जीव विज्ञान
Biology

कक्षा / Class XI

2026-27

विद्यार्थी सहायक सामग्री
Student Support Material



केन्द्रीय विद्यालय संगठन~Kendriya Vidyalaya Sangathan

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संदेश

शिक्षा केवल पुस्तकों तक सीमित ज्ञान नहीं है; यह स्वयं को पहचानने, अपने विचारों को विस्तार देने और जीवन की चुनौतियों का आत्मविश्वास से सामना करने की सतत् यात्रा है। केन्द्रीय विद्यालय संगठन का सदैव यह प्रयास रहा है कि प्रत्येक विद्यार्थी के लिए ऐसा शिक्षण वातावरण हो, जहाँ जिज्ञासा को प्रोत्साहन मिले, सीखना आनंददायी बने और प्रत्येक बालक अपनी अंतर्निहित क्षमताओं को पहचानकर उन्हें विकसित कर सके।

राष्ट्रीय शिक्षा नीति 2020 ने शिक्षा को सिर्फ रटने से समझने, सूचना से ज्ञान और ज्ञान से जीवनोपयोगी दक्षताओं की ओर अग्रसर किया है। आज का समय कृत्रिम बुद्धिमत्ता (Artificial Intelligence – AI), डिजिटल नवाचार और निरंतर बदलती तकनीकों का है। ऐसे युग में केवल तथ्यों का ज्ञान पर्याप्त नहीं है; आवश्यक है कि विद्यार्थी मनन- चिंतन करना सीखें, प्रश्न पूछें, समस्याओं का समाधान खोजें और नए विचारों के साथ आगे बढ़ें। यही क्षमताएँ उन्हें भविष्य के लिए तैयार करेंगी।

इन्हीं उद्देश्यों को ध्यान में रखते हुए केन्द्रीय विद्यालय संगठन के पाँचों आंचलिक शिक्षा एवं प्रशिक्षण संस्थानों (ZIETs) के माध्यम से, समर्पित एवं अनुभवी शिक्षकों द्वारा कक्षा 9 से 12 के विद्यार्थियों के लिए यह विद्यार्थी सहायक सामग्री तैयार की गई है। यह केवल परीक्षा की तैयारी की संकलन सामग्री नहीं है, बल्कि विषयों को सरलता से समझने, अवधारणाओं को स्पष्ट करने, नियमित अभ्यास करने और आत्मविश्वास के साथ आगे बढ़ने का एक विश्वसनीय साथी है।

इस सामग्री में विषय-वस्तु को विद्यार्थियों की आवश्यकताओं के अनुरूप सरल, व्यवस्थित एवं दक्षता-आधारित दृष्टिकोण से प्रस्तुत किया गया है। मुझे प्रसन्नता है कि इसे हमारे शिक्षकों के अनुभव, नवाचार और विद्यार्थियों के प्रति उनकी प्रतिबद्धता ने समृद्ध बनाया है। मुझे विश्वास है कि यह सामग्री विद्यार्थियों की सीखने की यात्रा को अधिक सहज, रोचक और प्रभावी बनाएगी तथा उन्हें बोर्ड परीक्षाओं के साथ-साथ जीवन की व्यापक चुनौतियों के लिए भी तैयार करेगी।

मेरा विश्वास है कि जब एक जिज्ञासु विद्यार्थी, प्रेरित शिक्षक और सार्थक शिक्षण संसाधन एक साथ आते हैं, तब शिक्षा केवल उपलब्धि का माध्यम नहीं रहती, बल्कि व्यक्तित्व निर्माण की एक सशक्त प्रक्रिया बन जाती है। यही भावना इस विद्यार्थी सहायक सामग्री के केंद्र में है।

मेरी हार्दिक शुभकामनाएँ हैं कि आप सभी सीखने की इस यात्रा में निरंतर आगे बढ़ें, अपने सपनों को नए आयाम दें और ज्ञान, संवेदनशीलता तथा नवाचार के साथ राष्ट्र निर्माण में अपना महत्वपूर्ण योगदान दें।

शुभकामनाओं सहित।

(विकास गुप्ता)

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COURSE STRUCTURE
CLASS XI (2026-27)
(THEORY)

Time: 03 Hours **Max. Marks: 70**

Unit	Title	Marks
I	Diversity of Living Organisms	15
II	Structural Organization in Plants and Animals	10
III	Cell: Structure and Function	15
IV	Plant Physiology	12
V	Human Physiology	18
	Total	**70**

CHAPTER 1: THE LIVING WORLD

CBSE Curriculum (26-27): Biodiversity; Need for classification; three domains of life; taxonomy and systematics; concept of species and taxonomical hierarchy; binomial nomenclature.

1. Biodiversity: massive variety of life—from pets and insects to plants and microscopic organisms
The Rule of Scale: The larger the area you explore (like moving from your backyard to a dense forest), the greater the number and kinds of organisms you will find.

- **Species:** Each distinct kind of plant, animal, or organism represents a specific **species**.
- **Biodiversity Defined:** This massive number and variety of organisms on Earth is called **biodiversity**.
- **The Current Count:** Scientists have identified and described between **1.7 to 1.8 million species** so far, and new ones are being discovered every day.

2. The Problem with Local Names

Living organisms are known by different local or regional names depending on the language, culture, and geographic location.

- **The Core Issue:** A single organism might have dozens of different names within a single country, and entirely different names globally.
- **The Consequence:** If scientists and researchers relied on local names, it would lead to massive communication barriers and confusion. It would be nearly impossible to ensure everyone is referring to the exact same organism.

3. The Solution: Identification and Nomenclature

- **Identification** is the process of correctly describing an organism so we know precisely what it is and what features make it unique.
- **Nomenclature** is the process of giving a scientific name to a living organism so that it is known by the exact same name all over the world.

ICBN International Code for Botanical Nomenclature
ICZN International Code for Zoological Nomenclature

Binomial nomenclature: -

This naming system given by Carolus Linnaeus. The system of providing a name with two components, the generic and the species is called binomial nomenclature. Each name has two components – the **Generic name** and the **specific epithet**. Ex.

Scientific name	Genus	Species Epithet
Mangifera indica	Mangifera	indica

Some universal rules of nomenclature: -

- Carolus Linius proposed Binomial System.
- Biological names are generally in **Latin** and written in **italics.** They are Latinised or derived from Latin irrespective of their origin.
- The first word in a biological name represents the **genus** while the second component denotes the **specific epithet.**
- Both the words in a biological name, when handwritten, are separately underlined, or printed in italics to indicate their Latin origin.
- The first word denoting the genus starts with a capital letter while the specific epithet starts with a small letter. It can be illustrated with the example of *Mangifera indica*.

Q. 1. Identify the botanical name of potato-
2. A binomial nomenclature consists of _____and_____.
3. a) Who proposed the concept of Binomial Nomenclature. Write the scientific name of housefly.
b) What are the rules of writing binomial nomenclature

1. Taxa (Singular: Taxon): These are the convenient, scientific categories used to group and study living organisms.

- **Function:** Organisms are placed into these categories based on shared, observable characteristics.
- **Examples:** "Mammals," "Plants," "Insects," or even specific groups like "Dogs" are all examples of taxa at different levels.

2. Taxonomy: The formal branch of biology dealing with the process of classification.

- **The Process:** Based on their unique characteristics, all living organisms are systematically grouped and classified into different **taxa**.
- **Core Principles:** It involves the characterization, identification, nomenclature (naming), and classification of organisms.

3. Systematics: An advanced branch of biology that goes beyond basic classification by integrating the **interrelationships** (evolutionary history and connections) between organisms.

- **Etymology:** Derived from the Latin word ***systema***, which translates to the *"systematic arrangement of organisms."*
- **Scope:** While taxonomy focuses on naming and grouping, systematics looks at the bigger picture—how different organisms evolved and how they relate to one another over time.

Why Do We Classify Organisms?

- Manages Vast Diversity: It organizes 1.7 to 1.8 million known species into a structured, manageable format.
- Identifies Shared Traits: It helps scientists understand how different species share common anatomical, physiological, or genetic features.
- Traces Evolutionary Paths: It reveals the ancestral and evolutionary connections (phylogeny) between different groups of life.
- Universal Communication: It ensures a standard framework so researchers globally are discussing the exact same organism.

Q. The process of grouping organisms based on similarities and evolutionary relationships is known as:

Ans. Classification

Taxonomic categories

- **Species** a group of individual organisms which can interbreed and produce breed able offspring.
- **Genus** comprises a group of related species which has more characters in common in comparison to species of other genera
- **Family** has a group of related genera with still less number of similarities as compared to genus and species.
- **Order** being a higher category, is the assemblage of families which exhibit a few similar characters.
- **Class** This category includes related orders.
- **Phylum** Classes constitute the next higher category called Phylum.
- **Kingdom** All phyla are assigned to the highest category called Kingdom

Q.1. Amongst family, species and genus which will show the least similarity?

Q. 2. Explain in brief about the concept of species. Also, provide three examples of species.

Hierarchy of Classification



	Animalia	Plantae	Animalia	Plantae
Phylum/Division	Chordata	Angiospermae	Chordata	Angiospermae
Class	Mammalia	Monocotyledonae	Mammalia	Dicotyledonae
Order	Carnivora	Poales	Primata	Sapindales
Family	Felidae	Poaceae	Hominidae	Anacardiaceae
Genus	Panthera	Triticum	Homo	Mangifera
Species	*Panthera leo*	*Triticum aestivum*	*Homo sapiens*	*Mangifera indica*

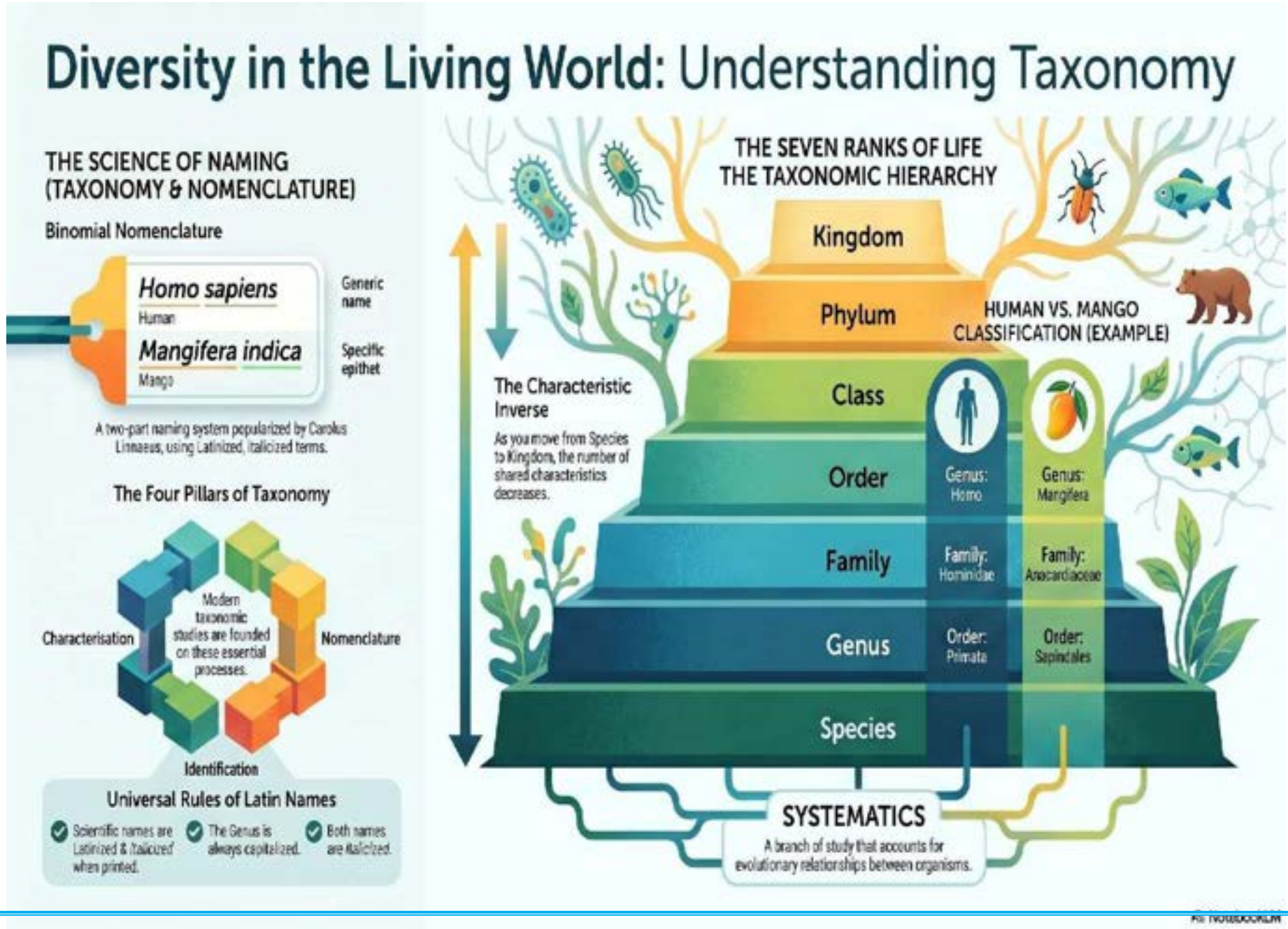
Q1.Write the correct sequence of the taxonomic hierarchy.

Q. 2. Write A, B, C, D, E and F in the given table below.

Common Name	**A**	**Wheat**
Biological Name	***Homo sapiens***	***Triticum aestivum***
Species	***sapiens***	***aestivum***
Genus	***Homo***	***Triticum***
Family	**B**	**Poaceae**
Order	**Primata**	**C**
Class	**D**	**Monocotyledonae**
Phylum/Division	**Chordata**	**E**
Kingdom	**F**	**Plantae**

See answer of intext Questions at page No. 158 in the Question Bank QR under Test Your Knowledge

Diversity in the Living World: Understanding Taxonomy



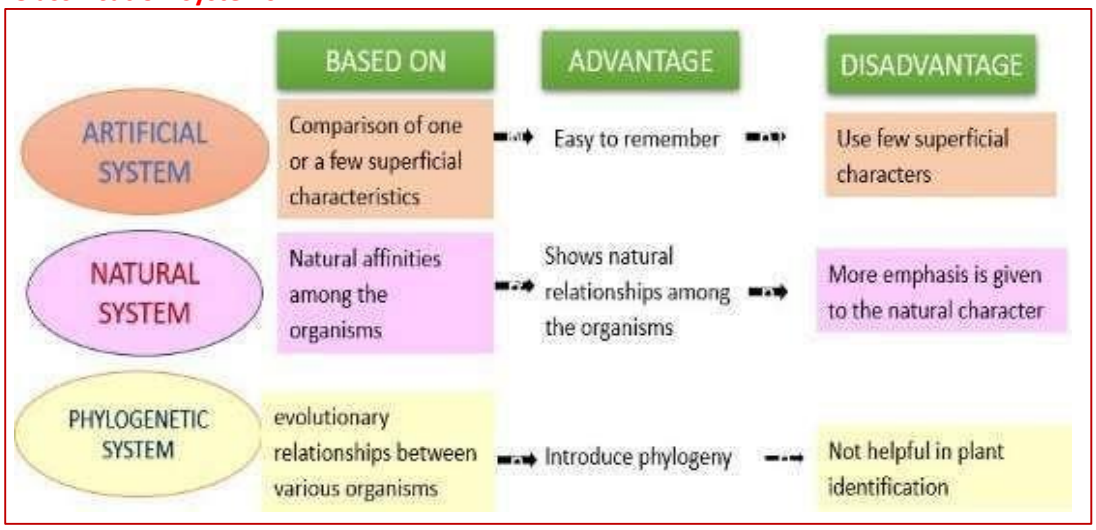
CHAPTER 2
BIOLOGICAL CLASSIFICATION

CBSE syllabus: Five kingdom classification; Salient features and classification of Monera, Protista and Fungi into major groups; Lichens, Viruses and Viroids.

Modern approaches in Taxonomy

Numerical Taxonomy	Based on quantity, Numbers and codes are assigned to all the characters and the data are then processed using a computer
Cytotaxonomy	Based on cytological information like chromosome number, structure, behavior
Chemotaxonomy	Based on the evidences from chemical constituents

Classification systems



Two Kingdom Classification

In Linnaeus' time a Two Kingdom system of classification with Plantae and Animalia kingdoms was developed that included all Plants and animals respectively.

Five Kingdom Classification

R.H. Whittaker (1969) proposed a Five Kingdom Classification.

The kingdoms defined by him were named Monera, Protista, Fungi, Plantae and Animalia. Animalia.

5 Kingdom classification of the living organism is based on the following 5 criteria :-

1	Structure of cells	Living organisms can be divided into two major categories on the basis of cell structure:- i. Prokaryotic cells. ii. Eukaryotic cells
2	Body organisation	The principle of evolution has revealed that the earliest organisms were simple unicellular. But in due course of time they evolved into multicellular organisms, becoming finally complex
3	Modes of Nutrition	He classified organisms on the basis of autotrophic and heterotrophic modes of nutrition
4	Phylogenetic Relationship	Phylogeny is the evolutionary history of an organism. Therefore, Phylogenetic relationships of organisms are alone are the index of their true kinship

Characteristics of the Five Kingdoms:-

SN	Characteristics	Monera	Protista	Fungi	Plantae	Animalia
1	**Cell Type**	Prokaryote	Eukaryote	Eukaryote	Eukaryote	Eukaryote
2	**Body Organisation**	Unicellular, cellular	Unicellular, Cellular	Multicellular, Tissue	Multicellular - cellular/ Tissue/ Organ	Multicellular- cellular/Tissue/ Organ/Organ system
3	**Nuclear Membrane**	Absent	Present	Present	Present	Present
4	**Mode of Nutrition**	Autotrophic (Photosynthetic /Chemosynthetic)Heterotrophic (Parasitic, Saprophytic)	Autotrophic (Photosyntheti) Heterotrophic (Parasitic, Saprophytic, Holozoic)	Heterotrophic (Saprophytic, Parasitic)	Photosynthetic	Heterotrophic (Holozoic Saprophytic, Parasitic)
5	**Cell Wall**	Present Non-cellulosic	Present in few, cellulose	Present, non-Cellulosic Polysaccharide (Chitin)	Present (Cellulose)	Absent

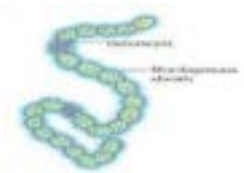
MONERA:-

- Cell is prokaryotic. Mostly unicellular but some are cell aggregates or colonial.
- They Include Eubacteria, Cyanobacteria, Archaeobacteria and Mycoplasma.

Groups of bacteria based on their shapes:-



Categories of bacteria

EUBACTERIA	Eubacteria or 'true bacteria' are characterised by the presence of a rigid cell wall, and if motile, a flagellum. They include:- **Chemosynthetic bacteria** Oxidize various inorganic substances such as nitrates, nitrites and ammonia and play important role in recycling nutrients like nitrogen, phosphorous, iron and Sulphur **Heterotrophic Bacteria** Most abundant, decomposers/parasitic beneficial as well as harmful, help in production of antibiotics, nitrogen fixation in legumes. Some are pathogens and may cause diseases like Cholera, typhoid, Tuberculosis, tetanus and citrus canker.
CYANOBACTERIA 	• Habitat:- Aquatic, freshwater, marine or grow in moist soil and rocks at the lower trunk of trees, symbiotically with fungi (lichen), inside coralloid root of *Cycas* . • Body Organization:-Unicellular or multicellular, filamentous, unbranched with heterocyst. Heterocyst are the special type o" cell present in the filament of some bl'e green algae. They consist of thick cell wall. without nuc'eoid and fix atmosphereic nitrogen Cell Wall Is made up of peptidoglycan and is covered by a sticky mucilage sheath which is made up of mucopolysaccharide. • Nutrition:- Photosynthetic.

ARCHAEOBACTERIA	• Habitat:- These are the most primitive bacteria originated on earth and can live in most extreme environment like Hydrothermal vents, salty (saline environment), hot sulphur springs, in the gut of ruminants. Methanogens: - They are archaebacteria which live symbolically in gut of ruminants. They secretes enzymes for the digestion of cellulose and produce methane. They are anaerobic and used in biogas plants. Halophiles: - They are archaebacteria which thrive in extreme saline (salty) environment like salt lakes, salt marshes and salt solutions. Thermoacidophiles: - They can live in hot and acidic environment like hot sulphur springs.

Q 1 . Blue-green algae belong to which kingdom?

Ans. Monera

Q 2. What is the main basis of classification in the five-kingdom system?

Ans. Structure of the nucleus

Q 1. Assertion: Two kingdom classification was insufficient.

Reason: Majority of organisms failed to fall into either of the categories in two kingdom classification.

Ans. both Assertion and Reason are true and Reason is the correct explanation of Assertion.

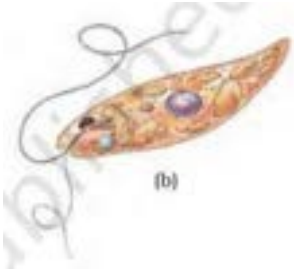
Q2. **Assertion:** Several ruminant animals contain methanogens within their gut.

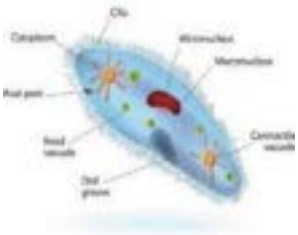
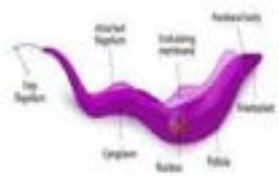
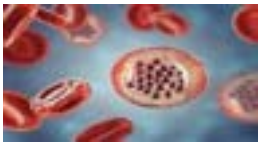
Reason: Methanogens help in the production of methane from dung of ruminants.

Ans. both Assertion and Reason are true but Reason is not the correct explanation of Assertion

PROTISTA

Protista are unicellular eukaryotes. These are broadly divided into 5 major groups:

1. CHRYSOPHYTES 	• They include diatoms and golden algae. • Habitat:- Aquatic-freshwater or Marine. • Nutrition:- It has photosynthetic nutrition. • Cell Wall in diatoms is composed of two thin overlapping halves which are overlapped with each other like soap in the soap box. It is embedded with silica and indestructible. • Their cell wall deposits accumulated at their habitat over billions of years which are known as diatomaceous earth. • This soil being gritty can be used in polishing and the filtration of oil and syrups. • Example:- *Pinnularia, Cyclotella* etc
2. **DINOFLAGELLATES** 	• Habitat: - Mostly marine. **Locomotion:-** locomotion by two flagella, one attached longitudinally and other transversally • Some species like red dinoflagellates like *Gonyaulax* undergoes such rapid multiplication that they make the entire sea surface red. This is called 'red tide'. Toxins released by such large numbers may even kill other marine animals such as fishes. Example:-*Gonyaulax, Noctiluca*.
3. **EUGLENOIDS** 	• Habitat:- Freshwater protist and live in stagnant water. • Locomotion: - Occurs by two flagella one long and one is short attached longitudinally. Nutrition: - Mixotrophic i.e. both photosynthetic and holozoic, In the presence of sunlight it forms food through photosynthesis. • In dark they ingest bacteria into its mouth (cytostome) and take them into the cytopharynx. • Cell wall is absent but covered by a protein layer called pellicle. • Phosynthetic pigment like that of higher plants. • Reproduction:- Binary fission. Example:- Euglena.

1.AMOEBOID 	• Habitat: - Aquatic- Freshwater or marine. • Some species lives as parasites (ex. Entamoeba) • Locomotion by pseudopodia. • Nutrition holozoic, some are parasitic. • Example:-*Amoeba, Entamoeba*
2. CILIATES 	• Habitat:- Aquatic and some are Parasitic (*Balantidium*) • Locomotion by cilia. • Nutrition holozoic with the help of cytopharynx. • Reproduction:- Binary fission. • They are mostly binucleated having one macro and one micronucleus. Osmoregulation by contractile vacuole. • Example*:- Paramecium, Balantidium, Vorticella, Opalina* etc.
3.FLAGELLATES 	• Habitat:- Mostly parasitic, Some are free living, • Nutrition: - Holozoic, and parasitic. • Locomotion with the help of flagella. Examples: - <u>*Trypanosoma gambience*</u> which causes sleeping sickness secondary host:- Tse – Tse fly <u>*Leismania Donovani*</u> which causes Kalazar secondary host- Sand fly,
4.SPOROZOAN 	Habitat:-Live as endoparasites in body fluids, hence, do not have need any locomotory organ. They cause infection by a spore – like stage in its life cycle. Example:-*Plasmodium vivax*-Malarial Parasite. Secondary host:- Female anopheles mosquito
4. SLIME MOULD 	• Habitat:- They are saprophytes, swim freely with help of pseudopodia along the decaying leaves, twigs etc engulfing dead and decaying materials. Cell Wall is absent in entire vegetative stage. Under favorable conditions they grow and fuse to form a mass of aggregation of amoebae called Plasmodium. • Under unfavorable conditions the cells of plasmodium differentiate and divide to form spore producing body known as sporangia. In Sporangia, the various thick walled spores are formed which are dispersed by wind.
5. PROTOZOA	• All protozoans are heterotrophs and live as predators or parasites. They are believed to be primitive relatives of animals.

Q.3**.** Which of the following is correctly matched?

Member	**Stored food**
A. Chrysophytes	i) fat
B. Dinoflagellates	ii) starch
C. Protozoa	iii) Fucoxanthin
D. Euglenoids	iv) Chrysolaminarin

Q.3. Which among the following is not a eukaryote?

Q.4. African Sleeping Sickness is caused by _____.

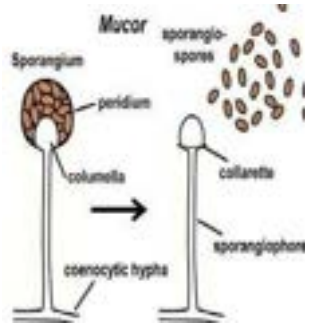
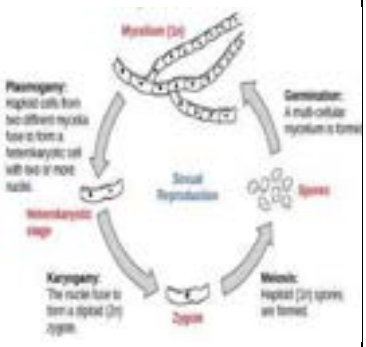
Q.5 **.**a) What is peculiar in the cell wall of diatoms?

b) What is diatomaceous earth? How it is formed?

KINGDOM FUNGI

- Multicellular, eukaryotic and saprophytes
- Habitat: - air, water and soil, on decaying logs, on tree trunk, on few plants and animals,as parasites, Live symbiotically with algae (lichen) roots of higher plant-Mycorrihiza.
- They mostly grow in warm and humid places.
- Mode of Nutrition saprophytic, parasitic or symbiotic(example lichens and mycorrhiza)
  Body Organisation: - Eukaryotic, unicellular or filamentous body called mycelium
- Cell wall is made up of Chitin.

Reproduction:-

Vegetative Reproduction	by fragmentation, budding and fission	
Asexual Reproduction	by formation of spores which are of following types a. Sporangiospores • Thick walled, Very light • Non- motile, endogenous • Formed inside sporangia b. Zoospores-Thin walled, Motile and flagellated.Endogenous, Formed inside zoosporangia c. Conidia-Non-motile,Arise mostly in chain and from exogenously on the special hyphal branches called conidiophores.Dispersed in the air	
Sexual reproduction	Types of sexual fusion: a. Isogamy:- The fusion between two morphologically similar gametes b. Anisgamy:- The fusion between two morphologically dissimilar gametes c. Oogamy:- It is the fusion between small and motile male gametes with the large and non-motile female gamete **Stages of sexual reproduction** • Plamogamy:- Fusion of cytoplasm of the two cells • Karyogamy:- The fusion of the nucleus of two cells • Meiosis:- It occurs in the zygote and result in the formation of four haploid spores, which are called meiospores. These spores germinate and forms new fungi	

❖ In some fungi like ascomycetes and basidiomycetes, the plasmogamy is delayed by karyogamy and results in the formation of a binucleated cell which is known as dikaryon cell and the phase is known as dikaryophase.

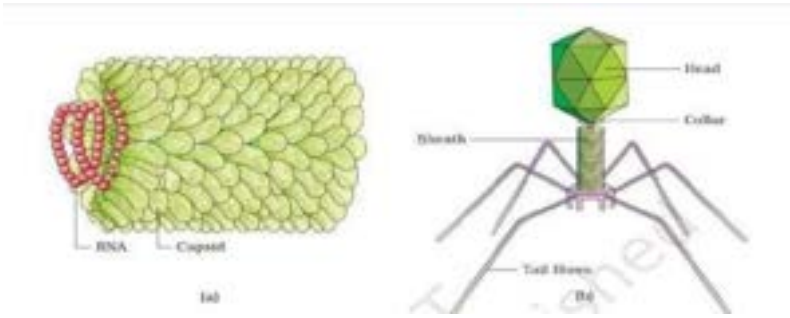
CLASSIFICATION OF FUNGI:-

DIVISION	CHARACTERISTCS
PHYCOMYCETES 	• Mycelium is aseptate i.e. septum absent multinucleated /coenocytic condition. • Asexual reproduction occurs by the formation of spores Terrestrial form **(sporangiospores)** Aquatic form **(Zoospores)** • Vegetative propagation occurs by fragmentation

	• Sexual Reproduction:- The sexual reproduction is **isogamous** or **oogamous**. • Plasmogamy is immediately followed by Karyongamy and result in the formation of zygote **(oospores)** • The meiosis occurs in the oospores and result in the formation of haploid meiospores which germinate to form new fungi. • ***Phytophthora, Albugo***
ASCOMYCETES 	• **Multicellular** with septate mycelium except *Saccharomyces* which is unicellular. • **Asexual Reproduction:-** Binary fission and budding in Yeast. • In others, conidia are produced exogenously. • Sexual spores ar ascospores produced inside asci in 4or 8 numbers. Fruiting bodies are ascocarps. Examplesr-*Aspergillus , Penicillium* • *Sacchomyces cerevicae* (Yeast),*Neurospora* used as study in experimental genetics, *Claviceps which* causes *ergot of Rye)*
BASIDIOMYCETES 	• They are **multicellular** with septate mycelium. • Asexual reproduction by the formation of **Chlamydia or oldia.** • Sexual spores known as **Basidiospores**, borne exogenously on basidia. Fruiting bodies are called basidiocarp. Ex:- *Agaricus compestris* (Mushroom), *Puccinia* which causes rust *which* causes smut disease in wheat
DEUTEROMYCETES 	• Commonly known as Imperfect fungi because only the asexual or imperfect stage is known. • Later when sexual stage is discovered, they are placed in correct class after identification. So this artificial assemblage of fungi is also called *waste paper basket of Fungi.* • Examples:- *Alternaria, Trichoderma*

Viruses

- Viruses regarded as connecting link between Non- Living and Living.
- As living organisms, they can multiply inside host cell but as non living they do not have cell structure and can be kept inactive in crystalline form for several years.
- Virus is composed of DNA/RNA core and protein capsule.
- Bacteriophages are viruses that infect the bacteria.
- Viruses cause disease like mumps, small pox, herpes, influenza and AIDS.



Viroids

- Infectious agent smaller than viruses cause potato spindle tuber disease.
- It was found to be a free RNA; it lacked the protein coat that is found in viruses, hence the name viroid.
- The RNA of the viroid was of low molecular weight.

Q 6. The infection in Viroids is caused by

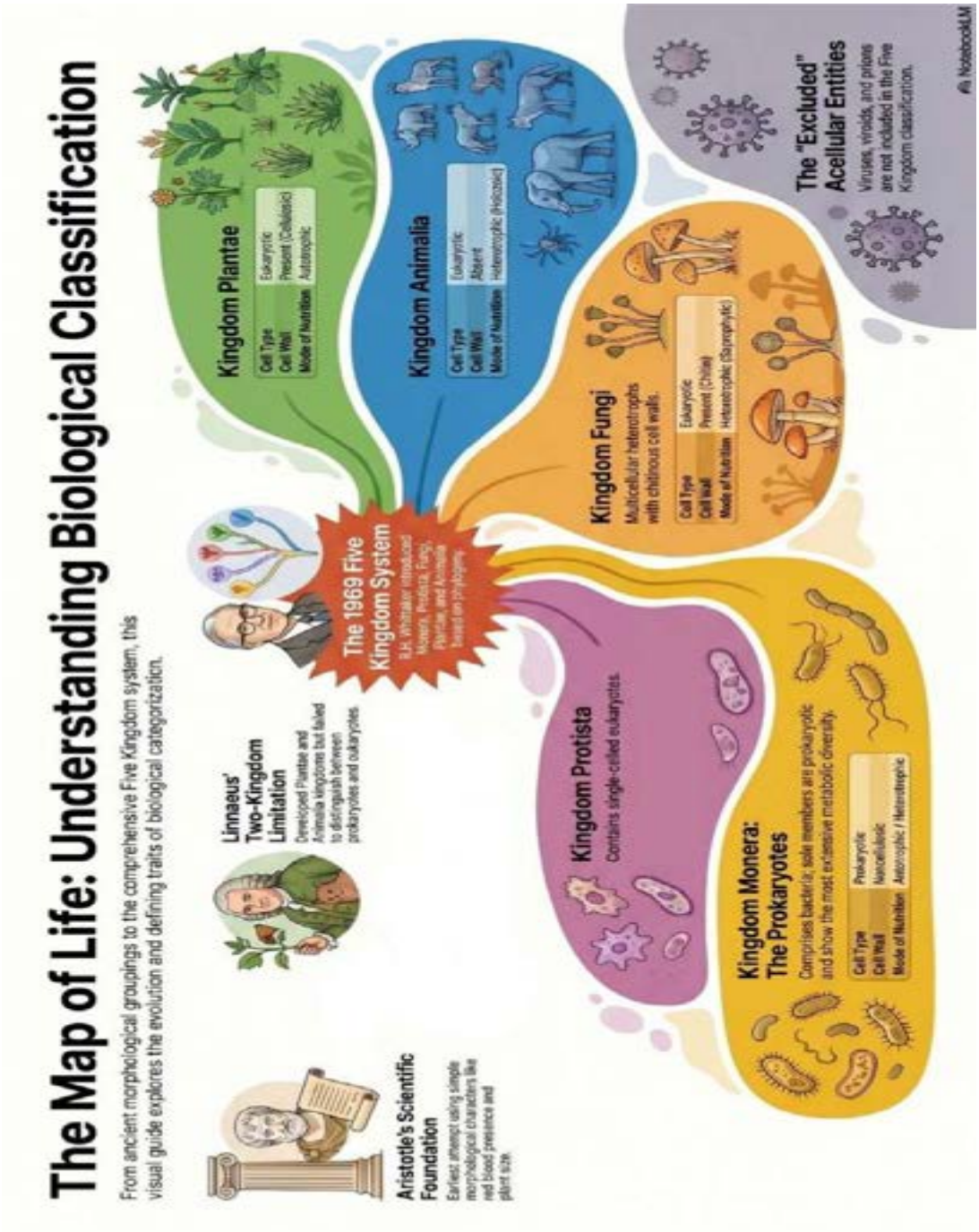
Q.7. Who discovered Viroids? Name one plant disease caused by Viroids.

Lichens

- Lichen is the symbiotic association between algae and fungi.
- Phycobiont is algal component which prepare food and mycobiont is the fungal component which provide shelter and absorb mineral nutrients and water.

Lichens are very good pollution indicators and do not grow in polluted areas.

See answer of intext Questions at page No. 158 in the Question Bank QR under Test Your Knowledge

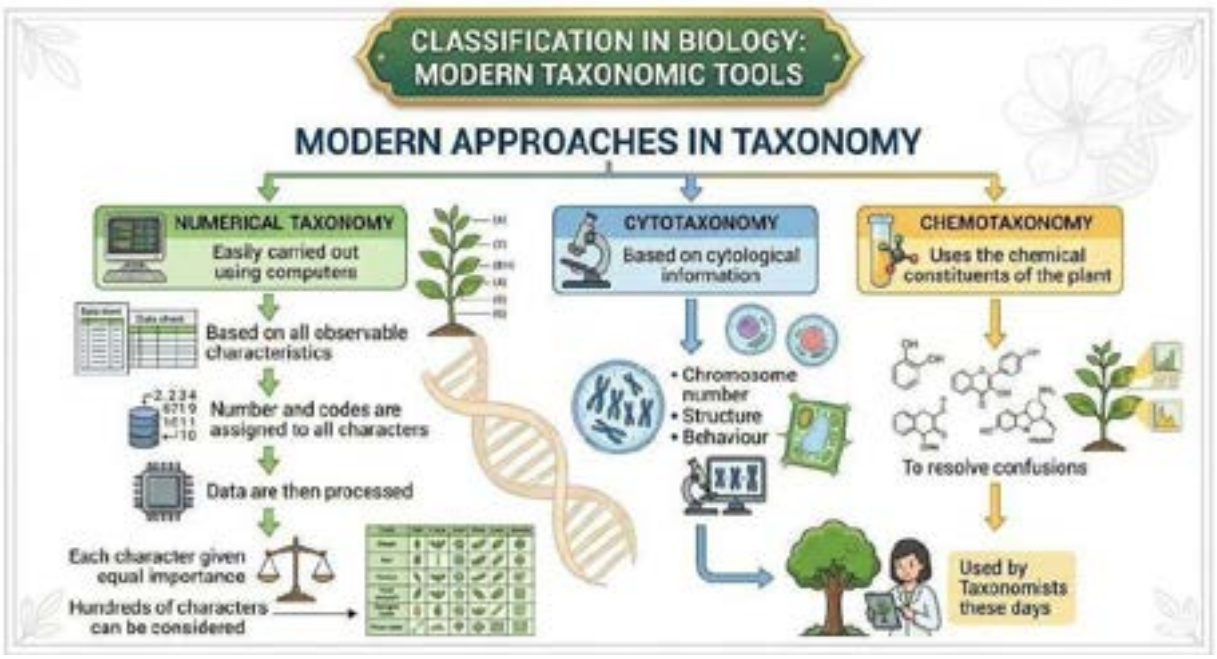


CHAPTER 3: PLANT KINGDOM

CBSE Curriculum (26-27): Classification of plants into major groups; Salient and distinguishing features and a few examples of Algae, Bryophyta, Pteridophyta, Gymnospermae and Angiosperms.

TYPES OF CLASSIFICATION

ARTIFICIAL	NATURAL	PHYLOGENETIC
• Earliest classification systems • Based on 1 or 2 external morphological characters such as form, habit or habitat. • Based mainly on vegetative characters. • Equal weightage to vegetative and sexual characters • Given by Linnaeus, based on Androecium characteristics. • Advantages: Easier. Differentiates between closely related species • Disadvantages: 1. Vegetative characters change with environment. 2. Since classification based on few characters, unrelated organisms may be placed together in one group.	• Based on natural affinities of organisms • Considers multiple characters • Considers external as well as internal characteristics such as ultrastructure, anatomy, embryology, phytochemistry etc. • Natural Classification for flowering plants given by George Bentham & Joseph Dalton Hooker • Advantage: Gives information about natural relationships and is more accurate. • Disadvantage: May have some discrepancies	• Based on evolutionary relationships of organisms • Organisms with common ancestors placed in same taxa. • Represented though *family tree charts known as Cladogram* • Dynamic field since it is based on emerging fossil records. • Hutchinson gave phylogenetic system of classification • Advantages: Chances of errors minimal • Disadvantages: Complete ancestry records for many organisms not yet available.



ALGAE

General Characteristics

- Simple thallus (sac) like body
- Autotrophic – Contain Chlorophyll
- Habitat:
  - ➢ Aquatic (fresh water and marine)
  - ➢ In moist areas – moist stones, soil and wood
  - ➢ Symbiotic – with Fungi (as Lichens)
  - ➢ Symbiotic With Sloth Bear

✓ Size & Form: Variable

- ➢ Very small: Colonial e.g. *Volvox*
- ➢ Filamentous: *Spirogyra, Ulothrix*
- ➢ Large, Plantlike Body: Marine Kelps such as *Laminaria*

Reproduction

- Vegetative: By Fragmentation
- Asexual: By Zoospores – flagellated motile
- Sexual: Fusion of gametes

✓ **Isogamous**: Both gametes morphologically & physiologically alike.

- ➢ Both flagellated & motile e.g. *Ulothrix*
- ➢ Both non flagellated e.g. *Spirogyra*

✓ **Anisogamous**: Gametes dissimilar, e.g. *Eudorina*

✓ **Oogamous**: Fusion of one large, non – motile female gamete with one small

Economic Importance - Benefits:

✓ Algae are responsible for half of total CO_2 fixation on Earth.

✓ Increase dissolve oxygen in water, due to photosynthesis

✓ Most important primary producers as they are first level of food chain.

✓ Source of food: 70 species of Marine Alga such as Porphyra, *Laminaria, & Sargassum*

✓ Source of Hydrocolloids or Water Holding Substances

* Algin: Brown Algae *Carrageen: Red Algae

**Gelidium & Gracillaria* – Red Algae. Used in ice creams

CHLOROPHYCEAE •Green Algae

PHAEOPHYCEAE •Brown Algae

RHODOPHYCEAE •Red Algae

Classification of Algae

CHLOROPHYCEAE: Green Alga

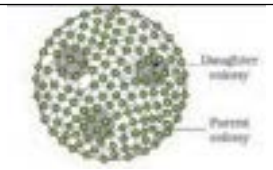
Vegetative Characters:

- Unicellular, Colonial or Filamentous
- Grass Green in colour due to presence of Chlorophyll a and b.
- Shape of chloroplast unique to different species. E.g. discoid, plate like, reticulate, cup shape, spiral or ribbon shape
- Chloroplasts have Pyrenoids – food storage bodies
- Pyrenoids contain protein and starch
- Double layer cell wall. Outer wall of pectin, inner rigid wall of cellulose

Reproduction:

- Vegetative Reproduction: Fragmentation
- Asexual Reproduction: By Zoospores.
  Motile flagellated spores, produced in zoosporangia
- Sexual Reproduction: May be
  - ✓ Isogamous ✓ Anisogamous ✓ Oogamous

Examples: Chlamydomonas , Ulothrix, Spirogyra, Chara



Colony of Volvox

Filament of Ulothrix



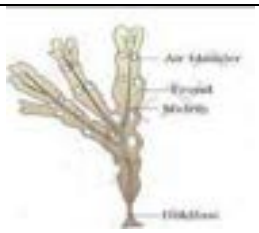
Q1. A major characteristic determining the deep olive-green to brown coloration of Phaeophyceae is the ratio of which accessory pigments?

Q2. Differentiate between the food storage structures and compositions found in Chlorophyceae versus Rhodophyceae.

PHAEOPHYCEAE: Brown Algae

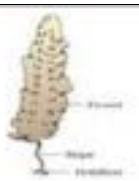
Vegetative Characters:

- Primarily marine
- Body Form:
  - ✓ Filamentous: *Ectocarpus*
  - ✓ Simple Branched
  - ✓ Profusely Branched: Kelps
- Pigments: Chlorophyll a & c. Carotenoids & Xanthophylls
- Colour: Olive Green to Brown. Depends on amount of Carotenoids & Xanthophylls



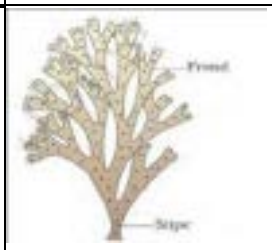
Fucus

- Food: Complex carbohydrates Laminarin & Mannitol
- Cell Wall: Made of Cellulose. Covered with gelatinous coating of **Algin** on the outside
- Plant Body: 3 parts
  - ➢ Holdfast – As anchor to substratum
  - ➢ Stipe - Stalk
  - ➢ Fronds – Leaf like, photosynthetic



Laminaria

- Vegetative: Fragmentation
- Asexual reproduction:
  - ➢ Biflagellate Zoospores
  - ➢ Flagella Lateral & unequal
  - ➢ Pyriform (Pear shaped) zoospores
- Sexual reproduction: Isogamous, Anisogamous, Oogamous
  - ➢ Fusion of gametes may be outside, or inside (in oogamous)
  - ➢ Gametes Pyriform with lateral flagella



Dictyota

RHODOPHYCEAE: Red Algae

Vegetative Characters:

- Mostly marine, found in warm areas
- Found close to surface of water as well as great depths with less light
- Body form: Multicellular with complex structures
- Pigments: Chlorophyll a & d, r-Phycoerythrin
- Cell Wall: Cellulose, Pectin, Polysulphate esters
- Food: Floridean Starch

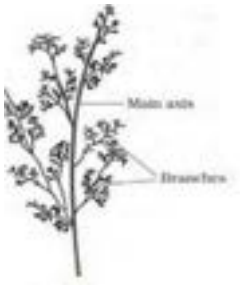


Porphyra

Reproduction:

- Vegetative Reproduction: Fragmentation
- Asexual Reproduction: Non-Motile Spores
- Sexual Reproduction:
  - ➢ Oogamous
  - ➢ Gametes non motile
  - ➢ Fertilization followed by complex post – fertilization developments

Examples: *Polysiphonia, Porphyra, Gracilaria, Gelidium*



Polysiphonia

TABLE 3.1 Divisions of Algae and their Main Characteristics

Classes	Common Name	Major Pigments	Stored Food	Cell Wall	Flagellar Number and Position of Insertions	Habitat
Chlorophyceae	Green algae	Chlorophyll *a, b*	Starch	Cellulose	2-8, equal, apical	Fresh water, brackish water, salt water
Phaeophyceae	Brown algae	Chlorophyll *a, c,* fucoxanthin	Mannitol, laminarin	Cellulose and algin	2, unequal, lateral	Fresh water (rare) brackish water, salt water
Rhodophyceae	Red algae	Chlorophyll *a, d,* phycoerythrin	Floridean starch	Cellulose, pectin and poly sulphate esters	Absent	Fresh water (some), brackish water, salt water (most)

Q.3 . Agar is obtained from *Gelidium* & *Gracilaria.* Both these Alga belong to which Class of Algae?
Q.4 Based on pigment and stored food material found in the three groups of Algae, justify the classification of Algae in to Green, Brown and Red Algae.

Q.5. Describe the architectural division of the plant body in a typical brown alga (such as *Laminaria* or *Fucus*).

Q.6 Compare the asexual spore characteristics of *Chlorophyceae* and *Phaeophyceae*.

BRYOPHYTA

General Characteristics:

- Habitat: Damp, Humid & shaded land.
- 'Amphibians of Plant Kingdom': Live on land but need water for sexual reproduction.

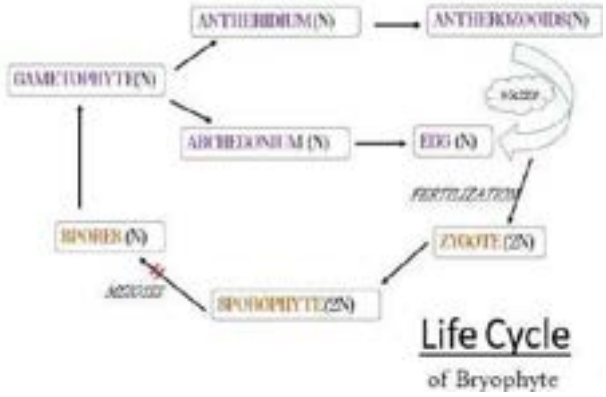
- Vegetative Characters:
  - ➢ Thallus like, more differentiated than Algae, Prostrate or erect
  - ➢ Attached to substratum by root like rhizoids
  - ➢ No true root, true stem or true leaves. i.e. do not show anatomical characters of stem, root and leaf.
  - ➢ Main plant body Gametophyte (n)

Reproduction & Life Cycle:

- Since main plant body is Gametophyte (n):
  - ➢ It reproduces through Gametes,Performs Sexual Reproduction
    - ✓ Male Sex Organ: Antheridium, Produces Biflagellate Antherozooids (male gamete)
    - ✓ Female Sex Organ: Archegonium, Produces single egg
    - ✓ Agent to carry Antherozooids to egg: Water
    - ✓ Fertilization Internal
  - Diploid Zygote (2n) formed Zygote develops into Sporophyte (2n)
  - Sporophyte attached to and dependent on parent Gametophyte
  - Reproduces through Spores (Asexual reproduction)
  - Meiosis (reduction division) occurs during Spore formation. Spores are haploid (n)
  - Spores develop into Gametophyte (n) – main plant body

Economic Importance: Benefits

- Food: For herbaceous mammals, birds etc
- Fuel: *Sphagnum,* a Moss provides peat. Used as fuel in early days.
- Packing Material: Can store water. So used for trans-shipment of living materials.
- Ecological Significance:
- Help in soil formation by decomposing rocks
  - Make barren area suitable for vegetation
  - Form dense mat on soil. Prevent soil erosion and reduce impact of rain.

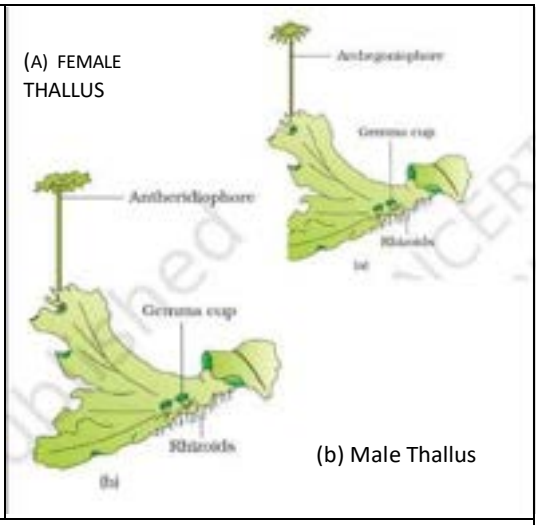


BRYOPHYTA: CLASSIFICATION



LIVERWORTS

- Gametophyte (n) thallus like
- Dorsiventral on substrate
- May have leaf like structures
- Asexual reproduction by Gemmae/ Gemma Cups
- Sexual reproduction through antherozooid & egg
- Male and female sex organs on same thallus
- Zygote gives rise to sporophyte (2n) dependent on parent gametophyte
- Sporophyte differentiated into foot, seta & capsules.
- Sporophyte forms haploid spores (n)
- Spores germinate to form independent Gametophyte (n)

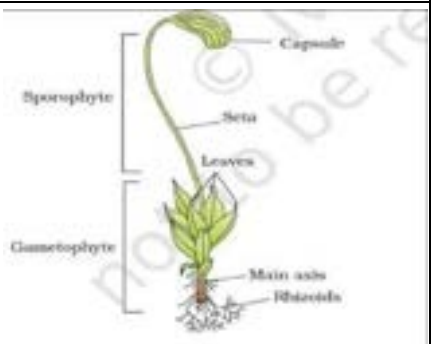


MOSSES:

Gametophyte

- Gametophyte main phase of life cycle: Reproduction through gametes
- 2 gametophytic stages:

Stage 1: Protonema	Stage 2: Leafy stage
Develops from spore	Develops from secondary protonema as a lateral bud
Creeping, green, filamentous, branched	Has leaf like, stem like & root like structures
2 substages: Primary & secondary protonema	Leafy structures spirally arranged Root like rhizoids multicellular & branched Bears Sex Organs



*Funaria (*Moss): Gametophyte & sporophyte

MOSS: Reproduction

- Vegetative: Fragmentation & Budding in secondary protonema
- Sexual Reproduction: In Gametophyte *On apex of leafy shoots*
  - Male Sex Organs: Antheridia
  - Female Sex Organs: Archegonia
- Zygote develops into sporophyte

MOSS: Sporophyte

- Sporophyte (2n) has 3 parts: Foot, Seta, and Capsule
- Capsule bears spores (n)
- Spores formed after meiosis
- Elaborate mechanism of spore dispersal



Spaghnum: Gametophyte

Question: In a green plant, plant body is divided into foot, seta and capsule. Identify the plant, state the name of group to which this plant belongs. Draw a neat diagram and label the three parts mentioned above.

Q.7. Why are Bryophytes commonly referred to as the "Amphibians of the Plant Kingdom" despite having adapted to live on land?

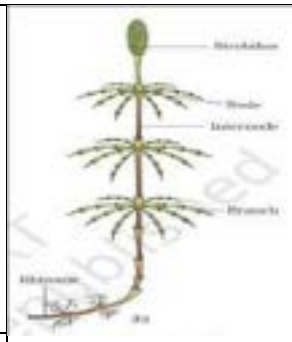
Q.8. An investigator discovers a plant body that does not show true anatomical markers of standard stems, roots, or leaves, but instead possesses a creeping, filamentous, green, and branched structural network. This stage is most likely:

Q.9. How does the nutritional dependency of the sporophyte generation differ between Algae and Bryophytes?

PTERIDOPHYTA

General Characteristics:

- Terrestrial Plants : Horsetails & Ferns
- Found in cool damp and shady places. Rarely in sandy areas.
- Main plant body Sporophyte
- Posses True root, true stem and true leaf
- First plants to posses Vascular Tissue – Xylem and Phloem
- E.g. *Selaginella*, *Equisetum*, Fern, *Salvinia*



Leaf may be:

- Small: Microphylls e.g. *Selaginella*
- Large: Macrophylls e.g. Ferns *Equisetum*



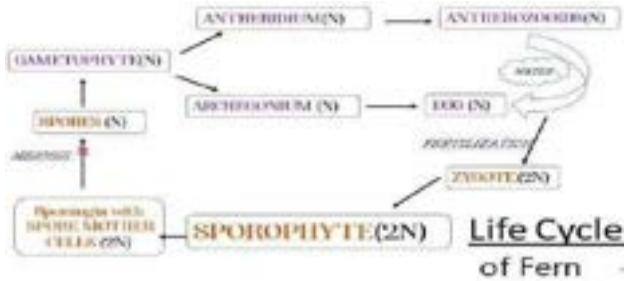
Selaginella with Microphylls



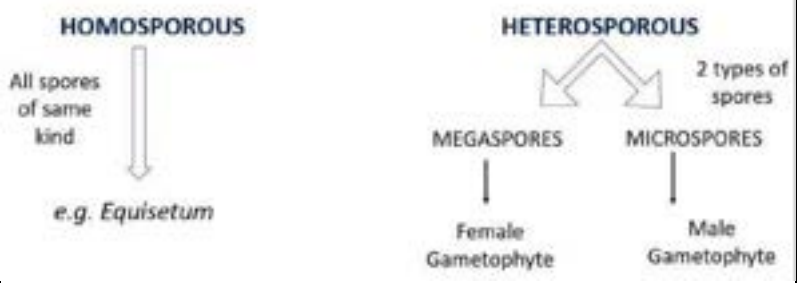
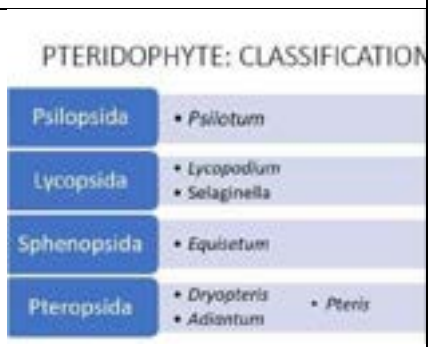
Fern with macrophylls

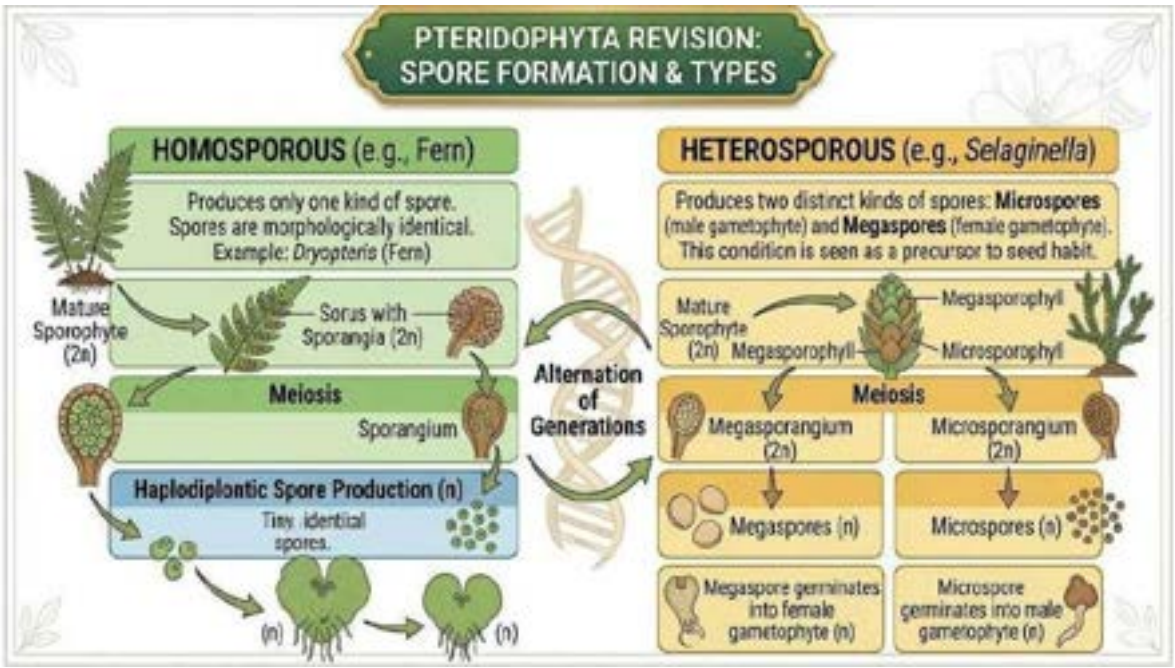


Salvinia



SPOROPHYTIC PHASE:

Types of Sporophytes based on Types of Spores  	Main plant body Sporophyte (2n): • Reproduces through Spores • Spores present on special leaf like structures known as <u>Sprophylls</u> - Fern • Sometimes sporophylls are arranged in compact structures known as <u>Cone</u> or <u>Strobili</u>. E.g. *Selaginella, Equisetum*
<u>GAMETOPHYTIC PHASE</u> • Gametophytes of Pteridophytes known as **PROTHALLUS** • Formed by germination of spores • Small, multicellular, photosynthetic & free living • Need cool, damp and shady places to grow • Bear sex organs: Antheridium & Archegonium	#Gametophytes require cool, damp, shady places to grow. Because of this specific restricted requirement and the need for water for fertilisation, the spread of living pteridophytes is limited and restricted to narrow geographical regions
PTERIDOPHYTE: SEXUAL REPRODUCTION: • Antheridium – Bears Male Gamete or Antherozoids. • Archegonium – Bears Egg Cell • Water is required for transfer of antherozoid from antheridium to egg cell in archegonium. • Fertilization takes place inside archegonium, zygote is formed • Development of zygote in to embryo takes place within female gametophyte – this is similar to development of seed in angiosperms. ➢ <u>Important step of Evolution</u> ➢ Indicates development of **SEED HABIT** Economic Importance: <u>Benefits</u> • Medicinal • Soil Binders • Ornamentals	



Question: Give 2 reasons why Pteridophytes are not spread in varied Geographical areas, but are restricted to damp and shaded places.

GYMNOSPERMS

General Characteristics:

- *Gymnos:* Naked*; Sperma:* Seeds
- Medium to large sized trees & shrubs. The giant
- redwood tree *Sequoia* is one of the tallest tree species
- Roots: Tap roots. May form symbiotic associations as
  - Mycorrhiza: *Pinus +* Fungus
  - Coralloid Root: *Cycas +* Cynaobacteria
- Stem:

➢ Unbranched:*Cycas*	➢ Branched: *Pinus*

- Leaf: Simple or Compound
  - ➢ Adapted to extreme temperature, humidity & wind. In conifers, the needle-like leaves reduce the surface area. Their thick cuticle and sunken stomata also help to reduce water loss.



Cycas

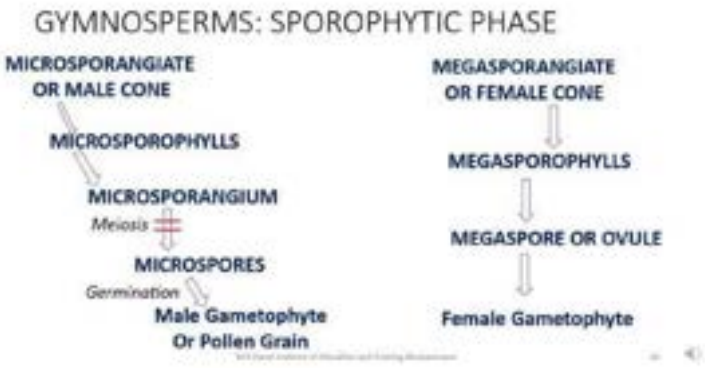
GYMNOSPERMS: SPOROPHYTIC PHASE:

Main plant body Sporophyte (2n):

- ➢ Reproduces through Spores
- ➢ Spores of 2 types: Heterosporous
- ➢ Spores contained in sporangium
- ➢ Sporangium present on sporophylls
- ➢ Sporophylls arranged on Cones or Strobili
  - ✓ Male & female cone on same plant: *Pinus*
  - ✓ Male & female cone on different plant: *Cycas*



Pinus





Gingko

GYMNOSPERMS: GAMETOPHYTIC PHASE

Female Gametophyte	Male Gametophyte
• Multicellular • Retained within Megasporangium • Bears two or more female sex organs or Archegonia • Receives male gamete from pollen tube • Female gamete after fertilization forms zygote, & then embryo • Ovule forms Seeds	• Highly reduced – known as pollen grain • Made of few cells • Development takes place within Microsporangia • Carried by air currents to Ovule on megasporophylls • Forms Pollen Tube and releases male gamete into archegonia

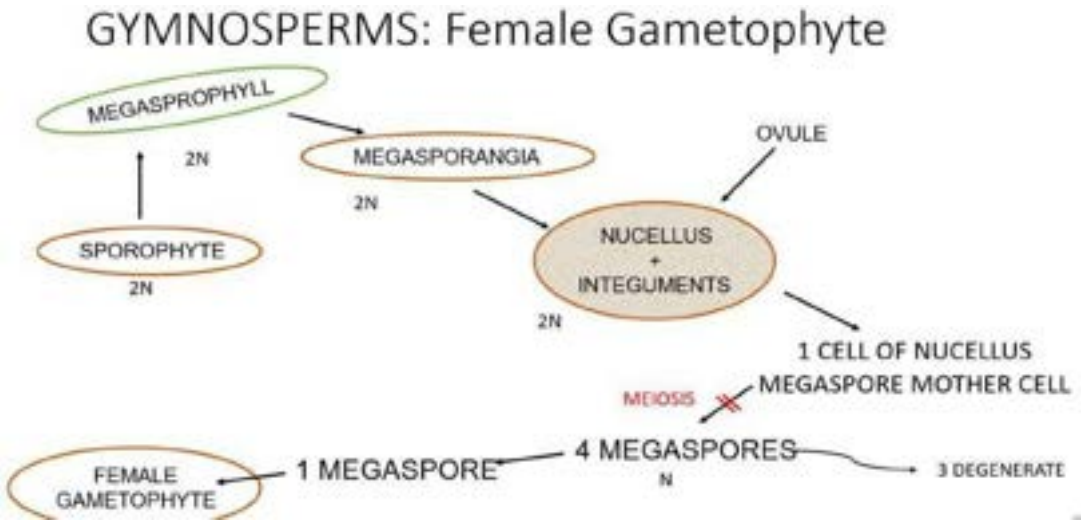
Q10. An anatomical examination of a gymnosperm root reveals an association with nitrogen-fixing cyanobacteria. What structural modification and genus are you observing?

Q.11. Coniferous plants exhibit specialized leaf adaptations like needle-like shapes, thick cuticles, and sunken stomata. What is the primary evolutionary advantage of these combined traits?

Q.12. Unlike Bryophytes and Pteridophytes, the female gametophyte of a Gymnosperm is completely dependent and never escapes the parent body. Where is it retained?

Q.13. Contrast the distribution of male and female reproductive cones between the genera Pinus and Cycas.

*In *Cycas* male and female cone on different trees, in *Pinus,* on same tree.



ANGIOSPERMS

General Characteristics:

- Flowering Plants
- Ovule enclosed in ovary; seeds enclosed in fruits
- Size: Variable
  - ➢ Smallest: *Wolffia* ➢ Tall: *Eucalyptus* (100m)
- Divided in to 2 Classes

	Dicotyledons	**Monocotyledons**
1.	Two cotyledons	One Cotyledon
2.	Tap root system	Fibrous root system
3.	Reticulate Venation	Parallel Venation
4.	Tetramerous & Pentamerous Flowers	Trimerous Flowers

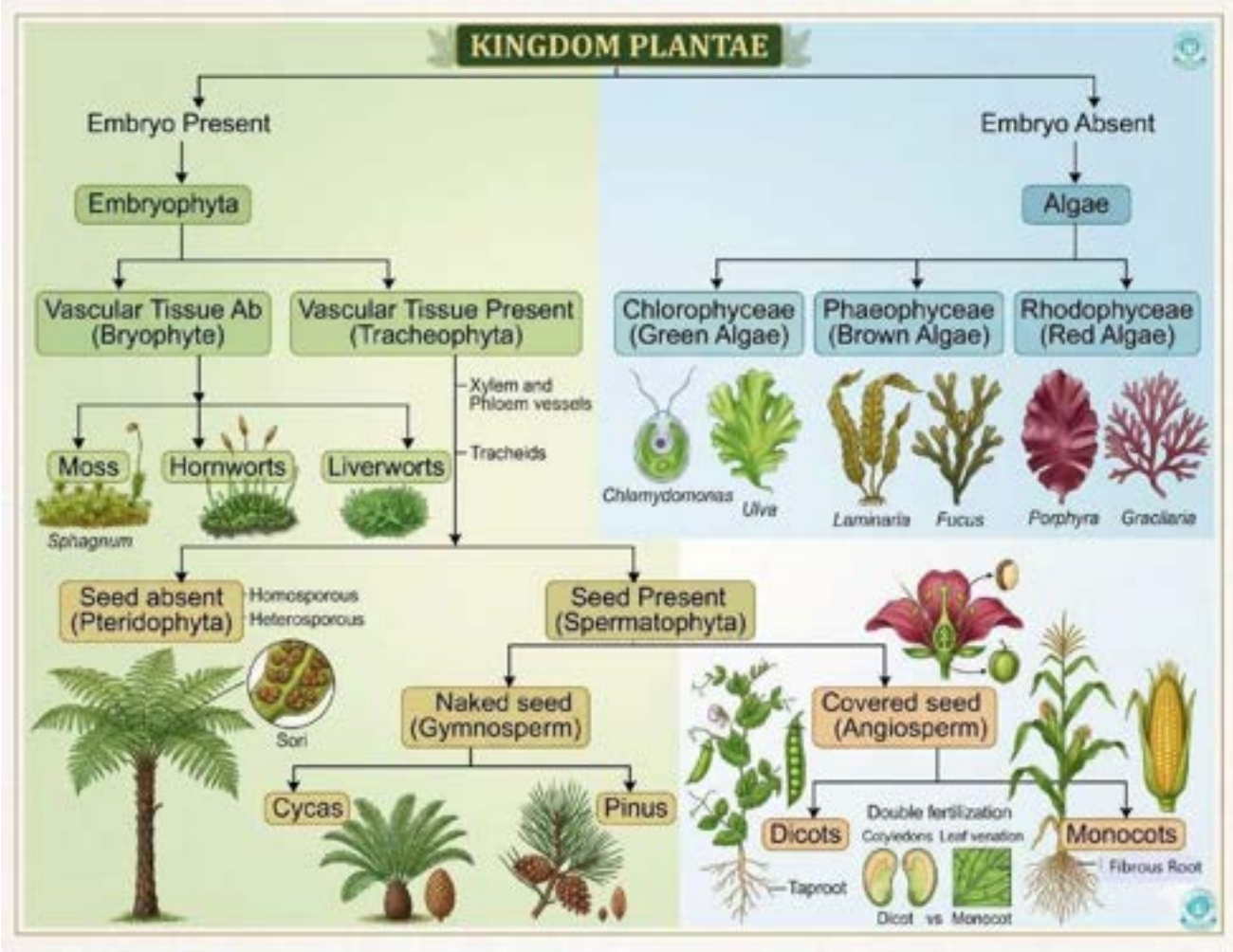
Question: Identify 2 adaptations of Gymnosperms that enable it to survive in extreme environments.

See answer of intext Questions at page No. 158 in the Question Bank QR under Test Your Knowledge

Comparisons

Features	Bryophyta	Pteridophyta	Gymnosperms	Angiosperms
Dominant Phase	• **Dominant Gametophyte** (e.g., Liverwort, Moss) Sporophyte & Gametophyte	• **Dominant Sporophyte** (e.g., Fern, Pine, Oak) Gametophyte	• **Dominant Sporophyte** (e.g., Fern, Pine, Oak) Gametophyte	• **Dominant Sporophyte** (e.g., Fern, Pine, Oak) Gametophyte
Ploidy	• **Haploid** (n) • **Diploid** (2n)	• **Haploid** (n) • **Diploid** (2n)	• **Haploid** (n) • **Diploid** (2n)	• **Haploid** (n) • **Diploid** (2n)
Body Differentiation	**Simple Thallus / Foliose** (no true organs), with single-cell rhizoids	• **Complex Structure:** True Roots, Stems, and diverse **Leaves**	• **Complex Structure:** True Roots, Stems, and diverse **Leaves**	• **Complex Structure:** True Roots, Stems, and diverse **Leaves**
Vascular System	• **Non-vascular** (lacks Xylem & Phloem)	• True **Vascular Bundles** (Xylem & Phloem) **Present**	• True **Vascular Bundles** (Xylem & Phloem) **Present**	• True **Vascular Bundles** (Xylem & Phloem) **Present**
Spore Type	• **Homospory** (single type of spore)	• Primarily **Homospory**; evolved **Heterospory**	• **Heterospory** (separate Microspores and Megaspores)	• **Heterospory** (separate Microspores and Megaspores)
Seed Development	• Seedless; produces spores only	• Seedless; produces spores only	• **Naked Seeds** (exposed on megasporophylls)	• Seeds enclosed within an **Ovary** (later a Fruit)
Flower and Fruit	• Flower and Fruit **Absent**	• Flower and Fruit **Absent**	• Flower and Fruit **Absent**	• True Flower and Fruit **Present**

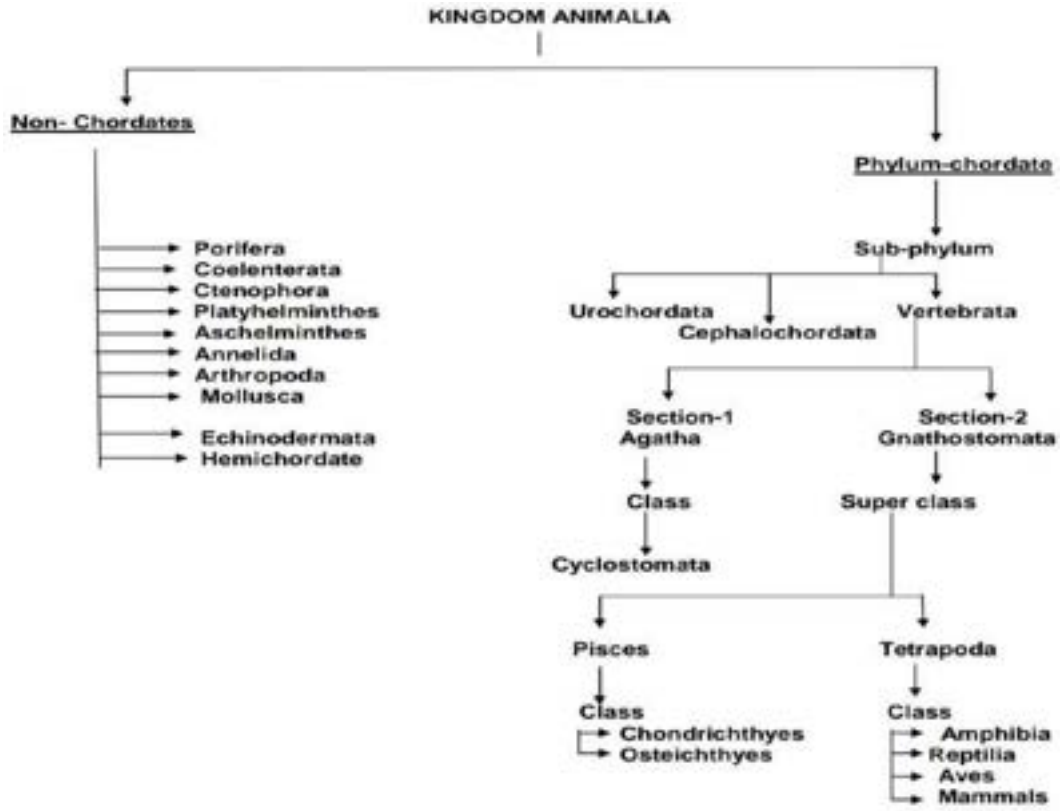
A comparative taxonomic overview of major plant divisions. Refined Scientific Diagram, 2024



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CHAPTER 4-Animal Kingdom

Salient features and classification of animals, non-chordates up to phyla level and chordates upto class level (salient features and at a few examples of each category). (No live animals or specimen should be displayed.)



BASIS OF CLASSIFICATION:-

- **Level of organization**

- Cellular level of organization:-The cells are loosely arranged and don't from tissues. Ex: - Porifera (SPONGES).
- Tissue level of organization: - The cells combine to form tissue and have similar structure & function .Ex:- Coelenterates, Ctenophore.
- Organ level of organization: - The two or more tissues combine to form organs.Ex:- Platyhelminthes.
- Organ-system level of organization:-The two or more different organs combine to form organ system. Ex:- Aschelminthes to all chordates

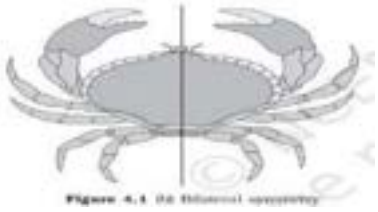
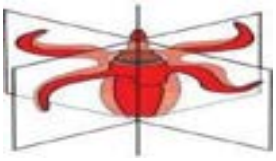
- **Digestive tract**

- **Incomplete: -**There is a mouth but no anus.
  Ex: - Coelenterates, Platyhelminthes.
- **Complete: -** They contain both mouth as well as anus.
  Ex:- Ctenophore , Aschelminthes to all chordates

- **Circulatory system**

- **Open circulatory system: -**In this the blood after flowing from heart remains in direct contact with the body cells. Here, sinuses are formed.
  Ex:- Arthropoda, mollusks, hemichordate
- **Closed circulatory system: -** In this the blood after flowing from heart does not make direct contact with the body cells.
  Ex:-Annelids, Echinodermata and all chordates.

Symmetry

symmetrical	**Bilateral symmetry**	**Radially Symmetrical**
body cannot be divided into two equal halves in any plane. Ex. Sponges. 	**body can be divided into two equal halves by any plane passing through the central axis.** Ex:-All chordates. 	**body is divisible into two equal halves in just one plane.** Coelentrates (hydra, sea anemone), ctenophores, adult echinoderms(star fish) 

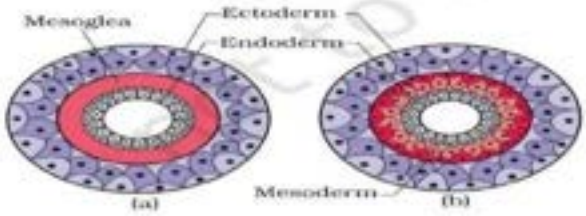
Germ layer- During embryonic development animals produced three germ layers.

Germ layers are three types-

(1) Ectoderm, (2) mesoderm (3) endoderm.

On the basis of germ layers organisms are two types-

Diploblastic	Triploblastic
Cells arranged in **two** embryonic layers. Outer- **ectoderm**. Inner **endoderm**. Middle **mesoglea** (undifferentiated). Example: Porifera, coelenterate and ctenophore.	Cells arranged in **three** embryonic layers Outer ectoderm, Inner endoderm and middle **mesoderm**. Examples: **Platyhelminthes to Chordates**.

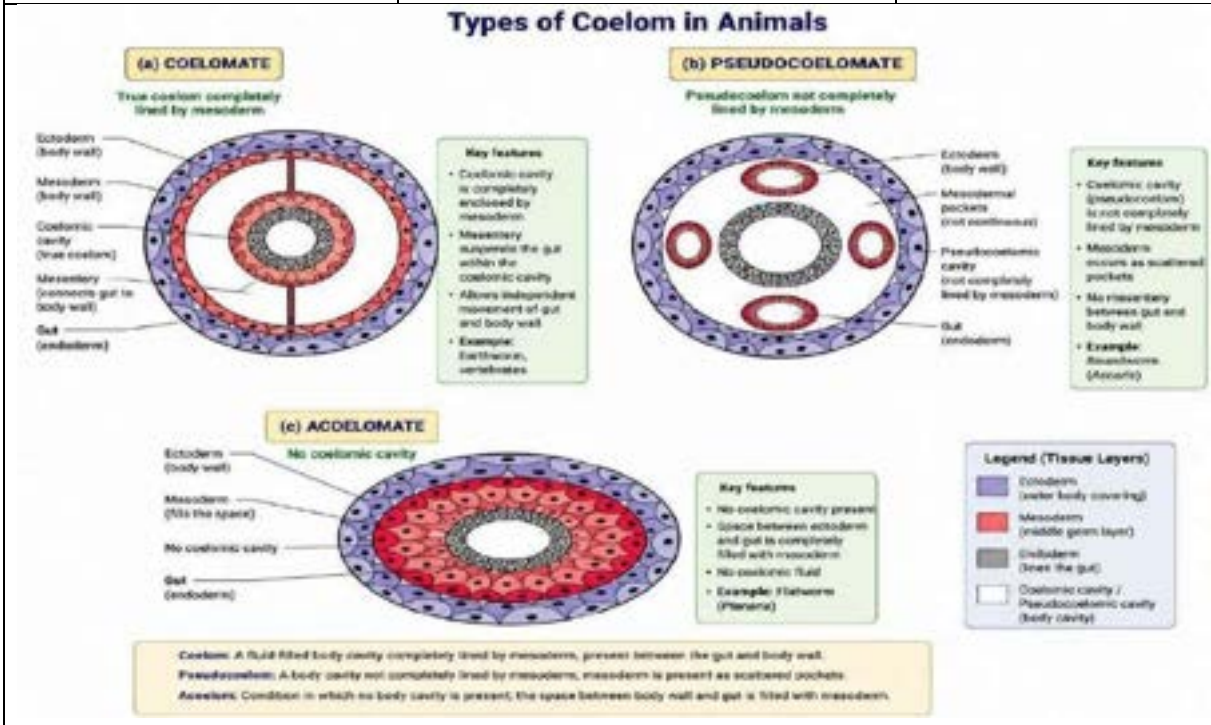


Diplblastic (b) Triploblastic

Q.1. What term describes animals with only two embryonic germ layers?

