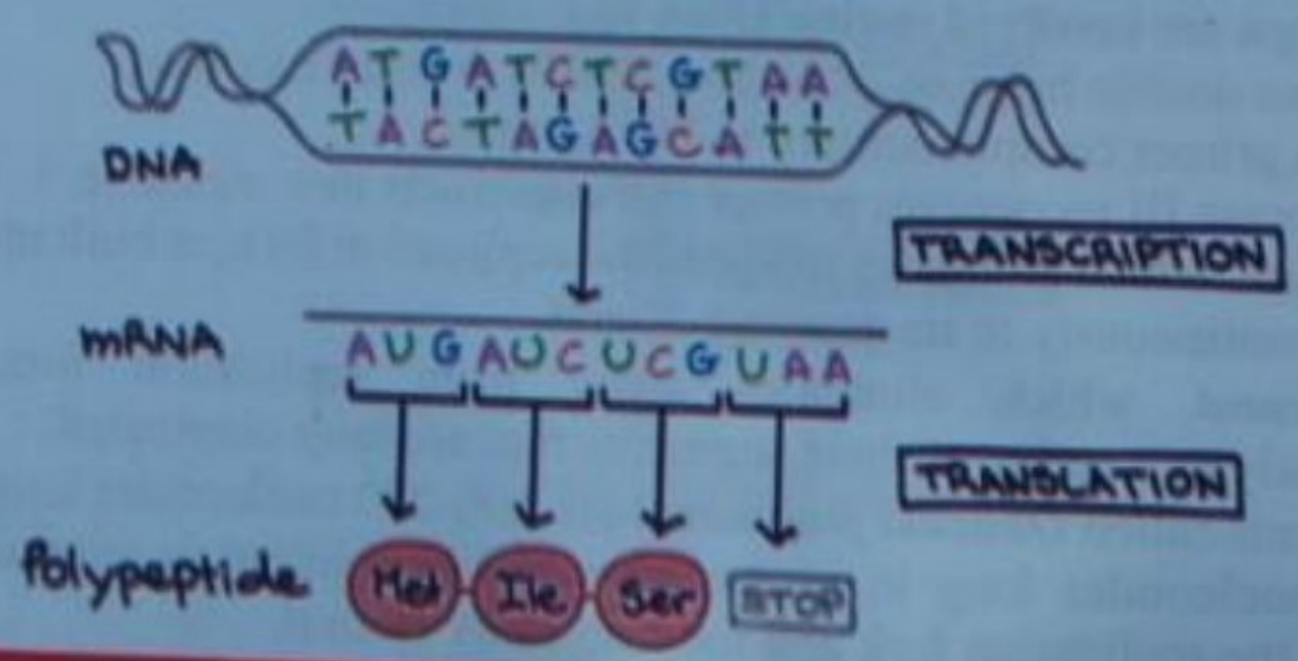
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MECHANISM OF GENE EXPRESSION

- Central dogma is the basic mechanism of reading and expressing genes in living organisms.
- The genetic information resides in DNA and flows down into RNA, which is then converted into proteins.
- The first step of central dogma is the transfer of information from DNA to RNA, which occurs when an mRNA copy of gene is produced. The process is called transcription. mRNA synthesized is complementary transcript of the copied gene.
- The second step of central dogma is the transfer of information from RNA to proteins, which occurs when the information contained in the mRNA is used to direct the synthesis of polypeptides by ribosomes. The process is called translation because sequence of nucleotides in mRNA is translated into amino acid sequence of polypeptide.

THE CENTRAL DOGMA



TRANSCRIPTION

Transcription is the process by which an RNA copy of the DNA sequence encoding the gene is produced with the help of an enzyme, ***RNA polymerase.***

Role of RNA Polymerase

- RNA polymerase enzyme synthesizes RNA from 5′ to 3′ .
- There is only one type of RNA in prokaryotes which is responsible for the synthesis of all three types of RNAs.
- In eukaryotes, ***RNA polymerase I*** synthesizes rRNA, ***RNA polymerase II*** mRNA and ***RNA polymerase III*** synthesizes tRNA.

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Mechanism of Transcription

(i) Binding

- Transcription starts from promoter on DNA template strand.
- The binding of RNA polymerase to the promotor is the first step in gene transcription.
- Promotor is located upstream of gene.
- Two binding sites in prokaryotes and eukaryotes are:

Promotor Site	Prokaryote	Eukaryote
TTGACA	-35	-75
TATAAT	-10	-25

(ii) Initiation

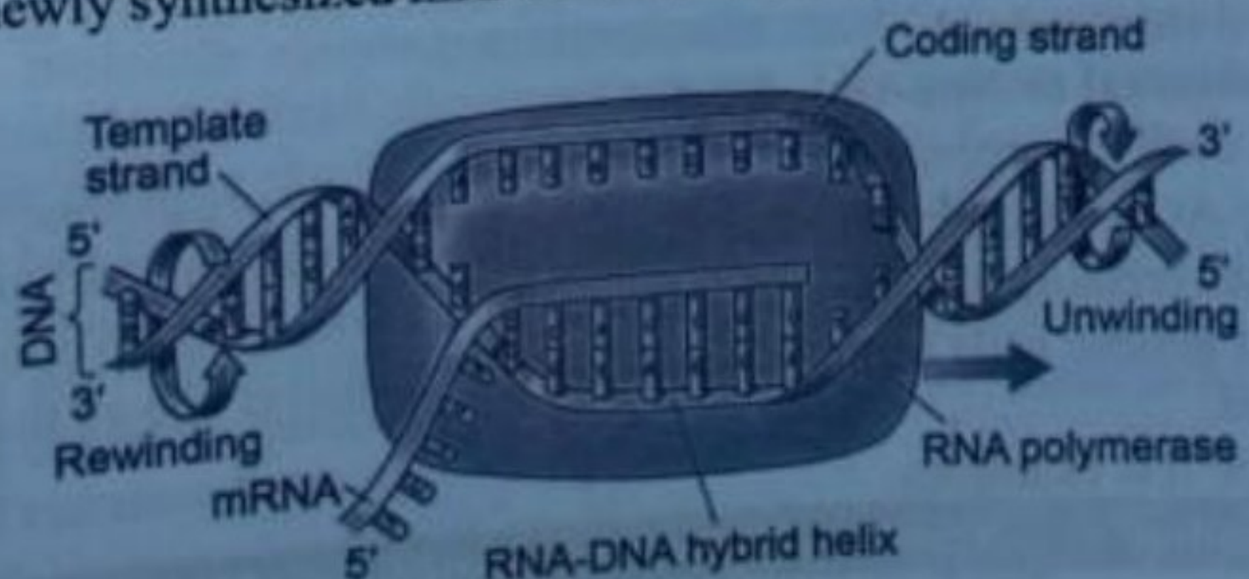
- One of the subunit of RNA polymerase sigma factor, is responsible for correct initiation of transcription process.
- Once the transcription has started, the sigma factor is released and the remaining part of the enzyme (core enzyme) moves on the template strand and completes the transcription of the gene.

