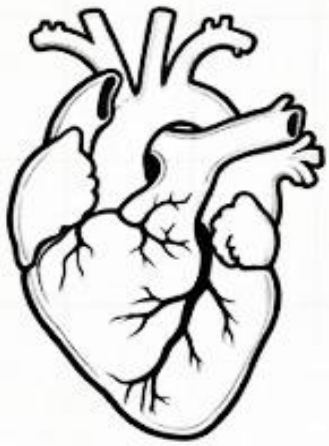
MVS FOUNDATION

FREE NOTES

BIOLOGY (314)

CHAPTERWISE NOTES



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The Kingdom Monera, Protoctista and Fungi

PART 1: KINGDOM MONERA

Kingdom Monera includes bacteria and cyanobacteria (blue-green algae). It is the only prokaryotic kingdom meaning no true nucleus (no nuclear membrane). Bacteria were the first cellular organisms to evolve on Earth 3.5 billion years ago.

Structure of Bacterial Cell:

- **Cell Wall** → Made of peptidoglycan (unique to bacteria), lipids, polysaccharides and proteins
- **Pili** → Short, thin tubular structures; used in conjugation
- **Flagella** → Longer and thicker than pili; used for movement
- **Plasma Membrane** → Made of lipids and proteins; present below cell wall
- **Nucleoid** → Special region where DNA is located (no nuclear membrane)
- **Plasmid** → Extra ring of DNA; carries antibiotic resistance genes; also called F-factor (Fertility factor)
- **Ribosomes** → Only 70S ribosomes present (no membrane-bound organelles)
- **Mesosomes** → Inner extensions of cell membrane; site of cellular respiration

Nutrition — 4 Types in Bacteria:

1. Autotrophs — synthesize their own food
2. Saprotrophs — feed on dead organic matter
3. Symbionts — use food from other organisms for mutual benefit
4. Parasites — absorb food from living organisms and cause harm

Respiration:

- Aerobic — uses oxygen
- Anaerobic — without oxygen
- Respiration occurs in mesosomes

Reproduction:

Asexual → Binary Fission One bacterium divides into two in about **20 minutes** under favourable conditions.

Sexual (Genetic Recombination) → Conjugation

- Two bacteria held together by pili
- A segment of DNA / F-factor transferred from donor (male) to recipient (female) cell

Harmful Bacteria — Diseases:

Bacterium	Disease
Vibrio cholerae	Cholera
Salmonella typhi	Typhoid
Clostridium tetani	Tetanus
Corynebacterium diph	Diphtheria
Mycobacterium tuberc	Tuberculosis

Beneficial Bacteria:

Bacterium	Activity
Rhizobium	Fixes atmospheric nitrogen in roots of legumes
Azotobacter	Makes soil fertile by fixing nitrogen
Streptomyces	Produces Streptomycin antibiotic
Lactobacillus	Ferments milk sugar to lactic acid — sets curd
Methanogenic b	Sewage treatment

Cyanobacteria (Blue-Green Algae):

- Earlier called blue-green algae
- Perform oxygenic photosynthesis (release oxygen like green plants)
- Changed Earth's early atmosphere by releasing oxygen
- No flagella
- Comparatively larger cells than bacteria

Three Groups of Kingdom Monera:

1. **Archaebacteria** — Live in extreme environments

- Methanogenic (sewage, intestines)
- Thermoacidophilic (hot springs)
- Halophilic (very salty conditions)

2. **Eubacteria** — All other bacteria (excluding cyanobacteria)
3. **Cyanobacteria** — Oxygenic photoautotrophs

PART 2: KINGDOM PROTOCTISTA (Unicellular Eukaryotes)

Protoctista are unicellular eukaryotes. They include Protozoa, Diatoms and unicellular algae.

Key Features:

- Have membrane-bound organelles — nucleus, mitochondria, chloroplast, golgi bodies, endoplasmic reticulum
- Mitochondria = respiratory organelle
- Nutrition — photosynthetic, parasitic or saprotrophic
- Locomotion — cilia or flagella (with 9+2 microtubules) or pseudopodia
- Reproduce both asexually and sexually

Classification of Protoctista:

Phylum Protozoa:

- Rhizopoda → Example: Amoeba
- Flagellata → Example: Euglena
- Ciliata → Example: Paramecium
- Sporozoa → Example: Plasmodium

Protistan Algae:

- Phylum Bacillariophyta → Diatoms
- Phylum Chlorophyta → Chlorella

Important Protoctists:

1. Amoeba

- Found in freshwater ponds and mud

- Blunt pseudopodia for locomotion and food capture
- Food vacuole for digestion
- Contractile vacuole for osmoregulation
- Asexual reproduction by binary fission

2. Entamoeba histolytica

- Causes **amoebic dysentery**
- Infects through contaminated food or water
- Symptoms: abdominal pain, nausea, blood and mucus in stool

3. Plasmodium (Malarial Parasite)

- Asexual phase in human blood
- Sexual phase in female Anopheles mosquito
- Male Anopheles does NOT cause malaria (feeds on plant juices)

4. Euglena

- Found in stagnant water
- Pellicle — elastic protein body covering
- Stigma (eyespot) — red pigment, sensitive to light
- Flagellum — for movement
- Contractile vacuole — osmoregulation
- Chloroplast — for photosynthesis
- Reproduction by binary fission

5. Diatoms

- Found in fresh and salt water and moist soil
- Unicellular, colonial or filamentous
- Cell walls contain **silica**
- Food source for aquatic animals
- Dead diatoms form **diatomaceous earth** — used as filters and furnace lining

Usefulness of Algae:

- Food for fish (phytoplankton)
- Rich source of Vitamins A and E
- Source of iodine, potassium and other minerals
- Blue-green algae fix atmospheric nitrogen — natural fertilizer
- Diatoms form diatomaceous earth — used as filters and furnace lining

PART 3: KINGDOM FUNGI

Fungi were earlier classified as plants without chlorophyll. Now placed in a separate kingdom. They are heterotrophic, eukaryotic organisms.

Key Characteristics:

- Unicellular (yeast) or multicellular
- Body made of thread-like filaments called hyphae
- Group of hyphae = mycelium
- Cell wall made of chitin
- Hyphae divided by partitions called septa
- Septa have pores — cytoplasm streams freely
- No chlorophyll — nutrition by absorption (saprotrophic)
- Reproduce both asexually (spores) and sexually (conjugation)

Five Main Kinds of Fungi:

1. **Myxomycetes** — Slime moulds, irregular shape
2. **Phycomycetes** — Unicellular, filamentous e.g. Rhizopus
3. **Ascomycetes** — Yeasts, Aspergillus, Penicillium, Neurospora
4. **Basidiomycetes** — Mushrooms, toadstools, rusts, smuts
5. **Deuteromycetes** — Reproduce only asexually e.g. Alternaria
6. **Lichens and Mycorrhizae** — Symbiotic associations

Yeast:

- Unicellular, ovoid shaped
- Saprotrophic nutrition
- Anaerobic respiration: $C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2 + 2ATP$
- Asexual reproduction by budding
- Sexual reproduction by conjugation → forms ascus with 8 ascospores

Rhizopus (Bread Mould):

- Grows on bread in warm and humid conditions
- White cottony mass = mycelium
- Thread-like structures = hyphae
- Greyish black colour due to spore formation in sporangium
- Asexual reproduction by spores
- Sexual reproduction by conjugation → zygospore → meiosis → haploid spores

Lichens:

- Combination of a fungus + green/blue-green alga
- **Symbiotic association** — alga prepares food, fungus gives protection and absorbs water and minerals

Harmful Fungi:

- Puccinia graminis — Wheat Rust (brown patches on wheat)
- Rhizopus — Bread Mould
- Ringworm and Athlete's foot — skin diseases in humans

Beneficial Fungi:

- Agaricus campestris — Edible mushroom
- Yeast — Bread, beer, wine, cheese making
- Penicillium notatum — Penicillin antibiotic (discovered by Alexander Fleming in 1927)
- Neurospora — used in genetics experiments
- Mycorrhizae — fungi associated with plant roots; help in mineral absorption

TOP 5 MOST IMPORTANT EXAM QUESTIONS WITH ANSWERS

Q1. Describe the structure of a bacterial cell.

Answer: A bacterial cell has the following parts:

- **Cell Wall** — outermost layer, made of peptidoglycan, gives shape and protection
- **Plasma Membrane** — below cell wall, made of lipids and proteins, encloses cytoplasm
- **Nucleoid** — region where circular DNA is located; no nuclear membrane
- **Plasmid** — extra ring of DNA; carries antibiotic resistance genes (F-factor)
- **Ribosomes** — 70S type; only membrane-bound organelle present is mesosome
- **Mesosomes** — inner extensions of cell membrane; site of respiration
- **Flagella** — for movement (in some bacteria)
- **Pili** — for conjugation (in some bacteria)
- **Slime Capsule** — present in some bacteria for protection

Q2. What is binary fission? Describe binary fission in bacteria.

Answer: Binary fission is a type of asexual reproduction in which one cell divides into two equal daughter cells.

In bacteria:

- The circular ring of DNA replicates
- The cell grows in size
- DNA is fully replicated and cell continues to grow
- Cell divides into two daughter cells
- This process takes approximately **20 minutes** under favourable conditions

Q3. Write the economic importance of bacteria (beneficial and harmful).

Answer: Harmful — Diseases caused by bacteria:

- Vibrio cholerae — Cholera
- Salmonella typhi — Typhoid
- Clostridium tetani — Tetanus
- Corynebacterium diphtheriae — Diphtheria
- Mycobacterium tuberculosis — Tuberculosis

Beneficial activities of bacteria:

- Rhizobium — fixes atmospheric nitrogen in roots of legumes
- Azotobacter — makes soil fertile by fixing nitrogen
- Streptomyces — produces Streptomycin antibiotic
- Lactobacillus — ferments milk sugar to lactic acid, sets curd
- Methanogenic bacteria — used in sewage treatment

Q4. Describe the life cycle of Plasmodium (malarial parasite).

Answer: Plasmodium is a protozoan parasite that causes malaria. Its life cycle has two phases:

Asexual phase (in human body):

- Sporozoites enter human blood through mosquito bite
- They first go to liver cells — tissue cycle (cryptozoites)
- Then enter red blood cells — asexual cycle (merozoites)
- Some merozoites become gametocytes — sexual cycle in RBCs

Sexual phase (in female Anopheles mosquito):

- Mosquito sucks blood containing gametocytes
- Gametes are formed in mosquito stomach
- Fertilization occurs → Zygote → Sporozoites formed
- Sporozoites move to salivary glands of mosquito
- Mosquito bites human and injects sporozoites

Note: Male Anopheles cannot cause malaria as it feeds on plant juices, not blood.

Q5. List the characteristics of Kingdom Fungi. Write about the economic importance of fungi.

Answer: Characteristics of Fungi:

- Eukaryotic, unicellular or multicellular
- Body made of hyphae; group of hyphae = mycelium
- Cell wall made of chitin
- Heterotrophic — nutrition by absorption (saprotrophic)

- No chlorophyll
- Reproduce by spores (asexual) and conjugation (sexual)
- Septa divide hyphae; have pores for cytoplasm flow

Economic Importance:

Harmful:

- Puccinia graminis — wheat rust, reduces yield
- Rhizopus — spoils bread
- Cause ringworm and athlete's foot in humans

Beneficial:

- Yeast — used for making bread, beer, wine, cheese
- Penicillium notatum — source of Penicillin antibiotic (discovered by Alexander Fleming in 1927)
- Agaricus campestris — edible mushroom
- Mycorrhizae — help plant roots absorb minerals
- Neurospora — used in genetics experiments

TOP 5 PYQs (Previous Year Questions) — Most Repeatedly Asked

PYQ 1. What is the difference between prokaryotes and eukaryotes? *(Asked in: 2019, 2021, 2023)*

Answer:

Feature	Prokaryotes	Eukaryotes
Nuclear membrane	Absent	Present
True nucleus	Absent	Present
Membrane-bound org	Absent (except mesosome)	Present
Ribosomes	70S	80S
Example	Bacteria, Cyanobacteria	Protoctista, Fungi, Plants, Animals

PYQ 2. Write the differences between bacteria and cyanobacteria. *(Asked in: 2018, 2020, 2022)*

Answer:

Bacteria	Cyanobacteria
Smaller cells	Comparatively larger cells
May have flagella	Do not have flagella
Some carry out anoxygenic photosynthesis (do not release O_2)	All carry out oxygenic photosynthesis (release O_2)
Sexual recombination by conjugation	Sexual recombination rarely observed

PYQ 3. What are mycorrhizae and lichens? How are they useful? *(Asked in: 2019, 2020, 2022, 2023)*

Answer: Mycorrhizae: A symbiotic association between fungi and roots of plants.

- Roots benefit by getting minerals from the environment
- Fungi get food from the plant in return

Lichens: A symbiotic association between a fungus and a green or blue-green alga.

- Alga prepares food by photosynthesis
- Fungus gives protection, absorbs water and minerals from surroundings
- Both organisms benefit from each other

Usefulness:

- Mycorrhizae improve mineral nutrition of plants — important in agriculture and forestry
- Lichens are pioneer organisms — first to grow on bare rocks; help in soil formation

PYQ 4. Describe the structure of Euglena. *(Asked in: 2018, 2021, 2022)*

Answer: Euglena is a freshwater flagellate found in stagnant water containing decaying organic matter.

Parts of Euglena:

- **Pellicle** — elastic protein body covering
- **Cytostome and Reservoir** — cell mouth opening into tubular cytopharynx leading to a vesicle (reservoir)
- **Stigma (Eyespot)** — prominent red pigment spot; sensitive to light
- **Contractile Vacuole** — for osmoregulation
- **Flagellum** — for movement (propulsion in water)
- **Chloroplast** — contains chlorophyll; for photosynthesis

- **Nucleus** — controls cell activities
- **Paramylum bodies** — food storage

PYQ 5. What is conjugation in bacteria? How does it differ from binary fission? *(Asked in: 2020, 2021, 2023)*

Answer: Conjugation (Sexual Recombination):

- A primitive form of sexual reproduction in bacteria
- Two bacteria come close together and are held by pili
- A segment of DNA or F-factor (sex factor/fertility factor) is transferred from the male donor cell to the female recipient cell
- Bacteria then separate and cell division occurs

Difference from Binary Fission:

Binary Fission	Conjugation
Asexual reproduction	Sexual/genetic recombination
One cell divides into two	DNA transferred between two different cells
No DNA exchange between cells	DNA segment exchanged
Results in identical daughter cells	Results in genetic variation
Takes about 20 minutes	More complex process

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Kingdom Plantae and Animalia

PART 1: KINGDOM PLANTAE

Plants are multicellular, eukaryotic, photosynthetic autotrophs (rarely heterotrophs) having cellulosic cell walls. All are embryophytes.

Classification of Kingdom Plantae:

1. Bryophyta — non-vascular, amphibians of plant kingdom
2. Pteridophyta — vascular, true roots, stem and leaves
3. Spermatophyta — seed producing, vascular
    - Gymnospermae — naked seeds, not enclosed in ovary
    - Angiospermae — seeds enclosed in ovary wall
        - Dicotyledons — two cotyledons in embryo
        - Monocotyledons — one cotyledon in embryo

BRYOPHYTA

Key Features:

- Called amphibians of plant kingdom — complete life cycle in both water and land
- Grow in damp, shady places especially in hills
- No vascular tissue (no xylem or phloem)
- No true roots, stems or leaves
- Plants anchored by rhizoids (unicellular in liverworts; multicellular in mosses)
- Main plant body is gametophyte (haploid)
- Sex organs are jacketed — surrounded by sterile cells
- Male sex organ = Antheridia; Female sex organ = Archegonia
- Sporophyte remains attached to and dependent on gametophyte

- Life cycle shows Alternation of Generations

Three Types of Bryophytes:

1. **Liverworts** — flat, ribbon-like (Example: Marchantia)
2. **Mosses** — small, leafy plant body (Example: Funaria)
3. **Hornworts** — flat thalloid body with horn-like sporophyte (Example: Anthoceros)

Comparison: Gametophytic vs Sporophytic Phase:

Gametophytic Phase	Sporophytic Phase
Haploid, generally autotrophic	Diploid, heterotrophic or partially autotrophic
Has antheridia and archegonia	Has spore-producing structure
Produces gametes by mitosis	Produces spores by meiosis
Dominant phase	Short-lived, attached to gametophyte

Importance of Bryophytes:

- Pioneers of vegetation — first to grow on rock, lava, sand, water
- Act as soil binders
- Mosses hold water better than soil — improve microhabitat
- Food source for fish and birds; dried body used as nesting material by birds

PTERIDOPHYTA

Key Features:

- Lower vascular plants — contain xylem and phloem
- Found in damp, shady places and hills
- Main plant body is sporophyte (diploid)
- Have true roots, stem and leaves
- Underground stem = rhizome; leaves = fronds
- Young leaves are circinately coiled
- Axis of leaf = rachis; leaflets = pinnae; divisions of pinnae = pinnules

- Spore-producing bodies = Sporangia, present in groups called sori (singular: sorus)
- Sori may be covered by indusium
- Spores germinate into gametophyte called prothallus
- Prothallus bears antheridia and archegonia
- Life cycle shows Alternation of Generations
- Gametophyte grows independent of sporophyte but lives for a short period

GYMNOSPERMAE

Gymnos = naked; Sperma = seed. Seeds are not enclosed in ovary — they are naked.

Key Features:

- Adult plant is a tall, woody, perennial tree or shrub, mostly evergreen
- Stem usually branched (unbranched in Cycas)
- Leaves may be simple (Pinus) or compound (Cycas)
- Vascular bundles in stem arranged in a ring, show secondary growth
- Bear cones — usually unisexual (male or female), rarely bisexual (Gnetum)
- Pollen grains are haploid, produced in microsporangia of male cones
- Pinus pollen grains have two wings for wind dispersal
- Ovules borne naked on megasporophylls of female cone — not enclosed in ovary
- Fertilized ovule develops into a seed

Common Gymnosperms: Pine (Pinus), Redwood (Sequoia), Juniper (Juniperus), Cedar (Cedrus), Cycas

Products: Timber, resins, turpentine, chilgoza (dry fruit), Sago (sabudana from Cycas)

ANGIOSPERMAE

Seeds always enclosed in fruit (mature, fertilized ovary). Examples: pea, mango, coconut, wheat, rice.

Two Classes:

1. Dicotyledons — two cotyledons in seeds
2. Monocotyledons — one cotyledon in seeds

Differences between Gymnosperms and Angiosperms:

Gymnosperms	Angiosperms
Seeds naked, not enclosed in ovary	Seeds enclosed in fruit (mature ovary)
Bear cones	Bear flowers
Xylem has mainly tracheids	Xylem has both vessels and tracheids

Differences between Dicots and Monocots:

Feature	Dicot	Monocot
Cotyledons	Two	One
Leaf venation	Reticulate (network)	Parallel
Flower	Pentamerous (parts in 5)	Trimerous (parts in 3)
Vascular bundles in stem	Arranged in a ring with cambium	Scattered, no cambium

FAMILIES OF ANGIOSPERMS

1. Fabaceae (Pea Family) — Dicot

Herbs, shrubs, rarely trees

- Flowers zygomorphic (divisible into two equal halves through one radius only), bisexual
- Calyx: 5 sepals; Corolla: 5 petals (papilionaceous — butterfly shaped)
- Petals: 1 standard + 2 wings + 2 keel petals
- Androecium: 10 stamens in two whorls (9+1) = diadelphous
- Gynoecium: superior, monocarpellary, unilocular
- Fruit: pod

Examples: Pea (Pisum sativum), Arhar (Cajanus cajan), Moong (Phaseolus aureus), Soyabean (Glycine max), Groundnut (Arachis hypogea), Chana (Cicer arietinum)

2. Malvaceae (China Rose Family) — Dicot

Herbs, shrubs or trees

- Flowers pentamerous, actinomorphic (divisible through any radius)
- Epicalyx present — additional whorl below calyx

- Calyx: 5 sepals; Corolla: 5 petals
- Androecium: indefinite, monadelphous (filaments fused forming staminal tube)
- Gynoecium: 5 carpels, syncarpous, superior ovary, axile placentation
- Fruit: capsule

Examples: Hibiscus (China rose/gurhal), Cotton, Bhindi, Hollyhock

3. Liliaceae (Lily Family) — Monocot

- Mostly perennial herbs; stem is rhizome or bulb-like
- Flowers bisexual, actinomorphic, trimerous (parts in 3 or multiples of 3), hypogynous
- Perianth: 6, petaloid, in two whorls of 3 each
- Stamens: 6 (3+3) in two whorls
- Carpels: 3, syncarpous, superior ovary, axile placentation
- Fruit: capsule

Examples: Onion (Allium cepa), Aloe (Aloe barbadensis), Tulip (Tulipa tulip), Lily (Lilium candidum)

4. Poaceae (Grass Family) — Monocot

Herbs, rarely woody (sugarcane)

- Inflorescence: spike of spikelets
- Flowers very small, inconspicuous
- Stamens: 3 (sometimes 6 in rice and bamboo)
- Carpels: 3, syncarpous, unilocular, superior ovary, single basal ovule
- Fruit: caryopsis (seed coat and ovary wall inseparably fused)

Examples: Rice (Oryza sativa), Wheat (Triticum aestivum), Maize (Zea mays), Sugarcane (Saccharum officinarum), Barley (Hordeum vulgare)

PART 2: KINGDOM ANIMALIA

General Features:

- Multicellular eukaryotes
- Ingestive, heterotrophic nutrition

- Power of locomotion
- Increased sensitivity through nervous system

Basis of Classification of Animals:

Organization:

- Cellular level — Sponges (Porifera)
- Tissue level — Cnidaria
- Organ system level — All other animals

Symmetry:

- Asymmetrical — Porifera (sponges)
- Radially symmetrical — Cnidaria, Echinoderm larvae
- Bilaterally symmetrical — All other animals

Body Cavity (Coelom):

- Acoelomates — no body cavity (Porifera, Cnidaria, Platyhelminthes)
- Pseudocoelomates — false body cavity (Aschelminthes/Roundworms)
- Eucoelomates — true body cavity (all other phyla)

Embryonic Layers:

- Diploblastic — two layers (ectoderm + endoderm) — Sponges, Cnidaria
- Triploblastic — three layers (ectoderm + mesoderm + endoderm) — all other animals

Notochord:

- Present — Chordata
- Absent — Non-chordata

MAJOR PHYLA OF KINGDOM ANIMALIA

1. Phylum Porifera (Sponges)

- Body with many pores — canal system
- Large aperture = osculum; large internal cavity = spongocoel
- No organs, movable parts or appendages

- Internal skeleton of calcareous or siliceous spicules or spongin fibres
- Reproduction: asexual by budding; also sexual
- Almost all marine

2. Phylum Cnidaria (Hydroids, Jellyfish, Sea Anemone, Corals)

- No head, no segmentation
- Body wall two-layered: epidermis + gastrodermis, mesogloea in between
- Cnidoblasts (stinging cells) present — carnivorous
- Asexual reproduction in sessile polyp stage; sexual in free-swimming medusa stage
- Radial symmetry
- All marine except Hydra (freshwater)