Coelom- The body cavity between body wall and gut wall. It must be lined by mesoderm.
It is key feature used for animal classification.

Acoelomate	Pseudocoelomate	Coelomate
Body cavity is completely **absent**. Example: **Platyhelminthes**.	Cavity present but **not** lined by mesoderm. Mesoderm exists as **scattered pouches**. Pouches sit between ectoderm and endoderm. Example: **Aschelminthes**.	Possess a true **coelom** (mesoderm-lined). Examples: Annelids, to chordates.



Key point- **Platyhelminthes** are Acoelomate but these are triploid.

Q.2. Which phylum contains the only true pseudocoelomate organisms?

Segmentation(metamerisation)-

In some organism the body is externally and internally divided into various segments called metamers with serial repetitions of at least some organs.

Ex: - Annelids, Arthropods.

Notochord

ALL VERTEBRATES ARE CHORDATES, BUT ALL CHORDATES ARE NOT VERTEBRATES

Origin: Mesodermally derived. **Shape**: Mid dorsal, solid and Rod-like structure. **Location**: Formed on the dorsal side. **Timing**: Appears during embryonic development.	In vertebrate notochord is replaced by hollow and jointed str. Called vertebral column. The animal with notochord is known as chordate. Ex:- Hemichordates to all vertebrates. The animal without notochord is known as non-chordates. Ex:- Porifera to Echinodermata

NON CHORDATES PHYLUMS

PHYLUM-PORIFERA

- Commonly known as sponges.
- Habitat: - Mostly marine, while very few are freshwater. Ex: - Spongilla(fresh water sponge)
- Symmetry: - They are **asymmetrical.,** Level of organisation:- **Cellular**
- Germ layer:-**Diploblastic**
- **Canal system:-**In sponges, the gathering of food, respiration and excretion and sperm transfer occurs through water canal system.

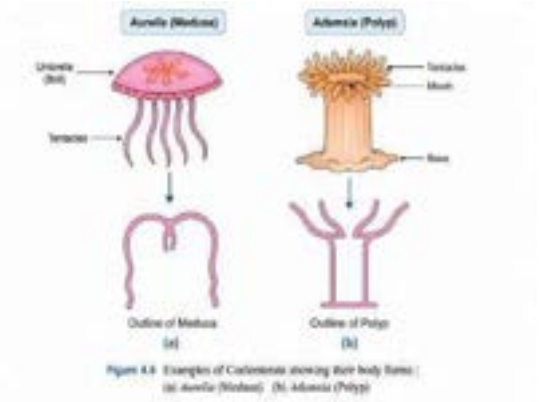


- Nutrition:-It is intracellular. Endoskeleton:-It is made up of siliceous or calcareous specule's and sponging fiber. Reproduction:-They are **hermaphrodite**.
- Development: - **Development is indirect** includes a larval stage called **amphiblastula.**
- Reproduction:-Asexual:-Occurs by fragmentation and budding.
- Fertilization **is internal.** Ex-Sycon (scypha), euspongia(bath sponge), spongilla(fresh water sponge)

Q.3. Which phylum is characterized by asymmetrical adult bodies?

PHYLUM-COELENTERATA

Commonly known as hydra and jellyfish



- Habitat:-They are mostly Marine,Some are freshwater (hydra).
- **Polymorphism**: - The phenomenon in which the organisms occurs in two or more different forms with different structure and function.
- Cnidarians' are of two types:-
- Polyp: - Non–motile, cylindrical, can live solitary (singly) or colonial, reproduce asexually.Ex- Hydra.
- Medusa:-Free swimming, umbrella shaped, solitary and reproduce sexually.Ex- Jellyfish.
- Symmetry:- They have radial symmetry.
- Level of organization:-They have tissue level of organization. They are diploblastic.
- Digestion:-The digestion is partially intercellular and intracellular.
- Respiration and excretion occurs through general body surface.
- Reproduction:-In organisms like obelia and physalia which involves both polyp and medusa reproduce by met agenesis in which the polyp reproduce by asexually i.e. by budding or by regeneration and give rise to medusa and the medusa reproduce sexually and give rise to polyp again. This is known as Metagenesis in which a diploid multicellular phase alternate with other diploid multicellular phase.
- Fertilization may be internal or external.
- Development is indirect includes a free-swimming, ciliated larval stage planula.

Ex-Polyp- Hydra (freshwater polyp).Sea anemone (adamsia). Panatela (sea pen).Gorgonian (sea fan). Meandering (brain coral)Medusa-Aurelia (jellyfish). Bath-Obelia, physalia.

Q.4. What are the stinging cells used for defense and capturing prey?

PHYLUM-CTENOPHORA



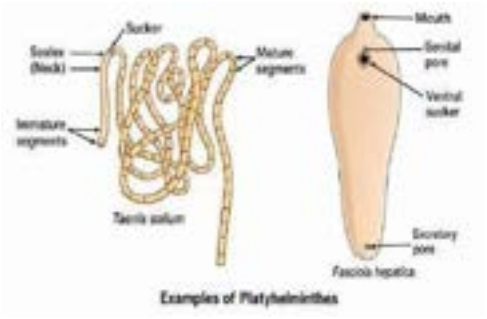
- Commonly called sea walnut or comb jellies.
- Habitat-Exclusively marine. Symmetry-Biradial symmetry.
- Level of organization –Tissue level. Germ layer-They are diploblastic.
- Locomotion- It occurs by light external rows of ciliated tract known as comb plates.
- Digestive tract-It is complete containing mouth that leads into pharynx and tow and pore.
- A central cavity forms the gut which is known as gastro vascular cavity which has a dual function i.e. the partial digestion of food and to gastro dermal cells.
- Respiration and Excretion-It occurs through general body surface.
- Reproduction-They are hermaphrodite but prefer cross fertilization.
- Fertilization is external.Development is indirect and includes a motile larva
- They show the property of bioluminescence.

Example- Hormiphora (sea walnut), Ctenoplana, Pleurobrochia (sea gooseberry).

Q.5. What structures do comb jellies use exclusively for locomotion?

PHYLUM-PLATYHELMINTHES

- Commonly known as flat worm.
- Habitat-They mostly lives as end parasite and the parasitic forms contain hook and sucker.
- Symmetry-They have bilateral symmetry. Level of organisation - Organ level.
- Germ layer – Triploblastic. Coelom-They are acoelomate.
- The anterior end of the body forms a small conical head which contain little brain and some sense organs.
- Digestive tract –It is incomplete i.e. it does not contain anus. Digestion of food is intercellular. Respiration occurs through general body surface.
  Excretion occurs through flame cells (proto nephridia) which leads into the excretory tubule and open out by excretory pore.
- Reproduction-They are hermaphrodite but prefer cross fertilization.



Examples of Platyhelminthes

- Fertilization is internal. Some posses a high degree of regeneration.
- Development is indirect include many larval stages.

Example-Taenia solium (tape worm), fasciola (liver fluke), schizostoma (blood fluke), planarian (planarian).

Q.6. Which specialized cells handle excretion and osmoregulation in flatworms?

PHYLUM: ASCHELMINTHES

- Aschehelminthes Commonly known as roundworm.

Habitat-Mostly endoparasite but may be free living. Germ layer-they are triploblastic Symmetry-they have bilateral symmetry.

- Coelom-They are pseudocoelomatls.,Level of organization-organ system level.
- Digestive tract-It is complete., Respiration occurs through general body surface.
- Execration is done by h-shaped intracellular canals.
- Reproduction-They are unisexual and the female is larger than male.
- The male has a copulatory organ., Fertilization is internal.
- Development may be direct (ascaris)or direct(wuchereria)
- Example-Ascaris (round worm)-cause ascariasis in human, Ancylostoma (hook worm), Wuchereria Cause elephantiasis in humans.

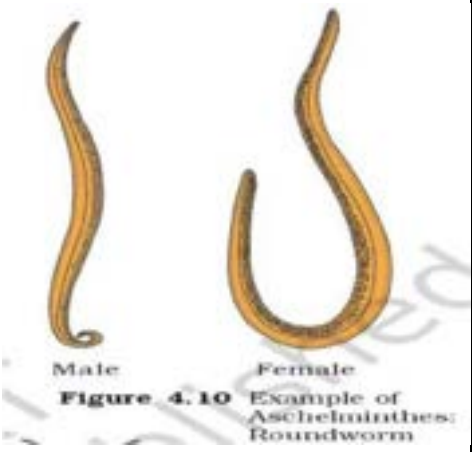


Figure 4.10 Example of Aschelminthes: Roundworm

Q.7.What type of body plan is found in roundworms?

PHYLUM: ANNELIDA

Commonly known as segmented worm.

- Habitat- Aquatic.Ex-leech. Terrestrial. Ex-Nereis, earthworm.
- Level of organization- Organ system level. Symmetry- They are bilaterally symmetrical.
- Germ layer –They are triploblastic. Coelom-They are true cellmates.
- Metamerization-They whole body is divided into various segments called metamers.
- In some organisms the unjointed appendages called parapodia which help in locomotion. Ex- Nereis(sand worm)
- In some organisms locomotion occurs by the contraction and relaxation of longitudinal and circular muscles. Ex- Leech, Earthworm etc.

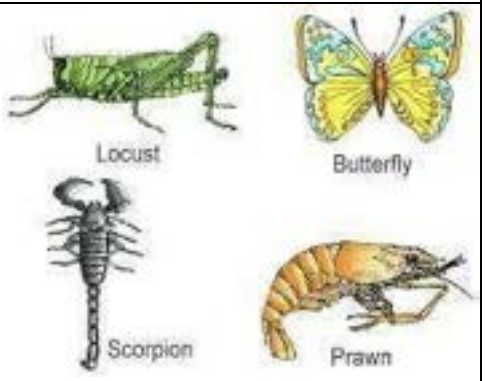

4.11 Examples of Annelida : (a) Nereis (b) Pheretima

- Circulatory system-Circulatory system is closed and the heart is dorsal. Heart is present in more numbers. Ex- In earthworm four pairs of heart are present.

- Respiration – Occurs through skin (cutaneous respiration).
- Excretion-Occurs through coiled tubules called metanephridia.
- Reproduction- They are hermaphrodite (Earthworm, leech) or unisexual (nereis).
- Development-Mostly indirect including a larval stage trochophore larva
  Example-Nereis (Sandworm), Pheretima (Earthworm), Hirudinaria (leech).

Q.8. Which blood vascular system type is found in the phylum Annelida?

PHYLUM: ARTHROPODA



- Commonly known as animals with jointed appendages.
- Habitat-Aquatic (Freshwater, marine), Terrestrial.
- Symmetry- Symmetry is bilateral.
- Level of organization-Organ system level.
- Germ layer-Triploblastic.
- They are coelomates.
- Their body is mostly divided into three segments:-
- 1.Head 2.Thorax 3.Abdomen.
- Mostly there are three pairs of legs are present:-
- But in crustaceans and Arachnida more than three pairs of legs are present.
- **Body Wall**:- All segments are covered by chitinous plates (Sclerosis) made up of chitin sugar.
- **Digestive tract**:- It is complete and digestion is extracellular.
- **Respiration**: takes place through gills, book gills, lungs and tracheal system.
- **Excretion**: takes place through *malpighian tubules*.
- **Circulatory system**: it is open type.
- **Reproduction**: - Sexes are separate, Fertilization is mostly internal. They are mostly oviparous. Development may be direct or indirect.

CLASS	EXAMPLES
1.Crustacea	*Daphnia* (water flea),*Palaemon* (Prawn),*Astacus* (Cray fish),*Cancer* (Crab),*Eupagurus* (Hermit crab) *Lucifer* (shrimp).
2. Chilopoda	*Scolopendra* (centipede).
3.Diplopoda	*Julus* - Millipede
4. Insecta	*Poecilocerus* (Grasshopper), *Periplaneta* (Cockroach), Anopheles /Culex/ Aedes (Mosquitoes), *Pieri*s (Butterfly),*Lepisma* (Silver fish),*Bombyx* (Silk moth),*Musca* (House fly),*Apis* (Honey bee), Ants and termites. Lac Insects (*Laccifer*):- The lac produced by these insects is used for making toys, varnishes, paints, polishes etc.
5. Arachnida	*Palamnaeus* (Scorpion),*Aranea* (Spider),*Limulus* (King Crab).

Q.9. What tough polysaccharide material makes up the chitinous exoskeleton of arthropods?

PHYLUM: MOLLUSCA



- Commonly known as soft bodied and shelled animals.
- Habitat: -Mostly aquatic (freshwater/ Marine),Few terrestrial (Moist soil).
- Symmetry: - 1. Bilateral in Cephalopods (Ex: - Octopus).
  2. Asymmetrical in gastropods (Ex:- snails).
- Germ layer: - They are triploblastic.Level of Organisation: - Organ system level.
- Coelom:- They are true coelomates. Shell: - It is non-cellular Calcium carbonate covering secreted by Mantle. Mantle: - It is a thin fleshy fold of dorsal body wall. It enclosed a cavity between the body and itself.
- Body is divided into three parts – head, visceral hump and muscular foot.
- Digestive tract: - It is complete. It has a rasping organ, Radula, which contains horny teeth.
- Respiration occurs through gills also called ctenidium.

- Circulatory system: - It's Blood is blue due to the presence of a blue colored copper containing pigment known as haemocyanin.
- Excretion occurs through one or more sac like kidney.
- Reproduction:- Sexes are separate,They are oviparous. Fertilization is internal (Gastropods) or external (cephalopods).
- Development is indirect includes a larval stage Glochidium.
- Examples :- Gastropods:- Pila (Apple Snail), Aplysia (Sea hore),Pinctada (Pearl Oyster),Dentalium (Tusk cell),Chaetopleura (Chit on) Cephalopods: Sepia (Cattle fish), Lalagos (the squid), Octopus (the devil fish).

Q.10. What is the soft, spongy layer of skin that covers the visceral hump called?

PHYLUM-ECHINODERMATA

- Commonly known as spiny-skinned animals.
- Habitat:- They are exclusively marine. Symmetry:- Bilateral symmetry in larva but radial symmetry in adult. Germs layer:- Triploblastic.
- Level of organization:- Organ system level.
- At larval stage the part of coelom is modified into a water filled ambulacral or water vascular system, which help in food capturing, respiration, distribution, excretion and locomotion.
- Mouth is present on ventral side known as oral surface and Anus is present on dorsal surface known as aboral surface.
- Circulatory System:- It is highly reduced and is of open typeHeart and respiratory pigments are absent.
- Reproduction:- Sexes are separate, Fertilization is external.
- Development is indirect includes a motile larva, bipinnaria.
- Example:- Asterias (Star fish),Ophiothrix (Brittle Star),Echinus (Sea Urchin)
  Anted on (Sea lily, feather star),Cucumaria (Sea Cucumber)

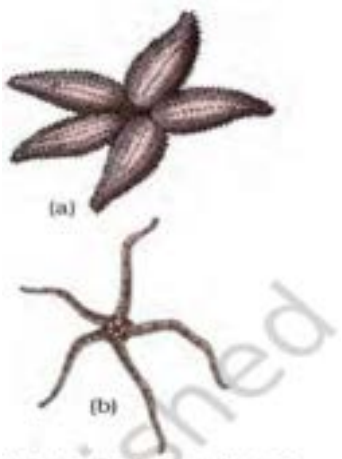


Figure 4.14 Examples of Echinodermata : (a) *Asterias* (b) *Ophiura*

Q.11. Which side of the body is the mouth located on in adult echinoderms?

PHYLUM-HEMICHORDATA

Commonly known as half chordates.

- Earlier placed as a sub-phylum in chordates but after that placed into non-chordates. Habitat:- Exclusively marine.
- Symmetry:- Bilateral symmetry.
- Level of organization:- Organ system level.
- Germ layer:- Triploblastic. Coelom:- True coelomates.
- Body is divided into three regions – proboscis, collar and trunk.
- Digestive tract:- It is complete and proboscis contain a hollow outgrowth from the gut.
- Respiration:- It takes place through gills.
- Circulatory system:- It is open and include a dorsal heart to longitudinal vessels.
- Excretion:- It occurs by a proboscis gland.
- Reproduction:- Sexes are separate.
- Fertilization is internal.
- Development is indirect includes a free swimming larva, Ex., balanoglossus

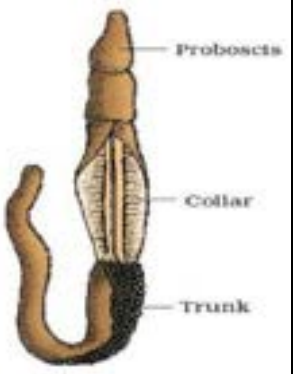


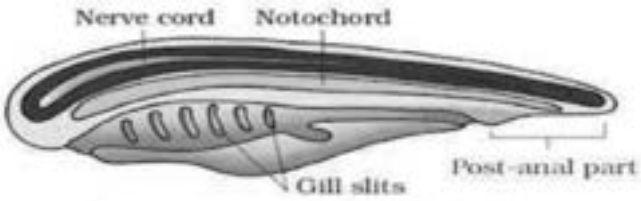
Figure 4.15 *Balanoglossus*

Q.12. Which worm-like marine animal group was previously classified as a sub-phylum of Chordata?

PHYLUM CHORDATA

Diagnostic Character:-

- Single, dorsal, hollow, nerve cord.
- A solid mid dorsal unjointed notochord.
- Paired pharyngeal gill slits
- Muscular tail.



Chordata characteristics (Body plan)

S.No.	Chordates	Non-chordates
1.	Notochord present.	Notochord absent.
2.	Central nervous system is dorsal, hollow and single.	Central nervous system is ventral, solid and double.
3.	Pharynx perforated by gill slits.	Gill slits are absent.
4.	Heart is ventral.	Heart is dorsal (if present).
5.	A post-anal part (tail) is present.	Post-anal tail is absent.

PHYLUM CHORDATES HAS THREE SUBPHYLUM

SUB-PHYLUM UROCHORDATA



Figure 4.17 *Ascidia*

- **Common Names**: Known as tunicates or sea squirts.
- **Habitat**: Live exclusively in marine environments.
- **Mobility**: Adults are fixed in one place (non-motile).
- **Feeding**: Filter feeders that strain food from water.
- **Body Cover**: Covered by a leathery shell called a tunic.
- **Tunic Material**: The tunic is made of plant-like cellulose.
- **Notochord**: Present only in the larval tail; disappears in adults.
- **Nerve Cord**: Larval nerve cord reduces to a single adult ganglion.
- **Gill Slits**: Multiple respiratory gill slits persist throughout life.

Metamorphosis: Advanced larvae degenerate into simpler adults (retrogressive metamorphosis).

SUB-PHYLUM CEPHALOCHORDATA



- Notochord extend form tip of snout to tail and persist throughout life.
- The dorsal hollow nerve cord also persists throughout life.
- A paired pharyngeal gills slits are present and persist up to adult.
- A tail persists throughout life.
- They lives in burrows and are filter feeder.
- Example: - Brachiostoma/ Amphioxus (Lancelet).

SUB-PHYLUM VERTEBRATA

Class cyclostomata



Figure 4.18 A jawless vertebrate - Petromyzon

Class Cyclostomata:-

- Jawless vertebrates. Habitat:- Exclusively marine and lives in burrows.
- They are most primitive vertebrates.
- They have unpaired fins.S keleton:- There is no exoskeleton but the endoskeleton is made up of cartilage.
- Digestive system:- Mouth is circular and sartorial type.
- Tongue forms horny teeth.
- Air bladder is absent. Buoyancy is provided by liver.
- Respiratory system:- It includes 5 to 16 pharyngeal gills.
- Circulatory system:- Heart is two chambered involving two auricle and two ventricle.
- RBCs are circular and nucleated. Circulatory system is closed.
- Sense Organs:- It includes olfactory sac, a pair of eye, only internal ear (Membranous labyrinth us) are present.
- Reproductive system:- Fertilization is external gonads are single.

	• Development:- Indirect and include a free-swimming filter-feeding larva. • They are cold-blooded (Poikilothermy). • Example:- Maxine (Hag fish), petromyzon (lampreys). **Q.13. Which jawless vertebrates migrate to freshwater for spawning and die shortly after?**

CLASSES OF VERTEBRATES

SUPER CLASS – PISCES:-**Class Chondrichthyes:-**

Environments: Includes both **marine** and **freshwater** species.

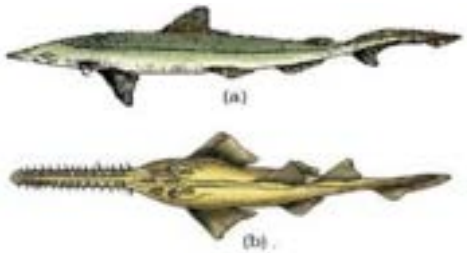


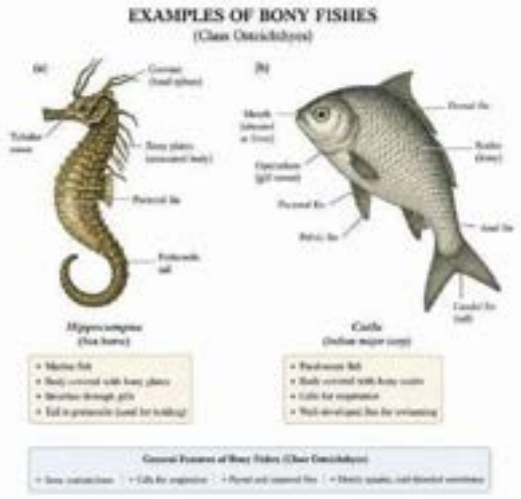
Figure 4.19 Example of Cartilaginous fishes : (a) Scoliodon (b) Pristis

- **Endoskeleton:** Made entirely of **bone**.
- **Body Anatomy & Structure**
- **Shape:** Characterized by a **streamlined** body.
- **Mouth Position:** Located **terminally** at the front.
- **Skin Cover:** Protected by **cycloid or ctenoid scales**.
- **Respiration & Buoyancy**
- **Gills:** Possess **four pairs** of gills.
- **Operculum:** A protective **bony cover** hiding the gills on each side.
- **Air Bladder:** Present to **regulate buoyancy** and prevent sinking.
- **Heart: Two-chambered** setup consisting of **one auricle and one ventricle**.
- **Temperature: Cold-blooded** (poikilothermic) organisms.
- **Sexes:** Completely **separate**. **Fertilization:** Occurs **externally** in water.
- **Egg Laying:** Primarily **oviparous**. **Life Cycle:** Undergoes **direct development** without a larval stage.
- **Marine:** *Exocoetus* (Flying fish), *Hippocampus* (Sea horse).
- **Freshwater:** *Labeo* (Rohu), *Catla* (Katla), *Clarias* (Magur).
- **Aquarium:** *Betta* (Fighting fish), *Pterophyllum* (Angel fish).

Q.14. What type of scales are found on the skin of cartilaginous fishes?

CLASS – OSTEICHTHYES

Commonly known as bony fish.



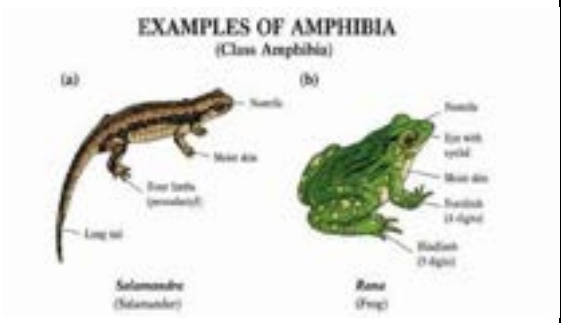
- **Habitats**: Found in both **marine** and **freshwater** environments.
- **Endoskeleton**: Characterized by a **bony** internal skeleton.
- **Body Shape**: **Streamlined** body built to reduce water resistance.
- **Mouth Position**: Mostly located at the **terminal** end of the body.
- **Gills**: Possess **four pairs of gills** used for breathing.
- **Operculum**: A protective **gill cover** that protects the gills on each side.
- **Scales**: Skin is layered with protective **cycloid or ctenoid scales**.
- **Air Bladder**: An internal organ present to **regulate buoyancy**, keeping them afloat.
- **Circulation**: Features a **two-chambered heart** containing one auricle and one ventricle.
- **Metabolism**: They are **cold-blooded** animals.
- **Sexes**: Distinct and **separate**.
- **Fertilisation**: Generally **external**

- **Development**: Mostly **oviparous** (egg-laying) with **direct development**.
- **Marine**: *Exocoetus* (Flying fish) and *Hippocampus* (Sea horse).
- **Freshwater**: *Labeo* (Rohu), *Catla* (Katla), and *Clarias* (Magur).
- **Aquarium**: *Betta* (Fighting fish) and *Pterophyllum* (Angel fish).

Q.15. What organ regulates buoyancy in bony fishes so they do not sink?

SUPER-CLASS TETRAPODA

CLASS AMPHIBIA



- Divisions: Body is divided into a head and trunk.
- Limbs: Most species possess two pairs of limbs.
- Tail: Present only in some species (e.g., salamanders).
- Skin: Characteristically moist and completely lacks scales.
- Eyes: Equipped with functional eyelids.
- Ear: Represented externally by a tympanum.
- Cloaca: A single common chamber where the alimentary canal, urinary tract, and reproductive tracts open to the exterior.
- Respiration: Takes place through the gills, lungs, or skin.
- Heart: Three-chambered layout consisting of two auricles and one ventricle.
- Temperature: Cold-blooded (poikilothermic) animals. Sexes: Completely separate (dioecious).
- Fertilization: Occurs externally. Egg Laying: Oviparous (lays eggs).
- Life Cycle: Indirect development involving larval stages
- *Bufo*: Toad, *Rana*: Frog, *Hyla*: Tree frog, *Salamandra*: Salamander, *Ichthyophis*: Limbless amphibian

Q.16. What common chamber serves as the exit for the alimentary, urinary, and reproductive tracts?

CLASS REPTILIA

- Commonly called creeping vertebrates.
  - Body is covered by dry and cornified skinepidermal scales or scutes.
  - They do not have external ear openings. Tympanum represents ear.
  - Heart is usually three-chambered, but four-chambered in crocodiles.
  - Reptiles are poikilotherms. Snakes and lizards shed their scales as skin cast.
  - Sexes are separate. Fertilisation is internal. They are oviparous and development is direct.Examples: *Chelone* (Turtle), *Testudo* (Tortoise), *Chameleon* (Tree lizard),
  - *Calotes* (Garden lizard), *Crocodilus* (Crocodile), *Alligator* (Alligator). *Hemidactylus* (Wall lizard), Poisonous snakes – *Naja* (Cobra), *Bangarus* (Krait), *Vipera* (Viper).

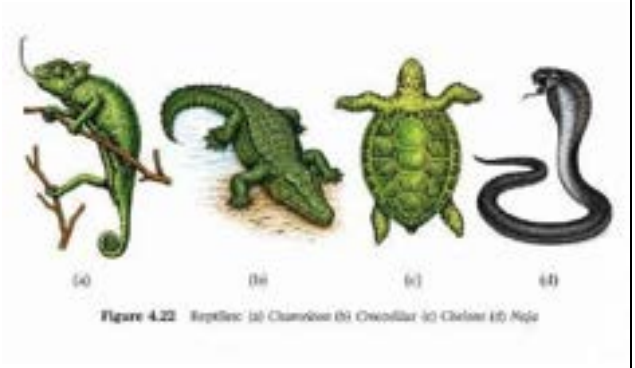
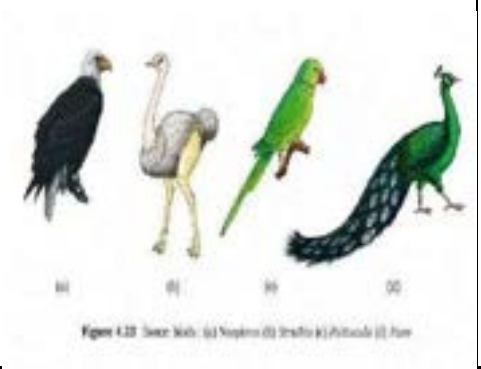


Figure 4.22

Q.17. What term describes organisms whose body temperature changes with the environment?

CLASS AVES

- Feathers: The defining characteristic feature of the class.
- Flight: Most can fly, except for flightless birds like the Ostrich.
- Beak: Present in all species instead of teeth.
- Forelimbs: Modified completely into wings for flight.
- Hind Limbs: Usually possess scales; modified for walking, swimming, or clasping branches.
- Skin: Entirely dry and glandless, except for an oil gland at the base of the tail.
- Endoskeleton: Fully ossified (bony) structure.



- Pneumatic Bones: Long bones are hollow and filled with air cavities to reduce weight.
- Digestive Tract: Features unique additional chambers called the crop and gizzard.
- Circulation: Features a completely four-chambered heart.
- Metabolism: Warm-blooded (homoiothermous); they maintain a constant body temperature.
- Respiration: Done via lungs, which are supplemented by connected air sacs.
- Sexes: Distinct and separate. Fertilisation: Takes place internally.

- Development: Oviparous (egg-laying) with direct development (no larval stage).

- There is no urinary bladder.
  Examples : *Corvus* (Crow), *Columba* (Pigeon), *Psittacula* (Parrot), *Struthio* (Ostrich), *Pavo* (Peacock), *Aptenodytes* (Penguin), *Neophron* (Vulture).

Q.18.Which unique respiratory structures supplement the lungs in birds to assist in flight?

CLASS- MAMMALIA

- Habitats: Highly diverse; found in polar ice caps, deserts, mountains, forests, grasslands, and dark caves. Locomotion: Adapted to live in water or fly in the air.
- Limbs: Possess two pairs of limbs modified for walking, running, climbing, burrowing, swimming, or flying.
- Mammary Glands: The most unique trait; milk-producing glands used to nourish young ones.
- Skin: Unique because it possesses hair.
- External Ears: Feature prominent external ears called pinnae.
- Dentition: Jaws contain different types of teeth (heterodont).
- Circulation: Features a four-chambered heart.
- Metabolism: Warm-blooded (homoiothermous); they maintain a constant body temperature.
- Respiration: Carried out entirely by lungs. Reproduction & Development
- Sexes: Distinct and separate. Fertilisation: Takes place internally.
- Development: Mostly viviparous (give birth to live young) with a few exceptions; development is direct.
- Examples:-Oviparous Mammals (Prototherian Mammals):- Ornithorhynchus (Duck-Billed platypus), Tachyglossus (Spiny Ant eater). Viviparous Mammals (Lutheran Mammals):- Microbus (kangaroo), pteropus (flying fox), Balaenoptera (blue whole), dolphins, Canis (dog), Felix (cat), panthera Leo (lion), panthera tigris (tiger), Panthera pardus (leopard), camelus (camel), Alphas (Elephant), Aqueous (horse).

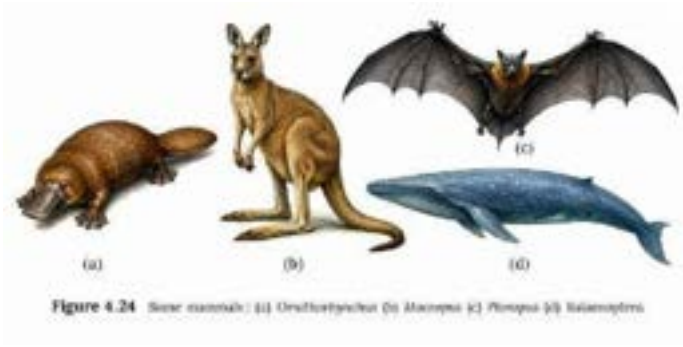


Figure 4.24 Some mammals : (a) Ornithorhynchus (b) Macropus (c) Pteropus (d) Balaenoptera

See answer of intext Questions at page No. 158 in the Question Bank QR under Test Your Knowledge

ANIMAL KINGDOM

Diverse multicellular organisms that lack cell walls and show heterotrophic mode of nutrition

BASIS OF CLASSIFICATION

- Level of organization (cellular to organ-system)
- Symmetry (asymmetry, radial, bilateral)
- Nature of body cavity (acoelomate, pseudocoelomate, coelomate)
- Segmentation
- Presence of notochord, gill slits, type of skeleton, etc.

NON-CHORDATES (10 PHYLA)

1. PORIFERA

- Cellular level of organisation
- Asymmetrical, no true tissues and organs
- Body with pores and canals
- Choanocytes present
- Example: *Sycon* (Scypha)

2. COELENTERATA (CNIDARIA)

- Tissue level of organisation
- Radial symmetry
- Cnidoblasts (stinging cells) present
- Incomplete digestive system
- Examples: *Hydra*, *Aurelia* (Jellyfish)

3. CTENOPHORA

- Tissue level of organisation
- Radial symmetry
- Comb plates for locomotion
- Marine, bioluminescent
- Example: *Pleurobrachia* (Sea walnut)

4. PLATYHELMINTHES

- Organ-system level
- Bilateral symmetry, acoelomate
- Body dorsoventrally flattened
- Incomplete digestive system
- Many are parasitic
- Examples: *Taenia* (Tape worm), *Fasciola* (Liver fluke)

5. ASCHELMINTHES

- Organ-system level
- Bilateral symmetry, pseudocoelomate
- Roundworms
- Complete digestive system
- Sexes separate (dioecious)
- Examples: *Ascaris* (Roundworm), *Wuchereria* (Filaria), *Ancylostoma* (Hookworm)

6. ANNELIDA

- Organ-system level
- Bilateral symmetry, coelomate
- Body metamerically segmented
- Closed circulatory system
- Nephridia for excretion
- Examples: *Nereis* (Sand worm), *Pheretima* (Earthworm), *Hirudinaria* (Leech)

7. ARTHROPODA

- Largest phylum of animals
- Organ-system level, coelomate
- Body segmented; head, thorax, abdomen
- Jointed appendages
- Chitinous exoskeleton
- Open circulatory system
- Examples: *Apis* (Honey bee), *Locusta* (Locust), *Prawn*, *Scorpion*

8. MOLLUSCA

- Second largest phylum
- Organ-system level, coelomate
- Soft body, usually inside a shell
- Muscular foot, mantle, mantle cavity
- Radula present in mouth
- Examples: *Pila* (Apple snail), *Octopus* (Devil fish), *Pinctada* (Oyster)

9. ECHINODERMATA

- Marine, organ-system level
- Adults radially symmetrical; larvae bilateral
- Endoskeleton of calcareous ossicles
- Water vascular system present
- Examples: *Asterias* (Star fish), *Echinus* (Sea urchin), *Cucumaria* (Sea cucumber)

10. HEMICHORDATA

- Marine, worm-like
- Organ-system level, coelomate
- Body with proboscis, collar and trunk
- Stomochord present in collar region
- Example: *Balanoglossus*, *Saccoglossus*

COMMON FEATURES OF ANIMALS

- Multicellular
- Heterotrophic nutrition
- Eukaryotic
- Mostly capable of movement
- Reproduction: Sexual or Asexual
- Development: Direct or Indirect

CHORDATES vs NON-CHORDATES

CHORDATES	NON-CHORDATES
1. Notochord present	Notochord absent
2. Dorsal, hollow, single nerve cord	Ventral, solid, double nerve cord
3. Pharynx perforated by gill slits	Gill slits absent
4. Heart ventral	Heart dorsal (if present)
5. Post-anal tail present	Post-anal tail absent

CHORDATES (Phylum Chordata)

- Notochord, dorsal hollow nerve cord, pharyngeal gill slits, post-anal tail (at least in embryonic stage)
- Organ-system level, bilateral symmetry, coelomate
- Closed circulatory system

PROTOCHORDATES (Marine)

1. UROCHORDATA (TUNICATA)

- Notochord present only in larval tail
- Examples: *Ascidia*, *Salpa*, *Doliolum*

2. CEPHALOCHORDATA

- Notochord extends from head to tail and is persistent
- Example: *Branchiostoma* (Amphioxus/Lancelet)

VERTEBRATES (Notochord replaced by vertebral column in adult)

A. AGNATHA (Lacks jaw)

1. CYCLOSTOMATA

- Jawless vertebrates
- Sucking circular mouth
- No paired fins
- Examples: *Petromyzon* (Lamprey), *Myxine* (Hagfish)

B. GNATHOSTOMATA (Bears jaw)

SUPER CLASS PISCES (Bear fins)

1. CHONDRICHTHYES (Cartilaginous fishes)

- Marine, cartilaginous endoskeleton
- Gill slits without operculum
- Placoid scales, powerful jaws
- Examples: *Scoliodon* (Dog fish), *Pristis* (Saw fish), *Trygon* (Sting ray)

2. OSTEICHTHYES (Bony fishes)

- Marine & freshwater
- Bony endoskeleton
- Gills covered by operculum
- Air bladder present
- Examples: *Catla*, *Labeo*, *Hippocampus* (Sea horse)

SUPER CLASS TETRAPODA (Bear limbs)

1. AMPHIBIA

- Live on land & in water
- Moist skin, no scales
- Three-chambered heart
- External fertilisation
- Examples: *Rana* (Frog), *Bufo* (Toad), *Salamandra*

2. REPTILIA

- Mostly terrestrial
- Dry, scaly skin
- Three-chambered heart (four in crocodiles)
- Internal fertilisation
- Examples: *Naja* (Cobra), *Calotes* (Lizard), *Crocodilus*

3. AVES (Birds)

- Body with feathers, beak
- Forelimbs modified into wings
- Four-chambered heart
- Warm-blooded
- Oviparous
- Examples: *Pigeon*, *Eagle*, *Peacock*, *Ostrich*

4. MAMMALIA

- Hair on body, mammary glands
- External ears, different types of teeth
- Four-chambered heart
- Warm-blooded
- Mostly viviparous
- Examples: Human, Dog, Whale, Kangaroo, Elephant, Bat

LEVEL OF ORGANISATION IN ANIMALS

CELLULAR →	TISSUE →	ORGAN →	ORGAN-SYSTEM
Porifera	Coelenterata, Ctenophora	Platyhelminthes	From Aschelminthes onwards

OTHER IMPORTANT TERMS

- **Direct development:** Young one resembles the adult.
- **Indirect development:** Larval stage is dissimilar to adult.
- **Oviparous:** Lay eggs.
- **Viviparous:** Give birth to young ones.
- **Dioecious:** Sexes separate; **Monoecious:** Both sexes in same individual.

CHAPTER-5: MORPHOLOGY OF FLOWERING PLANTS

CBSE syllabus (2026-27)
Morphology of different parts of flowering plants: root, stem, leaf, inflorescence, flower, fruit and seed, Description of family Solanaceae.

Morphology- It is a branch of biology which deals with external characteristics of organism.

Parts of a Typical angiosperm

ROOT

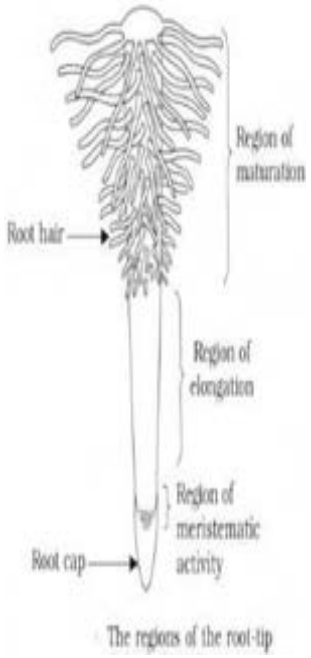
It is typical non-green underground descending part of a plant that gives lateral branches and keeps the plant erect.

Characteristics:-

1. Non-green and non-photosynthetic.
2. Descending and underground.
3. Nodes and internodes are absent.
4. It possesses unicellular root hair for absorption.
5. Positively geotropic, hydrotropic but negatively phototropic.

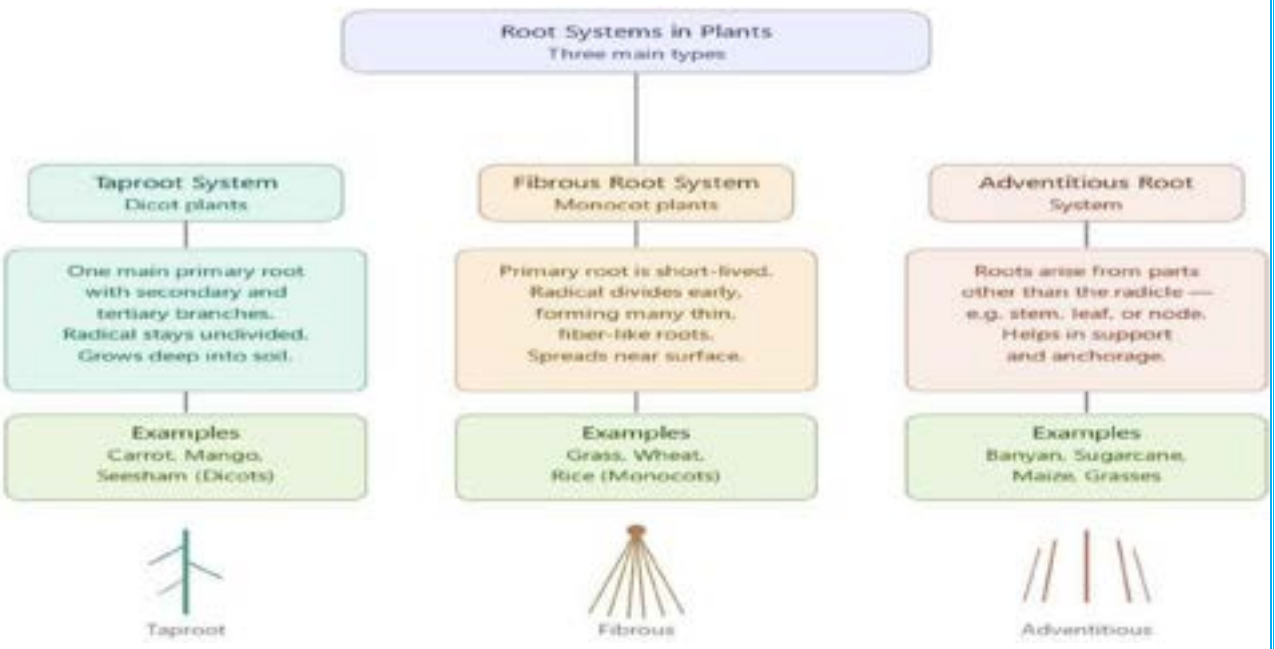
Zones of a Root — Structural Overview

Region	Physical Characteristics	Primary Function
Root Cap	Thimble-like structure covering the apex.	Protects the apical meristem as it penetrates the soil.
Zone of Cell Division	Small cells with dense protoplasm; located just above the cap.	Mitosis (continuous cell division) to create new root material.
Zone of Elongation	Cells stop dividing and undergo rapid enlargement.	Lengthens the root, pushing it deeper into the earth.
Root Hair Zone	Contains fine, unicellular epidermal extensions.	Absorption of water and dissolved minerals.
Zone of Maturation	Cells differentiate into specialized permanent tissues.	Differentiation into vascular tissues (Xylem and Phloem).



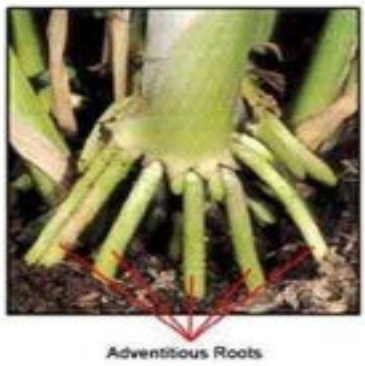
The regions of the root-tip

Q.1. Root hair zone is the most important part of the root for absorption of water. How do these hair maximize the water absorption?









Q.2. Name the part modified for food storage in the following:
a) Carrot b) Radish c) Potato d) Dahlia e) Tuemeric f) Sweet potato

STEM
It is the main ascending erect axis of the plant which develop from plumage and epicotyls of the embryo
Characteristics: It is generally erect and grows away from the soil. So, that is positively phototropic and negatively hydrotropic and geotropic. It posses nodes and internodes. It forms various lateral appendages like leaves, branches, buds, flower etc. It also forms terminal buds. Young stem is green and photosynthetic while old one is non-green. Hair if born on the stem is generally multicellular. Lateral branches are exogenous.

Function of stem

i. Spreading out branches bearing leaves, flowers and fruits.
ii. It conducts water, minerals and photosynthates.
iii. Some stems help in storage of food, support, protection and vegetative propagation.

LEAF

It is a thin, green, flat dorsiventral lateral and aerial part of a plant which is mostly involved in photosynthesis.

Dicot leaf: A dicot leaf is called a dorsiventral leaf because its dorsal (upper) and ventral (lower) surfaces differ structurally, and stomata are more numerous on the lower surface."E.g. Mango, Sunflower

Monocot leaf:

"A monocot leaf is called an isobilateral leaf because both surfaces are nearly alike and stomata are present in almost equal numbers on both surfaces." E.g. Maize, Wheat, Grass

Characteristics of leaf: -

i. Always born on the node of stem.
ii. In most cases there is an auxiliary bud in the axial of leaf.
iii. It is exogenous in origin and develops from leaf prim odium (Meristmatic tissue of leaf).
iv. It is green and performs photosynthesis.
v. Each leaf has three main parts: -
a. Leaf base b. Petiole c. Leaf lamina



Leaf Venation

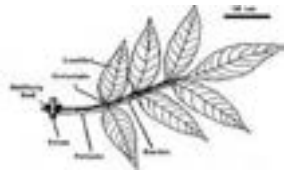
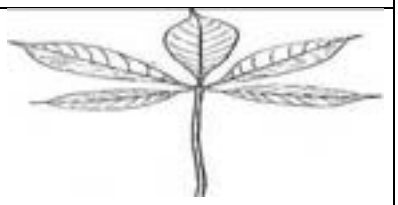
The distribution of veins and vein lets on leaf lamina is called leaf venation.It is of two types

Reticulate venation	**Parallel Venation**
The vein lets are irregularly distributed and forms a network called reticulate venation. Most decocts have reticulate venation. Ex:-Ficus, Mango (Magnifier indicia), Cucurbit a, Mulberry, Vitas viniferous, Papaya etc 	In this all the vein lets run parallel to each other and don't form a network. Most monocots have parallel venation.  Ex: - Banana, Cannae, Wheat, rice, millets, sugarcane, fan palm (Brasses), Bamboo, grasses etc.

Types of Leaves

i.**Simple Leaves:-** The leaves having a single entire lamina are called simple leaves. A simple leaf always contains a bud into its axil.	E.g.:-Peepal, Ficus, Mango etc.	
i.**Compound leaf**:- A leaf is called compound when the incisions of lamina reach up to the midrib and breaks into a number of leaflets. A leaflet doesn't contain any bud into its axial.	E.g. Neem, Rose etc.	

Types of Compound leaf

1.Pinnate Compound leaves:- The midrib also called rachis forms a number of leaflets. E.g.Neem, Rose	**Example:** Neem, Rose etc.	
2. Palmately Compound leaves:- When the two or more leaflets are attached at a common point i.e. at the tip of petiole.	E.g. Silk cotton(Bombax), Cannabis	

INFLORESCENCE

The arrangement of flowers on inflorescence axis or peduncle that is connected to the stem is known as inflorescence. **Peduncle:** - Main axis of inflorescence.

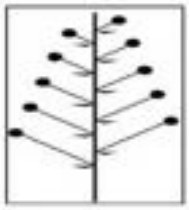
Acropetal succession: - The new flowers arise on apex and mature flowers present on the base.

Centripetal succession: - The younger flower at centre and older at periphery.

Basipetal succession: - Younger flower at the base and mature are present at the apex.

Centrifugal succession: -The mature flowers are present at the centre while the yougerflower are present at the periphery.

TYPES OF INFLORESENCE

Simple Racemose Inflorescence	**Cymose Inflorescence**
It is indeterminate with the main axis growing continuously and flowers arranged acropetally (youngest at the tip). E.g. Mustard, Radish 	It si determinate with the main axis ending in a terminal flower and young buds developing below, often in a basipetal order. E.g. Brinjal, Jasmine 

Q. 3. Differentiate between racemose and cymose inflorescence.

Taxonomy of flowers

Floral Symmetry: -

a. **Actinomorphic** (⊕) - Flowers which have radial symmetry. Ex:- Mustard, Dhatura, chilli, Hibiscus, seclanum.

b. **Zygomorphic** (%) – A flower which have bilateral symmetry. Ex:-*Pisum sativum*, gulmohar bean, Cassia.

c. **Asymmetrical**: - A flower which is unsymmetrical. Ex:- Canna.

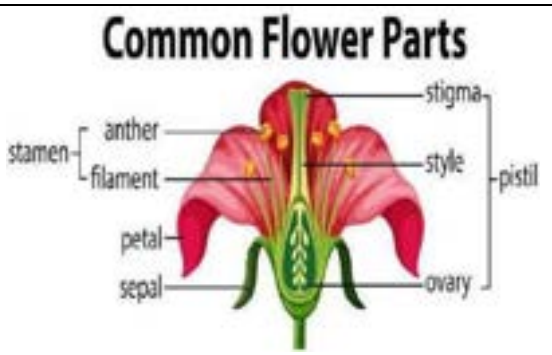
Number of floral parts:-

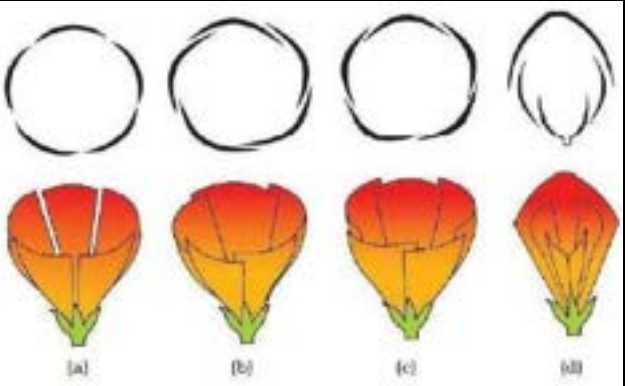
Types of Flower on the **basis of floral appandages**-

a. Trimerous: - Floral parts are three or multiple of three.
b. Tetramerous: - Floral parts are four or multiple of four.
c. Pentamerous: - Floral parts are five or multiple of five.

Bracteate and Ebracteate: - Flower with bracts - reduced leaf found at the base of the pedicel are called bracteate and those without bracts ebracteate.

Flower		
Unisexual: one type of sex organ either male or female		**Bisexual**: which contain both gynoecium as well as Androecium
Staminate flower e.g.Corn, Cucumber	Pistillate flower e.g.Corn, Cucumber	Stigma, style and ovary combine to form pistil, carpel or gynoecium.

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• All sepals are collectively called calyx.
• All petals are collectively called corolla.
Calyx (K):- Polysepalous – When sepals free Rose, tomato, chilies etc.
Gamosepalous- When sepals are joined together -Dhatura.
Corolla (C) - Polypetalous- Petals are free. Ex:- Rose, Mustard, China, rose etc.
Gamopetalous- Petals are fused in whorls or in parts.
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Aestivation: - The mode of arrangement of sepals or petals in relation to one another in a flower is known as aestivation.
i. Valvate: - The petals of worls meet by their edges or margins but donot overlap.e.g. Calatropis.
ii. Twisted: - The margins of petals are overlapped in regular manner.e.g. (Lady finger).
iii. Imbricate: - The margins of petals are overlapped but in irregular manner.e.g. Cassia, Gulmohar.
iv. Vexillary: - Total five petals are present Dorsal one (called standard) is largest. Two are lateral called the wings. Ventral ones are smallest called keel.
Ex: - Pea and bean (Family papilionaceae).
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Q.4. The aestivation found in Hibiscus, Brinjal and Pea and draw their diagram.

Perianth (P): -In some flowers, there is no distinction between sepals and petals. Such floral parts are known as perianth (tepal).

Androecium: - Anther and filament of all stamens combine to form androecium.

Cohesion of stamen: -**Monoadelphous: -** All the stamen of the flower are united in one bundle by the fusion of their filament. Ex: - Hibiscus.

Diadelphous: - All the stamen of the flower are united in two bundles by the fusion of their filament. Ex:- Pea (Pisum sativum).

Polyadelphous: - All the stamens are fused and forms more than two bundles. Ex:- Citrus

Synadndrous: - Anthers as well as filaments are fused. Ex:- Cucurbits

Polyandrous: - Stamens are indefinite and are free. Ex:- Ranunculus (butter cup).

Epipetalous- When the stamens are attached to petals by their filament.

Gynoecium:-

1. **Types of ovary on the basis of cohesion of carpel**:-

Syncarpous:-When all the carpels are fused.Ex:- Hibiscus, mustard, tomato, lemon, cucurbita.

Apocarpous:- When all the carpals are free.Ex:- Lotus, Rose, Ranunculus.

2. **Types of ovary on the basis of position of calyx, corolla, androecium in respect of the ovary on thalamus-**

a) Hypogenous flower (Superior ovary):- Ovary occupies the highest position by the other floral parts situated below it. Ex:- Mustard, Brinjal (Selenium melongena), China rose, citrus.

b) Epigynous flower (Inferior Ovary):- Margins of the thalamus grow upward enclosing the ovary completely. Ex:- Cucurbita

c) Perigynous flower:- If gynoecium is situated in the centre and other parts of flower are located on the rim of thalamus almost at the same level.Ex:- Plum, Rose, Peach.

Q.5. Describe the arrangement of floral members in relation to their insertion on thalamus

Placentation -The arrangement of ovules within the ovary is called placentation.

a) Marginal Placentation - The placenta forms a ridge along the ventral suture of the ovary and the ovules are borne on this ridge

Ex:- Pisum sativum (Pea).

b) Axial Placentation - When the placenta is axial and the ovules are attatched to it.in a multilocular ovary. E.g.:- Hibiscus, tomato, lemon etc.

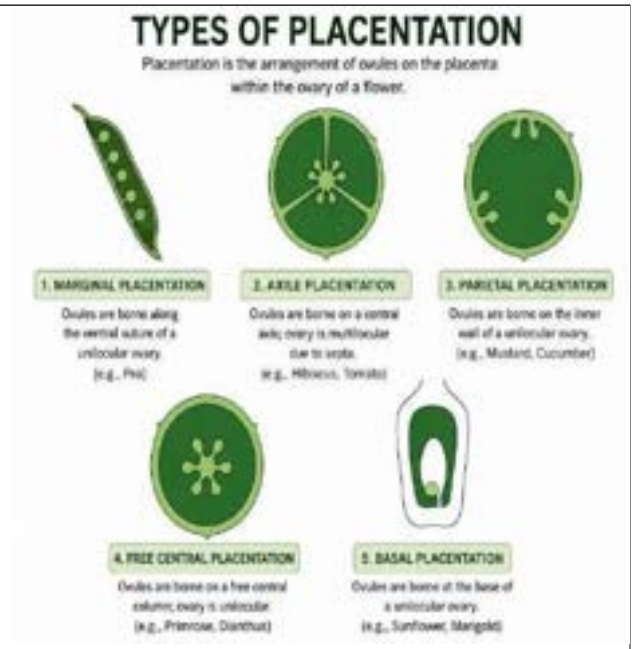
c) Parietal Placentation - The ovules develop on the inner wall of the ovary or on the peripheral part.

E.g.:- Cucurbita (Cucumber, melon, water melon etc).

d) Free central placentation – When the ovules are borne on central axis and septa are absent. E.g.:- Dianthus, Primrose etc.

e) Basal placentation – The placenta develops at the base of ovary and a single ovule is attached to it.

E.g.:-Asteraceae (sunflower, marigold).



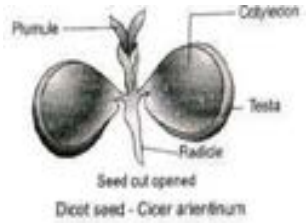
Q.6. Give two examples of each type of placentation and draw the diagram.

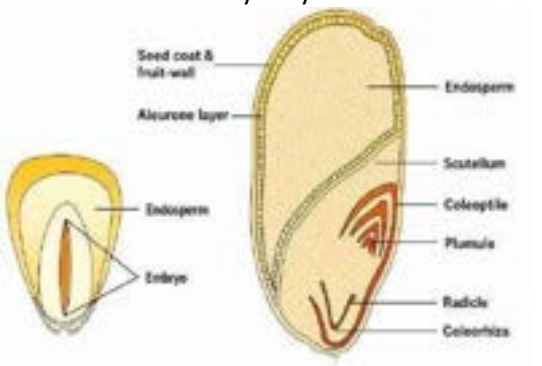
FRUIT-It is a ripened ovary which is formed after fertilization. Fruit consists of pericarp and seeds.

Parthenocarphy:- The process of development of fruit without fertilization is known as parthenocarphy.

SEED - A seed is a basic part of a plant, which is found enclosed within the fruit. It is a ripened ovule formed after fertilization. It is made up of a seed coat and an embryo. During the development of the fruit, the wall of the ovary becomes the pericarp. In some plants, the ovary walls dry out completely, while in some it remains fleshy.

Dicot seed (Non-endospermic or ex-aluminous/non-albuminous).	**Monocot seed (Endospermic or albuminous)**
• It contains two cotyledons. • Endosperm is absent. • Ex: - Gram, almond, Pea, Apple, Mango, Orange, Coffee and groundnut.	• It contains one cotyledon. • Endosperm persists. • Function of scutellum. • It is a rudimentary cotyledon





Q.7. What are the part of seed and an emryo?.

DESCRIPTION OF FAMILY SOLANACEAE - It is commonaly called potato family. Plants mostly herbs and shrubs but rarely small trees. It is widely distributed in tropics, subtropics and even temperate zones.

Vegetative Characters

Stem - Herbaceous rarely woody, aerial, erect, cylindrical, branched, solid or hollow, hairy or glabrous, underground stem in potato.

Leaves - Alternate, simple, rarely, pinnately compound, exstipulate, reticulate venation.

Floral characters -

Inflorescence - Solitary, axiliary or cymose.

Flower- Bisexual, Actinomorphic.

Calyx- Sepals five, united, persistent, valvate aestivation.

Corolla- Petals five, united, valvate aestivation.

Androecium - Stamens five, epipetalous.

Gynoecium -Bicarpellary, Syncarpous, superior ovary, binocular, Placentation axial.

Fruit - Berry or capsule.

Seeds – Many, endospermous

Floral Formula - $\oplus \, ♀ \, K_{(5)} \, \widehat{C_{(5)} \, A_5} \, \underline{G}_{(2)}$

Economic Importance -

- Source of food (Potato, tomato, potato, brinjal).
- Spices (chilly)
- Medicine (Belladonna, ashwagandha).
- Fumigatory (Tobacco).
- Ornamentals (Petunia).

Q.8. Write the floral formula of a flower which, is bisexual; actinomorphic; sepals five, petals five, valvate aestivation, petals five; valvate aestivation; stamens five, epipetalous; ovary bicarpellary, syncarpous, superior, bilocular with axile placentation.

Q.9. Draw the floral diagram and floral formula of Solanaceae family. (Hint: The diagram and formula given above.) Draw floral diagram of family Solanaceae.

See answer of intext Questions at page No. 158 in the Question Bank QR under Test Your Knowledge

MORPHOLOGY OF FLOWERING PLANTS

VEGETATIVE ORGANS (Plant Body)

1. ROOT



Usually underground. Anchors the plant in the soil and absorbs water and minerals. May store food in some plants.

TYPES

- Tap root
- Fibrous root
- Adventitious root

2. STEM



Usually aerial part. Supports leaves, buds, flowers and fruits; conducts water, minerals and food.

MODIFICATIONS

- Underground: Rhizome, Tuber, Bulb, Corm
- Aerial: Runner, Stolon, Tendril, Thorn
- Stem tendril, Phylloclade

3. LEAF



Lateral appendage of stem. Main site of photosynthesis, transpiration and gaseous exchange.

PARTS OF A LEAF

- Leaf base
- Petiole
- Lamina (leaf blade)
- Stipules (in some plants)

REPRODUCTIVE ORGANS (Flower and its Parts)

FLOWER (Modified Shoot)



Reproductive organ of angiosperms. Bracts at the base form the calyx. Different whorls on the thalamus (receptacle) are:

1. CALYX (Sepals)



Outermost whorl. Usually green. Protects the flower in bud stage.

2. COROLLA (Petals)



Usually brightly coloured and attractive. Helps in attracting pollinators.

3. ANDROECIUM (Stamens)



Male reproductive whorl. Each stamen has anther and filament.

4. GYNAECOIUM (Carpels)



Female reproductive whorl. One or more carpels (pistil) present.

5. OTHER PARTS



Thalamus (Receptacle): Base on which floral whorls are borne. Nectaries: May be present.

FRUIT AND SEED (After Fertilization)



Ovary develops into fruit. Ovules develop into seeds.

CHAPTER: 6 ANATOMY OF FLOWERING PLANTS

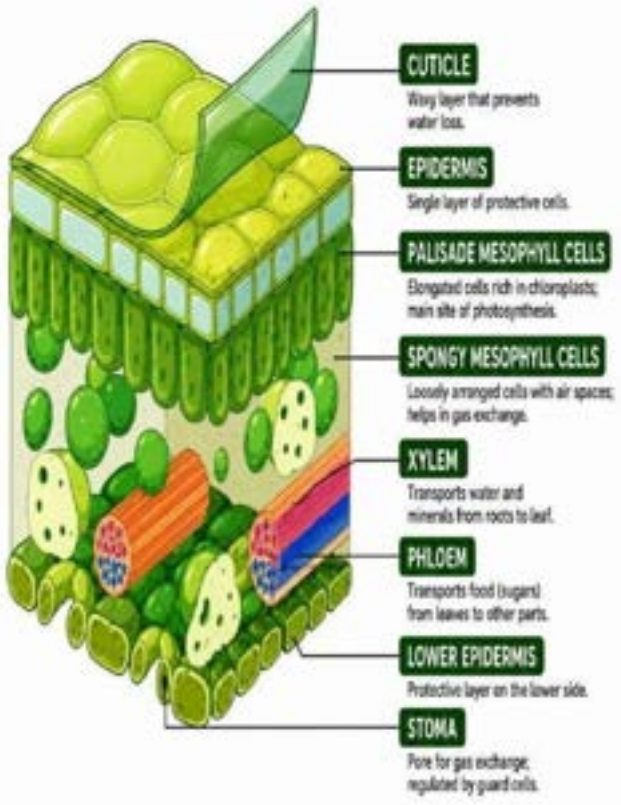
CBSE Syllabus 2026-27
Anatomy and functions of tissue systems in dicots and monocots.

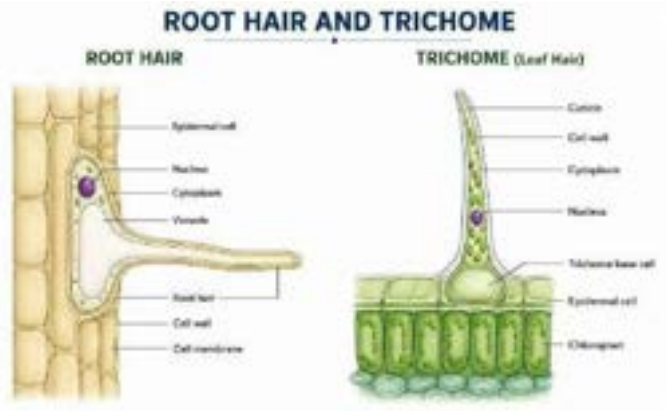
Study of internal structure of plants/animals is called anatomy.
Plants have **cells** as the basic unit, cells are organized into **tissues** and in turn the tissues are organized into **organs**. There are **three types of tissue systems** on the basis of their structure and location.

1. The epidermal tissue system
2. The ground or fundamental tissue system
3. The vascular or conducting tissue system.

Epidermal Tissue System

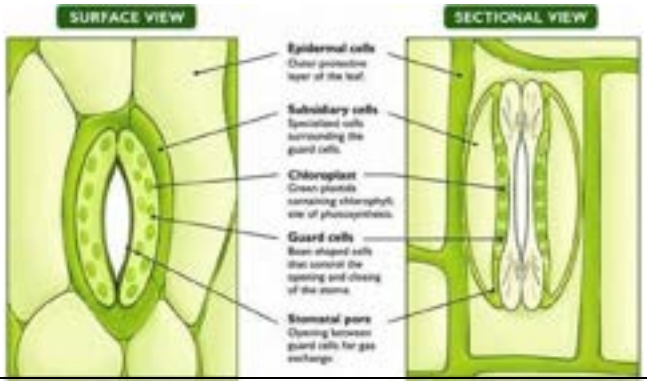
- Consists of Epidermal cells (The outermost single layer of cells).
- Parenchymatous elongated and compact cells with a small amount of cytoplasm lining the cell wall and a large vacuole.
- Presence of waxy thick layer called the cuticle- it prevents the loss of water. Cuticle is absent in roots.
- Stomata (present in the epidermis of leaves)
- **Stomatal apparatus** composed of two bean shaped cells known as guard cells which enclose stomatal pore.
- Specialized cells known as subsidiary cells around guard cells. The outer walls of guard cells (away from the stomatal pore) are thin and the inner walls (towards the stomatal pore) are highly thickened.
- In grasses, the guard cells are **dumb-bell shaped.**
- Stomata regulate the process of transpiration and gaseous exchange.
- The guard cells possess chloroplasts and regulate the opening and closing of stomata.
- **Epidermal appendages** -
- **Trichomes -** Multicellular epidermal hairs on the stem the are called trichomes.
- They may be branched / unbranched, soft / stiff and may even be secretory.
- The trichomes help in preventing water loss.
- **Root hairs:** The root hairs are unicellular elongations of the epidermal cells. They help absorb water and minerals from the soil due to transpiration.





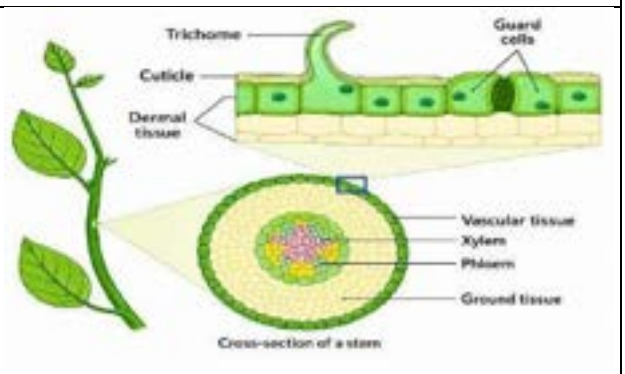
Stomata – The stomata are structures present on the surface of leaves. They regulate transpiration and gaseous exchange. The stomatal aperture, guard cells and subscidary cells together called stomatal apparatus.

Q.1. What is stomatal apparatus? Explain the structure of stomata with a labelled diagram.



The Ground or Fundamental Tissue System

All tissues except epidermis and vascular bundles It consists of simple tissues such as parenchyma, collenchymas and sclerenchyma. Parenchymatous cells are usually present in cortex, pricycle, pith and medullary rays, in the primary stems and roots. In leaves the ground tissue consists of thin-walled chloroplast containing cells called mesophyll.



The vascular or conducting tissue system

The vascular system consists of complex tissues, the phloem and the xylem.
The xylem and phloem together constitute <u>vascular bundles</u>.

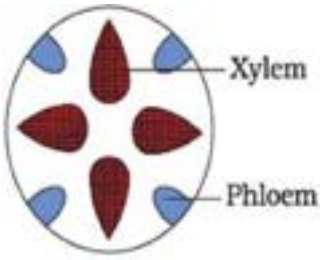
Types of vascular bundles:

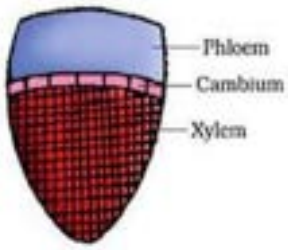
1. **Radial**- Xylem and Phloem tissues are arranged alternately along different radii (In Roots)
2. **Conjoint**— Xylem and Phloem are jointly situated along the same radius

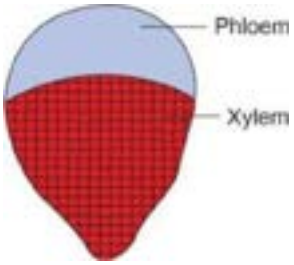
2 types of Conjoint vascular bundles

i) **Conjoint open -** Vascular bundles <u>having cambium</u>, possess the ability to form secondary xylem and phloem tissues, and hence are called open vascular bundles. (In Dicots)

ii) **Conjoint closed -** When the vascular bundles <u>have no cambium</u> present in them, they do not form secondary tissues and are referred to as closed. (In Monocots)



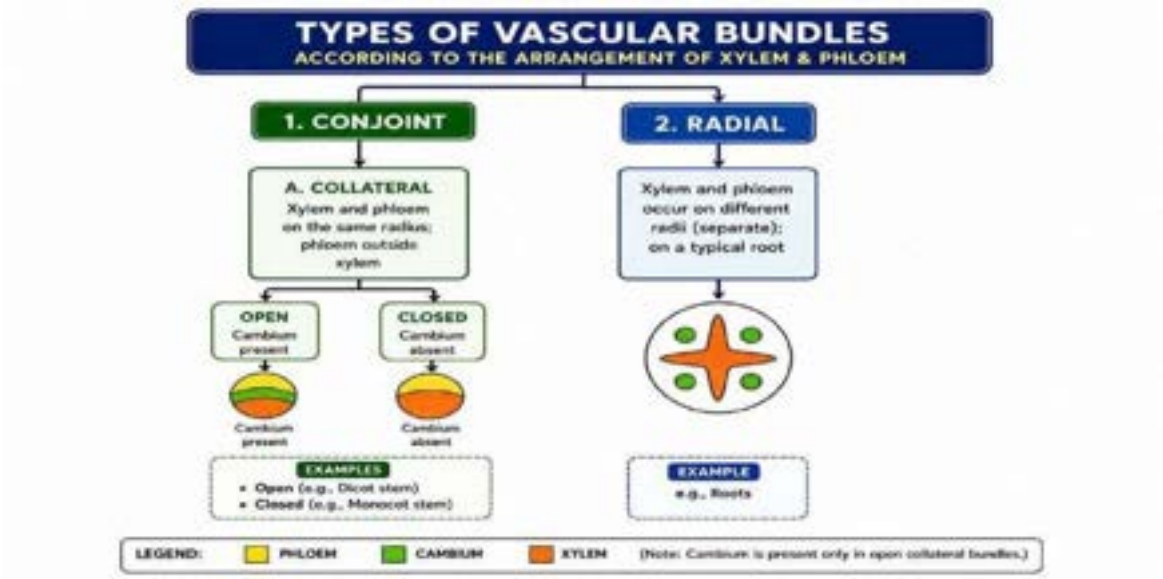




Radial **conjoint open** **conjoint closed**

Q.2. Vascular bundles are referred as open or closed. How do they differ from one another? Can it be used for classification of plants?

Q.3. Classify vascular bundles on the basis of position of the protoxylem.

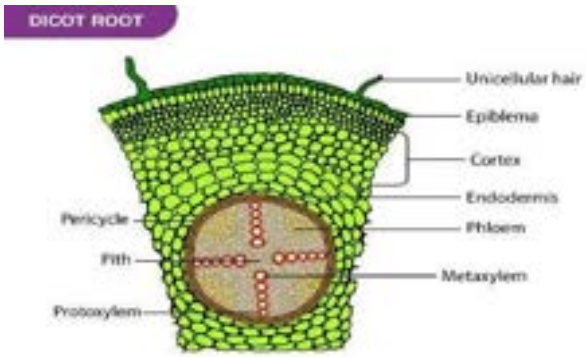


Anatomy of Dicot Root

- Epiblema -the outermost layer
- The cortex-consists of several layers of thin-walled parenchyma cells with intercellular spaces.
- Endodermis-The innermost layer of the cortex with a single layer of barrel shaped cells without any intercellular spaces.
- Casparian strips The walls of the endodermal cells have a deposition of water-impermeable, waxy material suberin in the form of casparian strips.
- Pericycle- Next to endodermis lies a few layers of thick-walled parenchymatous cells
- There are usually two to four xylem and phloem patches.
- The pith is small or inconspicuous.
- Stele : All tissues on the innerside of the endodermis such as pericycle, vascular bundles and pith constitute the stele.

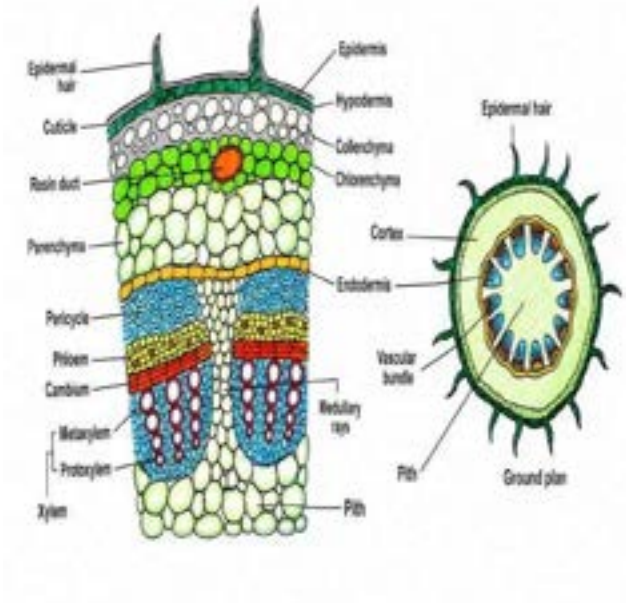
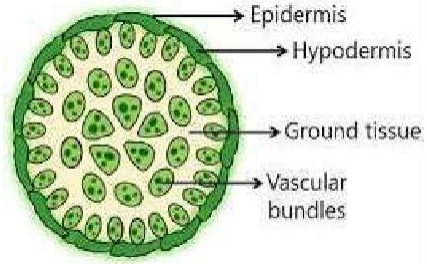
Anatomy of Monocot Root

- The outermost layer is epidermis which forms unicellular root hairs.
- Cortex consists of multilayered thin walled parenchymatous cells with intercellular space.
- Endodermis: Innermost layer of cortex is known as endodermis.
- casparian strips: It is also a single layer of barrel shaped cells without any intercellular spaces. The tangential as well as radial walls of endodermis have a deposition of water impermeable waxy substance made up of suberin.
- Pericycle is present but it does not give rise to cambium. So that the secondary growth is absent.
- These are usually more than six xylem and phloem patches. Such vascular bundle is known as polymorph.
- Pith: - Pith is large and well developed.





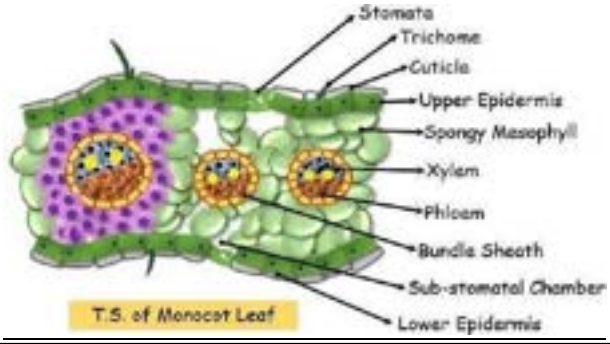
Q.4. Which chemical substance is found in Casparian strips present in dicot roots?

Anatomy of Dicot Stem	Anatomy of Monocot Stem
• Epidermis: - the outermost protective layer of stem covered by a thin layer of cuticle. It may bear trichome's and a few stomata. • Cortex: - The cells arranged in multiple layers between epidermis and pericycle constitute cortex. It has three sub zones: - • Hypodermis: - Consists of a few layers of collenchymatous cells just below the epidermis, which provide mechanical strength to the young stem. • Cortical layers: - Present below hypodermis consists of rounded thin walled parenchymatous cells with conspicuous intercellular spaces. • Endodermis: - It is the innermost layer of cortex. • Pericycle: -Pericycle is present on the inner side of the endodermis and above phloem in form of semi-lunar patches of sclerenchyma. • Vascular bundle: - A large number of vascular bundles are arranged in a ring, which is characteristic feature of decoct stem. Each vascular bundle is conjoint, open and with end arch protoxylem. • Pith: - A large numbers of rounded, parenchymatous cells with large intercellular spaces which occupy the central portion of the stem constitute the pith.	• Monocot stem has a sclerenchymatous hypodermis. • It has a large number of scattered vascular bundles. • Vascular bundles are surrounded by a sclerenchymatous bundle sheath cells and a large conspicuous parenchymatous ground tissue. • Vascular bundles are conjoint and closed. • Peripheral vascular bundles are generally smaller than centrally located ones. • Phloem parenchyma is absent and water filled cavities are present with vascular bundles.
	

Q.5. You are given a cut transverse section of young stem of a plant from your school garden to observe it under the microscope. How would you ascertain whether it is a monocot stem or a dicot stem? Give any three reasons.