(iii) Elongation

- The DNA strands open up at the place where enzyme is attached to the template strand forming transcription bubble.
- RNA polymerase transcribes only one strand of DNA, which is called ***template or antisense strand***.
- Other strand is called ***coding strand or sense strand or opposite strand***.
- The transcription bubble moves down the DNA, leaving the growing strand protruding from the bubble.

(iv) Termination

- The stop sequences at the end of gene terminate the synthesis of mRNA.
- The simplest stop signal is a series of GC base pairs followed by a series of AT base pairs.
- The RNA formed in this region forms a GC hairpin followed by four or more U ribonucleotides.
- The hairpin causes RNA polymerase to stop synthesis.
- In ***bacteria,*** newly synthesized mRNA is directly released into the cytoplasm.



Post-Transcriptional Modification

- In ***eukaryotes,*** mRNA has to travel a large distance from inside the nucleus to ribosomes outside in cytoplasm.
- In eukaryotes mRNA is protected from action of nucleases and phosphatases by addition of 7-methyl GTP is linked 5′ to 5′ with first nucleotide, while poly A tail linked to 3′ end of the RNA.

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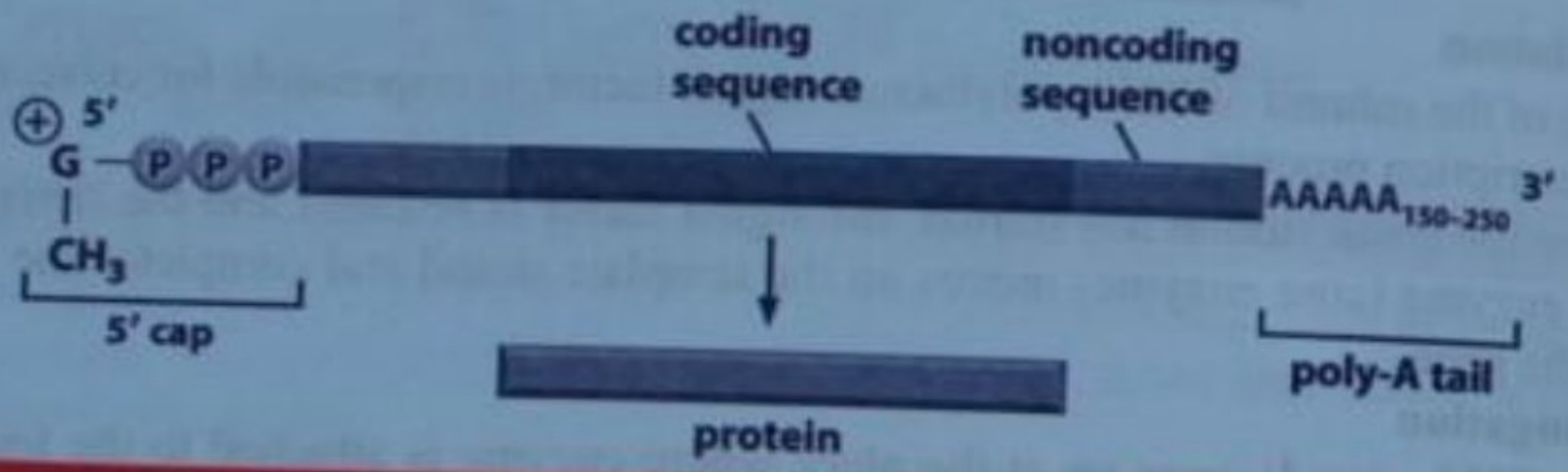
POINT TO PONDER

Can you answer following?

(1) Why we use terms "antisense & sense"?

(2) How 7-methyl GTP is linked 5' to 5'?

RNA capping and polyadenylation



GENETIC CODE

- ***Genetic code*** is a combination of three nucleotides, which specify a particular amino acid.
- As there are three nucleotides in a codon so it is also called as triplet code.
- Triplet code present on mRNA is called codon while on tRNA is called anticodon.

Codons

- There are total 64 codons for 20 amino acids.
- ***Marshal Nirenberg, Philip Leader and Har Gobind Khorana*** tested all 64 codons by making artificial mRNAs and triplet codons and using them to synthesize protein or amino-acyl tRNA complexes in cell free system.
- Out of 64 codons, 3 codons UAA, UAG and UGA do not code for any amino acid and so known as ***nonsense codon*** or stop codon.
- Every gene starts with initiation codon AUG, which encodes the amino acid methionine. This is called ***start codon.***

Genetic Code – Universal or Non-Universal

- The genetic code is universal. It is same in almost all the organisms.
- For example AGA specifies arginine in bacteria, in humans and all other organisms.
- Because of universality of codon, the gene can be transferred from one organism to another.
- The study of genetic code of mitochondrial DNA however shows that genetic code is not that universal.
- Following are few examples:

Codon	Specifies (Nuclear)	Specifies (Mitochondrial)
UGA	Stop codon	Tryptophan
AUA	Isoleucine	Methionine
AGA, AGG	Arginine	Stop codon

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UUU, UUC — Phenyl alanine UUA, UUG — leucine	UCU, UCC, UCA, UCG — serine	UAU, UAC — tyrosine UAA, UAG — stop	UGU, UGC — cysteine UGA — stop UGG — tryptophan
CUU, CUC, CUA, CUG — leucine	CCU, CCC, CCA, CCG — proline	CAU, CAC — histidine CAA, CAG — glutamine	CGU, CGC, CGA, CGG — arginine
AUU, AUC, AUA — isoleucine AUG — methionine	ACU, ACC, ACA, ACG — threonine	AAU, AAC — asparagine AAA, AAG — lysine	AGU, AGC — serine AGA, AGG — arginine
GUU, GUC, GUA, GUG — valine	GCU, GCC, GCA, GCG — alanine	GAU, GAC — aspartic acid GAA, GAG — glutamic acid	GGU, GGC, GGA, GGG — glycine

TRANSLATION

- It is the process by which amino acids are arranged in form of polypeptide chain according to the sequence of nucleotides in mRNA.

Formation of Aminoacyl-tRNA

- Particular tRNA molecules become attached to specific amino acids through the action of activating enzymes called aminoacyl-tRNA synthetase.
- For 20 different amino acids, there are 20 different tRNA and enzymes.