3. Phylum Platyhelminthes (Flat Worms)

- Elongated, soft, dorsoventrally flattened worms
- No body cavity (acoelomate)
- Suckers or hooks for attachment to host
- Alimentary canal has only one opening — mouth (tapeworm has no alimentary canal)
- Mostly parasites; few free-living (Planaria)
- **Examples:** Planaria (free-living), Fasciola (liver fluke — parasite of sheep), Taenia (tapeworm — parasite of human intestine)

4. Phylum Aschelminthes (Roundworms)

- Elongated cylindrical body
- Pseudocoelom (false body cavity)
- Alimentary canal opens at both ends — mouth and anus
- Sexes separate; males smaller than females
- Mostly parasitic; some free-living in soil
- **Examples:** Ascaris (intestinal roundworm in humans), Pinworm, Wucheria (filariworm)

5. Phylum Annelida (Earthworms, Leeches)

- Elongated, segmented, coelomate worms
- Body with setae or parapodia for locomotion
- Well developed digestive system — alimentary canal open at both ends
- Excretory organs called nephridia
- Sexes united (earthworm) or separate (Nereis)
- Regeneration quite frequent
- **Examples:** Nereis, Pheretima (earthworm), Hirudinaria (leech)

6. Phylum Arthropoda (Crab, Scorpion, Insect, Spider)

- Segmented body — head, thorax, abdomen
- Head and thorax often fused = cephalothorax
- Jointed legs — one pair each on body segments
- Exoskeleton of chitinous cuticle, shed at intervals (moulting)
- Sexes usually separate

Classes of Arthropoda:

Class	Features	Example
Arachnida	Cephalothorax, 4 pairs of walking legs, simple eyes	Scorpion
Crustacea	Carapace (dorsal covering), 13 pairs of legs, compound eyes	Prawn
Myriapoda	Numerous segments, 1-2 pairs of legs per segment, compound eyes	Millipede, Scolopendra
Insecta	Head + 3-segmented thorax + abdomen, 3 pairs of legs, 2 pairs of wings, compound eyes	Cockroach

7. Phylum Mollusca (Snails, Squids, Oysters)

- Soft, unsegmented body with hard calcareous shell
- Muscular foot for locomotion
- Shell usually univalved or bivalved
- Sexes separate or united

- Examples: Pila (apple snail), Unio (freshwater mussel), Sepia (cuttlefish), Octopus

8. Phylum Echinodermata (Starfish, Sea Urchin, Sea Cucumber)

- Marine animals, unsegmented body
- Head absent; body surface with 5 radiating areas
- Radial symmetry (adults); bilateral symmetry (larvae)
- Endoskeleton of dermal calcareous ossicles with spines
- Movement by tube feet
- Regeneration of lost parts is a peculiarity
- Examples: Asterias (starfish), Ophiura (brittle star)

PHYLUM CHORDATA

Three Main Characters:

1. Notochord present at some stage of life (replaced by backbone in vertebrates)
2. Dorsal tubular nerve cord
3. Gill slits present at some stage of life

Three Subphyla:

Subphylum	Features	Example
Urochordata	Notochord only in larval stage; bag-shaped body in adult	Herdmania
Cephalochordata	Notochord and nerve cord throughout life	Amphioxus
Vertebrata	Notochord replaced by vertebral column (backbone)	All backboned animals

Subphylum Vertebrata:

Super class Agnatha (jawless):

- Class Cyclostomata — no jaws, 7 pairs of gill slits, no paired fins
- Example: Petromyzon (Lamprey)

Super class Gnathostomata (jawed):

- Class 1: Chondrichthyes

- Class 2: Osteichthyes
- Class 3: Amphibia
- Class 4: Reptilia
- Class 5: Aves
- Class 6: Mammalia

Class 1: Chondrichthyes (Cartilaginous Fish)

- Mouth ventral; tail heterocercal
- Skeleton cartilaginous
- 5 to 7 pairs of gills; operculum absent
- Example: Scoliodon (dog fish)

Class 2: Osteichthyes (Bony Fish)

- Mouth terminal; tail homocercal
- Skeleton bony
- 4 pairs of gills; operculum present
- Example: Labeo (Rohu)

Class 3: Amphibia

- Live partly in water, partly on land
- Skin smooth or rough, rich in glands
- Two pairs of pentadactyl limbs (five-fingered), digits without claws
- Heart three-chambered
- Larvae breathe by gills; adults breathe by lungs
- Eggs laid in water
- Examples: Rana (Frog), Bufo (Toad), Salamandra, Ichthyophis

Class 4: Reptilia

- Terrestrial or aquatic
- Body covered with horny scales; skin dry

- Pentadactyl limbs with clawed digits (absent in snakes)
- Respiration by lungs
- Heart three-chambered (four-chambered in crocodiles)
- Eggs with leathery shell
- Examples: Tortoise, Turtle, Calotes (garden lizard), Naja naja (cobra), Crocodile, Gharial

Class 5: Aves (Birds)

- Warm-blooded (homoiothermal/endothermal) — body temperature constant
- Body covered with feathers; scales only on hind limbs
- Body: head + neck + trunk
- Jaws with horny beak, no teeth
- Forelimbs modified into wings for flight
- Pneumatic bones (with air spaces) — makes skeleton light
- Heart four-chambered; lungs connected with air sacs
- Voice box = syrinx (at junction of trachea and bronchi)
- All oviparous (lay eggs); eggs with calcareous shell
- Examples: Struthio (Ostrich), Pavo (Peacock), Columba (Pigeon), Corvus (Crow)

Class 6: Mammalia (Mammals)

- Body covered with hair
- Mammary glands (milk glands) present
- Sweat and oil glands in skin
- External ears (pinna) present
- Heart four-chambered; warm-blooded (homoiothermal)
- Seven neck vertebrae
- Mostly viviparous (give birth to young); some primitive mammals oviparous
- Foetus nourished through placenta
- Dentition: thecodont (teeth in sockets) and heterodont (four types of teeth)

Classification of Mammalia:

Sub-class	Features	Example
Prototheria	No external ear, no placenta, mammary glands nipples, oviparous	Duck-billed Platypus (Ornithorhynchus)
Metatheria	External ear present, no placenta, marsupium present, immature young born	Kangaroo (Macropus)
Eutheria	External ear well developed, placenta present, young born	Most mammals

Important Orders of Sub-class Eutheria:

Order 1: Rodentia

- Herbivorous, terrestrial
- Incisors long, sharp, chisel-shaped
- **Example:** Rat, Squirrel

Order 2: Cheiroptera (Flying Mammals)

- Forelimbs adapted for flight; patagium works as wing
- Nocturnal (active at night)
- Use echolocation to avoid objects (like radar)
- **Example:** Bat

Order 3: Carnivora

- Flesh-eating mammals
- Large, sharp canines; fingers with sharp claws
- **Example:** Lion, Tiger, Cat, Dog

Order 4: Primates

- Highly developed brain
- Eyes forward — binocular (depth perception) vision
- Opposable thumb and greater toe for grasping
- **Example:** Monkey, Apes, Man

Order 5: Cetacea

- Aquatic; fish-like shape but breathe by lungs
- Forelimbs changed into paddles; no neck
- **Example:** Whale

Order 6: Proboscidea

- Large, herbivorous, terrestrial
- Upper lip and nose fused into long mobile trunk
- Huge tusks (incisors) in males
- **Example:** Elephant

Order 7: Ungulata

- Hoofed, herbivorous mammals
- Usually domesticated by man
- **Example:** Deer, Cow, Sheep

Q1. What is alternation of generations? Describe the life cycle of a bryophyte.

Answer: Alternation of Generations is the regular alternation of the haploid gametophyte generation with the diploid sporophyte generation in the life cycle of a plant.

Life cycle of Bryophyte:

- The main plant body is the gametophyte (haploid) — it is larger, dominant and photosynthetically active
- The gametophyte bears male sex organs (antheridia) and female sex organs (archegonia)
- Male gamete from antheridia fuses with female gamete from archegonia to form a diploid zygote
- The zygote develops into a sporophyte (diploid)
- The sporophyte remains attached to and dependent on the gametophyte for food and minerals
- The sporogenous tissue in the sporophyte undergoes meiosis to produce haploid spores

Q2. Give the differences between dicot and monocot plants with examples.

Answer:

Feature	Dicotyledons	Monocotyledons

Cotyledons in seed	Two	One
Leaf venation	Reticulate (network)	Parallel
Flower parts	Pentamerous (in 5 or multiples of 5)	Trimerous (in 3 or multiples of 3)
Vascular bundles in stem	Arranged in a ring, with cambium	Scattered, without cambium
Root system	Tap root system	Fibrous root system
Examples	Pea, mango, rose	Rice, wheat, maize, onion

Dicot families: Fabaceae, Malvaceae Monocot families: Liliaceae, Poaceae

Q3. Describe the characteristics of Phylum Chordata and its three subphyla.

Answer: Three main characters of Phylum Chordata:

1. Notochord present at some stage of life (replaced by vertebral column in vertebrates)
2. Dorsal tubular nerve cord present
3. Gill slits present at some stage of life (larva or adult)

Three Subphyla:

Urochordata:

- Notochord present only in larval stage (in tail region)
- Body bag-shaped, covered by tunic in adult
- Limbs absent
- Example: Herdmania

Cephalochordata:

- Notochord and nerve cord remain throughout life and extend through entire body length
- Body elongated, flattened from sides
- Limbs or paired fins absent
- Example: Amphioxus

Vertebrata:

- Notochord replaced by vertebral column (backbone)

- Body with well-developed head and paired fins or limbs
- Cartilaginous or bony endoskeleton
- Dorsal nerve cord divided into brain and spinal cord
- Example: All backboned animals (fish, frog, lizard, bird, human)

Q4. Write the characteristic features of Class Mammalia. Describe the three sub-classes of Mammalia with examples.

Answer: Characteristics of Mammalia:

- Body covered with hair
- Mammary (milk) glands present
- Sweat and oil glands in skin
- External ears (pinna) present
- Heart four-chambered; warm-blooded (homoiothermal)

Three Sub-classes:

Prototheria:

- No external ear
- Mammary glands without nipples
- Placenta absent
- Females are oviparous (lay eggs)
- Example: Duck-billed Platypus (Ornithorhynchus)

Metatheria:

- External ear present
- No placenta for nourishment to embryo
- Marsupium (pouch) present in females
- Immature young ones are born and kept in pouch
- **Example:** Kangaroo (Macropus)

Eutheria:

- External ear well developed
- Placenta present for nourishing embryo
- Mature young ones are born
- **Example:** Most mammals — humans, dog, cat, rat, elephant, whale

Q5. Differentiate between Gymnosperms and Angiosperms. Give the characteristics of any two families of Angiosperms.

Answer: Differences:

Feature	Gymnosperms	Angiosperms
Seeds	Naked, not enclosed in ovary	Enclosed in fruit (mature ovary)
Reproductive structures	Cones	Flowers
Xylem	Mainly tracheids; vessels usually absent	Both vessels and tracheids
Examples	Pinus, Cycas, Cedrus	Pea, mango, wheat, onion

Family 1: Fabaceae (Dicot — Pea family)

- Flowers zygomorphic, bisexual
- Calyx: 5 sepals; Corolla: 5 petals (papilionaceous — butterfly shaped)
- Androecium: 10 stamens, diadelphous (9+1)
- Gynoecium: monocarpellary, superior ovary
- Fruit: pod
- Examples: Pea (Pisum sativum), Arhar (Cajanus cajan), Groundnut (Arachis hypogea)

Family 2: Poaceae (Monocot — Grass family)

- Flowers very small, inconspicuous
- Stamens: 3 (sometimes 6 in rice and bamboo)
- Carpels: 3, syncarpous, unilocular, superior ovary
- Fruit: caryopsis (seed coat and ovary wall inseparably fused)
- Examples: Rice (Oryza sativa), Wheat (Triticum aestivum), Maize (Zea mays), Sugarcane (Saccharum officinarum)

TOP 5 PYQs (Previous Year Questions) — Most Repeatedly Asked

PYQ 1. What is the difference between Bryophytes and Pteridophytes? *(Asked in: 2018, 2020, 2022, 2023)*

Answer:

Feature	Bryophytes	Pteridophytes
Vascular tissue	Absent (non-vascular)	Present (xylem and phloem)
Dominant generation	Gametophyte (haploid)	Sporophyte (diploid)
True roots	Absent (only rhizoids)	Present
Spore-producing bodies	Present on sporophyte	Sporangia on underside of fronds
Gametophyte	Large, dominant, autotrophic	Small, independent (prothallus)
Examples	Marchantia (liverwort), Funaria (moss)	Fern

PYQ 2. List the differences between Chondrichthyes and Osteichthyes with examples. *(Asked in: 2019, 2020, 2021, 2022)*

Answer:

Feature	Chondrichthyes	Osteichthyes
Skeleton	Cartilaginous	Bony
Mouth	Ventral	Terminal
Tail	Heterocercal	Homocercal
Gills	5 to 7 pairs; operculum absent	4 pairs; operculum present
Example	Scoliodon (dog fish)	Labeo (Rohu)

PYQ 3. Give the characteristic features of Class Aves (Birds) with examples. *(Asked in: 2018, 2019, 2021, 2023)*

Answer:

- Warm-blooded (homoiothermal/endothermal) — constant body temperature
- Body covered with feathers; scales only on hind limbs
- Body: head + neck + trunk
- Jaws with horny beak; no teeth

- Forelimbs modified into wings for flight
- Pneumatic (hollow) bones — make skeleton light for flight
- **Examples:** Struthio (Ostrich), Pavo (Peacock), Columba (Pigeon), Corvus (Crow)

PYQ 4. Describe the main phyla of non-chordate animals with one example each. *(Asked in: 2019, 2020, 2022)*

Answer:

Porifera: Body with pores, canal system, osculum, spongocoel; almost all marine. Example: Sycon.

Cnidaria: Cnidoblasts (stinging cells) present; radial symmetry; polyp and medusa stages; all marine except Hydra. Example: Hydra, Jellyfish.

Platyhelminthes: Dorsoventrally flattened; no body cavity; mostly parasites; gut with one opening (mouth). Example: Taenia (tapeworm), Fasciola (liver fluke).

Aschelminthes: Cylindrical body; pseudocoelom; gut open at both ends; sexes separate. Example: Ascaris (roundworm).

Annelida: Segmented body; true coelom; nephridia for excretion; setae for locomotion. Example: Pheretima (earthworm).

Arthropoda: Jointed legs; chitinous exoskeleton; segmented body. Example: Cockroach, Prawn.

Mollusca: Soft unsegmented body; calcareous shell; muscular foot. Example: Pila (snail), Sepia.

PYQ 5. What are the characteristic differences between Reptilia and Amphibia? *(Asked in: 2018, 2020, 2021, 2023)*

Answer:

Feature	Amphibia	Reptilia
Skin	Smooth or rough, moist, rich in glands	Dry, covered with horny scales
Digits	Without claws	With clawed digits
Tympanum	Present on body surface	Small, depressed (absent in snakes)
Eggs	Laid in water, without shell	Laid on land, with leathery shell
Examples	Frog (Rana), Toad (Bufo)	Cobra (Naja naja), Tortoise, Crocodile

3

Tissues and Other Levels of Organization

PART 1: PLANT TISSUES

A tissue is a group of cells with a common origin, structure and function. The study of tissues is called histology.

Two Main Categories of Plant Tissues:

1. Meristematic (dividing)
2. Permanent (non-dividing)

MERISTEMATIC TISSUE

Key Features:

- Composed of immature, undifferentiated cells
- No intercellular spaces
- Cells are rounded, oval or polygonal; always living and thin-walled
- Each cell has abundant cytoplasm and a prominent nucleus
- Vacuoles may be small or absent

Three Types of Meristematic Tissue:

Type	Location	Function
Apical Meristem	Root tip and shoot tip	Growth in length of plants and their branches
Intercalary Meristem	Bases of leaves or bases of internodes	Internodal growth; growth of leaf lamina in (monocots)
Lateral Meristem	Cambium between xylem and phloem; cork cambium in cortex of dicots	Growth in thickness of plant body (secondary growth)

PERMANENT TISSUE

- Growth has stopped completely or for the time being
- Cells may be living or dead; thin-walled or thick-walled
- Thin-walled permanent tissues are generally living; thick-walled may be living or dead

Two Types:

1. Simple Tissue — made of only one type of cells
2. Complex Tissue — made of more than one type of cells working together as a unit

SIMPLE PLANT TISSUES

Three Types: Parenchyma, Collenchyma, Sclerenchyma

1. Parenchyma

- Living tissue
- Oval or round, thin-walled with sufficient cytoplasm
- Prominent nucleus and intercellular spaces
- Cell wall made of cellulose
- Functions: storage, photosynthesis, gives rigidity (when turgid)
- Distribution: pith and cortex of stem and root, mesophyll of leaves, endosperm of seed

2. Collenchyma

- Living tissue
- Elongated cells with thick primary walls; thickenings more at corners of cells
- Wall made of cellulose and pectin; intercellular spaces present
- Function: gives mechanical support to the plant body

3. Sclerenchyma

- Dead tissue; walls uniformly thick with lignin
- Function: mainly a supporting tissue; can withstand strains and protect inner thin-walled cells
- Distribution: fibres in stems of many plants; sclereids commonly in fruits and seeds

COMPLEX PLANT TISSUES (Vascular Tissues)

Xylem and phloem form a continuous vascular system from roots through stem and leaves. They form vascular bundles in roots and stems.

XYLEM (Greek xylo = wood)

Component	Living/Dead	Structure	Function

Tracheids	Dead	Long cells with pointed ends; walls thick with lignin; have pores	Conduct water and minerals upward
Vessels	Dead	Shorter and broader than tracheids; end walls open; join to form long tube	Conduct water and minerals upward
Xylem Fibres	Dead	Long cells with very thick lignin; no pores	Support
Xylem Parenchyma	Living	Small thin-walled cells with cellulose walls	Storage

PHLOEM

Component	Living/Dead	Structure	Function
Sieve tube	Living	Elongated sieve elements; end walls have perforations (sieve plates)	Translocate food assimilated in leaves
Companion cell	Living	Long, rectangular cells associated with sieve	Help sieve tubes in translocation
Phloem fibre	Dead	Very long cells with thick lignified walls	Support
Phloem Parenchyma	Living	Elongated cells; thin cellulose cell walls	Storage

THEORIES OF SHOOT APEX AND ROOT TIP GROWTH

1. Tunica Corpus Theory (for vegetative shoot apex)

- Two zones in apical meristem:
    - Tunica (tunic = cover) — one or more peripheral layers of cells; show anticlinal divisions (perpendicular to periphery) — brings about surface growth
    - Corpus (corpus = body) — mass of cells enclosed by tunica; cell division is irregular and at various planes — results in growth in volume
- Tunica gives rise to: epidermis and cortex
- Corpus gives rise to: endodermis, pericycle, pith and vascular tissue

2. Histogen Theory (for apical meristem of stem and root)

- Meristematic cells form promeristem which differentiates into three zones:
    - Dermatogen — gives rise to epidermis of stems and epiblema of roots

- Periblem (middle layer) — gives rise to cortex of stems and roots
- Plerome — gives rise to pericycle, pith and vascular tissue

- Each zone = a group of initials called a histogen (tissue builder)

PART 2: ANIMAL TISSUES

Four Types of Animal Tissues:

1. Epithelial tissue — protection by covering, secretion, absorption
2. Connective tissue — binding, support, transport
3. Muscular tissue — movement and locomotion
4. Nervous tissue — control and co-ordination

EPITHELIAL TISSUE

Structural Characteristics:

- Cells closely packed with NO intercellular spaces
- Arise from a non-cellular basement membrane
- Not supplied with blood vessels
- Function: line surfaces, help in absorption, secretion, bear cilia

Types of Epithelial Tissue:

Type	Structure	Location	Function
Squamous Epithelium	Flattened cells; centrally placed nucleus; i margins	Lining of air sacs in lungs kidney tubules; blood capillaries	Exchange of O_2 and CO_2; absorption; exchange of materials
Cuboidal Epithelium	Cube-like cells; centrally placed nucleus; cells polygonal	Lining of salivary and pancreatic ducts; sweat and salivary glands	Absorption; secretion
Ciliated Epithelium	Have cilia at free ends	Lining of kidney tubules	Flow of nephric filtrate
Columnar	Long column-like cells;	Lining of stomach and	Secretion and absorption

Epithelium	nucleus at basal end	intestine	
Ciliated Columnar Epithelium	Cilia at free ends	Lining of trachea	Flow of fluids in a particular direction

Simple Epithelium — epithelial cells in a single layer Stratified (Compound) Epithelium — epithelial cells in many layers; present where there is lot of wear and tear e.g. skin and inner lining of cheeks

CONNECTIVE TISSUE

Two Components: (a) Matrix — the ground substance (b) Cells

Three Types of Connective Tissue:

A. Proper Connective Tissue:

1. **Areolar** — most widely spread connective tissue
    - Fibroblasts — form yellow (elastin) and white (collagen) fibres in matrix
    - Macrophages — engulf bacteria and micro-pathogens
    - Mast cells — secrete heparin; helps in clotting of blood
2. **Adipose** — has specialized cells that store fat; provides padding
3. **Fibrous** — mainly made up of fibroblasts; forms tendons and ligaments

B. Supporting Connective Tissue:

Feature	Cartilage	Bone
Matrix	Made of chondrin	Made of ossein; contains calcium, phosphorus and magnesium salts
Cells	Chondrocytes; lie singly or in groups in fluid-filled spaces	Osteocytes; lie on lamellae (concentric rings); give out branched processes
Arrangement	May be elastic (yellow fibres — pinna of ear)	Spongy (irregular; at ends of long bones) or Compact circles around Haversian canal)
Nature	Flexible and strong	Hard and rigid

C. Fluid Connective Tissue:

Blood:

- Complex of blood cells and plasma (plasma = matrix)
- Red Blood Cells (Erythrocytes) — transport O_2 and CO_2
- White Blood Cells (Leucocytes) — defence against bacteria, viruses and other invaders

Lymph: Second type of fluid connective tissue

MUSCLE TISSUE

- Composed of long excitable cells with parallel microfilaments of contractile proteins (actin, myosin, troponin, tropomysin)
- Muscle cell = muscle fibre (due to elongated shape)

Four Characteristics of Muscle Fibres:

1. Excitability — respond to stimulus
2. Extensibility — can stretch
3. Contractility — can contract
4. Elasticity — move back to original position

Three Types of Muscle Fibres:

Feature	Striated (Voluntary/Skeletal)	Unstriated (Involuntary/Smooth)	Cardiac
Location	Attached to skeleton — head, limbs, face	Walls of body organs — stomach, intestines	Walls of heart
Shape	Elongated, cylindrical, unbranched	Spindle shaped, tapering	Elongated, cylindrical, branched
Striations	Present	Absent	Present (faint)
Sarcolemma	Thin and tough (present)	Thin cell membrane, no sarcolemma	Thin
Nucleus	Multi-nucleated, peripheral	Uninucleated, centrally placed	One nucleus per unit, centrally placed
Blood supply	Rich	Poor	Rich

Intercalated dis	Absent	Absent	Present
Control	Voluntary	Involuntary	Involuntary

NERVOUS TISSUE

- Two kinds of cells: Neurons and Neuroglia cells
- Neuron is the functional unit of nervous tissue
- Nervous tissue constitutes: brain, spinal cord, nerves, sensory cells and sense organs

Parts of a Neuron:

- **Cyton** — main cell body of the neuron; contains nucleus, mitochondria and Nissl bodies (dark granules made of RNA and Protein)
- **Dendrites** — smaller branching processes of the cyton (Gk. dendros = tree); receive stimulus
- **Axon** — the long, single process of cyton; transmits impulse to muscle or gland; constitutes the nerve fibre
- **Medullary sheath** — extra sheath covering the axon; made of myelin (lipid-like substance); secreted by Schwann cells; makes nerve fibre medullated
- **Nodes of Ranvier** — gaps where medullary sheath is broken; not continuous
- **Non-medullated** — nerve fibres without medullary sheath

Transmission of Nerve Impulse: Dendrites receive stimulus → transmit through cyton → axon transmits to muscle (to contract) or gland (to secrete)

LEVELS OF ORGANISATION — CELL TO ORGANISM

From smallest to largest (in correct sequence):

Cell → Tissue → Organ → Organ System → Organism

1. **Cellular Level** — organization of activities by different organelles in a single cell. Example: white blood cell, green cell of leaf
2. **Tissue Level** — aggregates of cells of same origin and function. Example: surface epithelium of skin, dividing cells at root cap
3. **Tissue System** — two or more different cell types combine for a particular activity (mainly in plants). Example: vascular tissue (xylem + phloem) in veins of leaf
4. **Organ Level** — distinct part of body composed of variety of tissues performing special functions. Example: liver (animal), leaf (plant)

5. **Organ System** — combination of organs devoted to one general function. Example: respiratory system (lungs + trachea + diaphragm) in man

6. **Organism** — complete individual made of different organ systems. Example: man, monkey, mustard plant

TOP 5 MOST IMPORTANT EXAM QUESTIONS WITH ANSWERS

Q1. Classify plant tissues and describe the three types of simple permanent tissues.