Identification of Monocot Stem-

- If the stem shows the following features, it is a monocot stem.
- Vascular bundles scattered-The vascular bundles are irregularly scattered in the ground tissue.
- Vascular bundles are closed-Cambium is absent; therefore, secondary growth does not occur.
- Ground tissue undifferentiated-Cortex and pith are not clearly separated.

Anatomy of Dicot leaf (dorsiventral leaf)	**Anatomy of Monocot leaf (Isobilateral leaf)**
• Epidermis: - It covers both upper and lower surface. It is covered by a layer of cuticle. • The abaxial epidermis (lower) bears more stomata than abaxial epidermis (upper) • Spongy Parenchyma- With large intercellular space. It is situated below palisade layer. • Vascular System- It include vascular bundles, which can be stem in the veins of midrib. The sizes of vascular bundles are dependent on the size of veins. Vascular bundles are surrounded by a thick layer of bundle sheath cells.  	• Stomata are present on the both surfaces of the epidermis. • Mesophyll is not differentiated into palisade and spongy parenchyma. • In grasses, certain adaxial epidermal cells along the veins modify themselves into large, empty, colorless cells known as bulliform cells. • When the bulliform cells in the leaves have absorbed water and are turgid, the leaf surface is exposed while when they are flaccid due to water stress, they make the leaves curl inwards to minimize water loss. • The parallel venation in monocots is reflected in the near similar sizes of vascular bundles (except in main veins) as seen in vertical sections of the leaves. 

Q.6. Differentiate between dicot and monocot leaves.

Q.7. Where are bulliform cells found? What is it significance?

See answer of intext Questions at page No. 158 in the Question Bank QR under Test Your Knowledge

ANATOMY OF FLOWERING PLANTS

Anatomy is the study of internal structure of plant organs.
It helps in supporting, conducting and storing various functions in plants.

PLANT ORGANS

1. ROOT

Main functions:
- Absorption of water
- Absorption of minerals
- Anchorage
- Storage

2. STEM

Main functions:
- Support
- Conduction
- Storage
- Photosynthesis (in green stems)

3. LEAF

Main functions:
- Photosynthesis
- Transpiration
- Gaseous exchange

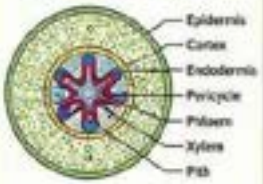
4. VASCULAR BUNDLE

Transport system of plants.

TYPES

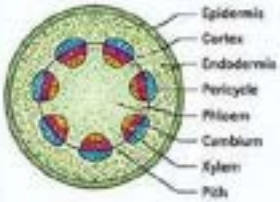
- **CONJOINT** — Xylem and phloem together
  - **COLLATERAL** — Phloem outside, xylem inside
    - **OPEN** — Cambium present
    - **CLOSED** — Cambium absent
  - **BICOLLATERAL** — Xylem in middle, phloem on both sides
- **RADIAL** — Xylem and phloem on different radii

T.S. OF DICOT ROOT



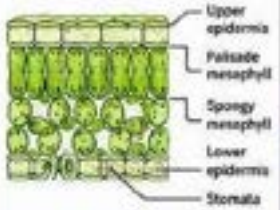
KEY FEATURES
- Radial vascular bundles
- Xylem and phloem alternate
- Pith present

T.S. OF DICOT STEM



KEY FEATURES
- Vascular bundles in ring
- Bundles open (cambium present)
- Cortex and pith well differentiated

T.S. OF DICOT LEAF



KEY FEATURES
- Dorsiventral leaf
- Palisade on upper side
- Spongy mesophyll with air spaces
- Stomata mostly on lower epidermis



Phloem | Xylem | Cambium

DIFFERENCE BETWEEN MONOCOT & DICOT STEM (IN T.S.)

Feature	Dicot Stem	Monocot Stem
Vascular bundles	Arranged in a ring	Scattered in ground tissue
Nature of bundles	Open (cambium present)	Closed (cambium absent)
Ground tissue	Cortex and pith well differentiated	Cortex and pith not differentiated
Secondary growth	Present	Absent
Example	Sunflower, Pea, Hibiscus	Maize, Wheat, Rice

SIGNIFICANCE

- Helps in identification and classification of plants
- Helps in conduction of water, minerals and food
- Provides mechanical strength and support
- Helps in storage and secretion of substances

SUMMARY Anatomy of flowering plants reveals the structure of roots, stems, leaves and vascular bundles, which helps in their functions, growth and survival.

Chapter-7: Structural Organisation in Animals

Syllabus 2026-27
Morphology, Anatomy and functions of different systems (digestive, circulatory, respiratory, nervous and reproductive) of frog.

Tissue - A group of similar cells along with intercellular substances perform a specific function. Such an organisation is called tissue.
Note-Basic tissues organise to form organs, and organs combine to form organ systems in multicellular organisms.

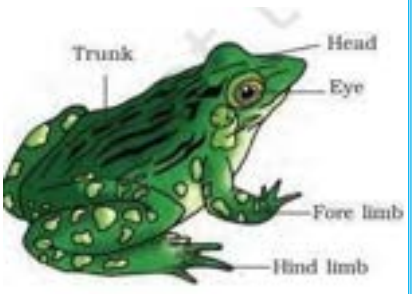
- This organisation helps in efficient and coordinated functioning of millions of cells in the body.
- Example: The heart contains all four types of tissues: Epithelial tissue, Connective tissue, Muscular tissue and Neural tissue.

Frogs (*Rana tigrina*)

- Habitat: **Amphibian** (both in water and land).
- Frogs are **cold-blooded animals** or **poikilotherms** (Their body temperature changes according to the environmental temperature).
- The protective colour adaptation is called **mimicry** or **camouflage (**Frogs can change their body colour depending on their surroundings).
- Summer sleep in frogs is called **aestivation** and winter sleep in frogs is called **hibernation** (these habits protect frogs from extreme heat and cold respectively).

Morphology of frog

- Frog skin is smooth and slippery due to the presence of mucus.
- Frogs do not drink water; they absorb water through their skin.
- The body of a frog is divided into two parts: Head and Trunk.
- Eyes are bulging and covered by a **nictitating membrane** for protection in water.
- A membranous **tympanum (ear)** is present on either side of the eyes to receive sound signals.



- Forelimbs and hind limbs help in:
  1. Swimming 2. Walking
  3. Leaping 4. Burrowing
- Hind limbs end in five digits, while forelimbs end in four digits.
- Feet have webbed digits that aid in swimming.
- Frogs show **sexual dimorphism** (males and females differ externally).
- Male frogs possess:
  1. Sound-producing vocal sacs.
  2. Copulatory pads on the first digit of forelimbs.

Q.1. Assertion: Frogs are sexually dimorphic organisms.

Reason: Females have copulatory pads on forelimb.

Q.2. State how frogs protect themselves from their enemies?

Nutrient storage and metabolism in frogs take place in-

a- Fat bodies **b- Cloaca** **c- both a and b** **d- neither a and b**

DIGESTIVE SYSTEM AND DIGESTION IN FROG

DIGESTIVE SYSTEM IN FROG

- The digestive system consists of alimentary canal and digestive glands.
- Frogs are carnivores, so their alimentary canal is short.

ALIMENTARY CANAL

MOUTH

Opens into buccal cavity.

BUCCAL CAVITY

Leads to pharynx.

PHARYNX

Connects buccal cavity to oesophagus.

OESOPHAGUS

A short tube that opens into the stomach.

STOMACH

Receives food from oesophagus.

INTESTINE

Continues from stomach.

RECTUM

Short, wider part of intestine.

CLOACA

Common chamber that opens outside.

DIGESTIVE GLANDS

LIVER

- Largest digestive gland.
- Secretes bile.
- Bile is stored in the gall bladder. (Green sac under the liver)

PANCREAS

- A digestive gland.
- Produces pancreatic juice containing digestive enzymes.

OTHER FEATURES
- Food is captured by the bilobed tongue.
- The alimentary canal is short because frogs are carnivores.

DIGESTION IN FROG

1. INGESTION

Food is captured by the bilobed tongue and swallowed.

2. DIGESTION IN STOMACH

HCl and gastric juices secreted from the walls of the stomach digest the food.

3. CHYME FORMATION

Partially digested food is called chyme.

4. INTO DUODENUM

Chyme passes from stomach to the duodenum (first part of small intestine).

5. ADDITION OF BILE AND PANCREATIC JUICE


- Duodenum receives bile from gall bladder and pancreatic juices from pancreas through a common bile duct.
- Bile emulsifies fats.
- Pancreatic juices digest carbohydrates and proteins.

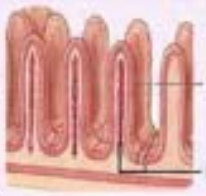
6. FINAL DIGESTION IN INTESTINE

Final digestion takes place in the intestine with the help of digestive enzymes.

KEY POINTS
- Alimentary canal is short.
- Liver – secretes bile (stored in gall bladder).
- Pancreas – secretes pancreatic juice (enzymes).
- Cloaca – common opening for digestive, urinary and reproductive systems.

8. EGESTION


Undigested solid waste moves into the rectum and passes out through the cloaca.

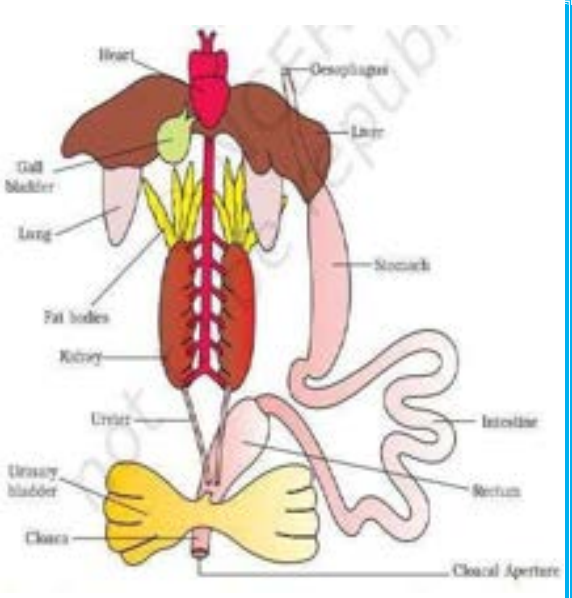
7. ABSORPTION


Digested food is absorbed by numerous finger-like folds in the inner wall of intestine called villi and microvilli.

Q.3. Frogs have a short alimentary canal. Illustrate its significance.

Q.4. Answer the followings related with the digestive system of frogs-
(i) How do frogs catch their prey?
(ii) Where is bile stored in the body of a frog?
(iii) Explain the digestion of food in frog.

Q.5. Draw the alimentary canal of frog and label in it
- **(i) Stomach**
- **(ii) Liver**
- **(iii) Intestine**
- **(iv) Rectum**



Diagrammatic representation of internal organs of frog showing complete digestive system

Respiration

- In water, the skin acts as the respiratory organ. Respiration through skin is called **cutaneous respiration**. Dissolved oxygen in water diffuses through the skin.
- On land, the following organs help in respiration:
  - Buccal cavity
  - Skin
  - Lungs
- Respiration through lungs (Located in the upper trunk region (thorax) is called **pulmonary respiration**.
- Air enters through the nostrils into the buccal cavity and then reaches the lungs.
- During **aestivation** and **hibernation**, gaseous exchange occurs through the skin.

Vascular System

- Frog has a well-developed **closed vascular system**.
- Frogs possess a **lymphatic system**.
- The blood vascular system consists of: Heart, Blood vessels and Blood.
- The lymphatic system includes: Lymph, Lymph channels, Lymph nodes.
- Heart is covered by a membrane called **pericardium**.
- Frog heart has **three chambers**: Two atria and one ventricle.
- A triangular structure called **sinus venosus** joins the right atrium.
- Sinus venosus receives blood through major veins called **vena cava**.
- The ventricle opens into a sac-like **conus arteriosus** on the ventral side.
- Frogs possess special venous systems:
  - **Hepatic portal system** → between liver and intestine
  - **Renal portal system** → between kidneys and lower body parts
- Blood consists of: Plasma and Blood cells (RBCs (erythrocytes), WBCs (leucocytes) and Platelets)
- **Frog RBCs are nucleated.** RBCs contain red pigment called **haemoglobin**.

Q.6. State the type of circulation in frog and also the number of chambers in the heart of the frog.
Q.7. How the RBSs of frog is different from humans?

Excretory system

- Frog is a ureotelic animal. Its excretory system consists of a pair of kidneys, ureters, cloaca and urinary bladder.
- Kidney is composed of structural and functional units called uriniferous tubules or nephrons.

- **In males the ureters act as a urinogenital duct which opens into the cloaca**.
- **In females the ureters and oviduct open separately in the cloaca**.
- Bidder's canal is found in Male frogs. The Bidder canal is located in the male frog's kidney. The Vasa-efferentia opens into the Bidder's canal. It receives sperm from the vasa efferentia and aids in sperm passage.

Q.8. Where do you find bidder's canal? State its function.

Q.9. Name the organ in frog that receives urine, faecal matter and gametes.

Control and Coordination

The chemical coordination

- It is carried out by hormones which are secreted by the endocrine glands. e.g. pituitary, thyroid, parathyroid, thymus, pineal body, pancreatic islets, adrenals and gonads.

The nervous system

- It consists of CNS (brain and spinal cord), PNS (cranial and spinal nerves) and ANS (sympathetic and parasympathetic). Brain is enclosed in a bony structure called brain box (cranium). It has three parts fore-brain, mid-brain and hindbrain.
- Forebrain- olfactory lobes, paired cerebral hemispheres and unpaired diencephalon.
- Midbrain- It has a pair of optic lobes.
- Hind-brain- It consists of cerebellum and medulla oblongata.
- The medulla oblongata passes out through the foramen magnum and continues into spinal cord.
- Spinal cord is enclosed in the vertebral column.
- There are ten pairs of cranial nerves arising from the brain.

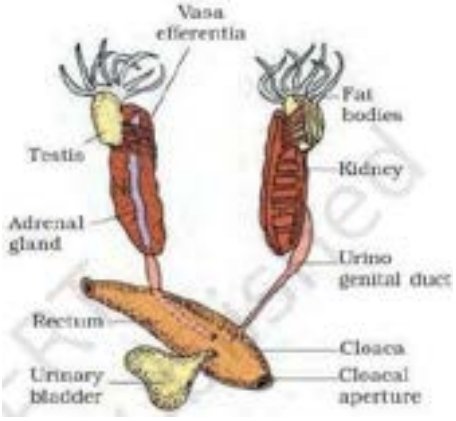
Sensory organs

- Touch (sensory papillae), taste (taste buds), smell (nasal epithelium), vision (eyes) and hearing (tympanum).
- Eyes in a frog are a pair of spherical structures situated in the orbit in the skull. These are simple eyes (possessing only one unit).
- Ear is an organ of hearing as well as balancing (equilibrium).

Q.10. State the different types of sense organs of frogs. Which organ also helps in balancing?

Male reproductive system

- It consists of a pair of testes.
- A testis is found adhered to the upper part of kidneys by a double fold of peritoneum called mesorchium.
- From testes 10-12 vasa efferentia arises. They enter the kidneys on their side and open into Bidder's canal and communicate with the urinogenital duct that comes out of the kidneys and opens into the cloaca.
- The cloaca is a small, median chamber that is used to pass faecal matter, urine and sperms to the exterior.



Male reproductive system

Q.11. (i) Yellowish ovoid testes are adhered to the upper part of kidneys by a double fold of peritoneum called

(a) Cloaca (b) Mesorchium (c) Bidder's canal (d) copulatory pads.

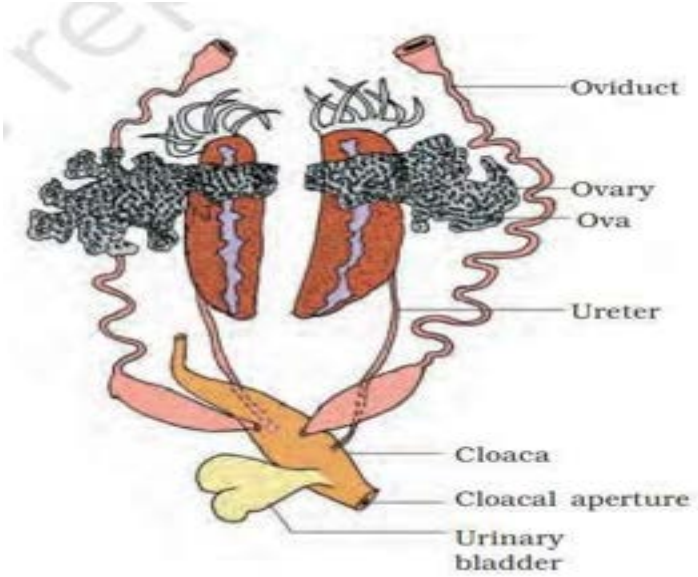
Q.12. Draw the Male reproductive system of frog and label in it

(i) Testis (ii) Vasa efferentia (iii) Urinogenital duct (iv)Cloacal aperture

Q.13. Why are testes in frogs attached near the kidneys through mesorchium?

Female reproductive system

- It includes a pair of ovaries.
- A pair of oviducts arising from the ovaries opens into the cloaca separately.
- A mature female can lay 2500 to 3000 ova at a time.
- Fertilization is external and takes place in water.
- Development is indirect and involves a larval stage called tadpole.
- Tadpole undergoes metamorphosis to form an adult.



Q.14. A female frog lays thousands of ova at a time. Why is this necessary?
Ans: Many eggs and tadpoles are eaten by predators or die naturally, so producing a large number increases the chances of survival of some offspring.

Economic Importance of Frog

- Frogs are beneficial for mankind because they eat insects and protect the crop.
- Frogs maintain ecological balance because these serve as an important link of food chain and food web in the ecosystem.
- In some countries the muscular legs of frog are used as food by man.

Q.15. Explain the role of frogs in maintaining ecological balance.
Q.16. How are frogs useful to farmers?

See answer of intext Questions at page No. 158 in the Question Bank QR under Test Your Knowledge

FROGS (*Rana tigrina*)



- Can live on land and in freshwater.
- Belong to class Amphibia (phylum Chordata).
- Cold blooded (poikilothermic).
- Change colour for camouflage (mimicry).
- Aestivation in summer and hibernation in winter.

1 MORPHOLOGY



- Skin smooth, slippery and moist (mucus present).
- Dorsal side olive green with dark spots; ventral side pale yellow.
- Absorbs water through skin.
- Body divisible into head and trunk; no neck and tail.
- Pair of nostrils above mouth.
- Eyes bulged with nictitating membrane; tympanum (ear) present.
- Forelimbs – 4 digits; hind limbs – 5 digits, large and muscular.
- Webbed digits on feet help in swimming.
- Sexual dimorphism: Males have vocal sacs and copulatory pad on first digit of forelimb.

2 DIGESTIVE SYSTEM



- Consists of alimentary canal and digestive glands.
- **Alimentary canal:** Mouth → buccal cavity → pharynx → oesophagus → stomach → intestine → rectum → cloaca.
- **Digestive glands:** Liver (bile, stored in gall bladder) and pancreas (pancreatic juice).
- Food captured by bilobed tongue.
- Digestion in stomach by HCl and gastric juices.
- Chyme passes to duodenum.
- Duodenum receives bile and pancreatic juice via common bile duct.
- Bile emulsifies fat; pancreatic juice digests carbohydrates and proteins.
- Final digestion in intestine.
- Absorption by villi and microvilli.
- Undigested waste passes to rectum and out through cloaca.

3 RESPIRATION



- Respiration occurs on land and in water.
- **In water:** Skin acts as aquatic respiratory organ (cutaneous respiration); O_2 diffuses through skin.
- **On land:** Buccal cavity, skin and lungs act as respiratory organs.
- Lungs are a pair of elongated, pink sac-like structures in thorax.
- Air enters through nostrils → buccal cavity → lungs.
- Pulmonary respiration occurs through lungs.
- During aestivation and hibernation, gaseous exchange occurs through skin.

4 VASCULAR SYSTEM



- Well-developed, closed type; single circulation.
- **Heart** 3-chambered: two atria and one ventricle; covered by pericardium.
- Sinus venosus opens into right atrium; receives blood from vena cava.
- Ventricle opens into conus arteriosus.
- Arteries carry blood away from heart; veins bring blood back to heart.
- Special venous connections:
  - Hepatic portal system (liver–intestine)
  - Renal portal system (kidney–lower body parts)
- Blood = Plasma + Cells (RBCs – nucleated, with haemoglobin; WBCs; Platelets).
- Lymphatic system present (lymph, lymph channels, lymph nodes).

5 EXCRETORY SYSTEM



- Consists of a pair of kidneys, ureters, urinary bladder and cloaca.
- **Kidneys:** bean shaped, made of nephrons.
- Ureters act as urinogenital ducts and open into cloaca (separately in females along with oviduct).
- **Urinary bladder:** thin-walled, opens into cloaca.
- Excretes urea → ureotelic animal.

6 CONTROL AND COORDINATION



- Includes nervous system and endocrine glands.
- **Endocrine glands:** Pituitary, thyroid, parathyroid, thymus, pineal body, pancreatic islets, adrenals, gonads.
- **Nervous system:**
  - **Central:** Brain and spinal cord
  - **Peripheral:** Cranial (10 pairs) and spinal nerves
  - **Autonomic:** Sympathetic and parasympathetic
- **Sense organs:** touch, taste, smell, vision (eyes), hearing (tympanum with internal ears).

7 MALE REPRODUCTIVE SYSTEM



- A pair of yellowish, ovoid testes near kidneys, attached by mesorchium.
- 10–12 vasa efferentia arise from testes.
- They enter kidneys and open into Bidder's canal.
- Finally communicate with urinogenital duct.
- Urinogenital duct opens into cloaca.
- Cloaca is common chamber for faeces, urine and sperms.

8 FEMALE REPRODUCTIVE SYSTEM

- A pair of ovaries near kidneys (no functional connection).
- A pair of oviducts arise from ovaries.
- Oviducts open separately into cloaca.
- A mature female lays 2500–3000 ova at a time.
- Fertilisation is external (in water).
- Eggs hatch into tadpoles; tadpoles undergo metamorphosis to form adult frogs.

9 IMPORTANCE



- Eat insects and protect crops.
- Maintain ecological balance as important link in food chains and food webs.
- In some countries, frog legs are used as food by humans.

CHAPTER-8 CELL : THE UNIT OF LIFE

Syllabus (2026-27): The Unit of Life Cell theory and cell as the basic unit of life, structure of prokaryotic and eukaryotic cells; Plant cell and animal cell; cell envelope; cell membrane, cell wall; cell organelles - structure and function; endomembrane system, endoplasmic reticulum, golgi bodies, lysosomes, vacuoles, mitochondria, ribosomes, plastids, microbodies; cytoskeleton, cilia, flagella, centrioles (ultrastructure and function); nucleus.

- **Cell is the fundamental structural and functional unit of life**

CELL THEORY

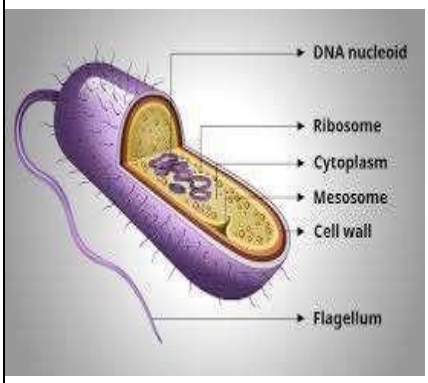
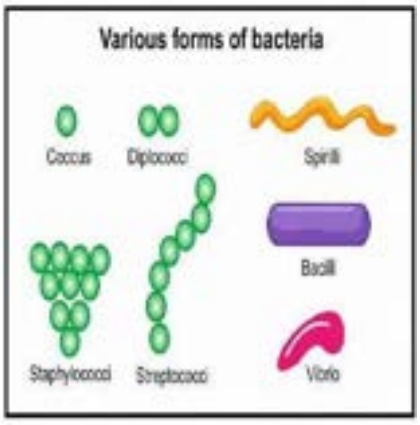
Proposed by: Schleiden (1838) and Schwann (1839)

- **Additions by: Rudolf Virchow (1855).**
- **All living organisms are made of cells.**
- **Cell is the basic unit of life.**
- **All cells arise from pre-existing cells(Virchow's addition)**

Cell structure

Cells differ greatly in size, shape and activities. For example, Mycoplasmas, the smallest cells, are only 0.3 mm in length while bacteria could be 3 to 5 µm. The largest isolated single cell is the egg of an ostrich.

Prokaryotic cell-

1. Definition: Prokaryotic cells are primitive, simple cells without a true nucleus and membrane-bound organelles. 2. Examples: Bacteria, Blue-green algae (cyanobacteria), Mycoplasma, Archaebacteria. 3. Cell envelope: It is outer covering and three layerd: outermost Glycocalyx second layer is cell wall and inner most plasma membrane.	4. Glycocalyx may be thin and loose called slime layer or thick and tough called capsule. 5. Cell wall is made up of peptidoglycan. 6. Cell membrane: Present beneath cell wall. Plasma membrane form enfoldings called mesosomes. **Mesosome** helps in cell wall formation, DNA replication, and respiration. **Nucleoid:** Region with a single circular DNA, not enclosed by a membrane. Ribosomes: (70S type), Plasmids: present	 

PLANT CELL **ANIMAL CELL**

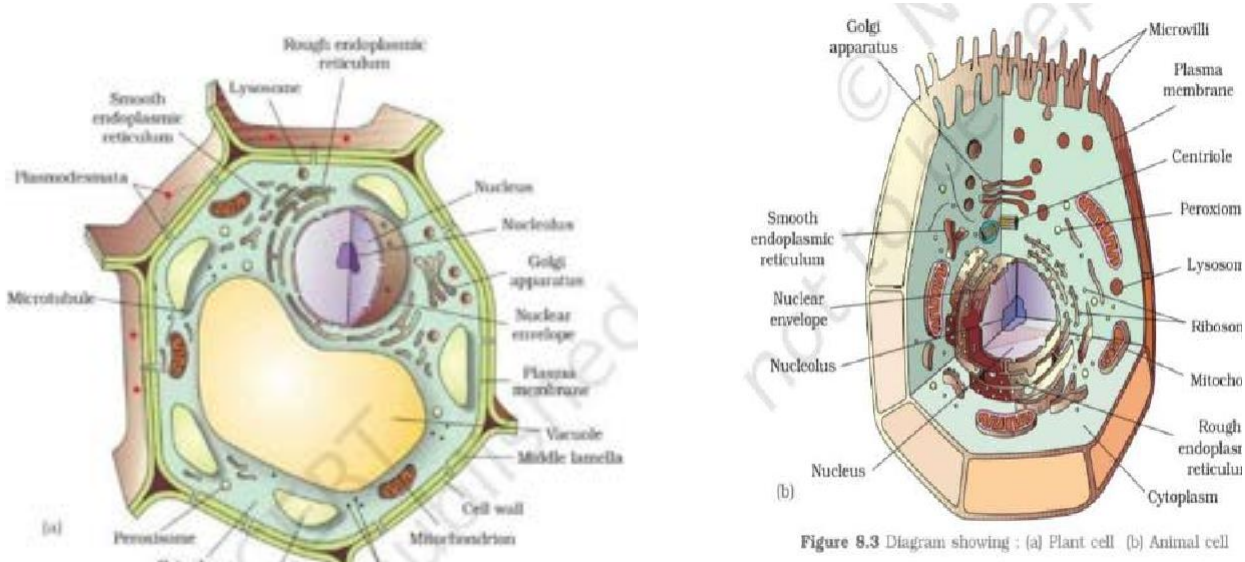


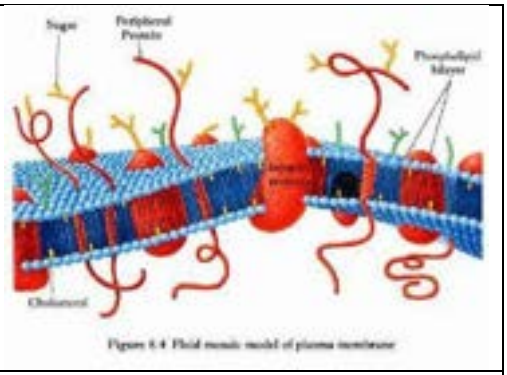
Figure 8.3 Diagram showing : (a) Plant cell (b) Animal cell

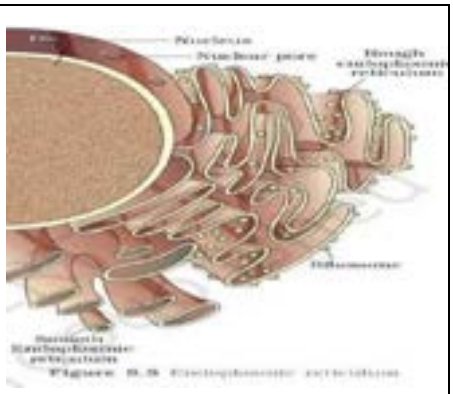
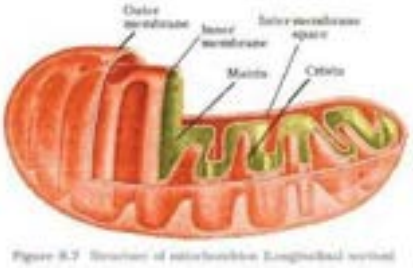
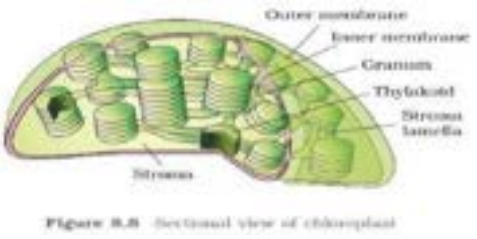
Eukaryotic cell

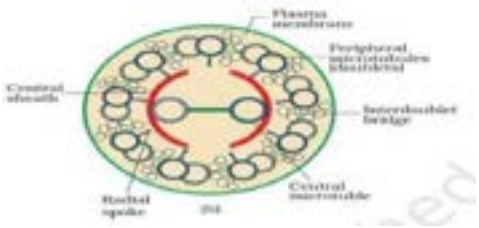
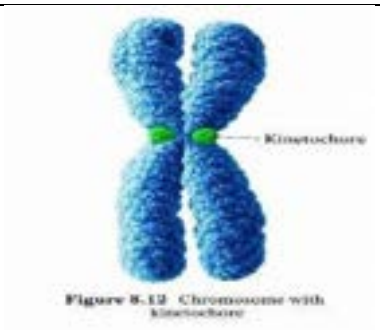
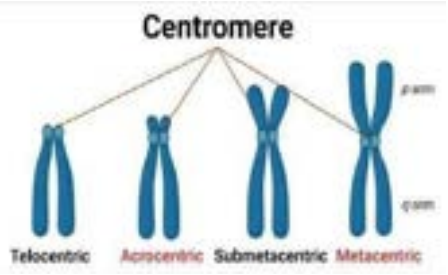
Eukaryotic cells possess an organised nucleus with a nuclear envelope.

Membrane-bound Organelles present: Mitochondria, Golgi Apparatus Lysosomes, Plastids, Vacuoles, Cell Membrane, and cytoskeleton.

CELL ORGANELLES-

Cell membrane- The plasma membrane is selectively permeable and facilitates transport of several molecules. • Cell membrane is mainly composed of lipids and proteins. The major lipids are phospholipids that are arranged in a bilayer. • Also possess protein and carbohydrate. Model of the cell membrane was proposed by Singer and Nicolson (1972) as fluid mosaic Model.	
Cell wall-non-living rigid structure. • An outer covering for the plasma membrane of fungi (made up of chitin) and plants (made up of cellulose). **Function-** gives shape to the cell and protects the cell, helps in cell-to-cell interaction and provides barrier to undesirable macromolecules	

Endoplasmic Reticulum (ER) -a network or reticulum of tiny tubular structures scattered in the cytoplasm. 1. **Rough ER**- ribosomes attached to their outer surface. They are extensive and continuous with the outer membrane of the nucleus. **Function**-involved in protein synthesis and secretion. **2. Smooth ER**- Due to absence of ribosomes they appear smooth. **Function-** site for synthesis of lipid. In animal cells lipid-like steroidal hormones are synthesised in SER.	
Golgi complex- Camillo Golgi (1898) first observed densely stained reticular structures near the nucleus; consist of many flat, disc-shaped sacs or cisternae. They have cis and trans form. **Function**- packaging materials. Materials to be packaged in the form of vesicles from the ER fuse with the *cis* face of the golgi apparatus.	
Lysosomes- Membrane bound vesicular structures formed by the process of packaging in the Golgi apparatus. **Function-**They have enzymes capable of digesting carbohydrates, proteins, lipids and nucleic acids	
Vacuoles- membrane-bound space found in the cytoplasm. It contains water, sap, excretory product and other materials. The vacuole is bound by a single membrane called tonoplast. It contains water, sap, excretory product and other materials not useful for the cell.	
Mitochondria- specifically stained structure. It has inner and outer membrane, The inner compartment is filled with a dense homogeneous substance called the **matrix** and inner membrane forms a number of infoldings called the cristae towards the matrix. • It is sites of aerobic respiration called power house of the cell and produced ATP.	
Plastids- Plastids are found in all plant cells and in euglenoides. They bear some specific pigments, thus imparting specific colours to the plants.ex- • chloroplast-perform photosynthesis • leucoplast • Chromoplast.	
Ribosomes- 80S type. Observed by dense particles by George Palade (1953). Composed of ribonucleic acid (RNA) and proteins and are not surrounded by any membrane. Each ribosome has two subunits, larger and smaller subunits. The two subunits of 80S	

ribosomes are 60S and 40S while that of 70S ribosomes are 50S and 30S.	
Cytoskeleton- An elaborate network of filamentous proteinaceous structures consisting of microtubules, microfilaments and intermediate filaments present in the cytoplasm. Function- support, motility, maintenance	
Cilia and flagella- hair-like outgrowths of the cell membrane. Cilia- are small structures work like oars, causing the movement. Flagella-comparatively longer. Function-cell movement.	
Nucleus- Well defined double membrane-bound organelle, Discovered by Robert Brown (1831). Components of Nucleus 1. Nuclear Envelope 2. Nucleoplasm (Nuclear Sap) 3. Chromatin as chromosomes 4. Nucleolus Chromatin contains DNA and histone protein, some non histone protein and RNA. Every chromosome has a primary constriction or the centromere on the sides of which disc shaped structures called kinetochores are present. Based on the position of centromere chromosomes are classified into four types- Telocentric, acrocentric, submetacentric and metacentric. **Function**- Stores hereditary information, Directs synthesis of proteins. Controls cell division and growth. Regulates metabolic activities. Formation of ribosomes etc.	 

See answer of intext Questions at page No. 158 in the Question Bank QR under Test Your Knowledge

CELL: STRUCTURE AND FUNCTION

Class 11 Biology

1. INTRODUCTION

- Cell is the basic structural and functional unit of life.
- Discovered by Robert Hooke (1665) in cork cells.
- All living organisms are made of one or more cells.
- Cell theory:
  - All organisms are composed of cells.
  - Cell is the basic unit of life.
  - All cells arise from pre-existing cells.



Cork cells (R. Hooke)

2. TYPES OF CELLS

Prokaryotic Cells

- No true nucleus
- No membrane-bound organelles
- Smaller in size (1–10 µm)
- Example: Bacteria, Cyanobacteria



Eukaryotic Cells

- True nucleus present
- Membrane-bound organelles present
- Larger in size (10–100 µm)
- Example: Plant cells, Animal cells, Fungi, Protists



3. BASIC STRUCTURE OF A EUKARYOTIC CELL

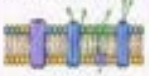


- **Plasma membrane:** Selectively permeable barrier.
- **Cytoplasm:** Fluid matrix, site of metabolic reactions.
- **Nucleus:** Control center; contains DNA.
- **Organelles:** Perform specific functions within the cell.

4. CELL ENVELOPE

Plasma Membrane

- Composed of lipid bilayer and proteins.
- Fluid mosaic model (S. J. Singer & G. L. Nicolson).
- Functions:
  - Protects the cell
  - Regulates entry and exit of substances
  - Cell communication



Fluid Mosaic Model

Cell Wall (in plants)

- Non-living, rigid layer outside plasma membrane.
- Made of cellulose, hemicellulose, pectin.
- Functions:
  - Provides shape and support
  - Protection
  - Prevents bursting



5. CELL ORGANELLES AND THEIR FUNCTIONS

Organelle	Functions
Nucleus	Stores genetic material (DNA), controls cell activities.
Endoplasmic Reticulum (ER)	Rough ER: Protein synthesis and transport. Smooth ER: Lipid synthesis, detoxification.
Ribosomes	Site of protein synthesis.
Golgi Apparatus	Modifies, sorts and packages proteins and lipids.
Mitochondria	Powerhouse of the cell; site of ATP production.
Lysosomes	Contain hydrolytic enzymes; intracellular digestion.
Peroxisomes	Breakdown of fatty acids; detoxification of harmful molecules.
Cytoskeleton	Maintains cell shape; helps in cell movement and intracellular transport.
Vacuoles (in plants)	Store cell sap; maintain turgor pressure.

6. CELL FUNCTIONS

Metabolism	All chemical reactions for energy and synthesis of molecules.
Growth	Increase in size and number of cells.
Reproduction	Formation of new cells/organisms.
Response to Stimuli	Detect and respond to changes in environment.
Transport	Movement of substances across membrane and within cell.
Homeostasis	Maintenance of stable internal conditions.

7. PLANT CELL vs ANIMAL CELL

Plant Cell	Animal Cell
• Cell wall present	• Cell wall absent
• Plastids (e.g., chloroplasts) present	• Plastids absent
• One large central vacuole	• Small or temporary vacuoles
• Fixed shape (usually rectangular)	• Irregular shape
• Centrioles absent (in higher plants)	• Centrioles present
• Stores food as starch	• Stores food as glycogen





KEY TAKEAWAY

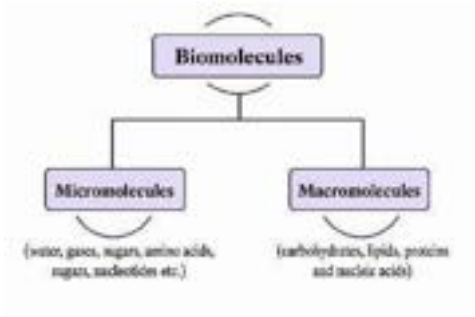
The cell is the fundamental unit of life. Its well-organized structure enables essential functions, ensuring survival, growth and reproduction of organisms.

CH-9 :BIOMOLECULES

Syllabus (2026-27): Chemical constituents of living cells: biomolecules, structure and function of proteins, carbohydrates, lipids, and nucleic acids; Enzyme - types, properties, enzyme action. (Topics excluded: Nature of Bond Linking Monomers in a Polymer, Dynamic State of Body Constituents Concept of Metabolism, Metabolic Basis of Living, The Living State)

Chemicals or molecules present in the living organism are known as biomolecules.

- Biomolecules are divided into two types- inorganic and organic.
- Inorganic biomolecules includes minerals, gases and water and organic biomolecules includes carbohydrates, fats, proteins, nucleic acids, vitamins, etc.

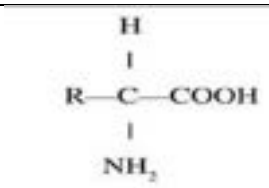
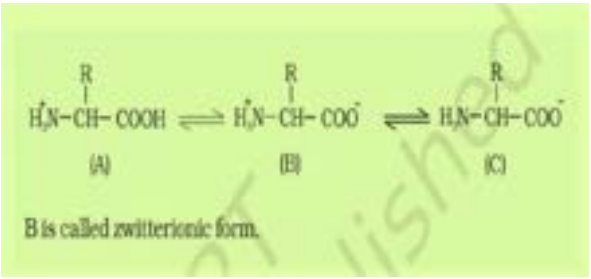


ANALYSIS OF CHEMICAL COMPOSITION

- Grind living tissue in trichloroacetic acid (Cl3CCOOH). The thick slurry is now strained to filtrate (acid-soluble) and retentate (acid-insoluble). The filtrate contains thousands of organic compounds and some inorganic compounds like sulphate, phosphate.
- The acid insoluble fraction, has only four types of organic compounds i.e., proteins, nucleic acids, polysaccharides and lipids.
- Weighs a small amount of living tissue and burnt it completely. The ash (dry weight) contains inorganic elements

- **1. PROTEINS.** Proteins are polypeptides. They are linear chains of amino acids linked by peptide bonds. Each protein is a polymer of amino acids. There are about 20 different amino acids exist naturally. Essential; amino acids: dietary amino acid. Non-essential: synthesized inside the body
- Proteins carry out many functions in living organisms, some transport nutrients across cell membranes, some fight infectious organisms, some are hormones, some are enzymes.
  - Collagen -most abundant protein in the animal world.
  - Rubisco- most abundant protein in the whole biosphere.

2. AMINO ACIDS

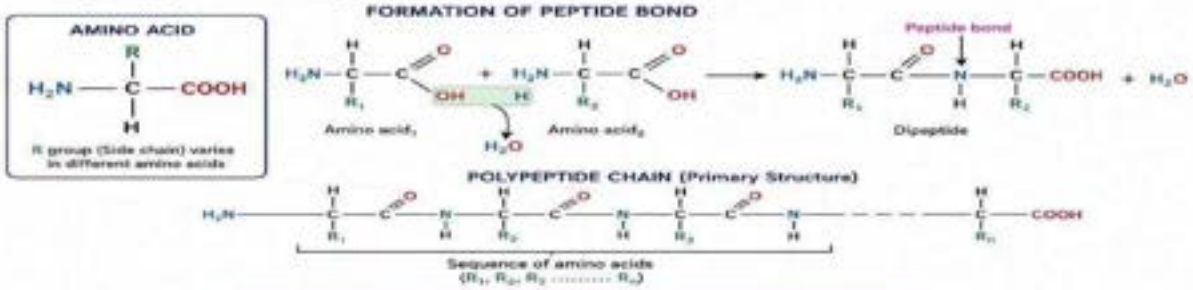
Amino acids are organic compounds containing an amino group and an acidic group as substituents on the same carbon i.e., the α-carbon. Hence, they are called α-amino acids.	
Zwitter ion: At specific pH an amino acid behaves as a zwitterion i.e. contains both positive and negative charge. **Peptide bond** • The amino group of one amino acid and the carboxyl group of another amino acid combine together with the loss of water and form a peptide bond. • Many amino acids join to form polypeptides (proteins	

Based on number of amino and carboxyl groups, amino acids can be- • Acidic eg. Glutamic acid • Basic eg. lysine • Neutral, eg. glycine	 **Amino acids**

PRIMARY STRUCTURE OF PROTEIN

The primary structure of a protein is the linear sequence of amino acids in a polypeptide chain.

- Proteins are polymers of amino acids.
- In a polypeptide chain, amino acids are linked to each other by peptide bonds.
- The sequence in which amino acids are arranged in the polypeptide chain constitutes the primary structure of the protein.



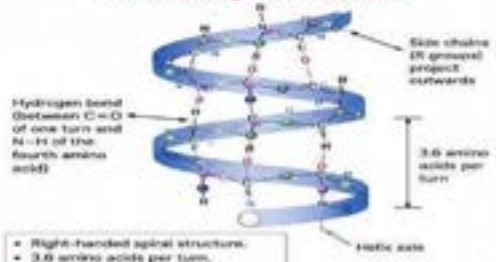
Primary structure = Linear sequence of amino acids in a polypeptide chain
(e.g., –Ala–Gly–Ser–Leu–Val–.....etc.)

SECONDARY STRUCTURE OF PROTEIN

The secondary structure of a protein refers to the regular folding or coiling of the polypeptide chain into α-helix or β-pleated sheet structures, stabilized by hydrogen bonds.

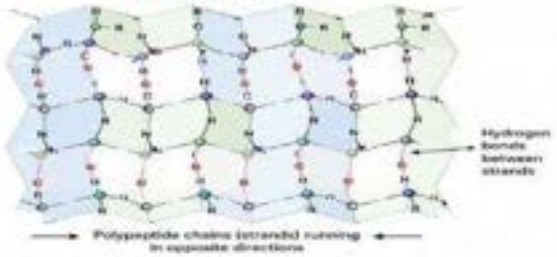
- It is a local folding of the polypeptide chain into a regular and repetitive structure.
- It is stabilized by hydrogen bonds between –C=O and –N–H groups of the peptide backbone.

1. α-HELIX (Right-handed helix)



- Right-handed spiral structure.
- 3.6 amino acids per turn.
- Rise per turn = 5.4 Å (0.54 nm)
- Distance between two successive amino acids = 1.5 Å (0.15 nm).
- Stabilized by intra-chain hydrogen bonds.
- Side chains (R groups) project outwards.

2. β-PLEATED SHEET

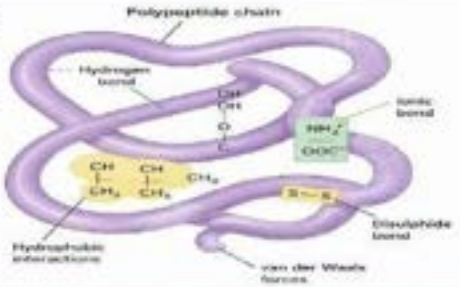


- Formed by two or more extended polypeptide chains placed side by side.
- Adjacent strands run in opposite directions (antiparallel).
- Stabilized by hydrogen bonds between –C=O of one strand and –N–H of the adjacent strand.
- R groups (side chains) project above and below the plane of the sheet.

TERTIARY STRUCTURE OF PROTEIN

The tertiary structure of a protein is the overall three-dimensional shape of a polypeptide chain.

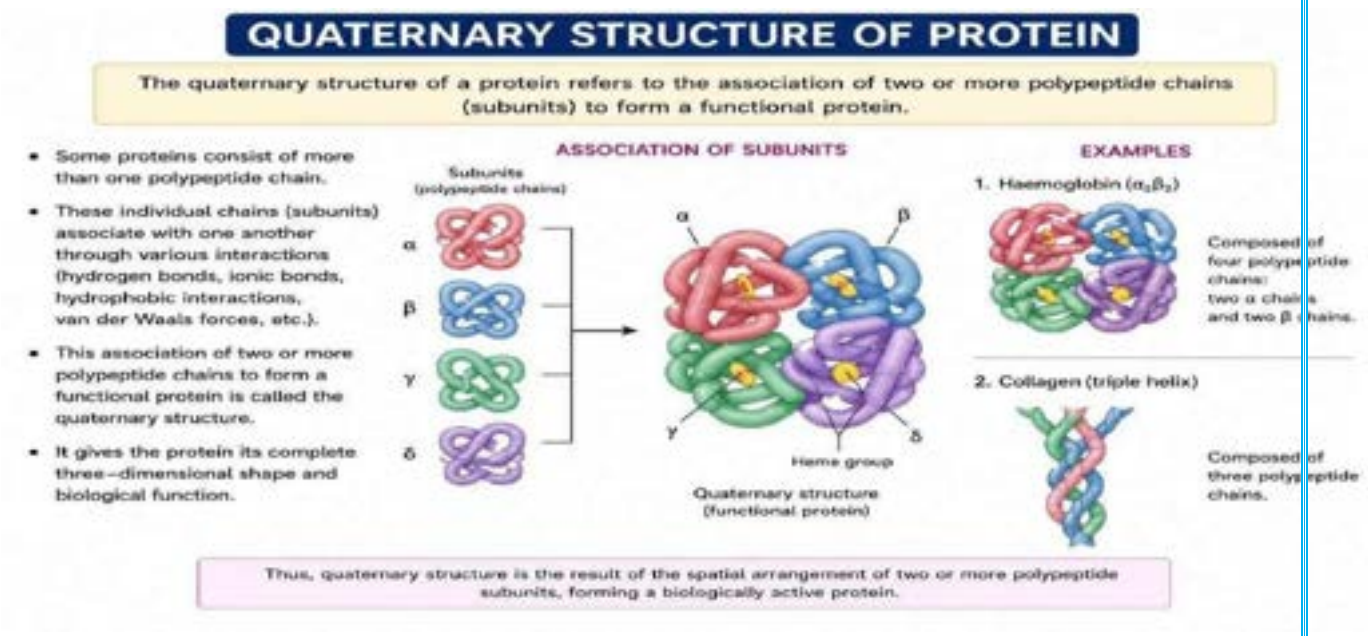
- It arises due to folding of the polypeptide chain in a specific manner.
- The tertiary structure is stabilized by various types of interactions between the R groups (side chains) of amino acids.
- These interactions include disulphide bonds, hydrogen bonds, ionic bonds, hydrophobic interactions and van der Waals forces.
- The tertiary structure gives a protein its unique shape and biological function.



Types of interactions stabilizing the tertiary structure

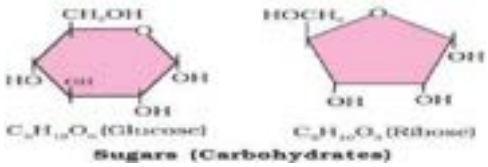
1. Disulphide bond (covalent bond)
2. Hydrogen bond
3. Ionic bond (salt bridge)
4. Hydrophobic interactions
5. van der Waals forces

The unique combination of these interactions folds the polypeptide chain into a specific 3-D structure, which determines the function of the protein.



3. CARBOHYDRATE

• Carbohydrates are polyhydroxy aldoses (e.g. glucose) or ketoses (e.g. fructose).
General formulae is $(CH_2O)_n$ .They are made up of saccharide monomers.
• Saccharide monomers join together by glycosidic linkage. On the basis of the number of saccharide units, the carbohydrates may be-
Monosaccharide
Disaccharide
Polysaccharide

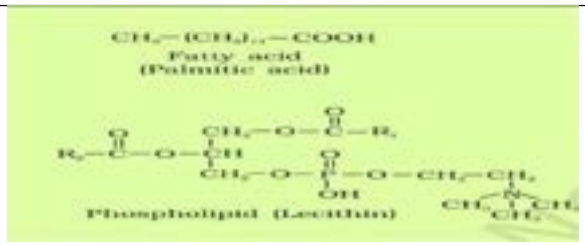
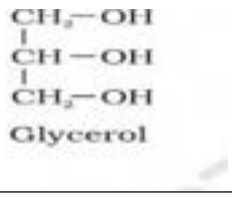


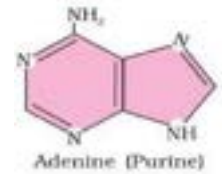
- **POLYSACCHARIDES**
- Carbohydrates (polysaccharides) are of two types –homopolymer and heteropolymer.
- Homopolymer is made up of only one type of monosaccharide units. Eg-cellulose, starch, glycogen, inulin, chitin.
- Heteropolymer is made up of two or more type of monosaccharides.
- Starch is the stored food of plants. It is a polymer of helically arranged glucose monomers which can hold iodine molecules and give blue black colour.
- Cellulose is a polymer of glucose molecules. It is the most abundant organic molecules on earth.
- Glycogen is the reserve food materials for animals, bacteria and fungi. In this, glucose molecules are arranged in highly branched bush like chain.
- Chitin is a complex polysaccharide having units of N –acetyl glucosamine.

4. LIPID

• Lipids are fatty, waxy, or oily compounds that are soluble in organic solvents and insoluble in polar solvents such as water.

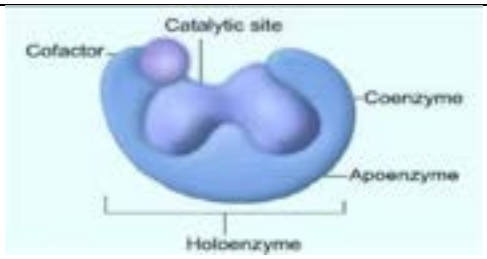
See answer of intext Questions at page No. 158 in the Question Bank QR under Test Your Knowledge

Phospholipids-They have phosphorous and a phosphorylated organic compound. E.g. Lecithin phospholipids, steroids and waxes• They contain long hydrocarbon chains. Example: fatty acids, glycerol, triglycerides,	
Glycerol- It is trihydroxy propane. • Triglycerides: Many lipids have glycerol esterified with acids. These are called as monoglycerides, triglycerides and triglycerides	

5.NUCLEIC ACID In the cell two types of nucleic acids are present - DNA (deoxyribonucleic acid) and RNA (ribonucleic acid) • DNA and RNA function as genetic material. • These are polynucleotide which is made up of nucleotides.	• Nucleotides are joined together by a phosphodiester bond. • Nucleotide is composed of a nitrogen base, a pentose sugar (5-C) and a phosphate	 

The nitrogen base is of two types-
Purine: adenine (A) and guanine (G)
Pyrimidine: cytosine (C), thymine (T) and uracil (U)
• Nucleotide: Nucleoside + phosphoric acid group
• Nucleoside: Nitrogenous bas + Pentose

ENZYMES

All enzymes are proteins except ribozymes (nucleic acid). They act as catalysts. They remain unchanged at the end of the reaction. Enzymes are highly substrate specific. Enzymes have active site where substrate binds.	 It gets damaged at high tem. i. e. denaturation. Complete enzyme (holoenzyme) has protein part (Apo enzyme as well as non-protein part (cofactor)
Nature of Enzyme Action -First, the substrate binds to the active site of the enzyme Formation of enzyme-substrate complex	• Formation of enzyme-product complex .The enzyme releases the products of the reaction and the free enzyme is ready to bind to another molecule of the substrate. $E + S \rightleftharpoons ES \longrightarrow EP \longrightarrow E + P$

Concept of activation energy

• The minimum amount of energy required by substrates to convert into the product is called an activation of energy.

• Enzymes lower the activation energy of the reaction they catalyse.

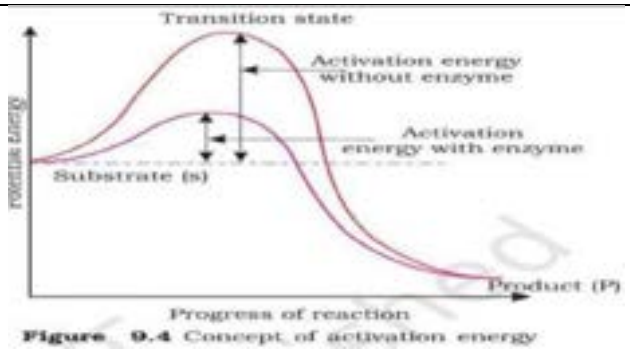


Figure 9.4 Concept of activation energy

Co-factors (non-protein constituent) - prosthetic groups, co-enzymes and metal ions.

• Prosthetic groups: organic compounds, tightly bound to the apoenzyme. For example, in peroxidase and catalase, which catalyze the breakdown of hydrogen peroxide to water and oxygen, haem is the prosthetic group and it is a part of the active site of the enzyme.

• Co-enzymes: organic compounds, loosely bound to the apoenzyme. e.g., coenzyme NAD and NADP contain the vitamin niacin.

• Metal ions: e.g., zinc is a cofactor for the proteolytic enzyme.

Classification and Nomenclature of Enzymes

Oxidoreductase: These enzymes catalyze oxidation and reduction reactions. E.g.- Dehydrogenase

Transferase: These enzymes catalyze the transfer of functional groups such as methyl or phosphate groups. E.g. – Transaminase

Hydrolases: These enzymes catalyze the hydrolysis reactions E.g.- Digestive enzymes

Ligases: These enzymes catalyze the joining of two molecules by making a bond. E.g.- DNA ligase

Isomerases: These class of enzymes brings about the isomerization reaction. E.g.- Isomerase

Lyases: Lyases bring about lysis and cleavage of various bonds. E.g.- Decarboxylase

Factors Affecting Enzyme Activity

Temperature and pH	Concentration of Substrate	Inhibitors
At specific temperature and pH enzyme shows optimum reaction. Low temperature preserves the enzyme in a temporarily inactive state whereas high temperature destroys enzymatic activity because proteins are denatured by heat.	With the increase in substrate concentration, the velocity of the enzymatic reaction rises at first. The reaction ultimately reaches a maximum velocity (Vmax) which is not exceeded by any further rise in the concentration of the substrate	Some chemicals that may inhibit the rate of reactions are called inhibitors. When the inhibitor closely resembles the substrate in its molecular structure and inhibits the activity of the enzyme, it is known as a competitive inhibitor. e.g., inhibition of succinic dehydrogenase by malonate

BIOMOLECULES

Biomolecules are the chemical substances present in living organisms. They are essential for structure, function and regulation of life processes.

1. CARBOHYDRATES



- Composed of C, H, O (H:O ≈ 2:1)
- Main source of energy

FUNCTIONS
- Energy giving
- Energy storing
- Structural

TYPES
- Monosaccharides (e.g., Glucose, Fructose)
- Disaccharides (e.g., Sucrose, Lactose)
- Polysaccharides (e.g., Starch, Glycogen, Cellulose)

2. PROTEINS



- Composed of C, H, O, N (Some contain S)
- Polymers of amino acids

FUNCTIONS
- Structural (e.g., Collagen)
- Enzymatic (e.g., Amylase)
- Transport (e.g., Hemoglobin)
- Hormonal (e.g., Insulin)
- Defence (e.g., Antibodies)
- Movement (e.g., Actin, Myosin)

STRUCTURE LEVELS
- Primary – sequence of amino acids
- Secondary – α-helix, β-sheet
- Tertiary – 3D structure
- Quaternary – association of subunits

3. LIPIDS

- Composed of C, H, O (O is less; may contain P, N)
- Insoluble in water; soluble in organic solvents

FUNCTIONS
- Long term energy storage
- Insulation and protection
- Structural component of cell membrane
- Hormonal (e.g., Steroids)

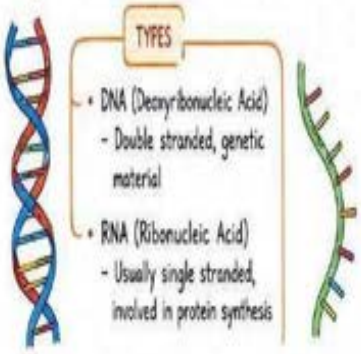


- Fats and Oils (Triglycerides)
- Phospholipids
- Waxes
- Steroids (e.g., Cholesterol)



4. NUCLEIC ACIDS

- Composed of C, H, O, N, P
- Store and transmit genetic information



TYPES
- DNA (Deoxyribonucleic Acid) – Double stranded, genetic material
- RNA (Ribonucleic Acid) – Usually single stranded, involved in protein synthesis

5. VITAMINS

- Organic compounds required in small amounts
- Regulate various metabolic processes



TYPES
- Fat soluble: A, D, E, K (Stored in body fat)
- Water soluble: B-complex, C (Not stored; excess excreted)

IMPORTANCE
- Essential for normal growth, immunity and metabolism
- Deficiency causes specific disorders

NOTE:
Water is also an important biomolecule and is essential for all life processes.



KEY POINTS
- All biomolecules are interconnected.
- They work together to build, maintain and regulate life.

CHAPTER-10: CELL CYCLE AND CELL DIVISION

Syllabus CBSE 2026-27: Cell cycle, mitosis, meiosis and their significance

TERMS	Definition
Condensation	Packing of interphase chromatin into distinct compact chromosomes during cell division
Homologous Chromosome	Two chromosomes of a pair, one inherited from each parent. Homologous chromosomes have same size and carry the same set of genes.
Sister Chromatids	Two chromatids of the same chromosome
Non-Sister Chromatids	Two chromatids of different chromosomes of a homologous pair
Centromere	Constricted region of chromosome that holds two sister chromatids together
Kinetochore	Small disc-shaped structures at the surface of centromere. Site of attachment of chromosome to mitotic spindle.
Metaphase Plate	The plane of alignment of the chromosomes at metaphase is referred to as the metaphase plate.
Interkinesis	Stage between Meiosis I and Meiosis II. Very short span.
Disjunction	Separation of homologous chromosomes during Anaphase I of Meiosis.

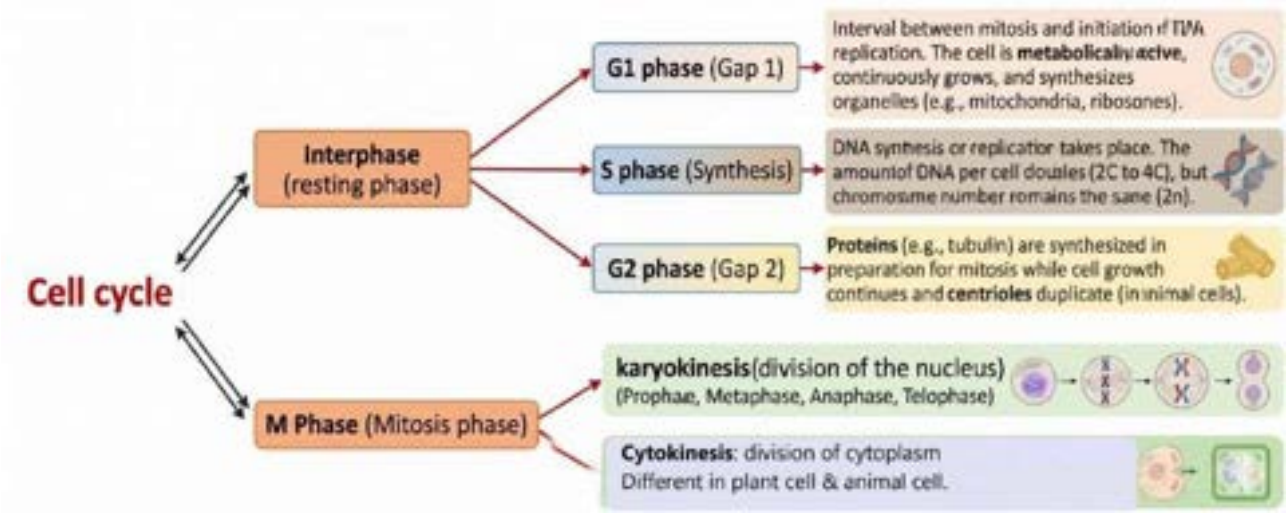
CELL CYCLE

- The sequence of events by which a cell duplicates its genome, synthesises the other constituents of the cell and eventually divides into two daughter cells is termed cell cycle.
- Cell growth is continuous process; DNA synthesis & cell division take place in specific phases.
- These events are under **genetic control.**
- Different kinds of cells have varied duration for cell cycle phases

Duration of cell Cycle

- Human Cell: 24 Hours
- Yeast Cell: 90 minutes

PHASES OF CELL CYCLE



Interphase: Even though the inter

phase is called the resting phase, it is *metabolically active phase*. During interphase the cell is preparing for division by:

a. Undergoing cell growth: Throughout the interphase
b. DNA replication in S phase
c. Centriole duplicates in the cytoplasm in <u>animal cell</u>

<u>M Phase/ Mitosis Phase</u>: Phase of actual cell division

- Starts with nuclear division, corresponding to separation of daughter chromosomes (karyokinesis)
- Ends with division of cytoplasm (cytokinesis).

<u>G0 Phase</u>: Animal Cells that do not divide exit G1 and enter a <u>quiescent stage</u> called G_0 e.g. Heart cells. Some cells that divide occasionally also stay in G_0 phase till they need to start dividing again, e.g. cells of liver & lungs.

In G_0 phase the cell <u>remains metabolically active without dividing</u>.



Question: The graph below shows DNA content through the cell cycle. Which region corresponds to the G2 phase?

a. Region where DNA content doubles b. Region where DNA content remains doubled

c. Region where DNA content halves d. Region where no DNA is present

<u>MITOSIS: Equational Division</u>

Mitosis results in formation of two daughter cells with equal number of chromosomes and identical genetic material.

Mitosis usually occurs in diploid (2n) cells, except in following cases:

1. In plants during the **gametophyte stage** of a plant's life cycle. It takes place when a haploid spore germinates to form a multicellular gametophyte (like in bryophytes) or when this mature gametophyte produces haploid gametes (such as in mosses and ferns).
2. In Animals: in drones of honey bees as they are haploid (n) organisms

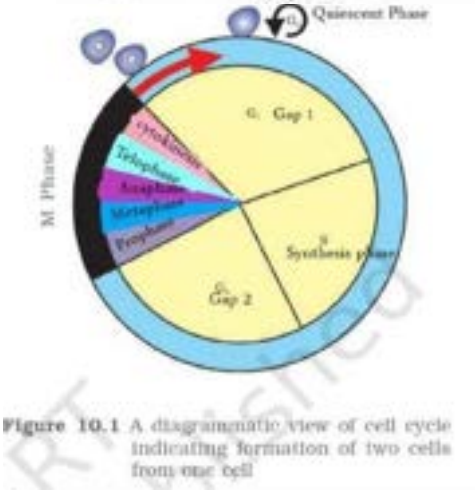
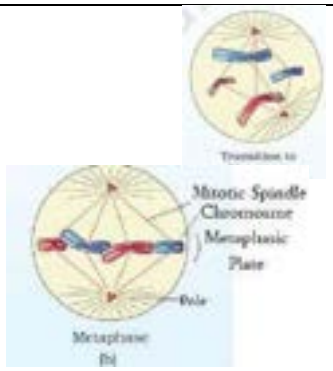
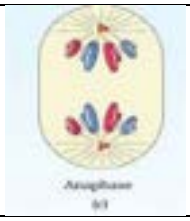


Figure 10.1 A diagrammatic view of cell cycle indicating formation of two cells from one cell

PROPHASE: ○ Chromatids condense to form chromosomes. ○ Sister chromatids can be seen attached at centromere of mitotic chromosome. ○ Centrosome divide to form two centrosomes that move to opposite poles of cell. ○ Centrosomes radiate out microtubules, known as Asters. ○ Microtubules/Asters are assembled into mitotic spindle – Mitotic Apparatus formed. ○ Nucleolus and nuclear envelope disappear. ○ Cell Organelles disappear.	

METAPHASE: ○ Condensation of chromosomes is completed, and they can be observed clearly under the microscope. ○ <u>At this stage morphology of chromosomes is most easily studied.</u> ○ Spindle fibres attached to kinetochores of chromosomes. ○ All the chromosomes come to lie at the equator of the spindle to form metaphase plate. ○ One chromatid of each chromosome connected by its kinetochore to spindle fibres from one pole; and its sister chromatid connected by its kinetochore to spindle fibres from the opposite pole.	
ANAPHASE: ○ <u>Centromeres split</u> – 2 chromatids formed are now referred as daughter chromosomes. ○ Daughter chromosomes move to opposite poles.	
TELOPHASE ○ Chromosomes cluster at opposite poles. ○ Decondensation of chromosomes to form chromatin. ○ Nuclear envelope assembles around chromosome cluster at two poles. ○ Nucleolus, Golgi complex, ER are formed again.	

<u>CYTOKINESIS:</u>

- Division of cells into two daughter cells by the separation of cytoplasm is called cytokinesis. Occurs at the end of which cell division gets completed.
- At the time of cytoplasmic division, organelles like mitochondria and plastids get distributed between the two daughter cells
- If cytokinesis does not occur after karyokinesis: Multinucleate cells formed. This is known as **Syncytium**, e.g. <u>Liquid endosperm of coconut</u>



<u>Cytokinesis in Plant Cell:</u>	**<u>Cytokinesis in Animal Cell:</u>**
A cell plate is formed at the centre of cell, that grows outwards	A furrow appears on plasma membrane of animal cell, that deepens towards centre of cell
Wall formation occurs from inside to outside	Wall formation occurs from outside to inside
cell-plate that represents the middle lamella between the walls of two adjacent cells.	Furrow represents an infolding of Cell membrane

Significance of Mitosis: Mitosis results in

1. Production of diploid daughter cells with identical genetic material
2. In growth of multicellular organisms
3. Cell growth disturbs the nucleo-cytoplasmic ratio. Mitosis helps restore this ratio.
4. Cell repair
5. Replacing the cells of lining such as upper layer of the epidermis, cells of the lining of the gut, and blood cells.
6. Growth of organism e.g. mitotic divisions in the meristematic tissues – the apical and the lateral cambium, result in a continuous growth of plants throughout their life.

Question: At which stage and substage of cell cycle, can morphology of chromosomes be most clearly studied? Justify your answer.

The M Phase: A Step-by-Step Guide to Mitosis

A detailed, chronological breakdown of the subphases ensuring a single parent cell divides into two genetically identical daughter cells.



PARENT CELL (2n)

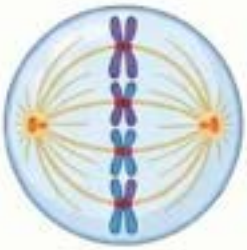
The Equational Division: Daughter cells retain the exact same number of chromosomes as the parent cell (e.g., 2n to 2n).

KARYOKINESIS: The Four Stages of Nuclear Division



PROPHASE: The Preparation

Chromosomal material condenses into compact mitotic chromosomes consisting of two chromatids; meanwhile, the nuclear envelope, nucleolus, and organelles like the ER and Golgi complex disappear.

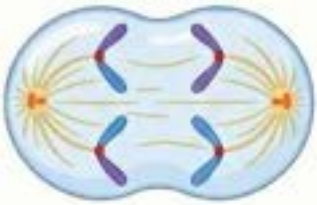


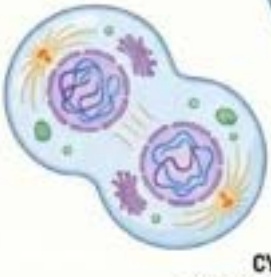
METAPHASE: The Alignment

Spindle fibres attach to the kinetochores of chromosomes, pulling them to the centre of the cell to align along the "metaphase plate" or equator.

ANAPHASE: The Separation

Each chromosome splits simultaneously at the centromere, and the daughter chromatids are pulled toward opposite poles of the cell.





TELOPHASE: The Reconstruction

Chromosomes reach their respective poles and decondense into chromatin while the nuclear envelope, nucleolus, and organelles reform around the two new nuclei.

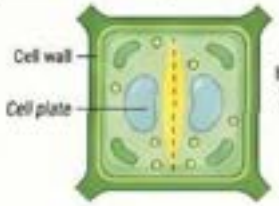
CYTOKINESIS: Dividing the Cytoplasm

Completing the Division: Following nuclear division, the cell itself divides its cytoplasm and organelles to produce two distinct daughter cells.

Animal Cell Furrowing

In animal cells, a furrow appears in the plasma membrane and deepens toward the centre, pinching the cell into two.





Plant Cell Plate Formation

Because of their rigid cell walls, plant cells form a *"cell plate" in the centre* that grows outward to meet the lateral walls, eventually forming the middle lamella.



DAUGHTER CELL (2n) **DAUGHTER CELL (2n)**

THE SIGNIFICANCE OF MITOSIS



Growth and Repair

Mitosis is responsible for the growth of multicellular organisms and the constant replacement of cells in the skin, gut lining, and blood.



Nucleo-cytoplasmic Ratio

As a cell grows, the ratio between the nucleus and cytoplasm is disturbed; mitosis restores this balance to allow for efficient cellular function.

MEIOSIS

Meiosis is a special type of cell division that results in reduction of chromosome number by half. Thus, one cycle of meiosis produces 4 haploid daughter cells.

Occurs during gametogenesis.

Key Features of Meiosis: Meiosis involves

1. Two cycles of nuclear & cytoplasmic divisions: Meiosis I and Meiosis II.
2. Only one cycle of DNA synthesis
3. Meiosis I is Heterotypic – Chromosome number is reduced.
   Meiosis II is homotypic – Chromosome number remains same.
4. Meiosis I starts after DNA is replicated and two sister chromatids are formed for each chromosome. This happens during S phase.

Need of Meiosis:

Sexual reproduction involves fusion of gametes.
This results in doubling of chromosome number (2n) - **Diploid**
Thus, prior to fertilization special cells – gametes are formed with half the chromosome number (n) – **Haploid.**
This reduction in chromosome number is done through meiosis.

5. Pairing of homologous chromosomes and recombination occurs during meiosis.

6. **Phases of Meiosis I**

PROPHASE I:	• longer and complex • Subdivided into the following five phases based on chromosomal behaviour
Subphase I: Leptotene	Chromosomes continue to become compact. Chromosomes begin to be visible under light microscope.
Subphase II: Zygotene Leptotene & Zygotene shorter subphases	Synapsis or pairing together of chromosomes starts formation of synaptonemal complex: A complex structure formed by a pair of synapsed homologous chromosomes. This is called a bivalent or a tetrad.
Subphase II: Pachytene	Bivalent chromosomes clearly appear as tetrads. Appearance of recombination nodules. Recombination Nodules are the sites at which **crossing over** occurs between non-sister chromatids of the homologous chromosomes.
Subphase II: Diplotene In oocytes of some vertebrates, diplotene can last for months or years	Dissolution of the synaptonemal complex. Formation of Chiasmata.
Subphase II: Diakinesis Diakinesis represents transition to metaphase	Terminalization of chiasmata. Chromosomes are fully condensed. Meiotic spindle is assembled to prepare the homologous chromosomes for separation. Nucleolus disappears and the nuclear envelope also breaks down.

Crossing Over:

- Crossing over is the exchange of genetic material between two homologous chromosomes.
- Crossing over is an enzyme-mediated process. The enzyme involved is called recombinase.
- Crossing over leads to recombination of genetic material on the two homologous chromosomes.
- Recombination begins with and ends by the end of Pachytene.
- At the end of crossing over, chromosomes remain linked at the site of crossing over.

Chiasmata:
Recombined homologous chromosomes of the bivalents separate from each other except at the sites of crossovers. Thus, they form X-shaped structures, are called chiasmata.

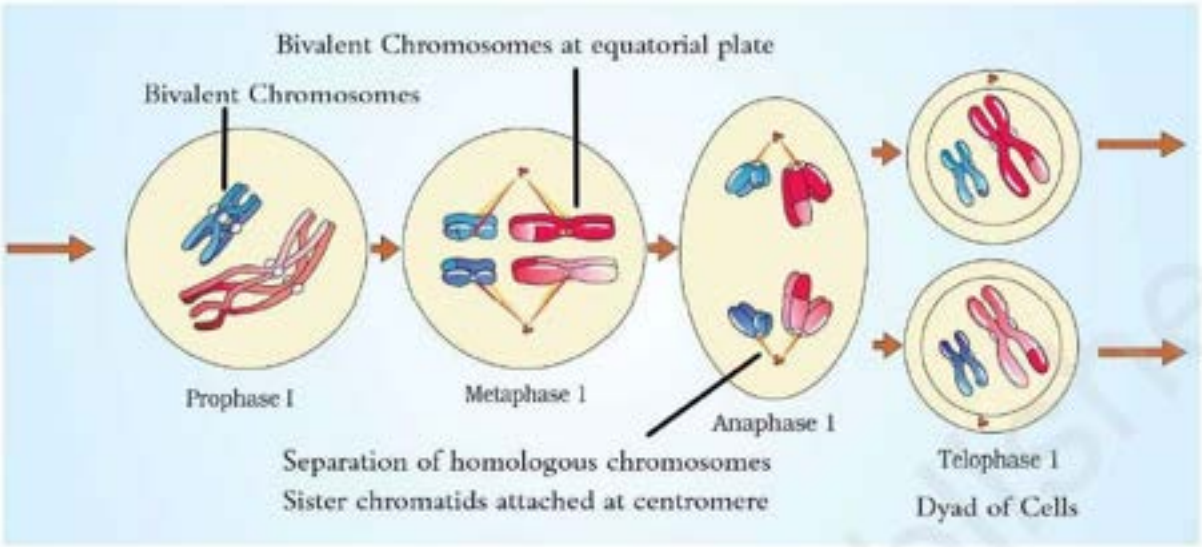


Figure 10.3 Stages of Meiosis I

Metaphase I	Bivalent chromosomes align on the equatorial plate Spindle formation complete. The microtubules from the opposite poles of the spindle attach to the pair of homologous chromosomes.
Anaphase I	Homologous chromosomes separate -**Disjunction** Centromere does not split. Sister chromatids remain attached together at Centromere
Telophase I	Nuclear membrane and nucleolus reappear Cytokinesis occurs forming dyad of cells Chromosomes do not decondense completely forming interphase Nucleus

Interkinesis: Stage between Meiosis I and Meiosis II. Very short span.

Meiosis II

Very similar to Mitosis. It is divided in 4 stages-

1. **Prophase II:** The nuclear membrane disappears by the end of prophase II. The chromosomes again become compact.
2. **Metaphase II:** chromosomes align at the equator and the microtubules from opposite poles of the spindle get attached to the kinetochores of sister chromatids
3. **Anaphase II:** splitting of the centromere of each chromosome (which was holding the sister chromatids together), allowing them to move toward opposite poles of the cell by shortening of microtubules attached to kinetochores
4. **Telophase II:** two groups of chromosomes once again get enclosed by a nuclear envelope

- **Cytokinesis** – results in the formation of a tetrad of cells i.e., four haploid daughter.

S. No.	Feature	Meiosis I	Meiosis II
1	**General Purpose**	Reduces the chromosome number	Separates sister chromatids, closely resembling normal mitosis.
2	**Prophase**	Long and complex, specifically divided into five sub-phases: Leptotene, Zygotene, Pachytene, Diplotene, and Diakinesis.	Much simpler and shorter, resembling a standard mitotic prophase.
3	**Synapsis & Crossing Over**	Homologous chromosomes pair up (synapsis) and exchange genetic material through crossing over.	No pairing of homologous chromosomes or crossing over occurs.
4	**Metaphase Alignment**	Chromosomes align as a pair along the equatorial plate – seen as tetrads	Individual chromosomes align along the equator.
5	**Anaphase Separation**	Homologous chromosomes separate and move to opposite poles, but sister chromatids remain attached at their unbroken centromeres.	Centromeres split simultaneously, allowing the sister chromatids to separate and move to opposite poles.
6	**End Result**	Concludes with Telophase I, producing a dyad of two cells.	Concludes with Telophase II, resulting in a tetrad of four haploid daughter cells.

Significance of meiosis

• Conservation of the specific chromosome number of each species across generations during sexual reproduction.