(1) **Initiation**

- In prokaryotes, polypeptide synthesis begins with the formation of initiation complex.
- First a tRNA molecule carrying a chemically modified methionine (called N-formyl methionine) binds to the small ribosomal subunit. This is done by initiation factor.
- Initiation factor position the tRNA on the ribosomal surface at the P site (peptidyl site) where peptide bond will form. Nearby two other sites will form.
- A site (for aminoacyl site) where successive aminoacyl-tRNA will bind.
- E site (for exit site) where empty tRNA will exit the ribosome.
- This initiation complex, guided by another initiation factor, binds to AUG on the mRNA.

(2) **Elongation/ Translocation**

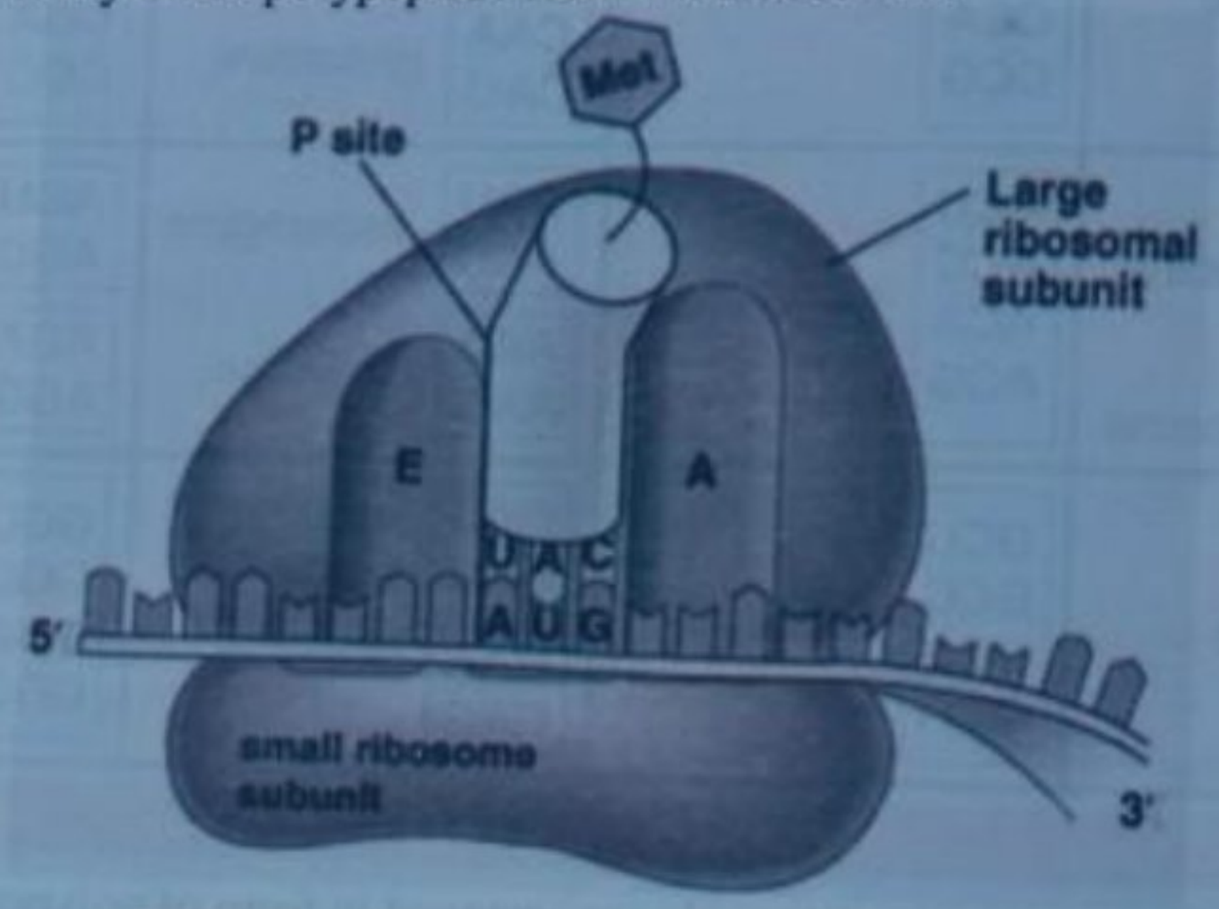
- Large ribosomal subunit binds with small subunit on mRNA.
- An elongation factor binds another aminoacyl-tRNA at A site.
- The two amino acids which now lie adjacent to each other undergo a chemical reaction, catalyzed by the large ribosomal subunit, which releases the initial methionine from its tRNA and attached it by a peptide bond to the second amino acid.
- The ribosome now moves (translocate) three more nucleotides along the mRNA molecule in the 5' → 3' direction, guided by another elongation factor.

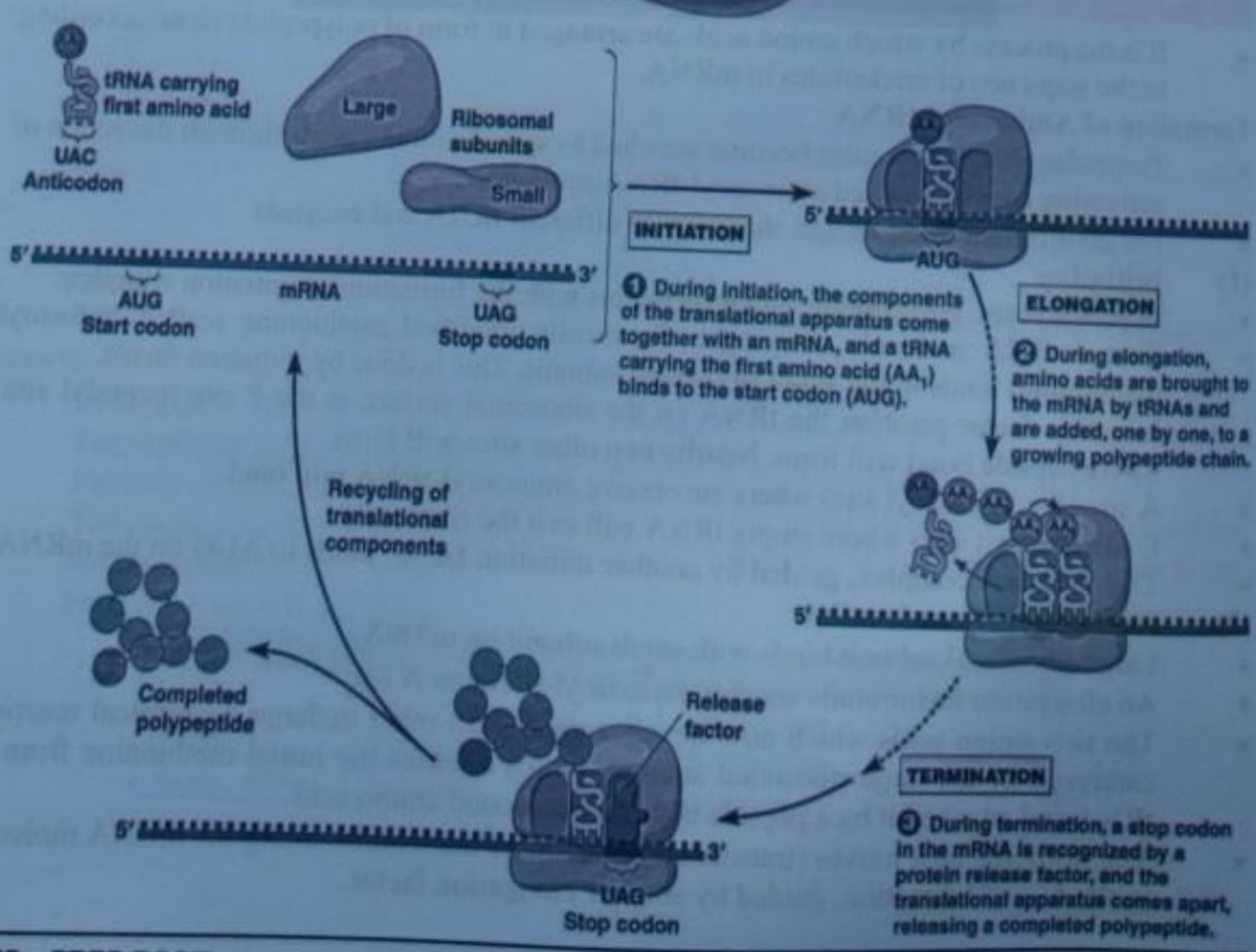
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- This movement translocate the initial tRNA to the E site and ejects it from the ribosome and repositions the growing polypeptide.
- Same process is repeated again and again.