Answer: Classification of Plant Tissues:

- Meristematic (dividing)
- Permanent — Simple (Parenchyma, Collenchyma, Sclerenchyma) and Complex (Xylem, Phloem)

Three Simple Permanent Tissues:

1. Parenchyma:

- Living; oval or round thin-walled cells with cellulose wall
- Prominent nucleus; intercellular spaces present
- Functions: storage, photosynthesis (in chlorenchyma), provides rigidity when turgid

2. Collenchyma:

- Living; elongated cells with thick primary walls; thickenings at corners of cells
- Wall made of cellulose and pectin
- Function: gives mechanical support to plant body

3. Sclerenchyma:

- Dead; thick walled cells; walls uniformly thick with lignin
- Two types: Fibres (elongated, pointed ends) and Sclereids (irregular shape, very thick wall)
- Function: supporting tissue; withstands strains; protects inner thin-walled cells

Q2. Describe the structure and functions of Xylem and Phloem.

Answer: Xylem: Conducting tissue; conducts water and salts upward from roots to leaves

Components:

- Tracheids (dead) — long cells with pointed ends; thick lignified walls with pores
- Vessels (dead) — shorter and broader; end walls open; join to form a long tube

- Xylem Fibres (dead) — very thick lignified walls; no pores; give support
- Xylem Parenchyma (living) — small thin-walled cells; storage

Phloem: Conducting tissue; conducts food synthesized in leaves to different parts of plant

Components:

- Sieve tube (living) — elongated elements; end walls have perforations (sieve plates)
- Companion cells (living) — long rectangular cells associated with sieve tubes; help in translocation
- Phloem Fibre (dead) — very long cells; thick lignified walls; give support

Q3. Describe the four types of animal tissues with their functions.

Answer:

1. Epithelial Tissue:

- Cells closely packed; no intercellular spaces; arise from basement membrane; no blood vessels
- Functions: protection (lines body surfaces), secretion, absorption

2. Connective Tissue:

- Has two components — matrix and cells; matrix and cells differ in different types
- Functions: binding, support, transport, protection
- Types: Areolar, Adipose, Fibrous (proper); Cartilage, Bone (supporting); Blood, Lymph (fluid)

3. Muscle Tissue:

- Long excitable cells (muscle fibres) with contractile proteins (actin, myosin)
- Properties: excitability, extensibility, contractility, elasticity
- Three types: Striated (voluntary — skeletal), Unstriated (involuntary — stomach, intestine),

4. Nervous Tissue:

- Two types of cells: neurons (functional unit) and neuroglia cells
- Neuron has cyton, dendrites and axon
- Dendrites receive stimulus; axon transmits impulse to muscles or glands

Q4. Write differences between striated, unstriated and cardiac muscle.

Answer:

Feature	Striated	Unstriated	Cardiac
Location	Skeleton (limbs, face)	Walls of stomach, intestine	Walls of heart
Shape	Elongated, cylindrical	Spindle shaped, tapering	Elongated, cylindrical
Striations	Present	Absent	Present (faint)
Nucleus	Multi-nucleated, peripheral	One, centrally placed	One per unit, centrally placed
Sarcolemma	Present (tough)	Absent	Present (thin)
Blood supply	Rich	Poor	Rich
Intercalated discs	Absent	Absent	Present
Control	Voluntary	Involuntary	Involuntary

Q5. Describe the structure of a neuron and explain the transmission of nerve impulse.

Answer: Structure of a Neuron:

A neuron has the following parts:

- **Cyton** — main cell body; contains nucleus, mitochondria and Nissl bodies (dark granules made of RNA and Protein)
- **Dendrites** — short, branching processes of cyton; receive stimulus
- **Axon** — one long process; transmits impulse; constitutes the nerve fibre
- **Medullary sheath** — extra covering around axon; made of myelin (lipid-like substance); secreted by Schwann cells; makes the nerve fibre medullated
- **Nodes of Ranvier** — gaps where medullary sheath is interrupted (not continuous)

Transmission of Nerve Impulse:

- Dendrites receive the stimulus
- Stimulus is transmitted through cyton to the axon
- Axon transmits the impulse through its branched ends to either:
  - A muscle — to order it to contract, or
  - A gland — to order it to secrete

The direction of impulse flow is always: Dendrites → Cyton → Axon

TOP 5 PYQs (Previous Year Questions) — Most Repeatedly Asked

PYQ 1. What is a tissue? Distinguish between simple and complex plant tissues. *(Asked in: 2018, 2020, 2021, 2023)*

Answer: Tissue — A group of cells with a common origin, structure and function. The study of tissues is called histology.

Feature	Simple Tissue	Complex Tissue
Cell types	Made of only one type of cells	Made of more than one type of cells
Examples	Parenchyma, Collenchyma, Sclerenchyma	Xylem, Phloem
Function	Each tissue performs one specific function	Different types of cells work together as a unit
Nature of cells	Cells may be living or dead	May have both living and dead cells together

PYQ 2. Differentiate between Xylem and Phloem. *(Asked in: 2019, 2020, 2022, 2023)*

Answer:

Feature	Xylem	Phloem
Function	Conducts water and minerals upward from root to leaves	Conducts food (metabolites) from leaves to different parts
Direction	Upward (unidirectional)	Bidirectional
Main components	Tracheids, Vessels, Xylem Fibres, Xylem Parenchyma	Sieve tubes, Companion cells, Phloem Fibre, Parenchyma
Living/Dead components	Mostly dead (except xylem parenchyma)	Mostly living (except phloem fibre)
Cell walls	Thick with lignin	Thin, made of cellulose

PYQ 3. Describe the types of epithelial tissue with their location and function. *(Asked in: 2018, 2019, 2021, 2022)*

Answer: Epithelial tissue has cells closely packed with no intercellular spaces; arise from a basement membrane; not supplied with blood vessels.

- **Squamous** — flattened cells; lining of air sacs (lungs), kidney tubules, blood capillaries; function: exchange of gases, absorption, exchange of materials
- **Cuboidal** — cube-like cells; lining of salivary and pancreatic ducts, sweat glands; function: absorption and secretion

- **Ciliated** — cells with cilia at free ends; lining of kidney tubules; function: flow of nephric filtrate
- **Columnar** — long column-like cells; lining of stomach and intestine; function: secretion and absorption
- **Ciliated Columnar** — cilia at free ends; lining of trachea; function: flow of fluids in particular direction
- **Brush-bordered Columnar** — numerous folds at free ends like bristles; lining of intestine; function: increase surface area for absorption

If epithelial cells are in one layer = Simple epithelium. If in many layers = Stratified epithelium (example: skin, inner lining of cheeks).

PYQ 4. Write the differences between meristematic and permanent tissue. *(Asked in: 2019, 2020, 2021, 2023)*

Answer:

Feature	Meristematic Tissue	Permanent Tissue
Cell division	Cells actively divide	Growth has stopped; cells do not divide
Cell nature	Undifferentiated, immature	Differentiated, mature
Cell wall	Thin-walled	Thin-walled (living) or thick-walled (dead)
Vacuoles	Small or absent	Large, well-developed
Cytoplasm	Dense, abundant	May be less dense
Location	Root tip, shoot tip, cambium	Pith, cortex, vascular bundles, surface
Examples	Apical meristem, lateral meristem	Parenchyma, xylem, phloem

PYQ 5. What are the levels of organization in living organisms? Explain with examples. *(Asked in: 2018, 2020, 2022)*

Answer: The levels of organization from lowest to highest are:

Cell → Tissue → Organ → Organ System → Organism

1. **Cellular Level** — organization of activities by organelles in a single cell. Example: white blood cell (animal); green cell of a leaf (plant)
2. **Tissue Level** — aggregates of cells of same origin and function. Example: skin epithelium (animal); dividing cells at root cap (plant)
3. **Tissue System** — two or more cell types combine to perform a particular activity (mainly in plants). Example: vascular tissue — xylem + phloem in veins of a leaf

4. **Organ Level** — distinct recognizable part of body composed of variety of tissues performing special functions. Example: liver (animal); leaf (plant)

5. **Organ System** — combination of organs devoted to one general function. Example: respiratory system — lungs + trachea + diaphragm (man); shoot system — leaves + stem + branches (plant)

6. **Organism** — complete individual made of different organ systems. Example: man, monkey, mustard plant

4

Root System

The root system is the descending (growing downwards) portion of the plant axis. When a seed germinates, radicle is the first organ to come out. It elongates to form the primary or tap root, which gives off secondary and tertiary lateral roots.

CHARACTERISTICS OF ROOTS

- Non-green — due to absence of chlorophyll
- Not divided into nodes and internodes
- Absence of leaves and buds
- **Positively geotropic** — grow towards gravity
- **Positively hydrotropic** — grow towards water
- **Negatively phototropic** — grow away from light

TYPES OF ROOT SYSTEMS

1. Tap Root System:

- Develops from the radicle; continues as primary root (tap root)
- Gives off lateral roots (secondary and tertiary)
- Provides very strong anchorage — reaches very deep into soil
- Main root system of **dicots**

2. Fibrous Root System:

- Primary root is short-lived
- A cluster of slender, fiber-like roots arises from base of radicle and plumule
- Shallow, spread horizontally — cannot provide strong anchorage
- Main root system of **monocots**

TYPES OF ROOTS

1. Tap Root:

- Primary and main root; develops from radicle
- Bears numerous branches; remains underground
- Found in dicots — sunflower, mustard, carrot, mango

2. Adventitious Root:

- Develops from any part of the plant except the radicle
- May be aerial or underground
- Grows from node (money plant, bamboo), stem cutting (rose), tree branch (banyan) or stem base (monocot fibrous roots)

REGIONS OF ROOT

From tip towards base — four regions in sequence:

1. Root Cap Region:

- Thimble-like structure; produced by meristematic zone
- Protects the tender apex (apical meristem) from harsh soil particles
- Root cap wears out but is constantly renewed
- In aquatic plants (Pistia, water hyacinth) root cap is like a loose thimble called root pocket

2. Region of Meristematic Cells:

- Small region of actively dividing cells = apical meristem
- Three zones:
  - **Dermatogen** — outermost layer; matures into epiblema and root cap
  - **Periblem** — inner to dermatogen; matures into cortex
  - **Plerome** — central region; matures into stele
- In monocots, root cap is formed by independent group of cells called Calyptrogen

3. Region of Elongation:

- Situated next to meristematic region
- Cells elongate and enlarge — makes root grow in length

4. Region of Maturation:

- Next to region of elongation
- Two sub-regions:
  - **Root hair (Piliferous) region** — unicellular hairs; absorb water and mineral salts from soil
  - **Permanent region** — lies behind root hair zone; without hairs; produces lateral roots; anchors plant; conducts water and minerals upwards

MODIFICATIONS OF ROOTS

A. TAP ROOT MODIFICATIONS (for food storage)

Type	Characters	Example
Conical	Base broad; tapers gradually towards apex	Carrot
Fusiform	Swollen in middle; tapering towards both ends	Radish
Napiform	Spherical at base; tapering sharply towards tip	Turnip
Tuberous	Thick and fleshy with no definite shape	4 O'clock plant

B. ADVENTITIOUS ROOT MODIFICATIONS

(i) For food storage:

Type	Characters	Example
Tuberous	Swollen roots from nodes of prostrate stem	Sweet Potato
Fasciculated	Swollen roots in a cluster from stem	Dahlia
Nodulose	Only apices of roots swollen like single beads	Mango-ginger
Moniliform	Roots alternately swollen and constricted; beaded appearance	Grasses, Sedges
Annulated	Looks like discs placed one above the other	Ipecac

(ii) For photosynthesis:

Assimilatory roots — exposed to sun; develop chlorophyll; turn green; manufacture food. Example: Tinospora (aerial root), orchid

(iii) For absorbing atmospheric moisture:

Epiphytic roots — aerial roots; greenish; covered with spongy tissue called **Velamen**; absorb atmospheric moisture. Example: orchid (Vanda)

(iv) For better gaseous exchange:

Pneumatophores (Respiratory roots) — grow vertically upward (negatively geotropic) into air; exposed tips have minute pores through which roots respire; appear like conical spikes coming out of water. Example: Mangroves, Rhizophora

(v) For sucking nutrition from host:

Sucking roots or Haustoria — parasitic plants give out haustoria which penetrate living host plant and suck food from phloem. Example: Cuscuta

(vi) For strong support:

Type	Characters	Example
Prop roots	Roots develop from tree branches; hang downwards; penetrate ground; heavy branches	Banyan
Stilt roots	Extra roots from nodes near base of stem; grow obliquely downwards; p soil; give strong anchorage	Sugarcane, Screwpine
Climbing roots	Roots arising from nodes of weak climbers; clasp support	Money plant, Betel
Clinging roots	Special clinging roots; enter crevices of support; fix the epiphyte	Epiphytes, Orchids

(vii) For buoyancy and respiration:

Floating roots — spongy, floating roots filled with air; arise from nodes of aquatic plants; help in floating and respiration. Example: Jussiaea

FUNCTIONS OF ROOTS

1. **Anchorage** — roots anchor the plant firmly to the soil (mechanical function)
2. **Absorption** — roots absorb water and mineral salts and conduct them upwards (physiological function)
3. **Special functions** — by undergoing modifications; food storage, assimilation, absorption of atmospheric moisture, sucking food from host, better gaseous exchange, floating, stronger anchorage and climbing

PRIMARY STRUCTURE OF ROOTS

A. DICOT ROOT (e.g. Gram)

From outside to inside:

1. **Epiblema** — single, outermost layer of thin-walled cells; some cells prolonged to form unicellular root hairs; protects and absorbs water

2. **Cortex** — large zone; many layered; cells thin-walled parenchymatous with intercellular spaces; stores food and water

3. **Endodermis** — innermost layer of cortex; cells barrel-shaped, closely packed; show band-like thickenings on radial walls called Casparian strips. Some cells opposite the protoxylem which lack these strips are called Passage cells — help movement of water and dissolved salts from cortex directly into xylem

4. **Stele** — all tissues inner to endodermis

5. **Pericycle** — single layer inner to endodermis; seat of origin of lateral roots, vascular cambium and cork cambium during secondary growth

6. **Vascular bundle** — xylem and phloem patches on alternate radii (radial arrangement); xylem is **exarch** (protoxylem towards periphery; metaxylem towards centre); 2-6 xylem patches (diarch to hexarch)

7. **Pith** — very small or absent (sometimes metaxylem meets in centre)

8. **Conjunctive parenchyma** — parenchyma separating xylem and phloem lying on different radii

B. MONOCOT ROOT (e.g. Maize)

1. **Epiblema** — outermost single layer; some cells prolonged into root hairs

2. **Cortex** — large zone; multilayered; parenchymatous; stores water and food

3. **Endodermis** — innermost layer of cortex; with casparian strips and passage cells

4. **Pericycle** — single layered; polygonal thin-walled cells; lateral roots originate from here

5. **Vascular bundle** — many patches of xylem and phloem; radially arranged; xylem is exarch and **polyarch** (many xylem patches)

6. **Pith** — large, well developed, parenchymatous or sclerenchymatous; stores food

7. **Conjunctive Parenchyma** — between xylem and phloem strands

DIFFERENCES BETWEEN DICOT AND MONOCOT ROOT

Characters	Dicot Root	Monocot Root
Number of vascular bundles	2-6 (di-hexarch)	Many (polyarch)
Pericycle	Seat of origin of lateral roots, vascular and cork cambium	Seat of origin of lateral roots only
Cambium	Present	Absent
Secondary growth	Present	Absent

Pith	Very small or absent	Large, well developed

ORIGIN OF LATERAL ROOTS (Endogenous Origin)

- Origin of lateral roots is **endogenous** — from deeper layers
- Seat of origin = **pericycle** (cells opposite the protoxylem divide)
- They form a hump in the endodermis
- Hump penetrates into the cortex and emerges as a lateral branch

SECONDARY GROWTH IN DICOT ROOTS

Secondary growth = increase in girth (width) of root. Found only in dicot roots. Lateral meristems involved: Vascular cambium and Cork cambium (both secondary in origin; arise from pericycle).

Steps of secondary growth:

1. Pericycle cells outside the protoxylem divide to form a strip of cambium
2. Another strip of vascular cambium appears in conjunctive tissue on inner side of phloem bundle
3. These two strips join laterally to form a ring — initially wavy but later becomes circular (due to over production of secondary xylem inner to primary phloem)
4. Vascular cambium divides — cells added towards periphery differentiate into secondary phloem; cells added towards centre differentiate into secondary xylem
5. Secondary tissue outer to protoxylem bundle differentiates into primary medullary rays — protoxylem does not get crushed
6. Cork cambium (Phellogen) also differentiates in pericycle
7. Cork cambium divides — gives rise to Cork (Phellem) towards outside and secondary cortex (Phelloderm) towards inside

TOP MOST IMPORTANT EXAM QUESTIONS WITH ANSWERS

Q4. Give the differences between dicot and monocot root.

Answer:

Characters	Dicot Root	Monocot Root
Number of vascular bundles	2-6 (di-hexarch)	Many (polyarch)

Pericycle	Origin of lateral roots, cambium and cork cambium	Origin of lateral roots only
Cambium	Present (secondarily)	Absent
Secondary growth	Present	Absent
Pith	Very small or absent	Large, well developed
Examples	Gram, mustard	Maize, wheat

Q5. Describe secondary growth in dicot roots.

Answer: Secondary growth is the increase in girth (width) of root. It occurs only in dicot roots. Lateral meristems involved are vascular cambium and cork cambium — both arising from pericycle.

Steps:

1. Pericycle cells outside protoxylem divide to form a cambium strip
2. Another cambium strip forms in conjunctive tissue inside phloem bundle
3. Both strips join to form a wavy ring which later becomes circular
4. Vascular cambium divides — produces secondary phloem towards outside and secondary xylem towards inside
5. Secondary tissue outer to protoxylem differentiates into primary medullary rays
6. Cork cambium (Phellogen) differentiates in pericycle
7. Phellogen produces Phellem (cork) towards outside and Phelloderm towards inside

TOP 5 PYQs (Previous Year Questions) — Most Repeatedly Asked

PYQ 1. What are the characteristics of roots? Name the two types of root systems with examples. *(Asked in: 2018, 2020, 2022, 2023)*

Answer: Characteristics:

- Non-green (no chlorophyll)
- No nodes and internodes
- No leaves and buds
- Positively geotropic (grow towards gravity)
- Positively hydrotropic (grow towards water)

- Negatively phototropic (grow away from light)

Two Types: Tap Root System:

- Develops from radicle; primary root with lateral roots; strong anchorage; deep penetration
- Found in dicots. Examples: gram, neem, chinarose

Fibrous Root System:

- Primary root short-lived; cluster of slender fiber-like roots; shallow; spread horizontally
- Found in monocots. Examples: maize, wheat, grass

PYQ 2. Explain the various modifications of adventitious roots with examples. *(Asked in: 2019, 2020, 2021, 2022)*

Answer: For food storage: Tuberous (sweet potato), Fasciculated (Dahlia), Nodulose (Mango-ginger), Moniliform (grasses)

For photosynthesis: Assimilatory roots — turn green in sunlight; manufacture food. Example: Tinospora, orchid

For absorbing moisture: Epiphytic roots — covered with Velamen tissue; absorb moisture from atmosphere. Example: Vanda orchid

For respiration: Pneumatophores — grow negatively geotropically out of water; have minute pores for breathing. Example: Mangroves (Rhizophora)

For sucking from host: Haustoria — penetrate host and suck food from phloem. Example: Cuscuta

For buoyancy: Floating roots — spongy, air-filled; help plant float and breathe. Example: Jussiaea

PYQ 3. Describe the origin of lateral roots. Why is it called endogenous? *(Asked in: 2019, 2021, 2023)*

Answer: The origin of lateral roots is called endogenous because they arise from a deep inner layer of the root — the pericycle — and not from the outer surface.

Process:

- Pericycle cells opposite the protoxylem divide actively
- They form a hump in the endodermis
- The hump penetrates through the cortex
- The hump differentiates into three regions: dermatogen, periblem and plerome
- Finally the lateral root emerges out of the parent root

The number of lateral roots formed in any region corresponds exactly to the number of xylem bundles in that region. Because these roots arise from the inner pericycle layer and have to break through endodermis and cortex, it is very difficult to pluck lateral roots from the main root.

PYQ 4. What are pneumatophores? Where are they found and what is their function? *(Asked in: 2018, 2020, 2021, 2023)*

Answer: Pneumatophores (also called respiratory roots) are special adventitious root modifications found in plants growing in marshy, waterlogged or swampy areas (mangroves).