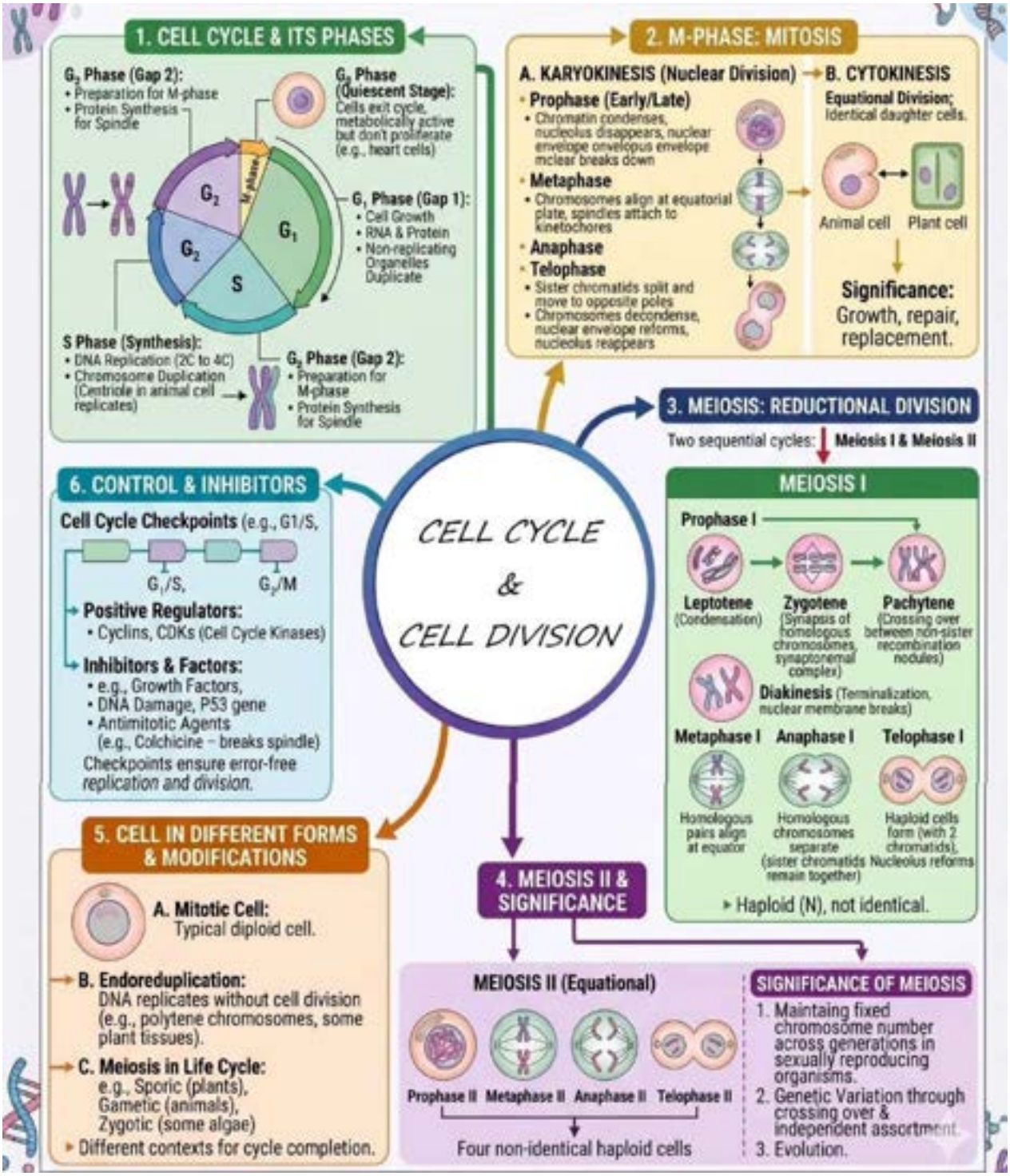
• It also increases the genetic variability in the population from one generation to next. Variations are important for Evolution.

Question: Explain the paradox, “Meiosis halves chromosome number and thus helps maintain chromosome number across generations".

MITOSIS VS MEIOSIS:

S. No.	**CRITERIA**	**MITOSIS (EQUATIONAL DIVISION)**	**MEIOSIS (REDUCTIONAL DIVISION)**
1	Main Purpose	Growth, Repair, Asexual reproduction	Gamete formation, Sexual reproduction
2	Occurs in cell type	Somatic Cells	Germ Cells
3	Number of divisions	Only 1	2 (sequential): Meiosis I & Meiosis II
4	Number of daughter cells & types	2 daughter cells, Diploid (2n)	4 daughter cells, haploid (n)
5	Genetic composition	Identical to parent	Different, Variations seen
6	Prophase	Short & simple	Long & Complex, involves synapsis & crossing over between non-sister chromatids
7	Centromere Splitting at Anaphase	Centromeres split at anaphase	Centromeres do not split, homologous chromosomes separate at anaphase

See answer of intext Questions at page No. 158 in the Question Bank QR under Test Your Knowledge


CELL CYCLE & CELL DIVISION
1. CELL CYCLE & ITS PHASES
G2 Phase (Gap 2):
• Preparation for M-phase
• Protein Synthesis for Spindle
G0 Phase (Quiescent Stage):
Cells exit cycle, metabolically active but don't proliferate (e.g., heart cells)
G1 Phase (Gap 1):
• Cell Growth
• RNA & Protein
• Non-replicating Organelles Duplicate
S Phase (Synthesis):
• DNA Replication (2C to 4C)
• Chromosome Duplication (Centriole in animal cell replicates)
G2 Phase (Gap 2):
• Preparation for M-phase
• Protein Synthesis for Spindle
M phase
G1
S
G2
2. M-PHASE: MITOSIS
A. KARYOKINESIS (Nuclear Division)
B. CYTOKINESIS
Prophase (Early/Late)
• Chromatin condenses, nucleolus disappears, nuclear envelope onvelopus envelope mclear breaks down
Metaphase
• Chromosomes align at equatorial plate, spindles attach to kinetochores
Anaphase
Telophase
• Sister chromatids split and move to opposite poles
• Chromosomes decondense, nuclear envelope reforms, nucleolus reappears
Equational Division; Identical daughter cells.
Animal cell
Plant cell
Significance: Growth, repair, replacement.
3. MEIOSIS: REDUCTIONAL DIVISION
Two sequential cycles: Meiosis I & Meiosis II
MEIOSIS I
Prophase I
Leptotene (Condensation)
Zygotene (Synapsis of homologous chromosomes, synaptonemal complex)
Pachytene (Crossing over between non-sister recombination nodules)
Diakinesis (Terminalization, nuclear membrane breaks)
Metaphase I
Anaphase I
Telophase I
Homologous pairs align at equator
Homologous chromosomes separate (sister chromatids remain together)
Haploid cells form (with 2 chromatids), Nucleolus reforms
▸ Haploid (N), not identical.
4. MEIOSIS II & SIGNIFICANCE
MEIOSIS II (Equational)
Prophase II
Metaphase II
Anaphase II
Telophase II
Four non-identical haploid cells
SIGNIFICANCE OF MEIOSIS
1. Maintaing fixed chromosome number across generations in sexually reproducing organisms.
2. Genetic Variation through crossing over & independent assortment.
3. Evolution.
5. CELL IN DIFFERENT FORMS & MODIFICATIONS
A. Mitotic Cell: Typical diploid cell.
B. Endoreduplication: DNA replicates without cell division (e.g., polytene chromosomes, some plant tissues).
C. Meiosis in Life Cycle: e.g., Sporic (plants), Gametic (animals), Zygotic (some algae)
▸ Different contexts for cycle completion.
6. CONTROL & INHIBITORS
Cell Cycle Checkpoints (e.g., G1/S, G2/M
Positive Regulators:
• Cyclins, CDKs (Cell Cycle Kinases)
Inhibitors & Factors:
• e.g., Growth Factors,
• DNA Damage, P53 gene
• Antimitotic Agents (e.g., Colchicine – breaks spindle)
Checkpoints ensure error-free replication and division.

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CHAPTER: 11 PHOTOSYNTHESIS IN HIGHER PLANTS

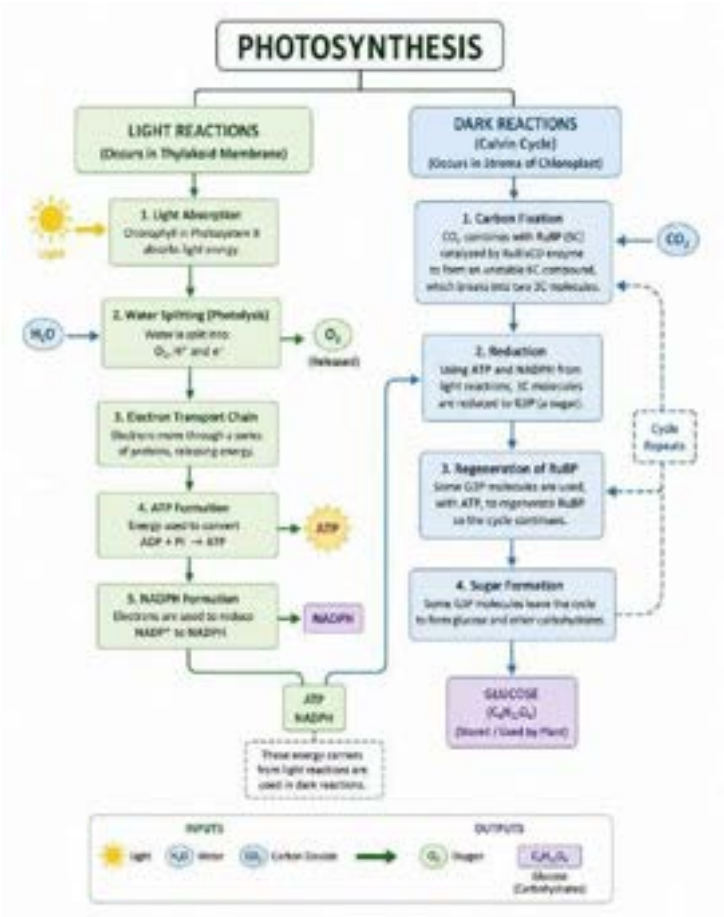
NCERT SYLLABUS (SESSION 2026-27): Defination and equation of photosynthesis, early experiments, site of photosynthesis, pigments involved in photosynthesis, light reaction, electron transport, use of ATP and NADPH , C_4 cycle, photorespiration, factors affecting photosynthesis.

Key Points:-

Photosynthesis is a physico-chemical process by which green plants use light energy to drive the synthesis of organic compounds. It is an enzyme regulated **anabolic process.**

$$6CO_2 + 12H_2O \xrightarrow{Light} C_6H_{12}O_6 + 6H_2O + 6O_2$$

Chlorophyll, light and $CO_2$is required for photosynthesis. It occurs only in green part of leaves and in presence of light.



Process of photosynthesis involves two steps:-

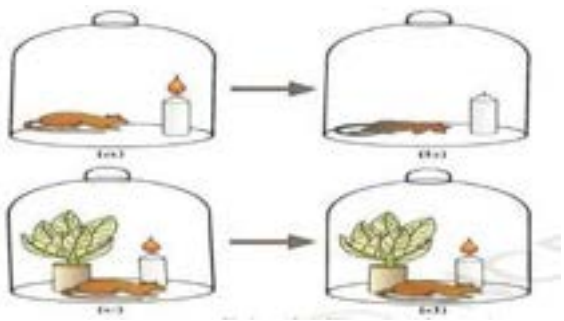
(a) **LIGHT REACTION:** It occurs in grana of chloroplast. Photolysis of water occurs along with release of CO_2. It synthesizes the energy in the form of ATP and NADPH required to drive out dark reaction.

(b) **DARK REACTION:** Occurs in stroma of chloroplast. It leads to reduction of CO_2 by utilizing energy in the form of ATP and NADPH. It leads to final product synthesis of sugar in plants.

Early Experiments:-

Joseph Priestley (1770):

He placed a mint plant in a closed jar with a burning candle and a mouse. The candle went out and the mouse died without the plant, but survived when the plant was present. He concluded that plants restore air and release oxygen.



Jan Ingenhousz (1779):

He observed aquatic plants producing

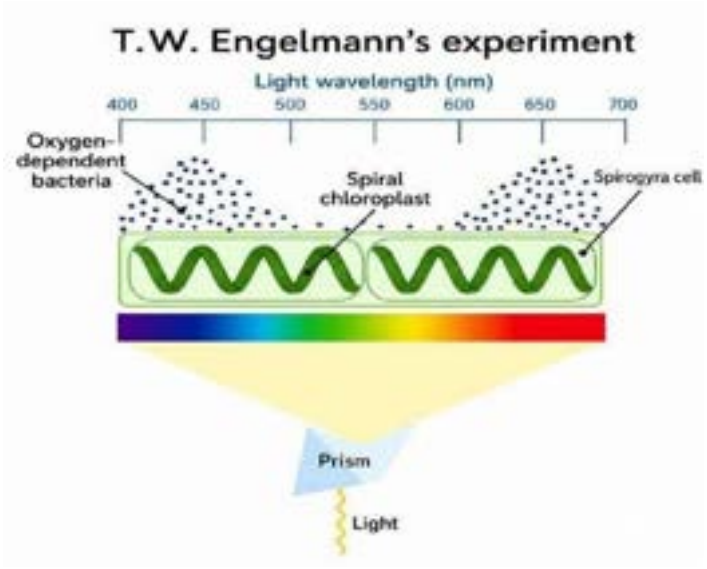
gas bubbles only in sunlight, not in darkness. He also found that only green parts of plants perform this process. He concluded that sunlight is essential for photosynthesis.

T.W. Engelmann (1883):

He used algae and split light using a prism, observing oxygen-seeking bacteria clustering in blue and red regions. He concluded that photosynthesis is highest in blue and red light.

Julius von Sachs:

He showed that starch is produced during photosynthesis by testing leaves with iodine. Only the illuminated parts of the leaf turned blue-black. He concluded that photosynthesis produces starch in chloroplasts.

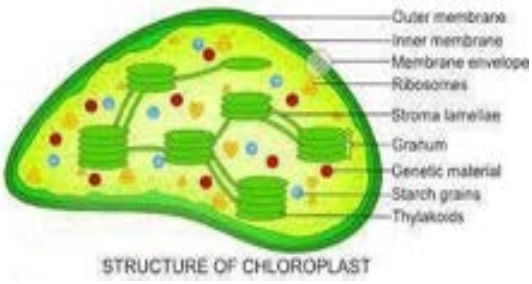


Where Does Photosynthesis Takes Place?

Chloroplasts are **green plastids** which function as the site of photosynthesis in eukaryotic photoautotrophs. Inside the leaves, chloroplast is generally present in mesophyll cells along their walls.

Within the chloroplast there is a membranous system consisting of grana, the stroma lamellae and the fluid stroma.

PS I(photosystem I) is present in non-appressed region of grana and stromal lamellae. PS II is present only in appressed region of grana. Stroma contains enzymes for dark reaction.



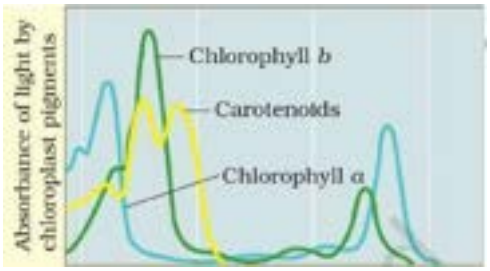
PS I ----

- present in non-appressed region of grana and stromal lamella.

PS II------ present only in appressed region of grana.

Absorption Spectrum: The absorption spectrum is the graph showing the amount of light absorbed by a pigment at different wavelengths.It helps to identify which colour of light is absorbed maximum by the pigment.In chlorophyll, maximum absorption occurs in the blue and red

regions of light. Minimum absorption occurs in the green region, so plants appear green.
It is studied using a spectrophotometer.

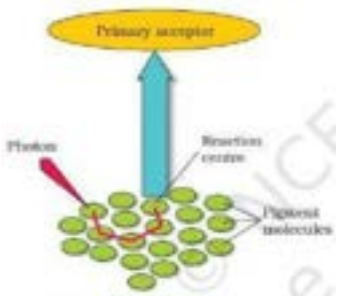




Action Spectrum: The action spectrum is the graph showing the rate of photosynthesis at different wavelengths of light.It indicates which colour of light is most effective for photosynthesis.Maximum photosynthesis occurs in blue and red light regions .Minimum photosynthesis occurs green light.It was studied by observing oxygen release during photosynthesis**.**

PIGMENT SYSTEM:-

It is found in grana of chloroplast. In photosystem the protein binds to pigment forming protein-pigment complex.Each pigment system has two components-a)Photochemical reaction centre: contain single chl a molecule.b)Antenna complex (light harvesting complex).Contain 2 types of reaction centres-



i) PS I: It contains chl a , chl b etc, absorbs 700 nm walelength of light (P_{700} is reaction centre).

ii) PS II: Contain chl a ,b absorbs light at 680 nm (reaction centre P_{680}.)

PHOTOSYSTEM I (PS I)	PHOTOSYSTEM II (PS II)
1. It is rich in Chl a and contain less chl b and carotenoids.	1. Contain chl a, b and carotenoids.
2. Chl a absorb at 700 nm (P_{700} reaction centre).	2. Chl a is absorbed at 680 nm (P_{680} reaction centre)
3. It is found in non-appressed region of grana and stromal lamella.	3. It is found only in appressed region of grana thylakoid.
4. It participates in both cyclic and non-cyclic photophosphorylation.	4. Participates only in non-cyclic photophosphorylation.
5. Molecular oxygen is not evolved during light reaction.	5. Molecular oxygen is evolved.

Questions-

Q1. Which pigment is directly involved in photosynthesis?
Q2. What is the spectrum showing the effectiveness of light in photosynthesis called?
Q3. Name the stack-like structures of thylakoids in chloroplasts.
Q4. Which membrane is the site of light reaction?
Q5. Name the accessory pigments present along with chlorophyll.
Q6. What is the reaction centre pigment of Photosystem I called?
Q7. Why PS I participates in both cyclic and non cyclic photophosphorylation but PS II does not?

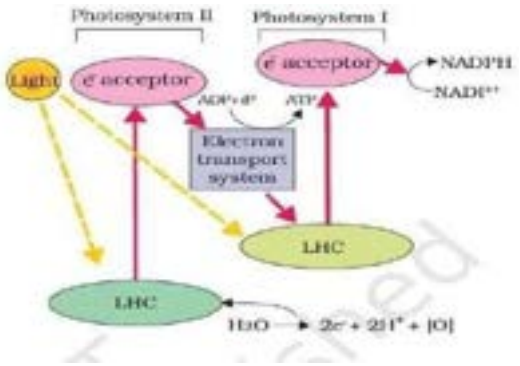
LIGHT REACTION:-These are light dependent reactions which occur in grana of chloroplast. Light reaction (photo chemical phase) includes:

1. Light absorption
2. Water splitting
3. Oxygen release
4. Formation of high energy chemical intermediates (ATP and NADPH).

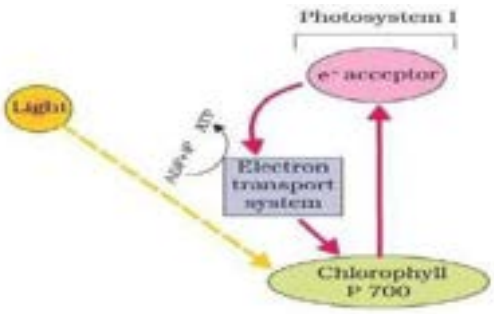
The process of light reaction involves **photophosphorylation**. The process of formation of ATP from ADP and inorganic phosphate in the presence of light energy is called photophosphorylation.

When chlorophyll a receives a photon of light, it becomes excited and expels extra energy alongwith electrons in both photosystems. This excited electron after travelling through a series of electron carriers is either cycled back (**cyclic photophosphorylation**) or it is consumed in reducing $NADP^+$ to NADPH through **non-cyclic photophosphorylation.** The extra energy carried by the electron is utilized in the formation of ATP. So, light reaction follows two pathways:-

Feature	**Non-Cyclic Photophosphorylation**	**Cyclic Photophosphorylation**
Photosystem (PS) Involved	Involves both **PS I** and **PS II**	Involves **PS I** only
Location	Occurs in **grana thylakoid** only	Occurs in both **stromal** and **grana thylakoid**
Electron Path	Electrons **do not return back** to the system (transported from water to NADP^+)	Excited electrons **return back** to the system
Oxygen (O_2) Evolution	Accompanied by the **release of oxygen**	**No evolution** of oxygen
Final Products	**NADPH** (and ATP) are synthesized	**Only ATP** is synthesized; no NADPH
Flow Pattern / Scheme	Forms a **"Z-scheme"** due to the uphill and downhill zigzag flow of electrons	Loop-like flow as electrons cycle back



Z-scheme of Light reaction



Cyclic photophosphorylation

NADP Reductase enzyme:- NADP Reductase (Ferredoxin–NADP Reductase) is an enzyme involved in the light reaction of photosynthesis. It is present on the stromal side of the thylakoid membrane in chloroplasts. It catalyzes the reduction of $NADP^+$ to NADPH using electrons received from ferredoxin.

Water Splitting Complex:- The Water Splitting Complex is a part of Photosystem II (PS II) present on the inner side of the thylakoid membrane in chloroplasts. It is also called the **Oxygen Evolving Complex (OEC)**. It splits water molecules during the light reaction of photosynthesis to release electrons, protons and oxygen.

Q8. During the light reaction of photosynthesis, a student observed a zig-zag movement of electrons involving both Photosystem II and Photosystem I. The teacher explained that this pattern is called the Z-scheme.

Based on this, answer the following:

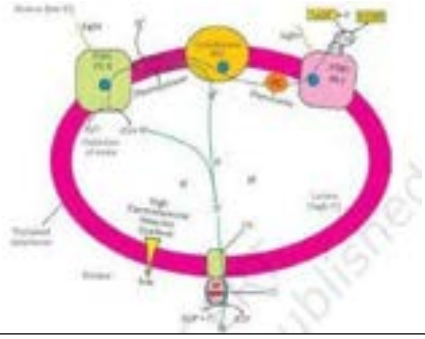
1. Why is the electron transport pathway called the Z-scheme?
2. Name the final electron acceptor in this process.

Q9. During the light reaction of photosynthesis, a blockage in a specific enzyme leads to the accumulation of electrons at the end of Photosystem I and prevents formation of reducing power.

CHEMIOSMOTIC HYPOTHESIS

This hypothesis was proposed by Mitchell in 1961.ATP synthesis is linked to development of proton gradient across the membrane of thylakoid and mitochondria. The process that causes development of proton gradient across the membrane is-

1. Splitting of water molecules. As electron passes through the photosystems, protons are transported across the membrane.
2. The **NADP reductase** enzyme is located in the stroma side of membrane. Electrons come out from the acceptor of electron of PSI, protons are necessary for reduction of NADP+ to NADP + H^+. This creates proton gradient across the thylakoids membrane along with pH in the lumen.
3. Gradient is broken down due to movement of proton across the membrane to the stroma through trans-membrane channel of **F_O of ATPase.**
4. ATP and NADPH produced due to movement of electron is used immediately to fix CO_2 to form sugar.



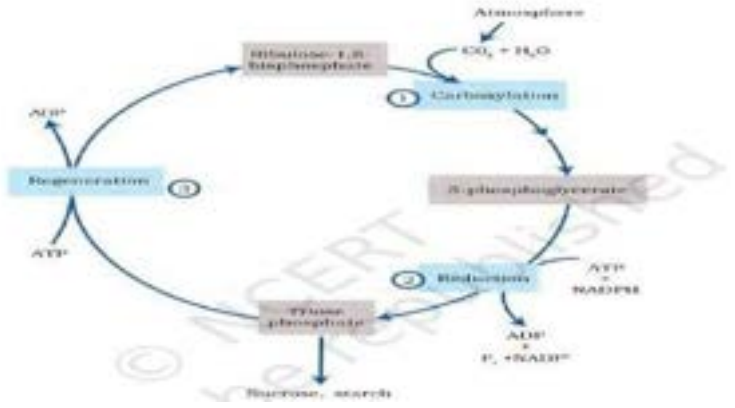
The product of light reaction used to drive the process leading to synthesis of sugar are called **biosynthetic phase** of photosynthesis.

Calvin Cycle /C3cycle/Reductive Pentose Sugar Phosphate Pathway:-

Malvin Calvin, Benson and their colleagues used radioactive ^{14}C and *Chlorella* and *Scenedesmus* algae to discover that first CO_2 fixation product is 3-carbon organic compound (3-phosphoglyceric acid) or PGA. Later on a new compound was discovered which contain 4-carbon compound called Oxaloacetic Acid (OAA).On the basis of number of carbon atoms in first stable product they are named C3 and C4 pathway.

Calvin cycle can be described under three stages: carboxylation, reduction and regeneration.

1. **Carboxylation:** is the fixation of CO_2 into 3-phosphoglyceric acid (3-PGA). Carboxylation of RuBP occurs in presence of enzyme **RuBP carboxylase (RuBisCO)** which results in the formation of two molecules of 3-PGA.
2. **Reduction:** is series of reaction that leads to formation of glucose. Two molecules of ATP and two molecules of NADPH are required for reduction of one molecule of $C0_2$. Six turn of this cycle are required for removal of one molecule of Glucose molecules from pathway.
3. **Regeneration:** is the generation of RuBP molecules for the continuation of cycle. This process require one molecule of ATP.



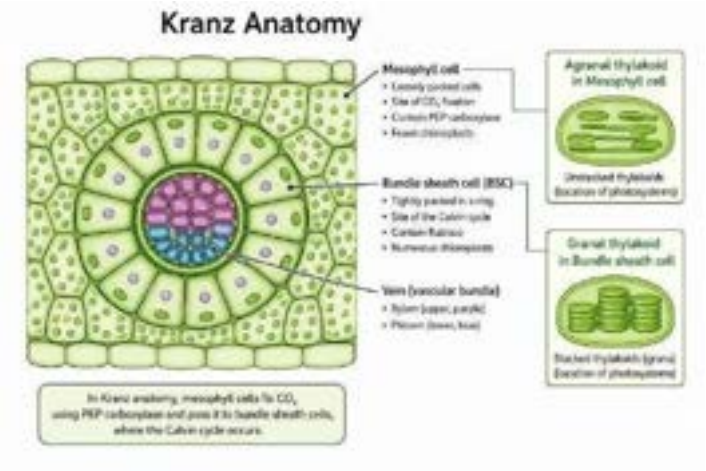
THE CALVIN CYCLE

In	Out
Six CO_2	One glucose
18 ATP	18 ADP
12 NADPH	12 NADP

- For every molecule of CO_2 entering the Calvin Cycle ,3 molecules of ATP and 2 molecules of NADPH is required.To make one molecule of glucose 6 turns of cycle is completed so total energy molecule required is 18 ATP and 12 NADPH.

  Enzyme : RUBISCO (Ribulose 1,5 bisphosphate carboxylase-oxygenase) is the main enzyme involved in Calvin cycle. It does carboxylation of RuBP under high CO_2 conditions. In low CO_2 and high O_2 it shows oxygenation activity and performs photorespiration. Present in mesophyll cells in C_3 plants.

Kranz Anatomy: Kranz anatomy is a characteristic feature of C_4 Photosynthesis found in C_4 plants such as maize and sugarcane, where the vascular bundles are surrounded by a layer of large bundle sheath cells, which are further surrounded by mesophyll cells forming a wreath-like arrangement. Chloroplasts are present in both mesophyll and bundle sheath cells, but bundle sheath chloroplasts usually have very few or no grana. This special arrangement helps in concentrating carbon dioxide around the enzyme RuBisCO, thereby minimizing photorespiration and increasing the efficiency of photosynthesis, especiallyunder conditions of high temperature and intense light.



Differences between C_3 and C_4 plants:

C_3 Plants	**C_4 Plants**
1. First stable product is a 3-carbon compound i.e 3-phosphogylceric acid (3-PGA).	1. First stable product is a 4 carbon compound oxaloacetic acid (OAA).
2. Optimum temperature is between 25-35^{0}C.	2. Temperature range is higher 35-40^{0}C.
3. Kranz anatomy is absent, contain only mesophyll cells.	3. Kranz anatomy present in leaves, both mesophyll cells and bundle sheath cells present.
4. Undergoes calvin C_3 cycle.	4. Undergo both C_3 and C_4 cycle(C_3 in mesophyll and C_4 in bundle sheath cell.)
5.Photorespiration occurs	5.Photorespiration absent
6. Photosynthically less efficient as Productivity is less.	6. Photosynthically more efficient as Productivity is more.
7. More energy efficient requires 3 ATP/ cycle.	7. Less energy efficient requires 5 ATP/cycle.

Questions:-

Q10. A scientist grew two sets of green plants under identical conditions except for the concentration of carbon dioxide. In Set A, the CO_2 concentration was normal, while in Set B, the CO_2 concentration was very low. After some time, the scientist observed that glucose synthesis decreased significantly in Set B.

Based on your understanding of the Calvin cycle, answer the following questions:

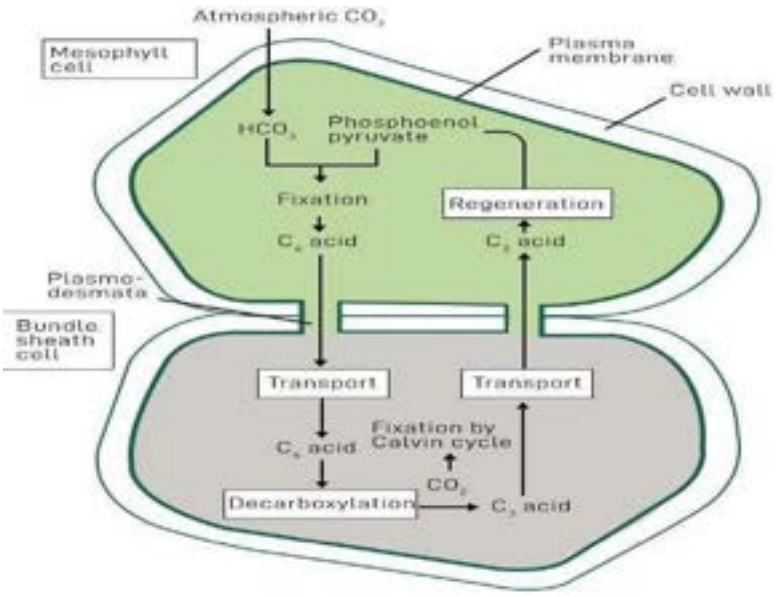
1. In which part of the chloroplast does the Calvin cycle occur?
2. Name the molecule that initially combines with CO_2 in the Calvin cycle.
3. Why did glucose synthesis decrease in Set B?
4. Name the enzyme responsible for fixation of CO_2 in the Calvin cycle.

C4 pathway/Hatch Slack Pathway:-

- This pathway was worked out by Hatch and Slack (1965,1967), mainly operational in plants growing in dry tropical region like Maize, Sugarcane, Sorghum etc.
- In this pathway first stable product is a 4-carbon compound **Oxaloacetic acid**(OAA) so called as C4 pathway.C4 plants have Kranz Anatomy (vascular bundles are surrounded by bundle sheath cells arranged in wreath like manner),characterized by large no of chloroplast, thick wall impervious to gases and absence of intercellular spaces.
- The primary CO_2 acceptor is a 3-carbon molecule **Phosphoenol Pyruvate** present in
- Mesophyll cells and enzyme involved is PEP carboxylase.
- OAA formed in mesophyll cell forms 4-carbon compound like malic acid or aspartic acid

which is transported to bundle sheath cells.

- In bundle sheath cell,it is broken into CO_2 and a 3-carbon molecule. The 3-carbon molecule is returned back to mesophyll cells to form PEP.
- The CO_2 molecules released in bundle sheath cells enters the Calvin cycle, where
- enzyme RuBisCO is present that forms sugar



In	Out
Six CO_2	One glucose
30 ATP	30 ADP
12 NADPH	12 NADP

HATCH AND SLACK CYCLE

Photorespiration(C-2 Cycle):

- It is the light dependent process of **oxygenation of RuBP** and release of carbon dioxide by photosynthetic organs of plants.
- Photorespiration decreases the rate of photosynthesis when oxygen concentration is increased from 2-3% to21%.
- Presence of light and higher concentration of Oxygen results in the binding of RuBisC0 enzyme with 0_2 to form.

$RuBisC0 + O_2 \rightarrow PGA + phosphoglycolate$

This pathway involves **Chloroplast , Peroxisome and Mitochondria.** Photorespiration do not occurs in C4 plants.

Questions:-

Q11. A biology student observed transverse sections of two leaves under a microscope. One leaf showed large bundle sheath cells arranged in a ring around vascular bundles, while the other did not.

Based on the observation, answer:

1. Which special anatomy was observed in the first leaf?
2. What type of photosynthetic pathway is associated with this anatomy?
3. Name one plant that shows this pathway.

4. State one advantage of this pathway over the C_3 pathway.

C3 plants	C4 plants
1. The leaves donot have Kranz anatomy. 2. Photorespiration occurs. 3. RuBisC0 is the first acceptor of CO2. 4. PGA is the first stable product. 5. Plants are adapted to all climates. 6. Mesophyll cells perform complete photosynthesis	1. The leaves show Kranz anatomy in leaves. 2. Photorespiration does not occur. 3. PEP is the first acceptor of CO_2. 4. OAA is the first stable product. 5. Plants are adapted to tropical climate. 6. Mesophyll cells perform only initial fixation.

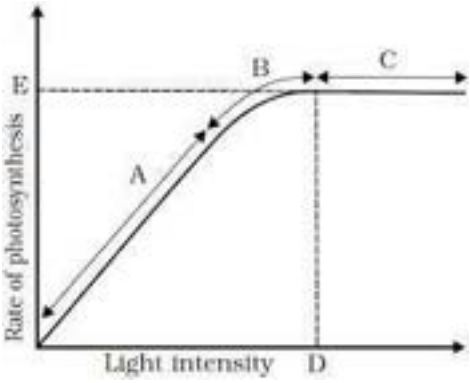
Factors affecting photosynthesis:

Light-as light intensity increases, the rate of photosynthesis also increases until light saturation point.

Carbon dioxide concentration- with increase in concentration of CO_2 rate of photosynthesis increase till the compensation point. Increase in concentration upto 0.05 per cent can cause an increase in CO2 fixation rates; beyond this the levels can become damaging for longer periods. C4 plants show **saturation at about 360 μlL^{-1} while C3 responds to increased CO2 concentration and saturation is seen only beyond 450 μlL^{-1}**. Thus, current availability of CO2 levels is limiting to the C3 plants. The fact that C3 plants respond to higher CO2 concentration by showing increased rates of photosynthesis leading to higher productivity has been used for some greenhouse crops such as tomatoes and bell pepper.

Temperature- it does not influence the rate of photosynthesis directly but at higher temperature enzyme activity is inhibited due to denaturation of enzymes which affect the dark reaction.

Water-due to increase in amount of water, rate of photosynthesis does not increase proportionally as after saturation no more water is required during photosynthesis.



Blackman's Law of Limiting Factors states:

If a chemical process is affected by more than one factor,then its rate will be determined by the factor which is nearest to its minimal value: it is the factor which directly affects the process if its quantity is changed.

Questions:-

Q12. A plant is kept under bright light, but the rate of photosynthesis does not increase because carbon dioxide supply is low. Which law explains this situation? Explain briefly.

See answer of intext Questions at page No. 158 in the Question Bank QR under Test Your Knowledge

PHOTOSYNTHESIS IN HIGHER PLANTS

Process by which green plants synthesize carbohydrates from CO_2 and H_2O in the presence of sunlight with the help of chlorophyll.

1. DEFINITION

Photosynthesis is the process in which light energy is trapped and used to convert CO_2 and H_2O into carbohydrates in the presence of chlorophyll.

2. OVERALL EQUATION

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

(Glucose) (Oxygen)

3. HISTORICAL ACCOUNT

- Jan Ingenhousz (1779) – Showed that light is essential and O_2 is released during photosynthesis.
- Julius von Sachs (1864) – Coined the term "photosynthesis".
- T.W. Engelmann (1883) – Action spectrum with filamentous alga.
- Robert Hill (1937) – Hill reaction: light driven evolution of O_2.
- Melvin Calvin (1948) – Elucidated Calvin cycle.

4. PIGMENT SYSTEM

Located in thylakoid membranes (grana)

a. Chlorophylls
- Chlorophyll a – primary pigment, blue green
- Chlorophyll b – accessory pigment, yellow green

b. Carotenoids
- Carotenes – orange
- Xanthophylls – yellow

Accessory pigments absorb light of various wavelengths and transfer energy to chlorophyll a (Reaction centre).

5. PHOTOSYNTHESIS

A. LIGHT REACTION (Photochemical phase)

Occurs in thylakoid membranes (grana and stroma lamellae)

Light energy → Chemical energy (ATP and NADPH)

Includes:
(i) Absorption of light by pigments
(ii) Conversion of light energy to chemical energy
(iii) Photolysis of water
(iv) Synthesis of ATP and NADPH
(v) Release of O_2

B. DARK REACTION (Biosynthetic phase)

Occurs in stroma of chloroplast

ATP and NADPH are used to reduce CO_2 into carbohydrates

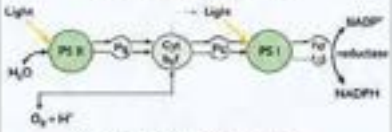
Includes:
(i) CO_2 fixation
(ii) Reduction
(iii) Regeneration of RuBP
→ Calvin cycle (C_3 cycle)

5.1 NON-CYCLIC PHOTOPHOSPHORYLATION

(Z-scheme)

Occurs in grana thylakoids

Involves both PS II and PS I

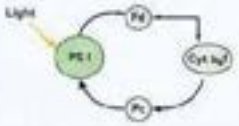


Products → ATP, NADPH and O_2

5.2 CYCLIC PHOTOPHOSPHORYLATION

Occurs in stroma lamellae

Involves only PS I



Generates only ATP (No NADPH, No O_2)

6. CHEMIOSMOTIC HYPOTHESIS

(Peter Mitchell)

Electron transport in thylakoid membranes leads to pumping of H^+ into thylakoid lumen.

↓

Creates proton gradient (high inside)

↓

H^+ flows back to stroma through CF_0–CF_1 (ATP synthase)

↓

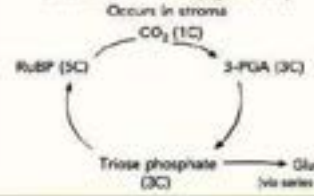
ADP + Pi → ATP (Photophosphorylation)

7. SYNTHESIS OF ATP AND NADPH

ATP synthesis	NADPH synthesis
$ADP + Pi \longrightarrow ATP$	$NADP^+ + 2e^- + H^+ \longrightarrow NADPH$
By chemiosmosis through ATP synthase (CF_0–CF_1 particles)	By $NADP^+$ reductase using electrons from Fd

8. CALVIN CYCLE (C_3 CYCLE)

Occurs in stroma



8.1 BALANCE SHEET OF CALVIN CYCLE

- CO_2 fixed – 6 molecules
- RuBP used – 6 molecules
- 3-PGA formed – 12 molecules
- ATP consumed – 18 molecules
- NADPH consumed – 12 molecules
- G3P (net) formed – 2 molecules
- Glucose synthesized – 1 molecule (from 2 G3P)

9. C_4 CYCLE (HATCH AND SLACK PATHWAY)

Occurs in C_4 plants to concentrate CO_2 and reduce photorespiration.

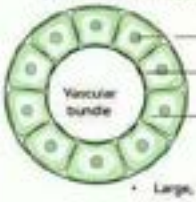
Steps:
1. CO_2 fixation in mesophyll cell by PEP carboxylase → Oxaloacetate (4C) → Malate / Aspartate
2. Transport to bundle sheath cells
3. Decarboxylation → Release of CO_2
4. CO_2 enters Calvin cycle (C_3 cycle)
5. Pyruvate returned to mesophyll cell → Regenerates PEP (uses ATP)

Example – Maize, Sugarcane, Sorghum

10. C_3 PLANTS vs C_4 PLANTS

Feature	C_3 Plants	C_4 Plants
Initial CO_2 acceptor	RuBP (5C)	PEP (3C)
First stable product	3-PGA (3C)	OAA (4C)
Site of CO_2 fixation	Mesophyll cell	Mesophyll cell
Site of Calvin cycle	Mesophyll cell	Bundle sheath cell
Photorespiration	High	Negligible
Kranz anatomy	Absent	Present
Example	Wheat, Rice, Gram, Pea	Maize, Sugarcane, Sorghum

11. KRANZ ANATOMY (In C_4 Plants)



- Large, thick-walled bundle sheath cells surround vascular bundle.
- Chloroplasts present in both mesophyll and bundle sheath cells.
- Helps in CO_2 concentration.

12. PHOTORESPIRATION (Warburg pathway)

- Occurs in presence of light.
- RuBisCO acts as oxygenase.
- RuBP + O_2 → 3-PGA + 2-PG
- 2-PG goes through series of reactions → releases CO_2
- No ATP or NADPH is produced.
- Reduces photosynthetic efficiency.
- More in C_3 plants, less in C_4 plants.

13. FACTORS AFFECTING PHOTOSYNTHESIS

1. Light – quality, intensity, duration
2. CO_2 concentration
3. Temperature
4. Water
5. Minerals
6. Chlorophyll content
7. O_2 concentration (high O_2 increases photorespiration)

14. BLACKMAN'S LAW OF LIMITING FACTOR

The rate of photosynthesis is controlled by the factor which is in shortest supply.

Even if other factors are abundant, the rate cannot increase unless the limiting factor is optimized.

SUMMARY FLOW: Light + H_2O → Light Reaction (ATP + NADPH + O_2) → Dark Reaction (Calvin Cycle) (Uses ATP & NADPH) → Carbohydrate (Glucose) + H_2O + O_2

Note: Light reaction stores energy in ATP and NADPH. Dark reaction uses this energy to fix CO_2 into carbohydrates.

CHAPTER12: RESPIRATION IN PLANTS

Exchange of gases; cellular respiration - glycolysis, fermentation (anaerobic), TCA cycle and electron transport system (aerobic); energy relations - number of ATP molecules generated; amphibolic pathways; respiratory quotient.

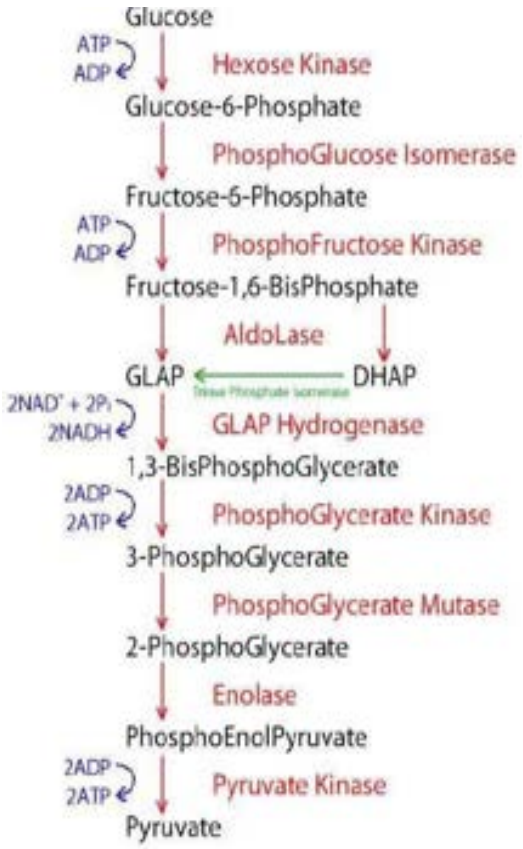
- **Cellular respiration:** the mechanism of breakdown of food materials within the cell to release energy, and the trapping of this energy for synthesis of ATP.
- The breaking of the C-C bonds of complex compounds through oxidation within the cells, leading to release of considerable amount of energy is called respiration.

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + \text{Energy}$$

Glycolysis (EMP Pathway)

Greek: Glycos = sugar, Lysis = splitting | Named after: **Gustav Embden, Otto Meyerhof, J.m Parnas**

The partial oxidation of glucose to pyruvic acid is called glycolysis. It occurs in cytoplasm of cell.It is common to both anaerobic & aerobic respiration. Glycolysis is a ten-step metabolic pathway that breaks down glucose into pyruvate, producing ATP and NADH. Here's a summary of the 10 steps:

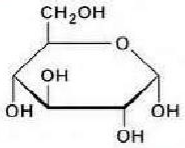
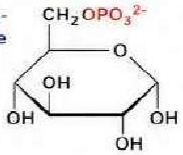
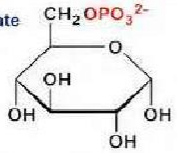
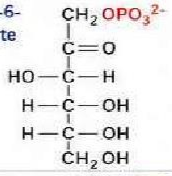
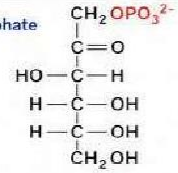
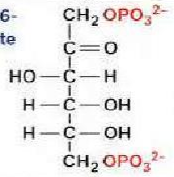
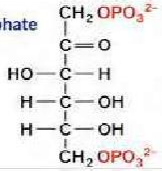
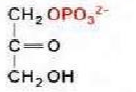
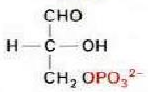
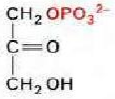
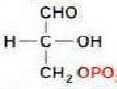
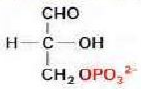
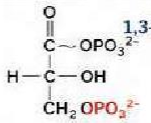
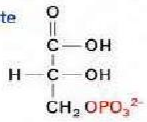
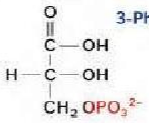
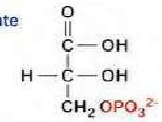
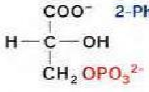
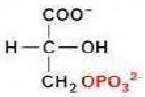
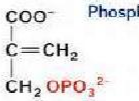
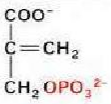


- 1molecule of Glucose forms 02 molecules of Pyruvate.
- 1 ATP is consumed in step 1
- 1 ATP is consumed in step 3
- 2NADH are produced in step 6
- 2 ATP are produced in step 7
- 2ATP are produced in step10

In absence of Oxygen-Total ATP formed = 4 ATP Total ATP consumed =2ATP Net Gain = 4ATP-2ATP
=2ATP

In presence of Oxygen-
2NADH = 6ATP
Total ATP Net Gain=6ATP+2ATP
=8ATP

Glycolysis: Molecular Structures and Steps

Substrate (Structure)	Enzyme (Cofactors)	Product (Structure)	Step Type
1 Glucose 	Hexokinase ATP → ADP	Glucose-6-phosphate 	Energy Investment
2 Glucose-6-phosphate 	Phosphoglucose Isomerase	Fructose-6-phosphate 	Isomerization
3 Fructose-6-phosphate 	Phosphofructokinase-1 ATP → ADP	Fructose-1,6-bisphosphate 	Energy Investment
4 Fructose-1,6-bisphosphate 	Aldolase	Dihydroxyacetone phosphate (DHAP)  + Glyceraldehyde-3-phosphate (GAP) 	Cleavage
5 Dihydroxyacetone phosphate (DHAP) 	Triose Phosphate Isomerase	Glyceraldehyde-3-phosphate (GAP) 	Isomerization
6 Glyceraldehyde-3-phosphate (GAP) 	Glyceraldehyde-3-phosphate Dehydrogenase 2 NAD^+ + 2 P_i → 2 NADH + 2 H^+	1,3-Bisphosphoglycerate (1,3-BPG) 	Energy Production
7 1,3-Bisphosphoglycerate (1,3-BPG) 	Phosphoglycerate Kinase 2 ADP → 2 ATP	3-Phosphoglycerate (3-PGA) 	Energy Production
8 3-Phosphoglycerate (3-PGA) 	Phosphoglycerate Mutase	2-Phosphoglycerate (2-PGA) 	Isomerization
9 2-Phosphoglycerate (2-PGA) 	Enolase 2 H_2O	Phosphoenolpyruvate (PEP) 	Dehydration
10 Phosphoenolpyruvate (PEP) 	Pyruvate Kinase 2 ADP → 2 ATP	Pyruvate 	Energy Production

Net Reaction (per glucose):

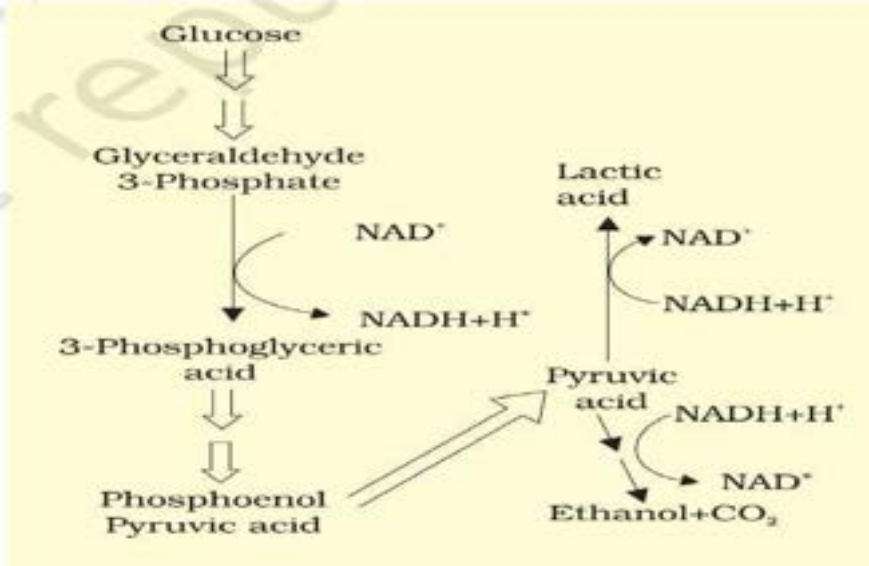
Glucose + 2 ADP + 2 P_i + 2 NAD^+ → 2 Pyruvate + 2 ATP + 2 NADH + 2 H^+ + 2 H_2O + 2 H^+

Net Gain:

2 ATP (net) and 2 NADH

Legend:

- ATP / ADP
- NADH
- Phosphate Group (PO_3^{2-})
- Enzyme



Fermentation

The process in which the incomplete oxidation of glucose is occurs under anaerobic conditions by sets of reactions where pyruvic acid is converted to CO2 and ethanol or Lactic Acid. Energy produced is 2ATP per molecule of glucose.

ALCOHOLIC FERMENTATION

Organisms: Yeast

Enzymes: Pyruvic acid decarboxylase + Alcohol dehydrogenase

Products: Ethanol + CO2

Note: Yeast is killed when alcohol reaches ~13%

OR

LACTIC ACID FERMENTATION

Organisms: Some bacteria, muscle cells (during exercise)

Enzyme: Lactate dehydrogenase

Product: Lactic Acid

Reducing agent: NADH+H+ reoxidised to NAD+

AEROBIC RESPIRATION: (Respiration in presence of Oxygen)

Pyruvate is transported from the cytoplasm into the mitochondria. The crucial events in aerobic respiration are:

• The complete oxidation of pyruvate by the stepwise removal of all the hydrogen atoms, leaving three molecules of CO2.(Kreb's Cycle)

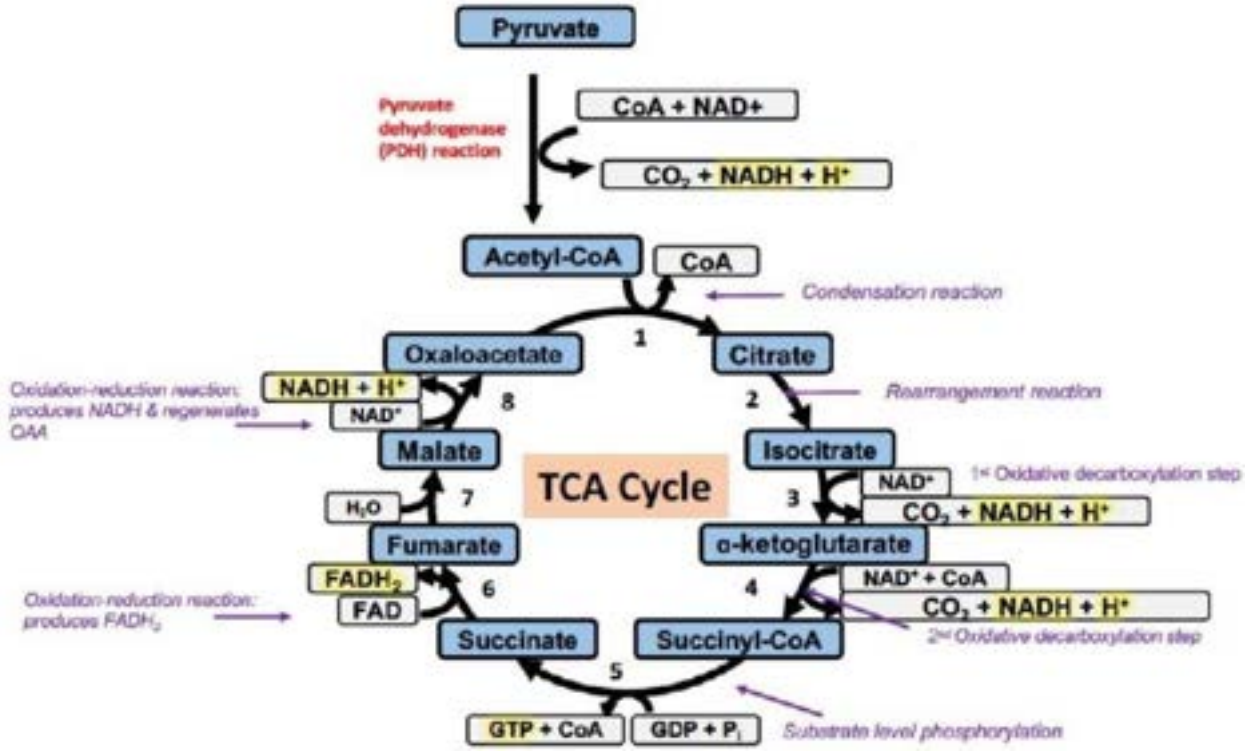
• The passing on of the electrons removed as part of the hydrogen atoms to molecular O2 with simultaneous synthesis of ATP.(Electron Transport System)

first process takes place in the matrix of the mitochondria while the second process is located on the inner membrane of the mitochondria.

Oxidative decarboxylation: It is linking step between Glycolysis & Krebs' cycle.*Pyruvate enters in mitochondrial matrix & undergoes **oxidative decarboxylation** by a complex set of reactions catalysed by **pyruvic dehydrogenase.**

During this process, two molecules of NADH produced, $2CO_2$ released (Decarboxylation) from the metabolism of two molecules of pyruvic acid & Acetyl Co.A (2 C compound) is formed.

$$\text{Pyruvic acid} + \text{CoA} + \text{NAD}^+ \xrightarrow[\text{Pyruvate dehydrogenase}]{Mg^{2+}} \text{Acetyl CoA} + CO_2 + \text{NADH} + H^+$$



Steps: Kreb's cycle occurs in matrix of Mitochondria.

1- Condensation of Acetyl group of Acetyl Co.A (2C) with Oxaloacetic acid (OAA)(4 C) and water to yield citric acid (6C) in presence of enzyme citrate synthase and a molecule of CoA is released & Citrate (6C) is formed.

2- Citrate is then isomerised to Isocitrate.

3- Two successive steps of decarboxylation occur (CO_2 released) leading to the formation of □-ketoglutaric acid & then Succinyl -Co A. Production of NADH occurs in each successive step respectively.

4- Conversion of succinyl-CoA to succinate occurs & a molecule of GTP is synthesized. From this GTP one ATP is synthesised

5- Conversion of Succinate to Fumerate. Production of $FADH_2$

6- Formation of Malate from Fumerate.

7- Regeneration of Oxaloacetate (OAA) (4C)

Thus –Per Pyruvate Molecule

3 NADH(in Krebs cycle + 1NADH (in Oxidative decarboxylation)= 4NADH equivalent to 12 ATP

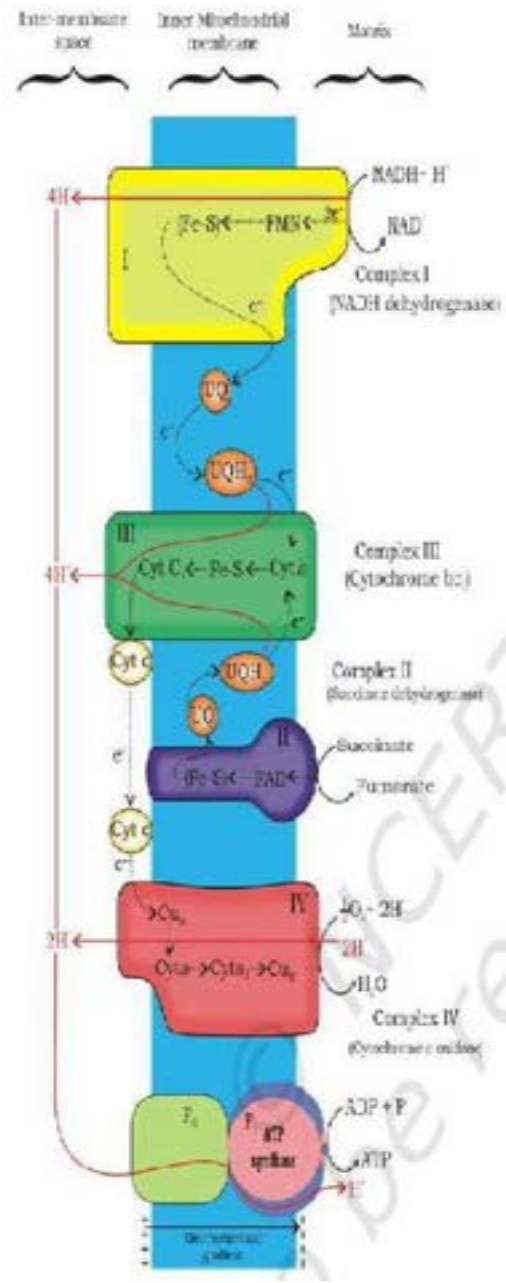
1 FADH2 equivalent to 2 ATP

1 GTP equivalent to 1 ATP

are produced. 1 GTP equivalent to 1 ATP

But these ATPs are produced through ETS. (Except from GTP).

Electron Transport System:



ETS is the final stage of aerobic respiration.

- It occurs on the **inner mitochondrial membrane**.
- Main function: release and utilise energy stored in **NADH + H^+** and **$FADH_2$**.

Definition

- ETS is a metabolic pathway in which electrons pass from one carrier to another and finally reduce oxygen to water.

Major Components of ETS

1. **Complex I – NADH Dehydrogenase**
   - Oxidises NADH + H^+
   - Transfers electrons to ubiquinone
2. **Complex II – Succinate Dehydrogenase**
   - Receives electrons from $FADH_2$
   - Transfers electrons to ubiquinone
3. **Ubiquinone (Coenzyme Q)**
   - Mobile electron carrier in inner membrane
4. **Complex III – Cytochrome bc_1 Complex**
   - Transfers electrons to cytochrome c
5. **Cytochrome c**
   - Small mobile protein
   - Carries electrons from Complex III to Complex IV
6. **Complex IV – Cytochrome c Oxidase**
   - Contains cytochromes a and a_3 and copper centres
   - Transfers electrons to oxygen
7. **Complex V – ATP Synthase**
   - Synthesises ATP from ADP + Pi

Flow of Electrons

$NADH/FADH_2$ → Complex I or II → Ubiquinone → Complex III → Cytochrome c → Complex IV → O_2

Role of Oxygen

- Oxygen acts as the **final hydrogen/electron acceptor**.
- Combines with electrons and H^+ to form water (H_2O).
- Essential for continuation of aerobic respiration.

ATP Yield

- 1 NADH → **3 ATP**
- 1 $FADH_2$ → **2 ATP**

Importance of ETS

- Produces maximum ATP during respiration.
- Couples electron transfer with ATP synthesis.
- Maintains energy supply of the cell.

Oxidative Phosphorylation and ATP Synthesis

1. Definition of Oxidative Phosphorylation

- In respiration, the energy derived from **oxidation-reduction** reactions is utilized to produce a proton gradient required for phosphorylation.
- This differs from photophosphorylation (in plants during photosynthesis), which uses light energy to create that gradient.
- Because the energy comes from oxidation, the process is specifically called **oxidative phosphorylation**.

2. The Mechanism (Chemiosmotic Hypothesis)

- The synthesis of ATP is linked to the membrane as explained by the **chemiosmotic hypothesis**.
- Energy released during the **Electron Transport System (ETS)** is used to synthesize ATP with the help of a specialized enzyme complex called **ATP synthase (Complex V)**.

3. Structure of ATP Synthase (Complex V)

The ATP synthase complex consists of two major components:

- **Headpiece:**

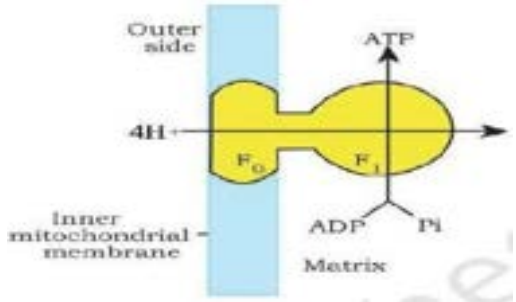
A peripheral membrane protein complex.
Functions as the **site for ATP synthesis** from ADP and inorganic phosphate ().

- **Component:**

An integral membrane protein complex.
Forms a **channel** through which protons () cross the inner mitochondrial membrane.

4. The Process of ATP Production

- **Proton Flow:** Protons move from the **intermembrane space** to the **matrix**.
- **Coupling:** The passage of these protons through the channel is coupled to the catalytic site of the component.
- **Energy Conversion:** This movement occurs down the **electrochemical proton gradient**, triggering the production of ATP.
- **Stoichiometry:** For every **one ATP** molecule produced, (four protons) must pass through the channel.



Respiratory Balance Sheet

Theoretical maximum ATP yield per glucose molecule (assuming ideal conditions):

Stage	Location	ATP	NADH	FADH2
Glycolysis	Cytoplasm	2 (net)	2	0
Pyruvate Oxidation (x2)	Mitochondrial Matrix	0	2	0
Krebs' Cycle (x2)	Mitochondrial Matrix	2	6	2
ETS (from NADH)	Inner Mito. Membrane	30 (10 NADH x 3)	—	—
ETS (from FADH2)	Inner Mito. Membrane	4 (2 FADH2 x 2)	—	—
TOTAL		38 ATP	10 NADH	2 FADH2

Amphibolic Pathway

The respiratory pathway is called amphibolic because it is involved in BOTH catabolism (breakdown) AND anabolism (synthesis).

Substrate	Entry Point into Respiratory Pathway
Carbohydrates	Glucose → Glucose-6-phosphate (first step)
Fats	Glycerol → PGAL; Fatty acids → Acetyl CoA
Proteins	Amino acids (after deamination) → Pyruvate or Acetyl CoA or Krebs' intermediates

FATS (Glycerol + Fatty acids)	→	CARBOHYDRATES (Glucose → EMP → Pyruvate → Acetyl CoA → Krebs' Cycle)	←	PROTEINS (Amino acids after deamination)

Respiratory Quotient (RQ)

Definition

- Respiratory Quotient (RQ) or Respiratory Ratio is the ratio of the volume of CO_2 evolved to the volume of O_2 consumed during respiration.

$$RQ = \frac{\text{Volume of } CO_2 \text{ evolved}}{\text{Volume of } O_2 \text{ consumed}}$$

Important Points

- RQ depends on the type of respiratory substrate used.
- Different food materials (carbohydrates, fats, proteins) have different RQ values.
- It helps to identify which substrate is being respired.

RQ of Different Respiratory Substrates

1. Carbohydrates

- In carbohydrates, equal amounts of CO_2 are produced and O_2 consumed.
- Therefore, RQ = 1

Example: Glucose Respiration

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + Energy$$

$$RQ = \frac{6CO_2}{6O_2} = 1$$

2. Fats

- More oxygen is required for oxidation of fats.
- Therefore, RQ is less than 1.

Example: Tripalmitin

$$2(C_{51}H_{98}O_6) + 145O_2 \rightarrow 102CO_2 + 98H_2O + Energy$$

$$RQ = \frac{102CO_2}{145O_2} \approx 0.7$$

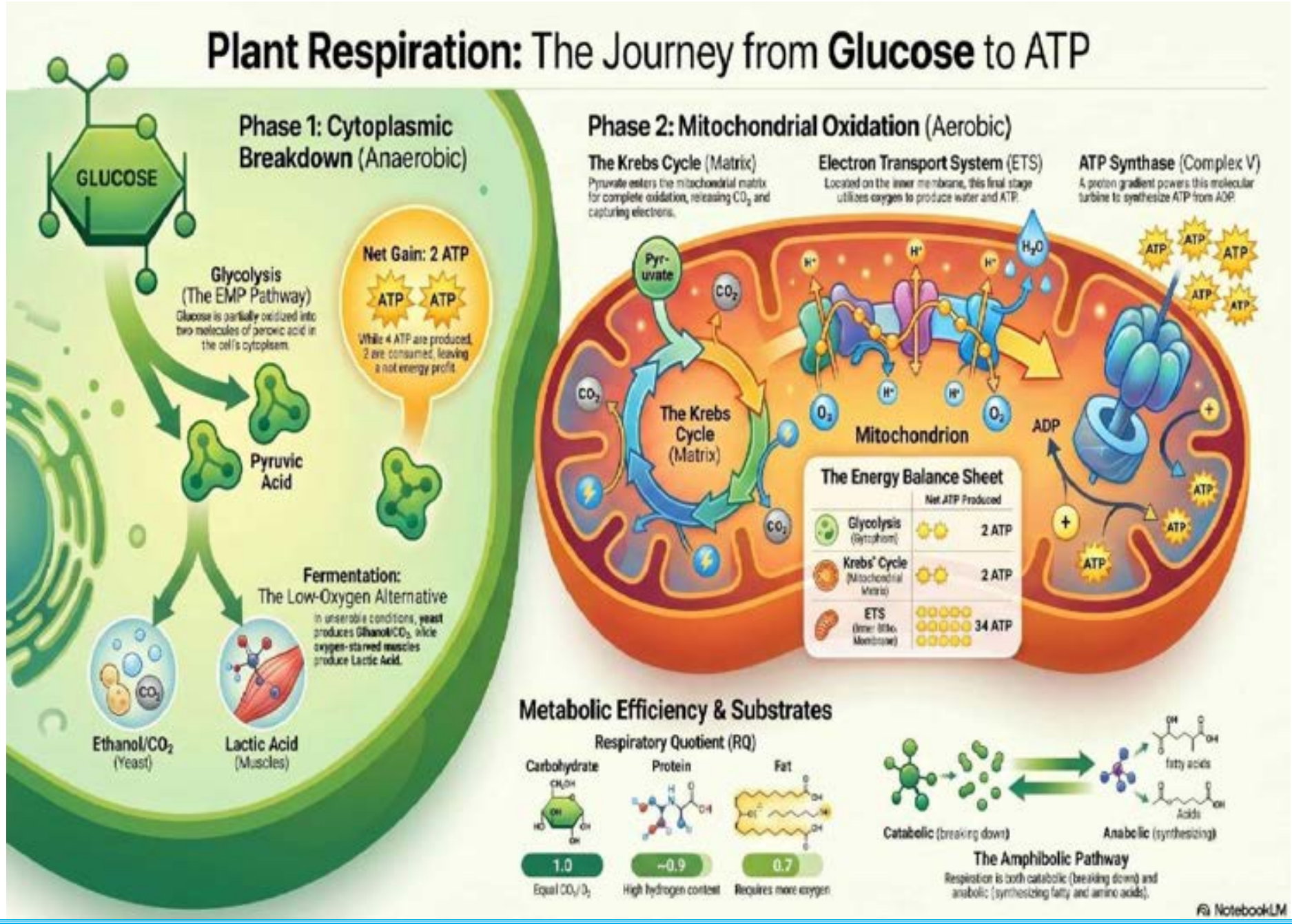
3. Proteins

- Proteins generally have RQ around 0.9

Significance of RQ

- Indicates the type of respiratory substrate used.
- Helps in studying metabolism and respiration.
- Used in physiological studies.

See answer of intext Questions at page No. 158 in the Question Bank QR under Test Your Knowledge


Plant Respiration: The Journey from Glucose to ATP
GLUCOSE
Phase 1: Cytoplasmic Breakdown (Anaerobic)
Glycolysis (The EMP Pathway)
Glucose is partially oxidized into two molecules of pyruvic acid in the cell's cytoplasm.
Net Gain: 2 ATP
ATP ATP
While 4 ATP are produced, 2 are consumed, leaving a net energy profit.
Pyruvic Acid
Fermentation: The Low-Oxygen Alternative
In anaerobic conditions, yeast produces Ethanol/CO2, while oxygen-starved muscles produce Lactic Acid.
Ethanol/CO2 (Yeast)
Lactic Acid (Muscles)
Phase 2: Mitochondrial Oxidation (Aerobic)
The Krebs Cycle (Matrix)
Pyruvate enters the mitochondrial matrix for complete oxidation, releasing CO2 and capturing electrons.
Electron Transport System (ETS)
Located on the inner membrane, this final stage utilizes oxygen to produce water and ATP.
ATP Synthase (Complex V)
A proton gradient powers this molecular turbine to synthesize ATP from ADP.
Pyr-uvate
CO2
H2O
H+
ATP
The Krebs Cycle (Matrix)
O2
Mitochondrion
ADP
The Energy Balance Sheet
Net ATP Produced
Glycolysis (Cytoplasm) 2 ATP
Krebs' Cycle (Mitochondrial Matrix) 2 ATP
ETS (Inner Mito. Membrane) 34 ATP
Metabolic Efficiency & Substrates
Respiratory Quotient (RQ)
Carbohydrate
Protein
Fat
1.0
Equal CO2/O2
~0.9
High hydrogen content
0.7
Requires more oxygen
fatty acids
Acids
Catabolic (breaking down)
Anabolic (synthesizing)
The Amphibolic Pathway
Respiration is both catabolic (breaking down) and anabolic (synthesizing fatty and amino acids).
NotebookLM

CHAPTER: 13 PLANT GROWTH AND DEVELOPMENT

SYLLABUS (SESSION 2026-27): Growth, Differentiation, Dedifferentiation and Redifferentiation, Development, Plant growth regulators (auxin, cytokinins, gibberellins, ethylene, abscisic acid).

GROWTH: Growth is a permanent and irreversible increase in size, volume, dry weight, or cell number of a plant.

Characteristics of Growth:-

1. Indeterminate Growth

Plants continue to grow throughout their life due to the presence of meristems.

2. Measurable Process

Growth can be measured in terms of length, area, volume, fresh weight, dry weight, or number of cells.

3. Irreversible Process

Growth cannot be reversed once it has occurred.

4. Cellular Basis of Growth

Growth occurs due to:

- Cell division
- Cell enlargement
- Cell differentiation

Phases of Growth:-

1. Meristematic Phase

- Cells divide actively.
- Cells are small, thin-walled, and dense with protoplasm.

2. Elongation Phase

- Cells enlarge rapidly due to vacuolation and cell wall expansion. Growth in seedlings can be measured by 'parallel line technique'. In the parallel line technique, equally spaced ink marks are drawn on a growing plant organ such as a root or stem, and the increase in distance between the marks after a period of time indicates the amount and region of growth.

3. Maturation Phase

- Cells attain maximum size and become differentiated for specific functions.

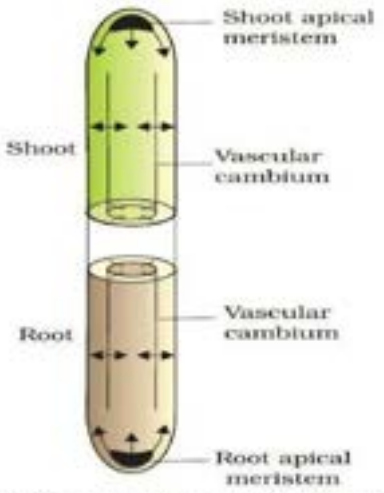


Figure 13.2 Diagrammatic representation of locations of root apical meristem, shoot apical meristem and vascular cambium. Arrows exhibit the direction of growth of cells and organ

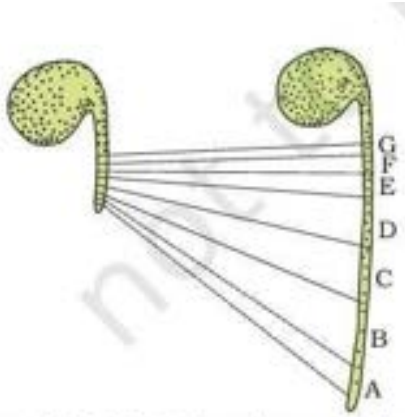


Figure 13.3 Detection of zones of elongation by the parallel line technique. Zones A, B, C, D immediately behind the apex have elongated most.

Questions:-

Q1. Fill in the blanks-

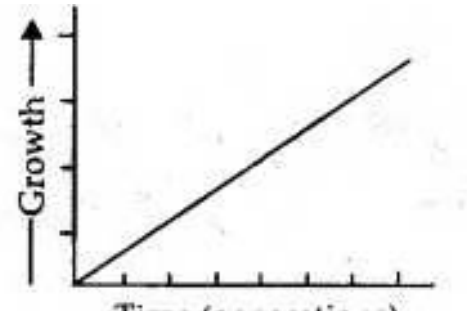
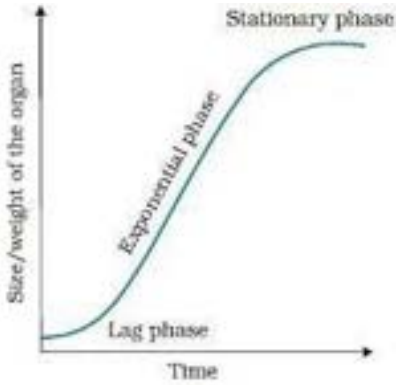
1. The increase in plant mass due to cell division and enlargement is called _____.
2. The ability of living cells to divide continuously is known as _____.
3. Growth occurring throughout the life of a plant is termed _____ growth.
4. The stage of growth in which cells increase rapidly in size is called the _____ phase.

Q2. A student observed the root tip of a germinating seed under a microscope and noted the following regions:

- Region A: Cells were actively dividing with dense cytoplasm.
- Region B: Cells showed rapid increase in length and vacuolation.
- Region C: Cells attained maximum size and started performing specific functions.

Identify the phases of growth represented by Regions A, B, and C. Also mention one characteristic feature of each phase.

GROWTH RATE: The increase in growth per unit time is called growth rate.

ARITHEMATIC GROWTH RATE	**GEOMETRIC GROWTH RATE**
1. Growth occurs at a constant rate. 2. Equal increase in each unit time. 3. Graph curve is linear (straight line). 4. Growth equation – $Lt + L_O = rt$ 5. Elongation of root at constant rate.  Fig.: Arithmetic growth curve	1. Growth rate increases proportionally with existing size. 2. Rapid and exponential increase. 3. Graph curve is sigmoid. 4. Growth equation- $W_1 = W_O e^{rt}$ 5. Growth of bacterial cells or embryo 

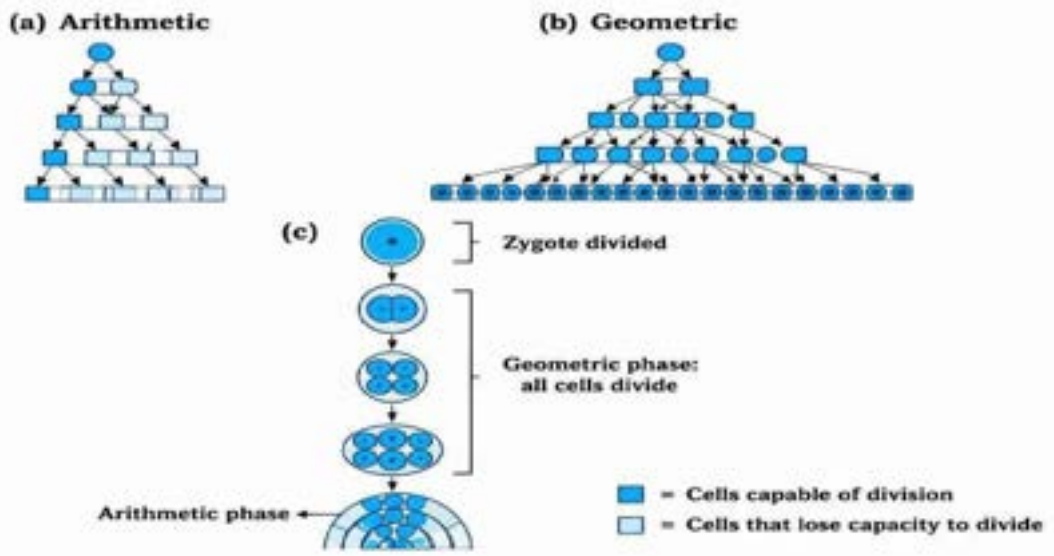


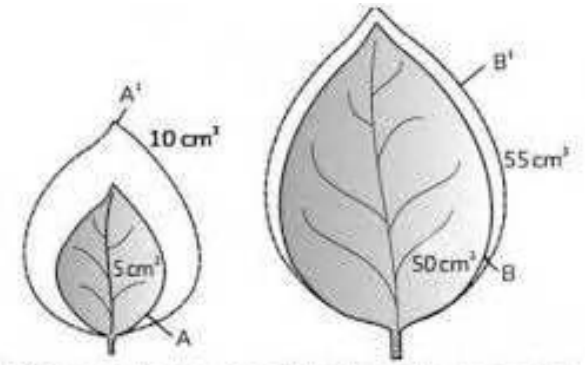
Figure 13.4 Diagrammatic representation of : (a) Arithmetic (b) Geometric growth and (c) Stages during embryo development showing geometric and arithmetic phases.