(3) Termination

- Elongation continues in this fashion until a chain-terminating non-sense codon is exposed (e.g. UAA).
- Nonsense codons do not bind to tRNA but they are recognized by release factors, that release the newly made polypeptide from the ribosomes.





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MUTATIONS

- Any change in heredity material/ DNA is called mutation.
- Changes in the DNA occur either due to mistake in replication or damage to the genetic message causing mutations.
- The mutations in somatic cells do not pass on to offspring and so have little evolutionary consequence than germ line changes.
- The mutation in germ line cell is passed to subsequent generations thus providing raw material from which natural selection produces evolutionary change.
- Mutations can broadly be classified as:
  - (i) Chromosomal Aberration
  - (ii) Point Mutation

(i) Chromosomal Aberration

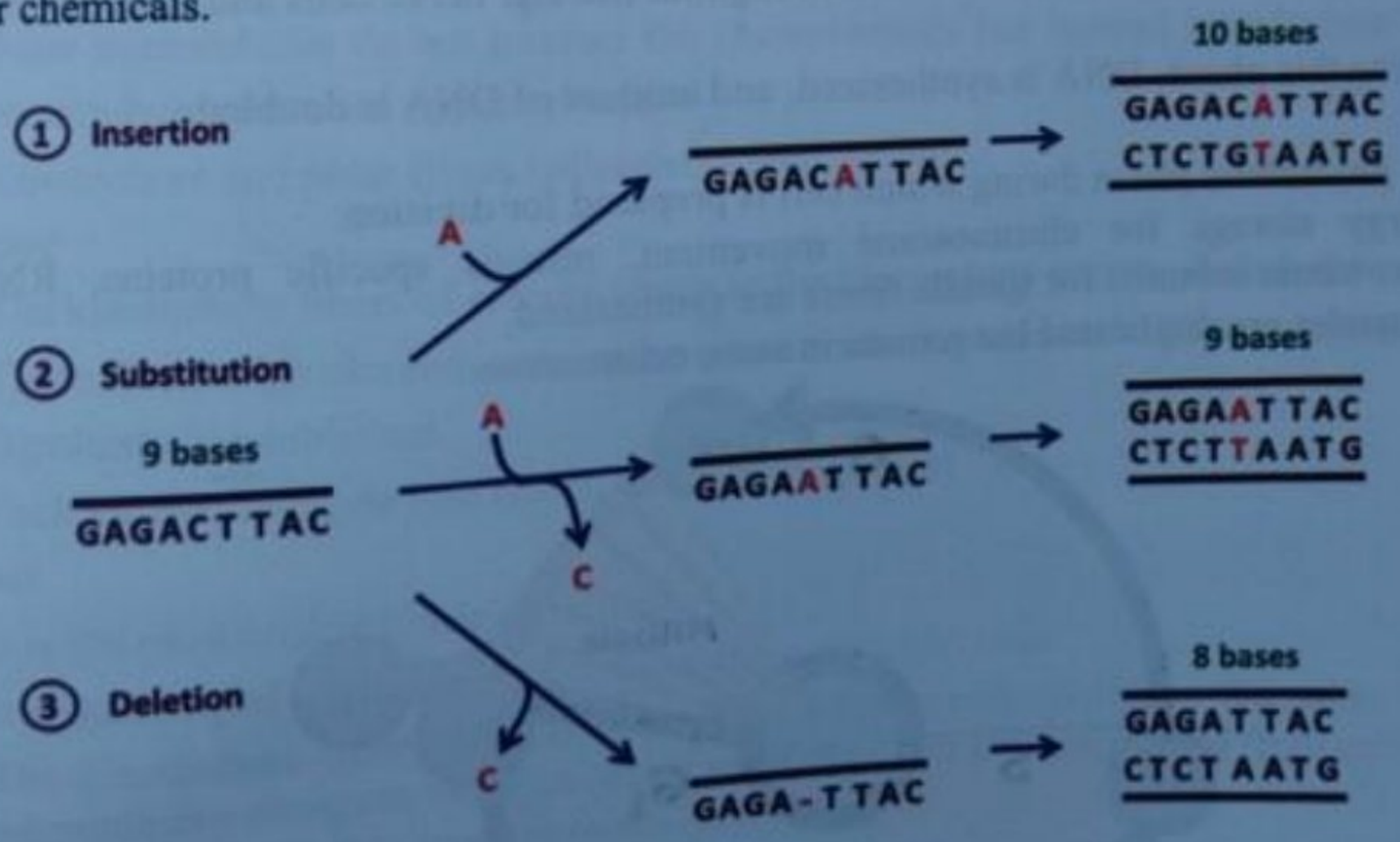
Chromosomal aberrations are mega-changes which involve:

- Presence of an extra chromosome
- Loss of chromosome
- Deletions, insertions, inversion etc in the parts of chromosome.

Such chromosomal aberrations lead to syndromes like Down's syndrome, Klinefelter's syndrome etc.

(ii) Point Mutations

- Such alterations that involve one or few base pairs in the coding sequence are called point mutations.
- Some point mutations occur due to spontaneous pairing errors that occur during DNA replication.
- Some point mutations result from damage to DNA caused by mutagens, usually radiations or chemicals.