Characters:

- Some roots grow vertically upward (negatively geotropic) into the air
- Exposed root tips possess minute pores (lenticels) through which roots exchange gases
- Appear like conical spikes or pegs coming out of water or mud

PYQ 5. Differentiate between dicot and monocot root. *(Asked in: 2018, 2019, 2020, 2021, 2022, 2023)*

Answer:

Characters	Dicot Root	Monocot Root
Number of vascular bundles	2-6 (di-hexarch)	Many (polyarch)
Pericycle function	Origin of lateral roots + cambium + cork cambium	Origin of lateral roots only
Cambium	Present (formed secondarily)	Absent
Secondary growth	Present	Absent
Pith	Very small or absent	Large and well developed
Xylem condition	Exarch, 2-6 patches	Exarch, polyarch (many patches)
Examples	Gram, mustard	Maize, wheat

5

Shoot System

STEM

Characteristics of Stem:

- Develops from plumule; positively phototropic and negatively geotropic
- Divided into nodes and internodes; bears leaves, buds, flowers and fruits
- Bears vegetative buds (apical/axillary) and floral buds

Stem vs Root (Key Differences):

- Stem develops from plumule; Root from radicle
- Stem is green (chlorophyll present); Root is non-green
- Stem has nodes/internodes; Root does not
- Lateral branch origin is exogenous (outer layers); Lateral root origin is endogenous (pericycle)
- Stem is negatively geotropic; Root is positively geotropic
- No root cap in stem; Root cap present in root

Shoot Apex

The shoot apex is terminal, dome-shaped, formed of apical shoot meristem. It has two zones:

- **Tunica** — outer 1-3 layers; gives rise to epidermis; cells divide anticlinally only
- **Corpus** — inner multilayered zone; cells divide in all directions; gives rise to procambium (vascular tissue) and ground meristem (ground tissue)

Origin of Lateral Branches: From axillary buds; development is exogenous

Types of Stem

- **Aerial** — erect, rigid (trees, shrubs, herbs)
- **Sub-aerial** — weak, trails on ground (creepers/climbers)
- **Underground** — buried in soil

Modifications of Stem

Underground Modified Stems

Type	Example
Rhizome	Ginger, Turmeric
Corm	Saffron, Yam, Gladiolus
Bulb	Onion
Tuber	Potato

Functions: Perennation + Food storage Identified as stems by: nodes/internodes, scaly leaves, buds

Sub-aerial Modified Stems

Type	Example	Function
Runner	Grass, Oxalis	Vegetative propagation
Stolon	Mint, Jasmine	Vegetative propagation
Offset	Water hyacinth	Vegetative propagation
Sucker	Chrysanthemum	Vegetative propagation

Aerial Modified Stems

Type	Example	Function
Stem Tendrils	Grape vine	Climbing
Thorns	Citrus, Duranta	Protection
Phylloclade	Opuntia	Photosynthesis + Water storage
Cladode	Asparagus	Photosynthesis (1-2 internodes only)

Functions of Stem

Primary: Support leaves, conduction of water/minerals (xylem) and food (phloem), bear flowers/fruits

Secondary: Storage (potato), Perennation (ginger), Vegetative propagation (sugarcane), Photosynthesis (Opuntia), Protection (Citrus thorns), Climbing (grape vine tendrils)

Internal Structure

A. Dicot Stem — e.g., Sunflower

- Epidermis → Cuticle covered, multicellular hairs
- Cortex:
  - Hypodermis — Collenchyma (mechanical support)
  - Middle layers — Parenchyma
  - Endodermis — Starch sheath (barrel-shaped cells)
- Stele:
  - Pericycle — Multilayered, parenchyma + sclerenchyma patches
  - Vascular bundles — Arranged in a ring; conjoint, collateral, open; endarch xylem
  - Medullary rays — parenchyma between vascular bundles
  - Pith — Central parenchymatous zone

B. Monocot Stem — e.g., Maize

- Epidermis — single layered, no hairs
- Ground tissue — undifferentiated parenchyma; peripheral hypodermis is sclerenchymatous
- Vascular bundles — numerous, scattered, collateral, closed, endarch xylem in "Y" shape; protoxylem disintegrates forming water cavity; each bundle surrounded by sclerenchymatous bundle sheath

Key Dicot vs Monocot Stem Differences:

Character	Dicot	Monocot
Hypodermis	Collenchymatous	Sclerenchymatous
Ground tissue	Differentiated	Undifferentiated
Vascular bundles	Ring arrangement, open	Scattered, closed
Bundle sheath	Absent	Present
Secondary growth	Present	Mostly absent
Water cavity	Absent	Present

Secondary Growth in Dicot Stem

Occurs due to two lateral meristems:

1. Vascular Cambium activity:

- Fascicular cambium (within vascular bundle) + Interfascicular cambium (from medullary ray cells) → form continuous cambium ring
- Cambium divides inward → Secondary Xylem (more in quantity)
- Cambium divides outward → Secondary Phloem

2. Cork Cambium (Phellogen) activity:

- Develops in cortex
- Outward → Phellem (Cork) — dead, suberized cells
- Inward → Phelloderm (Secondary cortex)
- Phellogen + Phellem + Phelloderm = Periderm
- **Lenticels** — loosely arranged non-suberized complimentary cells; allow gaseous exchange
- **Bark** = all dead cells outside active phellogen

Wood

Wood = Secondary xylem produced by vascular cambium in dicot stem

Annual Rings:

- Spring wood (Early wood) — wide vessels, more active cambium, lighter in colour
- Autumn wood (Late wood) — narrow vessels, less active cambium, darker
- Spring + Autumn wood together = One Annual Ring
- Science of tree-age determination by annual rings = Dendrochronology

Sap Wood vs Heart Wood:

Sap Wood	Heart Wood
Outer, light coloured	Central, dark coloured
Functional, living cells present	Non-functional, no living cells
Vessels not plugged	Vessels plugged with tyloses
Less durable	More durable, commercially valuable

LEAF

Structure of Leaf

- Leaf base — attaches to stem node; bears stipules (dicots) or sheath (monocots)
- Petiole — stalk; petiolate or sessile
- Lamina — green, flattened; mid rib is most prominent vein

Venation

- Reticulate — network pattern; dicots (e.g., Peepal — unicostate; Grape vine — multicostate)
- Parallel — parallel rows; monocots (e.g., Canna — unicostate; Palm — multicostate)

Types of Leaves:

- Simple — undivided lamina; incisions do not reach midrib
- Compound — lamina divided into leaflets; incisions reach midrib
    - Pinnate — leaflets on rachis (e.g., Neem)
    - Palmate — leaflets radiate from tip of petiole (e.g., Silk cotton)

Key rule: Axillary bud present in axil of leaf but NOT of leaflet

Phyllotaxy

- Alternate — one leaf per node (mango, china rose)
- Opposite Decussate — successive pairs at right angles (Tulsi, Calotropis)
- Opposite Superposed — successive pairs in same plane (Guava)
- Whorled — more than two leaves per node (Nerium)

Modifications of Leaves

Modification	Example	Function
Leaf Tendril	Pea, Glory lily	Climbing
Spines	Opuntia, Aloe	Protection, reduce transpiration
Phyllode	Australian Acacia	Photosynthesis
Pitcher	Nepenthes	Insect trapping

Bladder	Utricularia	Insect trapping

Internal Structure of Leaf

Dicot Leaf — Dorsiventral

- Upper epidermis → lower epidermis
- Stomata mainly on lower surface; guard cells kidney/reniform shaped
- Mesophyll differentiated:
  - Palisade cells — below upper epidermis; radially elongated, compactly arranged; abundant chloroplasts
  - Spongy cells — loosely arranged; fewer chloroplasts; store gases
- Vascular bundles — conjoint, collateral, closed; xylem on upper side (ventral), phloem on lower side (dorsal); surrounded by bundle sheath

Monocot Leaf — Isobilateral

- Stomata on both surfaces; guard cells dumbbell-shaped
- Mesophyll — only spongy tissue (no palisade)
- Bulliform cells present on upper epidermis — motor cells that help leaf roll/unroll; reduce transpiration

Special Structures:

- **Bulliform cells** — monocot upper epidermis; leaf rolls on losing water
- **Hairs** — reduce transpiration; protect from sunlight
- **Hydathodes** — water stomata; always open; located at vein endings near leaf margins; responsible for **guttation**

FLOWER

Flower = modified shoot (nodes very close; floral leaves in whorls)

Four whorls:

1. **Calyx** (sepals) — protection
2. **Corolla** (petals) — attract pollinators
3. **Androecium** (stamens) — filament + bilobed anther + connective; produces pollen
4. **Gynoecium** (carpels) — ovary + style + stigma; ovules → seeds; ovary → fruit

Flower Variations:

- Complete/Incomplete; Bisexual/Unisexual; Monoecious/Dioecious
- Actinomorphic (regular) — divided equally in any plane (mustard)
- Zygomorphic (irregular) — divided in one plane only (pea)
- Asymmetrical — cannot be divided equally (Canna)
- Hypogynous — superior ovary (china rose, mustard)
- Perigynous — half inferior ovary (peach, plum)
- Epigynous — inferior ovary (sunflower, cucumber)

Stamens: Monadelphous (china rose), Diadelphous (pea), Polyadelphous (lemon), Syngenecious (sunflower), Epipetalous (brinjal), Didynamous (tulsi), Tetradynamous (mustard)

Carpels: Monocarpellary (pea), Syncarpous (tomato), Apocarpous (lotus)

Placentation

Type	Example
Marginal	Pea, Gram
Axile	China rose, Tomato, Bhindi
Parietal	Mustard, Cucumber
Basal	Sunflower
Free central	Dianthus, Primula
Superficial	Water lily (Nymphaea)

INFLORESCENCE

Inflorescence = arrangement of flowers on floral axis (peduncle)

Two major types:

Racemose	Cymose
Main axis has unlimited growth	Growth is limited
Axis does not end in flower	Axis ends in a flower

Flowers in acropetal order	Flowers in basipetal order

Racemose types: Raceme (mustard), Spike (Achyranthes), Spikelet (wheat), Catkin (mulberry), Spadix (banana), Corymb (Candytuft), Umbel (coriander), Capitulum/Head (sunflower)

Cymose types: Monochasial (cotton), Dichasial (Dianthus, jasmine), Multichasial (Calotropis)

Special types:

- Hypanthodium — Fig, Peepal (flowers on inner wall of fleshy receptacle)
- Cyathium — Euphorbia
- Verticillaster — Tulsi, Salvia

FRUIT

True fruit = ripened ovary developing after fertilization

- Ovules → Seeds
- Ovary wall → Pericarp (epicarp + mesocarp + endocarp)

False fruit — other floral parts also contribute (apple, pear — thalamus; fig — receptacle)

Parthenocarpic fruit — develops without fertilization; seedless (banana, grapes)

Three Types:

1. Simple — from single ovary (pea, tomato)
2. Aggregate — from apocarpous ovary, etaerio of fruitlets (Calotropis, Ranunculus)
3. Composite/Multiple — from entire inflorescence (mulberry, pineapple)

Edible Parts of Common Fruits:

Fruit	Edible Part
Mango	Mesocarp
Apple/Pear	Fleshy thalamus
Coconut	Endosperm
Orange	Juicy hairs from endocarp

Banana	Mesocarp and endocarp
Tomato	Pericarp and placentae
Fig	Fleshy receptacle
Wheat	Starchy endosperm
Strawberry	Succulent thalamus

TOP MOST IMPORTANT EXAM QUESTIONS (Chapter 7)

Q1. Distinguish between dicot leaf and monocot leaf on the basis of internal structure. *(Asked in: 2017, 2019, 2020, 2022)*

Answer:

Feature	Dicot Leaf	Monocot Leaf
Orientation	Dorsiventral (horizontal)	Isobilateral (vertical)
Stomata	Mainly lower epidermis	Both surfaces equally
Guard cells	Kidney/reniform shaped	Dumbbell shaped
Bulliform cells	Absent	Present (upper epidermis)
Mesophyll	Palisade + spongy tissue	Only spongy tissue
Vascular system	Network; midrib bundle large, others decrease towards margin	In rows; all bundles similar in size

Dicot leaf has three layers — epidermis (with stomata), mesophyll (palisade + spongy), and vascular system. Vascular bundles are conjoint, collateral, closed; xylem towards upper surface (ventral), phloem towards lower (dorsal).

Q2. What is placentation? Describe the various types of placentation.

Answer: Placentation is the manner in which placentae (bearing ovules) are distributed in the ovary.

- **Marginal** — monocarpellary, one-chambered ovary; ovules along fused margins (pea, gram)
- **Axile** — polycarpellary, syncarpous; many chambers; ovules on central axis (china rose, tomato, bhindi)
- **Parietal** — polycarpellary, syncarpous; one chamber; ovules on inner walls where margins of carpels meet (mustard, cucumber)

- **Basal** — bi/polycarpellary, syncarpous; one chamber; single ovule at base of ovary (sunflower)
- **Free Central** — syncarpous; unilocular (no septae); ovules on central placenta (Dianthus, Primula)
- **Superficial** — polycarpellary, multilocular; ovules all over inner walls of chambers (water lily — Nymphaea)

Q3. What are the modifications of stem? Give examples and their functions.

Answer: Stems are modified for performing special functions:

Underground modifications:

- Rhizome (ginger, turmeric) — perennation and food storage
- Corm (saffron, yam) — perennation and food storage
- Bulb (onion) — food storage
- Tuber (potato) — food storage (stores starch; bears "eyes")

Sub-aerial modifications:

- Runner (grass) — vegetative propagation along soil surface
- Stolon (mint) — arches down, strikes roots, forms new plants
- Offset (water hyacinth) — thicker runner; in aquatic plants
- Sucker (chrysanthemum) — underground runner emerging obliquely

Aerial modifications:

- Stem tendrils (grape vine) — climbing support
- Thorns (citrus, Duranta) — protection from grazing animals
- Phylloclade (Opuntia) — photosynthesis and water storage in xerophytes
- Cladode (Asparagus) — phylloclade with only 1-2 internodes; photosynthesis

6

Nitrogen Metabolism

MOLECULAR NITROGEN

- Nitrogen is present in atmosphere as dinitrogen (N2) — **78.03% by volume**
- Combined form present as Chile saltpetre (sodium nitrate) in South America
- Molecular nitrogen (N2) is **triple bonded (N≡N)** — hence highly stable and not reactive under normal conditions
- Boiling point of nitrogen = **-195.8°C** (lower than oxygen)
- Proteins in living organisms contain about **16% nitrogen**
- In living cells, nitrogen is constituent of amino acids, proteins, enzymes, vitamins, alkaloids, nucleic acids and some growth hormones

Nitrogen Cycle

Air has 78% N2 but most living beings cannot use it directly. The nitrogen cycle converts it into a usable form.

Key steps:

- Lightning fixes N2 to NH3
- Nitrogen fixing bacteria (Rhizobium in legume roots) convert N2 to NH3
- Plants absorb nitrates from soil and reduce to NH3 for metabolism
- Dead organisms and excreta (urea) decomposed by bacteria into NH3
- Another set of bacteria converts NH3 into nitrates — left in soil for plants
- Denitrifying bacteria convert nitrates back to N2 in atmosphere

NITROGEN FIXATION

Definition: The conversion of molecular nitrogen (N2) into compounds of nitrogen, especially ammonia (NH3), is called nitrogen fixation. It is a reductive process — stops if oxygen is present.

Two Types:

A. Abiological Nitrogen Fixation (without living cell)

Two subtypes:

1. **Industrial** — Haber's Process:
   - $N_2 + 3H_2 \rightarrow 2NH_3$ (at 500°C, 1000 atmosphere pressure, iron oxide catalyst)
2. **Natural** — During lightning storms:
   - $N_2 + O_2 \rightarrow 2NO \rightarrow 2NO_2 \rightarrow$ hydrated $\rightarrow$ nitrite and nitrate trickle down to earth

B. Biological Nitrogen Fixation (in living cell)

- Reduction of molecular nitrogen to ammonia by living cells
- Enzyme responsible = Nitrogenase (Mo-Fe containing protein)
- Oxygen prevents biological nitrogen fixation

FREE LIVING AND SYMBIOTIC NITROGEN FIXATION

Free Living Nitrogen Fixers:

Organism	Type
Clostridium	Anaerobic bacteria (Non-photosynthetic)
Klebsiella	Facultative bacteria (Non-photosynthetic)
Azotobacter	Aerobic bacteria (Non-photosynthetic)
Rhodospirillum	Purple, non-sulphur bacteria (Photosynthetic)
Anabaena	Cyanobacteria (Photosynthetic)

Symbiotic Nitrogen Fixers:

System	Symbionts
Lichens	Cyanobacteria + Fungus
Bryophyte	Cyanobacteria + Anthoceros
Pteridophyte	Cyanobacteria + Azolla
Gymnosperm	Cyanobacteria + Cycas
Angiosperms (Legumes)	Rhizobium
Angiosperms (Non-legumes)	Actinomycete (Alnus, Myrica, Purshia)

Mechanism of Biological Nitrogen Fixation

Requirements:

1. Molecular nitrogen (N2)
2. Strong reducing power — reduced FAD (FADH2) and reduced NAD (NADH2)
3. Energy source — ATP (provided by photosynthesis and respiration)
4. Enzyme Nitrogenase (Mo-Fe containing protein)
5. Compound to trap ammonia (since NH3 is toxic to cells)

Stepwise reduction:

N2 → Diamide (N2H2) → Hydrazine (N2H4) → Ammonia (2NH3)

Each step requires 2 electrons and 2H+

General equation: N2 + 16ATP + 8H+ + 8e- → 2NH3 + 16ADP + 16Pi

NH3 is immediately combined with organic acids to form amino acids (not liberated as it is toxic)

Symbiotic Fixation in Legumes — Role of Leghemoglobin

- In legumes, nitrogen fixation occurs in specialized root nodules formed by interaction between *Rhizobium* and legume roots
- Nodules contain special protein — LEGHEMOGLOBIN
- Leghemoglobin is formed only due to symbiosis — neither Rhizobium alone nor legume alone can make it
- Rhizobium gene codes for Heme part; Legume root cell gene codes for Globin part
- Function of Leghemoglobin = Oxygen scavenger — lowers partial pressure of O2 so that nitrogenase can work under anaerobic conditions
- Additional proteins called Nodulins also help in establishing and maintaining symbiosis
- Free living microbes and cyanobacterial symbiosis do NOT possess leghemoglobin

NITRATE AND AMMONIA ASSIMILATION BY PLANTS

Plants that do not fix nitrogen use nitrate and ammonia as combined nitrogen sources.

Nitrate is reduced to ammonia in **two steps:**

Step 1: Nitrate → Nitrite

- Enzyme: Nitrate Reductase (contains FAD, cytochrome, NADPH/NADH, molybdenum)
- Location: Cytosol
- Equation: $NO_3^- + NADH + H^+ \rightarrow NO_2^- + NAD^+ + H_2O$
- Nitrate reductase is inducible (more nitrate = more enzyme made)
- Excess NH_4^+ has negative effect on nitrate reductase synthesis
- Light also increases nitrate reductase activity

Step 2: Nitrite → Ammonia

- Enzyme: Nitrite Reductase
- Location: Chloroplast or Plastids (nitrite transported from cytosol)
- Equation: $NO_2^- + 3NADPH + 3H^+ \rightarrow NH_3 + 3NADP^+$
- Reduced ferredoxin also provides electrons
- Ammonia must be used quickly — accumulation is toxic
- Some plants/algae leach out excess ammonia

Summary of oxidation states:

- Most oxidized form of nitrogen = **Nitrate (NO_3^-)**
- Most reduced form of nitrogen = **Ammonium (NH_4^+)**

AMINO ACID SYNTHESIS BY PLANTS

Ammonium (NH_4^+) is the most reduced form of inorganic nitrogen and is the major source for amino acid production.

Amino acid structure:

- Two functional groups: (i) Amino group ($-NH_2$) and (ii) Carboxyl group ($-COOH$)
- General structure: R-C(H)(NH_2)-COOH

Two major reactions for amino acid biosynthesis:

Reductive Amination Reaction

- Ammonia combines with a **keto acid**
- Most important keto acid = **alpha-ketoglutaric acid** (from Krebs cycle)

- Enzyme: **Glutamate dehydrogenase**
- Reaction: α-ketoglutaric acid + NH3 → **Glutamic acid**
- Similarly: Oxaloacetic acid + NH3 → Aspartic acid
- Reductive amination = major **"port of entry"** for ammonia into metabolic stream

Transamination Reaction

- Transfer of amino group (-NH2) from an already synthesized amino acid to a keto acid
- Enzyme: Transaminases
- Example reaction:
  - α-Ketoglutaric acid + Aspartic acid → Glutamic acid + Oxaloacetic acid
  - (Keto acid) + (Amino acid) → (Amino acid) + (Keto acid)
- Large number of amino acids are synthesized by this route

Key difference:

- Reductive amination — uses free ammonia (NH3) directly
- Transamination — transfers amino group from one amino acid to a keto acid

TOP 5 MOST IMPORTANT EXAM QUESTIONS (Chapter 10)

Q1. What is nitrogen fixation? Distinguish between biological and abiological nitrogen fixation with examples. *(Asked in: 2018, 2020, 2021, 2022, 2023)*

Answer: Nitrogen fixation is the conversion of molecular nitrogen (N2) into ammonia (NH3). It is a reductive process and is inhibited by oxygen.

Biological Nitrogen Fixation	Abiological Nitrogen Fixation
Takes place inside a living cell	Takes place without any living cell
Enzyme nitrogenase is required	No enzyme needed
Occurs at normal temperature and pressure	Requires high temp/pressure (industrial) or lightning (natural)
Example: Rhizobium in legume root nodules	Example: Haber's process, lightning storms

In Haber's process: N2 + 3H2 → 2NH3 (at 500°C, 1000 atm, iron oxide catalyst)

In biological fixation: N2 + 16ATP + 8H+ + 8e- → 2NH3 + 16ADP + 16Pi

Q2. Describe the mechanism of biological nitrogen fixation. What are the requirements for biological nitrogen fixation? *(Asked in: 2017, 2019, 2020, 2021, 2023)*

Answer: Requirements for biological nitrogen fixation:

1. Molecular nitrogen (N2)
2. Reducing power — reduced FADH2 and NADH2 (from photosynthesis and respiration)
3. Energy — ATP (from photosynthesis and respiration)
4. Enzyme Nitrogenase (Mo-Fe protein)
5. Compound to trap ammonia (since NH3 is toxic)

Mechanism: Nitrogenase binds to N2 at its binding site. Hydrogen from reduced coenzymes is added stepwise: N2 → Diamide (N2H2) → Hydrazine (N2H4) → Ammonia (2NH3)

NH3 is immediately combined with organic acids (keto acids) to form amino acids. 16 ATP molecules are consumed per molecule of N2 reduced.

Q3. What is leghemoglobin? What is its role in nitrogen fixation in legumes? How is it formed? *(Asked in: 2016, 2018, 2019, 2021, 2022)*

Answer: Leghemoglobin is a special oxygen-scavenging protein found exclusively in root nodules of leguminous plants. It is formed as a result of symbiosis between Rhizobium bacteria and legume roots — neither organism alone can synthesize it. Rhizobium gene codes for the Heme part while the legume root cell gene codes for the Globin part. Both together constitute leghemoglobin.

Role: Leghemoglobin acts as an oxygen scavenger. It lowers the partial pressure of oxygen in the root nodule, creating anaerobic conditions necessary for nitrogenase to function. This is important because nitrogenase is inhibited by oxygen. A group of proteins called nodulins also help in establishing symbiosis and maintaining root nodule functioning.