Absolute Growth Rate;

Absolute growth rate is the measurement and comparison of total growth per unit time. It gives the actual increase in size, length, area, or weight of a plant organ during a specific period. For example, if a leaf increases in area from 5 cm^2 to 10 cm^2 in one day, the increase of 5 cm^2 represents the absolute growth rate.

Relative Growth Rate:

Relative growth rate is the growth per unit time expressed on a common basis, such as per unit initial size or weight. It shows the efficiency of growth of a plant system. For example, a smaller leaf may show a higher relative growth rate than a larger leaf because it grows faster in proportion to its initial size.



Diagrammatic comparison of absolute and relative growth rates. Both leaves A and B have increased their area by 5 cm^2 in a given time to produce A^1, B^1 leaves.

Conditions for Growth:

Plant growth is affected by both external and internal factors. External factors include water, oxygen, nutrients, light, and temperature, which are essential for metabolic activities and cell enlargement, while internal factors include genetic makeup and plant growth regulators such as auxins, gibberellins, cytokinins, abscisic acid, and ethylene that control and coordinate various growth processes.

Q3.A botanist recorded the growth of two plant seedlings over a period of 5 days.

- Seedling A increased in dry weight from 20 g to 50 g.
- Seedling B increased in dry weight from 5 g to 20 g.

Based on the data, answer the following:

1. Calculate the Absolute Growth Rate (AGR) of both seedlings.
2. Which seedling shows a higher Relative Growth Rate (RGR)? Give reason.

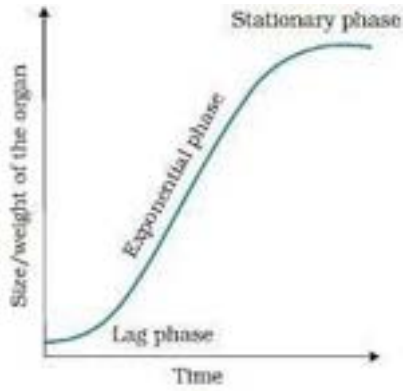
Hint -Absolute Growth Rate (AGR)

$$AGR = \frac{W_2 - W_1}{t_2 - t_1}$$

Q4. A group of students investigated the growth pattern of a developing fruit over several weeks. They measured its fresh weight regularly and plotted the observations on a graph. Initially, growth was very slow despite active metabolic processes. Later, the fruit showed rapid increase in mass due to active cell division and enlargement. After maturity, growth almost stopped though the fruit remained physiologically active.

Questions

1. Identify the type of growth curve obtained.
2. Why is growth slow during the initial phase?
3. Which phase shows maximum growth rate?
4. State one reason for attainment of stationary phase.
5. Name the mathematical growth shown during rapid growth phase.



Differentiation:-

Differentiation is the process by which cells derived from the root apical and shoot apical meristems mature and perform specific functions by developing permanent shape, size, and structure.
Example: Formation of xylem vessels and tracheids.

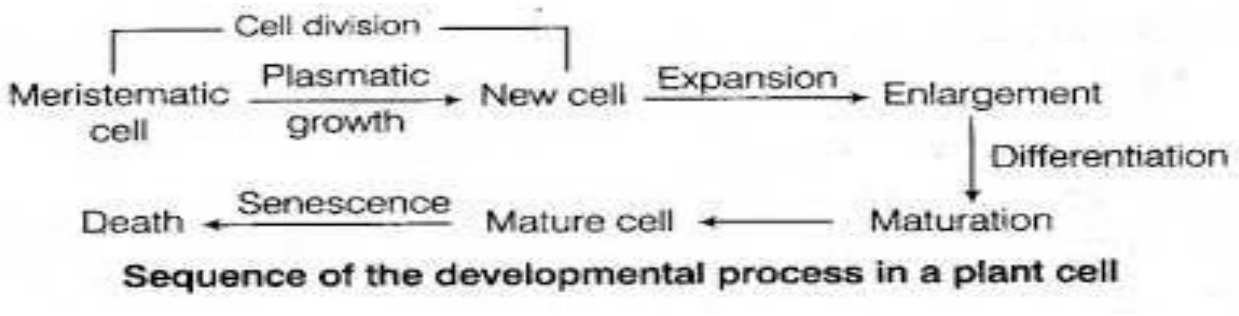
Dedifferentiation:-

Dedifferentiation is the process in which living differentiated cells regain the capacity to divide under certain conditions.
Example: Formation of interfascicular cambium and cork cambium from permanent tissues.

Redifferentiation:-

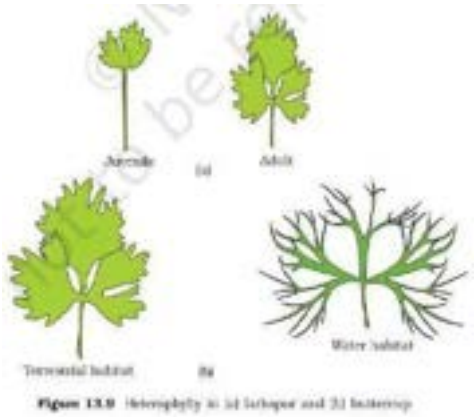
Redifferentiation is the process in which the cells formed after dedifferentiation mature again and lose the capacity to divide to perform specific functions.
Example: Cells produced by cambium differentiate into secondary xylem and secondary phloem.

DEVELOPMENT: Development is the sum of two processes: growth and differentiation.



Sequence of the developmental process in a plant cell

PLASTICITY:- Plasticity is the ability of plants to modify their growth, development, and structure in response to environmental conditions or different phases of life. Due to plasticity, plants can produce different forms of leaves, roots, or branches depending on factors such as light, water, temperature, and habitat. This ability helps plants adapt successfully to changing environmental conditions. For example, buttercup plants produce different leaf shapes in aquatic and terrestrial conditions, a phenomenon called heterophylly.



Plant Growth Regulators: -

Plant Growth Regulators are small, simple molecules of diverse chemical composition that regulate plant growth and development.

The five major plant hormones are:

1. **Auxins** – previously known as *growth hormones*
   Example: Indole-3-acetic acid (IAA)
2. **Gibberellins** – first discovered as substances causing "bakanae disease" in rice.
   Derivatives of terpenes.
   Example: Gibberellic acid (GA_3)
3. **Cytokinins** – It promotes cytokinesis. Adenine derivatives (N^6-furfurylamino purine).
   Example: Kinetin, Zeatin
4. **Abscisic acid (ABA)** – formerly called *dormin* or *abscisin.* This hormone is derivative of carotenoids.
   Acts mainly as a growth inhibitor.
5. **Ethylene** – a gaseous plant hormone associated with fruit ripening.
   Example: Ethene gas

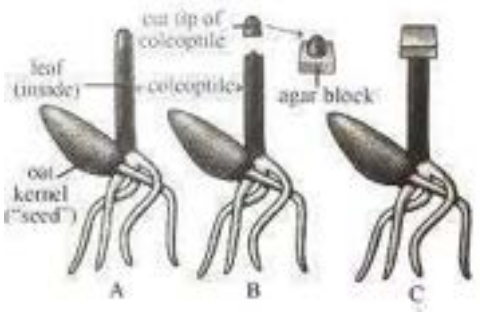
Characteristics of Plant Growth Regulators

- They are produced naturally in plants in minute quantities.
- They regulate growth, differentiation and development.
- They may function either as growth promoters or growth inhibitors.

- Their action depends on concentration, location and developmental stage of the plant.
- Different PGRs interact with each other to control physiological activities.
- One PGR may perform multiple functions, and different PGRs may show similar effects.

Discovery of plant growth regulators:-

1. Charles Darwin and Francis Darwin demonstrated the presence of a growth-promoting substance in coleoptile tips during experiments on phototropism on Canary grasses.
2. Frits Went later isolated this substance and named it auxin on oat plant.
3. Gibberellins were discovered during the study of the bakanae disease of rice caused by the fungus *Gibberella fujikuroi*.
4. Cytokinins were discovered by F. Skoog and Carlos O. Miller during experiments on cell division in tobacco pith cells.



5. Abscisic acid (ABA) was identified from studies related to dormancy and abscission, where substances called dormin and abscisin II were later found to be the same compound.
6. Ethylene was recognised as a gaseous plant hormone after observations that it promoted fruit ripening, senescence and abscission in plants.

Auxin:

- Auxins help in cell elongation in stems and coleoptiles.
- They promote root initiation in stem cuttings and are used in vegetative propagation.
- Auxins regulate phototropism and geotropism in plants.
- They promote apical dominance by inhibiting the growth of lateral buds.
- Auxins prevent early abscission of leaves and fruits.
- They promote flowering in some plants such as pineapple.
- Auxins help in fruit development and can induce parthenocarpy (development of seedless fruits).
- Synthetic auxins like 2,4-D are used as weedicides to control broad-leaved weeds.
- Auxins promote vascular tissue differentiation.

Apical Dominance*: Apical dominance is the phenomenon in which the apical bud (terminal bud) of a plant inhibits the growth of lateral or axillary buds. This occurs due to the production of auxin in the apical bud, which moves downward and suppresses the development of side branches. When the apical bud is removed, the inhibitory effect of auxin decreases, allowing lateral buds to grow and produce branches. This helps the plant grow vertically and efficiently receive sunlight***.**

Questions-

Q5. A gardener removed the apical bud of a potted plant and observed rapid growth of lateral branches after a few days.

Name the phenomenon responsible for this observation and identify the plant growth regulator involved.

Answer- Read notes above.

Q6. Case study based question-

A researcher transferred a terrestrial plant to waterlogged conditions. After several weeks, newly formed leaves became thinner with reduced cuticle thickness and larger air spaces. The older leaves retained their original structure. The scientist explained that plants modify their morphology and anatomy in response to changing surroundings.



Questions

1. Which property of plants allows such modifications?
2. Why did older leaves not show modification?
3. Which tissue adaptation helps the plant survive in waterlogged conditions?
4. What advantage do larger air spaces provide?
5. Name the phenomenon by which the same genotype produces different phenotypes.

Cytokinins:

- Cytokinins promote **cell division (cytokinesis)** in plant tissues.
  Example: Rapid cell division in fruits, seeds and meristematic regions.
- They help in **cell enlargement** and differentiation when present along with auxins.
- Cytokinins promote the growth of **lateral buds** and help overcome apical dominance.
  Example: Growth of side branches after reduction of auxin effect.
- They delay **senescence (ageing)** of leaves by promoting nutrient mobilisation and chlorophyll retention.
  Example: Leaves remain green for a longer time.
- Cytokinins promote **nutrient mobilisation** to areas where they are produced or applied.
- They help in **chloroplast development** and promote chlorophyll synthesis in leaves.
- Cytokinins are widely used in **plant tissue culture** to stimulate shoot formation.
  Example: Kinetin and zeatin used in tissue culture media.
- Natural cytokinins are found abundantly in regions of active cell division such as **root apices, developing fruits and seeds**.
  Example: Zeatin isolated from maize grains.

Gibberellins:

- Gibberellins promote **stem elongation** and increase the length of internodes.
  Example: Bolting in rosette plants like cabbage and beet.
- They help in breaking **seed dormancy** and promote germination.
  Example: Germination of barley seeds.

- Gibberellins stimulate the production of **α-amylase enzyme** in germinating cereal grains, which helps in starch breakdown.
- They promote **flowering** in some plants, especially long-day plants and biennials.
- Gibberellins increase **fruit size** and improve fruit shape.
  Example: Elongation of grape stalks and increase in grape size.
- They promote **bolting** and flowering in plants with rosette habit.
  Example: Beet, cabbage.
- Gibberellins can induce **parthenocarpy** (formation of seedless fruits).
- They help delay **senescence** of leaves and fruits in some plants.
- Gibberellins are used to increase the yield of plants such as **sugarcane** by increasing stem length and sugar content.

COMPARATIVE ACCOUNT OF COMPLIMENTARY AND ANTAGONISTIC PLANT HORMONES

COMPLIMENTARY PLANT HORMONES				ANTAGONISTIC PLANT HORMONES			
Hormones Involved	Nature of Interaction	Physiological Effect (Combined Action)	Example	Hormones Involved	Nature of Interaction	Physiological Effect (Opposite Action)	Example
Auxin + Gibberellin	Complimentary	Promote cell elongation and stem growth	Elongation of stem in dicot plants	Auxin Cytokinin	Antagonistic	Auxin promotes rooting; Cytokinin inhibits rooting	Root formation in cuttings
Auxin + Cytokinin	Complimentary	Promote cell division (callus formation)	Tissue culture (callus growth)	Gibberellin Abscisic acid (ABA)	Antagonistic	Gibberellin breaks seed dormancy; ABA maintains dormancy	Seed dormancy and germination
Gibberellin + Cytokinin	Complimentary	Promote cell division and shoot growth	Shoot formation in tissue culture	Auxin Abscisic acid (ABA)	Antagonistic	Auxin promotes growth; ABA inhibits growth	Growth under stress conditions
Auxin + Ethylene	Complimentary	Promote fruit ripening	Ripening of climacteric fruits (e.g. tomato)	Ethylene Cytokinin	Antagonistic	Ethylene promotes senescence; Cytokinin delays senescence	Senescence of leaves and flowers
Gibberellin + Ethylene	Complimentary	Promote flowering in some plants	Flowering in pineapple	Cytokinin Abscisic acid (ABA)	Antagonistic	Cytokinin promotes growth; ABA inhibits growth	Growth during water stress

Key Point: Complimentary hormones act together to enhance a particular physiological process, whereas antagonistic hormones act in opposition to regulate and balance plant growth and development.

Questions-

Q5. A farmer noticed that some plants in his field were showing poor growth and delayed flowering. An agricultural scientist suggested spraying different plant growth regulators on different crops. In one crop, spraying a hormone promoted rapid stem elongation and increased sugar yield. In another crop, treatment with a different hormone delayed leaf ageing and promoted the growth of lateral buds and cell division.
Based on the above information, answer the following questions:

1. Name the hormone that promotes stem elongation and increases sugar yield in sugarcane.

2. Name the hormone responsible for delaying senescence and promoting cell division.
3. Which hormone helps in overcoming dormancy of seeds and buds?

4. State one commercial application of cytokinins.
5. Why are plant growth regulators called chemical messengers?

Answer- Read notes above

Ethylene:

- Ethylene promotes **fruit ripening**.
  Example: Ripening of banana, mango and tomato fruits.
- It enhances **senescence** and **abscission** of leaves, flowers and fruits.
- Ethylene promotes **horizontal growth** of seedlings and swelling of the axis.
- It helps plants respond to **mechanical stress**.
- Ethylene promotes the formation of **adventitious roots** and root hairs.
- It breaks **seed and bud dormancy** in some plants.
- Ethylene promotes **flowering** in certain plants.
  Example: Pineapple.
- It increases the rate of **respiration** during fruit ripening (respiratory climacteric).
- Ethylene is widely used in agriculture for **artificial fruit ripening**.
  Example: Ethephon releases ethylene and promotes synchronized fruit ripening.

ABSCISSIC ACID:

- Abscisic acid acts mainly as a **growth inhibitor** in plants.
- It induces **dormancy** in seeds and buds, helping plants survive unfavourable conditions.
- ABA promotes **senescence** and **abscission** of leaves, flowers and fruits.
- It plays an important role in **stomatal closure** during water stress, reducing water loss through transpiration.
- ABA helps plants tolerate various **stress conditions** such as drought and cold.
- It inhibits **seed germination** under unfavourable conditions.
- ABA regulates several aspects of plant growth and development by interacting with other plant hormones.

Questions:-

Q. A farmer stores ripe bananas together with unripe bananas to speed up ripening.
(a) Which plant hormone is responsible for this effect?
(b) Mention one other function of this hormone.

Q. A student observes that plants kept in darkness become tall and weak with elongated internodes.
(a) Which hormone mainly causes stem elongation?
(b) Name the phenomenon shown by such plants.
(c) Mention one agricultural use of this hormone.

See answer of intext Questions at page No. 158 in the Question Bank QR under Test Your Knowledge

PLANT GROWTH AND DEVELOPMENT

I. GROWTH

Definition
Irreversible permanent increase in size, dry weight, mass or volume of cells or organs.

1. Characteristics of Growth
- Increase in protoplasm
- Measurable change
- Uses energy
- Occurs by cell division and enlargement

2. Conditions for Growth
- Water
- Oxygen
- Nutrients
- Temperature
- Light

3. Phases of Growth
(i) Meristematic Phase
→ Active cell division

(ii) Elongation Phase
→ Cell enlargement and vacuolation

(iii) Maturation Phase
→ Cells attain maximum size and differentiation

4. Growth Rates
(i) Arithmetic Growth
(one daughter cell continues division)
→ Linear growth
Example: Root apical meristem

(ii) Geometric Growth
(both daughter cells divide)
→ Exponential growth
Example: Some algae, bacteria

(iii) Logistic Growth
(S-shaped curve)
→ Due to limited nutrients and space
Example: Growth of most plant populations

5. Growth Measurement
(i) Absolute Growth Rate (AGR)
→ Increase in size or mass per unit time

Formula:

$$AGR = \frac{W_2 - W_1}{t_2 - t_1} / t_2 - t_1$$

(ii) Relative Growth Rate (RGR)
→ Increase in size per unit initial size per unit time

Formula:

$$RGR = \frac{(\log W_2 - \log W_1)}{t_2 - t_1}$$

6. Differentiation, Dedifferentiation and Redifferentiation
(i) Differentiation
→ Cells mature structurally and functionally.
Example: Xylem cells

(ii) Dedifferentiation
→ Mature cells regain capacity to divide.
Example: Cork cambium, interfascicular cambium

(iii) Redifferentiation
→ Dedifferentiated cells mature again.
Example: Secondary xylem and cork cells

7. Development
Sum of growth and differentiation leading to qualitative and quantitative changes.

8. Plasticity
Ability of plants to form different structures under different environmental conditions.

(i) Heterophylly
Example: Different leaves in Cotton, Coriander, Buttercup

(ii) Environmental Plasticity
Example: Sun leaves and shade leaves

II. PLANT GROWTH REGULATORS (PGRs)

Definition
Small, simple organic molecules produced in minute quantities that regulate growth and development.

Discovery of PGRs

Auxin
- Darwin and Francis Darwin (phototropism)
- Isolated by Frits Went

Gibberellin
- Discovered while studying 'Bakanae' disease of rice caused by fungus *Gibberella fujikuroi*

Cytokinin
- Discovered by F. Skoog and C. O. Miller while studying cell division in tobacco pith

Abscisic Acid (ABA)
- Isolated from studies on dormancy and abscission
- Dormin and Abscisin II were found to be the same compound

Ethylene
- Recognised as gaseous hormone from observations on fruit ripening, senescence and abscission

Functions of Major Plant Growth Regulators

1. AUXINS (Example: IAA)
- Promote cell elongation
- Promote root initiation in cuttings
- Show phototropism and geotropism
- Maintain apical dominance
- Prevent abscission of leaves and fruits
- Promote parthenocarpy (seedless fruits)
- Promote vascular tissue differentiation
- Synthetic auxin 2,4-D used as weedicide

2. GIBBERELLINS (Example: GA_3)
- Promote stem elongation (increase internode length)
- Cause bolting in rosette plants (e.g., Cabbage, Beet)
- Break seed dormancy and promote germination
- Stimulate α-amylase synthesis in germinating grains
- Increase fruit size and improve shape
- Promote flowering in some plants
- Induce parthenocarpy

3. CYTOKININS (Example: Kinetin)
- Promote cell division (cytokinesis)
- Promote growth of lateral buds and overcome apical dominance
- Delay senescence of leaves
- Promote nutrient mobilisation
- Promote chloroplast development and chlorophyll synthesis
- Used in tissue culture for shoot induction

4. ETHYLENE (Gaseous)
- Promote fruit ripening (e.g., Banana, Mango, Tomato)
- Promote senescence and abscission of leaves, flowers and fruits
- Promote horizontal growth and swelling of the axis
- Break seed and bud dormancy in some plants
- Induce adventitious roots and root hairs
- Promote flowering in some plants (e.g., Pineapple)
- Increase rate of respiration in ripening fruits

5. ABSCISIC ACID (ABA)
- Acts mainly as a growth inhibitor
- Induces seed and bud dormancy
- Promotes senescence and abscission
- Causes stomatal closure during water stress
- Helps plants tolerate stress conditions like drought and cold
- Inhibits seed germination
- Interacts with other hormones to regulate growth and development

Chapter 14: Breathing And Exchange Of Gases

Syllabus 2026-27

Respiratory organs in animals (recall only); Respiratory system in humans; mechanism of breathing and its regulation in humans - exchange of gases, transport of gases and regulation of respiration, respiratory volume; disorders related to respiration - asthma, emphysema, occupational respiratory disorders.

Respiratory organs

Group of Animals	Respiratory Organ/Method	Type of Respiration	Description
Lower invertebrates (sponges, coelenterates, flatworms)	Entire body surface	Diffusion	Exchange of O_2 and CO_2 takes place by simple diffusion over the body surface.
Earthworms	Moist cuticle	Cutaneous respiration	Respiration occurs through the moist skin/cuticle.
Insects	Tracheal tubes	Tracheal respiration	A network of tubes transports atmospheric air within the body.
Aquatic arthropods and molluscs	Gills	Branchial respiration	Special vascularised gills help in exchange of gases in water.
Fishes	Gills	Branchial respiration	Fishes respire through gills.
Amphibians	Lungs and moist skin	Pulmonary and cutaneous respiration	Amphibians like frogs respire through lungs as well as moist skin.
Reptiles, Birds, Mammals	Lungs	Pulmonary respiration	Respiration occurs through lungs.

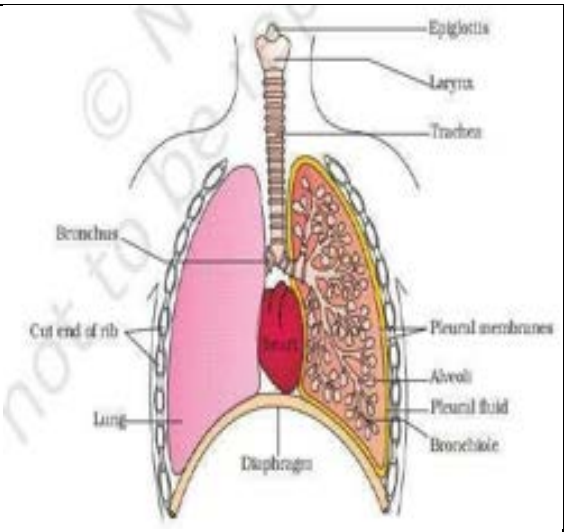
Cutaneous respiration Exchange of respiratory gases through the thin, moist, permeable and highly vascularised skin.	**Buccopharyngeal respiration** Exchange of respiratory gases through thin, vascular lining of buccopharyngeal cavity.
Branchial respiration Exchange of respiratory gases through gills.	**Pulmonary respiration** Exchange of gases through lungs.

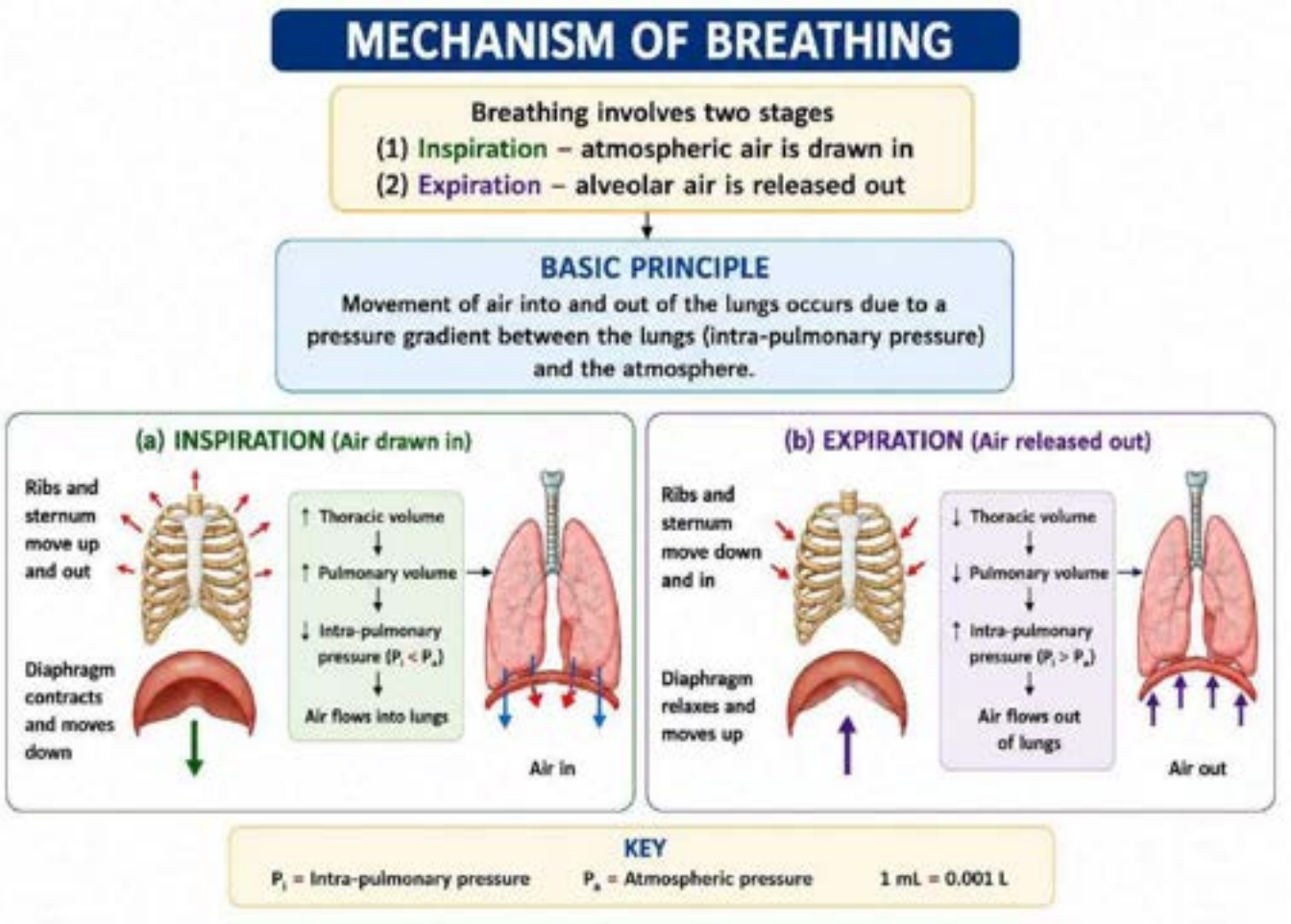
Respiratory system in humans

- The **larynx** is a cartilaginous box responsible for sound production and is called the "sound box."
- During swallowing, the **epiglottis** covers the glottis to prevent food from entering the larynx.
- Bronchi, bronchioles, and alveoli together form the lungs.
- Humans have two lungs covered by a double-layered **pleura**.
- Pleural fluid between pleural membranes reduces friction during breathing.

Q.1. Give the role of epiglottis and pleura.

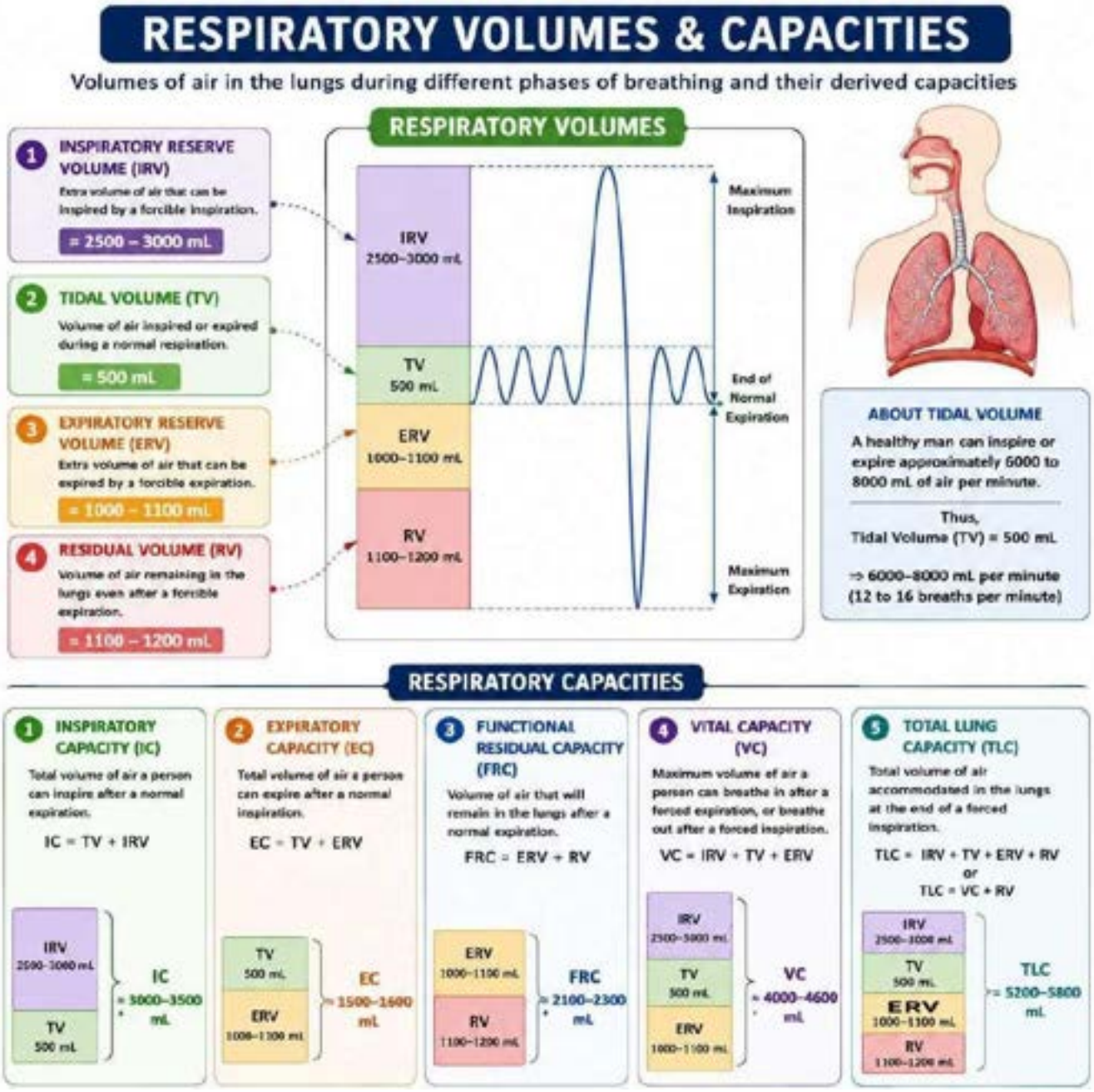
Conducting part of the respiratory system includes – External nostrils, Nasal passage, Pharynx, Larynx, Trachea, Bronchi, Bronchioles up to terminal bronchioles	**Respiratory (exchange) part includes –** alveolar ducts and alveoli.
Functions – Transport air to alveoli Remove foreign particles Humidify air Warm air to body temperature	**Function –** Alveoli are the site of gas exchange between blood and atmospheric air.

Atmosphere ↓↑ External nostrils ↓↑ Nasal cavity ↓↑ Pharynx ↓↑ Larynx ↓↑ Trachea ↓↑ Bronchi ↓↑ Bronchioles ↓↑ Lungs $\underset{CO_2}{\overset{O_2}{\rightleftharpoons}}$ Blood **Pathway of air flow**	**Steps of Respiration** 1. Breathing or pulmonary ventilation ○ Intake of atmospheric air ○ Release of CO_2-rich alveolar air 2. Diffusion of O_2 and CO_2 across alveolar membrane. 3. Transport of gases by blood 4. Diffusion of gases between blood and tissues. 5. Utilisation of O_2 by cells and release of CO_2 during catabolic reactions.	 **Diagrammatic view of human respiratory system**



Q.2. Trace the pathway for inspiration.

Q.3. How diaphragm and ribs supports inspiration and expiration?



Q.4. Distinguish between Vital Capacity and Total Lung Capacity.

Exchange of gases

- Alveoli are the primary sites for exchange of gases in the lungs.
- Gas exchange also occurs between blood and body tissues.
- Oxygen (O_2) and carbon dioxide (CO_2) are exchanged mainly by simple diffusion.
- Diffusion occurs due to pressure/concentration gradients.
- Factors affecting the rate of diffusion include:

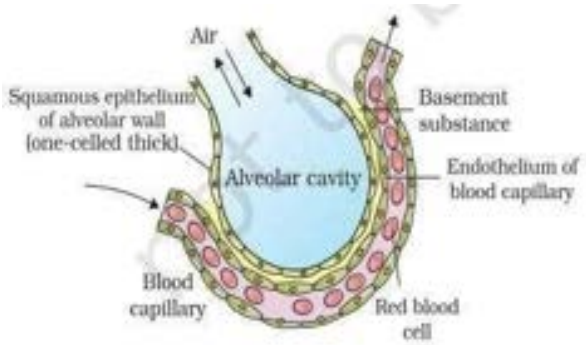


Figure 14.4 A Diagram of a section of an alveolus with a pulmonary capillary.

1. Pressure gradient
2. Solubility of gases

- CO_2 is 20–25 times more soluble than O_2.
- Therefore, CO_2 diffuses much faster through the diffusion membrane compared to O_2.
- Thickness of diffusion membrane
- The diffusion membrane consists of three layers:
- Thin squamous epithelium of alveoli
- Endothelium of alveolar capillaries
- Basement substance between them
- The pressure exerted by an individual gas in a mixture is called partial pressure.
- pO_2 - Partial pressure of oxygen and pCO_2 - Partial pressure of carbon dioxide

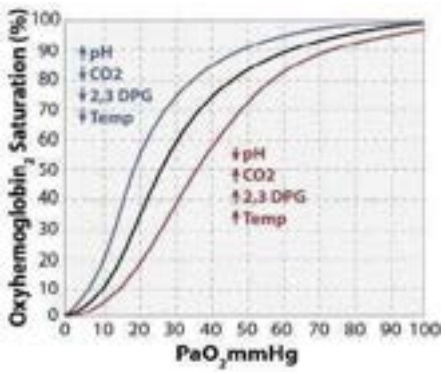
Q.5. What are the factors that affect the rate of diffusion between the blood and tissues?

Q.6. How CO_2 exchange between blood and alveoli is favoured inspite having lower partial pressure as compared to partial pressure of O_2?

Aspect	Oxygen (O_2) Transport	Carbon Dioxide (CO_2) Transport
Transport by RBCs	About 97% transported by RBCs	About 20–25% transported by haemoglobin as carbamino-haemoglobin
Transport in Plasma	About 3% dissolved in plasma	About 7% dissolved in plasma
Other Form of Transport	—	About 70% transported as bicarbonate ions
Amount Transported per 100 mL Blood	Oxygenated blood delivers about 5 mL O_2 to tissues	Deoxygenated blood delivers about 4 mL CO_2 to alveoli

Transport of gases

- A sigmoid curve is obtained when percentage saturation of haemoglobin with O_2 is plotted against the pO_2 . This curve is called the **Oxygen dissociation curve** and is highly useful in studying the effect of factors like pCO_2, H^+ concentration on binding of O_2 with haemoglobin.



Q.7. Why do human beings have difficulty breathing at high elevations?

Q.8. How the Oxygen dissociation curve will get deviated if body temperature increases?

Factors affecting Formation and Dissociation of oxyhaemoglobin.

Factors	In Alveoli	In Tissues
(pO_2)	High	Low
(pCO_2)	Low	High
H^+ Concentration	Lesser	High
Temperature	Lower	Higher
Effect on Haemoglobin	Formation of oxyhaemoglobin	Dissociation of oxygen from oxyhaemoglobin

Q.9. What are the factors that favour the formation of oxyhaemoglobin in lungs?

Q.10. Assertion - A drop in the blood pH causes an increase in heart rate.

Reason- Increased Heart Rate increases the rate at which CO2 is delivered to the lungs, where CO2 is removed.

Regulation of respiration

Component/Area	Function in Regulation of Respiration
Respiratory Rhythm Centre	Present in the medulla region of the brain; primarily responsible for regulating respiratory rhythm
Pneumotaxic Centre	Present in the pons region of the brain; moderates the functions of the respiratory rhythm centre
Effect of Pneumotaxic Centre	Reduces the duration of inspiration and alters respiratory rate
Chemosensitive Area	Located adjacent to the rhythm centre; highly sensitive to CO_2 and H^+ concentration
Response to Increased CO_2 and H^+	Activates the chemosensitive area, which signals the rhythm centre to adjust respiration for elimination of these substances
Aortic Arch Receptors	Detect changes in CO_2 and H^+ concentration and send signals to the rhythm centre
Carotid Artery Receptors	Recognise changes in CO_2 and H^+ concentration and help in remedial respiratory actions
Role of Oxygen	Has an insignificant role in regulation of respiratory rhythm

Q.11. Name the area that regulate and moderates the functions of the respiratory rhythm centre.

Disorders related to respiration

Respiratory Disorder	Description	Cause	Effects/ Symptoms	Prevention
Asthma	Difficulty in breathing due to inflammation of bronchi and bronchioles	Inflammation of bronchi and bronchioles	Wheezing and breathing difficulty	maintain a clean, well-ventilated home
Emphysema	Chronic disorder in which alveolar walls are damaged	cigarette smoking	Decreased respiratory surface area	Avoid smoking
Occupational Respiratory Disorders	Disorders caused by long-term exposure to industrial dust	Dust from industries such as grinding and stone-breaking	Inflammation, fibrosis, and serious lung damage	Use protective masks

Q.12. Why there is Decreased respiratory surface area in a person suffering from emphysema?

See answer of intext Questions at page No. 158 in the Question Bank QR under Test Your Knowledge

Living cells use O_2 for energy production and produce CO_2 as a waste. Breathing (respiration) is the process of exchange of O_2 from the atmosphere with CO_2 produced by the cells.

OVERVIEW OF RESPIRATION (STEPS)

1. Breathing (Pulmonary Ventilation)
Air is inspired and expired.

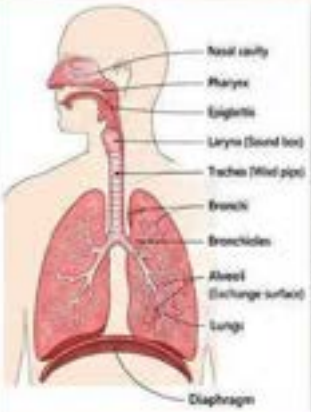
→ **2. Exchange of Gases**
O_2 and CO_2 diffuse across alveolar membrane.

→ **3. Transport of Gases**
Gases are transported by blood to tissues and back to lungs.

→ **4. Exchange at Tissues**
O_2 and CO_2 diffuse between blood and tissues.

→ **5. Utilisation of O_2**
O_2 is used by cells for catabolic reactions (cellular respiration); CO_2 is released.

1. RESPIRATORY ORGANS



- External nostrils → Nasal passage → Nasal chamber → Pharynx.
- Pharynx opens into larynx; glottis is covered by epiglottis during swallowing.
- Larynx helps in sound production.
- Trachea divides into right and left primary bronchi.
- Bronchi → secondary bronchi → tertiary bronchi → bronchioles → terminal bronchioles → alveoli.
- Alveoli are thin-walled, vascularised sacs; site of gas exchange.
- Lungs are covered by double-layered pleura with pleural fluid.

Conducting Part: From nostrils to terminal bronchioles. Functions – conducts air, filters dust, humidifies and warms air.

Exchange Part: Alveoli and their ducts. Site of diffusion of O_2 and CO_2.

2. MECHANISM OF BREATHING

(A) INSPIRATION



- Diaphragm contracts (moves downward).
- External intercostal muscles contract; ribs and sternum move upward and outward.
- Thoracic volume increases.
- Intra-pulmonary pressure falls below atmospheric pressure.
- Air rushes into lungs.

(B) EXPIRATION



- Diaphragm relaxes (moves upward).
- Intercostal muscles relax; ribs and sternum move downward and inward.
- Thoracic volume decreases.
- Intra-pulmonary pressure rises above atmospheric pressure.
- Air is expelled out.

RESPIRATORY VOLUMES AND CAPACITIES (Approximate Values)

Volumes

- Tidal Volume (TV) : 500 mL
- Inspiratory Reserve Volume (IRV) : 2500–3000 mL
- Expiratory Reserve Volume (ERV) : 1000–1100 mL
- Residual Volume (RV) : 1100–1200 mL

Capacities (Combinations)

- Inspiratory Capacity (IC) = TV + IRV
- Expiratory Capacity (EC) = TV + ERV
- Functional Residual Capacity (FRC) = ERV + RV
- Vital Capacity (VC) = IRV + TV + ERV
- Total Lung Capacity (TLC) = VC + RV

Measured by spirometer and used for clinical assessment of lung function.

3. EXCHANGE OF GASES (By Diffusion)

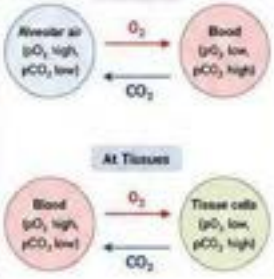
Partial Pressures (mm Hg)

Site	pO_2	pCO_2
Atmospheric air	159	0.3
Alveolar air	104	40
Blood (Deoxygenated)	40	45
Blood (Oxygenated)	95	40
Tissues	40	45

Factors facilitating diffusion:

- Favourable partial pressure gradients
- High solubility of CO_2 (20–25 times more than O_2)
- Very thin diffusion membrane (alveolar epithelium + basement membrane + capillary endothelium; total thickness < 1 µm)

Exchange of Gases

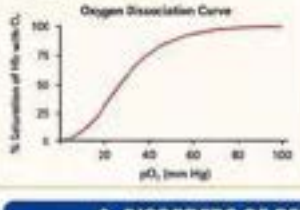


O_2 diffuses from alveoli → blood → tissues.
CO_2 diffuses from tissues → blood → alveoli.

4. TRANSPORT OF GASES

(A) TRANSPORT OF OXYGEN

- ~97% carried by RBCs as oxyhaemoglobin.
- ~3% dissolved in plasma.
- Each haemoglobin molecule binds 4 O_2 molecules.
- Oxygen dissociation curve (sigmoid):
  - In alveoli (high pO_2, low pCO_2, low H^+, low temp.): O_2 binds to Hb.
  - In tissues (low pO_2, high pCO_2, high H^+, high temp.): O_2 is released.
- 100 mL oxygenated blood delivers ~5 mL O_2 to tissues.

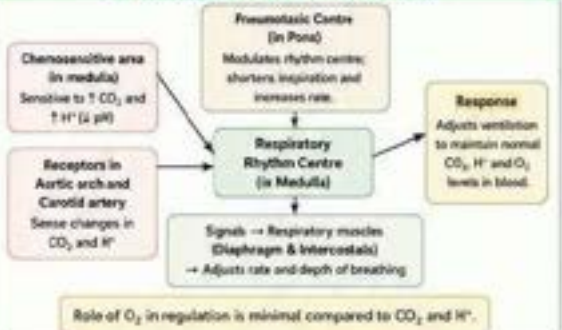


(B) TRANSPORT OF CARBON DIOXIDE

- ~70% carried as bicarbonate (HCO_3^-).
- ~20–25% carried as carbamino-haemoglobin.
- ~7% dissolved in plasma.
- $CO_2 + H_2O \rightleftharpoons H_2CO_3 \rightleftharpoons HCO_3^- + H^+$ (Catalysed by carbonic anhydrase in RBCs and plasma)
- In tissues (high pCO_2): CO_2 enters blood → forms HCO_3^-.
- In alveoli (low pCO_2): $HCO_3^- \rightarrow CO_2 + H_2O$ (reverse reaction) → CO_2 is exhaled.
- 100 mL deoxygenated blood delivers ~4 mL CO_2 to alveoli.

Chloride shift: Exchange of Cl^- and HCO_3^- across RBC membrane helps maintain electrical neutrality.

5. REGULATION OF RESPIRATION



Role of O_2 in regulation is minimal compared to CO_2 and H^+.

6. DISORDERS OF RESPIRATORY SYSTEM

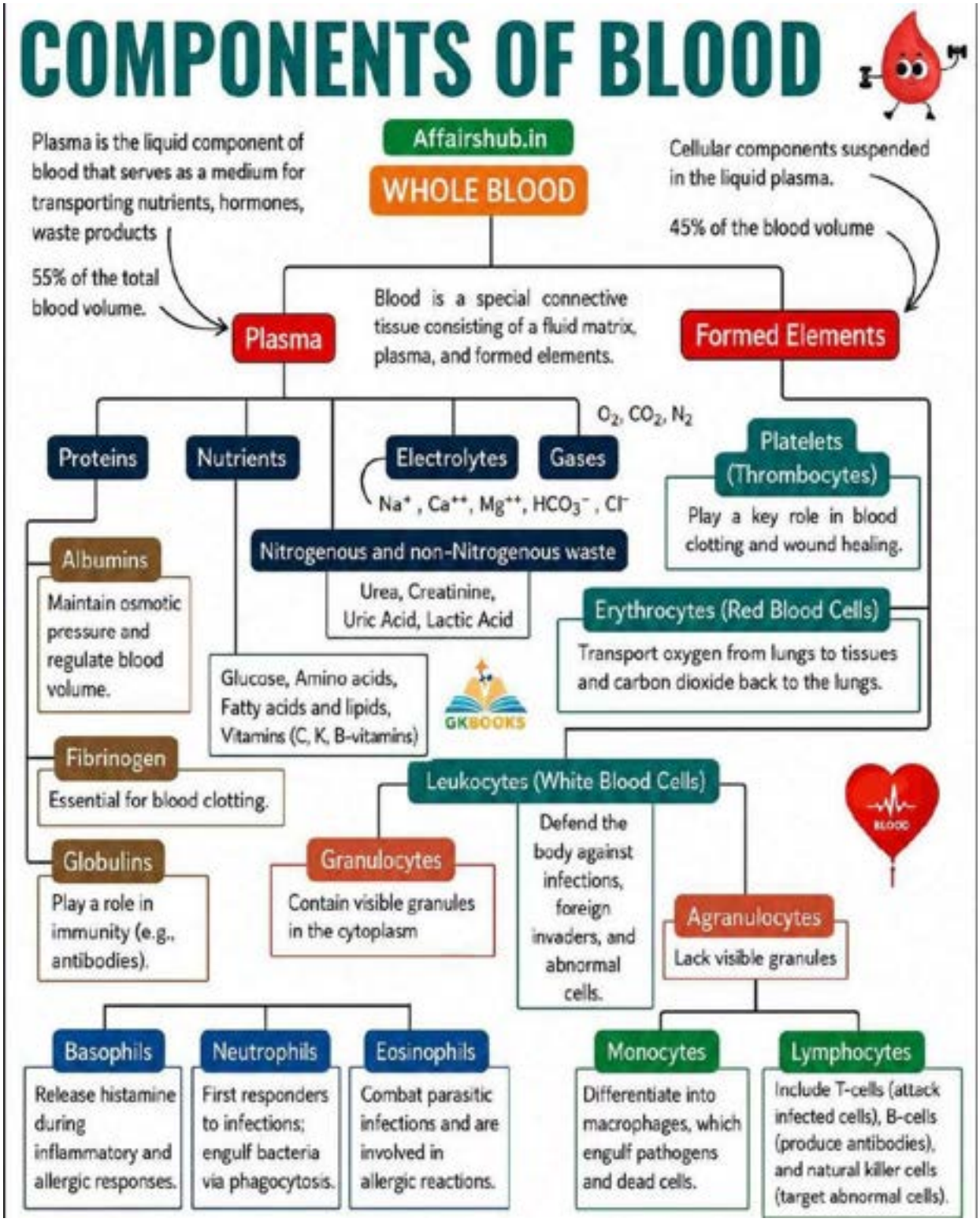
Asthma	Inflammation of bronchi and bronchioles; causes difficulty in breathing and wheezing.
Emphysema	Alveolar walls are damaged; respiratory surface is decreased. Major cause: cigarette smoking.
Occupational Respiratory Disorders (e.g., Silicosis)	Long exposure to dust (in mining, grinding, stone-breaking, etc.) causes inflammation, fibrosis and serious lung damage. Use of protective masks is essential.
Pneumonia	Infection and inflammation of alveoli; filled with fluid or pus; causes fever, cough and breathing difficulty.

Chapter 15: Body Fluids And Circulation

Syllabus 2026-27

Composition of blood, blood groups, coagulation of blood; composition of lymph and its function; human circulatory system - Structure of human heart and blood vessels; cardiac cycle, cardiac output, ECG; double circulation; regulation of cardiac activity; disorders of circulatory system - hypertension, coronary artery disease, angina pectoris, heart failure.

Composition of blood



Q.1. Give the role of Globulin, Albumins, Basophils, Neutrophils and Eosinophils.
Q.2. Differentiate the function of T- lymphocytes and B- lymphocytes.

Blood groups (Two groupings are ABO and Rh.)

ABO grouping -

- ABO grouping is based on the presence or absence of two surface antigens (chemicals that can induce immune response) on the RBCs namely A and B.
- Plasma of different individuals contains two natural antibodies (proteins produced in response to antigens).
- Blood of a donor has to be carefully matched with the blood of a recipient before any blood transfusion to avoid severe problems of clumping (destruction of RBC).

Combinations of antigens and antibodies in different blood groups

Blood group	Antigen (on the surface of R.B.Cs)	Antibody (in plasma)	Alleles
A	A	anti B	I^AI^A, I^Ai
B	B	anti A	I^BI^B, I^Bi
AB	A and B	None	I^AI^B
O	None	anti A and anti B	ii

- Blood group O can be donated to persons with any other blood group - hence called universal donors.
- Persons with AB group can accept blood from persons with AB as well as from people with other groups of blood- hence called universal recipients.

Q.4. Where the antigen and antibodies are found?

Blood Groups and Donor Compatibility

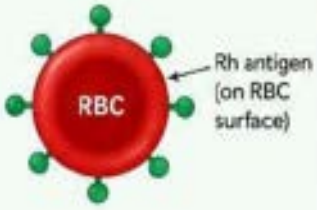
Donor	Recipients agglutinating blood of O A B AB	Possible recipients having blood group	Prospective donors having blood group	Remarks
O	− − − −	O, A, B, AB	O	Donor
A	+ − + −	A, AB	O, A	−
B	+ + − −	B, AB	O, B	−
AB	+ + + −	AB	O, A, B, AB	Universal recipient

Q.5. Why blood group "AB" and "O" is called universal recipients and universal donors respectively?

Rh grouping and erythroblastofoetalis

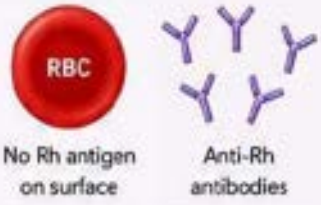
1. RH POSITIVE (Rh+ve)

- Rh antigen similar to one present in Rhesus monkeys (hence Rh), observed on the surface of RBCs of majority (nearly 80 per cent) of humans.



2. RH NEGATIVE (Rh–ve)

- Those in whom this antigen is absent.
- An Rh–ve person, if exposed to Rh+ve blood, will form specific antibodies against the Rh antigens.



3. BLOOD TRANSFUSION

- Rh group should also be matched before transfusions.



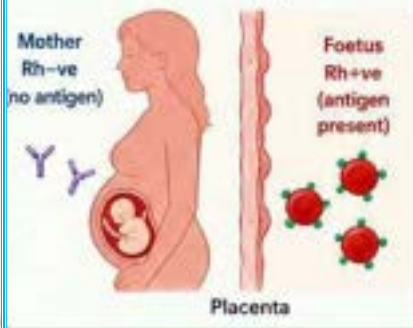
LEGEND

- Rh antigen
- Anti-Rh antibody

4. ERYTHROBLASTOSIS FOETALIS – Rh INCOMPATIBILITY BETWEEN MOTHER AND FOETUS

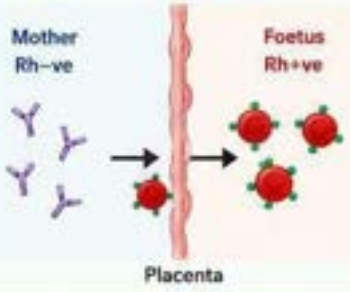
1 FIRST PREGNANCY

- Rh antigens of the foetus do not get exposed to the Rh–ve blood of the mother as the two bloods are well separated by placenta.



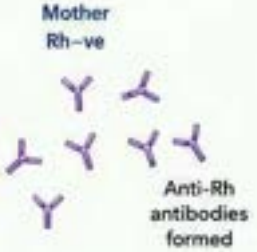
2 DURING DELIVERY OF FIRST CHILD

- There is a possibility of exposure of the maternal blood to small amounts of Rh+ve blood from the foetus.



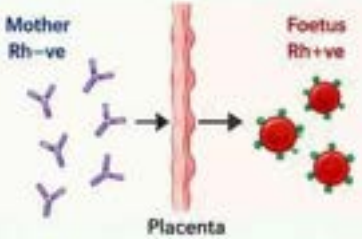
3 AFTER DELIVERY OF FIRST CHILD

- The same mother starts preparing antibodies against Rh antigen in her blood.



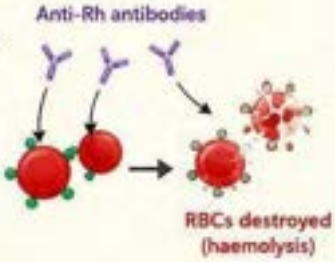
4 SUBSEQUENT PREGNANCIES

- The Rh antibodies from the mother (Rh–ve) can leak into the blood of the foetus (Rh+ve).



5 EFFECT ON FOETUS

- The antibodies destroy the foetal RBCs.



6 RESULT

- Could be fatal to the foetus or could cause severe anaemia and jaundice to the baby – erythroblastosis foetalis.



7 PREVENTION

Can be avoided by administering anti-Rh antibodies to the mother immediately after the delivery of the first child.

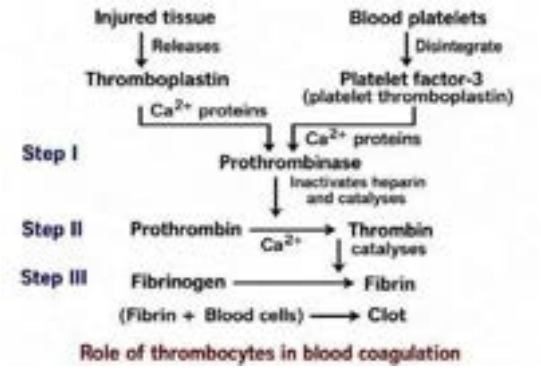


Q.6. A doctor suggested to a couple not to have more than one child. Why?

Q.7. How can erythroblastosis fetalis be prevented?

Coagulation of blood

- **How blood clot is fromed?**



Role of thrombocytes in blood coagulation

Composition of lymph and its function

Lymp is a colourless fluid containing specialised lymphocytes.
Responsible for the immune responses of the body.
Lymph is also an important carrier for nutrients, hormones, etc.
Fats are absorbed through lymph in lacteals present in the intestinal villi.
When blood passes through capillaries in tissues, some water along with many small water-soluble substances move out into spaces between the cells of tissues leaving larger proteins and most of the formed elements in blood vessels.
An elaborate network of vessels called lymphatic system collects this fluid and drains it back to major veins.

Circulatory Pathways

Feature	Open Circulatory System	Closed Circulatory System
Definition	Blood pumped by the heart passes through large vessels into open spaces/body cavities called sinuses	Blood pumped by the heart always circulates through a closed network of blood vessels
Found In	Arthropods and molluscs	Annelids and chordates
Blood Flow	Blood flows freely in body cavities	Blood remains confined within blood vessels
Regulation of Flow	Less precise regulation	More precise regulation
Advantage	Simpler system	Efficient transport and better control of circulation

Q.8. Which type of Circulatory System is more efficient in circulation?

Comparative structure of vertebrate heart-

Group of Animals	Heart Chambers	Type of Circulation	Special Features
Fishes	2-chambered (1 atrium + 1 ventricle)	Single circulation	Heart pumps deoxygenated blood to gills for oxygenation; oxygenated blood goes to body and returns deoxygenated to heart
Amphibians, Reptiles (except crocodiles)	3-chambered (2 atria + 1 ventricle)	Incomplete double circulation	Oxygenated and deoxygenated blood mix in the single ventricle(Partial mixing of oxygenated and deoxygenated blood)
Crocodiles, Birds, Mammals	4-chambered (2 atria + 2 ventricles)	Double circulation	Complete separation of oxygenated and deoxygenated blood

Q.9. What advantage does the 4-chambered heart offers as to the 3-chambered heart?

Human circulatory system - Structure of human heart and blood vessels

- **Circulatory system** – Blood vascular system and lymphatic system are together referred to as Circulatory system in vertebrates.
- Human circulatory system is also called the **blood vascular system**.
- It consists of:
- A muscular chambered heart
- A network of closed branching blood vessels
- Blood (circulating fluid)

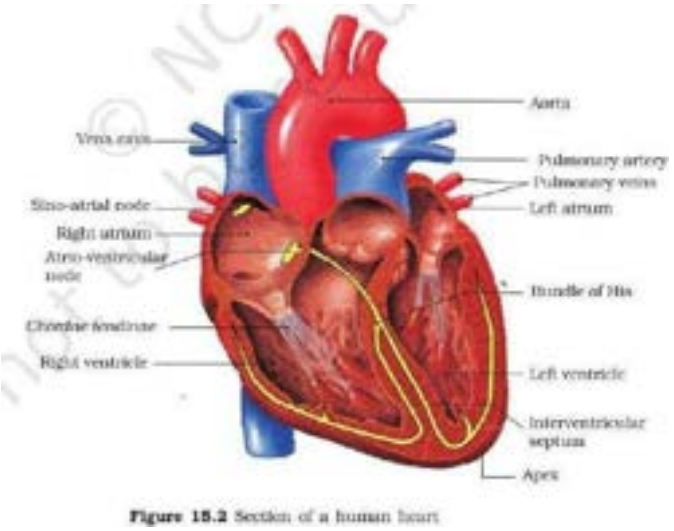


Figure 15.2 Section of a human heart

Heart -

- Heart is a **mesodermally derived organ**.
- It is protected by a **double-walled membranous bag** called the **pericardium**.
- The pericardium encloses **pericardial fluid**.

Septa in the heart-

Interatrial septum	Interventricular septum	Atrioventricular septum
Thin muscular wall	Thick muscular wall	Thick fibrous tissue
Separates right and left atria	Separates right and left ventricles	Separates atrium and ventricle

Valves of heart(Openings between chambers are guarded by valves)

Right Side	Left Side
Opening between right atrium and right ventricle has the **Tricuspid valve f**ormed of three muscular flaps (cusps)	Opening between left atrium and left ventricle has the **Bicuspid valve / Mitral valve**

Semilunar Valves

- Openings of ventricles into arteries are guarded by semilunar valves.
- Right ventricle → Pulmonary artery and Left ventricle → Aorta

Functions of Valves

- Allow blood flow only in one direction: From atria → ventricles and From ventricles → arteries
- Prevent backward flow of blood

Difference between artery and vein

Basis	Arteries	Veins
Direction of Blood Flow	Carry blood away from the heart	Carry blood towards the heart
Type of Blood	Usually carry oxygenated blood	Usually carry deoxygenated blood
Exception	Pulmonary artery carries deoxygenated blood	Pulmonary vein carries oxygenated blood
Wall Thickness	Thick, elastic and muscular walls	Thin, less elastic walls
Lumen	Narrow lumen	Wide lumen
Blood Pressure	Blood flows with high pressure	Blood flows with low pressure
Valves	Valves absent	Valves present to prevent backflow
Position in Body	Usually deep seated	Often closer to skin surface

THE HEART: MUSCLES & NODAL (CONDUCTION) SYSTEM

The heart is not just a pump, it has its own electrical system that initiates and controls its rhythmic beating.

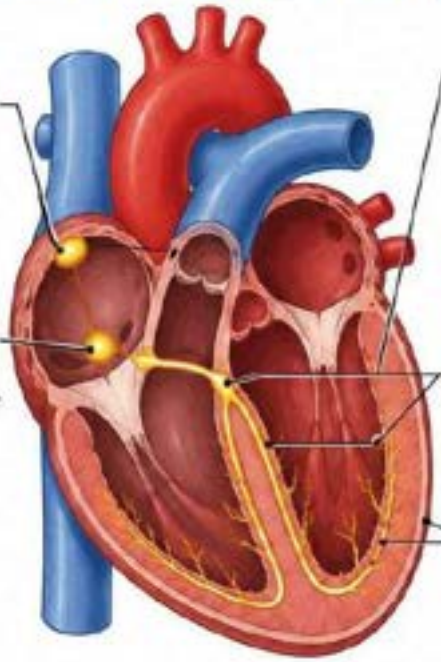
1. CARDIAC MUSCLES

- The entire heart is made of cardiac muscles.
- The walls of **ventricles** are much thicker than that of the **atria**.
- Cardiac muscles contract in a coordinated and rhythmic manner to pump blood efficiently.



Thick wall of ventricle | Thin wall of atrium

NODAL (CONDUCTION) SYSTEM OF THE HEART



Sino-atrial node (SAN)
Located in the right upper corner of the right atrium.

Atrio-ventricular node (AVN)
Located in the lower left corner of the right atrium, close to the atrio-ventricular septum.

Atrioventricular bundle (AV bundle)
A bundle of nodal fibres continues from AVN, passes through the atrio-ventricular septum to emerge on the top of the interventricular septum and immediately divides into right and left bundles.

Right & Left bundles
The AV bundle divides into right and left bundles on the interventricular septum.

Purkinje fibres
These branches give rise to minute fibres throughout the ventricular musculature of the respective sides called Purkinje fibres.

2. NODAL TISSUE

- A specialised cardiac musculature called nodal tissue is distributed in the heart.
- It forms the heart's electrical conduction system.
- Major components are shown in the diagram.

3. AUTOEXCITABILITY OF NODAL TISSUE

Nodal musculature has the ability to generate action potentials without any external stimuli, i.e., it is **autoexcitable**.

Part of Nodal System	Approx. Rate of Action Potentials Generated (per minute)
Sino-atrial node (SAN)	70–75 (maximum)
Atrio-ventricular node (AVN)	40–60
AV bundle	20–40
Purkinje fibres	15–30

The SAN can generate the maximum number of action potentials (70–75 min^{-1}) and is responsible for initiating and maintaining the rhythmic contractile activity of the heart.

Therefore, it is called the **PACEMAKER**.

4. HEART BEAT (NORMAL)

Our heart normally beats **70–75** times in a minute.

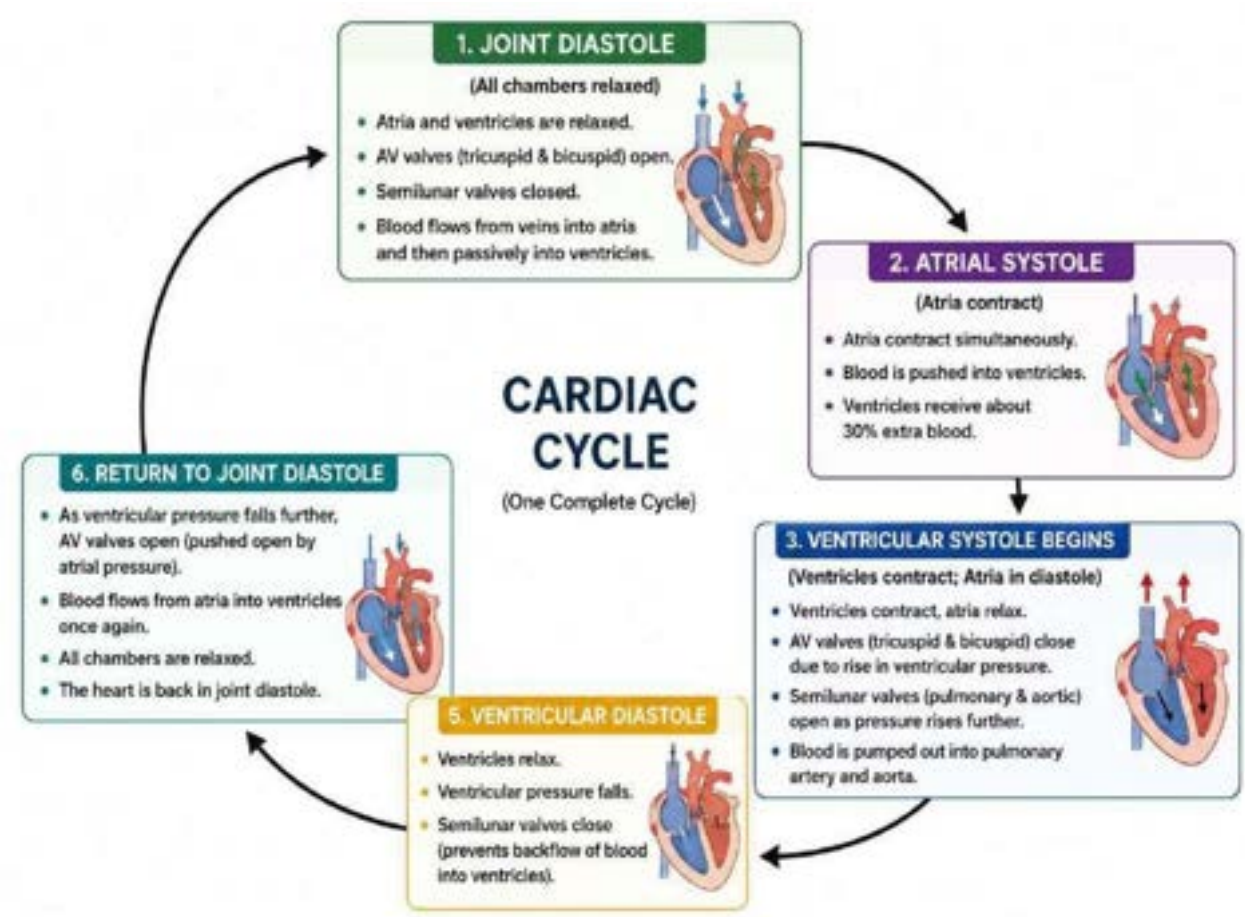
Average heart rate = **72** beats min^{-1}.

This rhythmic beating ensures efficient circulation of blood throughout the body.

Q.10. Trace the pathway from origin of heart beat and its conduction.

Q.11. Why SA node is called as natural pacemaker?

Cardiac cycle



Q.12. Assertion - The AV node delay the electrical impulse moving from the SA node and the atria to the ventricles.
Reason- The delay allows the atria to empty completely, filling ventricles fully before they contract.

- The heart beats 72 times per minute,i.e., that many cardiac cycles are performed per minute.
- The duration of a cardiac cycle is 0.8 seconds.
- During a cardiac cycle, each ventricle pumps out approximately 70 mL of blood which is called the stroke volume.
- The stroke volume multiplied by the heart rate (no. of beats per min.) gives the cardiac output.
- **Stroke volume (70 mL) X Heart rate (72) = Cardiac output (5000 mL i.e. 5 L)**
- During each cardiac cycle two prominent sounds are produced which can be easily heard through a stethoscope.
    - "lub" is associated with the closure of the tricuspid and bicuspid valves
    - "dub" is associated with the closure of the semilunar valves.

Q.13. Assertion - After exercising regularly for several months, our resting heart rate decreases, but our cardiac output at rest is unchanged.
Reason- The heart, like any other muscle, becomes stronger through regular exercise. The stronger heart would have a lesser stroke volume, which would allow for the decrease in heart rate.

ECG

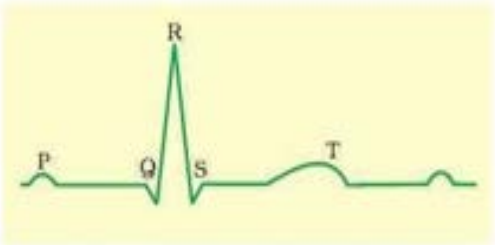
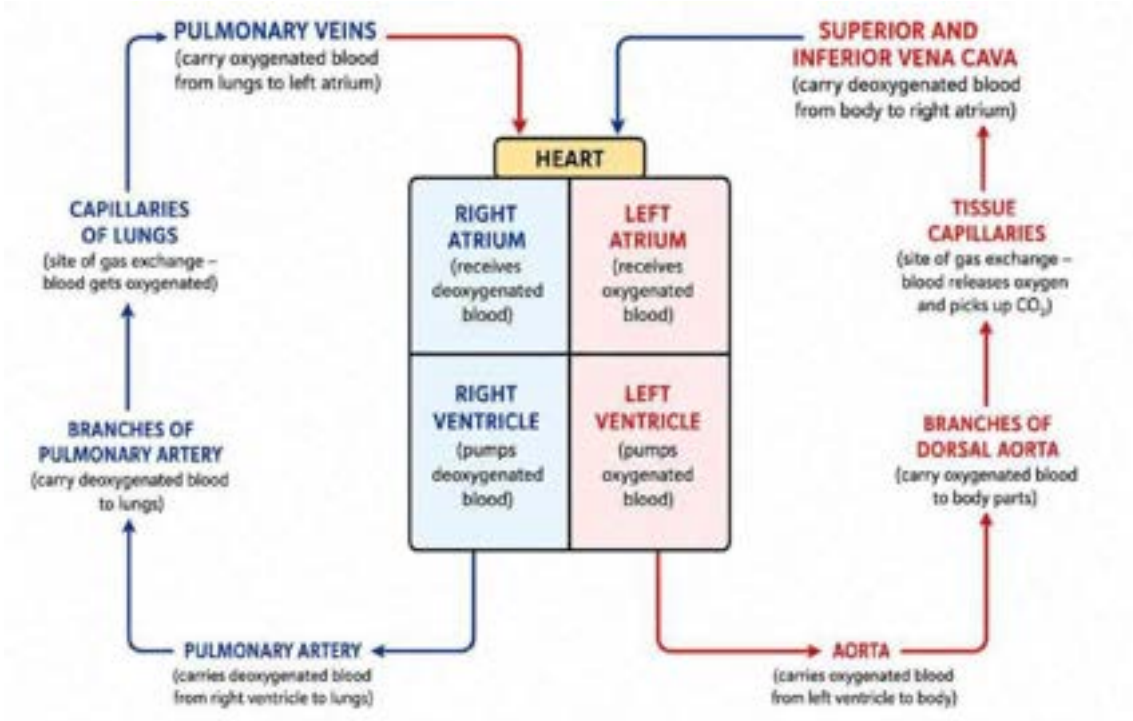


Figure 15.3 Diagrammatic presentation of a standard ECG

Electrocardiograph (ECG machine) is used to record an **electrocardiogram (ECG)**.
ECG is the graphical representation of the **electrical activity of the heart** during one cardiac cycle.
P-wave - Represents **depolarisation (electrical excitation) of atria**.
Leads to **contraction of both atria**.
QRS complex - Represents **depolarisation of ventricles**.
Initiates **ventricular contraction**. (Marks the **beginning of systole).**
T-wave- Represents **repolarisation of ventricles**.
Ventricles return from excited state to normal state.
End of T-wave marks the **end of systole**.
Heart rate can be determined by counting the number of **QRS complexes** in a given time.
Any deviation from the normal ECG pattern may indicate: **Heart abnormality** and **Cardiac disease**.
Therefore, ECG has **great clinical importance**.

Q.14. Which wave in the ECG is of clinical significance?

Double circulation



- Blood passes through the heart twice in each complete circuit round the body.
- Blood pumped by the right ventricle enters the pulmonary artery, whereas the left ventricle pumps blood into the aorta.
- **Pulmonary circulation** -deoxygenated blood pumped into the pulmonary artery is passed on to the lungs from where oxygenated blood is carried by the pulmonary veins into left atrium.
- **Systemic circulation** - oxygenated blood entering the aorta is carried by a network of arteries, arterioles and capillaries to tissues from where the deoxygenated blood is collected by a system of venules, veins and vena cava and emptied into right atrium.
- The systemic circulation provides nutrients, O2 and other essential substances to the tissues and takes CO2 and other harmful substances away for elimination.
- The hepatic portal vein carries blood from intestine to the liver before it is delivered to the systemic circulation.
- **Coronary circulation** - special coronary system of blood vessels is present in our body exclusively for the circulation of blood to and from the cardiac musculature.

Q.15. Which part of the human heart contains the most oxygenated blood?

Q.16. Why the systemic circulation is called the larger circulation?

Regulation of cardiac activity

Regulatory Factor	Source/Type	Effect on Heart Rate
Intrinsic Regulation (Myogenic activity)	Specialised nodal tissue of the heart	Maintains normal heartbeat automatically
Sympathetic Nervous System (ANS)	Neural signals from sympathetic nerves	Increases heart rate
Parasympathetic Nervous System (ANS)	Neural signals from parasympathetic nerves	Decreases heart rate
Adrenal Medullary Hormones	Hormones secreted by adrenal medulla	Increases heart rate

Disorders of circulatory system

Disorder	Definition/Meaning	Causes	Main Symptoms/Effects
High Blood Pressure (Hypertension)	Blood pressure higher than normal level (above 140/90 mm Hg) Normal BP = 120/80 mm Hg (120 = systolic pressure, 80 = diastolic pressure)	Increased pressure of blood in arteries	Can lead to heart diseases; affects brain and kidneys
Coronary Artery Disease (CAD)	Disease affecting arteries supplying blood to the heart muscle	Deposits of calcium, fat, cholesterol, and fibrous tissue causing narrowing of arteries (atherosclerosis)	Reduced blood flow to heart muscles
Angina (Angina Pectoris)	Acute chest pain due to insufficient oxygen supply to heart muscles	Conditions affecting blood flow to the heart	Severe chest pain
Heart Failure (Congestive Heart Failure)	Heart is unable to pump blood effectively to meet body needs	Weak pumping ability of heart	Congestion in lungs, poor blood circulation
Cardiac Arrest	Sudden stopping of heart beating	Electrical malfunction or severe heart conditions	Loss of heartbeat, unconsciousness, no blood circulation
Heart Attack (Myocardial Infarction)	Damage to heart muscle due to inadequate blood supply	Blockage in coronary arteries	Chest pain, breathlessness, sweating

Q.17. Which of the following is associated with the deposition of cholesterol and plaque in the lumen of arteries?

See answer of intext Questions at page No. 158 in the Question Bank QR under Test Your Knowledge

1. BODY FLUIDS

A. BLOOD

- Fluid connective tissue.
- Volume: ~7–8% of body weight (5–6 L).
- pH: 7.35–7.45 (Slightly alkaline).
- **Functions:**
  - Transport
  - Regulation
  - Protection

COMPOSITION OF BLOOD

(i) PLASMA (55%)

- Pale yellow fluid (90–92% water)
- **Proteins:** Albumin, Globulins, Fibrinogen
- **Other solutes:** Glucose, Amino acids, Lipids, Mineral ions, Hormones, Gases, Wastes, Vitamins, etc.

(ii) FORMED ELEMENTS (45%)

- **Erythrocytes (RBCs):**
  - Biconcave, anucleate
  - Contain haemoglobin
  - Carry O_2
- **Leukocytes (WBCs):**
  - Nucleated
  - Defence and immunity
- **Platelets (Thrombocytes):**
  - Cell fragments
  - Help in clotting

B. LYMPH

- Colourless fluid derived from tissue fluid.
- Contains water, salts, lymphocytes, fats.
- **Functions:**
  - Returns excess tissue fluid to blood
  - Absorbs fats from intestine
  - Defence (immunity)

C. TISSUE FLUID

- Formed by filtration of plasma from capillaries.
- Bathes tissue cells.
- **Functions:**
  - Exchange of materials between blood and cells
  - Maintains medium for cellular activities

2. CIRCULATORY SYSTEM – OVERVIEW

Closed, double circulation with heart as the pump and blood vessels as the conduits for blood flow.

HEART → Four-chambered muscular pump. (Right & Left atria and ventricles)

BLOOD VESSELS → Arteries → Arterioles → Capillaries → Venules → Veins

BLOOD → Transported throughout the body

3. THE HEART

LOCATION & PROTECTION

- In thoracic cavity between the lungs.
- Enclosed in a double-walled membrane – Pericardium.
- Pericardial fluid reduces friction.



CHAMBERS & VALVES

- Right atrium → Right ventricle (Tricuspid valve)
- Left atrium → Left ventricle (Bicuspid/Mitral valve)
- **Semilunar valves:** Pulmonary valve & Aortic valve Prevent backflow.

CARDIAC CYCLE (One heartbeat)

1. **Diastole (Relaxation):** All chambers relaxed; blood enters atria from veins.
2. **Atrial Systole:** Atria contract; blood flows into ventricles.
3. **Ventricular Systole:** Ventricles contract; blood pumped out to arteries.

Average heart rate: 72 times/min (at rest).

4. BLOOD VESSELS

ARTERIES

- Carry blood away from heart.
- Thick, elastic, muscular walls.
- No valves.
- High pressure, pulsatile flow.



VEINS

- Carry blood towards heart.
- Thin, less elastic walls.
- Have valves to prevent backflow.
- Low pressure, non-pulsatile flow.



CAPILLARIES

- Microscopic, one cell thick.
- Connect arterioles and venules.
- Site of exchange of gases, nutrients, wastes, etc.



5. DOUBLE CIRCULATION

(A) PULMONARY CIRCULATION

(Heart ↔ Lungs)

Right ventricle → Pulmonary artery → Lungs (Gas exchange) → Pulmonary veins → Left atrium

Function: Deoxygenated blood goes to lungs for oxygenation and returns oxygenated.

(B) SYSTEMIC CIRCULATION

(Heart ↔ Body Parts)

Left ventricle → Aorta (Arteries) → Body tissues (Exchange) → Venae cavae (Veins) → Right atrium

Function: Oxygenated blood goes to body tissues; deoxygenated blood returns to heart.