Examples

Sickle Cell Anemia

In sickle cell anemia, a point mutation leads to change of amino acid glutamic acid into valine at position 6 from N terminal end in hemoglobin β chain. This consequently alters the tertiary structure of the hemoglobin molecule, reducing its ability to carry oxygen.

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Phenylketonuria

In phenylketonuria, phenylalanine is not degraded because of defective enzyme phenylalanine hydroxylase. Phenylalanine consequently accumulates in the cells leading to mental retardation, as brain fails to develop in infancy.

CELL CYCLE

- Sequence of changes which involves period of growth, replication of DNA followed by cell division.
- It comprises two phases i.e. interphase and mitotic phase. Mitotic phase is phase of apparent cell division.
- In human cells, average cell cycle is about 24 hours while in yeast is of only 90 minutes.

INTERPHASE

- It is period of non-apparent division.
- It is period between two consecutive divisions.
- It was misleadingly called as resting phase.
- It is period of great biochemical activity.
- It is further divided into G1-phase, S phase and G2-phase. In humans, mitosis takes 30 minutes, G1 9 hours, S phase 10 hours and G2 4.5 hours.

G1 Phase

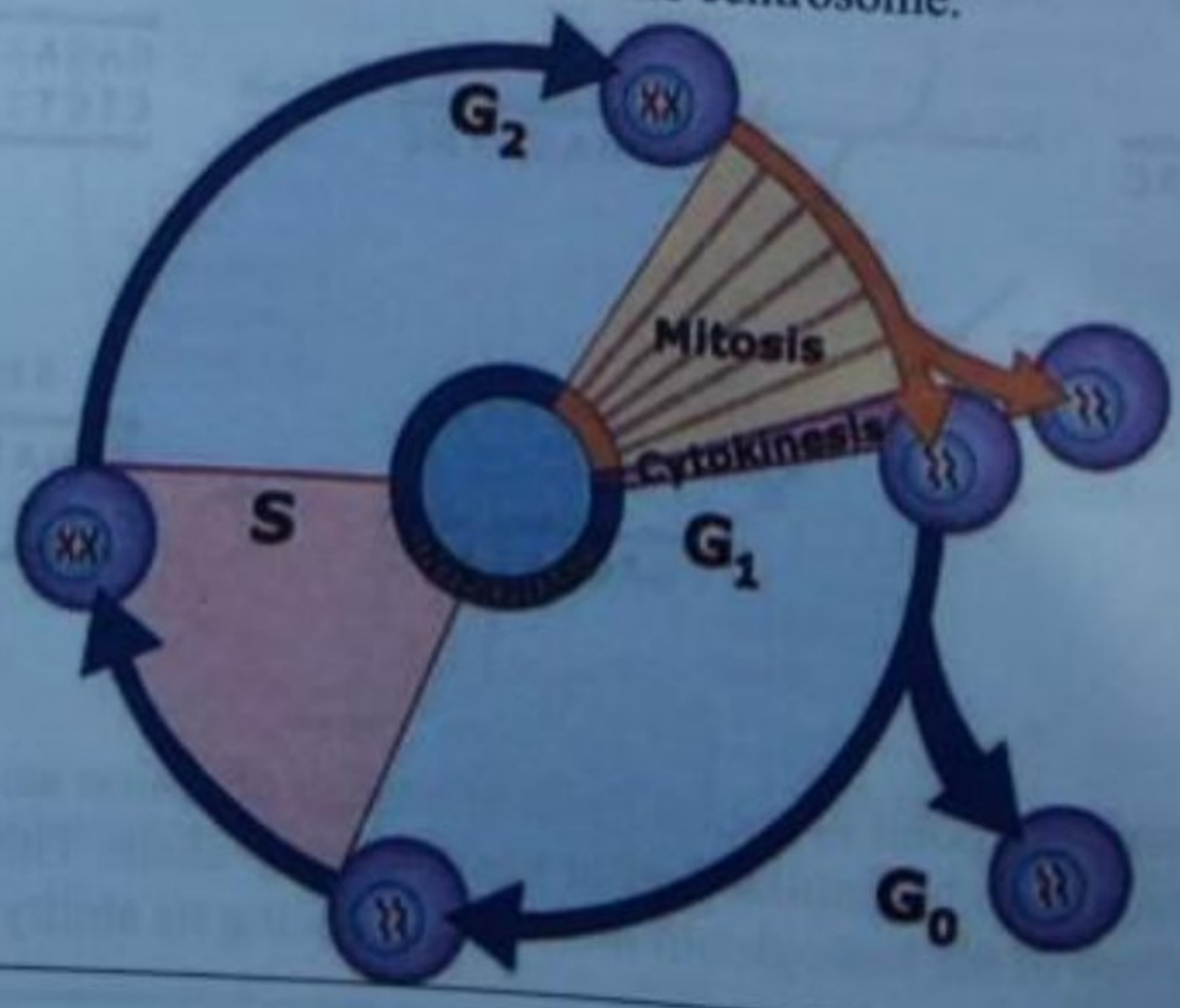
- It is period of extensive metabolic activity.
- In it cell normally grows in size, specific enzymes are synthesized and DNA base units are accumulated for the DNA synthesis.
- Post-mitotic cell can exit the cell cycle during G1 entering a phase called G0 and remain for days, weeks or even some cases throughout life e.g. nerve cells and cells of eye lens.

S Phase

- During this phase, DNA is synthesized, and amount of DNA is doubled.

G2 Phase

- It is pre-mitotic phase during which cell is prepared for division.
- Energy storage for chromosome movement, mitosis specific proteins, RNA and microtubule subunits for spindle fibers are synthesized.
- Centrioles are duplicated but remain in same centrosome.



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MITOSIS

- It is the type of cell division, which ensures the same number of chromosomes in the daughter cells as that in the parent cells.
- It takes place in haploid as well as diploid cells.
- Mitosis is a continuous process but conventionally it can be divided into karyokinesis and cytokinesis.

KARYOKINESIS

- Division of nucleus is called karyokinesis.
- It can further be divided into four phases.

Prophase

- The chromatin material is condensed by folding.
- Chromosomes appear as thin threads (0.25-50 μm in length) at the beginning of prophase.
- Chromosomes become more and more thick ultimately each chromosome is visible having two sister chromatids, attached at centromere.
- Towards the end of prophase, nuclear envelope disappears, nucleoli disappear, and nuclear material is released in the cytoplasm.
- Cytoplasm becomes more viscous.
- Two pairs of centrioles separate and migrate to opposite sides of the nucleus.
- Mitotic apparatus starts to establish.
- Three sets of microtubules originate from each pair of centrioles.

(i) One set of astral microtubules that radiate outward and form aster.

(ii) Kinetochore microtubules which are attached to chromosome at kinetochore.