Q4. Describe the process of nitrate reduction in plants. Name the enzymes involved and mention where in the cell each reaction occurs. *(Asked in: 2017, 2018, 2020, 2022, 2023)*

Answer: Plants absorb nitrate from soil and reduce it to ammonia in two steps:

Step 1 — Nitrate to Nitrite:

- Enzyme: Nitrate Reductase (contains FAD, cytochrome, NADPH/NADH, molybdenum)
- Location: Cytosol
- Equation: $NO_3^- + NADH + H^+ \rightarrow NO_2^- + NAD^+ + H_2O$
- Nitrate reductase is inducible — high nitrate increases enzyme synthesis; excess NH_4^+ inhibits it; light also promotes it

Step 2 — Nitrite to Ammonia:

- Enzyme: Nitrite Reductase (accepts electrons from NADH, NADPH, FADH2, reduced ferredoxin)
- Location: Chloroplast or Plastids
- Equation: $NO_2^- + 3NADPH + 3H^+ \rightarrow NH_3 + 3NADP^+$

Ammonia must be used quickly as accumulation is toxic. It is immediately incorporated into amino acids via reductive amination.

Q5. What is transamination? How does it differ from reductive amination? Describe both reactions with examples. *(Asked in: 2016, 2017, 2019, 2020, 2021, 2023)*

Answer: Both are reactions for amino acid biosynthesis in plants.

Reductive Amination:

- Free ammonia (NH_3) combines directly with a keto acid
- Enzyme: Glutamate dehydrogenase (a dehydrogenase)
- Example: α-ketoglutaric acid + $NH_3 \rightarrow$ Glutamic acid
- This is the major "port of entry" for ammonia into the metabolic stream
- Also: Oxaloacetic acid + $NH_3 \rightarrow$ Aspartic acid

Transamination:

- Amino group (-NH_2) is transferred from an existing amino acid to a keto acid
- Enzyme: Transaminases
- Example: α-Ketoglutaric acid + Aspartic acid → Glutamic acid + Oxaloacetic acid
- A large number of different amino acids are synthesized by this route

Key difference: Reductive amination uses free inorganic NH_3 directly. Transamination transfers an amino group from one organic molecule (amino acid) to another — no free ammonia is used.

7

Photosynthesis

PHOTOSYNTHESIS

Definition: Photosynthesis is the process by which green plants, algae and chlorophyll-containing bacteria, in the presence of sunlight, combine water and carbon dioxide to form carbohydrates (food). Oxygen is released as a by-product.

Overall Equation: $6CO_2 + 12H_2O \rightarrow (\text{Chlorophyll} + \text{Sunlight}) \rightarrow C_6H_{12}O_6 + 6H_2O + 6O_2$

Key points:

- O_2 released comes from water molecule (H_2O) — NOT from CO_2
- Splitting of water by light = Photolysis of water
- CO_2 is fixed (reduced) to glucose ($C_6H_{12}O_6$)
- Site of photosynthesis = Mesophyll cells of leaf (contain chloroplasts)

Significance:

- Light energy converted into chemical energy
- Only natural process releasing O_2 for aerobic respiration
- Autotrophs (green plants) make food; heterotrophs depend on them
- Fossil fuels (coal, gas, oil) = stored photosynthetic products from ancient geological periods

Landmark Scientists:

- Joseph Priestley (1772) and Jan Ingenhousz (1779) — plants take up CO_2 and release O_2; only in sunlight and by green parts
- Robert Hill (1939) — isolated chloroplasts evolve O_2 when illuminated in presence of electron acceptor (Hill Reaction)

PHOTOSYNTHETIC PIGMENTS

Pigments are located on **thylakoid membranes** of chloroplast. Two main classes:

1. Chlorophylls (Principal pigments)

- Absorb maximally in violet-blue and red region

- Reflect green light — hence leaves appear green
- Chlorophyll-a (Chl-a) = essential/primary pigment; present in all autotrophs except photosynthetic bacteria; represents the reaction centre
- Chlorophyll-b = accessory pigment

2. Carotenoids (Accessory pigments)

- Carotene (orange-yellow) + Xanthophyll
- Absorb light in wavelengths not absorbed by chlorophylls
- Transfer energy to Chl-a
- Carotene breaks down into Vitamin A molecules; gives carrot its colour
- Collectively called **accessory pigments** or **harvesting centre**

Photosystems:

- Reaction centre (Chl-a) + Accessory pigments packed together = **Photosystem**
- 250-400 Chl-a molecules = one photosystem
- Two types: **PSI** and **PSII**

Feature	Photosystem I (PSI)	Photosystem II (PSII)
Reaction centre	Chl-a P700 (absorbs 700 nm)	Chl-a P680 (absorbs 680 nm)
Primary electron acceptor	Iron-sulphur protein (Fe-S protein)	Pheophytin (modified Chl-a)
Electron carriers	Plastocyanin, Ferredoxin, Cytochrome	Pheophytin, Plastoquinone, Cytochrome

Absorption Spectrum vs Action Spectrum

Absorption Spectrum — graph showing relative absorbance of different wavelengths of light by a pigment

Action Spectrum — graph showing effectiveness of different wavelengths of light in stimulating the rate of photosynthesis (measured by O2 produced)

Key facts:

- Photosynthesis is maximum in blue and red light
- Photosynthesis is minimum in green and yellow light (reflected back)
- Action spectrum closely matches absorption spectrum of Chl-a

ROLE OF SUNLIGHT

- Light consists of small particles/packets of energy called **photons** (single photon = quantum)
- Chlorophyll absorbs light → excited state → electron moves to outer orbit
- Excited chlorophyll returns to **ground state** by releasing energy as heat, fluorescence, or doing work
- In photosynthesis, this energy **splits water** (photolysis) to produce H+ and OH- ions

PHOTOCHEMICAL PHASE (LIGHT REACTION)

Location: Thylakoids / Grana of chloroplast Requires: Light

Electron Transport Chain (ETC) in Photosynthesis:

PSII absorbs light → P680 excited → electrons transferred to pheophytin (primary acceptor) → P680 oxidised → splits water (photolysis) → O2 released → electrons from water replace lost electrons in P680

Electrons flow: H2O → PSII (P680) → electron transport chain → PSI (P700) → NADP → NADPH2

Energy released during electron transport → ATP synthesis (Photophosphorylation)

Products of Light Reaction = Assimilatory power = ATP + NADPH2

Photophosphorylation

Definition: Synthesis of ATP from ADP + Pi using light energy during the electron transport chain in photosynthesis.

Two types:

A. Non-Cyclic Photophosphorylation

- Both PSI and PSII functional
- Electron flow: H2O → PSII → PSI → NADP (one-directional, never returns)
- Products: ATP + NADPH2 + O2
- Occurs in all green plants and cyanobacteria

B. Cyclic Photophosphorylation

- Only PSI functional
- Electrons from P700 → primary acceptor → electron carriers → return back to P700 (circular flow)
- Products: ATP only (No NADPH2, No O2 evolved — no photolysis of water)

- Occurs mainly in photosynthetic bacteria (purple sulphur bacteria)

Feature	Cyclic	Non-cyclic
Photosystems	PSI only	PSI + PSII
Electron source	P700 (returns to same)	Water (does not return)
O2 evolved	No	Yes
Products	ATP only	ATP + NADPH2 + O2
Occurs in	Photosynthetic bacteria	All green plants, cyanobacteria

BIOSYNTHETIC PHASE (DARK REACTION)

Location: Stroma of chloroplast Requires: ATP + NADPH2 (from light reaction); light NOT directly required Also called: Carbon fixation reactions / Calvin cycle

Two major pathways:

C3 Cycle / Calvin Cycle

Discovered by: Melvin Calvin

Three steps:

Step 1 — Carboxylation: CO2 + RuBP (5-carbon) → 2 molecules of 3-PGA (3-phosphoglyceric acid) — 3-carbon compound Enzyme: RuBP Carboxylase/Oxygenase (Rubisco) — most abundant protein on earth First stable product = 3-PGA (3-carbon) → name C3 cycle

Step 2 — Reduction: 3-PGA + ATP + NADPH2 → Triose phosphate (3-carbon carbohydrate) Triose phosphate → glucose, sucrose

Step 3 — Regeneration: Triose phosphate + ATP → RuBP regenerated → cycle continues

C4 Cycle / Hatch-Slack Cycle

Adaptation for hot, dry environments Examples: Sugarcane, Maize, Jowar, Bajra

Kranz Anatomy

- Vascular bundles surrounded by a sheath of large parenchyma cells (wreath-like = Kranz)
- **Two types of chloroplasts (dimorphic):**
    - Mesophyll chloroplasts — smaller, well developed grana (granal), do NOT accumulate starch
    - Bundle sheath chloroplasts — larger, lack grana (agranal), contain starch grains

C4 Pathway steps:

- CO_2 acceptor in mesophyll = **PEP (Phosphoenol pyruvic acid)** — 3-carbon
- Enzyme: **PEP Carboxylase (PEPCo)** — works efficiently even at low CO_2
- CO_2 + PEP → **Oxaloacetic acid (OAA)** — 4-carbon compound (first stable product)
- OAA travels to bundle sheath cells → releases CO_2 → C3 cycle (Calvin cycle) operates here
- In bundle sheath: CO_2 + RuBP (Rubisco) → 3-PGA → continues as C3 cycle

Two carboxylase enzymes in C4:

1. PEP Carboxylase (PEPCo) — in mesophyll cells
2. RuBP Carboxylase (Rubisco) — in bundle sheath cells

C3 vs C4 Plants:

Feature	C3 Plants	C4 Plants
CO_2 fixation	Once only	Twice (mesophyll + bundle sheath)
CO_2 acceptor	RuBP (5-C)	PEP (3-C) in mesophyll; RuBP in bundle sheath
CO_2 fixing enzyme	Rubisco (less efficient at low CO_2)	PEPCo (highly efficient even at low CO_2)
First stable product	3-PGA (3-carbon)	OAA (4-carbon)
Leaf anatomy	One type chloroplast; no Kranz anatomy	Two types (dimorphic); Kranz anatomy present
Photorespiration	Present (reduces efficiency)	Absent (higher efficiency)
Efficiency	Less efficient; lower yield	More efficient; higher yield
Examples	Wheat, Rice, Pea	Sugarcane, Maize, Jowar, Bajra

FACTORS AFFECTING RATE OF PHOTOSYNTHESIS

Internal Factors:

1. Chlorophyll content — directly proportional to photosynthesis rate
2. Leaf age and anatomy — stomata number, intercellular spaces, palisade/spongy proportion, cuticle thickness
3. Demand for photosynthate — rapidly growing plants show higher rate

External Factors:

Light: Directly proportional to rate within physiological limits. Compensation point = light intensity at which CO_2 used in photosynthesis = CO_2 produced in respiration. Maximum in red and blue light; minimum in green/yellow light. Only 1-2% of incident sunlight is actually absorbed by green plants.

Temperature: Optimum range 5°-37°C. Q10 = 2 (rate doubles with every 10°C rise). Above 37°C dark reaction enzymes get denatured — rapid fall.

Carbon dioxide: Normal atmospheric concentration is 0.03% — always a limiting factor. Rate increases up to 3% CO_2 concentration.

Water: Indirect effect — water loss causes stomata to close, reducing CO_2 absorption.

Oxygen: Excess O_2 reduces photosynthesis by promoting aerobic respiration.

Mineral elements: Mg (component of chlorophyll), Cu, Mn, Cl (components of photosynthetic enzymes) — deficiency reduces rate.

CHEMOSYNTHESIS

Definition: The process in which certain bacteria use chemical energy released during biological oxidation of inorganic substances (H_2S, NH_3) to reduce CO_2 to carbohydrates — without light and without chlorophyll.

Such bacteria = **Chemosynthetic autotrophs**

Common chemosynthetic organisms:

- Nitrifying bacteria — Nitrosomonas and Nitrobacter (oxidise NH_3 to NO_2)
- Sulphur bacteria, Iron bacteria
- Hydrogen and methane-producing bacteria

Photosynthesis vs Chemosynthesis:

Feature	Photosynthesis	Chemosynthesis
Organisms	All green plants, cyanobacteria	Colourless anaerobic bacteria
Energy source	Light energy	Chemical energy from oxidation of inorganic substances
Pigments	Required (chlorophyll)	Not required
O_2 evolution	Yes	No
Photophosphorylation	Yes (ATP produced)	No

CHEMIOSMOTIC SYNTHESIS

- Process in which energy stored as H+ ion gradient across a membrane is used to synthesise ATP from ADP + Pi
- Enzyme: ATP Synthase
- Energy source: Difference in H+ ion concentration across inner membrane of mitochondrion or chloroplast
- Chloroplasts use chemiosmosis to generate ATP during photosynthesis
- Prokaryotes cannot use chemiosmosis — they lack membrane-bound organelles (no mitochondria or chloroplast) to maintain H+ gradient
- Nobel Prize (1978): Peter Mitchell for chemiosmotic model of ATP synthesis

TOP MOST IMPORTANT EXAM QUESTIONS (Chapter 11)

Q2. Distinguish between cyclic and non-cyclic photophosphorylation. *(Asked in: 2016, 2018, 2019, 2021, 2022, 2023)*

Answer:

Feature	Cyclic	Non-cyclic
Photosystems	PSI only	PSI + PSII both
Electron source	Chlorophyll P700 (electrons return to same P700)	Water (photolysis); electrons do not
NADPH2	Not produced	Produced (NADP is final acceptor)
O2 evolution	No (no photolysis of water)	Yes (as by-product of photolysis)
ATP production	Yes	Yes
Location	Mainly photosynthetic bacteria (purple sulphur bacteria)	All green plants, cyanobacteria

In non-cyclic photophosphorylation, electron flow is unidirectional (H_2O → PSII → PSI → NADP) — called Z-scheme. In cyclic, electrons cycle back to P700.

Q3. Describe the Calvin cycle (C3 cycle) of dark reaction. Name the first stable product and the enzyme involved.

Answer: Calvin cycle occurs in stroma of chloroplast, discovered by Melvin Calvin. It has three stages:

Step 1 — Carboxylation: CO_2 + RuBP (ribulose bisphosphate, 5-carbon) → 2 molecules of 3-PGA (3-phosphoglyceric acid, 3-carbon). First stable product = 3-PGA. Enzyme = Rubisco (RuBP carboxylase/oxygenase) — most abundant protein on earth. This process is called carboxylation.

Step 2 — Reduction: 3-PGA + ATP + NADPH2 (from light reaction) → Triose phosphate (3-carbon carbohydrate). Triose phosphate is used for synthesis of glucose, sucrose and starch.

Step 3 — Regeneration: Triose phosphate + ATP → RuBP regenerated → cycle continues.

The cycle requires products of light reaction (ATP + NADPH2) but does not directly need light, hence called dark reaction.

8

Respiration In Plants

RESPIRATION

Definition: Respiration is the stepwise oxidation of complex organic molecules and release of energy as ATP for various cellular metabolic activities. It involves exchange of gases between the organism and the external environment.

ATP = Energy currency of the cell

Two types:

External Respiration (Breathing) — mere exchange of gases between organism and environment; physical process

Cellular Respiration — biochemical process occurring within cells; oxidises food to obtain energy; catalyzed by enzymes

Aerobic vs Anaerobic Respiration:

Feature	Aerobic	Anaerobic
Oxygen	Required	Not required
Oxidation	Complete	Incomplete
Location	Cytoplasm + Mitochondria (eukaryotes); membrane (prokaryotes)	Cytoplasm only
ATP produced	38 ATP	2 ATP
End products	$CO_2 + H_2O$	Ethyl alcohol + CO_2 (yeast) or Lactic acid (muscles)
Organisms	Higher organisms (plants + animals)	Lower organisms (bacteria, fungi); higher animals under O_2 deficiency
Equation	$C_6H_{12}O_6 \rightarrow 6CO_2 + 6H_2O + 38$ ATP	$C_6H_{12}O_6 \rightarrow$ 2 Ethyl alcohol + $2CO_2$ + 2ATP (yeast) Lactic acid + 2ATP (muscles)

Common processes in both:

- Oxidation reaction to release energy from food

- Use of coenzymes (NAD, FAD) as hydrogen carriers
- Use of ATP for energy transfer

EXTERNAL RESPIRATION / GASEOUS EXCHANGE IN PLANTS

Gases enter/exit plants by simple diffusion through:

- General body surface (stems, roots, fruits, seeds)
- **Lenticels** — openings in bark of tree trunk
- **Stomata** — in leaves and young green stems

Plants do NOT need O2 carrier (unlike animals with blood) because:

- O2 requirement is lower in plants
- Large surface area (leaves) allows sufficient diffusion

Day vs Night gas exchange:

- Daytime: Rate of photosynthesis > Rate of respiration → Plants give out O2 (excess from photosynthesis)
- Night: No photosynthesis → Plants give out only CO2
- Animals give out CO2 at all times

CELLULAR RESPIRATION

First stage in ALL pathways (both aerobic and anaerobic) = Glycolysis

Glycolysis (Embden-Meyerhof-Parnas Pathway)

- Location: Cytosol
- Common to both aerobic and anaerobic respiration
- Substrate: Glucose (6-carbon)
- Product: 2 molecules of Pyruvic acid (3-carbon)
- Net ATP gain: 2 ATP (4 produced − 2 used in activation)
- Also produces: 2 NADH

Three major phases of Glycolysis:

1. **Phosphorylation (Activation):** Glucose → Glucose-6-phosphate → Fructose 1,6-diphosphate; uses 2 ATP

2. **Splitting:** Fructose 1,6-diphosphate → 2 molecules of 3-carbon sugar phosphate
3. **Oxidation (Dehydrogenation):** Each 3-C sugar phosphate oxidised by removal of H → NADH; 2 ATP produced per molecule

Overall equation: Glucose + 4ADP + 4Pi + 2NAD → 2 Pyruvic acid + 4ATP + 2NADH (Net gain = 2 ATP)

Fermentation

Occurs under anaerobic conditions (no O2 or insufficient O2)

Purpose: Regenerate NAD+ from NADH so glycolysis can continue producing 2 ATP

Alcoholic fermentation (Yeast): Pyruvic acid → Ethyl alcohol (C_2H_5OH) + CO_2 Equation: $C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2 + 2ATP$

Lactic acid fermentation (Muscle cells, Lactobacillus): Pyruvic acid → Lactic acid Equation: $C_6H_{12}O_6 \rightarrow$ 2 Lactic acid + 2ATP

Note: No further ATP is released during fermentation itself

Muscle pain during exercise = accumulation of lactic acid under anaerobic conditions

Industrial applications of fermentation:

- Bakeries — bread, cakes, biscuits
- Breweries — wine, alcoholic drinks
- Vinegar production, tanning of leather
- Ethanol for gasohol fuel (Brazil)
- Everyday food — idli, dosa, bhatura, dhokla (leavening by CO_2)

Fate of Pyruvic Acid in Aerobic Respiration

In presence of O2, pyruvic acid enters mitochondria →

- Decarboxylation (removal of CO_2) + Dehydrogenation (removal of H) →
- Forms Acetyl CoA (2-carbon)
- Acetyl CoA = connecting link between glycolysis and Krebs cycle
- Acetyl CoA can also be generated from fats and proteins

Krebs Cycle / Citric Acid Cycle / TCA Cycle

- Discovered by: Sir Hans Krebs in 1930s

- Location: Matrix of mitochondria
- Substrate entering: Acetyl CoA (2-carbon)

Steps:

- Acetyl CoA (2C) + Oxaloacetate (4C) → **Citrate (6C)** — initiates cycle
- Citrate undergoes decarboxylation and dehydrogenation reactions
- 2 carbon atoms lost as CO2 (2 decarboxylation reactions)
- Hydrogen added to carriers in 4 dehydrogenation reactions → 3 NADH2 + 1 FADH2
- 1 ATP made directly per turn
- Oxaloacetate regenerated at end

Two turns of Krebs cycle per glucose molecule (2 pyruvate → 2 Acetyl CoA)

Summary equation: 2 Pyruvic acid + 8NAD + 2FAD + 2ADP → 6CO2 + 8NADH + 2FADH2 + 2ATP

Significance of Krebs Cycle:

- Major pathway to release reduced coenzymes and energy
- Common pathway for breakdown of carbohydrates, fatty acids and amino acids
- Fatty acids → β-oxidation → Acetyl CoA → Krebs cycle
- Amino acids → deamination → Krebs cycle
- Provides intermediates for synthesis of amino acids, nucleotides, chlorophyll, fats

Respiratory Chain / Electron Transport Chain (ETC) / Oxidative Phosphorylation

Location: Inner membrane (cristae) of mitochondria

Process:

- Hydrogen carriers (NADH, FADH2) move to inner mitochondrial membrane
- H is split into H+ and electrons (e-)
- Electrons passed stepwise from one carrier to next → downhill energy terms → finally to O2 (final acceptor) → reduced to H2O
- Energy released at each step → used to make ATP from ADP + Pi = Oxidative Phosphorylation
- Final enzyme: Cytochrome oxidase

ATP yield:

- Each NADH2 → 3 ATP
- Each FADH2 → 2 ATP (FADH2 enters at lower energy level)

Poisons: CO (carbon monoxide) and H2S block H-transfer system → stop ATP generation

Overall ATP Budget for Aerobic Respiration of 1 Glucose:

Stage	CO2	ATP	NADH	FADH2
Glycolysis	—	2	2	—
Pyruvate → Acetyl CoA	2	—	2	—
Krebs cycle	4	2	6	2
Total	**6CO2**	**4 ATP**	**10 NADH**	**2 FADH2**

From ETC: 10 NADH × 3 = 30 ATP; 2 FADH2 × 2 = 4 ATP **Total = 4 + 30 + 4 = 38 ATP**

(Note: Some biologists say 36 ATP because 2 NADH from glycolysis must enter mitochondria against concentration gradient, consuming 2 ATP. Prokaryotes = 38 ATP as they lack mitochondria)

Amphibolic Pathway

- **Photosynthesis** = anabolic (building up) pathway
- **Respiration** = catabolic (breaking down) pathway
- **Both occurring together** = Amphibolic pathway (amphi = two)

Compensation Point: The light intensity at which photosynthesis just compensates for respiration. Amount of CO2 consumed in photosynthesis = amount of CO2 generated in respiration.

RESPIRATORY QUOTIENT (R.Q.) AND FACTORS AFFECTING RESPIRATION

R.Q. = Volume of CO2 evolved / Volume of O2 consumed

Substrate	R.Q.	Examples
Carbohydrates	= 1	Stem, roots
Proteins	< 1	Protein-rich seeds (pulses)
Fats and oils	> 1	Oil-containing seeds (mustard)

For fats: RQ > 1 because more energy released per mole of fat than per mole of glucose.