SIGNIFICANCE

- Continuous supply of O_2 and nutrients to cells.
- Removal of CO_2 and wastes.
- Transport of hormones.
- Helps in temperature regulation and pH balance.

6. REGULATION OF HEART RATE

Controlled by **Cardiac Centre** in medulla oblongata.

Sympathetic (Accelerator) Nerves

- Increase heart rate
- Release noradrenaline

↓

Heart rate ↑

Factors affecting heart rate

- Age
- Exercise
- Emotions
- Hormones
- Body temperature

Parasympathetic (Vagal) Nerves

- Decrease heart rate
- Release acetylcholine

↓

Heart rate ↓

7. BLOOD CLOTTING (COAGULATION)

Injury to blood vessel → Platelets break → Release clotting factors

→ **Fibrinogen** (plasma protein) converted to fibrin (by thrombin)

→ Fibrin threads form a mesh → Blood clot formed → Prevents blood loss.

Clot later dissolves by plasmin when healing occurs.

8. DISORDERS

- Hypertension: High blood pressure
- Atherosclerosis: Fatty deposits in arteries
- Coronary Heart Disease
- Anaemia: Deficiency of RBCs / Hb
- Haemophilia: Deficiency of clotting factor
- Thrombosis: Clot formation in vessels

Chapter-16: Excretory Products and their Elimination

Modes of excretion - ammonotelism, ureotelism, uricotelism; human excretory system – structure and function; urine formation, osmoregulation; regulation of kidney function - renin - angiotensin, atrial natriuretic factor, ADH and diabetes insipidus; role of other organs in excretion; disorders - uremia, renal failure, renal calculi, nephritis; dialysis and artificial kidney, kidney transplant.

Excretory products:

Products (like- ammonia, urea, uric acid, carbon dioxide, water and ions like Na^+, K^+, Cl^-, phosphate, sulphate, etc.) get accumulated in animals either due to metabolic reactions or by other means and need to be eliminated totally or partially from the body, as they may prove harmful for the body.

Nitrogenous excretory wastes:

Excretion:The process of removal of waste products from the body is called as excretion.

Excretion

ON THE BASIS OF TYPE OF EXCRETORY PRODUCTS

Ammonotelism

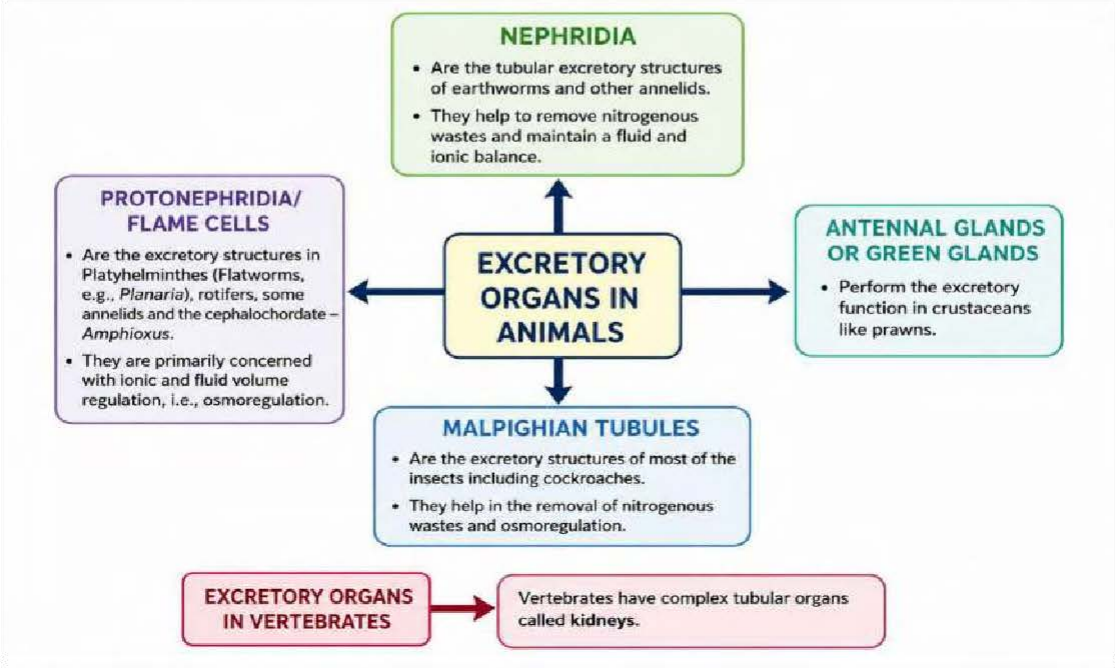
- Excretion of ammonia.
- Bony fishes,aquatic amphibians and aquatic insects.

Ureotelism

- Excretion of urea.
- Mammals, many terrestrial amphibians and marine fishes mainly excrete urea.

Uricotelism Excretion of Uric acid.

Reptiles, birds, land snails and insects excrete nitrogenous wastes as uric acid in the form of pellet or paste with a minimum loss of water.



Human Excretory System

- In humans, the excretory system consists of – kidneys (one pair),- ureters(one pair) ,a urinary bladder and a urethra

Kidneys are reddish brown, bean shaped structures situated between the levels of last thoracic and third lumbar vertebra close to dorsal inner wall of abdominal cavity.

Each kidney of an adult human measures 10-12 cm in length, 5-7 cm in width, 2- 3 cm in thickness with an average weight of 120- 170 g.

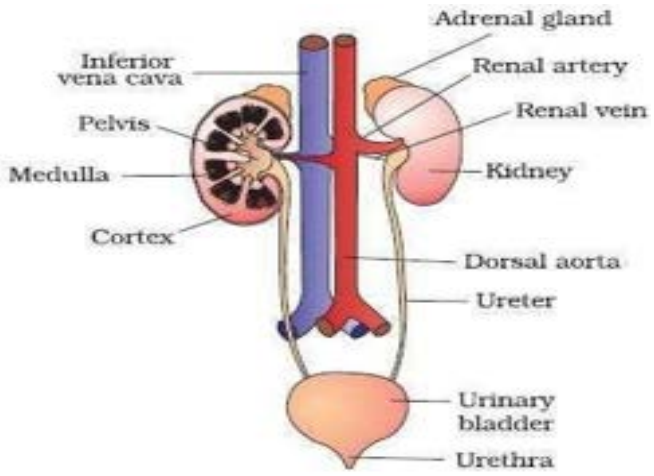


Figure 19.1 Human Urinary system

Internal Structure of Kidney

Hilum – a is a notch towards the centre of inner concave surface of kidney. Through it ureter, blood vessels and nerves enter.

Renal pelvis- a broad funnel shaped space inner to hilum.

Calyces- are projections in the renal pelvis called calyces.

Capsule - is a tough outer layer of kidney. **Cortex-** There are two zones inside the kidney. The outer zone is called cortex .

Medulla - The inner zone inside the kidney is called medulla.

Medullary pyramids- are conical masses in medulla which project into the calyces (sing.:calyx).

Columns of Bertini - The cortex extends in between the medullary pyramids as renal columns called **Columns of Bertini.**

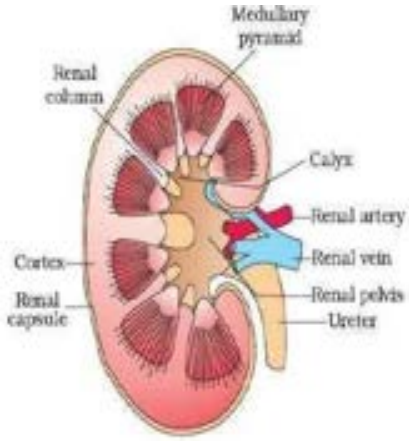


Figure 19.2 Longitudinal section (Diagrammatic) of Kidney

Q.1. Draw a Label the diagram of longitudinal section of Kidney

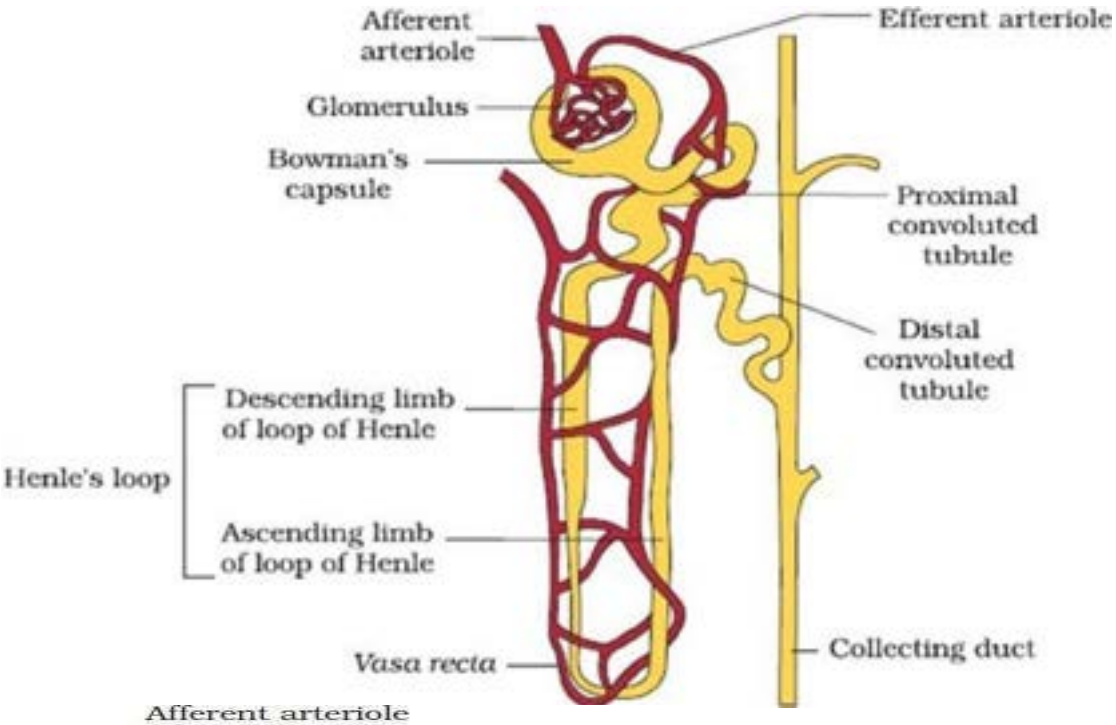
Q.2. Differentiate between ammonotelism , Ureotelism and Uricotelism.

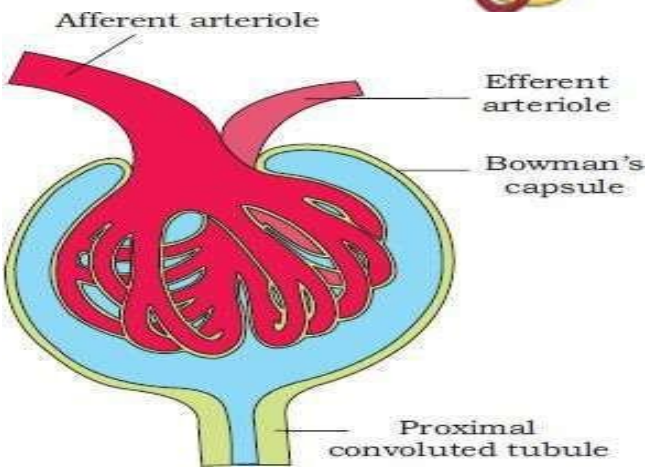
Q.3. What is the excretory organ of Planaria.

Nephrons – Cortical nephrons - the nephrons (majority) in which, the loop of Henle is too short and extends only very little into the medulla.

Juxta medullary nephrons- the nephrons (some) in which the loop of Henle is very long and runs deep into the medulla.

CORTICAL	JUXTA MEDULLARY
Glomeruli are in the outer cortex.	Glomeruli are close to inner margin of the cortex.
Short loops of Henle.	Long loops of Henle
Henle's loops extend only to a short distance in the medulla.	Henle's loops are found deeper in the medulla.
Vasa rectae are absent.	Vasa rectae are present
They are more common (85%)	They are less common (15%)





complex tubular structures, which form the structural and functional units of kidney.

- Each kidney has nearly one million **nephrons.**
- Each nephron has two parts – the **glomerulus** and the **renal tubule**.
- **Afferent arteriole -** a fine branch of renal artery entering Bowmen's capsule carrying blood to the glomerulus.

Glomerulus - a tuft of capillaries formed by the afferent.

Efferent arteriole- Blood from the glomerulus is carried away by an efferent arteriole.

Bowman's capsule - renal tubule begins with a double walled cup-like structure called **Bowman's capsule**, which encloses the glomerulus.

Malpighian body or Renal corpuscle- Glomerulus along with Bowman's capsule.

Proximal convoluted tubule (PCT) **-** The renal tubule continues further to form a highly coiled network – **proximal convoluted tubule** (PCT).

Henle's loop - A hairpin shaped, next part of the tubule which has a descending and an ascending limb.

Distal convoluted tubule (DCT) – The ascending limb continues as another highly coiled tubular region called **distal convoluted tubule** (DCT).

Collecting duct- a long, straight tube which extends from cortex of the kidney to the inner parts of medulla and DCTs of many nephrons open into it.

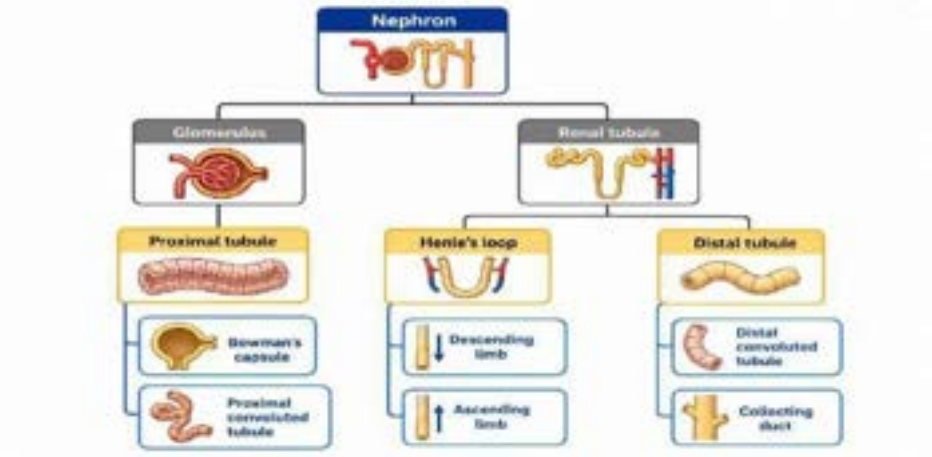
Renal pelvis - many collecting ducts converge and open into the renal pelvis through medullary pyramids in the calyces.

Malpighian corpuscle, PCT and DCT of the nephron are situated in the cortical region of the kidney whereas the loop of Henle dips into the medulla.

Peritubular capillaries- The efferent arteriole emerging from the glomerulus forms a fine capillary network around the renal tubule called the peritubular capillaries.

Vasa recta - A minute vessel of peritubular capillary network runs parallel to the Henle's loop forming a 'U' shaped *vasa recta*.

- *Vasa recta* is absent or highly reduced in cortical nephrons.



Q.4. The parts of a nephron are highly organized and divided between the cortical and medullary regions of the human kidney.

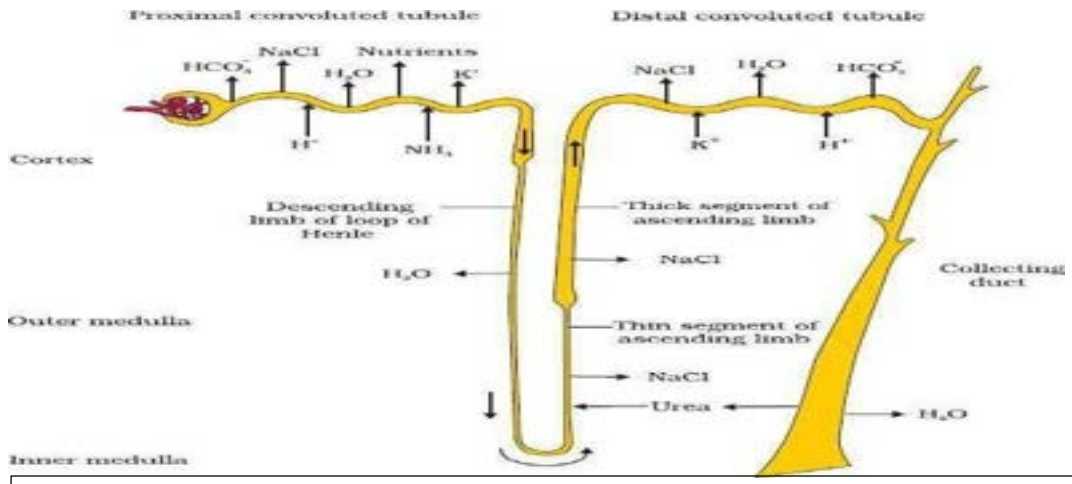
1. **Name the two components that collectively form the Malpighian body (or Renal corpuscle).**
2. **Based on your notes, list the two highly coiled tubular regions of the nephron that are strictly situated within the cortical region of the kidney.**
3. **Where do the distal convoluted tubules (DCTs) of many different nephrons eventually open into?**

Urine formation

- It involves three main processes which takes place in different parts of the nephron -
    1) Glomerular filtration
    2) Reabsorption and
    3) Secretion

1) Glomerular filtration / ultra filtration

- First step in urine formation, is the filtration of blood, which is carried out by the glomerulus and is called **glomerular filtration**.
- On an average,1100-1200 ml of blood is filtered by kidneys per minute which constitute roughly 1/5th of the blood pumped out by each ventricle of the heart per minute.
- The glomerular capillary blood pressure causes filtration of blood through 3 layers, i.e., the endothelium of glomerular blood vessels, the
- epithelium of Bowman's capsule and a basement membrane between these two layers.
- **Podocytes**– are epithelial cells of Bowman's capsule which are arranged in an intricate manner so as to leave some minute spaces called filtration slits or slit pores.
- **Ultra filtration** - Blood is filtered so finely through these membranes, that almost all the constituents of the plasma except the proteins pass onto the lumen of the Bowman's capsule. Hence, considered as a process of **ultra filtration.**
- **Glomerular filtration rate** (GFR) -The amount of the filtrate formed by the kidneys per minute.
- GFR in a healthy individual is approximately 125 ml/minute, i.e., 180 litres per day.
- **Regulation of glomerular filtration rate -** The kidneys have built-in mechanisms for regulation of glomerular filtration rate.



Q.5. The process of urine formation is vital for maintaining the body's ionic and fluid balance and involves three sequential steps.

(a) Name the three main processes involved in urine formation. (1 Mark)

(b) Explain why glomerular filtration is specifically referred to as "ultrafiltration". (1 Mark)

(c) A large amount of fluid (nearly 180 liters per day) is filtered by the human glomueruli, yet a healthy adult passes only about 1.5 liters of urine daily. Account for this significant volume difference by naming the renal process responsible. (1 Mark)

By juxta glomerular apparatus (JGA) –

- is a special sensitive region formed by cellular modifications in the distal convoluted tubule and the afferent arteriole at the location of their contact.
- efficient mechanism of regulation of GFR.
- A fall in GFR activates the JG cells to release **renin** which can stimulate the glomerular blood flow and thereby the GFR back to normal.

2) Reabsorption

- **Reabsorption-**is the process in which nearly 99 per cent of the filtrate has to be reabsorbed by the renal tubules.
- **Tubular epithelial cells-** present in different segments of nephron perform this either by **active or passive mechanisms**.
- **Active mechanism** – When the substances are absorbed against their concentration gradient by the expenditure of energy.
- Substances like glucose, amino acids, Na+, etc., in the filtrate are reabsorbed actively.
- **Passive mechanism -** When the substances are absorbed along their concentration gradient. Their is no expenditure of energy.
- The nitrogenous wastes are absorbed by passive transport. -
- Reabsorption of water also occurs passively in the initial segments of the nephron .

3) Tubular secretion

- During urine formation, the tubular cells secrete substances like H^+, K^+ and ammonia into the filtrate.
- an important step in urine formation as it helps in the maintenance of ionic and acid base balance of body fluids.

FUNCTION OF THE TUBULES

Proximal Convoluted Tubule (PCT):

- **Reabsorption**- PCT is lined by simple cuboidal brush border epithelium which increases the surface area for reabsorption.
- Nearly all essential nutrients, and 70-80 per cent of electrolytes and water are reabsorbed by this segment.
- **Maintenance of pH and ionic balance of body fluids-** by selective secretion of hydrogen ions, ammonia and potassium ions into the filtrate and by absorption of $HCO3^-$ from it.

Henle's Loop:

- Reabsorption in this segment is minimum.
- **Maintenance of high osmolarity of medullary interstitial fluid** this region plays a significant role in it.
- The **descending limb of loop of Henle is permeable to water but almost impermeable to electrolytes**.
- This concentrates the filtrate as it moves down.
- The **ascending limb is impermeable to water but allows transport of electrolytes actively or passively**. Therefore, as the concentrated filtrate pass upward, it gets diluted due to the passage of electrolytes to the medullary fluid.

Distal Convoluted Tubule (DCT):

- **Conditional reabsorption of Na^+ and water** takes place in this segment.
- **Reabsorption of $HCO3^-$**.
- **Maintenance the pH and sodium-potassium balance in blood** by selective secretion of hydrogen and potassium ions and NH3. **Collecting Duct:**
- Long duct, extends from the cortex of the kidney to the inner parts of the medulla.

Concentration of urine - Large amounts of water is reabsorbed from this region to produce a concentrated urine.

- **Maintenance of osmolarity**- It allows passage of small amounts of urea into the medullary interstitium to keep up the osmolarity.
- **Maintenance of pH and ionic balance of blood** - by the selective secretion of H^+ and K^+ ions.

- This mechanism helps to maintain a concentration gradient in the medullary interstitium.
- Presence of such interstitial gradient helps in an easy passage of water from the collecting tubule thereby concentrating the filtrate (urine).
- Human kidneys can produce urine nearly four times concentrated than the initial filtrate formed.

Q:6. The process of urine formation is a highly coordinated physiological phenomenon occurring across different segments of a nephron.
(a) Identify the specific segment of the nephron where ultrafiltration takes place, and name the unique cell type that forms the filtration slits.
(b) The daily glomerular filtrate formed is about 180 liters, but the volume of urine released is only around 1.5 liters. Name the process responsible for this massive volume reduction, and state which epithelial modification in the Proximal Convoluted Tubule (PCT) maximizes its efficiency.
(c) Tubular secretion is considered a crucial step in urine formation. Justify this statement by explaining its primary function in maintaining body homeostatic balance.

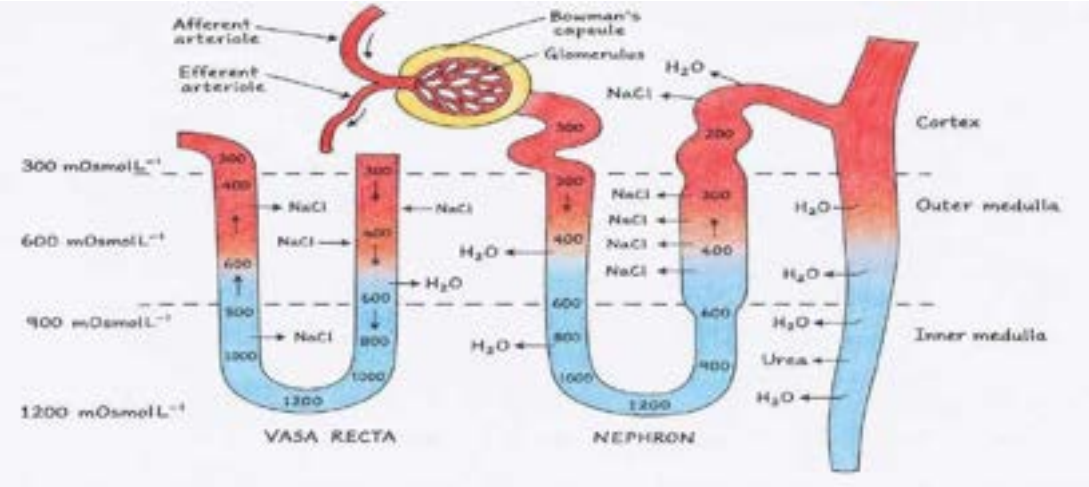
Q:7. The counter-current mechanism in the kidney is essential for the concentration of filtrate and the conservation of body water.
(a) Identify the two distinct U-shaped tubular/vascular structures in the kidney that run parallel to each other and interact to maintain this mechanism.
(b) The diagram below represents the directional flow of fluid within the loop of Henle and blood within the vasa recta:

Fluid Flow in Loop of Henle:		Blood Flow in Vasa Recta:	
[Descending] -> [Ascending]		[Descending] -> [Ascending]	
(↓)	(↑)	(↓)	(↑)

Explain why the flow of fluid/blood in these structures is described as "counter-current."
(c) If a physiological inhibitor completely halts the active transport of sodium chloride out of the thick ascending limb of Henle's loop, what will be the immediate effect on the osmolarity of the medullary interstitium?

Mechanism of concentration of the filtrate /Counter current mechanism:

- Mammals produce **concentrated urine**.
- The **Henle's loop** and ***vasa recta*** play a significant role in this.
- **Counter current** - Flow of filtrate in the two limbs of Henle's loop is in opposite directions and thus forms a counter current.
  The flow of blood through the two limbs of *vasa recta* is also in a counter current pattern.
- The proximity between the Henle's loop and *vasa recta*, as well as the counter current in them help in maintaining an increasing osmolarity towards the inner medullary interstitium, i.e., from 300 $mOsmolL^{-1}$ in the cortex to about 1200 $mOsmolL^{-1}$ in the inner medulla.
- This gradient is mainly caused by **NaCl** and **urea.**

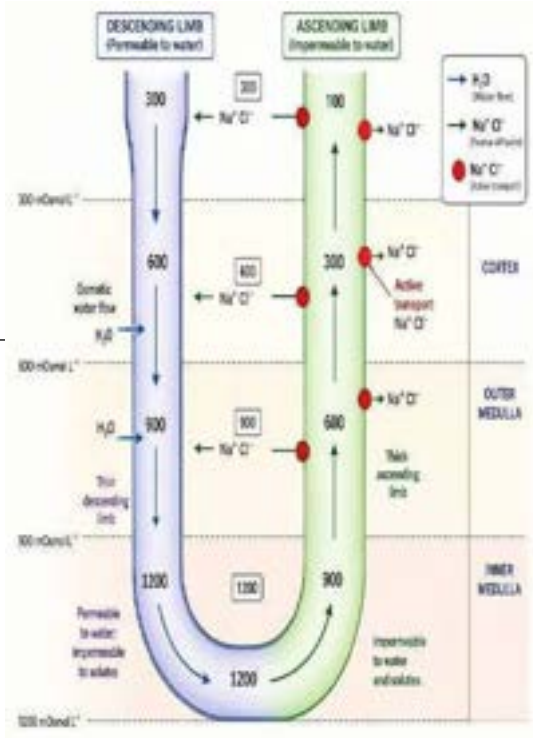


Counter current mechanism

NaCl is transported by the ascending limb of Henle's loop which is exchanged with the descending limb of *vasa recta*.

NaCl is returned to the interstitium by the ascending portion of *vasa recta*. Similarly, small amounts of urea enter the thin segment of the ascending limb of Henle's loop which is transported back to the interstitium by the collecting tubule.

This transport of substances facilitated by the special arrangement of Henle's loop and *vasa recta* is called the **counter current mechanism.**



Regulation of kidney function

- The hypothalamus, JGA and the heart efficiently regulate the functioning of kidneys
- Osmoreceptors in the body are activated by changes in blood volume, body fluid volume and ionic concentration.
- **Hypothalamus**

– Excessive loss of fluid from the body activates these receptors which stimulate hypothalamus to release **antidiuretic hormone (ADH) or vasopressin** from **neurohypophysis**.

– ADH facilitates water reabsorption from DCT thereby preventing diuresis (excessive loss of water from the body).

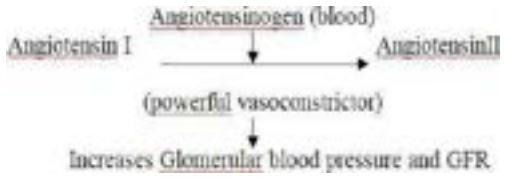
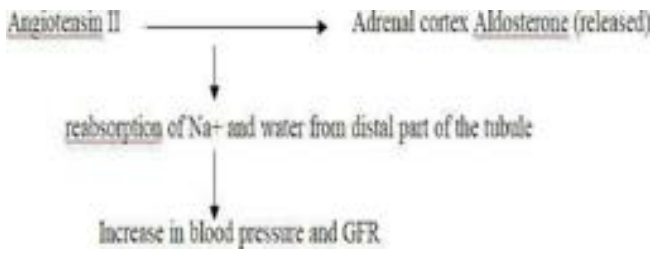
– **Increase in body fluid volume** can switch off the osmoreceptors and suppress the ADH release thus retaining the required water in the body.

– ADH constrics blood vessels causing an increase in blood pressurewhich increases the glomerular blood flow and thereby the GFR.

- **JGA (Juxtaglomerular apparatus) and Renin-Angiotensin mechanism**

– A fall in glomerular blood flow / glomerular blood pressure/GFR - activates JG cells to release **rennin.**

RAAS Mechanism

Effect of Renin	Effect of Aldosterone
	

- **Heart**

– Increase in blood flow to atria of heart causes release of **Atrial Natriuretic Factor** (ANF).

– ANF causes vasodilation (dilation of blood vessels) and thereby decreases blood pressure.

– ANF mechanism acts as a check on the renin-angiotensin mechanism.

Q.8. Imagine a scenario where an athlete chugs a large amount of water immediately after a race, causing a rapid expansion of their total body fluid and blood volume.
(a) How will this sudden increase in fluid volume impact the osmoreceptors in the body and the subsequent release of ADH from the neurohypophysis? (1 Mark)
(b) Because of the increased blood volume, the blood flow to the atria of the heart rises sharply. Name the specific factor released by the heart walls in response to this stretch. (1 Mark)
(c) Why is the cardiac regulatory mechanism described as a "check" or a safety valve on the Renin-Angiotensin mechanism? Contrast their final impact on blood pressure. (1 Mark)

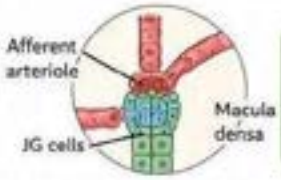
RAAS Mechanism of Regulation in Kidney

(Renin–Angiotensin–Aldosterone System)



1. Trigger (Fall in Blood Pressure / ↓ Effective Blood Volume)

- Low blood pressure
- Low Na^+ in distal tubule (macula densa)
- Sympathetic stimulation (β_1-adrenergic)



2. Renin Release

Juxtaglomerular cells of afferent arteriole release renin into blood.

3. Angiotensinogen to Angiotensin I

Renin converts liver-derived angiotensinogen to angiotensin I.



4. Angiotensin I to Angiotensin II

Angiotensin I is converted to angiotensin II by ACE (Angiotensin Converting Enzyme) mainly in lungs.



5. Actions of Angiotensin II

Vasoconstriction



- Constricts arterioles
- ↑ Peripheral resistance
- ↑ Blood pressure

Stimulation of Aldosterone Secretion



From adrenal cortex (zona glomerulosa)

Increase in ADH Secretion



From posterior pituitary

Increase in Thirst (Hypothalamus)



Leads to increased water intake

Increase in Proximal Tubule Na^+ Reabsorption



Direct effect on proximal tubules

6. Actions of Aldosterone (on DCT & Collecting Duct)



- ↑ Na^+ reabsorption
- ↑ Water reabsorption (indirectly)
- ↑ K^+ and H^+ secretion

7. Net Result

- ↑ Blood volume
- ↑ Blood pressure
- Restoration of fluid and electrolyte balance

8. Negative Feedback

Rise in blood pressure and blood volume inhibits renin release.

Abbreviations:

RAAS – Renin Angiotensin Aldosterone System
ACE – Angiotensin Converting Enzyme
ADH – Antidiuretic Hormone
DCT – Distal Convoluted Tubule

MICTURITION

Urine formed gets stored in urinary bladder till a voluntary signal is given by the central nervous system (CNS) for contraction of smooth muscles of bladderand simultaneous relaxation of the urethral sphincter causing the release of urine character.
Role of other organs in excretion:

- Lungs - remove large amounts of CO2 (18 litres/day) and also significant quantities of water every day.
- Liver- secretes bile-containing substances like bilirubin, biliverdin, cholesterol, degraded steroid hormones, vitamins and drugs. Most of these substances ultimately pass out along with digestive wastes.

Sweat	Sebum
Secreted by Sweat glands.	Secreted by sebaceous glands.
Sweat is a watery fluid containing NaCl, small amounts of urea, lactic acid, etc.	It is an oily secretion composed of complex mixture of lipids having triglycerides, free fatty acids, cholesterol and its esters.
It cools body surface and Helps in the removal of some wastes	It lubricates the hair and prevents wetting of hair and drying up of skin.

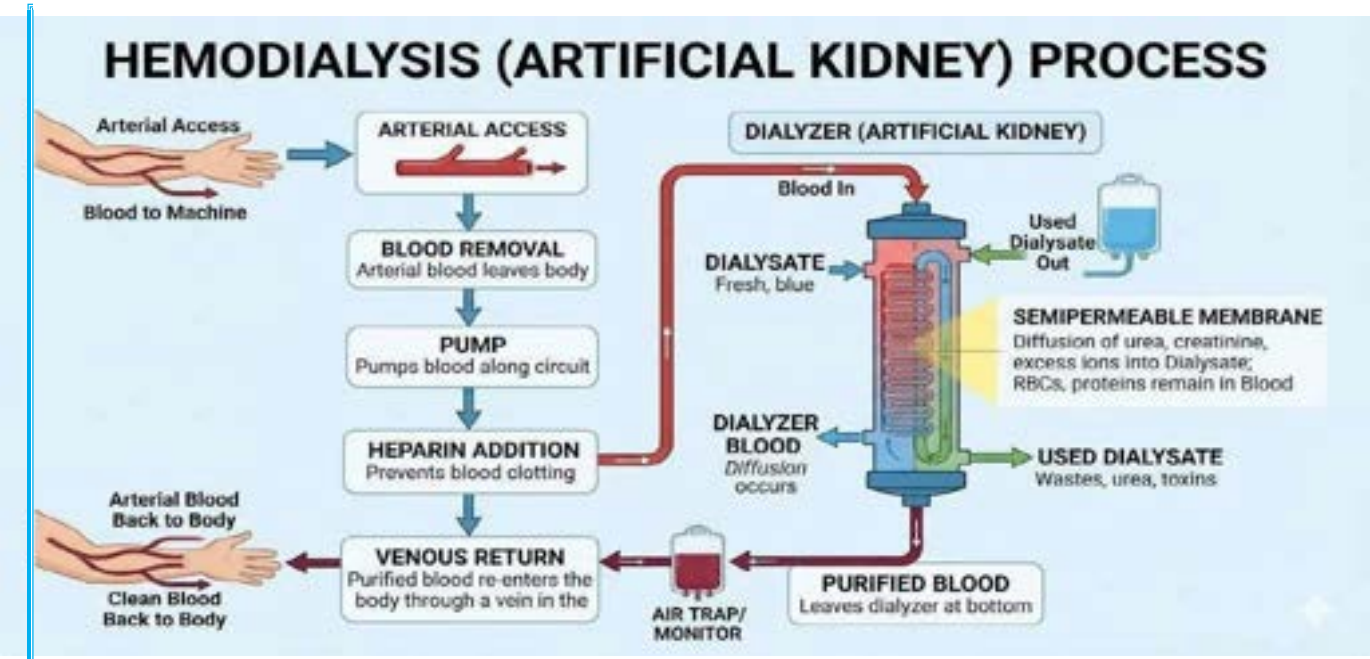
Disorders of the excretory system

- **Uremia** - Malfunctioning of kidneys leading to accumulation of urea in blood and may lead to kidney failure.
- In such patients, urea can be removed by a process called **hemodialysis**.

- - Blood drained from a convenient artery is pumped into a dialysing unit after adding an anticoagulant (heparin).
- The unit contains a coiled cellophane tube surrounded by a fluid (dialysing fluid)having the same composition as that of plasma except the nitrogenous wastes.

– The porous cellophane membrane of the tube allows the passage of molecules based on concentration gradient.

– As nitrogenous wastes are absent in the dialysing fluid, these substances freely move out, thereby clearing the blood. The cleared blood is pumped back to the body through a vein after adding anti- heparin to it.



- **Kidney transplantation** - ultimate method in the correction of acute **renal failures** (kidney failure).

– A functioning kidney is used in transplantation from a donor, preferably a close relative, to minimise its chances of rejection by the immune system of the host.

- **Renal calculi:** Stone or insoluble mass of crystallised salts (oxalates, etc.) formed within the kidney.
- **Glomerulonephritis:** Inflammation of glomeruli of kidney.

- **An adult human excretes, on an average, 1 to 1.5 litres of urine per day.**
- **The urine formed is a light yellow coloured watery fluid which is slightly acidic (pH-6.0) and has a characteristic odour. On an average, 25-30 gm of urea is excreted out per day. Various conditions can affect the characteristics of urine.**
- **Analysis of urine helps in clinical diagnosis of many metabolic disorders as well as malfunctioning of the kidney.**
- **For example, presence of glucose (Glycosuria) and ketone bodies (Ketonuria) in urine are indicative of diabetes mellitus (due to lack of insulin secretion from Pancreas).**

Q:9.A 52-year-old patient is diagnosed with chronic uremia resulting from severe renal failure. The doctor recommends immediate clinical intervention to filter the patient's blood artificially.
(a) Define uremia based on the composition of the patient's blood.
(b) Name the medical process or apparatus used to treat this condition, and identify the key nitrogenous waste that is removed from the patient's blood during this procedure.
(c) Explain the functional principle of this artificial process. Why does the waste move from the patient's blood into the dialyzing fluid without the loss of essential plasma proteins?

See answer of intext Questions at page No. 158 in the Question Bank QR under Test Your Knowledge

EXCRETION IN HUMAN BEING

Class 11 – NCERT

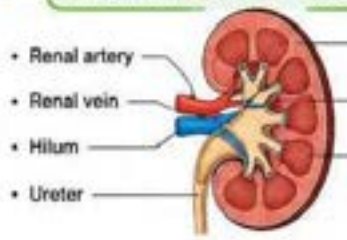
1. INTRODUCTION

- Excretion is the process of removal of metabolic wastes produced in the body.
- Essential for maintaining internal balance (homeostasis).
- Wastes are toxic and must be removed regularly.

2. EXCRETORY ORGANS IN HUMAN BEINGS

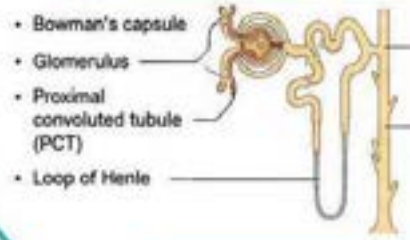
- Kidneys
- A pair of ureters
- Urinary bladder
- Urethra

3. HUMAN KIDNEY – STRUCTURE



- Pair of bean-shaped organs located in the abdominal cavity.
- Each kidney has about 1 to 1.5 million nephrons (functional units).
- Main parts:
  - Renal cortex
  - Renal medulla
  - Renal pelvis

4. NEPHRON – STRUCTURAL AND FUNCTIONAL UNIT



- Each kidney contains about 1–1.5 million nephrons.
- Site of urine formation.
- Two main parts:
  - Renal corpuscle (Bowman's capsule + Glomerulus)
  - Renal tubule (PCT, Loop of Henle, DCT, Collecting duct)

5. FORMATION OF URINE

Urine is formed in three main steps in the nephron:

1. **Ultrafiltration** – Filtration of blood in glomerulus to form glomerular filtrate (in Bowman's capsule).
2. **Selective reabsorption** – Useful substances (glucose, amino acids, water, salts, etc.) are reabsorbed back into blood.
3. **Tubular secretion** – Some wastes and excess ions are secreted from blood into the tubule.

Final product (urine) contains urea, uric acid, creatinine, excess salts and water.

6. TRANSPORTATION AND STORAGE OF URINE

Urine formed in collecting ducts
↓
Passes into renal pelvis
↓
Goes to ureter
↓
Stored in urinary bladder
↓
Expelled out through urethra

7. COMPOSITION OF URINE

- 95% water
- 2.5% urea
- 1.5% other substances (uric acid, creatinine, excess salts, pigments, etc.)

8. REGULATION OF KIDNEY FUNCTION

- Regulated by:
  - Nervous system (via autonomic nerves)
  - Hormones:
    - ADH (vasopressin) – Increases water reabsorption.
    - Aldosterone – Increases Na^+ reabsorption and K^+ secretion.
    - ANP – Decreases Na^+ reabsorption.
- Helps in maintaining water, salt balance and blood pressure.

9. SIGNIFICANCE OF EXCRETION

- Removes toxic metabolic wastes.
- Maintains water, salt and electrolyte balance.
- Helps in regulation of blood pH and volume.
- Maintains homeostasis.

CHAPTER 17- LOCOMOTION & MOVEMENT

CBSE Syllabus2026-27 Types of movement - ciliary, flagellar, muscular; skeletal muscle, contractile proteins and muscle contraction; skeletal system and its functions; joints; disorders of muscular and skeletal systems - myasthenia gravis, tetany, muscular dystrophy, arthritis, osteoporosis, gout.

- **Movement:** movement refers to any change in the position or posture of a living organism or its body parts.
- **Locomotion:** locomotion specifically refers to the movement that allows an organism to change its position or move from one place to another.
- **Type of Movements:**

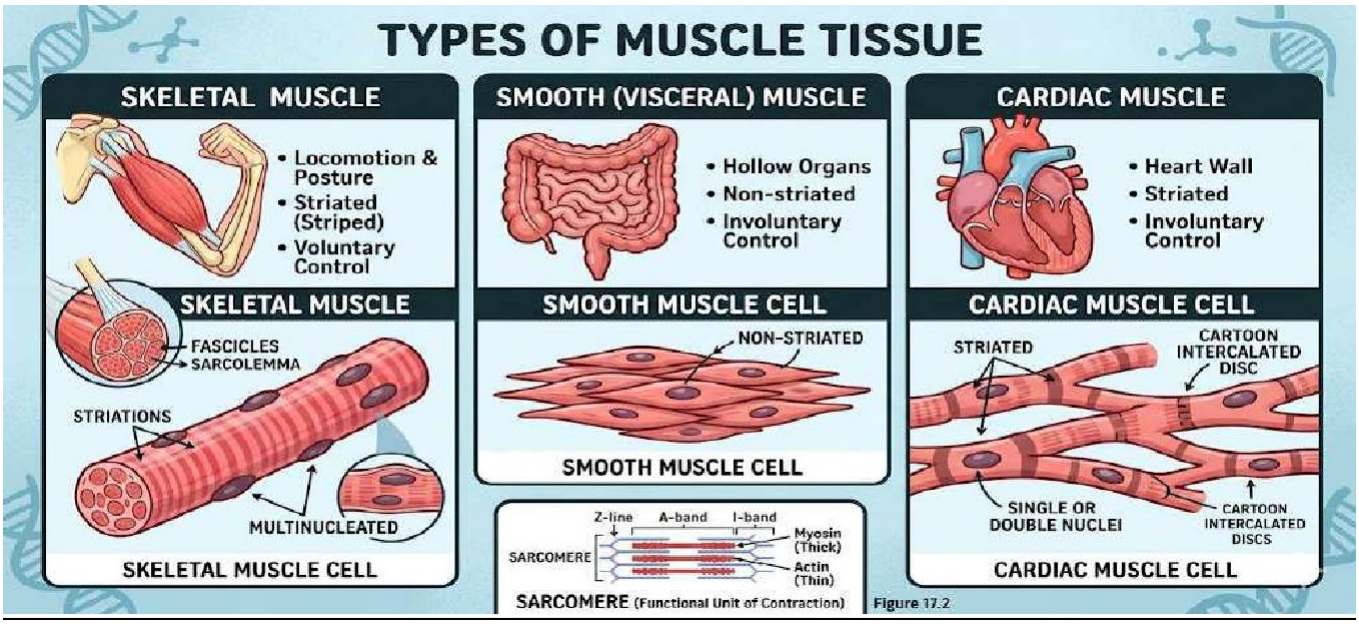
Type of Movement	Occurrence/Examples	Main Features	Functions
Amoeboid Movement	Amoeba, macrophages, leucocytes	Caused by streaming of protoplasm; pseudopodia and microfilaments involved	Helps in movement and engulfing particles
Ciliary Movement	Ciliated epithelium of trachea and female reproductive tract	Produced by coordinated beating of cilia	Removes dust from trachea; helps movement of ovum
Muscular Movement	Limbs and body parts	Depends on coordination of muscular, skeletal and nervous systems	Helps in locomotion and body movements

Muscles

- Origin: Muscle is a specialized tissue of mesodermal embryonic origin.
- Body Weight: Accounts for about 40–50% of an adult human's body weight.
- Key Properties: Exhibits four unique properties:
  - *Excitability* (ability to respond to a stimulus)
  - *Contractility* (ability to shorten/contract)
  - *Extensibility* (ability to be stretched)
  - *Elasticity* (ability to return to original shape)

Feature	Skeletal Muscle	Visceral (Smooth) Muscle	Cardiac Muscle
Location	Closely associated with the skeletal components of the body.	Found in the inner walls of hollow visceral organs (e.g., alimentary canal, reproductive tract).	Exclusively located in the wall of the heart.

Appearance	Striped / Striated under the microscope.	Non-striated and smooth in appearance.	Striated with cells arranged in a unique branching pattern.
Regulation	Voluntary (under direct control of the central nervous system).	Involuntary (not under voluntary control of the nervous system).	Involuntary (the nervous system does not control activities directly).
Primary Functions	Locomotion and changes in body posture.	Assists in internal transportation (e.g., food through the digestive tract, gametes through the genital tract).	Rhythmic pumping of blood throughout the body.

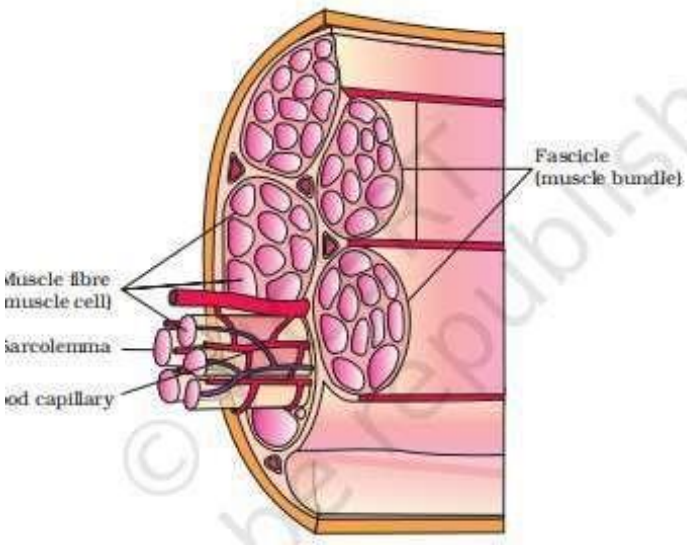


Questions

Q1. Differentiate between skeletal, smooth and cardiac muscles on the basis of structure, location and function.

Q2. Why are skeletal muscles called voluntary muscles while smooth and cardiac muscles are called involuntary muscles?

Q3. Explain how smooth muscles and cardiac muscles are adapted to perform their specific functions in the body.



Structure of a Skeletal Muscle

1. **Fascia**: The tough outer layer connecting all muscle bundles.

2. **Fascicles:** The individual muscle bundles inside.

3. **Sarcolemma:** The outer plasma membrane of a muscle cell/fibre.

4. **Sarcoplasm**: The muscle cell cytoplasm containing multiple nuclei.

5 **Sarcoplasmic Reticulum**: The internal storage house for Calcium ions

3. **Myofibrils:** Parallel internal filaments that create the light and dark stripes.

Questions

Q4. What is fascia and what is its function in skeletal muscle?

Q5. Name the cell membrane and cytoplasm of a muscle fibre.

Q6.What is the role of sarcoplasmic reticulum and myofibrils in muscle fibres?

Anatomy of a Myofibril (The Sarcomere)

The striated appearance of a myofibril is due to the distribution of two major proteins: Actin and Myosin.

- **I-Band (Isotropic band):**
  - The light band containing the thin protein Actin.
  - Bisected in the middle by an elastic fiber called the Z-line, to which actin filaments are firmly attached.
- **A-Band (Anisotropic band):**
  - The dark band containing the thick protein Myosin.
  - Held together in the exact middle by a thin fibrous membrane called the M-line.
- **Sarcomere:**
  - **T**he functional unit of muscle contraction.
  - Defined as the portion of the myofibril located between two successive Z-lines.
- **H-Zone:**
  - The central, lighter part of the thick A-band that is not overlapped by thin actin filaments when the muscle is at rest.

Structure of Contractile Proteins

1. Actin (Thin Filament)

- F-Actin: Two long, twisted chains made of tiny round beads called G-actin.
- Tropomyosin: Two long threads that wrap around the actin chains.
  - Troponin: Small protein locks placed along the tropomyosin threads. In a resting muscle, they cover up the spots where myosin needs to grab.

2. Myosin (Thick Filament)

- Structure: A bundle made of many individual units called meromyosins (which look like golf clubs).
- Heavy Meromyosin (HMM): The "head" and "short arm" that stick out to form a cross-arm.
  - The head acts as an ATPase enzyme to break down energy (ATP).
  - It has specific spots to bind with ATP and actin.
- **Light Meromyosin (LMM):** The straight "tail" part of the monomer**.**

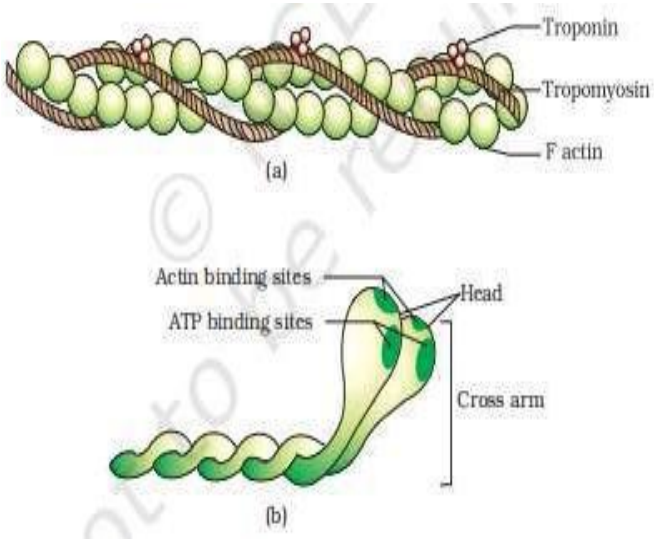


Figure 17.3 (a) An actin (thin) filament (b) Myosin monomer (Meromyosin)

Questions

Q.7 What are the two regulatory proteins found on a thin (actin) filament?

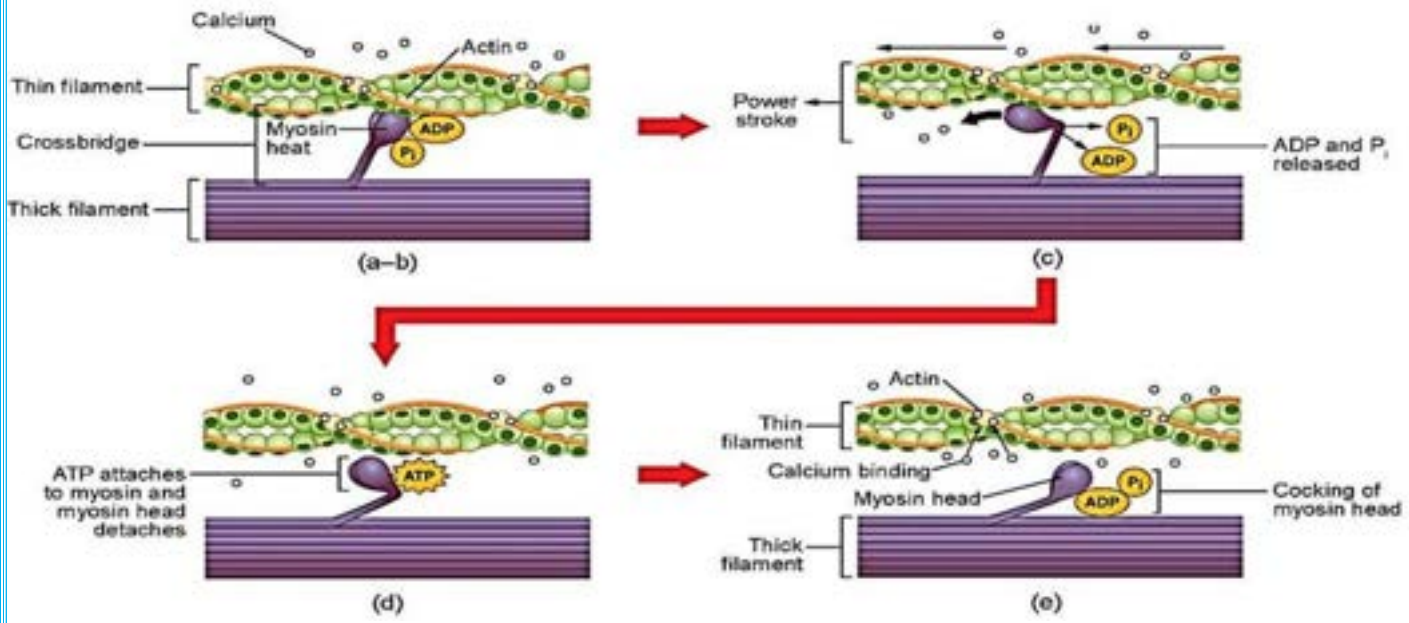
Q.8. Which part of the myosin monomer acts as an active ATPase enzyme?

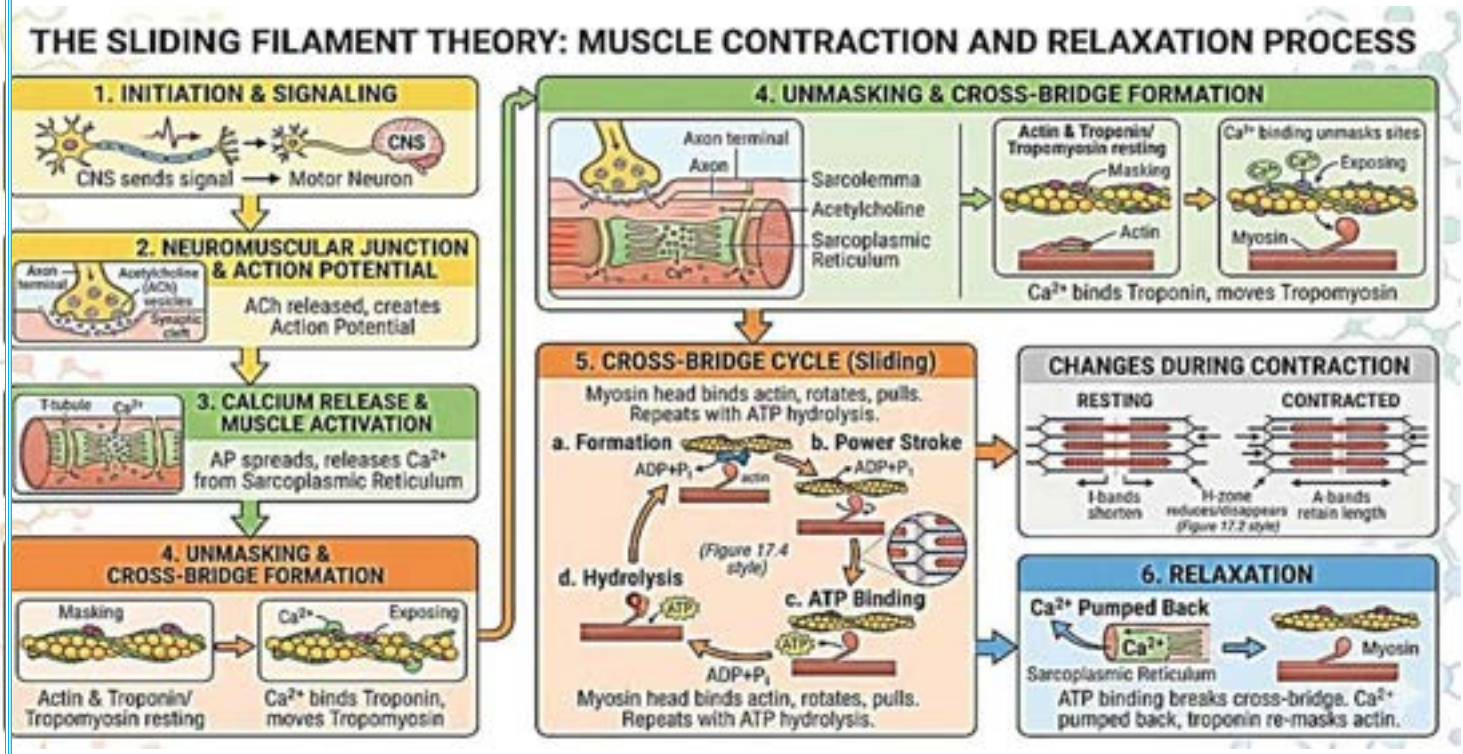
Q.9. What is the structural monomer (building block) of an F-actin chain?

Q.10. Which protein component physically masks the active myosin-binding sites when a muscle is at rest?

Mechanism of Muscle Contraction

1. **Core Concept:** Muscle contraction happens when thin filaments (actin) physically slide over thick filaments (myosin).
2. **The Signal:** The central nervous system (CNS) sends a nerve impulse via a motor neuron.
3. **The Trigger:** The neurotransmitter Acetylcholine is released at the neuromuscular junction, generating an action potential.
4. **The Key Ion:** This electrical impulse causes the sarcoplasmic reticulum to release Calcium ions into the muscle cell.
5. **The Unmasking:** calcium Ions binds to troponin, which shifts tropomyosin out of the way, uncovering the hidden binding sites on the actin filament.
6. **The Cross-Bridge**: Utilizing energy from ATP hydrolysis, the myosin head binds tightly to the exposed site on the actin**.**
7. **The Power Stroke:** The myosin head rotates, pulling the actin filaments toward the center of the 'A' band, shortening the sarcomere to cause a contraction.
8. **Band Changes:** During this shortening, I-bands shorten, the H-zone reduces/disappears, but the A-bands stay the exact same length.
9. **The Release (Relaxation):** A new ATP binds to the myosin head, breaking the cross-bridge. When calcium Ions is pumped back into storage, the actin sites are covered again, and the muscle relaxes**.**





Q11. Differentiate between skeletal, smooth, and cardiac muscles on the basis of structure, location, and function. Explaining why they are classified as voluntary or involuntary.
Q.12. Explain how smooth muscles and cardiac muscles are adapted to perform their specific roles in the body.
Q.13. Define the following anatomical terms of a muscle fibre: Fascia, Sarcolemma, Sarcoplasm, Sarcoplasmic Reticulum, and Myofibrils.
Q.14. Describe the molecular composition of thick and thin filaments, highlighting regulatory proteins, monomers, and active enzymatic sites.
Q.15. Explain the roles of Acetylcholine (ACh) and ATP in the muscle contraction process, and define muscle fatigue.

Muscle Fatigue and Fibre Types

- Muscle Fatigue: Repeated, intensive contraction leads to the anaerobic breakdown of glycogen, causing an accumulation of lactic acid, which results in fatigue.

Red Fibres vs. White Fibres

Feature	Red Fibres (Aerobic)	White Fibres (Anaerobic)
Myoglobin Content	High (gives a distinct reddish appearance)	Low (appears pale or whitish)
Mitochondria	Plenty (optimizes high oxygen utilization)	Few
Sarcoplasmic Reticulum	Relatively less	High
Energy Pathway	Primarily Aerobic metabolism	Depends on Anaerobic processes

Q.16. What are red muscle fibers? Why do they exhibit their characteristic color and high resistance to fatigue?

SKELETAL SYSTEM

1. Framework of bones and cartilages.
2. Helps in movement and body support.
3. Human skeletal system contains:
    - 206 bones
    - Few cartilages

Functions of Skeletal System

- Support to body
- Protection of organs
- Helps in movement
- Muscle attachment
- Gives body shape

Division	Components	Number of Bones
Axial Skeleton	Skull, vertebral column, ribs, sternum	80
Appendicular Skeleton	Limbs and girdles	126

AXIAL SKELETON

1. Skull

Important Points

- Total bones = 22
- Cranial bones = 8
- Facial bones = 14
- Protects brain.
- Hyoid bone:
    - U-shaped
    - Present at base of buccal cavity.

Ear Ossicles

Bone	Function
Malleus	Increase the amplitude of the sound wave.
Incus	
Stapes	

Q17. Provide a detailed structural breakdown of the human skull bones.

Vertebral Column

Features

- Made of 26 vertebrae.
- Protects spinal cord.
- Supports head.
- Attachment point for ribs and muscles.

Types of Vertebrae

Region	Number
Cervical	7
Thoracic	12
Lumbar	5
Sacral	1 fused
Coccygeal	1 fused

Ribs and Sternum

- 12 pairs of ribs present.
- Sternum = flat bone on ventral thorax.
- Ribs + sternum + thoracic vertebrae form rib cage.

Types of Ribs

Type	Pairs	Feature
True ribs	1–7	Directly attached to sternum
False ribs	8–10	Indirectly attached
Floating ribs	11–12	No ventral attachment

Appendicular Skeleton

Fore lmb Bones	Hind Limbs Bones
Humerus	Femur
Radius	Tibia
Ulna	Fibula
Carpals (8)	Tarsals (7)
Metacarpals (5)	Metatarsals (5)
Phalanges (14)	Phalanges (14)
	Patella

Girdles

Pectoral Girdle

- Formed by:
  - Clavicle
  - Scapula
- Attaches forelimbs to axial skeleton.

Pelvic Girdle

- Made of two coxal bones.
- Coxal bone formed by fusion of:
  - Ilium
  - Ischium
  - Pubis
- Acetabulum articulates with femur.

JOINTS: Point where two bones meet

Types of Joints

Joint Type	Feature	Example
Fibrous	Immovable	Skull sutures
Cartilaginous	Slight movement	Between vertebrae
Synovial	Freely movable	Knee joint

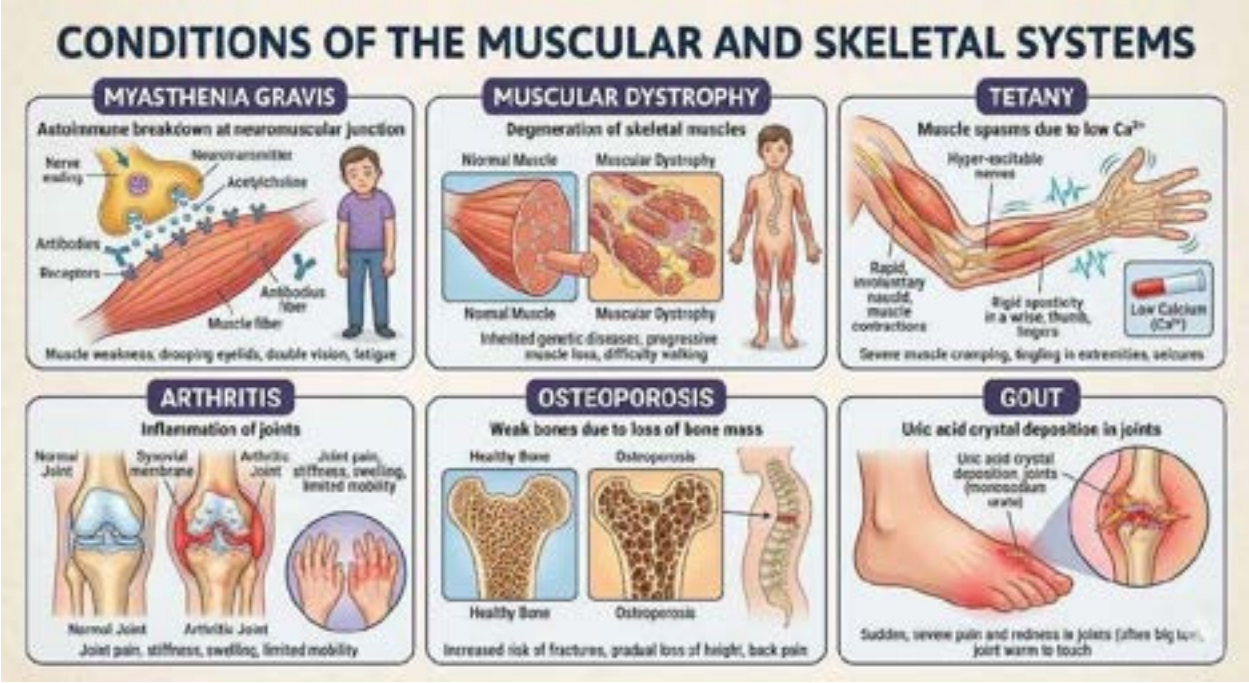
Types of Synovial Joints

Joint	Example
Ball and socket	Shoulder
Hinge	Knee
Pivot	Atlas-axis
Gliding	Carpals
Saddle	Thumb

DISORDERS OF MUSCULAR AND SKELETAL SYSTEM

Disorder	Main Feature
Myasthenia gravis	Muscle weakness due to autoimmune disorder
Muscular dystrophy	Degeneration of skeletal muscles
Tetany	Muscle spasms due to low Ca^{2+}
Arthritis	Inflammation of joints

Osteoporosis	Weak bones due to loss of bone mass
Gout	Uric acid crystal deposition in joints



Q.18. Describe the human vertebral column and thoracic cage, specifying structural counts and passing elements.

Q.19. Outline the anatomical composition of the human appendicular limbs.

Q.20. Identify the specific types of joints/articulations for the following examples:

Q.21. Write brief clinical briefs explaining the underlying pathology of Myasthenia Gravis, Osteoporosis, and Gout.

See answer of intext Questions at page No. 158 in the Question Bank QR under Test Your Knowledge

Movement and Locomotion

1. Movement & Locomotion

Movement
- Essential feature of living beings
- Change in position or posture

Locomotion
- Voluntary movement causing change of place

Purpose
- Search of food
- Shelter
- Mate
- Suitable breeding ground
- Favourable climate
- Escape from enemies

Types of movement in human cells
- Amoeboid movement (e.g., WBC, Macrophages) – by pseudopodia
- Ciliary movement – in ciliated epithelium (trachea, oviduct, etc.)
- Muscular movement – by contraction of muscles (limbs, jaws, tongue, etc.)

2. Muscles

Types of muscles (based on location & nature)

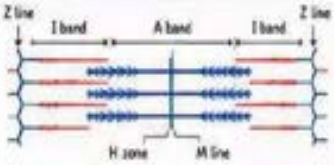
Skeletal (Striated)	Visceral (Smooth)	Cardiac (Striated)
• Attached to bones • Striated • Voluntary • For locomotion & posture	• In walls of visceral organs • Non-striated • Involuntary • E.g., alimentary canal, uterus	• In heart • Striated & branched • Involuntary • Auto-rhythmic

Properties of muscles
Excitability • Contractility • Extensibility • Elasticity

3. Structure of Skeletal Muscle

- **Muscle** – Organ made of many fascicles (muscle bundles)
- **Fascicle** – Bundle of muscle fibres wrapped in connective tissue (fascia)
- **Muscle fibre (cell)** – Long, cylindrical, multinucleate cell; surrounded by sarcolemma; contains sarcoplasm
- **Myofibrils** – Many myofibrils in sarcoplasm; show alternate dark & light bands
- **Sarcomere** – Functional unit between two Z lines

4. Sarcomere (Structure)



Thin (Actin) filament — Thick (Myosin) filament

- I band (light) – actin (thin) filaments only
- A band (dark) – myosin (thick) filaments
- H zone – central part of A band (myosin only)
- M line – holds thick filaments in middle
- Z line – bisects I band; actin attached
- In resting state – actin partially overlaps myosin

5. Contractile Proteins

Actin (Thin Filament)

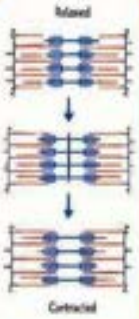

- Two F actins helically wound
- Each F actin – polymer of G actins
- Tropomyosin runs along it
- Troponin at regular intervals
- In resting state – troponin masks myosin binding sites

Myosin (Thick Filament)


- Polymer of meromyosins
- Each meromyosin has:
  - Globular head + short arm (HMM)
  - Tail (LMM)
- Head has ATPase activity
- Binding sites for ATP & actin

6. Mechanism of Muscle Contraction (Sliding Filament Theory)

1. Neural signal from CNS → motor neuron → neuromuscular junction
2. Neurotransmitter (Acetylcholine) released → action potential in sarcolemma
3. Action potential spreads → Ca^{2+} release from sarcoplasmic reticulum
4. Ca^{2+} binds troponin → active sites on actin exposed
5. Myosin head (with ADP + P_i) binds actin → cross bridge formation
6. Power stroke → ADP + P_i released → actin pulled towards centre of A band → Z lines move closer → sarcomere shortens
7. New ATP binds myosin → cross bridge breaks → myosin head re-cocks → cycle repeats



During contraction
- I band ↓
- H zone ↓
- A band – no change

Relaxation
Ca^{2+} pumped back → troponin again masks sites → sarcomere returns to original length

Muscle Fibres

Red fibres (Aerobic)	White fibres (Anaerobic)
• More myoglobin (red colour) • More mitochondria • Use O_2 for ATP production • Fatigue resistant	• Less myoglobin (pale/white) • Fewer mitochondria • Depend on anaerobic glycolysis • Fatigue easily

7. Skeletal System

Axial Skeleton (80 bones)
- Skull (22)
  - Cranial (8)
  - Facial (14)
  - Hyoid (1)
  - Ear ossicles (3 each ear)
- Vertebral Column (26)
  - Cervical (7)
  - Thoracic (12)
  - Lumbar (5)
  - Sacral (1 fused)
  - Coccygeal (1 fused)
- Sternum (1)
- Ribs (12 pairs)
  - True ribs (1–7)
  - Vertebrochondral (8–10)
  - Floating ribs (11–12)

Appendicular Skeleton (126 bones)

Upper limb (30 bones each)
- Pectoral girdle (each half)
  - Clavicle
  - Scapula
- Arm – Humerus
- Forearm – Radius, Ulna
- Wrist – Carpals (8)
- Palm – Metacarpals (5)
- Fingers – Phalanges (14)

Lower limb (30 bones each)
- Pelvic girdle (each half) – Coxal bone (Ilium, Ischium, Pubis)
- Thigh – Femur (longest bone)
- Leg – Tibia, Fibula
- Ankle – Tarsals (7)
- Foot – Metatarsals (5)
- Toes – Phalanges (14)

Functions: Support • Protection • Movement • Blood cell formation • Mineral storage

8. Joints

Where two or more bones meet

Fibrous Joints (Immovable)	• Bones joined by fibrous tissue • No movement • E.g., Sutures of skull	
Cartilaginous Joints (Semi-movable)	• Bones joined by cartilage • Limited movement • E.g., Between vertebrae, pubic symphysis	
Synovial Joints (Freely movable)	• Synovial cavity with fluid • Allow free movement • Types: – Ball & socket (shoulder) – Hinge (knee, elbow) – Pivot (atlas–axis) – Gliding (between carpals) – Saddle (carpal–metacarpal of thumb)	

9. Disorders

- **Myasthenia gravis** – Auto immune disorder affecting neuromuscular junction → fatigue, weakening & paralysis.
- **Muscular dystrophy** – Progressive degeneration of skeletal muscle (genetic).
- **Tetany** – Rapid spasms (wild contractions) due to low Ca^{2+} in body fluid.
- **Arthritis** – Inflammation of joints.
- **Osteoporosis** – Age-related disorder → decreased bone mass, more chances of fractures.
- **Gout** – Inflammation due to accumulation of uric acid crystals in joints.

CHAPTER: 18 NEURAL CONTROL AND COORDINATION

CBSE SYLLABUS 2026-27 Neuron and nerves; Nervous system in humans - central nervous system; peripheral nervous system and visceral nervous system; generation and conduction of nerve impulse

- **Coordination in Body** Coordination = process by which organs work together.
- Helps maintain **homeostasis** (stable internal environment).

Example during exercise:

- Muscles need more energy and oxygen.
- Respiration rate increases.
- Heartbeat increases.
- Blood flow increases.
- After exercise, organs return to normal condition.

Q.1 If the neural system stopped coordinating body activities during exercise, what problems would occur in oxygen supply and muscle activity? Explain.

Systems Involved in Coordination.

System	Function	Speed
Neural System	Quick coordination through nerve impulses	Fast
Endocrine System	Chemical coordination through hormones	Slow

Neural system Made up of specialised cells called **neurons**.

Neurons can:

- detect stimuli
- receive stimuli
- transmit impulses

Q3. If neurons could detect stimuli but were unable to transmit impulses, how would the body's response to dangerous situations be affected? Explain. (2 marks).

Q.4. Why are neurons called specialised cells in the neural system?(1 mark)

Neural System in Different Animals

Organism	Neural Organisation
Hydra	Network of neurons
Insects	Brain + ganglia + neural tissues
Vertebrates	Highly developed neural system

Q.5.Question Why do vertebrates need a more highly developed neural system than Hydra?

Hint Vertebrates perform more complex activities and need better coordination and faster responses

Human Neural System

The human neural system has 2 main parts:

Part	Full Form	Parts included	Function
CNS	Central Neural System	Brain, Spinal Cord	Information processing and control
PNS	Peripheral Neural System	Contains all nerves Connected to CNS.	Connects body parts with CNS

Types of nerve fibres

Type	Function
Afferent fibres	Carry impulses from organs to CNS
Efferent fibres	Carry impulses from CNS to organs

Q.6. What problem would occur if efferent fibres stopped functioning properly?

Q.7. Why are afferent fibres important in the body?

PNS

Division	Function
Somatic Neural System	Controls skeletal muscles
Autonomic Neural System	Controls involuntary organs and smooth muscles

Q.8. Why is the autonomic neural system called an involuntary system?

Autonomic Neural System

Division	Main Function
Sympathetic Nervous System	Active during stress/emergency
Parasympathetic Nervous System	Restores normal condition

The visceral nervous system

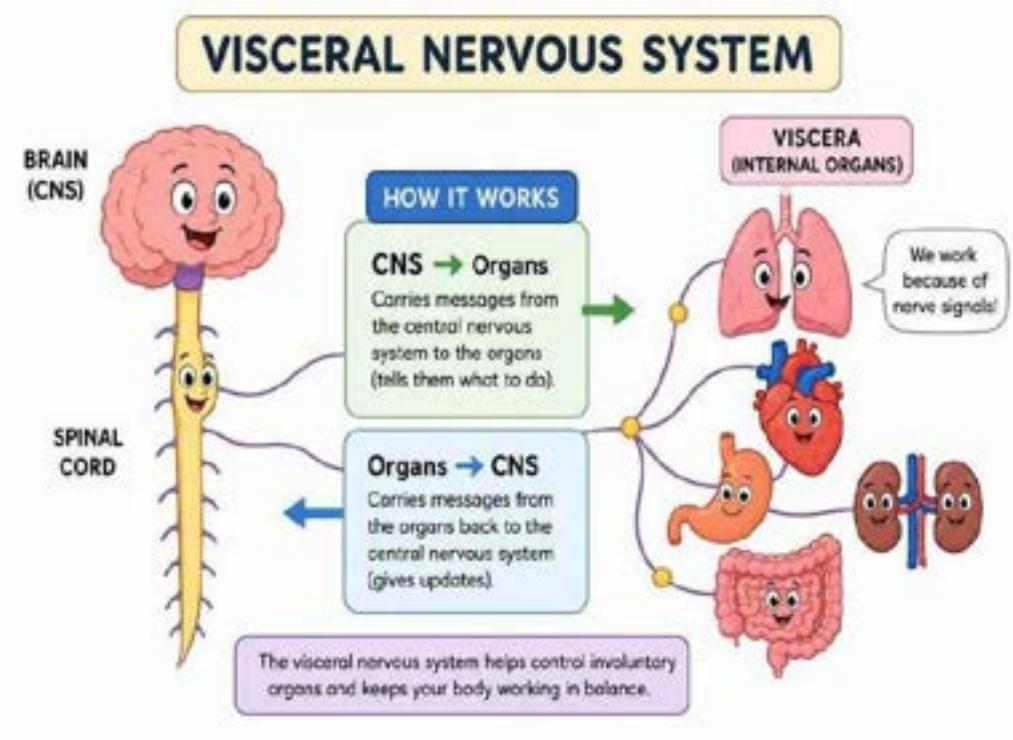
part of the peripheral nervous system that controls the internal organs of the body.

It carries messages:

- from the brain and spinal cord to the organs, and
- from the organs back to the brain and spinal cord.

It helps in automatic activities like:

- heartbeat
- breathing
- digestion
- maintaining body balance



Questions

Q.9. If the visceral nervous system suddenly stopped functioning, how would digestion and heartbeat be affected? Explain logically.

Q10. Why are activities like breathing and heartbeat controlled automatically instead of consciously by humans?

Q11. During exercise, why does the visceral nervous system increase breathing rate and heartbeat automatically?

Q.12. A person touches a hot object and quickly removes the hand before thinking about it. How does the nervous system help in this rapid response?

Q.13. Why would the body face difficulty in maintaining balance if communication between organs and the brain stopped?