(iii) Polar microtubules do not interact the chromosomes but instead interdigitate with polar microtubules from the opposite pole.

- Kinetochore and polar fibers collectively form spindle.

Metaphase

- The kinetochore fibers of spindle attach to the kinetochore region of chromosome.
- These fibers align chromosomes at the equator forming equatorial plate or metaphase plate.
- Bipolarity is established.
- Each kinetochore gets two fibers, one from each pole.

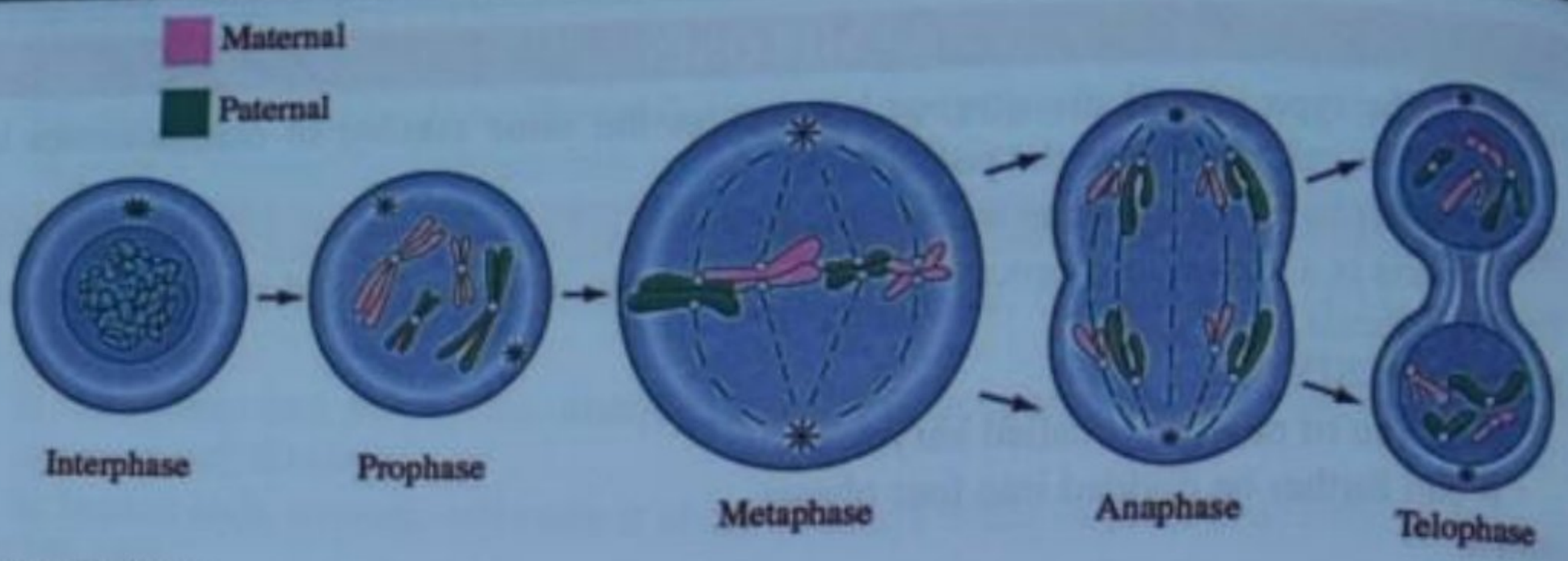
Anaphase

- It is the most critical phase of mitosis.
- It ensures equal distribution of chromatids in daughter cells.
- The kinetochore fibers contract towards their respective poles, at the same time polar microtubules elongate, exert force and sister chromatids are separated from centromere.
- Half sister chromatids travel towards each pole.

Telophase

- Chromosomes reach at their respective poles.
- The chromosomes decondense due to unfolding, ultimately disappear as chromatin.
- Mitotic apparatus disorganizes.
- Nuclear membrane and nucleoli reappear.
- Two nuclei are formed at two poles of cell.

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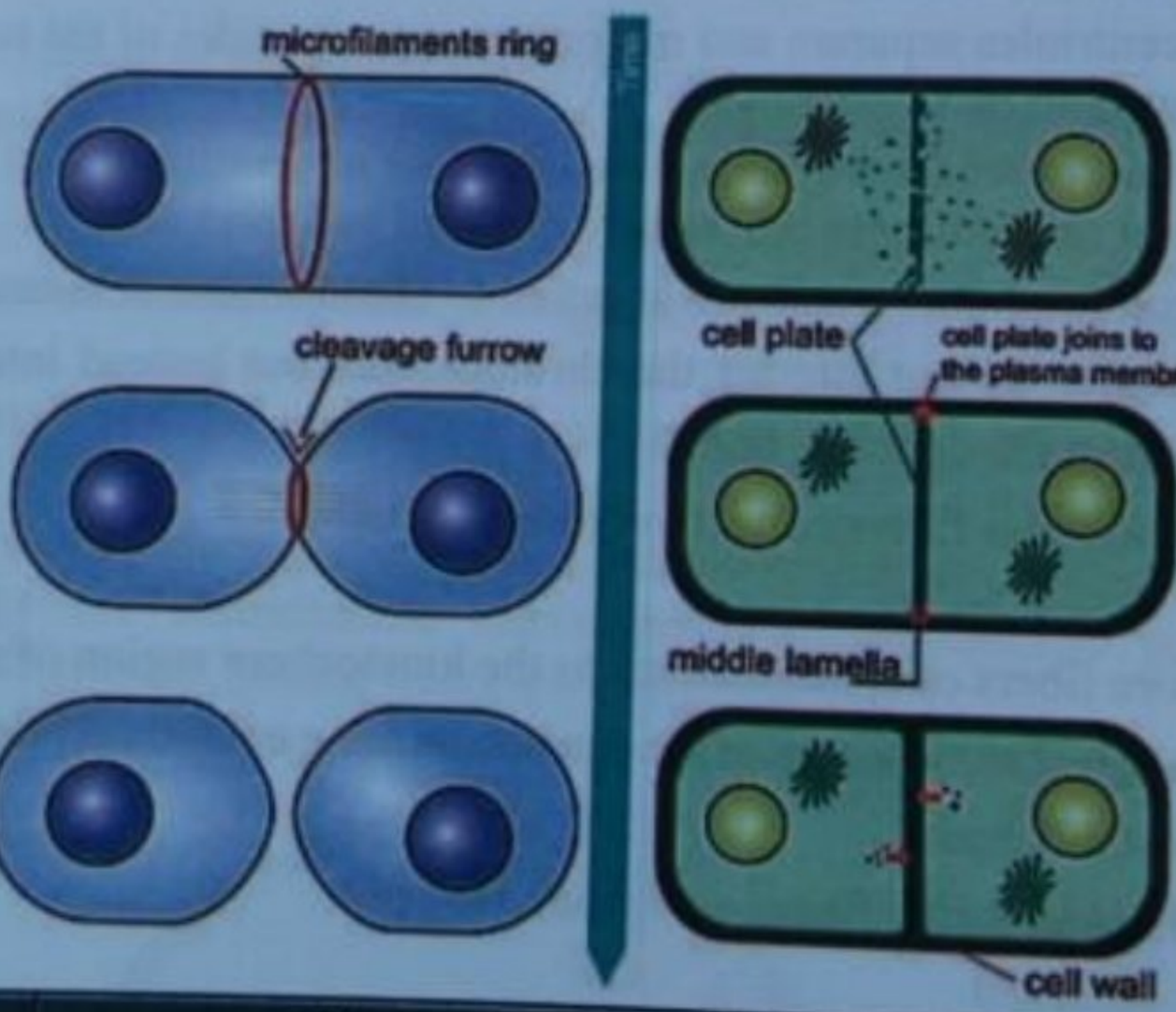
CYTOKINESIS