Factors affecting rate of respiration:

- **Temperature** — Optimum 30-35°C (enzymes work best); reduced beyond 50°C and at 0-10°C
- **Oxygen** — Rate increases with rise in O2 concentration up to a limit
- **CO2** — Rate decreases if CO2 accumulates around respiratory tissue
- **Water** — Very low in dry seeds; respiration starts immediately when water supplied
- **Type of substrate** — Determines the RQ value

PHOTORESPIRATION

- Occurs in chloroplast in presence of light, high O2 and low CO2
- Enzyme RUBISCO has same active site for both CO2 and O2
- When O2 conc. is high, RUBISCO catalyzes oxygenation of RuBP:

RUBP + O2 → (Rubisco) → 2PGA + 1 Phosphoglycolate

- Phosphoglycolate undergoes reactions in mitochondria and peroxisomes
- 2 phosphoglycolate → 1 PGA + 1 CO2
- No ATP produced (unlike normal respiration)
- Causes loss of about 25% carbon fixed during dark reaction
- Occurs only in C3 plants (absent in C4 plants)

Significance: Protects plants from photo-oxidative damage by utilizing excess solar energy that would otherwise damage photosynthetic pigments.

PENTOSE PHOSPHATE PATHWAY (PPP) / HMP PATHWAY

Full name: Hexose-Monophosphate Shunt Pathway or Direct Oxidation of Glucose Pathway

- Found in: Microbes (bacteria, some fungi) and highly metabolically active animal tissues
- **Location:** Cytosol (does NOT require ETC or mitochondrion)

Process:

- Glucose → Glucose-6-phosphate (consumes 1 ATP)
- 6 molecules oxidized → 6 NADPH2 produced (first step)
- Further oxidation → 6 molecules of Ribulose-5-phosphate (pentose sugar) + 6 CO2 + 6 more NADPH2

- Total: 12 NADPH2 produced → if entered ETC → 36 ATP
- Net ATP = 36 − 1 (used) = **35 ATP**

Why called PPP: Side product is pentose phosphate sugar (Ribulose-5-Phosphate)

Significance:

- Ribulose-5P → Ribose-5P → raw material for RNA synthesis
- Ribose-5P − O → Deoxyribose-5P → raw material for DNA synthesis
- More efficient than glycolysis (uses only 1 ATP vs 2 ATP in glycolysis)

TOP 5 MOST IMPORTANT EXAM QUESTIONS (Chapter 12)

Q1. Describe the process of glycolysis. Where does it occur? What are the products?

Answer: Glycolysis (Embden-Meyerhof-Parnas pathway) occurs in the **cytosol** of all cells. It is common to both aerobic and anaerobic respiration. Substrate = Glucose (6-carbon).

Three phases:

Phase 1 — Activation/Phosphorylation: Glucose is phosphorylated using 2 ATP → Glucose-6-phosphate → Fructose 1,6-diphosphate.

Phase 2 — Splitting: Fructose 1,6-diphosphate → two 3-carbon sugar phosphate molecules (interconvertible). This is the origin of the term glycolysis (splitting of glucose).

Phase 3 — Oxidation: Each 3-C sugar phosphate is oxidized by removal of H → NADH produced; 2 ATP produced per 3-carbon compound = 4 ATP total.

Products: 2 Pyruvic acid + 4 ATP + 2 NADH (net 2 ATP since 2 were used in activation)

Equation: Glucose + 4ADP + 4Pi + 2NAD → 2 Pyruvic acid + 4ATP + 2NADH

Q2. Describe the Krebs cycle. What is its significance?

Answer: Krebs cycle occurs in the matrix of mitochondria. Discovered by Sir Hans Krebs in 1930s. Also called TCA (tricarboxylic acid) cycle or citric acid cycle.

Pyruvic acid → enters mitochondria → decarboxylated and dehydrogenated → Acetyl CoA (2-carbon) + CO_2 + NADH.

Acetyl CoA (2C) + Oxaloacetate (4C) → Citrate (6C) → α-ketoglutarate (5C) → with loss of CO_2 and NADH → succinyl CoA → succinate → fumarate → malate → Oxaloacetate (4C) regenerated.

Per turn: 3 NADH + 1 $FADH_2$ + 1 ATP + 2 CO_2 produced. Two turns per glucose = 6 NADH + 2 $FADH_2$ + 2 ATP + 4 CO_2.

Summary: 2 Pyruvic acid + 8NAD + 2FAD + 2ADP → 6CO2 + 8NADH + 2FADH2 + 2ATP

Significance: Major pathway for controlled release of energy; common pathway for breakdown of glucose, fatty acids (via β-oxidation → Acetyl CoA) and amino acids (via deamination); provides intermediates for synthesis of amino acids, nucleotides, chlorophyll and fats.

Q3. Give the overall ATP budget for aerobic respiration. Account for all 38 ATP molecules.

Answer:

Stage	Location	ATP	NADH	FADH2
Glycolysis	Cytosol	2 ATP (net)	2 NADH	—
Pyruvate → Acetyl CoA	Mitochondria matrix	—	2 NADH	—
Krebs cycle (2 turns)	Mitochondria matrix	2 ATP	6 NADH	2 FADH2
Total direct	—	4 ATP	10 NADH	2 FADH2

From ETC (Respiratory Chain on inner mitochondrial membrane): 10 NADH × 3 ATP each = 30 ATP 2 FADH2 × 2 ATP each = 4 ATP

Grand Total = 4 + 30 + 4 = **38 ATP**

Overall equation: C6H12O6 + 6O2 → 6CO2 + 6H2O + 38 ATP

Note: Some biologists calculate 36 ATP because the 2 NADH from glycolysis (in cytoplasm) must enter mitochondria against concentration gradient, consuming 2 ATP. Prokaryotes get 38 ATP as they lack mitochondria.

Q4. What is fermentation? Explain alcoholic and lactic acid fermentation with equations. Give industrial uses of fermentation.

Answer: Fermentation is the anaerobic process that occurs in the cytosol under conditions of oxygen absence or deficiency. Pyruvic acid (from glycolysis) is reduced and NADH is oxidized back to NAD+ so that glycolysis can continue.

Alcoholic fermentation (Yeast/microbes): Pyruvic acid → Ethyl alcohol (C2H5OH) + CO2 C6H12O6 → 2C2H5OH + 2CO2 + 2ATP

Lactic acid fermentation (Muscle cells, Lactobacillus): Pyruvic acid → Lactic acid C6H12O6 → 2 Lactic acid + 2ATP

No additional ATP is released in fermentation itself — only 2 ATP come from glycolysis.

Industrial uses: bakeries (bread, cakes, biscuits), breweries (wine, alcoholic drinks), vinegar production, tanning and curing of leather, gasohol fuel production (Brazil), making idli, dosa, bhatura, dhokla.

Muscle pain during prolonged exercise is due to accumulation of lactic acid under anaerobic conditions.

Q5. What is photorespiration? How does it differ from normal respiration? Why is it called a wasteful reaction?

Answer: Photorespiration is the respiration initiated in chloroplasts occurring in the presence of light, high O2 concentration and low CO2 concentration. Rubisco enzyme has the same active site for both CO2 and O2. At high O2, it catalyzes oxygenation of RuBP:

RuBP + O2 → (Rubisco) → 2PGA + 1 Phosphoglycolate

Phosphoglycolate is then broken down through reactions in mitochondria and peroxisomes. 2 phosphoglycolate → 1 PGA + 1 CO2. No ATP is produced.

Photorespiration vs normal respiration:

Feature	Normal Respiration	Photorespiration
Location	Cytoplasm + Mitochondria	Chloroplast + Mitochondria + Peroxisome
Substrate	Glucose	RuBP
Products	ATP + CO2 + H2O	Only CO2 + PGA (no ATP)
Time	Day and night	Only during day (needs light)
Plants	C3 and C4 both	Only C3 plants

Photorespiration is called wasteful because it causes loss of about 25% of carbon fixed in dark reaction and produces no ATP. However, it has one use — it protects plants from photo-oxidative damage by utilizing part of the excess solar energy.

TOP 5 PYQs — MOST REPEATED IN EXAMS

PYQ 1. Distinguish between aerobic and anaerobic respiration. Write the equation for both.

Answer: Aerobic respiration requires O2, leads to complete oxidation of glucose to CO2 and H2O, occurs in cytoplasm and mitochondria of eukaryotes, produces 38 ATP, occurs in higher organisms. Equation: C6H12O6 + 6O2 → 6CO2 + 6H2O + 38 ATP.

Anaerobic respiration occurs in complete absence of O2, leads to incomplete oxidation, occurs only in cytoplasm, produces only 2 ATP, occurs in bacteria, fungi and in higher organisms under O2 deficiency. Equations: C6H12O6 → 2C2H5OH + 2CO2 + 2ATP (yeast) or C6H12O6 → 2 Lactic acid + 2ATP (muscles).

Common feature: Glycolysis is the first step in both.

PYQ 2. Explain oxidative phosphorylation / Electron Transport Chain (ETC). What is the role of oxygen?

Answer: ETC occurs on inner membrane (cristae) of mitochondria. Hydrogen carriers (NADH, FADH2 from glycolysis and Krebs cycle) move to inner mitochondrial membrane. Hydrogen splits into H+ and electrons.

Electrons pass stepwise through a series of carriers (including cytochromes) at decreasing energy levels. At each transfer, energy is released and used to synthesize ATP from ADP + Pi (oxidative phosphorylation). The final enzyme is cytochrome oxidase which transfers electrons to oxygen — the terminal acceptor. O_2 is reduced to water: $2H^+ + 2e^- + \frac{1}{2}O_2 \rightarrow H_2O$.

Role of O_2: Acts as the final/terminal electron acceptor. It accepts electrons and H^+ from the last carrier and gets reduced to water. Without O_2, the entire ETC stops and no ATP is produced by this pathway.

Each NADH → 3 ATP; Each $FADH_2$ → 2 ATP ($FADH_2$ enters at lower energy level). Poisons like CO and H_2S block the H-transfer system and stop ATP generation.

PYQ 3. Explain the Pentose Phosphate Pathway (PPP/HMP pathway). Where does it occur? What are its advantages?

Answer: PPP (Hexose Monophosphate Shunt) is an alternative respiratory pathway occurring in the cytosol of microbes (bacteria, fungi) and highly metabolically active animal tissues. It does not require ETC or mitochondria.

Glucose → Glucose-6-phosphate (uses 1 ATP) → oxidized in two steps producing 12 $NADPH_2$ + 6 CO_2 + 6 molecules of Ribulose-5-phosphate (pentose sugar). Ribulose-5P regenerates Glucose-6-P through intermediate compounds (as in Calvin cycle).

If 12 $NADPH_2$ enter oxidative phosphorylation → 36 ATP produced. Net = 36 − 1 = 35 ATP per glucose.

Advantages over glycolysis: Uses only 1 ATP (vs 2 in glycolysis); produces pentose sugars used as raw material for RNA synthesis (ribose-5P) and DNA synthesis (deoxyribose-5P); produces $NADPH_2$ needed for many biosynthetic reactions.

9

Circulation of Body Fluids

1. CIRCULATORY SYSTEM

The system responsible for flow of blood and lymph through the body. It performs transport of nutrients, gases, wastes, hormones, heat distribution, and protection against pathogens.

Two Types:

- **Open Circulatory System** — Blood flows freely in body cavity (haemocoel), not in closed vessels. Found in prawns and insects. Low pressure.
- **Closed Circulatory System** — Blood flows in well-defined vessels. High pressure maintained. More efficient. Found in all vertebrates.

2. CIRCULATORY SYSTEM OF COCKROACH

- Open type circulatory system
- Blood is colorless, called haemolymph
- Body cavity = haemocoel, divided into 3 sinuses by dorsal and ventral diaphragms:
    - Dorsal/Pericardial sinus (encloses heart)
    - Perivisceral sinus (visceral organs)
    - Perineural sinus (ventral nerve cord)
- Heart has 13 chambers with ostia guarded by valves
- Blood has no respiratory pigment — does NOT carry gases
- Functions: nutrient transport, hydrostatic pressure, water reservoir

3. HUMAN CIRCULATORY SYSTEM

Components:

1. **Heart** — muscular pumping organ
2. **Blood vessels** — arteries, veins, capillaries
3. **Blood** — fluid connective tissue

4. **Lymphatic system** — lymph nodes + lymph vessels

THE HUMAN HEART

- Fist-sized, made of cardiac muscle
- 4 chambers: 2 Atria (upper) + 2 Ventricles (lower)
- Covered by pericardium
- Ventricles have thick walls for pumping to longer distances

Valves:

- **Tricuspid valve** — between right atrium and right ventricle
- **Bicuspid (Mitral) valve** — between left atrium and left ventricle
- **Semilunar valves** — at origin of aorta and pulmonary artery
- Valves prevent backflow of blood

CARDIAC CYCLE & HEARTBEAT

- **Systole** = Contraction | Diastole = Relaxation
- **1st sound "Lubb"** — closure of AV valves (atrial systole)
- **2nd sound "Dubb"** — closure of semilunar valves (ventricular systole)

Conduction pathway:

SA Node → AV Node → Bundle of HIS → Purkinje Fibers → Ventricular contraction

- **SA Node** (Sino-Atrial Node) = natural pacemaker, located in upper right atrium
- Influenced by nerves, hormones, CO_2, O_2, and heat
- If SA node is damaged → artificial pacemaker is implanted

ECG (Electrocardiogram): Records heartbeat as a graph; detects heart disorders

BLOOD VESSELS

Feature	Artery	Capillary	Vein
Direction	Away from heart	Links arteries to veins	Towards heart
Wall	Thick, elastic, muscular	Single endothelium layer	Thin, less muscular

Valves	Absent	One semilunar valve	Present throughout
Blood pressure	High, pulsatile	Falling, non-pulsatile	Low, non-pulsatile
Lumen	Small	Extremely narrow	Large
Blood type	Oxygenated (except pulmonary artery)	Mixed	Deoxygenated pulmonary vein)

Note: Arteries → Arterioles → Capillaries → Venules → Veins

DOUBLE CIRCULATION & PATH OF BLOOD

Blood passes through heart **twice** in one complete circulation:

Body → Venae Cavae → Right Atrium → Tricuspid Valve → Right Ventricle → Pulmonary Artery → Lungs → Pulmonary Vein → Left Atrium → Bicuspid Valve → Left Ventricle → Aorta → Body

- **Pulmonary artery** = only artery carrying deoxygenated blood
- **Pulmonary vein** = only vein carrying oxygenated blood
- **Superior vena cava** = brings deoxygenated blood from head/shoulders
- **Inferior vena cava** = brings deoxygenated blood from lower body

4. BLOOD — COMPONENTS & FUNCTIONS

Composition:

- **Plasma (55%)** — pale yellow liquid; contains albumin, globulin, fibrinogen
- **Cellular components (45%)** — RBC, WBC, Platelets

Blood cell formation = Haemopoiesis (occurs in bone marrow)

Cell	Number/mm^3	Function
RBC (Erythrocytes)	5,000,000	Transport O_2 and CO_2
WBC (Leucocytes)	4,000–8,000	Immunity, engulf bacteria
Platelets	250,000	Blood clotting

WBC types:

- Granulocytes: Neutrophils (engulf bacteria), Eosinophils (antihistamine), Basophils (histamine/heparin)
- Agranulocytes: Monocytes (phagocytosis), Lymphocytes (antibody production)

Blood disorders:

- Polycythemia — increased RBC
- Anaemia — decreased RBC
- Leukaemia — increased WBC
- Leukopenia — decreased WBC

BLOOD CLOTTING (COAGULATION)

Thromboplastin (from platelets) + Prothrombin (plasma protein) + Ca^{2+} ions → Thrombin Thrombin + Fibrinogen → Fibrin (insoluble fibres) Fibrin + RBC → CLOT (Scab)

- **Haemophilia =** genetic disease where blood fails to clot

BLOOD GROUPS

Blood Group	Antigen (on RBC)	Antibody (in Plasma)
A	A	b
B	B	a
AB	A, B	None
O	None	a, b

- **Universal Donor = Blood Group O** (no antigens)
- **Universal Recipient = Blood Group AB** (no antibodies)
- **Agglutination** = clumping of RBCs when mismatched blood is transfused

Rh Factor: Rh+ mother with Rh− embryo → antibodies produced → danger of clumping in foetus

BLOOD PRESSURE

- **Systolic pressure** = pressure during ventricular contraction (higher) = **120 mm Hg**
- **Diastolic pressure** = pressure during ventricular relaxation (lower) = **75 mm Hg**
- **Normal reading** = **120±5 / 75±5 mm of mercury**
- Measured by **Sphygmomanometer**
- **Pulse rate** = ~70 beats per minute (felt at wrist)

5. LYMPHATIC SYSTEM

- Consists of lymph ducts, lymph nodes, and lymph vessels
- No pumping mechanism — fluid moves by muscle movement
- Lymph nodes concentrated in neck, armpits, and groins

Lymph = clear, colorless fluid that moves out of capillary walls; modified tissue fluid

Functions of Lymph:

- Supplies nutrition to areas blood cannot reach
- Drains excess tissue fluid back into blood
- Absorbs fats from small intestine (via lacteals)
- Collects nitrogenous waste
- Lymphocytes in lymph fight bacteria

Lymphoid organs:

- **Spleen** (largest) — haemopoiesis in foetus, destroys old RBCs ("graveyard of RBCs"), blood reservoir
- **Tonsils** — filter pathogens

6. IMMUNITY

Immunity = body's ability to resist harmful disease-causing organisms

Type	Description
Natural	Present from birth
Acquired — Active	Develops after disease/vaccination; long-lasting
Acquired — Passive	Readymade antibodies injected; short-lived (e.g., ATS)

T-cells vs B-cells:

T-Cells	B-Cells
Mature in thymus	Mature in lymphoid tissue (tonsils, appendix)
Identify and destroy antigens directly	Produce antibodies
Life span 3–4 years	Antibodies are short-lived

Immuno-deficiency Disorders:

- **SCID** — absence of both T and B cells from birth
- **AIDS** — caused by HIV; destroys T-cells and immune system

AIDS transmission: sexual contact, infected blood transfusion, contaminated needles, infected mother to foetus

7. DISORDERS OF BLOOD AND HEART

- **Hypertension** — blood pressure above normal (>120/75); caused by stress, obesity, age, poor diet
- **Atherosclerosis** — fat deposits (atheroma) on inner artery walls → narrowing of lumen
- **Arteriosclerosis** — hardening and loss of flexibility of artery walls with age
- **Treatment:** Ballooning angioplasty (stent) or heart bypass surgery

TOP 5 MOST IMPORTANT EXAM QUESTIONS & ANSWERS

Q1. What is double circulation? Describe the path of blood through the human circulatory system.

Answer: Double circulation means blood passes through the heart twice in one complete circulation.

Path: Deoxygenated blood from body → Superior/Inferior Vena Cava → Right Atrium → Tricuspid Valve → Right Ventricle → Pulmonary Artery → Lungs (CO_2 released, O_2 absorbed) → Pulmonary Vein → Left Atrium → Bicuspid Valve → Left Ventricle → Aorta → Body tissues.

Q2. Explain the process of blood coagulation with a flow chart.

Answer: When a blood vessel is injured:

Thromboplastin (from platelets) + Prothrombin + Ca^{2+} → Thrombin Thrombin + Fibrinogen → Fibrin (insoluble) Fibrin + RBC → Clot (Scab) → Stops blood loss

Haemophilia is a genetic disorder in which blood fails to clot.

Q3. What are blood groups? Why is blood group O called universal donor and AB called universal recipient?

Answer: Human blood is classified into four groups — A, B, AB, and O — based on antigens present on RBC surface and antibodies in plasma.

- **Group O = Universal Donor** because it has no antigens on RBCs, so it does not trigger any antibody reaction in any recipient.
- **Group AB = Universal Recipient** because it has no antibodies in plasma, so it does not react against antigens of any donor blood group.

Q4. Differentiate between active immunity and passive immunity. Give one example of each. *(Asked: 2017, 2019, 2021, 2022)*

Answer:

Active Immunity	Passive Immunity
Develops when body is exposed to a pathogen or given a vaccine	Developed by injecting readymade antibodies
Long-lasting / lifelong	Short-lived
Example: BCG vaccine (TB), DPT vaccine	Example: Anti-Tetanus Serum (ATS)

Q5. Describe the cardiac cycle and explain the role of SA node and AV node in heartbeat.

Answer: The cardiac cycle is the sequence of events in one complete heartbeat:

- **Atrial Systole:** SA node fires impulse → atria contract → AV valves open → blood enters ventricles → "Lubb" sound (closure of AV valves)
- **Ventricular Systole:** Impulse passes SA Node → AV Node → Bundle of HIS → Purkinje Fibers → ventricles contract → "Dubb" sound (closure of semilunar valves)
- **Joint Diastole:** All chambers relax, venae cavae and pulmonary vein fill atria

SA Node (natural pacemaker) initiates heartbeat. AV Node receives impulse and passes it to ventricles via Bundle of HIS. Normal heart rate = 70 beats/minute.

TOP 5 PREVIOUS YEAR QUESTIONS (PYQs) FROM NIOS/CBSE

PYQ 1: Differentiate between open and closed circulatory system with examples. *(NIOS 2017, 2019, 2022)*

Answer:

Open Circulatory System	Closed Circulatory System
Blood flows freely in body cavity	Blood flows in closed vessels
Low pressure	High pressure
Less efficient	More efficient
Example: Cockroach, prawn, insects	Example: All vertebrates including humans

PYQ 2: Compare the structure and function of arteries, veins, and capillaries. *(NIOS 2018, NIOS 2020, 2021)*

Answer: (refer to the comparison table in the revision notes above — all three vessels differ in wall thickness, lumen size, presence of valves, blood pressure, and type of blood carried)

PYQ 3: What is blood pressure? Differentiate between systolic and diastolic pressure. Name the instrument used to measure it. *(NIOS 2016, 2019, 2021, 2023)*

Answer:

- **Blood pressure** = pressure exerted by blood on artery walls during circulation
- **Systolic pressure** = pressure during ventricular contraction = 120 mm Hg
- **Diastolic pressure** = pressure during ventricular relaxation = 75 mm Hg
- **Normal BP** = 120±5 / 75±5 mm Hg
- **Instrument** = Sphygmomanometer
- **Abnormally high BP** = Hypertension

PYQ 4: What is lymph? Give any three functions of the lymphatic system. *(NIOS 2017, 2020, 2022)*

Answer: Lymph is the clear, colorless fluid that moves out of blood capillary walls into intercellular spaces. It is a modified tissue fluid.