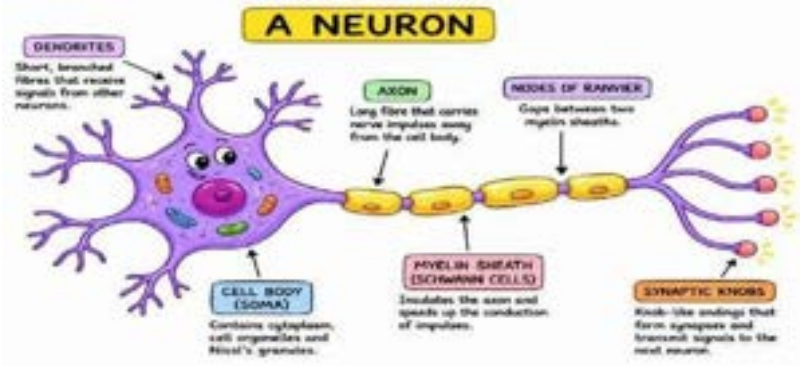
Q.14. How does the visceral nervous system help maintain homeostasis during stressful situations?

NEURON:

Neuron as Structural and Functional Unit of Neural System

Neuron is made up of three major parts-**cell body, dendrite** and **axon.**

- Cell body contains cytoplasm, cell organelles and Nissl's granules.
- Short fibres projecting out from cell body are called dendrites.



- The axon is long fibre having branched structure at the end that terminates into
- Nob like structure called **synaptic knob.**
- Based on number of axon and dendrites neuron are of three types-

1. **Multipolar**-one axon and two or more dendrite. Found in cerebral cortex.
2. **Bipolar-** One axon and one dendrite found in retina of eyes.
3. **Unipolar**- Cell body with only one axon found in embryonic stage

Q15. Draw a well labeled diagram of a typical neuron. Label any six parts. (3Marks)
Q.16. Define a neuron. Name the three major parts of a neuron.
Q.17. Differentiate between dendrites and axon based on structure and function.
Q.18. What are synaptic knobs? Mention their location in a neuron.
Q.19. Classify neurons based on number of axons and dendrites. Write one feature of each type.
Q.20. Match the following types of neurons with their correct location:

There are two types of axons-

Myelinated- fibres are enveloped with **Schwann cells** to form myelin sheath around the axon. The gap between two myelin sheaths is called **nodes of Ranvier.** Found in spinal and cranial nerves.

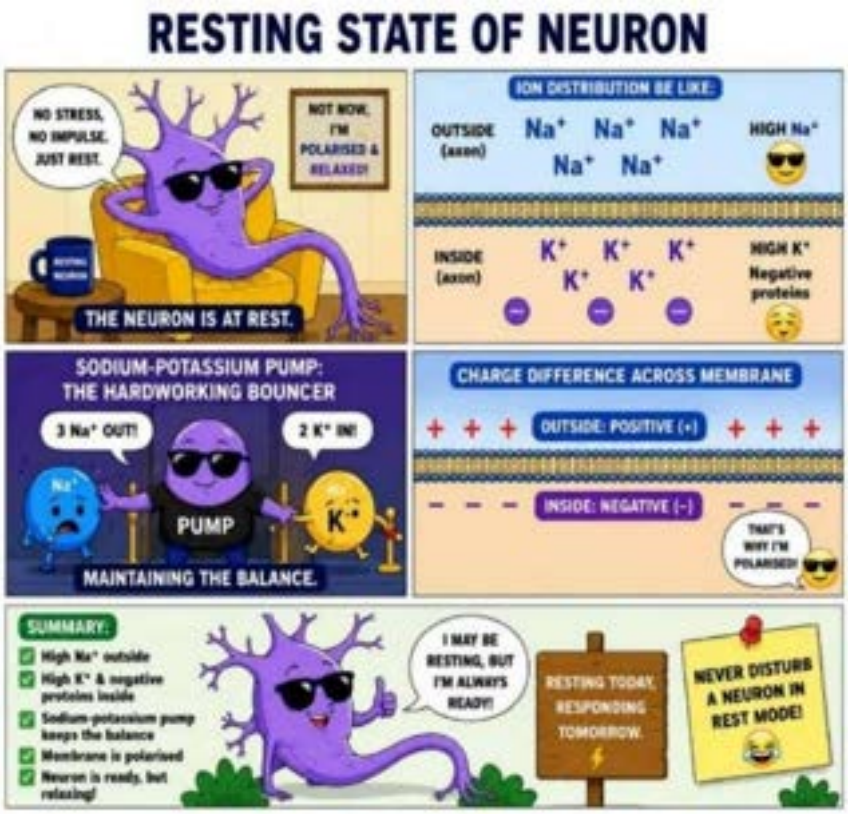
Unmyelinated- fibre is enclosed by Schwann cells that do not form myelin sheath around the axon. Found in autonomous and somatic neural system.

Q.21. Differentiate between myelinated and unmyelinated axons on the basis of structure and location

Resting Potential

Resting Potential – Point Wise

- Neuron membrane is polarised in resting state.
- Outer side of membrane is positively charged.
- Inner side of membrane is negatively charged.
- Due to unequal distribution of ions.
- More Na^+ ions are outside the membrane.
- More K^+ ions are inside the membrane.
- Membrane is more permeable to K^+ than Na^+.
- Sodium–potassium pump maintains ion balance.
- Difference in charge creates resting potential.



Q.22. In the resting state of a neuron, the outer side of the membrane is _____charged.

Q.23. Which ion is present in higher concentration inside the neuron membrane?
Q.24. Name the mechanism that maintains the unequal distribution of ions across the neuron membrane.
Q.25. Explain the resting state of a neuron membrane. How is the resting potential maintained in the neuron?

Conduction of Nerve Impulse

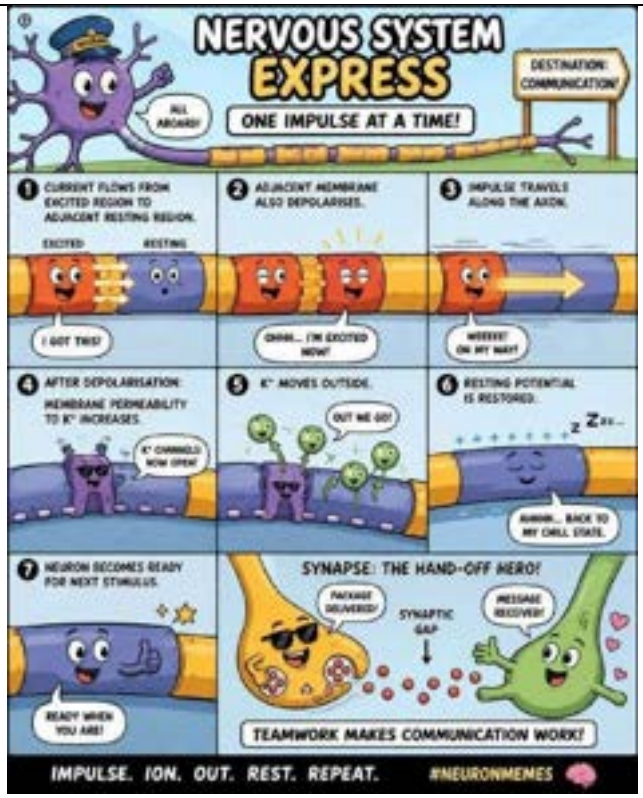
- Current flows from excited region to adjacent resting region.
- Adjacent membrane also depolarises.
- Impulse travels along the axon.
- After depolarisation:
  - Membrane permeability to K^+ increases.
  - K^+ moves outside.
- Resting potential is restored.
- Neuron becomes ready for next stimulus.

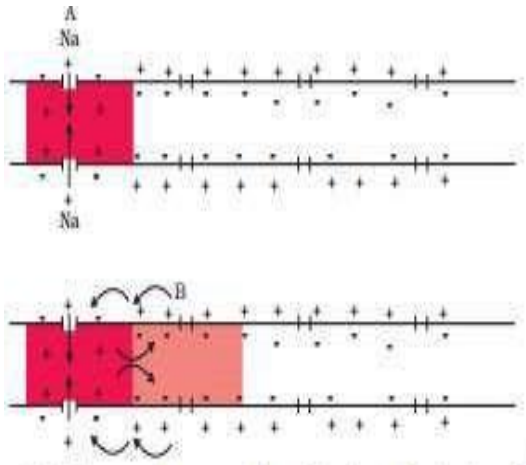
Synapse

- Junction between two neurons.
- Formed by:
  - Pre-synaptic neuron
  - Post-synaptic neuron
- Gap between neurons is called **synaptic cleft**.

Types of Synapses

1. Electrical Synapse
   - Pre- and post-synaptic membranes are very close.
   - Current passes directly.
   - Transmission is very fast.
   - Rare in humans.
2. Chemical Synapse
   - Synaptic cleft present.
   - Neurotransmitters involved.
   - More common.
3. Transmission Across Chemical Synapse
   - Axon terminal contains synaptic vesicles.
   - Vesicles contain neurotransmitters.
   - Arrival of impulse releases neurotransmitters into synaptic cleft.
   - Neurotransmitters bind to receptors on post-synaptic membrane.
   - Ion channels open.
   - New impulse generated in post-synaptic neuron.
   - Response may be: Excitatory or Inhibitory





re 18.2 Diagrammatic representation of impulse conduction through an axon (at points A and B)

CENTRAL NEURAL SYSTEM (CNS)

Brain – Main Functions

- Brain is the control and coordination centre of the body.
- Processes and stores information.
- Controls:
  - Voluntary movements
  - Balance and posture
  - Breathing, heartbeat, kidney functions
  - Body temperature
  - Hunger and thirst
  - Sleep–wake (circadian) rhythm
  - Endocrine gland activities
- Responsible for:
  - Vision
  - Hearing
  - Speech
  - Memory
  - Intelligence
  - Emotions and thoughts

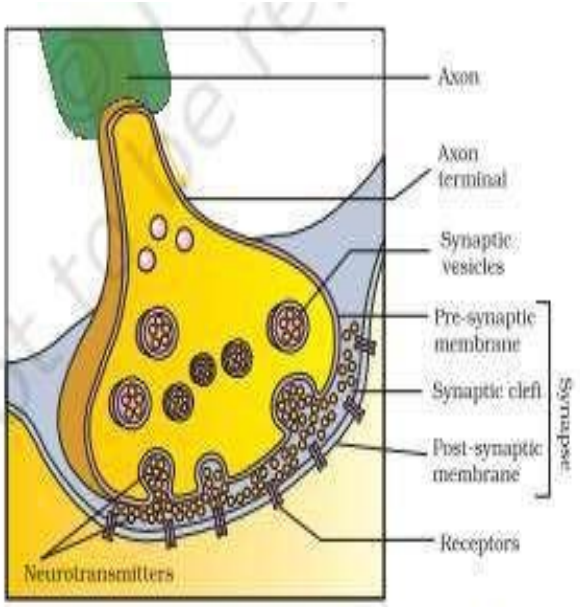
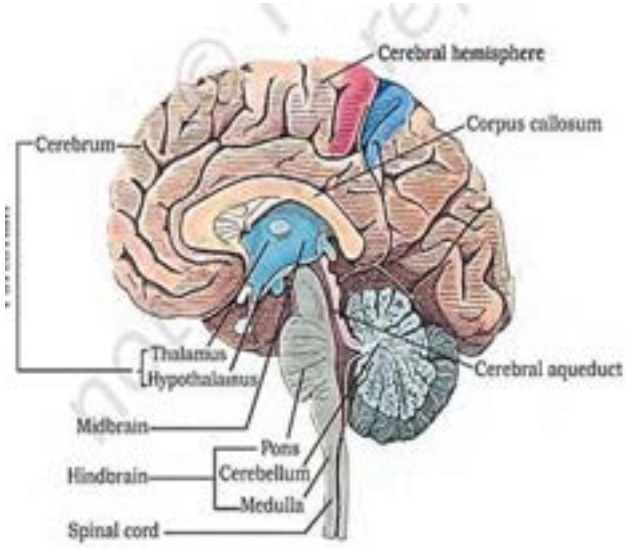


Figure 18.3 Diagram showing axon terminal and synapse



Structure	Function
Skull	Protects brain externally
Dura mater	Tough outer covering
Arachnoid	Thin middle membrane
Pia mater	Inner membrane attached to brain

Major Part of Brain	Structures Included	Structural Features
Forebrain	**Cerebrum, Thalamus, Hypothalamus**	Largest and most developed part of brain
Cerebrum	Left and right cerebral hemispheres connected by corpus callosum	Surface highly folded forming cerebral cortex; outer grey matter and inner white matter present
Thalamus	Located below cerebrum	Oval-shaped sensory relay centre surrounded by cerebrum
Hypothalamus	Present at base of thalamus	Small region containing many neurosecretory cells and control centres

Limbic System	Amygdala, hippocampus and associated structures	Inner deep structures of cerebral hemispheres
Midbrain	Corpora quadrigemina and cerebral aqueduct	Located between fore brain and hindbrain; dorsal side has four rounded lobes
Corpora Quadrigemina	Four rounded swellings	Two superior and two inferior lobes present
Cerebral Aqueduct	Narrow canal through midbrain	Connects cavities of brain and allows flow of cerebrospinal fluid
Hindbrain	**Pons, Cerebellum, Medulla Oblongata**	Posterior part of brain connected with spinal cord
Pons	Fibre tracts	Bridge-like structure connecting different regions of brain
Cerebellum	Two cerebellar hemispheres	Highly folded and convoluted surface with many neurons
Medulla Oblongata	Lower part of brain stem	Continuous with spinal cord
Brain Stem	Midbrain, pons and medulla oblongata	Connects brain to spinal cord

Q.26. If someone receives a blow on the back of neck, what would be the effect on the person's CNS?

Q.27. What do grey and white matter in the brain represent?

Q.28. Prateek was feeling very thirsty & hungry in noon as he was engaged in urgent work & could not take breakfast today. He asked his mother to provide him lunch immediately as he was very hungry.

Q.29. Answer the following questions-

(a) Name the part of human brain that controls the thirst & hunger.

(b) In which part of brain it is located.

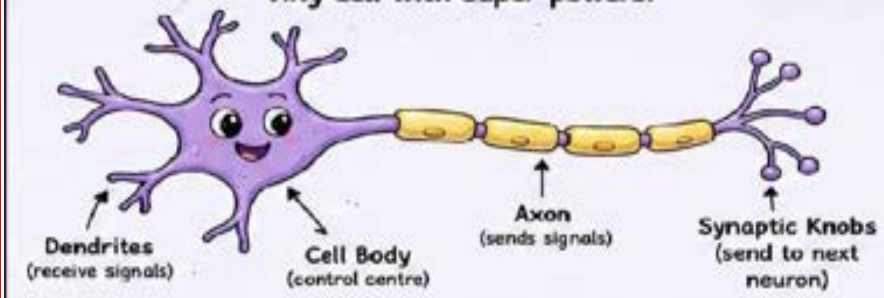
Write down main works of cerebellum.

See answer of intext Questions at page No. 158 in the Question Bank QR under Test Your Knowledge

NEURON: SMALL CELL, BIG JOBS!

MEET THE NEURON

Tiny cell with super powers!



TYPES OF NEURONS

MULTIPOLAR



One axon, two or more dendrites. Found in cerebral cortex.

BIPOLAR



One axon, one dendrite. Found in retina of eyes.

UNIPOLAR



Cell body with only one axon. Found in embryonic stage.

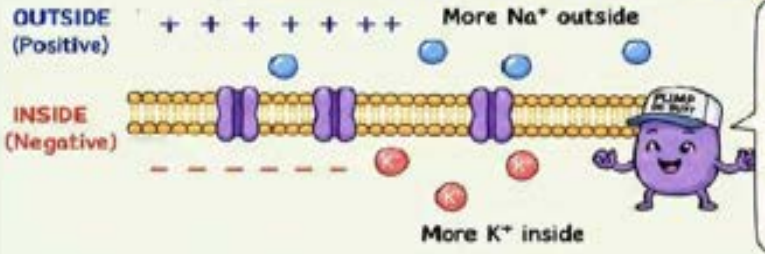
WIRED DIFFERENTLY



- Receive
- Process
- Transmit

REPEAT!

RESTING BUT NOT RELAXING!



- More permeable to K^+ than Na^+
- Sodium–potassium pump maintains ion balance
- Difference in charge creates resting potential

AXONS: MYELINATED vs UNMYELINATED

MYELINATED



Surrounded by Schwann cells to form myelin sheath. Gaps are Nodes of Ranvier. Found in spinal and cranial nerves.

FAST & SMOOTH!

UNMYELINATED



Enclosed by Schwann cells but no myelin sheath. Found in autonomic and somatic neural system.

SLOW BUT STEADY!

VISERAL NERVOUS SYSTEM: THE BODY'S AUTO PILOT



- Controls heartbeat
- Helps in breathing
- Aids digestion
- Maintains body balance

★ NEURON DOESN'T JUST THINK, IT LINKS, IT WORKS, IT KEEPS YOU GOING!

NEURAL CONTROL AND COORDINATION
(Complete Chapter Mind Map)

1. NEURAL SYSTEM

- Composed of highly specialised cells called neurons.
- Detect, receive and transmit different kinds of stimuli.
- Simple in lower invertebrates (e.g., Hydra – network of neurons).
- Better organised in insects (brain, ganglia and neural tissues).
- More developed in vertebrates.

2. HUMAN NEURAL SYSTEM

Divided into two main parts

(i) CENTRAL NEURAL SYSTEM (CNS)
- Consists of brain and spinal cord.
- Site of information processing and control.

(ii) PERIPHERAL NEURAL SYSTEM (PNS)
- Consists of all the nerves outside CNS.
- Nerve fibres of two types :
  - a. Afferent fibres – carry impulses from organs/tissues to CNS.
  - b. Efferent fibres – carry impulses from CNS to organs/tissues.

PNS is divided into

A. Somatic Neural System
- Relays impulses from CNS to skeletal muscles.

B. Autonomic Neural System (ANS)
- Transmits impulses from CNS to involuntary organs and smooth muscles.

Further divided into

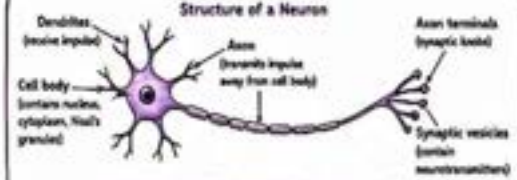
(i) Sympathetic Neural System
- Prepares the body for emergencies ("fight or flight").

(ii) Parasympathetic Neural System
- Conserves energy; maintains normal body functions.

Visceral Nervous System
- Part of PNS; carries impulses to and from viscera (internal organs) through nerves, fibres, ganglia and plexuses.

3. NEURON – STRUCTURAL & FUNCTIONAL UNIT

Structure of a Neuron



Types of Neurons (by number of processes)

Multipolar	Bipolar	Unipolar
• One axon and two or more dendrites. • Found in cerebral cortex.	• One axon and one dendrite. • Found in retina of eye.	• One axon only (cell body on the side). • Found usually in embryonic stage.

Types of Axons

Myelinated Axon
- Enveloped by Schwann cells forming myelin sheath.
- Gaps between myelin sheaths are nodes of Ranvier.
- Found in spinal and cranial nerves.

Non-myelinated Axon
- Enclosed by Schwann cell without myelin sheath.
- Commonly found in autonomic and somatic neural systems.

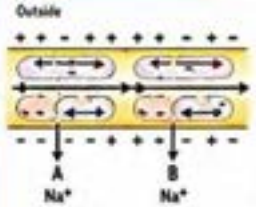
4. GENERATION & CONDUCTION OF NERVE IMPULSE

Resting State (Polarised Membrane)
- More permeable to K^+, nearly impermeable to Na^+.
- Inside axon: high K^+ and negatively charged proteins, low Na^+.
- Outside axon: low K^+, high Na^+.
- Sodium-potassium pump maintains gradient (3 Na^+ out, 2 K^+ in).
- Outer side positive, inner side negative = Resting potential.

Generation of Action Potential
1. Stimulus applied at a point (A) → membrane becomes permeable to Na^+.
2. Na^+ rushes in → polarity reverses (depolarisation).
3. Current flows from A to adjacent region (B) inside the axon and from B to A outside.
4. Polarity at B reverses → action potential generated at B.
5. Process continues along the axon → impulse conducted.

Repolarisation
- Permeability to K^+ increases.
- K^+ diffuses out → restores resting potential.
- Fibre again ready for further stimulation.

Impulse Conduction (at points A and B)



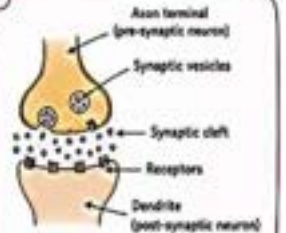
Red arrows – current flow outside
Blue arrows – current flow inside

5. TRANSMISSION OF IMPULSES (SYNAPSE)

Types of Synapses

1. Electrical Synapse
   - Pre- and post-synaptic membranes in very close proximity.
   - Current flows directly from one neuron to another.
   - Transmission is faster.
   - Rare in our system.
2. Chemical Synapse
   - Pre- and post-synaptic membranes separated by synaptic cleft.
   - Transmission by neurotransmitters.

Mechanism at Chemical Synapse
1. Impulse reaches axon terminal of pre-synaptic neuron.
2. Synaptic vesicles move to membrane and release neurotransmitters in synaptic cleft.
3. Neurotransmitters bind to specific receptors on post-synaptic membrane.
4. Ion channels open → ions enter.
5. New potential generated in post-synaptic neuron (excitatory or inhibitory).



6. CENTRAL NEURAL SYSTEM (CNS)

Brain – The Command and Control Centre

Controls voluntary movements, balance, vital involuntary organs, thermoregulation, hunger, thirst, circadian rhythms, endocrine glands, behaviour, memory, intelligence, emotions, thoughts, vision, hearing, speech.

Protected by
- Skull
- Cranial meninges
  1. Duro mater (outer)
  2. Arachnoid (middle)
  3. Pia mater (inner)

Brain Divided into Three Major Parts

A. FOREBRAIN (Cerebrum, Thalamus, Hypothalamus)

1. Cerebrum
   - Largest part.
   - Divided into left and right hemispheres by a deep cleft.
   - Hemispheres connected by corpus callosum.
   - Outer layer – Cerebral cortex (grey matter): folds; motor, sensory and association areas.
   - Inner layer – White matter (myelinated fibres).
2. Thalamus
   - Major coordinating centre for sensory and motor signals.
3. Hypothalamus
   - At base of thalamus.
   - Controls body temperature, hunger, thirst.
   - Contains neurosecretory cells → secrete hypothalamic hormones.

Limbic System
- Inner parts of cerebral hemisphere and deep structures (amygdala, hippocampus, etc.).
- Involved in olfaction, autonomic responses, sexual behaviour, emotional reactions (excitement, pleasure, rage, fear) and motivation.

B. MIDBRAIN
- Located between thalamus/hypothalamus and pons.
- Contains a canal – cerebral aqueduct.
- Dorsal portion has four round swellings (lobes) called corpora quadrigemina.

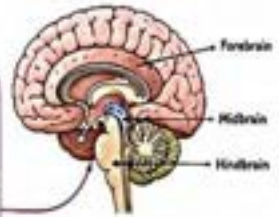
Functions
- Receives and integrates visual, tactile and auditory inputs.
- Involved in visual and auditory reflexes.

C. HINDBRAIN (Brain Stem)

1. Pons
   - Bridge-like structure.
   - Contains fibre tracts that interconnect different regions of brain.
   - Helps in regulation of breathing.
2. Cerebellum
   - Highly convoluted surface.
   - Integrates information from semicircular canals of ear and auditory system.
   - Coordinates voluntary movements, balance and posture.
3. Medulla Oblongata
   - Continuous with spinal cord.
   - Contains centres for respiration, cardiovascular reflexes and gastric secretions.

Brain Stem
Composed of midbrain, pons and medulla oblongata.
- Forms connections between brain and spinal cord.
- Controls vital life-sustaining functions.

Sagittal Section of Human Brain



★ SUMMARY

- Neural system coordinates and integrates functions and maintains homeostasis.
- Neurons are excitable cells; resting potential is due to ion gradients.
- Nerve impulse is conducted along axon by wave of depolarisation and repolarisation.
- Synapse is junction between neurons; at chemical synapses transmission occurs by neurotransmitters.
- Human neural system has CNS (brain & spinal cord) and PNS (somatic + autonomic).
- Brain has three major parts – forebrain, midbrain and hindbrain with specialised functions.

KEY TERMS

Neuron, Dendrite, Axon, Synapse, Neurotransmitter, Resting potential, Action potential, Depolarisation, Repolarisation, Myelin sheath, Node of Ranvier, CNS, PNS, Somatic nervous system, Autonomic nervous system, Sympathetic, Parasympathetic, Cerebrum, Thalamus, Hypothalamus, Limbic system, Midbrain, Pons, Cerebellum, Medulla oblongata, Brain stem.

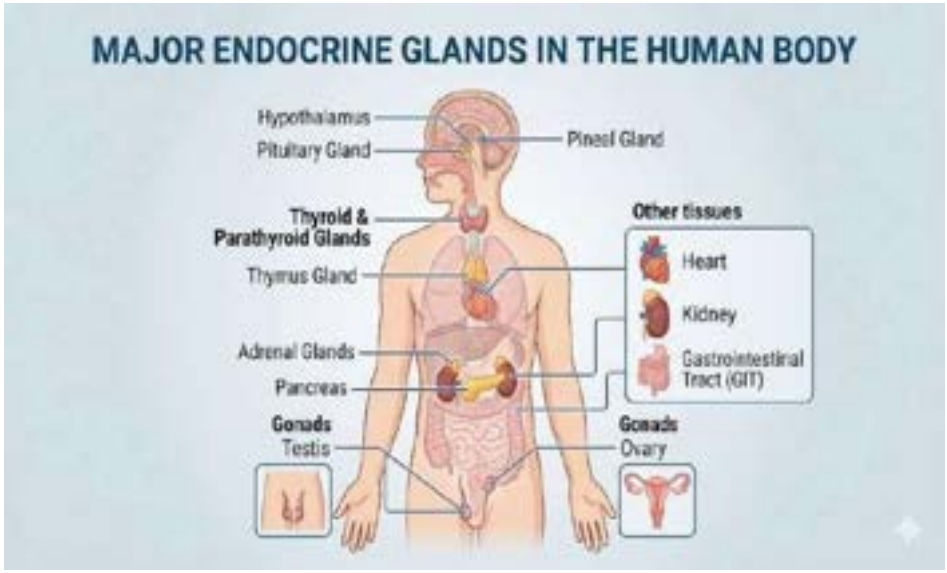
EXERCISES (HOTS/GIST (Quick Recall)

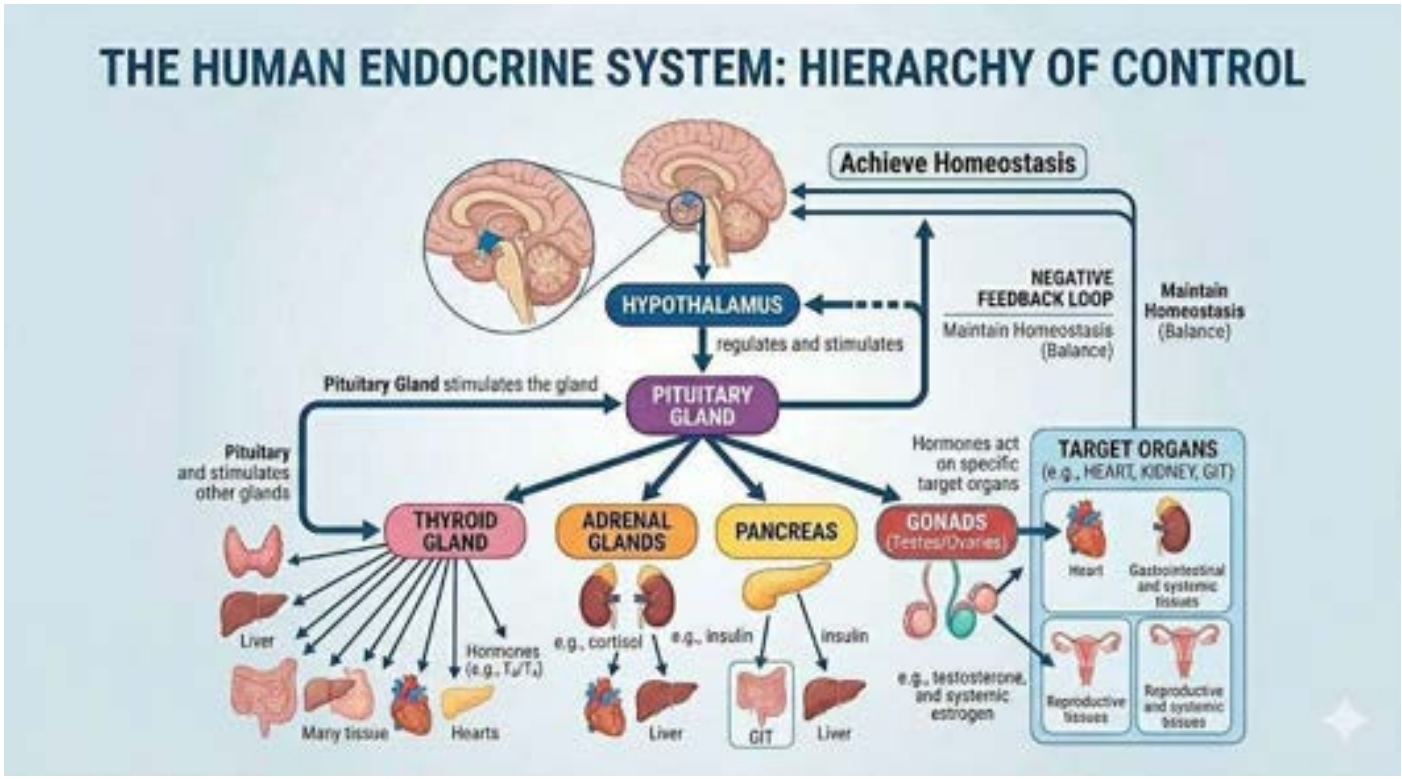
2. Compare:
   (a) CNS & PNS
   (b) Resting potential & action potential
3. Explain:
   (a) Polarisation
   (b) Depolarisation
   (c) Transmission across chemical synapse
4. Draw labelled diagrams of:
   (a) Neuron
   (b) Brain
5. Write short notes on:
   (a) Neural coordination
   (b) Forebrain
   (c) Midbrain
   (d) Hindbrain
   (e) Synapse
6. Give a brief account of mechanism of synaptic transmission.
7. Explain the role of Na^+ in the generation of action potential.
8. Differentiate between:
   (a) Myelinated & non-myelinated axons
   (b) Dendrites & axons
   (c) Thalamus & hypothalamus
   (d) Cerebrum & cerebellum
9. Answer:
   (a) Which part of human brain is most developed?
   (b) Which part acts as master clock?
10. Distinguish between:
    (a) Afferent & efferent neurons
    (b) Conduction in myelinated & unmyelinated fibres
    (c) Cranial nerves & spinal nerves

CHAPTER -19 CHEMICAL COORDINATION & INTEGRATION

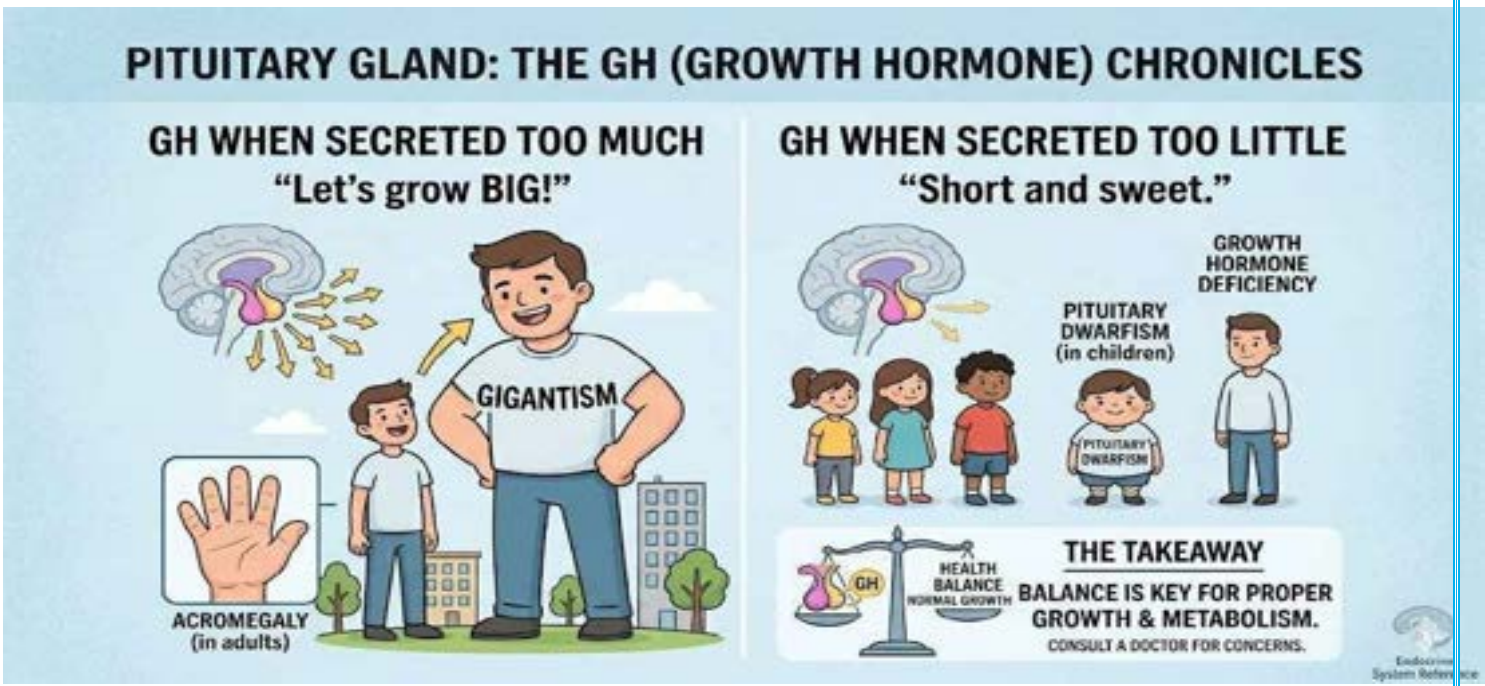
CBSE Syllabus 2026-27 Endocrine glands and hormones; human endocrine system - hypothalamus, pituitary, pineal, thyroid, parathyroid, adrenal, pancreas, gonads; mechanism of hormone action (elementary idea); role of hormones as messengers and regulators, hypo - and hyperactivity and related disorders; dwarfism, acromegaly, cretinism, goiter, exophthalmic goitre, diabetes, Addison's disease.

- **Endocrine glands** → ductless, secrete hormones
- **Hormones** → non-nutrient chemical messengers produced in trace amounts

ENDOCRINE GLANDS • Hypothalamus • Pituitary • Pineal • Thyroid & Parathyroid • Thymus • Adrenal • Pancreas • Gonads (Testis, Ovary) • Other tissues → Heart, Kidney, GIT	



Endocrine Gland	Hormone	Main Function	Disorder Due to Deficiency	Major Symptoms
Pituitary (Anterior)	Growth Hormone (GH)	Stimulates growth of bones, muscles, and organs.	Pituitary Dwarfism (in children)	Significantly stunted growth, short stature, proportionate body parts.
Pituitary (Anterior)	Thyroid-Stimulating Hormone (TSH)	Stimulates the thyroid gland to produce its hormones.	Secondary Hypothyroidism	Symptoms identical to primary hypothyroidism (see Thyroid).
Pituitary (Anterior)	Adrenocorticotropic Hormone (ACTH)	Stimulates the adrenal cortex to release cortisol.	Secondary Adrenal Insufficiency	Fatigue, weakness, weight loss, low blood pressure.
Pituitary (Posterior)	Anti-diuretic Hormone (ADH)	Regulates water balance by causing kidneys to retain water.	Diabetes Insipidus	Extreme thirst (polydipsia), excessive urination (polyuria), dilute urine.



Q.1. Which master gland, located at the base of the brain, controls other endocrine glands?
Q.2. What is the term for the state of internal balance and stability maintained by the endocrine system?

Pineal Gland:

- Location: Deep in the center of the brain it is Pine shaped
- Main Hormone: Melatonin (secreted in response to darkness).
- Primary Function: Regulates the body's internal clock (circadian rhythm) and sleep-wake cycles.
- Deficiency Effect: Leads to insomnia, disrupted sleep patterns, daytime fatigue, and mood disturbances.

Q.3. Where is the pineal gland located, and what is its characteristic shape?
Q.4 Which major hormone does the pineal gland secrete, and what triggers its release?
Q.5. What is the primary biological role of the pineal gland in humans?

Endocrine Gland	Key Hormone(s)	Primary Function	Deficiency Condition/Disease	Key Symptoms of Deficiency
Thyroid	Thyroxine (T4) & Triiodothyronine (T3)	Regulate the body's metabolic rate, energy levels, and body temperature.	Hypothyroidism (e.g., Hashimoto's disease)	Fatigue, weight gain, cold intolerance, slow heart rate, depression, dry skin.
		Crucial for brain development in infancy.	Congenital Hypothyroidism (formerly Cretinism)	Severely stunted physical and mental development if untreated.
			Goiter (due to iodine deficiency)	Enlarged thyroid gland (swelling in the neck).
Parathyroid	Parathyroid Hormone (PTH)	Regulates calcium levels in the blood and bones.	Hypoparathyroidism	Low blood calcium (hypocalcemia), muscle cramps, spasms, tetany, tingling.

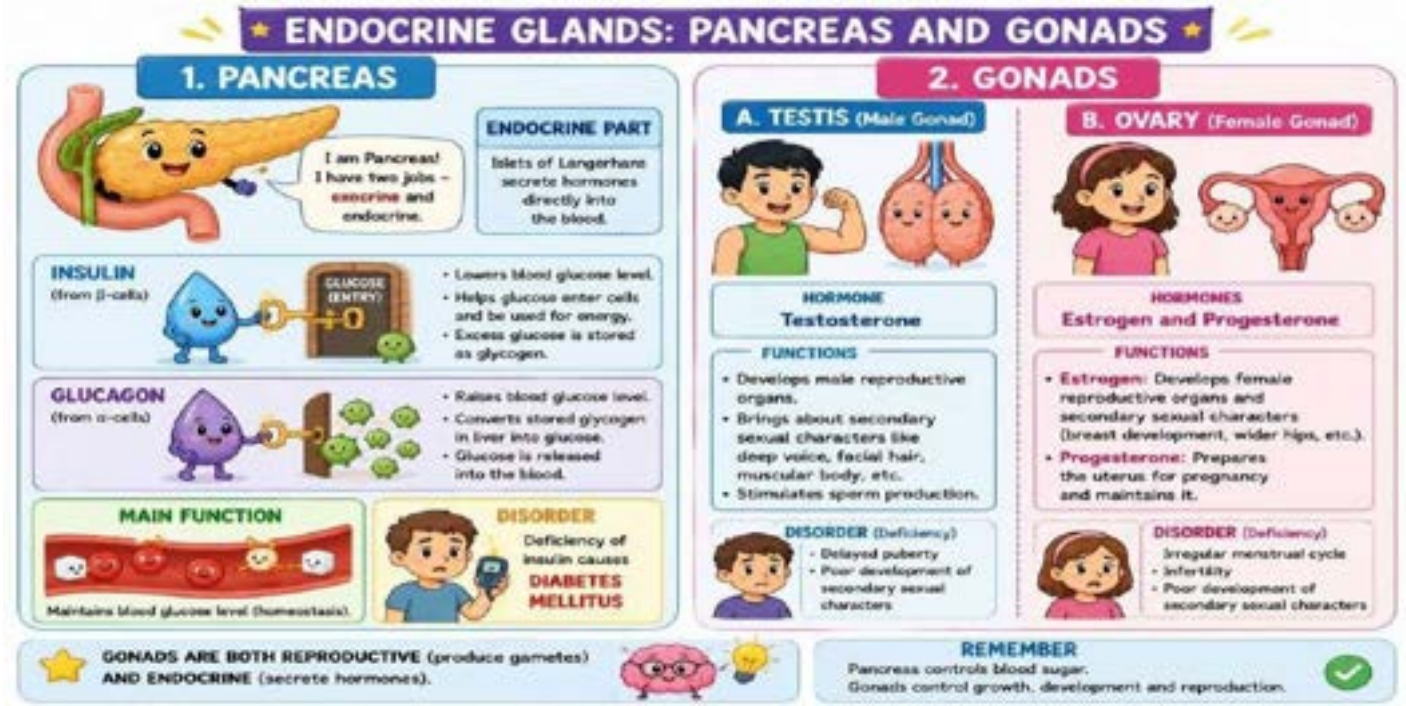
Q.6. Differentiate between hypothyroidism and hyperthyroidism.
Q.7. What is cretinism? Mention one symptom.
Q.8. Why is iodine added to common salt?
Q.9. Which endocrine gland is known as the "master gland" and how does it control thyroid secretion?
Q.10. How do thyroid hormones help in growth and metabolism?

See answer of intext Questions at page No. 158 in the Question Bank QR under Test Your Knowledge

Endocrine Gland	Hormone(s)	Main Function	Disorders Due to Deficiency	Major Symptoms
Thymus Gland 	Thymosin (includes thymosin, thymopoietin, thymulin, etc.)	Promotes the growth, maturation and differentiation of T-lymphocytes (T-cells), which are essential for immune function.	Immunodeficiency (Thymic Hypoplasia/ Aplasia)	• Recurrent infections (bacterial, viral, fungal) • Poor immune response • Increased susceptibility to diseases
Adrenal Gland 	Cortisol (glucocorticoid) Aldosterone (mineralocorticoid) Androgens (adrenal androgens)	• Cortisol: Helps in stress response, regulates metabolism, and reduces inflammation. • Aldosterone: Regulates salt and water balance, maintains blood pressure. • Androgens: Contribute to secondary sexual characteristics and libido.	Addison's Disease (Primary Adrenal Insufficiency)	• Fatigue, weakness • Weight loss • Low blood pressure • Nausea, vomiting • Salt craving • Hyperpigmentation (darkening of skin)

Q.11. Name the hormone that regulates salt and water balance in the body.
Q.12. Which gland secretes cortisol?
Q.13. What is the main function of thymosin?

Endocrine Gland	Hormone	Main Function	Disorder Due to Deficiency	Major Symptoms
Pancreas	**Insulin**	Lowers blood glucose level by promoting uptake of glucose by cells.	**Diabetes Mellitus**	High blood sugar, excessive thirst, frequent urination, fatigue.
Pancreas	**Glucagon**	Raises blood glucose level by converting glycogen into glucose.	**Hypoglycemia (rare)**	Low blood sugar, dizziness, sweating, weakness.
Testis (Male Gonad)	**Testosterone**	Development of male reproductive organs and secondary sexual characters.	**Hypogonadism**	Delayed puberty, poor muscle development, infertility.
Ovary (Female Gonad)	**Estrogen**	Development of female secondary sexual characters and regulation of menstrual cycle.	**Estrogen Deficiency**	Irregular menstruation, delayed puberty, weak bones.
Ovary (Female Gonad)	**Progesterone**	Prepares uterus for pregnancy and maintains pregnancy.	**Progesterone Deficiency**	Irregular menstrual cycle, difficulty in maintaining pregnancy.



ENDOCRINE GLANDS: PANCREAS AND GONADS
1. PANCREAS
I am Pancreas! I have two jobs – exocrine and endocrine.
ENDOCRINE PART
Islets of Langerhans secrete hormones directly into the blood.
INSULIN
(from β-cells)
GLUCOSE (ENTRY)
• Lowers blood glucose level.
• Helps glucose enter cells and be used for energy.
• Excess glucose is stored as glycogen.
GLUCAGON
(from α-cells)
• Raises blood glucose level.
• Converts stored glycogen in liver into glucose.
• Glucose is released into the blood.
MAIN FUNCTION
Maintains blood glucose level (homeostasis).
DISORDER
Deficiency of insulin causes
DIABETES MELLITUS
2. GONADS
A. TESTIS (Male Gonad)
HORMONE
Testosterone
FUNCTIONS
• Develops male reproductive organs.
• Brings about secondary sexual characters like deep voice, facial hair, muscular body, etc.
• Stimulates sperm production.
DISORDER (Deficiency)
• Delayed puberty
• Poor development of secondary sexual characters
B. OVARY (Female Gonad)
HORMONES
Estrogen and Progesterone
FUNCTIONS
• Estrogen: Develops female reproductive organs and secondary sexual characters (breast development, wider hips, etc.).
• Progesterone: Prepares the uterus for pregnancy and maintains it.
DISORDER (Deficiency)
Irregular menstrual cycle
• Infertility
• Poor development of secondary sexual characters
GONADS ARE BOTH REPRODUCTIVE (produce gametes) AND ENDOCRINE (secrete hormones).
REMEMBER
Pancreas controls blood sugar.
Gonads control growth, development and reproduction.

Q.14. Why does deficiency of insulin lead to diabetes mellitus?

Q.15. How do insulin and glucagon work together to maintain homeostasis?

Q.16. A boy shows poor development of secondary sexual characters during puberty. Which gland or hormone may be deficient? Explain.

CHEMICAL COORDINATION AND INTEGRATION

Hormones are chemical messengers produced in trace amounts. They regulate growth, metabolism, reproduction and maintain homeostasis.

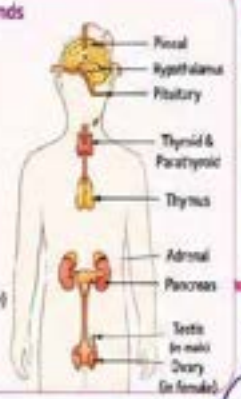
1. ENDOCRINE SYSTEM ★

- Consists of ductless glands and hormone producing tissues/cells.
- Hormones are released into blood and act on target organs.

2. HUMAN ENDOCRINE SYSTEM ★

Major endocrine glands

- Hypothalamus
- Pituitary
- Pineal
- Thyroid
- Parathyroid
- Thymus
- Adrenal
- Pancreas
- Gonads (Testis, Ovary)



3. MECHANISM OF HORMONE ACTION ★

A. Hormones with membrane receptors
(Peptide/Protein hormones)

Hormone + Receptor → Hormone-Receptor complex → Second messenger (e.g. cAMP, IP3, Ca^{2+}) → Cellular response

B. Hormones with intracellular receptors
(Steroid, Thyroid hormones)

Hormone → Receptor (in cytoplasm) → Hormone-Receptor complex → Enters nucleus and acts on DNA → Gene expression → Cellular response

4. ENDOCRINE GLANDS AND THEIR HORMONES ★

Hypothalamus
Releasing & inhibiting hormones regulate pituitary.

Pituitary
"Master gland"
Controls other glands.
(See functions in right map)

Pineal
Melatonin
Regulates sleep-wake cycle (24-hour rhythm).

Thyroid
T3, T4 (thyroxine)
↑ BMR, growth, metabolism.
Calcitonin ↓ blood Ca^{2+} level.

Parathyroid
PTH
↑ blood Ca^{2+} level.
Ca^{2+} homeostasis.

Thymus
Thymosin
Maturation of T-lymphocytes, immunity.

Adrenal
Cortex: Cortisol, Aldosterone
Medulla: Adrenaline, Noradrenaline

Pancreas
Insulin ↓ blood glucose
Glucagon ↑ blood glucose

Gonads
Testis: Testosterone
Ovary: Estrogen, Progesterone

5. DISORDERS DUE TO HORMONAL IMBALANCE

- **Dwarfism** — ↓ Growth hormone in childhood
- **Gigantism** — ↑ Growth hormone in childhood
- **Acromegaly** — ↑ Growth hormone in adult
- **Cretinism** — ↓ Thyroid hormone in childhood
- **Goitre** — Iodine deficiency → enlarged thyroid
- **Exophthalmic Goitre** (Graves' disease) — Hyperthyroidism with bulging eyes
- **Diabetes Mellitus** — ↓ Insulin or insulin resistance
- **Addison's Disease** — ↓ Adrenal cortex hormones

6. HORMONES FROM OTHER ORGANS ★

- **Heart** → Atrial Natriuretic Factor (ANF) → Decreases blood pressure (Dilates blood vessels)
- **Kidney** → Erythropoietin (EPO) → Stimulates RBC formation
- **Gastrointestinal Tract**
  - Gastrin → Stimulates HCl & pepsinogen secretion
  - Secretin → Stimulates pancreatic secretion of HCO_3^- and water
  - Cholecystokinin (CCK) → Stimulates pancreatic enzymes & gall bladder contraction
  - Gastric Inhibitory Peptide (GIP) → Inhibits gastric secretion and motility

7. KEY POINTS

- Hormones travel in blood and act on specific target organs.
- Each hormone has specific receptors in target cells.
- Hormones maintain homeostasis by positive and negative feedback.
- Neural system is fast and short-lived; endocrine system is slow but long-lasting.
- Hormones regulate growth, metabolism, reproduction, stress response and other body functions.

Remember!
Endocrine system works with nervous system to coordinate and integrate the activities of the body.

Test Your Knowledge

Quiz			
Chapter 1 : The Living World	Chapter 6 : Anatomy of Flowering Plants	Chapter 11 : Photosynthesis in Higher Plants	Chapter 16 : Excretory Products and their Elimination
Chapter 2 : Biological Classification	Chapter 7 : Structural Organisation in Animals	Chapter 12 : Respiration in Plants	Chapter 17 : Locomotion and Movement
Chapter 3 : Plant Kingdom	Chapter 8 : Cell : The Unit of Life	Chapter 13 : Plant Growth and Development	Chapter 18 : Neural Control and Coordination
Chapter 4 : Animal Kingdom	Chapter 9 : Biomolecules	Chapter 14 : Breathing and Exchange of Gases	Chapter 19 : Chemical Coordination and Integration
Chapter 5 : Morphology of Flowering Plants	Chapter 10 : Cell Cycle and Cell Division	Chapter 15 : Body Fluids and Circulation	

Question Bank			
Chapter 1 : The Living World	Chapter 6 : Anatomy of Flowering Plants	Chapter 11 : Photosynthesis in HigherPlants	Chapter 16 : Excretory Products and their Elimination
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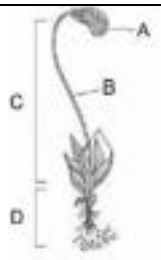
CBSE CLASS 11 BIOLOGY SAMPLE PAPER - 2026-27

Question Paper & Answer Scheme

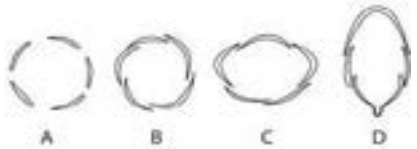
General Instructions:

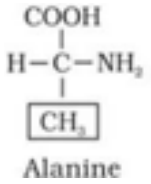
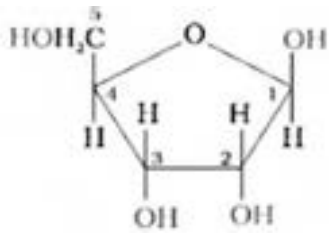
Read the following instructions carefully and follow them:

1. **Question paper is divided into FIVE sections – Section A, B, C, D and E.**
2. **Section A – questions number 1 to 16 are multiple choice type questions. Each question carries 1 mark.**
3. **Section B – questions number 17 to 21 are very short answer type questions. Each question carries 2 marks.**
4. **Section C – questions number 22 to 28 are short answer type questions. Each question carries 3 marks.**
5. **Section D – questions number 29 and 30 are case-based questions. Each question carries 4 marks. Each question has subparts with internal choice in one of the subparts.**
6. **Section E – questions number 31 to 33 are long answer type questions. Each question carries 5 marks.**
7. **There is no overall choice. However, internal choices have been provided in some questions. A candidate has to write answer for only one of the alternatives in such questions.**
8. **Kindly note that there is a separate question paper for Visually Impaired candidates.**
9. **Wherever necessary, neat and properly labelled diagrams should be drawn.**

S.No	QUESTION/EXPECTED OUTCOMES/VALUE POINTS	Marks	Total Marks
	SECTION – A		
1	Choose the incorrect match. a) Order - a group of related families b) Genus - a group of related species c) Class - a group of related order d) Division - a group of related phyla **Answer: d) Division - a group of related phyla**	1	1
2	Deuteromycetes are called imperfect fungi because a) Sexual reproduction has not been observed b) They lack zygospore c) They form conidiospores d) All of the above **Answer: d) All of the above**	1	1
3	**In the given figure A, B, C, and D represent** a) A – Apophysis, B – Capsule, C – Sporophyte, D – Gametophyte b) A – Capsule, B –Seta, C – Sporophyte, D – Gametophyte c) A – Apophysis, B –Seta, C – Sporophyte, D – Gametophyte d) A – Apophysis, B – Capsule, C – Gametophyte, D – Sporophyte **Answer: b) A – Capsule, B –Seta, C – Sporophyte, D – Gametophyte** 	1	1
4	The option that is not the respiratory organ of phylum Arthropoda is a) Tracheal system b) Gills c) Water vascular system d) Book lungs **Answer: c) Water vascular system**	1	1
5	In most simple type of canal system of Porifera, water flows through which of the following way?	1	1

	(a) Ostia → Spongocoel → Osculum → Exterior (b) Spongocoel → Ostia → Osculum → Exterior c) Osculum → Spongocoel → Ostia → Exterior d) Osculum → Ostia l → Spongocoel→ Exterior **Answer: a) Ostia → Spongocoel → Osculum → Exterior**		
6	In racemose inflorescence, flowers are arranged in a) centrifugal order b) centripetal order c) acropetal order d) basipetal order **Answer: c) acropetal order**	1	1
7	Match the following. COLUMN 1 / COLUMN 2 A. Structural and functional unit of a myofibril — I. H zone B. Protein of thin filament — II. Myosin C. Protein of thick filament — III. Sarcomere D. Central part of thick filament not overlapped by thin filament — IV. Actin V. **Codes** A B C D (a) I II III IV (b) I III II IV (c) I IV III II (d) III IV II I **Ans: (d) III IV II I**	1	1
8	How many equational divisions are necessary in a cell of onion root tip to form 128 cells (a) 64 (b) 128 (c) 6 (d) 7 **Answer: (d) 7**	1	1
9	Mobilization of stored food in germinating seeds is triggered by (a) auxins (b) cytokinins (c) gibberellins (d) ethylene **Answer: (c) gibberellins**	1	1
10	The proportion of PAR from the total incident solar radiation is (a) about 60% (b) about 70% (c) more than 80% (d) less than 50% **Answer: (d) less than 50%**	1	1
11	In the resting stage of a neuron, concentration gradient generates due to the (a) High concentration of *K*+ and low concentration of *Na*+ inside the axon (b) High concentration of *Na*+ and low concentration of *K*+ inside the axon (c) Low concentration of *Na*+ outside the axon (d) High concentration of *K*+ outside the axon **Answer: (a) High concentration of *K*+ and low concentration of *Na*+ inside the axon**	1	1
12	Oxyhaemoglobin dissociation at tissues occurs under **a)** Low pO_2 and low pCO_2 b) Low pO_2, high pCO_2 and high H^+ **b)** Low pO_2 and low H^+ and low pCO_2 d) Low pO_2 and low H^+ and high pCO_2 **Answer: b) Low pO_2, high pCO_2 and high H^+**	1	1

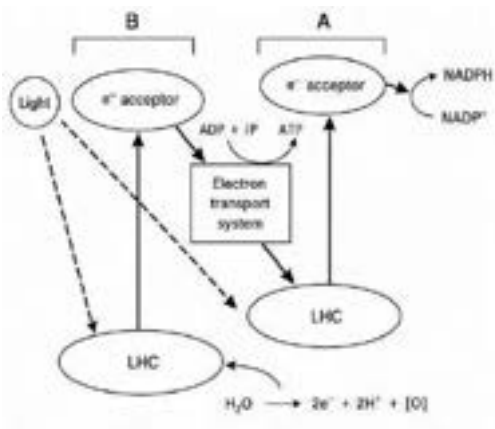
13	Assertion (A): RAAS gets activated in a person suffering from diarrhoea. Reason (R): Both loss of water and electrolytes takes place in such a patient. **Answer: (A) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation.**	1	1
14	Assertion (A): A person with blood group O is considered to be universal recipient. Reason (R): O blood group has no antigens, but have anti-A and anti-B antibodies. **Answer: D) If A is false , but R is true.**	1	1
15	Assertion (A): The myosin rich zone called A-band maintains its length during sarcomere constraction. Reason (R): The length of I-band remains the same during muscle contraction. **Answer: (C) Assertion (A) is true, but Reason (R) is false.**	1	1
16	Assertion (A): ADH increases the volume of urine by increasing the reabsorption of water from the urine. Reason (R): Failure of secretion of ADH causes diabetes insipidus. **Answer: (D) Assertion (A) is false, but Reason (R) is true.**	1	1
	SECTION – B		
17	Give reason: A. Sea appear red (red tides). B. Deuteromycetes known as imperfect fungi. C. Diatoms form diatomaceous earth. D. Viruses did not find a place in classification **Answer:** A. **Sea appears red during red tides** because of the rapid multiplication (blooms) of red-pigmented dinoflagellates such as Gonyaulax in seawater. B. **Deuteromycetes are called imperfect fungi** because their sexual stage of reproduction is absent or not known. C. **Diatoms form diatomaceous earth** because their cell walls contain silica and accumulate in large amounts at the bottom of water bodies after death, forming deposits called diatomaceous earth. D. **Viruses do not find a place in classification** because they show characteristics of both living and non-living organisms and can reproduce only inside living host cells.	1/2x4	2
18	The male and female frog can be identified by the difference in their morphological features. A. Name this phenomenon. B. Give two differences between male and female frogs. **A.** The phenomenon is called **sexual dimorphism**. **B.** Two differences between male and female frogs: 1. Male frogs are usually smaller, while female frogs are larger in size. **2.** Male frogs possess vocal sacs and copulatory pad on the first digit of the forelimbs, while female frogs do not. **OR** The figure given below shows different types of aestivation: a) How is 'B' different from 'C'? b) In 'D' they have different types petals like keel, wings, standard. Arrange them in correct order. Answer: **B – Twisted aestivation C – Imbricate aestivation**  	1 1 1	2

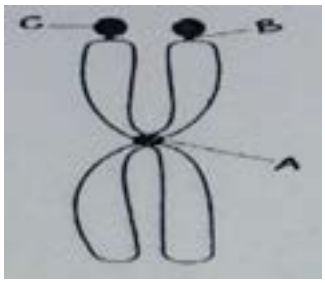
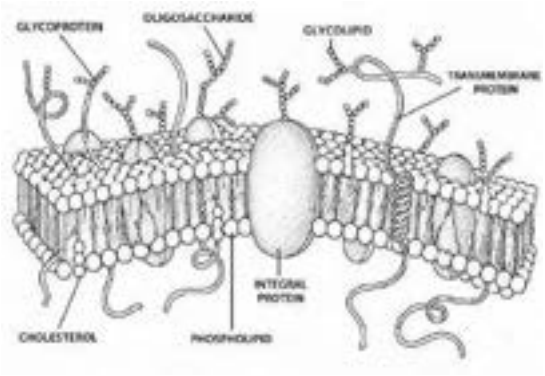
	In **D,** the petals belong to a **papilionaceous corolla** (vexillary aestivation). Their correct arrangement is: 1.**Standard (vexillum)** – outermost large petal 2.**Wings** – two lateral petals 3.**Keel** – two innermost fused petals		
19	Draw the structure of alanine amino acid and ribose sugar. Answer:  Alanine  	1+1	2
20	What is stroke volume? What is its relation with cardiac output. **OR** What is neuromuscular junction and how a neural signal cause the release of calcium ions into the sarcoplasm? Answer: **Stroke volume** is the amount of blood pumped out by one ventricle of the heart during a single heartbeat. • In a healthy adult at rest, it is about **70 mL per beat**. The relation between **stroke volume** and **cardiac output** is: Cardiac Output = Stroke Volume X Heart Rate Where: • **Cardiac Output (CO)** = total blood pumped by the heart per minute • **Stroke Volume (SV)** = blood pumped per beat • **Heart Rate (HR)** = number of beats per minute Example: If SV = 70 mL/beat and HR = 72 beats/min, CO = 70 X 72 = 5040 ml/min approx. = 5 l/min So, cardiac output increases if either stroke volume or heart rate increases. **OR** A **neuromuscular junction** is the junction between a motor neuron and a skeletal muscle fibre where the nerve impulse is transmitted to the muscle. It includes: • the axon terminal of the neuron, • the synaptic cleft, • and the motor end plate of the muscle fibre. A neural signal cause the release of calcium ions into the sarcoplasm as follows: 1. A nerve impulse reaches the axon terminal of the motor neuron at the neuromuscular junction. 2. The neurotransmitter **acetylcholine (ACh)** is released into the synaptic cleft. 3. ACh binds to receptors on the muscle membrane (sarcolemma), causing depolarization and generation of a muscle action potential.	+1 1 + 1	2

	4. The action potential spreads over the sarcolemma and travels down the **T-tubules.** 5. This stimulates the **sarcoplasmic reticulum (SR)** to open calcium channels. 6. Calcium ions (Ca^{2+}) are released from the SR into the **sarcoplasm**. **7.** The released calcium binds to **troponin,** allowing actin and myosin interaction, which initiates muscle contraction.		
21	Give the name of the nitrogenous waste which is produced in birds. In what form is it eliminated from the body? What is the advantage of this type of excretion? Answer: Birds excrete uric acid in the form of pellet or paste (semi-solid) form. It helps in conservation of water.	½+ ½ +1	2
	SECTION – C		
22	The predominant stage of the life cycle of moss is the gametophyte which consists of two stages. a) What are these two stages and how they developed. b) Name two examples of mosses. The dominant gametophyte of moss has two stages: 1. **Protonema stage** o It is the first stage that develops from the germination of a spore. o It is green, branched, and filamentous, resembling algae. 2. **Leafy stage (gametophore)** o Buds arise from the protonema and develop into the upright leafy plant body. o This stage bears the sex organs: ▪ **Antheridia** (male) ▪ **Archegonia** (female) • **E.g.** Funaria, Sphagnum	 1 1 1	3
23	Observe the given figure showing various types of placentation. Identify the type of placentation. Give one example of each. Answer: a) Marginal e.g. Pea b) Parietal e.g. Watermelon c) Free Central e.g. Primrose 	1/2x6	3
24	Non-protein constituents called cofactors are bound to the enzyme to make the enzyme catalytically active. a) Name the protein portion of enzyme. b) What happens to the catalytic activity when the cofactor is removed from the enzyme. c) Mention any two kind of cofactors with examples. Answer: a) The protein portion of an enzyme is called the apoenzyme. b) When the cofactor is removed, the enzyme becomes inactive and loses its catalytic activity. The complete active enzyme is called a holoenzyme. c) Two kinds of cofactors with examples are: 1. Coenzyme – organic non-protein cofactors o Example: NAD^+, Coenzyme A 2. Prosthetic group – tightly bound cofactors o Example: Haem in catalase and peroxidase enzymes **OR**	 1 1 ½+ ½ 2 1	3

	a) Identify the substages of meiosis in which following events occurs b) i)Synapsis ii) Terminalisation of chiasmata c) iii)Appearance of recombination nodules iv) Crossing over. Answer: Substages of Prophase I of meiosis: i) Synapsis → Zygotene ii)Terminalisation of chiasmata → Diakinesis iii)Appearance of recombination nodules → Pachytene iv)Crossing over → Pachytene **c)** Write one significance of meiosis in sexually reproducing organisms. Answer: One significance of meiosis in sexually reproducing organisms is that it **maintains the chromosome number constant** from generation to generation. Meiosis reduces the chromosome number to half in gametes, and fertilization restores the diploid number.		
25	There are different types of plastids in plant cells. Name them and write their functions Answer: The different types of plastids in plant cells are: i)Chloroplasts - Contain chlorophyll. Function: Carry out photosynthesis and prepare food. ii)Chromoplasts - Contain coloured pigments like carotenoids. Function: Give colour to fruits and flowers. iii)Leucoplasts - Colourless plastids mainly found in underground parts. Function: Store food materials such as starch, oils, and proteins.	½x6	3
26	Give the schematic representation of Kreb'scycle. Answer: The **Krebs cycle** (also known as the citric acid cycle or TCA cycle) is a series of eight mitochondrial chemical reactions used by aerobic organisms to release stored energy through the oxidation of acetyl-CoA. It generates ATP, CO_2, and energy carriers (NADH,FADH) for the electron transport chain.	**½** **½** 1 **½** **½**	3
27	In what kind of plants do you come across Kranz anatomy ? To which conditions are those plants better adapted? How are these plants better adapted than the plants which lack this anatomy? Answer: Kranz anatomy is found in **C4 plants** such as Maize, Sugarcane, and Sorghum. The word KRANZ means "wreath," referring to the ring-like arrangement of bundle sheath cells around the vascular bundles in their leaves. C4 plants are especially well adapted to: • **High temperatures** • **Intense sunlight** • **Dry or semi-arid conditions** • **Low carbon dioxide concentrations** In C4 plants, photosynthesis occurs with the help of a special mechanism involving mesophyll cells and bundle sheath cells (Kranz anatomy). This gives them several advantages over plants lacking Kranz anatomy (mostly C3 plants): 1. **Reduced photorespiration** C4 plants concentrate CO_2 around the enzyme RuBisCO, preventing oxygen from competing with CO_2. This greatly reduces wasteful photorespiration.	1 1 1	3

	2. **Higher photosynthetic efficiency** They can continue efficient photosynthesis even under high temperature and bright light. 3. **Better water-use efficiency** Their stomata do not need to remain open for long periods, so less water is lost through transpiration. 4. **Greater productivity in hot climates** Because less energy is wasted and water loss is reduced, C4 plants grow faster and produce more biomass in tropical and subtropical regions. So, compared with plants lacking Kranz anatomy, C4 plants are more efficient in hot, dry environments and perform photosynthesis more effectively under stressful conditions.		
28	i) Name the excretory organs found in Aschelminthes and leeches. ii) Name the arterioles through which blood enters and leaves the glomerulus. iii) Name the collecting tubules converge into a short and thick duct. Answer: i) • In Aschelminthes, the excretory organs are **renette cells** (or an H-shaped excretory canal system). • In Leech, the excretory organs are **nephridia**. ii) • Blood enters the glomerulus through the **afferent arteriole**. • Blood leaves the glomerulus through the **efferent arteriole**. iii) The collecting tubules converge into a short and thick duct called the **duct of Bellini** (papillary duct).	1 1 1 1	3
	SECTION – D Question Nos. 29 and 30 are case-based questions. Each question has subsections with internal choice in one sub-section.		
29	A student prepared transverse sections of stems from two angiosperm plants, P and Q, and observed the following features under the microscope: • In Plant P, vascular bundles were arranged in a ring. Cambium was present between xylem and phloem. • In Plant Q, vascular bundles were scattered throughout the ground tissue. Cambium was absent, and each vascular bundle was surrounded by a sclerenchymatous bundle sheath. • Both plants possessed xylem and phloem tissues for conduction. The student concluded that both plants belong to the same category of angiosperms because both contain vascular tissues. i) Identify the type of vascular bundles present in Plant P and Plant Q. Ans: Type of vascular bundles • **Plant P:** Conjoint, collateral, **open** vascular bundles (because cambium is present). • **Plant Q:** Conjoint, collateral, **closed** vascular bundles (because cambium is absent). ii) State whether Plant P and Plant Q are monocots or dicots. Ans: Type of angiosperms • Plant P: Dicot stem • Plant Q: Monocot stem	1x4	4

	iii) Give one structural difference in the arrangement of vascular bundles between the two plants. Ans: iii) One structural difference in arrangement of vascular bundles • In Plant P, the vascular bundles are arranged **in a ring** near the periphery. • In Plant Q, the vascular bundles are **scattered throughout the ground tissue**. iv) Why is the student's conclusion incorrect? Explain logically. Ans: The student's conclusion is incorrect because the mere presence of vascular tissues (xylem and phloem) only shows that both are vascular plants, not that they belong to the same category of angiosperms. Plant P shows dicot features: vascular bundles in a ring, presence of cambium, open vascular bundles. Plant Q shows monocot features: scattered vascular bundles, absence of cambium, closed vascular bundles with bundle sheath. Therefore, although both plants have vascular tissues, they belong to different categories of angiosperms: dicots and monocots. **OR** What is the difference between conjoint and radial vascular bundles and where are they found? Answer: In conjoint vascular bundles xylem and phloem occur in the same bundle, on same radius. E.g. Stems In radial vascular bundles xylem and phloem occur on different radius alternating with each other. E.g. Roots		
30	Observe the figure and answer the questions given below:  i) Identify A and B and name the process. Ans: A - Photosystem I, B - Photosystem II Process – Non – cyclic photophosphorylation/ Z scheme ii) What is the function of the electron transport system in the diagram? **Answer:** The electron transport system transfers electrons from Photosystem II to Photosystem I and helps in the formation of ATP. iii) What is the role of LHC in photosynthesis? **Answer:** LHC (Light Harvesting Complex) absorbs light energy and transfers it to the reaction centre of the photosystem. iv) What are the products formed by the splitting of water in the light reaction? **Answer:** Splitting of water produces electrons ($2e^-$), protons ($2H^+$), and oxygen ([O]). **OR** ii)Why did ATP synthesis continue for a short duration even after NADPH production stopped? Ans: ATP synthesis continue for a short duration even after NADPH production stopped because electron flows can shift from non-cyclic to cyclic photophosphorylation.	1x4	4
	SECTION – E		
31	Attempt either option A or B. A i. Highlight the important characteristics of Chordates. (Any four) ii. Differentiate the class Chondrichthyes from Osteichthyes, give examples of each class.	2 3	5

	OR B. Provide a technical term for the following and the phylum in which it belongs: a. Balancing organ in Cockroach _____ _____ b. A stinging organ of jellyfish _____ _____ c. Free-floating form of sea anemones _____ _____ d. Rasping organ in snails / pila. _____ _____ e. Common opening of alimentary and urogenital tract. _____ _____	1/2x10	
32	The nucleoplasm contains small spherical shaped structures. a) Name the structures and their function. b) Name the openings seen in nuclear envelope and state their function. c) Name the type of chromosomes on the basis of position of centromere and label the parts A, B and C.  a) The small spherical structures present in the nucleoplasm are called **nucleoli.** **Function:** They help in the synthesis of ribosomal RNA (rRNA) and formation of ribosomes. b) The openings in the nuclear envelope are called **nuclear pores.** **Function:** They allow exchange of materials such as RNA, proteins, and other substances between the nucleus and cytoplasm. c) The chromosome shown is an **acrocentric chromosome** because the centromere is situated near one end. **Labels:** • **A** → Centromere • **B** → Satellite • **C** → Telomere	2 2 1	5
	OR Q. Explain the fluid mosaic model of plasma membrane with the help of diagram and explain different modes of transport by giving examples. Ans: The **Fluid Mosaic Model** was proposed by S. J. Singer and G. L. Nicolson in 1972. According to this model, the plasma membrane is a thin, flexible, and dynamic structure made of lipids and proteins.  **Explanation of Fluid Mosaic Model** 1. The plasma membrane is mainly composed of a **phospholipid bilayer**. 2. Phospholipids are arranged with: ○ Hydrophilic heads facing outward ○ Hydrophobic tails facing inward 3. Proteins are embedded within the lipid bilayer like a mosaic pattern.	5	

	4. Some proteins are partially embedded, while others pass completely through the membrane. 5. Cholesterol molecules help maintain membrane fluidity. 6. The membrane is flexible and allows movement of substances across it. **Modes of Transport Across Plasma Membrane** 1. Passive Transport Movement of substances from higher concentration to lower concentration without using energy. Diffusion - Movement of molecules from a region of higher concentration to lower concentration. **Example:** Movement of oxygen and carbon dioxide across the membrane. Higher concentration → Lower concentration Osmosis - Movement of water through a semipermeable membrane from higher water concentration to lower water concentration. **Example:** Absorption of water by root hairs. 2. Facilitated Diffusion Movement of substances through special carrier proteins without energy. **Example:** Transport of glucose into cells. 3. Active Transport Movement of substances against the concentration gradient using ATP energy. **Example:** Absorption of mineral ions by plant roots; sodium-potassium pump in animal cells. ATP → Energy for active transport 4. Endocytosis Cell membrane engulfs materials to bring them inside the cell. **Example:** Amoeba engulfing food particles. 5. Exocytosis Removal of materials from the cell by fusion of vesicles with the plasma membrane. **Example:** Secretion of hormones and enzymes.		
33	a) In old age people suffer from stiffness and inflammation in joints. What is this condition called? What is the cause of osteoporosis? Ans: The condition in which old people suffer from stiffness and inflammation in joints is called **arthritis.** **Cause of osteoporosis:** Osteoporosis is caused by a decrease in bone density due to loss of calcium and minerals from bones. It commonly occurs because of ageing, hormonal changes, and deficiency of calcium or vitamin D. b) Explain the sliding theory of the mechanism of muscle contraction. Ans: The **sliding filament theory** explains the mechanism of muscle contraction. According to this theory, muscle contraction occurs when thin filaments slide over thick filaments, shortening the muscle fibre without changing the length of the filaments. 1. **Structure of Muscle Fibre** Muscle fibres contain two types of protein filaments: ○ **Actin** (thin filament) ○ **Myosin** (thick filament)	2 3	5

2. **Stimulation by Nerve Impulse**
   A nerve impulse reaches the muscle fibre and releases calcium ions from the sarcoplasmic reticulum.
3. **Formation of Cross Bridges**
   Calcium exposes the binding sites on actin. The heads of myosin attach to actin forming cross bridges.
4. **Sliding of Filaments**
   Using energy from ATP, myosin heads pull the actin filaments inward. As a result, actin filaments slide over myosin filaments.
5. **Shortening of Sarcomere**
   The distance between Z-lines decreases and the sarcomere shortens, causing muscle contraction.
6. **Relaxation**
   When stimulation stops, calcium ions return to storage sites, cross bridges break, and the muscle relaxes.

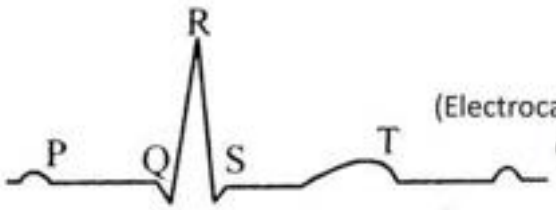
ATP → Energy for sliding of actin over myosin

3

OR

Draw a standard ECG and explain the different segments in it.

Ans:



A standard ECG (Electrocardiogram) records the electrical activity of the heart.

1. **P Wave**
   - Represents depolarization (contraction) of the atria.
   - Indicates the beginning of atrial systole.
2. **QRS Complex**
   - Represents depolarization of the ventricles.
   - Ventricular contraction begins during this phase.
   - Atrial repolarization also occurs here but is hidden.
3. **T Wave**
   - Represents repolarization (relaxation) of the ventricles.
   - Indicates the beginning of ventricular relaxation.
4. **P–Q Segment (P–R Interval)**
   - Time taken for the impulse to travel from atria to ventricles through the AV node.
5. **S–T Segment**
   - Represents the period when ventricles remain completely depolarized and contracting.
6. **R–R Interval**
   - Time between two successive heartbeats.
   - Used to calculate heart rate.

KENDRIYA VIDYALAYA SANGATHAN

SAMPLE QUESTION PAPER-01 (UNSOLVED)

SESSION ENDING EXAMINATION 2025-26

SUBJECT – (044) BIOLOGY

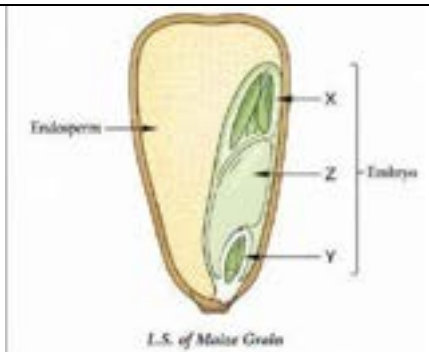
CLASS - XI

Maximum Marks: 70 **Time: 3 Hours**

General Instructions:

- All questions are compulsory.
- The question paper has five sections and 33 questions.
- **Section–A** has 16 questions of 1 mark each; **Section–B** has 5 questions of 2 marks each; **Section– C** has 7 questions of 3 marks each; **Section– D** has 2 case-based questions of 4 marks each; and **Section–E** has 3 questions of 5 marks each.
- There is no overall choice. However, internal choices have been provided in some questions. A student has to attempt only one of the alternatives in such questions.
- Wherever necessary, neat and properly labelled diagrams should be drawn.