In Animal Cell

Late telophase → Astral microtubules → Activation of actin & myosin → Contractile ring → Cleavage furrow → Two daughter cells

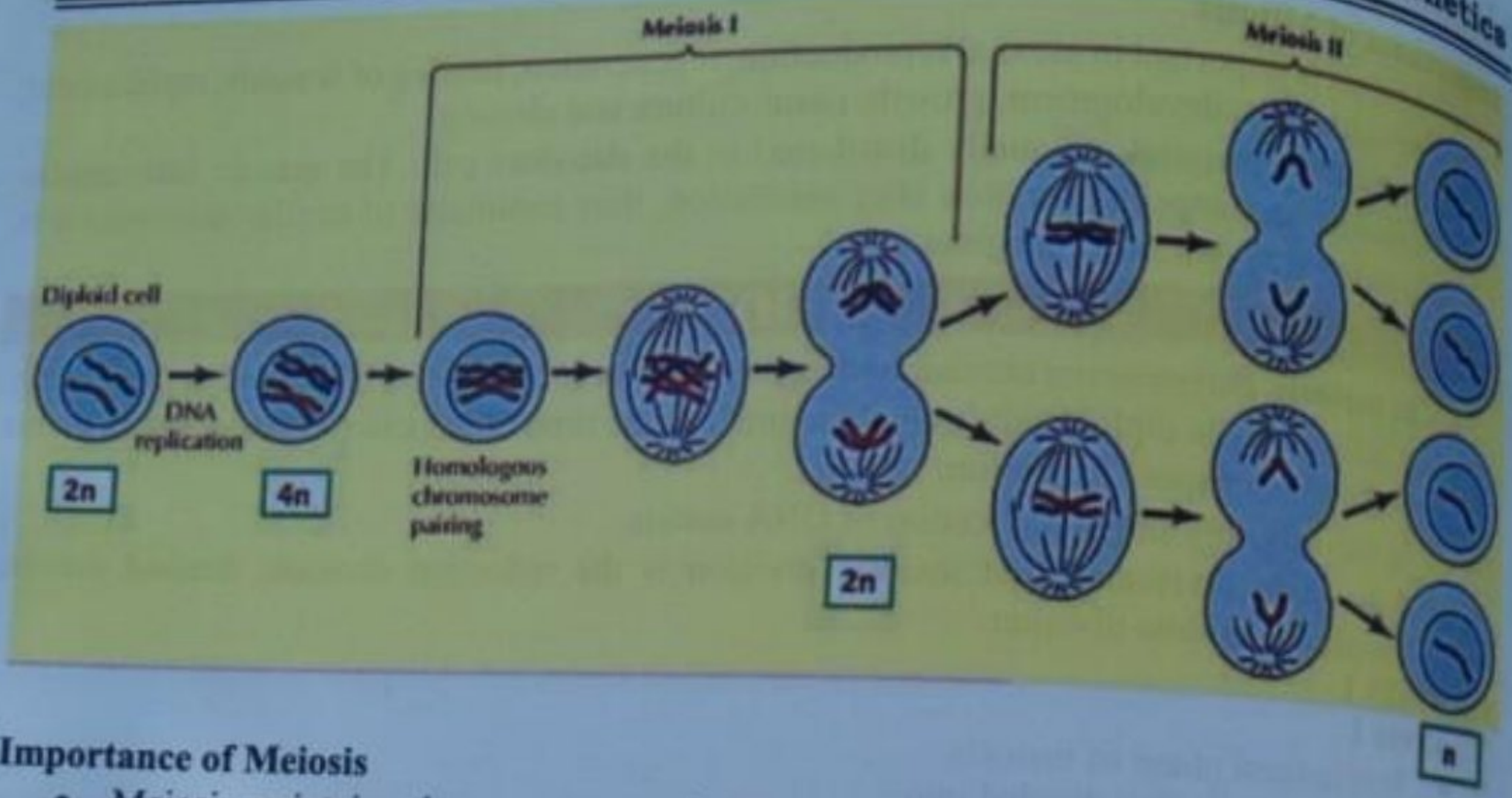
In Plant Cell

Golgi complex → Vesicles → Phragmoplast → Two daughter cells



Feature	Plants	Animals
Centriole	Absent	Present
Mitotic apparatus	Spindles	Centriole, asters, spindles
Change in cells shape	No	Yes
Cytokinesis	Inward to outward	Outward to inward
	Phragmoplast	Furrowing, cleavage of cell membrane
Functions	Gamete formation, vegetative propagation, tissue culturing, growth	Asexual reproduction, healing, regeneration, cloning, replacement of worn out and old RBCs, development, growth

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Importance of Meiosis

- Meiosis maintains chromosome number constant generation after generation
- ***Crossing over and random assortment of chromosomes*** are two significant happenings of meiosis.
- Both these phenomenon cause variations and modifications in the genome which is the ***basis for evolution***

MITOSIS AND MEIOSIS

Feature	Mitosis	Meiosis
Definition	Chromosome number is same in daughter cells as in parent cell	Chromosomes number is reduced to half
Constancy of chromosome no.	Cell to cell	Generation to generation
Pairing	No	Yes
Crossing over	No	Yes
Variations	No	Yes
Evolution	No	Yes
Cells involved	Both diploid and haploid / Somatic cells	Only diploid / Reproductive cells
Reproduction	Asexual	Sexual
Divisions	Single	Two (I & II)
Interphase	Long	Short
G_2	Yes	No
Daughter cells	2	4
Replication of chromosome	Yes	No
Role in plants	Gamete formation, propagation	Spore formation
Role in animals	Asexual reproduction, development, growth	Gamete formation