Functions:

1. Supplies nutrition and oxygen to areas blood cannot reach
2. Drains excess tissue fluid back into blood (via subclavian vein)
3. Absorbs and transports fats from small intestine through lacteals
4. Lymphocytes in lymph nodes destroy bacteria and pathogens

PYQ 5: What is AIDS? How does HIV affect the immune system? Name any two modes of transmission of HIV. *(NIOS 2016, 2018, 2019, 2021, 2022, 2023)*

Answer:

- **AIDS** = Acquired Immuno Deficiency Syndrome
- Caused by **HIV** (Human Immuno Virus)
- HIV causes massive reduction in **T-cells**, ultimately destroying the entire immune system, making the body unable to fight infections

Transmission:

1. Sexual contact with HIV-infected person
2. Blood transfusion from infected person
3. Sharing contaminated needles
4. From infected mother to foetus through placenta

10

Coordination and Control Nervous and Endocrine System

1. NERVOUS SYSTEM — BASIC TERMS

Stimulus = agent causing change in organism's activity Impulse = wave of electrical disturbance travelling across nerve cell Response = change in activity caused by stimulus Receptors = nerve cells that receive stimulus and send impulses to CNS Effectors = muscles/glands that respond to impulses from CNS Sensory (afferent) nerve = carries impulse from receptor to CNS Motor (efferent) nerve = carries impulse from CNS to muscle/gland Nerve = bundle of axons connecting CNS to body parts

2. DIVISIONS OF NERVOUS SYSTEM

Central Nervous System (CNS) = Brain + Spinal Cord (site of information processing)

Peripheral Nervous System (PNS) = all nerves entering/leaving brain and spinal cord

PNS divided into:

- Afferent (sensory) pathway
- Efferent (motor) pathway:
    - Somatic nervous system (voluntary muscles)
    - Autonomic nervous system (ANS) — involuntary organs
        - Sympathetic (stimulatory — emergency response)
        - Parasympathetic (calming — restores normal conditions)

3. NERVOUS SYSTEM OF COCKROACH

- Brain = supra-oesophageal ganglion (above oesophagus)
- Sub-oesophageal ganglion (below oesophagus)
- Connected by circumoesophageal connectives
- Double ventral nerve cord with 3 thoracic + 6 abdominal ganglia
- Sympathetic system = frontal ganglion + visceral ganglion

4. HUMAN BRAIN

Brain is protected by 3 meninges: Duramater (outer, tough), Arachnoid (middle, web-like), Piamater (inner, vascular). Space filled with cerebrospinal fluid.

Three regions:

(a) Forebrain:

- **Cerebrum** — largest part; divided into right and left cerebral hemispheres. Outer = gray matter (cell bodies), Inner = white matter (axon fibres). Corpus callosum connects two hemispheres. Functions: voluntary movement, sensory processing, thinking, reasoning, memory
- **Thalamus** — relay centre for sensory impulses (pain, pleasure) to cerebrum
- **Hypothalamus** — controls eating, drinking, sex behavior; controls pituitary secretions; regulates body temperature and body fluids

(b) Midbrain — small tubular connector between forebrain and hindbrain

(c) Hindbrain:

- **Cerebellum** — maintains body balance; coordinates muscular activity
- **Medulla oblongata** — controls breathing, coughing, swallowing, heartbeat, alimentary canal movement (all involuntary)
- **Pons** — connects different parts of brain

Brain gives off **12 pairs of cranial nerves**

5. SPINAL CORD

- Extends from medulla downward through backbone
- Protected by same 3 meninges and cerebrospinal fluid
- Arrangement reversed: white matter outside, gray matter inside
- Functions: carries out spinal reflexes; conducts sensory impulses to brain; sends motor responses from brain to body

6. NEURON — STRUCTURE

- **Cell body (perikaryon)** — nucleus + organelles + Nissl granules
- **Dendrites** — short branching processes; receive impulses; up to 200 in one neuron
- **Axon** — long fibre; carries impulse away from cell body to terminal branches
- **Myelin sheath** — fatty covering on axon; such fibres = myelinated/medullated fibres

- **Node of Ranvier** — gaps in myelin sheath
- **Synapse** = junction between two neurons or neuron and muscle

7. CONDUCTION OF NERVE IMPULSE

Along the neuron (Electrical):

- Resting nerve fibre is **polarized** — positive outside (due to more Na^+ ions outside)
- On stimulation → Na^+ ions rush in → **depolarization** (charge becomes negative)
- This triggers depolarization of next region → wave travels forward
- Previous region becomes **repolarized** by sodium pump
- Nerve impulse = self-propagating wave of depolarization and repolarization

All or None Principle: If stimulus reaches minimum threshold, impulse travels at its own speed — intensity of stimulus cannot increase speed of transmission.

Over the Synapse (Chemical):

- Axon terminal releases **acetylcholine**
- Acetylcholine stimulates next neuron → new impulse starts
- Acetylcholine is then broken down → synapse ready for next transmission

8. REFLEX ACTION

Reflex action = automatic, quick, involuntary response to a stimulus

Two types:

- **Simple (Inborn) reflex** — natural, no prior learning needed (knee jerk, eye blink, pupil narrowing in light)
- **Conditioned reflex** — acquired through repeated experience (salivation on seeing food, applying brakes while driving)

Reflex Arc pathway:

Stimulus → Receptor → Afferent nerve (dorsal root) → Spinal cord → Intermediate neuron → Motor neuron → Efferent nerve (ventral root) → Effector (muscle/gland)

9. SENSE ORGANS

Eye

Three layers of eyeball:

- **Sclera** (outer, tough, white) — continues as transparent cornea in front
- **Choroid** (middle, blood vessels, dark) — prevents reflection
- **Retina** (innermost, sensitive) — contains rods (dim light) and cones (bright light and colour)

Key parts:

- **Yellow spot** — area of best/sharpest vision; maximum cones
- **Blind spot** — where optic nerve forms; no sensory cells; no image perceived
- **Iris** — circular curtain; circular muscles narrow pupil; radiating muscles dilate it
- **Lens** — biconvex, held by suspensory ligament attached to ciliary body
- **Aqueous humour** (front) — keeps lens moist; protects from shock
- **Vitreous humour** (back, jelly) — maintains shape of eyeball; protects retina

Accommodation: Changing lens curvature to focus. For near vision — ciliary muscles contract → lens becomes thicker. For distant vision — lens flattens.

Eye defects:

- **Myopia** (near-sighted) — image forms in front of retina → corrected by concave lens
- **Hypermetropia** (far-sighted) — image forms behind retina → corrected by convex lens
- **Cataract** — lens turns opaque → surgically removed, replaced by intraocular lens

Ear

- **External ear** — pinna (directs sound), auditory canal
- **Middle ear** — tympanum (ear drum), malleus → incus → stapes, Eustachian tube (equalizes pressure)
- **Internal ear** — Cochlea (hearing, organ of corti), Vestibule with 3 semicircular canals (balance)

Mechanism of hearing: Sound waves → ear drum vibrates → malleus → incus → stapes → oval window → cochlea fluid moves → organ of corti → auditory nerve → brain

Balance: Semicircular canals (static balance); Utriculus + sacculus (dynamic/motion balance)

10. ENDOCRINE SYSTEM

Endocrine glands = ductless glands; secrete hormones directly into blood → carried to target cells.

Properties of hormones: secreted in tiny amounts; biologically very active; excess and deficiency both cause disorders; not stored in body; can be proteins, glycoproteins, amines, or steroids.

PITUITARY GLAND (Master Gland)

Hangs from base of mid-brain; connected to hypothalamus via pituitary stalk. Two parts: Anterior + Posterior.

Source	Hormone	Function / Disorder
Anterior	Growth Hormone (GH/STH)	Promotes skeletal growth. Deficiency → Dwarfism; Excess in child → Gigantism; in adult → Acromegaly
Anterior	TSH	Stimulates thyroid
Anterior	ACTH	Stimulates adrenal cortex
Anterior	FSH	Egg/sperm formation
Anterior	LH	Ovulation; testosterone production
Anterior	Prolactin	Milk production
Posterior	ADH (Vasopressin)	Water reabsorption in kidney. Deficiency → Diabetes insipidus
Posterior	Oxytocin	Uterus contraction during childbirth

THYROID GLAND

Bilobed, in front of neck on trachea. Secretes thyroxine and calcitonin.

Thyroxine — regulates basal metabolism, growth, body temperature, mental development.

Hypothyroidism (under-secretion):

- Simple goitre — thyroid swelling; due to iodine deficiency
- Cretinism — dwarfism + mental retardation (in children)
- Myxoedema — swelling of face/hands, sluggishness (in adults)

Hyperthyroidism (over-secretion): Exophthalmic goitre — increased metabolic rate, rapid heartbeat, protruding eyes

Calcitonin — regulates calcium levels in blood (moves Ca^{2+} from blood to bones when levels are high)

PARATHYROID: Two pairs of small glands embedded in thyroid. Secretes parathormone — raises blood calcium by releasing calcium from bones.

THYMUS: Located at base of neck. Produces hormones for T-lymphocyte maturation. Atrophies after puberty.

ADRENAL GLANDS: One above each kidney. Two parts: Medulla + Cortex.

Adrenal Medulla → secretes Adrenaline (emergency hormone):

- Increases heartbeat and blood pressure
- Increases blood supply to muscles
- Releases glucose from liver into blood

Adrenal Cortex → secretes:

- **Glucocorticoids** (e.g. cortisone) — raises blood glucose under stress; adapts body to extreme conditions
- **Mineralocorticoids** (e.g. aldosterone) — water retention; increases Na^+ and Cl^- reabsorption in kidneys

PANCREAS (Islets of Langerhans)

Both exocrine and endocrine. Three cell types:

Cell	Hormone	Function
Alpha cells	Glucagon	Breaks glycogen → glucose; raises blood sugar
Beta cells	Insulin	Promotes glucose utilization; stores glucose as glycogen; lowers blood sugar
Gamma cells	Somatostatin	Inhibits both insulin and glucagon

Insulin deficiency → Diabetes mellitus (hyperglycemia) — excess sugar in blood and urine, excessive thirst and urination, weight loss.

Insulin excess → Hypoglycemia — low blood sugar; brain coma possible.

GONADS

Testes — produce testosterone (by interstitial cells) → develops male secondary characters at puberty (facial hair, deep voice)

Ovaries — produce estrogen (from follicles) → breast development, fat deposition, uterus preparation; produce progesterone (from corpus luteum) → maintains uterus during pregnancy

Placenta — produces HCG (human chorionic gonadotropin) → maintains corpus luteum to keep secreting progesterone during pregnancy

STOMACH AND INTESTINE HORMONES

- **Gastrin** — secreted by stomach pyloric mucosa → stimulates gastric juice secretion
- **Secretin** — secreted by duodenum lining → stimulates pancreatic juice
- **Cholecystokinin** — stimulates bile release from gall bladder

11. FEEDBACK MECHANISM

The amount of hormone secreted is determined by body's need. When level rises, gland is told to slow down (negative feedback). When level falls, gland is stimulated again.

Example (Thyroid): Hypothalamus → TSH-RH → Anterior Pituitary → TSH → Thyroid → Thyroxine When thyroxine level rises → pituitary stops TSH → thyroxine decreases → cycle repeats

12. HORMONAL vs NERVOUS COORDINATION

Property	Hormonal	Nervous
Signal type	Chemical	Electrical (chemical at synapse)
Speed	Slow	Very rapid (0.7–120 m/s)
Effect	General (widespread)	Localized (specific muscle/gland)
Growth effect	Can affect growth	Cannot affect growth
Duration	Short-term or long-lasting	Short-lived

13. PHEROMONES

Secretions released by one individual into the environment that produce a specific response in other members of the same species. Examples: ants following trail, honeybee alarm pheromone, female moth attracting male from kilometers away.

TOP 5 MOST IMPORTANT EXAM QUESTIONS & ANSWERS

Q1. What is reflex action?. *(Asked: 2016, 2018, 2019, 2021, 2022, 2023)*

Answer: Reflex action is an automatic, quick, involuntary response to a stimulus.

Pathway: Stimulus → Receptor (skin) → Sensory neuron (dorsal root) → Spinal cord → Intermediate neuron → Motor neuron → Efferent nerve (ventral root) → Effector (muscle contracts)

Simple reflexes are inborn (knee jerk); conditioned reflexes are learned (salivation at food).

Q2. Name the hormones of the pituitary gland. What are the effects of over and under secretion of Growth Hormone?

Answer: Pituitary (master gland) secretes from anterior lobe: GH, TSH, ACTH, FSH, LH, Prolactin. From posterior lobe: ADH, Oxytocin.

Growth Hormone (GH/STH):

- Under-secretion in childhood → Dwarfism (short stature)

- Over-secretion in childhood → Gigantism (abnormally tall)
- Over-secretion in adult → Acromegaly (enlargement of hands, feet, facial bones)

Q3. Describe the thyroid gland. What are the effects of hypo and hyperthyroidism?

Answer: Thyroid is bilobed, located in the front of the neck on the trachea. It secretes thyroxine (regulates metabolism, growth, body temperature) and calcitonin (regulates blood calcium).

Hypothyroidism (deficiency):

- Simple goitre — enlarged thyroid due to iodine deficiency
- Cretinism — dwarfism and mental retardation in children
- Myxoedema — swelling of face, sluggishness in adults

Hyperthyroidism (excess): Exophthalmic goitre — increased metabolic rate, rapid heartbeat, protruding eyes

Q4. What is insulin? What happens when insulin is not secreted in the body?

Answer: Insulin is a hormone secreted by beta cells of the Islets of Langerhans in the pancreas.

Functions: promotes glucose utilization by body cells; stimulates storage of excess glucose as glycogen in liver.

Deficiency of insulin → Diabetes mellitus (hyperglycemia):

- High blood glucose level
- Sugar excreted in urine
- Excessive thirst due to water loss through urination
- Weight loss and weakness
- In severe cases — loss of eyesight

Excess insulin → Hypoglycemia (low blood sugar) → brain coma

TOP 5 PYQs — FREQUENTLY REPEATED IN EXAMS

PYQ 1: Differentiate between sympathetic and parasympathetic nervous systems. Give two examples of their effects. *(NIOS 2016, 2018, 2020, 2022)*

Answer:

Sympathetic	Parasympathetic
Prepares body for emergency	Restores normal conditions

Dilates pupil	Constricts pupil
Speeds up heartbeat	Slows down heartbeat
Increases blood sugar	No effect on blood sugar
Decreases intestinal peristalsis	Increases intestinal peristalsis

PYQ 2: What is the structure of a neuron? How is the nerve impulse conducted along it? *(NIOS 2017, 2019, 2021,)*

Answer: A neuron has a cell body (nucleus, organelles), dendrites (receive impulses), and axon (carries impulse away). Axon may be covered by myelin sheath with nodes of Ranvier.

Conduction: Resting fibre is polarized (+outside). Stimulus causes Na^+ to rush in → depolarization (charge reverses) → this triggers next region to depolarize → self-propagating wave moves along fibre → previous area repolarized by sodium pump. At synapse — acetylcholine released → chemical transmission to next neuron.

PYQ 3: Explain the feedback mechanism of hormone control with the example of thyroxine. *(NIOS 2017, 2019, 2021, 2022, 2023)*

Answer: Feedback mechanism is a self-regulating system where the product of a gland's activity controls the gland's further secretion.

Thyroid example: Hypothalamus secretes TSH-RH → Anterior pituitary releases TSH → TSH stimulates thyroid → Thyroid releases thyroxine When thyroxine level in blood rises → pituitary stops releasing TSH (negative feedback) → thyroxine secretion slows When thyroxine falls → pituitary resumes TSH release → cycle continues

PYQ 4: What are the functions of the different parts of the human brain? *(NIOS 2016, 2018, 2020, 2022)*

Answer:

- **Cerebrum** — thinking, reasoning, memory, voluntary movements, sensory processing
- **Thalamus** — relay centre for sensory impulses (pain, pleasure) to cerebrum
- **Hypothalamus** — body temperature regulation, controls pituitary, motivated behaviour
- **Cerebellum** — body balance, muscular coordination
- **Medulla oblongata** — breathing, heartbeat, swallowing, involuntary actions
- **Spinal cord** — spinal reflex actions, sensory/motor relay between brain and body

PYQ 5: Name the different hormones of the adrenal gland and state their functions. *(NIOS 2016, 2018, 2020, 2021, 2023)*

Answer: Adrenal gland has two parts — medulla and cortex.

Adrenal medulla → Adrenaline:

- Increases heartbeat and blood pressure
- Increases blood supply to muscles
- Releases glucose from liver (prepares body for emergency — "fight or flight")

Adrenal cortex →

- Glucocorticoids (e.g. cortisone): raises blood glucose under stress; adapts body to extreme conditions
- Mineralocorticoids (e.g. aldosterone): increases Na^+/Cl^- reabsorption in kidneys; controls water retention and blood pressure

11

Reproduction In Plants

1. MODES OF REPRODUCTION

Three types: Vegetative, Asexual, Sexual

In asexual and vegetative reproduction: single parent involved, no gametic fusion, offspring genetically identical to parent.

Vegetative reproduction — new plantlets from somatic cells, buds, or organs (root, stem, leaf, bud)

Fragmentation — filament breaks, each fragment grows (Spirogyra)

Fission — binary or multiple fission in unicellular organisms (bacteria, yeast)

Budding — bud-like outgrowth separates and grows (yeast)

Asexual spores — microscopic, protected by wall; germinate in suitable conditions (bread mould, fern, moss)

Sexual reproduction — fusion of haploid male and female gametes → fertilization → diploid zygote; meiosis involved; offspring genetically different from parents

Apomixis — seeds produced without pollination and fertilization (dandelion); diploid somatic cell of ovule forms embryo; asexual process but seed dispersal like sexual plants.

2. REPRODUCTION IN CHLAMYDOMONAS

Haploid unicellular freshwater alga; pear-shaped with 2 flagella, cup-shaped chloroplast, single nucleus, eyespot, pyrenoid.

Asexual Reproduction:

- **Zoospores** (when plenty of water) — protoplasm divides mitotically → 2–16 flagellate zoospores → each grows into adult
- **Aplanospores** (thin film of water) — non-flagellate; form palmella stage
- **Hypnospores** — thick-walled, dark; form when water dries; survive until conditions improve

Sexual Reproduction:

- **Isogamy** (C. eugametos) — morphologically identical gametes fuse; zygote divides by meiosis → 4 haploid zoospores
- **Anisogamy** (C. braunii) — different sized gametes; larger female gamete fertilized by smaller male

- **Oogamy** (C. coccifera, C. ooganum) — whole female cell = one egg; 32–64 biflagellate male gametes; one fertilizes egg

In all cases: zygote develops thick wall, enters dormancy (zygospore), then undergoes meiosis to form 4 haploid zoospores.

3. REPRODUCTION IN SPIROGYRA

Free-floating filamentous alga; cylindrical cells with 1–14 spiral ribbon chloroplasts, pyrenoids, large vacuole, central nucleus.

Vegetative Reproduction: Fragmentation — filament breaks at transverse septum; each fragment grows by mitosis.

Sexual Reproduction — Conjugation (isogamy):

Scalariform Conjugation (two filaments, ladder-like appearance):

- Two filaments align → pairing cells form conjugation tube
- Gamete from one cell (male) migrates to other (female) through tube by amoeboid movement
- Gametes fuse → diploid zygospore (thick-walled, dark) in female cells; male cells become empty
- On return of favourable conditions → meiosis → 4 haploid nuclei, 3 degenerate → 1 grows into new filament

Lateral Conjugation (one filament only): Male and female cells alternate; conjugation tube forms between adjacent male and female cells.

4. REPRODUCTION IN ANGIOSPERMS (FLOWERING PLANTS)

Classification by life span:

- **Annuals** — complete life cycle in one season (pea)
- **Biennials** — two seasons; vegetative in first, reproduce in second (radish)
- **Perennials** — live several years; flower and fruit every year (mango, peepal)
- **Monocarpic** — reproduce once and die (bamboo, agave, all annuals and biennials)
- **Polycarpic** — flower and fruit many times (mango, apple, guava)

Factors affecting flowering: Temperature (vernalisation) and Light (photoperiodism)

Parts of a flower

- Calyx (sepals) — accessory/non-essential whorl

- Corolla (petals) — accessory/non-essential whorl
- Androecium (stamens) — essential whorl (male)
- Gynoecium/Pistil (carpels) — essential whorl (female)

5. STAMEN, MICROSPORANGIA AND POLLEN GRAIN

Stamen = anther (4 pollen sacs/microsporangia) + filament

Wall layers of microsporangium: Epidermis (outermost) → Middle layer → Tapetum (innermost, nourishes pollen grains)

Microsporogenesis: Microspore mother cells → meiosis → 4 haploid microspores in a tetrad → each = male gametophyte (pollen grain)

Pollen grain wall: Outer exine (sporopollenin; with germ pores through which pollen tube grows) + Inner intine (thin, cellulosic)

Pollen grain divides into: large vegetative cell + small generative cell. Pollen grain = male gametophyte (not the gamete itself).

6. OVULE AND FEMALE GAMETOPHYTE

Ovule = integumented megasporangium; develops on placenta in ovary.

Parts of ovule: Nucellus (parenchymatous tissue), Integuments (1–2 coverings), Micropyle (aperture), Chalaza (opposite end to micropyle), Funiculus (stalk), Hilum (point of attachment).

Megasporogenesis: Megaspore mother cell (in nucellus) → meiosis → 4 haploid megaspores → 3 degenerate → 1 functional megaspore

Development of embryo sac (female gametophyte): Functional megaspore → 3 successive mitotic divisions → 8 haploid nuclei → arrangement into 7 cells:

- **Micropylar end:** Egg apparatus = 1 egg cell (female gamete) + 2 synergids
- **Chalazal end:** 3 antipodal cells
- **Centre:** 2 polar nuclei → fuse → secondary nucleus (diploid)

Functions: Egg cell → zygote (after syngamy); Secondary nucleus → primary endosperm nucleus (after triple fusion); Synergids → direct pollen tube to egg; Antipodal cells → provide nutrition and degenerate.

7. POLLINATION

Pollination = transfer of pollen grains from anther to stigma of a flower.

Self-pollination = same flower or same plant (pea, gram) **Cross-pollination** = different plant of same species (maize, palm)

Importance: Results in fertilization; stimulates ovule → seed; new gene combinations (cross-pollination); pollen tube hormones stimulate fruit formation.

Agencies of cross-pollination:

- **Anemophily** (wind) — small, light, winged pollen; large hairy stigma; no nectar/scent (grasses)
- **Entomophily** (insects) — large, coloured, scented flowers; nectar; e.g. Salvia by bees
- **Hydrophily** (water) — aquatic plants; large pollen numbers; float on water (Hydrilla, Vallisnaria)
- **Zoophily** (animals/birds) — bright colour, size, scent attracts animals (Canna pollinated by sunbird)

Adaptations promoting cross-pollination: Unisexuality (papaya, maize), Dichogamy (maturation at different times — sweet pea), Self-sterility (Petunia, apple)

Devices ensuring self-pollination: Cleistogamy (flowers remain closed), Homogamy (simultaneous maturation, groundnut)

8. FERTILIZATION AND DOUBLE FERTILIZATION

- Pollen grain lands on stigma → germinates → pollen tube grows through germ pore
- Pollen tube grows through stigma and style → enters ovule through micropyle
- Tube nucleus degenerates → 2 sperms (male gametes) released into embryo sac
- **Syngamy:** One sperm + egg cell → diploid zygote → develops into embryo
- Triple fusion: Other sperm + secondary nucleus → primary endosperm nucleus (3n) → develops into endosperm

Both fusions together = Double Fertilization (unique to angiosperms)

Significance of fertilization**:** Stimulus for ovary growth → fruit formation; recombination of genes.

9. POST-FERTILIZATION EVENTS

Endosperm develops before embryo; provides nutrition to developing embryo. Three types: Nuclear (most common — maize, wheat, rice), Cellular, Helobial.

Development of embryo: Zygote → embryonal cell + suspensor cell → suspensor pushes embryo into endosperm → embryonal cell differentiates into radicle, plumule, cotyledon → integuments harden → seed coat

Seed = ripened ovule. Contains: seed coat (testa + tegmen), embryo (embryonal axis + cotyledon/s), endosperm (in albuminous seeds).