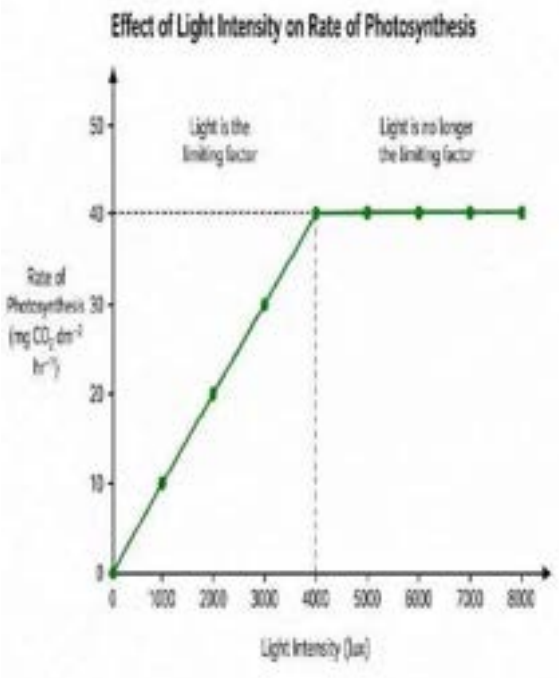
SECTION – A		
Q. NO	**QUESTION**	**MARKS**
1.	Match column I with column II for housefly classification and select the correct option using the codes given below. COLUMN I COLUMN II A. Family (i) Diptera B. Order (ii) Arthropoda C. Class (iii) Muscidae D. Phylum (iv) Insecta (a) A-(iii), B-(i), C-(iv), D-(ii) (b) A-(iii), B-(ii), C-(iv), D-(i) (c) A-(iv), B-(iii), C-(ii), D-(i) (d) A-(iv), B-(ii), C-(i), D-(iii)	1
2.	In which one of the following, the genus name, its two characters and its phylum are not correctly matched, whereas the remaining three are correct? *(a)* Pila (i) Body segmented Mollusca (ii) Mouth with radula *(b)* Asterias (i) Spiny skinned Echinodermata (ii) Water vascular system (c)Sycon (i) Pore bearing Porifera (ii) Canal system *(c)* Periplaneta (i) Jointed appendages Arthropoda (ii) Chitinous exoskeleton	1

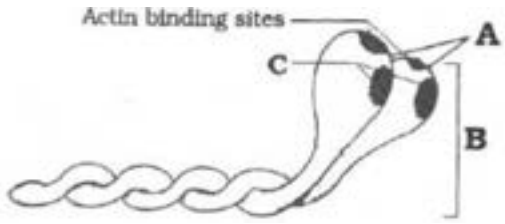
3.	Select the correct route for the passage of sperms inmale frogs. (a) Testes →Vasa efferentia →Kidney →Seminalvesicle →Urinogenital duct →Cloaca (b) Testes →Vasa efferentia →Bidder's canal Ureter →Cloaca (c) Testes →Vasa efferentia →Kidney →Bidder'scanal →Urinogenital duct →Cloaca (d) Testes →Bidder's canal →Kidney →Vasaefferentia →Urinogenital duct →Cloaca	1
4.	Select the correct combination of the statements (a-d) regarding the characteristics of certain organisms (1) Methanogens are Archaebacteria which produce methane in marshy areas. (2) Nostoc is a filamentous blue-green alga which fixes atmospheric nitrogen. (3) Chemosynthetic autotrophic bacteria synthesize cellulose from glucose. (4) Mycoplasma lack a cell wall and can survive without oxygen. The correct statements are (a) (2), (3) (b) (1), (2), (3) (c) (2), (3), (4) (d) (1), (2), (4)	1
5.	A student observed the following labelled diagram of a maize grain embryo: • Part X • Part Y • Part Z The teacher asked students to identify Part Z. Part Z is called: (a) Plumule (b) Coleorhiza (c) Coleoptile (d) Scutellum  *L.S. of Maize Grain*	1
6.	Choose the incorrect statement from the following? (a) Cofactor plays crucial role in catalytic activity of the enzymes (b) Zn is activator of carboxypeptidase (c) Coenzymes are inorganic compounds (d) Catalase and peroxidase have haem as prosthetic group	1
7.	Read the following five statements (A to E) and select the option with all correct statements (1) Mosses and Lichens are the first organisms to colonise a bare rock. (2) Selaginella is a homosporous pteridophyte. (3) Coralloid roots in Cycas have VAM. (4) Main plant body in bryophytes is gametophytic, whereas in pteridophytes it is sporophytic. (5) In gymnosperms, male and female gametophytes are present within sporangia located on sporophyte. Options: (a) (2), (3) and (5) (b) (1), (3) and (4) (c) (2), (3) and (4) (d) (2), (4) and (5)	1
8.	Which statement is wrong for Krebs' cycle? (a) There is one point in the cycle where FAD+ is reduced to $FADH_2$. (b) During conversion of succinyl CoA to succinic acid, a molecule of GTP is synthesised.	1

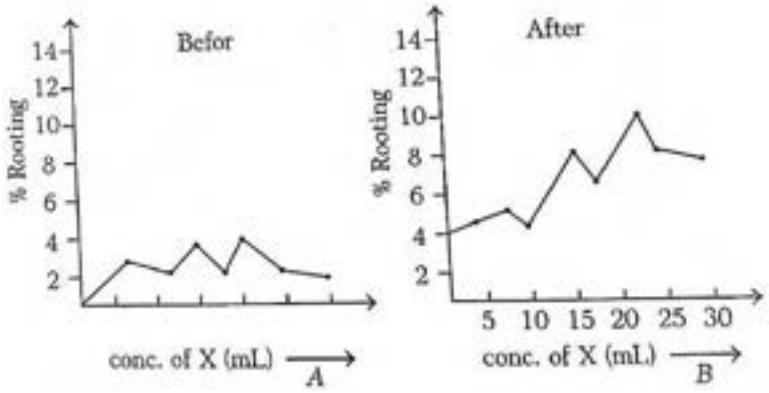
	(c) The cycle starts with condensation of acetyl group (acetyl CoA) with pyruvic acid to yield citric acid. (d) There are three points in the cycle where NAD+ is reduced to NADH + H+.	
9.	Which of the following hormones of the gastrointestinal tract is wrongly matched with its function? Select the correct option.	1
10.	During intense physical exercise, the concentration of carbon dioxide in blood increases. This stimulates the respiratory control centers in the brain to maintain normal gas balance in the body. Based on this information, what happens when the CO_2 level increases in blood? (a) Respiration rate become faster to compensate oxygen requirement. (b) Chemosensitive area adjacent to respiratory rhythm center gets activated. (c) Respiratory rhythm center in medulla gets activated to regulate breathing rate. (d) All the above	1
11.	The following graph shows the relationship between light intensity and the rate of photosynthesis in a green plant. After a certain point, the graph becomes constant even when light intensity increases further. What is the most appropriate reason for this observation? (a) Chlorophyll gets destroyed completely (b) Light is no longer the limiting factor (c) Carbon dioxide production stops (d) Oxygen inhibits photosynthesis immediately	1

	Column I		Column II
A	Gastrin	1	Inhibition of gastric secretions
B	Gastric inhibitory peptide (GIP)	2	Stimulates secretion of pancreatic juice and bile juice
C	Secretin	3	Secretion of gastric juice
D	Cholecystokinin	4	Stimulates secretion of pancreatic juice

	A	B	C	D
a	3	1	4	2
b	2	1	4	3
c	3	4	2	1
d	2	3	4	1



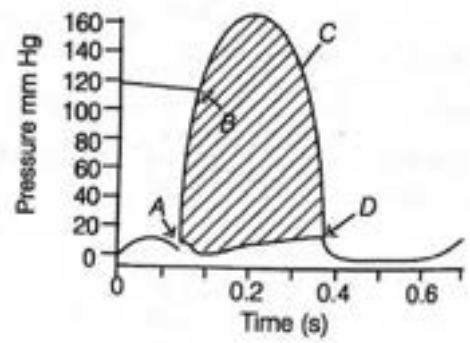
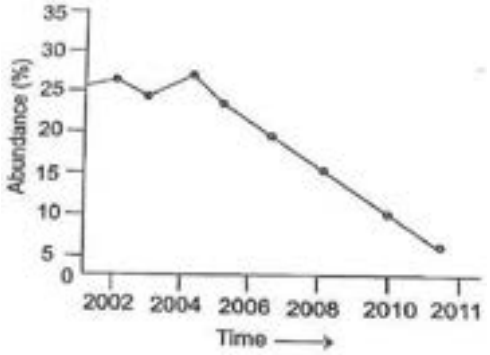
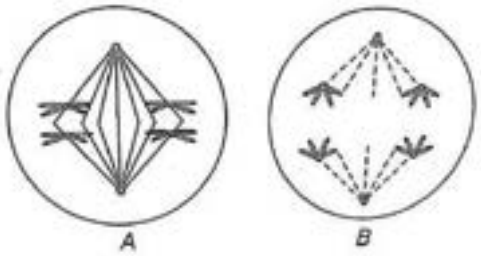
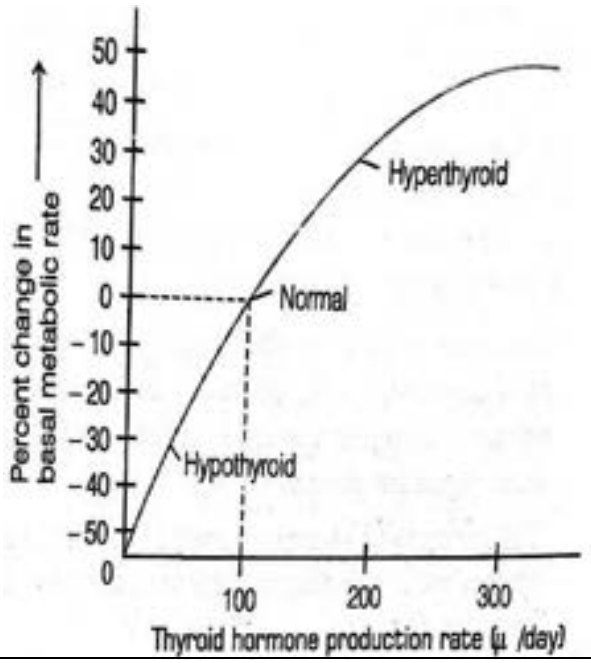
12.	The above figure is related with myosin monomer (meromyosin). Identify A to C – (A) A-head, B -cross arm, C -GTP binding sites (B) A-head, B -cross arm, C -$Ca+^2$ binding sites (C) A-head, B -cross arm, C -ATP binding sites (D) A-cross arm, B -head, C -ATP binding sites 	1
Question No. 13 to 16 consist of two statements – Assertion (A) and Reason (R). Answer these questions selecting the appropriate option given below: A. Both A and R are true and R is the correct explanation of A. B. Both A and R are true and R is not the correct explanation of A. C. A is true but R is false. D. A is False but R is true		
13.	**Assertion (A):** In Liverworts, both male and female sex organs may be present on same thalli or different thalli. **Reason (R):** A sporophyte is formed from the zygote which is differentiated into foot, seta and capsule.	1
14.	**Assertion (A):** In lymphatic system, lymph is known as tissue fluid. **Reason (R):** It comprises of plasma proteins, RBCs and WBCs.	1
15.	**Assertion (A):** Apical dominance is decreased by removal of shoot tip. **Reason (R):** Due to accumulation of auxin in lateral parts, growth is inhibited.	1
16.	**Assertion (A):** Transmission of nerve impulse across a synapse is accomplished by neurotransmitters. **Reason (R):** Transmission across a synapse usually requires neurotransmitters because there is a small space, i.e., synaptic cleft, that separates one neuron from another.	1
SECTION – B		
17.	**"A healthy adult at rest processes roughly 420 Liters of air through tidal ventilation in one hour. However, during a period of moderate cardiovascular exercise, this hourly volume can increase up to fourfold, even though the total anatomical capacity of the lungs remains completely unchanged."** Based on this statement, analyze the following: 1. Formulate the physiological mechanism by which the body achieves this massive increase in hourly air volume without changing total lung size. 2. Deduce how the Anatomical Dead Space (the roughly 150 mL of air that stays in the conducting respiratory passages) impacts the efficiency of gas exchange when a person shifts from quiet breathing to shallow, rapid breathing under stress.	2
18.	A. Name the plants with coralloid roots and also give the role of coralloid roots. OR B. Which features were responsible for formation of seed habit in pteridophytes?	2
19.	A. Which of the following possess more characters in common? (i) Phylum or family	2

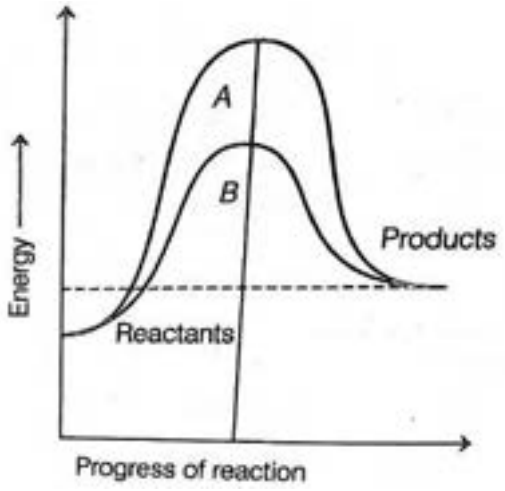
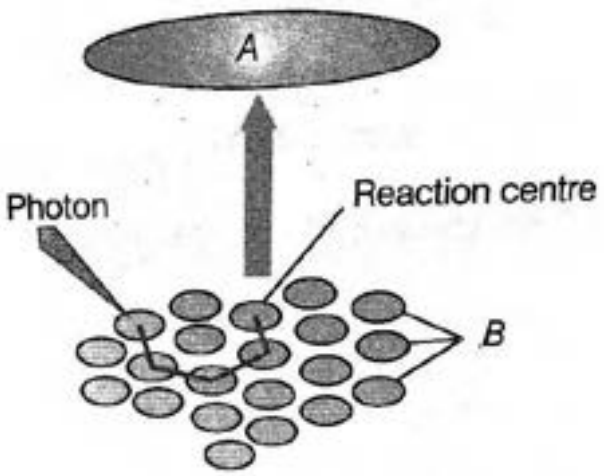
	(ii) Species or genus B. Give one reason for your answer.	
20.	A. (i) What does the term fluidity in plasma membrane signifies? (ii) Name any two method for passages of substances across the membrane. OR B. (i) Give the significance of cristae in mitochondria. (ii) How new mitochondria arises in the cell?	2
21.	A. Which one of the plant growth regulators would you use if you are asked to (i) quickly ripen a fruit. (ii) delay leaf senescence. (iii) bolt a rosette plant. (iv) induce immediate stomatal closure in leaves OR B. Plant growth regulators are the chemicals that controls the growth and development of the plants. Two graphs given below represent two conditions (A) Before and (B) After the application of a hormone.  (i) Which hormone is referred here as 'X'? (ii) Why is there a difference in the percentage of rooting as visible from the graphs above?	2
	SECTION – C	
22.	A biology student visited a fish market and observed two different groups of fishes. One group had a cartilaginous skeleton with multiple uncovered gill slits, while the other group had a bony skeleton and gills covered by an operculum. The student prepared the following comparison table:	3

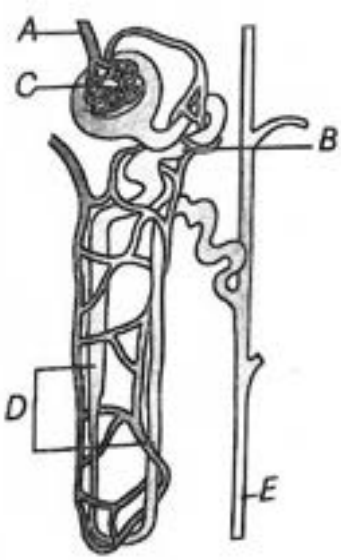
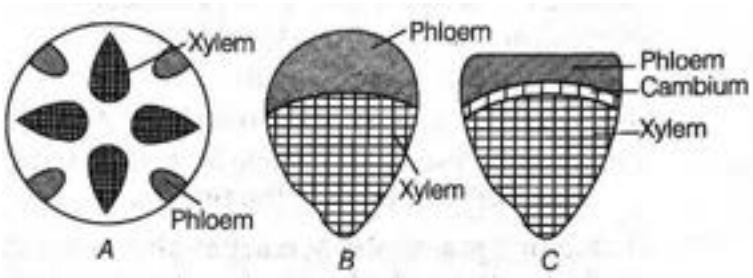
Feature	**Fish A**	**Fish B**
Endoskeleton	Cartilaginous	Bony
Gill covering	Absent	Present
Swim bladder	Absent	Present

Based on the above data, answer the following:

1. Identify the classes to which Fish A and Fish B belong.
2. Mention any two adaptive advantages of swim bladder in bony fishes.
3. Name one example each of Fish A and Fish B.

23.	Observe the given figure for cardiac cycle and answer following questions. (i) Give the labelling of A, B, C and D with respect to the opening and closure of the valve. (ii) Name the valve that produces lub and dub sound on its closure. 	3
24.	Given below is a graphical representation of abundance of lichens in a given area for a period of ten Years. Study the graph carefully and answer the following questions (i) What conclusion can be drawn from the graph? (ii) Give reason for your conclusion. (iii) Comment upon the components that make up lichens. 	3
25.	Give the schematic representation of Kreb's cycle.	3
26.	Observe the given figure for cell division and answer following questions. (i) Name the stages of cell division represented in A and B, respectively. (ii) Also explain any one of the stage from 'A' and 'B'. 	3
27.	The data below shows the levels of thyroid hormone production rate which can cause hypothyroidism and hyperthyroidism in the human. (i) With reference to the above graph what could be one of the reason behind hypothyroidism in the body? (ii) What symptoms can be seen if hypothyroidism occurs during pregnancy? (iii) Give two important function of thyroid hormone. 	3
28.	Give three differences between racemose inflorescence and cymose inflorescence	3

	SECTION – D	
29.	Enzymes catalyse reaction in specific manner. The reaction will be proceeded without enzyme but presence of enzyme makes a huge change in the rate of a reaction. Observe the given graph showing a chemical reaction taking place in the presence and absence of an enzyme. A. Based on the energy level difference between the substrate reactant and products identify the type of reaction. B. Which of the two curves depicts the reaction catalysed by enzyme? Give reason.  ***Attempt either subpart C or D.*** C. If a chemical closely resembling the substrate is added to the reaction, which of the curves in the graph will be affected? **OR** D. In which type of reaction the energy level of the product will be lower than the energy level of the substrate?	4 (1+2+1)
30.	Light is essential for photosynthesis. There are pigments that trtap light and the light energy is converted into chemical energy. These pigments get associated to form light harvesting complex. In the figure below, parts A and B shows the portion of the light harvesting complex. Study the figure and answer the questions that follows.  A. Label the parts marked as A and B in the figure. B. How does the both photosystems differentiates from each other in terms of a reaction centre? ***Attempt either subpart C or D.*** C. Give the significance of assessory photosynthetic pigments. **OR** D. Which type of chlorophyll pigment molecule is found in the reaction centre?	4 (1+2+1)

	SECTION – E	
31.	A. (i) Study the given structure carefully and label the parts given as A, B, C, D and E. (ii) Give one major function of each of these.  **OR** B. (i) How is glomerular filtrate maintained in hypertonic and hypotonic state in descending and ascending limb of loop of Henle, respectively? (ii) What is the effect of ADH on collecting tubules?	5
32.	A. (i) Identify the type A, B and C as indicated in the diagram below.  (ii) Name the type of plant and the plant part in which the above are found. (iii) Write any two difference by which you will identify T.S. of dicot stem from T.S. of dicot root? **OR** B. Describe the internal structure of a dorsiventral leaf with the help of labelled diagram.	5
33.	A. (i) What is a centromere? (ii) How does the position of centromere form the basis of classification of chromosomes? Support your answer with diagram showing the position of centromere on different types of chromosomes. **OR** B. (i) Mention three types of plastids with their functions. (ii) Give two types of ribosomes with their subunits.	5

KENDRIYA VIDYALAYA SANGATHAN

SAMPLE QUESTION PAPER-02

SESSION ENDING EXAMINATION

BIOLOGY (044)

CLASS XI

Maximum Marks: 70 **Time: 3 hours**

General Instructions:

(i) All questions are compulsory.

(ii) The question paper has five sections and 33 questions.

(iii) Section–A has 16 questions of 1 mark each; Section–B has 5 questions of 2 marks each; Section– C has 7 questions of 3 marks each; Section– D has 2 case-based questions of 4 marks each; and Section–E has 3 questions of 5 marks each.

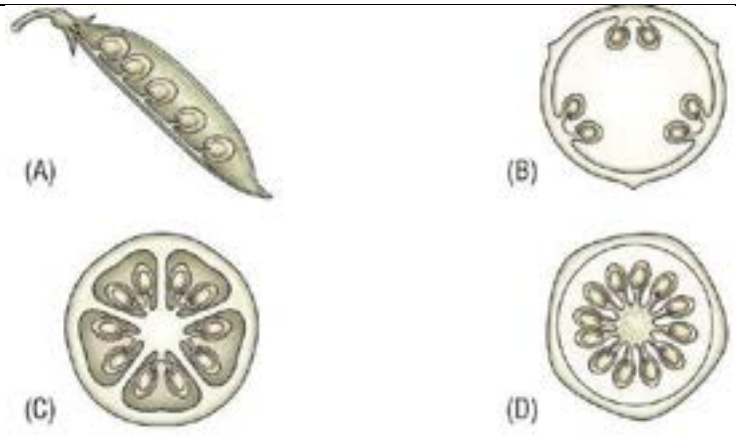
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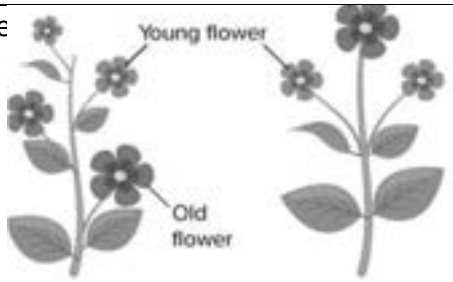
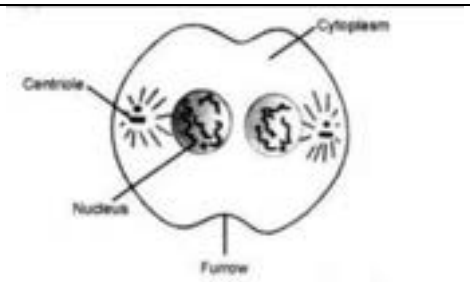
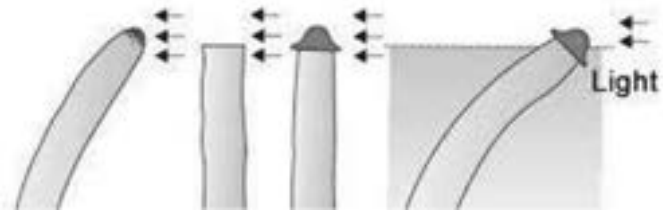
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2	A student studied different types of placentation in flowers and observed a floral diagram of *Dianthus*. The ovules were attached to a central axis inside a unilocular ovary without septa. Based on this observation, identify the diagram that correctly represents the placentation found in *Dianthus*.	1

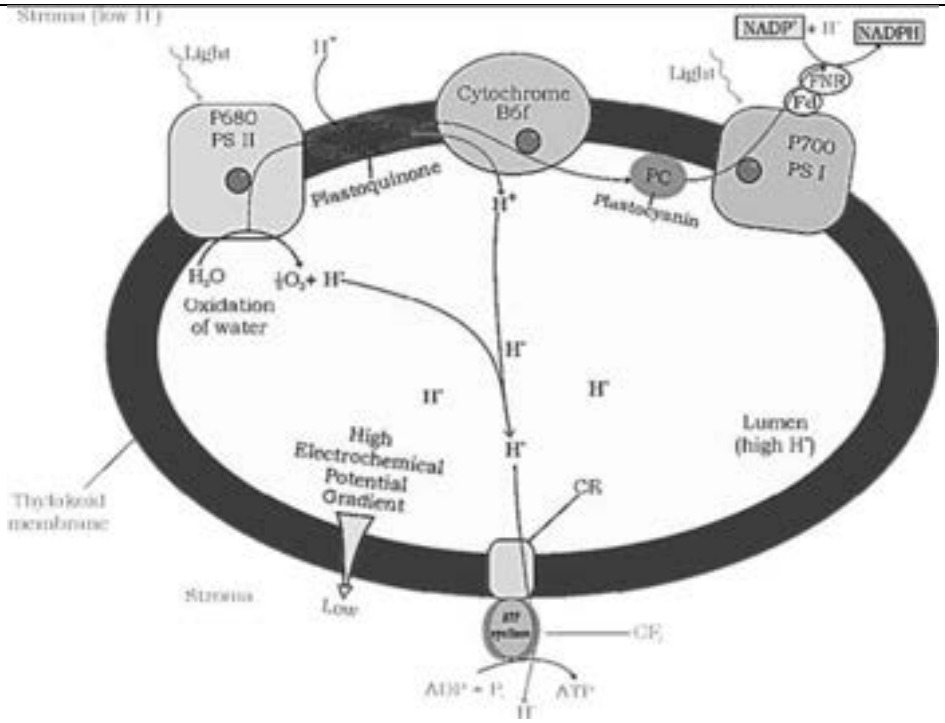
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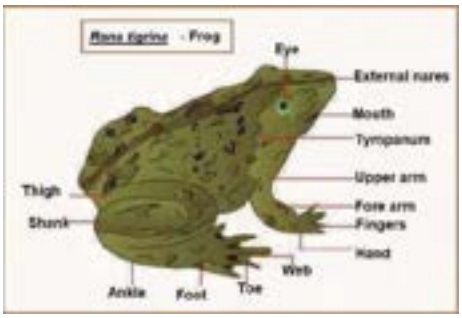

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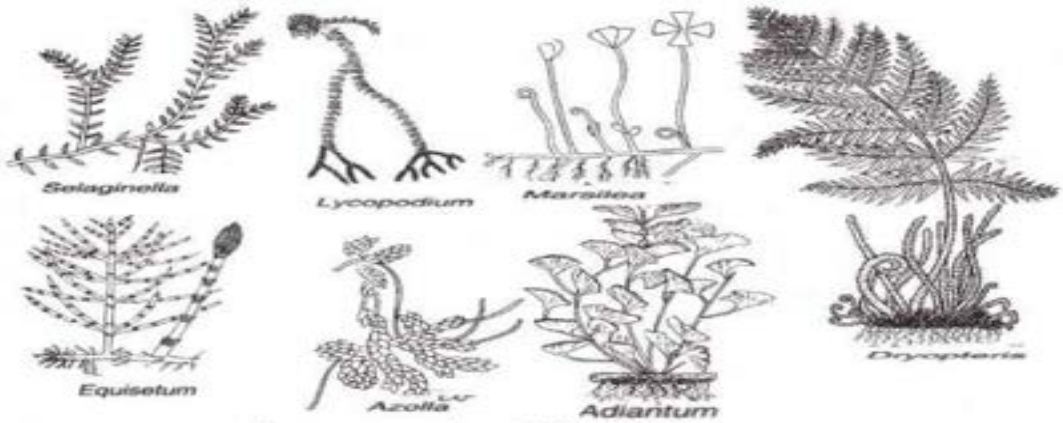
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11	During the transmission of a nerve impulse through a nerve fibre the electric potential on the inner side of the axonal membrane is (a) First negative then positive and continue to be positive (b) first negative than positive and back to be negative (c) first positive than negative and back to be positive (d) first positive than negative and continue to be negative	1
12	Which of the following statement is not correct for viruses (a) viruses are obligate parasites (b) Viruses can multiply only when there inside the host cell (c) viruses cannot pass through bacterial filters (d) virus are made of proteins and DNA or RNA (never both RNA and DNA)	1
	Question No. 13 to 16 consist of two statements – Assertion (A) and Reason (R). Answer these questions selecting the appropriate option given below: (a) Both A and R are true and R is the correct explanation of A. (b) Both A and R are true and R is not the correct explanation of A. (c) A is true but R is false. (d) A is False but R is true	

13	Assertion all vertebrates are chordates but all chordates are not vertebrates. Reason : Notochord is a characteristic feature of chordates only	1
14	Assertion: Catecholamines are called fight or flight hormones: Reason: Noradrenalin or norepinephrine Both hormones rapidly release in emergency situation..	1
15	Assertion : lipids often separate along with the macro molecules in the acid insoluble fractions. Reason : lipids are often esters of fatty acids with glycerol	1
16	Assertion: Lymph is a colourless fluid containing specialised lymphocytes which are responsible for the immune response of the body Reason: Lymph is an important carrier for nutrient, hormones, etc.	1
	SECTION- B	
17	Name the two group of nephrons on the basis of their position in the kidney? How are they different from each other . OR ANF mechanism act as a check on the rennin angiotensin mechanism. Justify.	2
18	Fill in the blanks at (A) , (B) , (C) and (D) Action potential reaches at axon terminal ⇩ Vesicles release (A) filled in vesicles ⇩ Chemicals present in synaptic cleft bind to (B) ⇩ Binding opens the (C) ⇩ New potential generated in (D) OR Which hormonal deficiency is responsible for the following : A) Diabetes mellitus B) Cretinism Write one symptom for each deficiency.	2

19	Name and differentiate be  n in A and B *A* *B*	2
20	Observe the figure given here and answer following questions: (i) Identify the cell shown here is as plant cell or an animal cell. Give reason in support of your answer. (ii) What phase takes place after this stage? 	2
21	Mention the ecological significance of Mosses OR (a) Why do members of Phaeophyceae vary in colour from olive green to various shades of brown *(b)* Name two filamentous green algae	2
	SECTION C	
22	a. Explain the mechanism by observing the following picture.  b. By application of which PGR the yield of sugarcane can be achieved up to 20 tons per acre. c. Name the type of Cytokinin which is present in Maize plant.	3
23	Give reason for each of the following : (a) The concentration of certain ions is higher inside the vacuole than in the cytoplasm (b) Golgi bodies are found near to the endoplasmic reticulum in a cell (c) Enzymes of lysosomes are referred to as the acid hydrolases.	3
24	*A)* Why is the coelom in Ascaris described as pseudocoelom? *B)* Write any four differences between the members of arthopoda and Mollusca.	3
25	Describe a sarcomere as the basic structural and functional unit of a muscle fiber (myofibril) with the help of a diagram.	3
26	Answer the questions with reference to the digestive system of frog A) Why is the alimentary canal of a frog short B) Name the two necessary digestive glands C) How is the absorption of digested food added in the intestine .	
27	Illustrate Celvin Cycle schematically.	3

	OR Fill in the blanks (A) ,(B),(C),(D), (E) , (F) and complete the C4 /Hatch -slack pathway . Atmospheric CO_2 enters (A) ⇓ CO2 is accepted by (B) and forms a four carbon acid/ Compound (C) ⇓ C4 acid enters into (D) and splits into CO2 AND (E) ⇓ CO2 enters Calvin cycle and 3C acid (F) is formed	
28	Eukaryotic cells have organelles which may: a. not be bound by a membrane b. bound by a single membrane c. bound by a double membrane Give 2 examples of the various sub-cellular organelles into each of these three categories.	3
	SECTION- D	
29	 Understanding how biological systems convert and store energy is a primary purpose of basic research. However, despite Mitchell's chemiosmotic theory, we are far from the complete description of basic processes such as oxidative phosphorylation and photosynthesis. After more than half a century, the chemiosmotic theory may need updating, thanks to the latest structural data on respiratory chain complexes. In particular, up-to-date technologies, such as those using fluorescence indicators following	4

	proton displacements, have shown that proton translocation is lateral rather than transversal with respect to the coupling membrane. Furthermore, the definition of the physical species involved in the transfer (proton, hydronium ion or proton currents) is still an unresolved issue, even though the latest acquisitions support the idea that protonic currents, difficult to measure, are involved. Look at the figure given below: (A) Where does the splitting of water molecules take place? (B) Where is PSII located in the chloroplast? (C) What is photophosphorylation? (D) Plastoquinone acts as.....	
30	Frogs, belonging to the class Amphibia in the phylum Chordata, are versatile creatures found in India, with Rana tigrina being the common species. They are cold-blooded, adjusting their body temperature to the environment. Displaying mimicry through color changes for camouflage, frogs undergo aestivation in summer and hibernation in winter, seeking refuge from extreme temperatures. Their smooth, moist skin absorbs water, and they never drink directly. Featuring a distinctive olive green dorsal side with dark spots, and a pale yellow ventral side, frogs lack a neck and tail. Sexual dimorphism is evident, with males possessing vocal sacs and a copulatory pad.  (i) Frogs eyes are generally covered by which membranous structure that is protective in function? a) Camouflage membrane b) Copulatory membrane c) Nictitating membrane d) Tympanum membrane (ii) _____is the unique and distinguishing as well as sexual character of male frog. a) Presence of webbed digits b) Presence of copulatory pad c) Presence of Nictitating membrane d) Presence of membranous tympanum (iii) What is mean by poikilotherms? OR Why Frogs are not seen during peak summer and winter?	4
	SECTION -E	
31	Bring out the differences between the mechanism of action of : (A) a protein hormone and (B) a steroid hormone in the human body along with diagram. OR (A) Why is propagation of nerve impulse faster in myelinated axons than in unmyelinated axons?	

	(B) Describe the sequence of events that lead to the generation and propagation of an action potential across a neuron.	
32	Differentiate between (one point each): a. Open and closed circulatory system b. Oviparity and viviparity c. Direct and indirect development d. Aceolomate and pseudocoelomate e. Polyp and medusa OR In pteridophytes, the main plant body is a sporophyte which is differentiated into true root, stem and leaves. These organs possess well-differentiated vascular tissues. Answer following questions based on your understanding: (i) What are Sporophylls? (ii) Name any two species of pteridophytes which shows heterospory. (iii) What are terms used for male and female sex organs in pteridophytes? (iv) Can pteridophytes surpass the advantages of gymnosperms? (v) Which habit of pteridophytes is a precursor of seed habit?  Some examples of Pteridophyta.	5
33	Why meiosis is called reductional division? Describe the key events of Prophase I of meiosis I cell division. Write the significance of meiosis in cell division? OR A) Starch, Cellulose, Glycogen, Chitin are polysaccharides found among the following. Choose the one appropriate and write against each: Cotton fibre, Exoskeleton of cockroach, Liver, Peeled potato B) Glycine and Alanine are different with respect to one substituent on the α-carbon. What are the other common substituent groups? Illustrate with structural diagrams only of both biomolecules. C) In plant, fungal and microbial cells, thousands of compounds other than primary metabolites are called secondary metabolites. Give names of any two of them which are useful to 'human welfare'.	5
		5

KENDRIYA VIDYALAYA SANGATHAN

SAMPLE QUESTION PAPER-02

SESSION ENDING EXAMINATION

BIOLOGY (044)

CLASS XI

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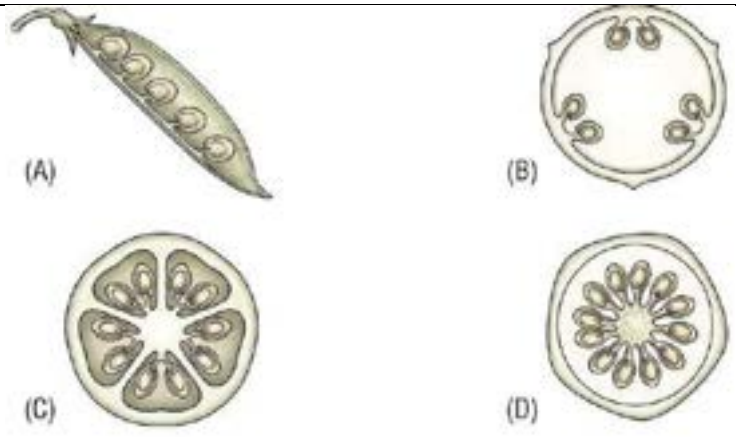
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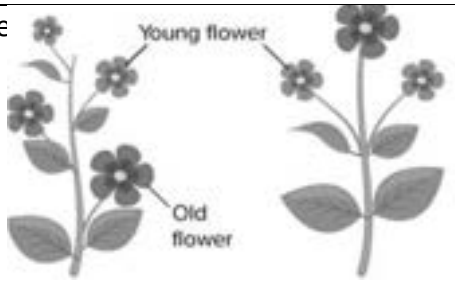
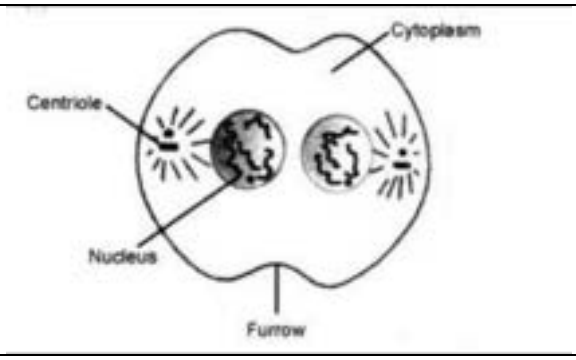
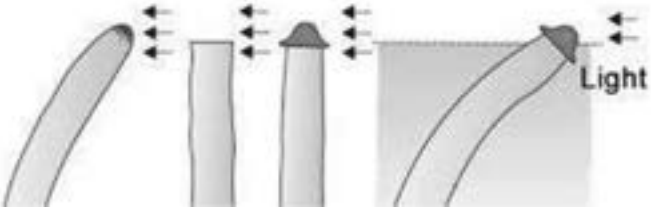
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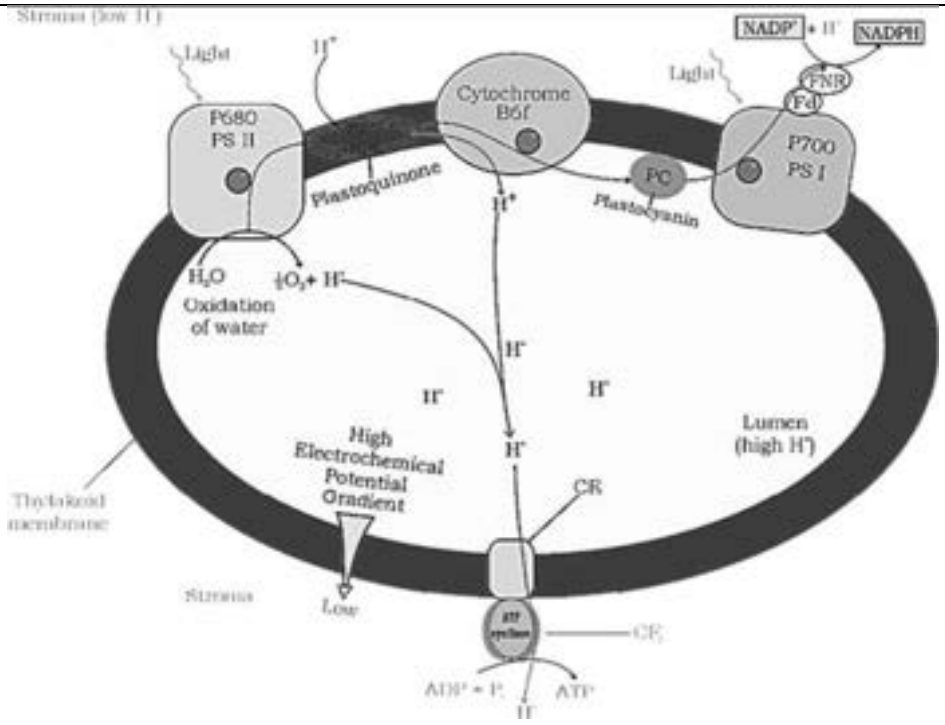

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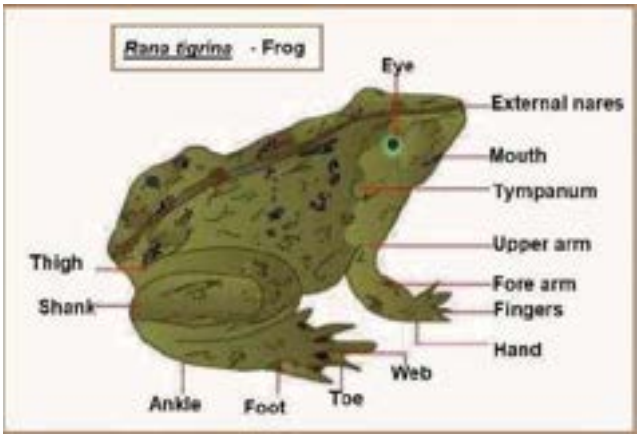
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12	Which of the following statement is not correct for viruses (a) viruses are obligate parasites (b) Viruses can multiply only when there inside the host cell (c) viruses cannot pass through bacterial filters (d) virus are made of proteins and DNA or RNA (never both RNA and DNA)	1
	Question No. 13 to 16 consist of two statements – Assertion (A) and Reason (R). Answer these questions selecting the appropriate option given below: (a) Both A and R are true and R is the correct explanation of A. (b) Both A and R are true and R is not the correct explanation of A. (c) A is true but R is false. (d) A is False but R is true	

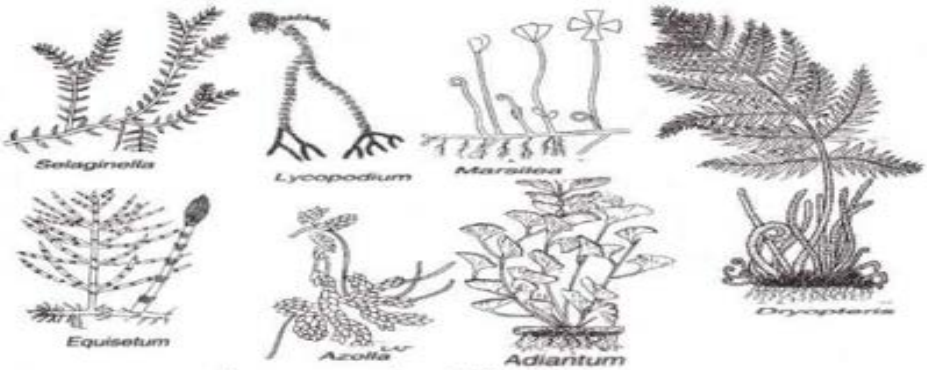
13	Assertion all vertebrates are chordates but all chordates are not vertebrates. Reason : Notochord is a characteristic feature of chordates only	1
14	Assertion: Catecholamines are called fight or flight hormones: Reason: Noradrenalin or norepinephrine Both hormones rapidly release in emergency situation..	1
15	Assertion : lipids often separate along with the macro molecules in the acid insoluble fractions. Reason : lipids are often esters of fatty acids with glycerol	1
16	Assertion: Lymph is a colourless fluid containing specialised lymphocytes which are responsible for the immune response of the body Reason: Lymph is an important carrier for nutrient, hormones, etc.	1
	SECTION- B	
17	Name the two group of nephrons on the basis of their position in the kidney? How are they different from each other . OR ANF mechanism act as a check on the rennin angiotensin mechanism. Justify.	2
18	Fill in the blanks at (A) , (B) , (C) and (D) Action potential reaches at axon terminal ⇩ Vesicles release (A) filled in vesicles ⇩ Chemicals present in synaptic cleft bind to (B) ⇩ Binding opens the (C) ⇩ New potential generated in (D) OR Which hormonal deficiency is responsible for the following : C) Diabetes mellitus D) Cretinism Write one symptom for each deficiency.	2

19	Name and differentiate be  n in A and B *A* *B*	2
20	 Observe the figure given here and answer following questions: (i) Identify the cell shown here is as plant cell or an animal cell. Give reason in support of your answer. (ii) What phase takes place after this stage?	2
21	Mention the ecological significance of Mosses OR (c) Why do members of Phaeophyceae vary in colour from olive green to various shades of brown *(d)* Name two filamentous green algae	2
	SECTION C	
22	a. Explain the mechanism by observing the following picture.  b. By application of which PGR the yield of sugarcane can be achieved up to 20 tons per acre. c. Name the type of Cytokinin which is present in Maize plant.	3
23	Give reason for each of the following : A) The concentration of certain ions is higher inside the vacuole than in the cytoplasm B) Golgi bodies are found near to the endoplasmic reticulum in a cell C) Enzymes of lysosomes are referred to as the acid hydrolases.	3
24	*C)* Why is the coelom in Ascaris described as pseudocoelom? *D)* Write any four differences between the members of arthopoda and Mollusca.	3
25	Describe a sarcomere as the basic structural and functional unit of a muscle fiber (myofibril) with the help of a diagram.	3
26	Illustrate Celvin Cycle schematically. OR Fill in the blanks (A) ,(B),(C),(D), (E) , (F) and complete the C4 /Hatch -slack pathway .	3

⇩

	Atmospheric Co_2 enters (A) ⇩ CO2 is accepted by (B) and forms a four carbon acid/ Compound (C) ⇩ CO2 enters Calvin cycle and 3C acid (F) is formed → C4 acid enters into (D) and splits into CO2 AND (E)	
27	Answer the questions with reference to the digestive system of frog A) Why is the alimentary canal of a frog short B) Name the two necessary digestive glands C) How is the absorption of digested food added in the intestine .	3
28	Eukaryotic cells have organelles which may: a. not be bound by a membrane b. bound by a single membrane c. bound by a double membrane Give 2 examples of the various sub-cellular organelles into each of these three categories.	3
	SECTION- D	
29	 Understanding how biological systems convert and store energy is a primary purpose of basic research. However, despite Mitchell's chemiosmotic theory, we are far from the complete description of basic processes such as oxidative phosphorylation and photosynthesis. After more than half a century, the chemiosmotic theory may need updating, thanks to the latest structural data on respiratory chain complexes. In	4

	particular, up-to-date technologies, such as those using fluorescence indicators following proton displacements, have shown that proton translocation is lateral rather than transversal with respect to the coupling membrane. Furthermore, the definition of the physical species involved in the transfer (proton, hydronium ion or proton currents) is still an unresolved issue, even though the latest acquisitions support the idea that protonic currents, difficult to measure, are involved. Look at the figure given below: (C) Where does the splitting of water molecules take place? (D) Where is PSII located in the chloroplast? (C)What is photophosphorylation? (D) Plastoquinone acts as.....	
30	Frogs, belonging to the class Amphibia in the phylum Chordata, are versatile creatures found in India, with Rana tigrina being the common species. They are cold-blooded, adjusting their body temperature to the environment. Displaying mimicry through color changes for camouflage, frogs undergo aestivation in summer and hibernation in winter, seeking refuge from extreme temperatures. Their smooth, moist skin absorbs water, and they never drink directly. Featuring a distinctive olive green dorsal side with dark spots, and a pale yellow ventral side, frogs lack a neck and tail. Sexual dimorphism is evident, with males possessing vocal sacs and a copulatory pad.  (i) Frogs eyes are generally covered by which membranous structure that is protective in function? a) Camouflage membrane b) Copulatory membrane c) Nictitating membrane d) Tympanum membrane (ii) _____is the unique and distinguishing as well as sexual character of male frog. a) Presence of webbed digits b) Presence of copulatory pad c) Presence of Nictitating membrane d) Presence of membranous tympanum (iii) What is mean by poikilotherms? OR Why Frogs are not seen during peak summer and winter?	4
	SECTION -E	

31	Differentiate between (one point each): a. Open and closed circulatory system b. Oviparity and viviparity c. Direct and indirect development d. Aceolomate and pseudocoelomate e. Polyp and medusa OR In pteridophytes, the main plant body is a sporophyte which is differentiated into true root, stem and leaves. These organs possess well-differentiated vascular tissues. Answer following questions based on your understanding: (i) What are Sporophylls? (ii) Name any two species of pteridophytes which shows heterospory. (iii) What are terms used for male and female sex organs in pteridophytes? (iv) Can pteridophytes surpass the advantages of gymnosperms? (v) Which habit of pteridophytes is a precursor of seed habit?  Some examples of Pteridophyta.	5
32	Why meiosis is called reductional division? Describe the key events of Prophase I of meiosis I cell division. Write the significance of meiosis in cell division? OR A) Starch, Cellulose, Glycogen, Chitin are polysaccharides found among the following. Choose the one appropriate and write against each: Cotton fibre, Exoskeleton of cockroach, Liver, Peeled potato B) Glycine and Alanine are different with respect to one substituent on the α-carbon. What are the other common substituent groups? Illustrate with structural diagrams only of both biomolecules. C) In plant, fungal and microbial cells, thousands of compounds other than primary metabolites are called secondary metabolites. Give names of any two of them which are useful to 'human welfare'.	5
33	Bring out the differences between the mechanism of action of : (A) a protein hormone and (B) a steroid hormone in the human body along with diagram. OR (A) Why is propagation of nerve impulse faster in myelinated axons than in unmyelinated axons? (B) Describe the sequence of events that lead to the generation and propagation of an action potential across a neuron.	5

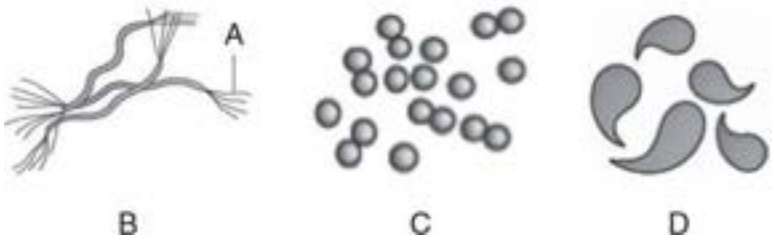
KENDRIYA VIDYALAYA SANGATHAN
SAMPLE QUESTION PAPER(2026-27)

CLASS XI BIOLOGY (044)

Time: 3 Hours **Maximum Marks: 70**

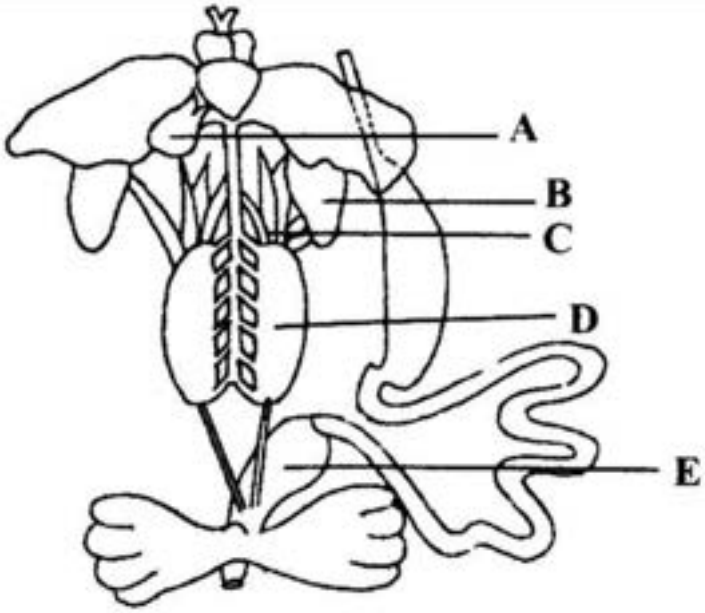
GENERAL INSTRUCTIONS

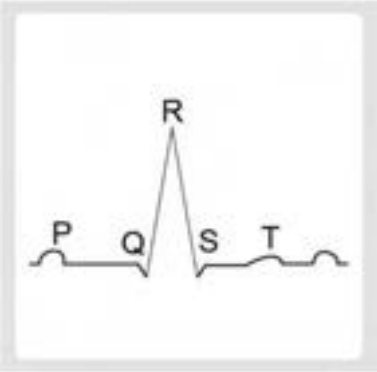
1. All questions are compulsory.
2. The question paper has five sections and 33 questions.
3. All questions are compulsory. **Section A** has 16 questions of 1 mark each; **Section B** has 5 questions of 2 marks each; **Section C** has 7 questions of 3 marks each; **Section D** has 2 case-based questions of 4 marks each; and **Section E** has 3 questions of 5 marks each.
4. There is no overall choice. However, internal choices are provided in some questions. A student has to attempt only one of the alternatives in such questions.
5. Wherever necessary, neat and properly labelled diagrams should be drawn.

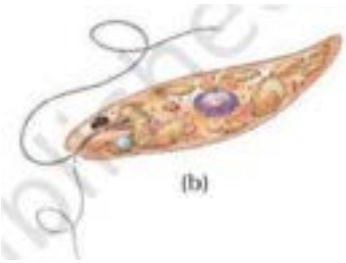
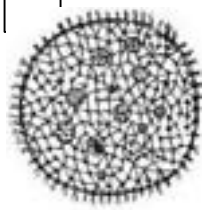
	SECTION A	
1.	A location with luxuriant growth of lichen on the trees indicated that the (a) Trees are very healthy (b) Trees are infested with diseases (c) Soil is deficient in certain micronutrients (d) Area is not polluted	1
2.	Identify the A, B, C and D in this figure.  (a) A–Spirilla, B–Vibrio, C–Flagellum, D–Cocci (b) A–Cocci, B–Flagellum, C–Spirilla, D–Vibrio (c) A–Vibrio, B–Spirilla, C–Cocci, D–Flagellum (d) A–Flagellum, B–Spirilla, C–Cocci, D–Vibrio	1
3.	A student observes an animal with a water vascular system and radial symmetry in adults. This animal belongs to: (a) Porifera (b) Coelenterata (c) Echinodermata (d) Aschelminthes	1
4.	A scholar of plant anatomy may **not** be an expert on: (a) Floral Formula and floral diagram (b) Mesophyll and spongy parenchyma	1

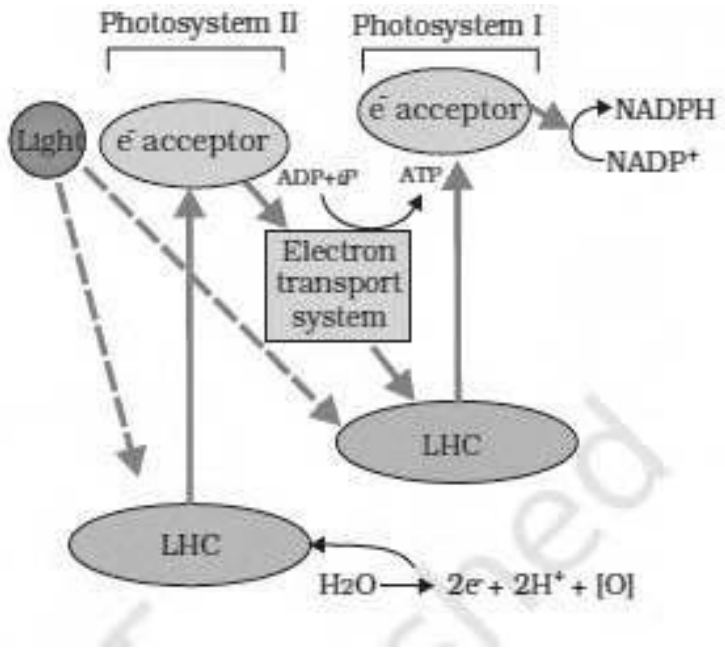
	(c) Shape of guard cells of grasses (d) Closed and open vascular bundles	
5.	The margins in the petals and sepals of Gulmohur overlap each other but not in any particular direction. This is known as: (a) Twisted aestivation (b) Imbricate aestivation (c) Marginal Placentation (d) Axile Placentation	1
6.	Which type of epithelial tissue forms the inner lining of fallopian tubes to move egg cell in a specific direction? (a) Squamous (b) Cuboidal (c) Ciliated (d) Glandular	1
7.	Palmitic acid found in palm oil is considered as a saturated fatty acid because: (a) It is linked to diabetes (b) It lacks double and triple bonds (c) It has only single bonds (d) Both b and c	1
8.	The inhibition of enzyme activity by a substance that resembles the substrate in its molecular structure is known as: (a) Allosteric inhibition (b) Competitive inhibition (c) Non-competitive inhibition (d) Feedback inhibition	1
9.	Crossing over occurs during which stage of Meiosis? (a) Leptotene (b) Zygotene (c) Pachytene (d) Diplotene	1
10	In C4 plants, the primary CO_2 acceptor is: (a) RuBP (b) PEP (c) OAA (d) PGA	1
11	The number of ATP molecules produced by the oxidation of one molecule of NADH + H^+ in the ETS is: (a) 1 (b) 2 (c) 3 (d) 4	1
12	The end product of glycolysis forms _____at low levels of oxygen. (a) Ethanol (b) Pyruvic acid (c) Acetyl CoA (d) Lactic acid	1
	Question No. 13 to 16 consist of two statements – Assertion (A) and Reason (R). Select the correct option: (a) Both A and R are true and R is the correct explanation of A. (b) Both A and R are true and R is not the correct explanation of A. (c) A is true but R is false. (d) A is false but R is true.	1
13	Assertion (A): Auxins promote apical dominance. Reason (R): In higher plants, the growing apical bud inhibits the growth of the lateral buds.	1
14	Assertion (A): A blood pressure reading of 140/90 mm Hg indicates hypertension. Reason (R): In this measurement, 140 mm Hg represents the systolic pressure.	1
15	Assertion (A): The anterior pituitary is regulated by hormones released from the hypothalamus. Reason (R): Hypothalamic hormones like GnRH pass through axons and are released from nerve endings directly into the posterior pituitary.	1

16	Assertion (A): Synovial joints allow limited or no movement. Reason (R): There is a presence of a fluid-filled synovial cavity between the articulating surfaces of the two bones.	1
	SECTION B	
17	Binomial Nomenclature was introduced to standardise the names of plants and animals all over the world. Write the complete names of the organisations responsible for formulating principles and criteria for nomenclature of standardised names of: a. Plants b. Animals	2
18	Why are enzymes known as biocatalysts? How does an enzyme affect the activation energy of a reaction?	2
19	Lysine is considered as essential amino acid while alanine is classified as non-essential amino acid. Which criteria is used for this classification of amino acids in to essential and non-essential? OR What are Zwitter ions? Explain the structure of Zwitter ions with the help of structural diagram of amino acids.	2
20	How is blood circulation in fishes different from that in humans? Which of these carry oxygen more efficiently?	2
21	An elderly female patient presents with a fracture following a minor fall. Her medical history indicates a decline in bone mass. Identify the age-related disorder and the specific hormonal imbalance commonly cited as a cause for this condition.	2
	SECTION C	
22	Archaebacteria are often referred to as 'Living Fossils' because they inhabit environments that resemble early Earth. Elaborate with help of habitat range of different groups of Archaebacteria.	3
23	A student claims that Chondrichthyes may be less evolved than Osteichthyes because the former lacks a bony skeleton. Do you agree with this claim? Justify your answer by comparing three specific features of these two groups of fishes.	3
24	a. Label the parts labelled A to E in the given diagram of internal organs of Frog.	3

	 b. If part A is removed, how will it affect digestion of food in frog?	
25	Draw a diagram to illustrate the 24 hour Cell Cycle of a human cell. Show the relative duration of phases of cell cycle with corresponding segments of suitable sizes.	3
26	Sketch a typical Sigmoid Growth Curve. Label the different phases (Lag, Log, Stationary). Explain why the growth curve eventually enters the "Stationary phase".	3
27	Why is the maintenance of a concentration gradient by the sodium-potassium pump essential for a neuron's excitability? Briefly describe the movement of ions across the Na-K pump during depolarisation and repolarisation of axonal membrane.	3
28	Explain the steps of Sliding Filament Theory of muscle contraction with the help of a diagram. OR Migratory birds capable of flying for long distances without tiring typically possess flight muscles that appear dark red. In contrast, domestic poultry that only perform short bursts of activity have whitish muscles. Analyse the cellular composition of the "red" muscles. Why are they better suited for sustained flight compared to the white ones?	3
	SECTION D	
29	A student was given two transverse sections of plant parts, 'X' and 'Y'. Section 'X' showed a large number of scattered vascular bundles, each surrounded by a bundle sheath, while 'Y' showed vascular bundles arranged in a ring with a distinct pith. (i) Identify 'X' and 'Y'. (1m) a. X: Dicot root, Y: Monocot root b. X: Dicot Stem, Y: Monocot Stem c. X: Monocot root, Y: Dicot root d. X: Monocot stem, Y: Dicot stem	4

	(ii) Terms used with respect to presence or absence of cambium in vascular bundles are: a. Endarch, exarch b. Open, close c. Monocot and dicot d. Softwood and hardwood Attempt either (iii) or (iv) (iii) State one major difference between the vascular bundles of 'X' and 'Y' regarding their structure (Open/Closed). OR (iv) Mention two anatomical features that help in identifying 'Y'. (2m)	
30	29. Electrocardiogram (ECG) is a graphical representation of the electrical activity of the heart during a cardiac cycle. A standard ECG consists of P-wave, QRS complex, and T-wave as shown in figure below.  (i) What does the P-wave represent? (1m) a. Atrial contraction b. Ventricular contraction c. Joint systole d. Joint diastole (ii) Heart beat and therefore diagnosis of heart health is indicated by: (1m) a. P wave b. QRS complex c. T wave Both a and c Attempt either (iii) or (iv) (iii) Why is the T-wave always followed by a pause? Explain in terms of the cardiac cycle. (2m) (iv) A stethoscope helps us hear two prominent heart sounds: lub and dub. Which events in cardiac cycle are responsible for production of these sounds?	4
	SECTION E	

	Study the figure shown below and answer the questions based on the organisms shown:   (b) a. Identify the organisms a and b. Name the Whittaker's Kingdom to which these organisms belong. b. The organism a are responsible for Red Tides. What are 'red tides'? How are they formed and what is their significance? c. Organism b is said to be connecting link between plants and animals as it shows certain characteristics of both kingdoms. Enlist 1 characteristics each of plant and animal kingdom shown by organism b. OR	5 (1+ 2+2)
	A. Identify the groups of plants represented in each of the following sets. B. Differentiate between the groups based on any two salient features. i. Set A: a  b  ii. Set B:  c  d	5 (2+ 3)

31	With respect to the cell organelle addressed as “Powerhouse of Cell”, answer the following questions: a. The lumen of the organelle is divided into two compartments. The inner compartment is filled with a dense substance. What is the name of this substance? b. How are the outer and inner membrane of this organelle different. Differentiate on the basis of their structure & function. c. Why is this organelle known as “powerhouse of cell”? d. This organelle is considered as ‘semi-autonomous’. Which components of this organelle make it semi-autonomous? OR Explain the Fluid Mosaic Model of the Plasma Membrane proposed by Singer and Nicolson. Illustrate the structure with a neat, labelled diagram.	5 (1+2+ 1+2) 5
32	The diagram below shows Photosystem II (PS II) and Photosystem I (PS I) connected by an electron transport chain.  a. What process is represented in this diagram? Which letter of English alphabet is commonly used to name this diagram? b. The movement of electrons from the primary acceptor of PS II to the electron transport system is described as "downhill," while the movement from PS II to its primary acceptor is "uphill." Explain this movement in terms of redox potential and energy states. Why is an input of light energy required for the "uphill" movement? c. What are LHC within Photosystem I and Photosystem II and what are they composed of? d. If the specific electron carrier "NADP reductase" is absent or malfunctioning, how would the flow of electrons change? OR	5

	With respect to the process of respiration in plants; answer the following questions: i. You are given the chemical equation for the respiration of Tripalmitin. Calculate the Respiratory Quotient (RQ) and interpret what this value implies about the oxygen demand of fats compared to carbohydrates. $2(C_{51}H_{98}O_6)+145O_2$----------> $102CO_2$ +98 H_2O + ENERGY (Tripalmitin) ii. In a controlled experiment involving yeast fermentation, a student observes that the culture stops growing and the cells die when the alcohol concentration in the solution reaches approximately 13 per cent. Analyse why this occurs and what it suggests about the limitations of natural fermentation. iii. Traditionally, respiration is viewed as a catabolic (breakdown) process. Explain the reasoning behind reclassifying the respiratory pathway as an "amphibolic pathway" instead.	

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Kendriya Vidyalaya Sangathan

Sample paper-5

SESSION ENDING EXAMINATION

Class: XI	**Max. Marks:** 70
Subject: Biology	**Duration:** 3 Hours
Subject Code: 044	

GENERAL INSTRUCTIONS

(i) This question paper contains 33 questions. All questions are compulsory.
(ii) Question paper is divided into five sections A, B, C, D and E.
(iii) Section A (Q.1–16): Multiple Choice Questions — 1 mark each.
(iv) Section B (Q.17–21): Very Short Answer Questions — 2 marks each.
(v) Section C (Q.22–28): Short Answer Questions — 3 marks each.
(vi) Section D (Q.29–30): Case-Based Questions — 4 marks each. Internal choice in one subpart.
(vii) Section E (Q.31–33): Long Answer Questions — 5 marks each.
(viii) There is no overall choice. Internal choice is provided in Sections B, C, D and E.
(ix) Wherever necessary, neat and properly labelled diagrams should be drawn.

SECTION A — Multiple Choice Questions (Q.1–16) [1 Mark Each]

Q.No.	Question	Marks
Q.1	Marine biologists observed a sudden increase in the population of a unicellular organism in coastal water. The organism had two flagella, cellulose plates on its body, and emitted light at night. Due to rapid multiplication, the water appeared red in colour and many fishes died because toxins were released into the sea. **Which group of organisms is being described in the above case?** **(a)** Diatoms **(b)**Euglenoids **(c)**Dinoflagellates **(d)**Slime moulds	1
Q.2	Which class of algae possess pigment fucoxanthin and pigment phycoerythrin respectively? **(a)** Phaeophyceae and Chlorophyceae **(b)** Phaeophyceae and Rhodophyceae **(c)** Chlorophyceae and Rhodophyceae **(d)** Rhodophyceae and Phaeophyceae	1

Q.No.	Question	Marks
Q.3	In a pea flower, 5 petals are arranged: one posterior, two lateral and two anterior, named _____, _____and _____respectively. **(a)** Keel, Wings and Standard **(b)** Standard, Keel and Wings **(c)** Wings, Standard and Keel **(d)** Standard, Wings and Keel	1
Q.4	Which one of the following represents parietal placentation?  A B C D **(a)** Option A **(b)** Option B **(c)** Option C **(d)** Option D	1
Q.5	A stem shows vascular bundles arranged in a ring. Each bundle is conjoint, collateral, and open. Which plant does it belong to? **(a)** Monocot stem **(b)** Dicot stem **(c)** Monocot root **(d)** Dicot root	1
Q.6	The common opening of alimentary canal, excretory and reproductive systems is called: **(a)** Rectum **(b)** Anus **(c)** Cloaca **(d)** Vent	1
Q.7	If ribosomes are removed from a cell, which activity will stop immediately? **(a)** Respiration **(b)** Protein synthesis **(c)** Lipid synthesis **(d)** Photosynthesis	1
Q.8	A cell lacking lysosomes would have difficulty in: **(a)** Energy production **(b)** Protein synthesis **(c)** Intracellular digestion **(d)** Transport of materials	1

Q.No.	Question	Marks
Q.9	Which of the following best explains the significance of meiosis? **(a)** Growth and repair **(b)** Genetic stability **(c)** Genetic variation and maintenance of chromosome number **(d)** Asexual reproduction	1
Q.10	A plant tissue shows high respiratory quotient (RQ > 1). Which substrate is most likely being respired? **(a)** Fats **(b)** Proteins **(c)** Organic acids **(d)** Polysaccharides	1
Q.11	If the partial pressure of oxygen in alveoli is 104 mm Hg and in deoxygenated blood is 40 mm Hg, oxygen will move: **(a)** From blood to alveoli by active transport **(b)** From alveoli to blood by diffusion **(c)** From blood to alveoli by diffusion **(d)** From alveoli to blood by facilitated diffusion	1
Q.12	A patient has persistently high blood sugar because of destruction of β-cells in the pancreas. Which hormone therapy would be most effective? **(a)** Glucagon **(b)** Insulin **(c)** Somatostatin **(d)** Cortisol	1

Direction (Q.13–16): For the following questions, two statements are given — one labelled as Assertion (a) and the other as Reason (R). Select the correct answer from the codes below:

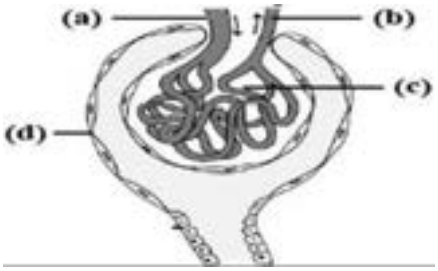
(a) Both A and R are true; R is the correct explanation of A.
(b) Both A and R are true; but R is NOT the correct explanation of A.
(c) A is true, but R is false.
(d) A is false, but R is true.

Q.No.	Question	Marks
Q.13	**Assertion (a):** In the five-kingdom classification, Monera includes only prokaryotic organisms. **Reason (R):** Monerans lack true nucleus and membrane-bound organelles.	1
Q.14	**Assertion (a):** Frogs have a three-chambered heart.	1

Q.No.	Question	Marks
	Reason (R): In frogs, oxygenated and deoxygenated blood are completely separated.	
Q.15	**Assertion (a):** Ribosomes are non-membrane bound organelles found in prokaryotic and eukaryotic cells. **Reason (R):** These are present only in the cytoplasm.	1
Q.16	**Assertion (a):** Adrenaline increases heart rate and blood glucose levels. **Reason (R):** Adrenaline is secreted by the adrenal cortex.	1

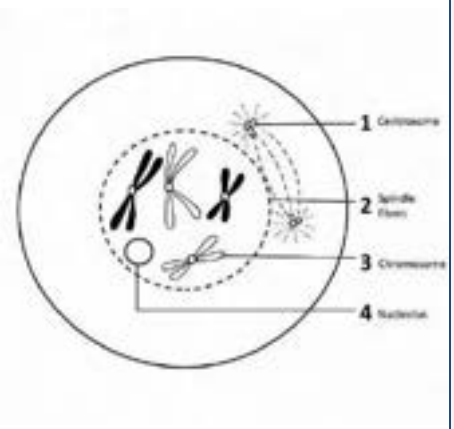
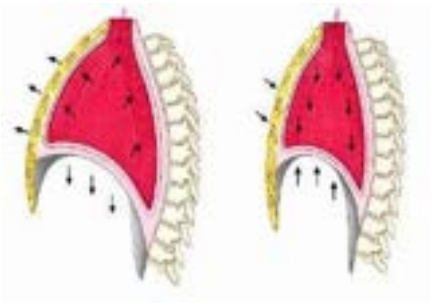
SECTION B — Very Short Answer Questions (Q.17–21) [2 Marks Each]

Q.No.	Question	Marks
Q.17	Give two reasons why Whittaker's Five Kingdom classification is considered superior to earlier systems.	2
Q.18	An animal shows bilateral symmetry, triploblastic organization, and a pseudocoelom. Identify the phylum and justify your answer.	2
Q.19	**Attempt either A or B** **A.** Provide the scientific term for the following: 1. The flat and extended portion of the leaf 2. A type of inflorescence in which main axis terminates in a flower 3. When a flower can be divided into two equal radial halves in any radial plane passing through the centre 4. A sterile stamen **— OR —** **B.** Identify the type of vascular bundle in the following diagrams (A and B in original paper) and state the difference between open and closed vascular bundles.  (A)  (B)	2
Q.20	In botanical gardens and tea gardens, gardeners trim the plants regularly so that they remain bushy. Does this practice have any scientific explanation?	2

Q.No.	Question	Marks
Q.21	**Attempt either A or B** **A.** A clinical researcher is studying two newly discovered synthetic chemical compounds, Compound X and Compound Y, designed to regulate glucose metabolism in cellular cultures. • Compound X is highly lipophilic (lipid-soluble) and easily diffuses across the plasma membrane of target cells. • Compound Y is a large, water-soluble peptide chain that cannot pass through the lipid bilayer. During an experiment, the researcher adds an enzyme that completely degrades all intracellular cAMP (cyclic adenosine monophosphate) inside the target cells before introducing the compounds. Questions: (i) Based on their chemical natures, predict which compound (X or Y) will utilize an intracellular receptor, and which one will bind to a membrane-bound receptor. (ii) Explain how the pre-treatment with the cAMP-degrading enzyme will affect the physiological response of Compound Y. Justify your answer by outlining its expected mechanism of action. **— OR —** **B.** Label parts a, b, c, d in the diagram of the renal corpuscle. 	2

SECTION C — Short Answer Questions (Q.22–28) [3 Marks Each]

Q.No.	Question	Marks
Q.22	Complete the table given below by identifying values a to f: **Class** | **Cell Wall** | **Stored Food** Chlorophyceae | (a) _____ | Starch (b) _____ | Cellulose + (c) _____ | Floridian Starch	3

Q.No.	Question	Marks
	(d) _____ | (e) _____+ Algin | Mannitol + (f) _____	
Q.23	Identify the type of aestivation with an example for each from the given information: a. When the petals or sepals are arranged without overlapping. b. The margin of sepal or petal overlap but not in any particular direction. c. When the margin of petals or sepals overlap in a particular direction.	3
Q.24	During an electron microscopy lab session, a student mistakenly labels a cell organelle responsible for organizing the mitotic spindle apparatus as a "centromere." Later, while observing a chromosome during anaphase, they note a constricted region where the spindle fibers are actively attached but cannot recall its exact identity. **(a)** Correct the student's terminological error by identifying which structure acts as the spindle-organizing center and which structure serves as the chromosomal attachment point. **(b)** Contrast these two structures based on their **chemical composition** and **structural organization** inside the cell. **(c)** Predict what would happen to a chromosome during cell division if its centromere were completely damaged or non-functional.	3
Q.25	Examine the figure and answer the questions: (a) Identify the stage. (b) Label parts 1 to 4. (c) What is the importance of part '1'? 	3
Q.26	**A.** Observe images (a) and (b) and mention the process performed as per each image.  **B.** What happens to the sternum and diaphragm during exhalation?	3

Q.No.	Question	Marks
	C. What term is used for the volume of air inspired or expired during normal respiration?	
Q.27	**Attempt either A or B** **A.** A patient presents with extreme dehydration and low blood pressure. Blood tests show elevated Renin and ADH levels. 1. Explain how high levels of ADH help the patient in this situation. 2. Which part of the nephron is most affected by high ADH levels? 3. What effect would an increase in Atrial Natriuretic Factor (ANF) have on this patient's blood pressure? **— OR —** **B.** If the father's blood is Rh^+, mother's blood is Rh^-, and the foetus's blood is Rh^+, a serious problem arises. 1. Mention the name of this abnormal condition. 2. How is this condition fatal to the foetus? 3. How can this abnormal condition be avoided?	**3**
Q.28	How is a nerve impulse transmitted across a synaptic cleft?	**3**

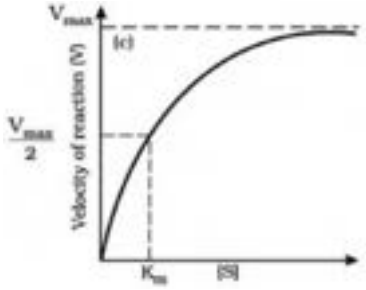
SECTION D — Case-Based Questions (Q.29–30) [4 Marks Each]

Q.No.	Question	Marks
Q.29	**Read the following passage and answer the questions:** *The complete oxidation of glucose in the presence of oxygen releases a large amount of energy stored in the substrate, producing CO_2 and H_2O. This process, known as aerobic respiration, involves glycolysis, the Krebs cycle, and the electron transport system. However, some organisms or tissues can function without oxygen by partially oxidizing glucose through fermentation, which yields far less energy.* **A.** State what is meant by 'fermentation' in the context of respiration. **B.** Yeast cells in an anaerobic environment produce ethanol and CO_2. Name the two enzymes involved in converting pyruvic acid to these products. **Attempt either C or D**	**4**

Q.No.	Question	Marks
	C. Compare alcoholic fermentation and aerobic respiration in terms of: (i) oxygen requirement and (ii) number of ATP molecules produced per glucose molecule. **— OR —** **D.** How is the production of curd from milk an example of fermentation? Name the type of fermentation involved.	
Q.30	**Read the following passage and answer the questions:** *A patient suffers from a muscle disorder causing severe cramping and inability to relax muscles after contraction. Doctors diagnose a malfunction in the calcium-pumping mechanism of the sarcoplasmic reticulum, preventing it from returning calcium to its storage, resulting in constant, low-level stimulation.* **A.** Based on the sliding filament theory, describe what happens to the I-band and A-band during muscle contraction. **B.** Which molecule provides the energy for the myosin head to swivel (power stroke) and pull the actin filaments? **Attempt either C or D** **C.** Which regulatory protein on the actin filament acts as the binding site for calcium ions, and what effect does this binding have? **— OR —** **D.** Why does the patient's condition (inability to pump calcium back) result in constant contraction?	**4**

SECTION E — Long Answer Questions (Q.31–33) [5 Marks Each]

Q.No.	Question	Marks
Q.31	**Attempt either A or B** **A.** 1. Mention salient features of Class Mammalia (any three). 2. Write differences between Chondrichthyes and Osteichthyes (any four). **— OR —** **B.** 1. Why are bryophytes called 'amphibians of the plant kingdom'? 2. Name the specific moss that provides peat and mention its ecological/commercial use.	**5**

Q.No.	Question	Marks
	3. Describe the role of mosses in ecological succession. 4. Differentiate between the gametophytic and sporophytic phases in bryophytes.	
Q.32	**Attempt either A or B** **A.** A student observes two different cell slides under a high-power electron microscope. Slide A shows a cell with a distinct nucleus, numerous membrane-bound organelles, and a rigid outer layer. Slide B shows a smaller cell lacking a defined nucleus, with DNA located in a central region called the nucleoid and small circular DNA structures. 1. Identify the types of cells in Slide A and Slide B. 2. Based on Slide A, explain the 'Endomembrane System' and name the organelles that constitute it. 3. The student notes circular DNA in Slide B. Identify this structure and explain its significance in modern biotechnology. 4. Why is the fluid mosaic model considered the most accepted model for the cell membrane? **— OR —** **B.** Observe the enzyme kinetics diagram (Michaelis-Menten curve)  1. Effect of change in substrate concentration on enzyme activity is graphically represented — after reaching Vmax, the reaction rate is not exceeded by any further rise in substrate concentration. Explain. 2. Mention any two other factors that affect enzyme activity. 3. Complete the diagrammatic representation showing the nature of enzyme action: E + S ⇌ ES ⇌ (a) _____ ⇌ E + (b) _____ 4. Define cofactor and prosthetic group.	5
Q.33	**Attempt either A or B** **A.** Compare C3 and C4 pathways on the basis of the following parameters:	5

Parameter	C3 Pathway	C4 Pathway
Primary CO_2 Acceptor molecule		
Initial Enzyme for carboxylation		

Q.No.	Question	Marks

First Stable Product		
Site of Calvin Cycle		
CO_2 fixation rate under high light condition		

— OR —

B. A student observes that although glycolysis provides immediate energy, cells heavily rely on the Krebs cycle to sustain complex life.

1. Why is the Krebs cycle considered an amphibolic pathway rather than just a catabolic one?
2. Calculate the net gain of NADH, $FADH_2$, and ATP from the complete oxidation of one glucose molecule during the Krebs cycle phase alone.
3. Explain the significance of Oxaloacetic acid (OAA) in the continuity of this cycle.
4. What is substrate level phosphorylation in the TCA cycle?

★ **All the Best!** ★