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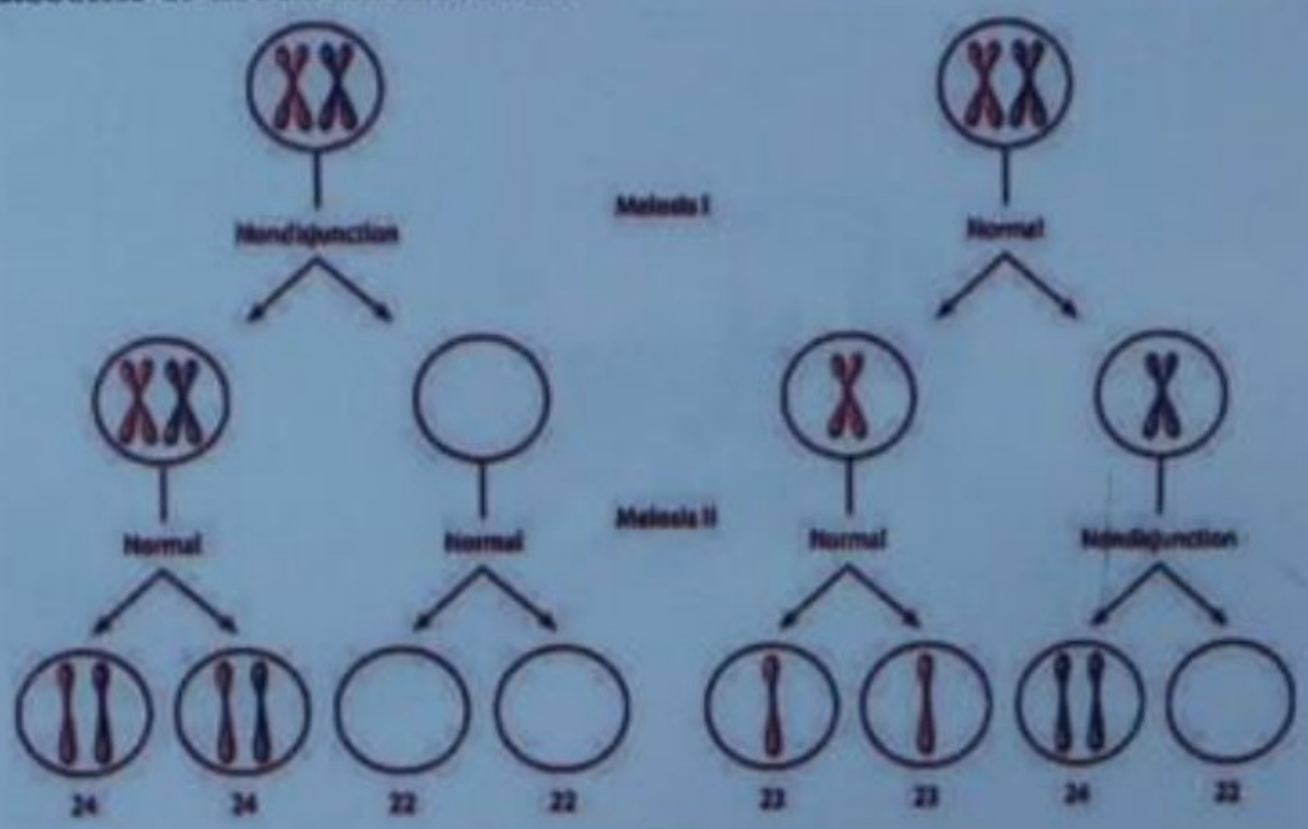
MEIOTIC ERRORS

NON-DISJUNCTION

- Chromosomes fail to segregate during anaphase and telophase and do not finish with equal distribution of chromosome among all the daughter nuclei.
- It results either increase or decrease in the number of chromosome causing serious physical, social and mental disorders.
- It may be in autosome or in sex chromosome.

POINT TO PONDER

Can you explain, why the chance of Down syndrome is increased with maternal age?



Number of chromosomes in gametes

Feature	Down's Syndrome	Klinefelter's Syndrome	Turner's Syndrome
Chromosome	2Ist autosome	Sex chromosome	Sex chromosomes
Chromosome No.	Additional 2n+1 47	Additional 2n+1 , 2n+2 , 2n+3 47 48 49	Missing 2n-1 45
Gamete	24	24	22
Gamete involved	Ova	Sperm	Egg
Chances	Teen age mother = 1/1000 40 years = 1/100 45 years = 3/100	1/1500	1/61000
Abortions	1/40	0	1/18
Affected Individuals	Flat, broad face, squint eyes with skin folded in the inner corner, protruding tongue, mental retardation, defective development of CNS	Phenotypically male with enlarged breasts tendency to tallness, obesity, small testes, no sperm at ejaculation, under development of secondary sex characters.	Often do not survive pregnancy, aborted mostly, if survived have female appearance, short stature, webbed neck, no ovaries, complete absences of germ cells.
Chromosomal relation	45 autosome+XY	44 autosome+XXY	44 autosome+X

Syndrome	Chromosome
Down	Trisomy 21
Patau	Trisomy 13
Edward	Trisomy 18
Turner	Monosomy (XO)
Metafemale	Trisomy (XXX)
Klinefelter	Trisomy (XXY)
Jacobs	Trisomy (XYY)

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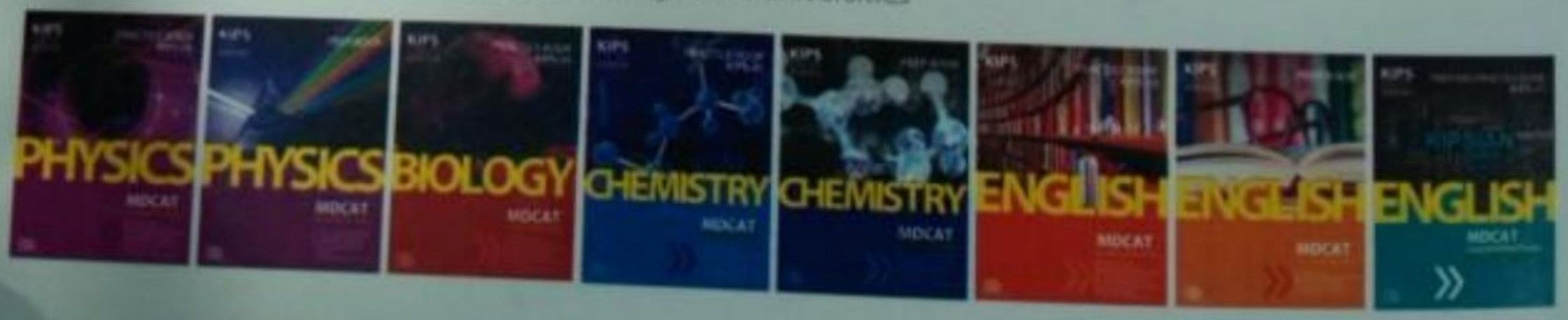
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