Dicot seed (gram): Two cotyledons, embryonal axis enclosed by fleshy cotyledons, hilum, micropyle, testa, tegmen.

Monocot seed (maize): One cotyledon (scutellum), testa and tegmen fused with pericarp, endosperm with aleurone layer (protein), embryo lateral to scutellum.

Fruit = ripened ovary. Protects seeds; aids dispersal; enriches soil.

Parthenocarpy = development of fruit without fertilization; seedless fruits (grapes, banana). Commercially valuable.

Seed germination: Imbibition of water → seed swells → enzymes convert reserve food → radicle emerges → plumule develops into shoot. Requires moisture, suitable temperature, oxygen.

Epigeal germination — cotyledons come above ground (bean, castor, neem) Hypogeal germination — cotyledons remain underground (maize, rice)

10. VEGETATIVE REPRODUCTION IN ANGIOSPERMS

New plants formed are genetically identical to parent.

Mode	Specialized part	Example
Natural — Roots	Adventitious roots	Asparagus, sweet potato
Natural — Stem	Rhizome	Ginger
	Tuber	Potato
	Bulb	Onion
	Corm	Zamikand (Colocasia)
	Runner	Lawn grass
	Sucker	Chrysanthemum, mint
Natural — Leaves	Adventitious buds on margin	Bryophyllum, Kalanchoe
Natural — Special	Bulbils (from flower buds)	Agave, Oxalis, pineapple
Artificial — Cutting	Stem cutting	Rose, money plant, sugarcane
Artificial — Layering	Branch bent into soil	Jasmine, strawberry, grapevine
Artificial — Gootee (air layering)	Ring of bark removed + moss	Citrus, mango
Artificial — Grafting	Scion inserted into stock	Rose, mango, citrus, apple
Artificial — Tissue culture	Callus from single cell	Orchids, Chrysanthemum, Asparagus

Grafting: Stock (disease-resistant rooted plant) + Scion (cutting of desired variety) → tissues unite → vascular continuity established. Used in dicots only.

Micropropagation: Small tissue/cell → nutrient medium → callus (unorganised mass) → hormones added → plantlets → mature plants. Produces unlimited identical plants from small tissue.

Advantages of vegetative reproduction: Rapid, genetically identical offspring, preserves desired varieties, food storage for perennation, quicker and cheaper.

Disadvantages: Overcrowding, no new varieties created, diseases transmitted rapidly.

TOP 5 MOST IMPORTANT EXAM QUESTIONS & ANSWERS

Q1. What is double fertilization? Explain syngamy and triple fusion with their products.

Answer: Double fertilization is the occurrence of two fusion events inside the embryo sac of angiosperms.

Syngamy: One sperm fuses with the egg cell → diploid zygote (2n) → develops into embryo.

Triple fusion: Second sperm fuses with the secondary nucleus (2n) → primary endosperm nucleus (3n) → develops into endosperm which provides food to the embryo.

Since both syngamy and triple fusion occur in the same embryo sac, the process is called double fertilization. This is a feature unique to angiosperms.

Q2. Describe the structure of a mature embryo sac. Name and state the function of each component.

Answer: The mature embryo sac has 8 haploid nuclei arranged in 7 cells.

At the micropylar end — egg apparatus (1 egg cell + 2 synergids). At the chalazal end — 3 antipodal cells. At the centre — 2 polar nuclei forming the secondary nucleus (diploid).

Functions: Egg cell fuses with sperm → zygote; Secondary nucleus fuses with second sperm → endosperm; Synergids direct pollen tube to egg; Antipodal cells provide nutrition and degenerate before fertilization.

Q3. What is pollination? Distinguish between self-pollination and cross-pollination. Give two characteristics each of wind-pollinated and insect-pollinated flowers. *(Asked: NIOS 2016, 2017, 2019, 2020, 2022)*

Answer: Pollination is the transfer of pollen grains from anther to stigma of a flower.

Self-pollination: pollen to same flower or same plant (pea, gram). Cross-pollination: pollen from one plant to another plant of same species (maize, palm).

Wind-pollinated (anemophilous): small, light, winged pollen; large, hairy, protruding stigma; no nectar or scent; large quantities of pollen produced.

Insect-pollinated (entomophilous): large, brightly coloured, scented flowers; nectar secreted to attract insects (e.g. Salvia pollinated by bees).

Q4. Differentiate between dicot and monocot seeds with examples. *(Asked: NIOS 2016, 2018, 2019, 2021, 2023)*

Answer:

Feature	Dicot seed (Gram/Pea)	Monocot seed (Maize)
Cotyledons	Two, fleshy	One (scutellum)
Seed coat	Testa + tegmen separable	Testa, tegmen and pericarp fused
Endosperm	Absent in mature seed (absorbed by embryo)	Present, massive; has aleurone layer
Embryonal axis	Enclosed by two cotyledons	Lateral to scutellum
Special features	Hilum and micropyle visible	Coleorhiza and coleoptile present

Q5. Describe the methods of artificial vegetative propagation in plants. Give two examples of each. *(Asked: NIOS 2016, 2017, 2018, 2020, 2021, 2023)*

Answer:

Cutting: Stem cuttings placed in soil or water; adventitious roots develop. Examples: rose, money plant, sugarcane.

Layering: Lower branch bent into soil with bark ring removed; roots develop → branch detached and grown separately. Examples: jasmine, strawberry, grapevine.

Aerial layering (Gootee): Ring of bark removed from branch → moist moss applied + sealed in polythene → roots appear → branch cut and planted. Used when bending is not possible.

Grafting: Scion (desired variety) inserted into stock (disease-resistant rooted plant); bound until vascular union occurs. Examples: mango, rose, citrus, apple.

Micropropagation (Tissue culture): Small piece of tissue placed in nutrient medium under aseptic conditions → forms callus → hormones added → plantlets develop → transplanted. Examples: orchids, Chrysanthemum, Asparagus.

TOP 5 PYQs — FREQUENTLY REPEATED IN EXAMS

PYQ 1: Explain scalariform conjugation in Spirogyra. *(NIOS 2017, 2019, 2021, 2022, 2023)*

Answer: Two filaments of Spirogyra lie parallel → cells of opposing filaments align face to face → conjugation tubes form between paired cells → cytoplasm of male cell moves amoeboidly through tube into female cell → gametes fuse → diploid zygospore (thick-walled, dark) forms in female cell; male cells become empty → on return of favourable conditions → meiosis → 4 haploid nuclei, 3 degenerate → 1 nucleus develops into new filament by mitosis. The arrangement resembles a ladder, hence called scalariform conjugation.

PYQ 2: What is grafting? Explain the role of stock and scion. *(NIOS 2016, 2017, 2020, 2021, 2022, 2023)*

Answer: Grafting is an artificial method of vegetative propagation in which a stem cutting of the desired plant (scion) is inserted into a rooted plant (stock). The stock is selected for disease resistance and physical strength. The scion carries the desired fruit or flower characteristics. After insertion, they are bound firmly until their tissues unite and vascular continuity is established. The grafted branch produces the characteristics of the scion, while the rest of the tree retains those of the stock. Examples: mango, apple, citrus, rose. Mostly practiced in dicots.

PYQ 3: What is parthenocarpy? Give two examples and its commercial value. *(NIOS 2016, 2018, 2019, 2021, 2022)*

Answer: Parthenocarpy is the development of fruit from an unfertilized ovary, resulting in seedless fruits. Examples: grapes and banana.

Commercial value: seedless fruits are highly preferred for eating; they contain abortive seeds that cannot grow into new plants; they contain sufficient growth hormones. Their seedless nature makes them more economically valuable in horticulture and food industry.

12

Reproduction and Population control

1. TYPES OF REPRODUCTION

Asexual Reproduction: Production of offspring from a single organism without formation of gametes. Common in bacteria, protista, lower plants and lower animals.

Sexual Reproduction: Production of offspring by formation and fusion of gametes. At fertilization, male and female gametes unite to form a zygote. Most animals and higher plants multiply this way.

2. ASEXUAL REPRODUCTION — GEMMULE

A gemmule is a reproductive body for asexual reproduction found in freshwater sponges (Spongilla) and some marine sponges.

Structure: Tiny hard ball containing undifferentiated cells called archaeocytes, surrounded by a resistant chitin covering (strengthened by spicules), with a small outlet called micropyle.

Importance: Gemmules survive unfavourable conditions (drought, freezing winter) when adult sponges die. When conditions improve, archaeocytes come out through micropyle and develop into a new sponge.

3. PUBERTY AND ADOLESCENCE

- Males attain puberty at **13–14 years**; Females at **11–13 years**
- WHO defines adolescence as period from **10 to 19 years**
- **Secondary sexual characters in males:** deepening of voice, beard, moustache, widening of shoulders, pubic/axillary hair, enlargement of genital organs
- **Secondary sexual characters in females:** pubic/axillary hair, widening of pelvis and hip, breast enlargement, onset of menstrual cycle

4. MALE REPRODUCTIVE SYSTEM

Organs: Pair of testes, pair of epididymis, pair of vasa deferentia, urethra, penis, accessory glands

(i) Testes: Male gonads, extra-abdominal, present in scrotal sac. Each testis ~4–5 cm long, ~12 g. Contain **seminiferous tubules** (produce sperms) and **Leydig cells** (secrete testosterone). Scrotum maintains temperature 2–3°C below body temperature for sperm development.

(ii) Epididymis: Long coiled tube attached to testis. Stores sperms in viable but immotile state.

(iii) Vas Deferens: Continues from epididymis, joins duct of seminal vesicle to form **ejaculatory duct**, which opens into urethra.

(iv) Urethra: 15–20 cm long. Common passage for semen and urine.

(v) Penis: Cylindrical, spongy, vascular copulatory organ. Tip is called **glans penis**, covered by **prepuce**.

Accessory Glands:

- **Seminal vesicles** — store sperms, secrete viscous seminal fluid (40–80% of ejaculate)
- **Prostate gland** — secretes alkaline fluid, keeps sperms alive (5–30% of ejaculate)
- **Cowper's (Bulbo-urethral) glands** — secrete white viscous alkaline mucous-like lubricant

5. SPERMATOZOA

Three parts: Head, Neck (midpiece), Tail

- **Acrosome** (tip of head) — contains enzymes, helps sperm penetrate egg during fertilization
- **Mitochondria** in midpiece — provide energy for movement
- One ejaculation releases ~200,000,000 (2×10^8) sperms
- Sperms move at 2 mm/minute inside female body

Course of Sperms: Seminiferous tubules → Vasa efferentia → Epididymis → Vas deferens → Urethra in penis

6. FEMALE REPRODUCTIVE SYSTEM

Organs: Pair of ovaries, pair of Fallopian tubes, uterus, vagina, external genitalia

(i) Ovaries: Produce ova; secrete oestrogen and progesterone. Process of egg formation = Oogenesis

Stages in ovary: Primary follicle → Secondary follicle → Graffian follicle (mature egg) → Ovulation → Corpus luteum (empty follicle)

(ii) Fallopian Tubes (Oviducts): 10–15 cm long. Proximal funnel-shaped end = infundibulum (with finger-like fimbrae). Site of fertilization.

(iii) Uterus: Pear-shaped, ~7 cm long. Three layers — innermost endometrium (richly vascular), middle myometrium, outermost perimetrium.

(iv) Vagina: Muscular tube 7–10 cm. Receives penis during coitus, acts as birth canal. Opening covered by membrane called hymen in virgin females.

7. MENSTRUAL CYCLE

- **Menarche:** First menstruation, ~11–13 years

- **Menopause:** Permanent stoppage, ~45–50 years
- **Cycle duration:** 28 days

Events:

- **Day 1–4:** Menstrual flow — uterine lining shed
- **Day 5–13:** Growth and maturation of Graffian follicle; oestrogen secreted
- **Day 13–14:** Ovulation — Graffian follicle ruptures, ovum released
- Corpus luteum forms → secretes progesterone
- Ovum reaches uterus on day 13–14, remains viable 48–72 hours
- If unfertilized → ovum degenerates → cycle repeats at day 28

If fertilized: Progesterone produced continuously by corpus luteum then placenta; menstruation stops throughout pregnancy.

8. FERTILIZATION AND EMBRYO DEVELOPMENT

- Sperms remain viable in female tract for **24–72 hours**
- Fertilization occurs in **Fallopian tube** — one sperm fuses with ovum → **zygote** (Day 1)
- Zygote divides → **Morula** (spherical mass of cells, Day 4)
- **Blastocyst** forms (Day 5)
- **Implantation** in uterine wall (Day 6–7)
- Embryo (pea-sized) at 4 weeks
- Foetus with human features and limbs at 6 weeks
- Birth at approximately **40 weeks**

9. PLACENTA

An association between maternal and foetal tissue for physiological exchange.

Functions:

- Supplies **oxygen and nutrients** from maternal blood to foetus
- Removes **CO_2 and excretory wastes** from foetal blood to maternal blood
- Permeable to antibodies

- Produces hormone **progesterone**
- Acts as barrier — prevents germs from passing to foetus (exception: **HIV** can pass through)

Umbilical cord: Blood vascular connection between foetus and uterine wall

Amnion: Sac enclosing embryo filled with amniotic fluid — acts as shock absorber

10. CHILDBIRTH

- Uterus contracts (labour) — triggered by hormone Oxytocin (from posterior pituitary)
- Amnion bursts → amniotic fluid discharged
- Uterus contracts vigorously → baby expelled
- Baby's lungs start functioning (first breath)
- Umbilical cord tied and cut
- Placenta discharged after birth
- Breasts start producing milk

11. LACTATION

- Secretion of milk from mammary glands = **Lactation**
- First secretion after childbirth = **Colostrum** — rich in nutrients, fats, proteins; contains IgA antibodies → provides **passive immunity** to newborn
- **Prolactin** (anterior pituitary) → stimulates milk **synthesis**
- **Oxytocin** (posterior pituitary) → stimulates milk **release**

12. TWINS

Type	How Formed	Sex
Fraternal twins	Two eggs released, fertilized by two different sperms	Can be different
Identical twins	One egg fertilized, divides into two separate embryos	Always same sex
Siamese twins	One egg that fails to separate completely	Same sex

13. NEW MEDICAL TECHNIQUES

- **Test Tube Baby (IVF):** Ripe ova collected from woman, fertilized with partner's sperms in a dish, embryo inserted into uterus

- **Artificial Insemination:** Frozen semen thawed and introduced into female by syringe at time of ovulation
- **Fertility Drugs:** FSH injected to stimulate follicle production in women whose ovaries fail to release ova

14. POPULATION TERMS

- **Demography:** Scientific and statistical study of human population
- **Birth Rate (Natality):** Number of live births per 1000 individuals per year
- **Death Rate (Mortality):** Number of deaths per 1000 individuals per year
- **Population Growth Rate:** Birth rate minus death rate
- **Census:** Official data of registered people in a selected area
- **Population Density:** Number of individuals per km^2

15. FACTORS FOR POPULATION EXPLOSION IN INDIA

1. Advancement in agriculture (less starvation)
2. Advancement in medicine (increased life span)
3. Religious and social customs (resistance to family planning)
4. Industrialization (better food distribution, employment)
5. Illiteracy (unaware of consequences)
6. Economic reasons (children as earners)
7. Desire for a male child

16. CONTRACEPTIVE METHODS

- **Rhythm method:** Avoiding intercourse during fertile period (not reliable)
- **Condoms/Diaphragms:** Barrier methods — prevent sperm meeting egg
- **IUD (Copper T):** Inserted in uterus — prevents implantation
- **Oral contraceptive pills:** Interfere with ovulation
- **Vasectomy:** Vas deferens cut and ligated in males (surgical)
- **Tubectomy:** Fallopian tubes cut and ligated in females (surgical)
- **MTP (Medical Termination of Pregnancy / Abortion):** Removal of unwanted foetus — always requires professional medical help

TOP 5 EXAM QUESTIONS FROM THIS CHAPTER (Most Frequently Asked)

Q1. What is placenta? Describe its functions in humans.

Answer: Placenta is an association between maternal and foetal tissue for physiological exchange. The developing embryo is attached to the uterus wall through it, connected by the umbilical cord.

Functions:

- Supplies oxygen and nutrients from maternal blood to foetal blood
- Removes carbon dioxide and excretory wastes from foetal blood to maternal blood
- Permeable to antibodies — provides immunity to foetus
- Produces hormone progesterone — maintains pregnancy
- Acts as a protective barrier against most germs (exception: HIV can cross)

Q2.the human male reproductive system and state the functions of its parts.

Answer:

Organ	Function
Testes	Produce sperms; secrete testosterone
Epididymis	Store sperms in viable but immotile state
Vas deferens	Passage of sperms to urethra
Seminal vesicles	Nourish and activate sperms
Prostate gland	Secretes alkaline fluid; keeps sperms alive
Urethra	Common passage for urine and semen
Penis	Copulatory organ

Q3. Describe the menstrual cycle in human females.

Answer:

- Duration: 28 days
- **Day 1–4:** Menstrual flow — uterine lining shed with blood
- **Day 5–13:** Graffian follicle matures; oestrogen secreted; uterine lining rebuilds
- **Day 13–14:** Ovulation — mature ovum released from Graffian follicle

- Corpus luteum forms → secretes progesterone
- Ovum survives 48–72 hours in uterus
- If not fertilized → ovum degenerates → uterine lining breaks down → next cycle begins
- If fertilized → implantation occurs → menstruation stops → pregnancy begins

Q4. Differentiate between identical twins and fraternal twins. How are Siamese twins formed?

Answer:

Feature	Identical Twins	Fraternal Twins
Origin	One egg fertilized, divides into two embryos	Two eggs fertilized by two different sperms
Genetic similarity	Genetically identical	Genetically different
Sex	Always same sex	Can be same or different sex

Siamese twins: Formed when a single fertilized egg starts to divide into two embryos but fails to separate completely. The twins remain physically joined. First case was in Siam (Thailand) in 1811.

Q5. What are the factors responsible for population explosion in India? What methods can be used to control population?

Answer: Factors for population explosion:

1. Advancement in medicine → increased life span
2. Advancement in agriculture → less starvation
3. Religious and social customs → resistance to family planning
4. Illiteracy → ignorance about consequences
5. Desire for a male child → more children born
6. Economic reasons → children used as earners

Methods of Population Control:

1. Education and awareness
2. Rhythm method (safe period)
3. Condoms / Diaphragms (barrier methods)
4. Intrauterine devices — Copper T

5. Oral contraceptive pills (interfere with ovulation)
6. Vasectomy (males) — vas deferens cut/ligated
7. Tubectomy (females) — Fallopian tubes cut/ligated
8. MTP (Medical Termination of Pregnancy) — last resort, under medical supervision

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Principles of Genetics

1. HEREDITY AND VARIATION

Heredity: The transmission of characters from one generation to the next, that is from parents to offspring.

Genetics: The study of science of heredity and the reasons governing variation between parents and their offspring.

Variation: Differences between parents and their offspring, or between offspring of same parents, or between members of the same population.

Sources of Variation: Mutation (sudden change in genes) and Genetic Recombination (gene exchange during meiosis).

2. MENDEL AND HIS EXPERIMENTS

Gregor Johann Mendel (1822–1884): Austrian monk; used garden pea (Pisum sativum); published results in 1865; called Father of Genetics.

Rediscovered in 1900 by: Tschermak, Correns and DeVries.

Seven traits studied by Mendel

1. Seed shape — Round vs Wrinkled
2. Seed colour — Yellow vs Green
3. Flower colour — Purple vs White
4. Flower position — Axial vs Terminal
5. Pod shape — Inflated vs Constricted
6. Pod colour — Green vs Yellow
7. Stem length — Tall vs Dwarf

Types of Crosses:

- **Monohybrid cross:** Parents differing in one pair of contrasting characters → F2 ratio = 3:1
- **Dihybrid cross:** Parents differing in two pairs of contrasting characters → F2 ratio = 9:3:3:1

3. MENDEL'S THREE LAWS OF INHERITANCE

Law 1 — Law of Segregation (Purity of Gametes): At the time of gamete formation, the two chromosomes of each pair separate (segregate) into two different cells forming gametes. Each gamete receives only one member of a pair of factors. This is a universal law.

Law 2 — Law of Dominance: When two genes of a pair represent contrasting characters, the expression of one is dominant over the other. Dominant character is expressed in both homozygous (TT) and heterozygous (Tt) conditions. Recessive character (tt) is expressed only in homozygous condition.

Law 3 — Law of Independent Assortment: In inheritance of two features, genes for the two different features are passed down into offspring independently. The segregation of one pair of factors is independent of any other pair.

Dihybrid ratio: 9 Tall Red : 3 Tall White : 3 Dwarf Red : 1 Dwarf White

4. IMPORTANT TERMS IN GENETICS

- **Gene:** A segment of DNA molecule that determines the unit of inheritance and expression of a particular character
- **Alleles:** Two or more alternative forms of a gene occupying the same locus on homologous chromosomes (e.g., T and t for height)
- **Trait:** Morphologically or physiologically visible character (e.g., flower colour)
- **Dominant trait:** Expresses itself in F1 heterozygous (Tt) condition
- **Recessive trait:** Suppressed in F1; expresses only in homozygous (tt) condition
- **Homozygous:** Individual with identical alleles for a trait (e.g., TT or tt)
- **Heterozygous:** Individual with dissimilar alleles for a trait (e.g., Tt)
- **Genotype:** Genetic constitution of an individual (e.g., TT, Tt, tt)
- **Phenotype:** Outward visible appearance of a trait (e.g., Tall or Dwarf)
- **F1 generation:** First filial — progeny from cross between two parents
- **F2 generation:** Second filial — progeny from self pollination of F1
- **Test cross:** Crossing F1 with homozygous recessive parent → ratio 1:1
- **Reciprocal cross:** Cross where sex of parents is reversed

5. DEVIATIONS FROM MENDEL'S LAWS

Incomplete Dominance: Neither allele is fully dominant; heterozygous shows intermediate phenotype. Example: Four O'clock plant (Mirabilis jalapa) and Snapdragon (Antirrhinum)

Cross: RR (red) × rr (white) → F1: Rr (Pink) → F2: 1 Red : 2 Pink : 1 White (ratio 1:2:1)

Here genotypic ratio = phenotypic ratio = 1:2:1

Codominance and Multiple Alleles: When both alleles are equally expressed in heterozygous condition. Example: Blood groups in humans — IA and IB are both dominant (codominant), giving AB group.

Blood Group Inheritance:

Genotype	Blood Group
IAIA and IAio	A
IBIB and IBio	B
IAIB	AB
ioio	O

Lethal Genes: Genes that kill the individual when present in homozygous condition. Example: Yellow coat colour gene (y) in mice — yy condition is lethal.

Pleiotropy: One gene controls several phenotypes. Example: White eye gene in Drosophila (homozygous) also causes vestigeal wings and curled abdomen.

Polygenic (Quantitative) Inheritance: A trait controlled by many genes with equal additive/cumulative effect. Example: Human skin colour (3–4 genes), human height, wheat kernel colour. Results in continuous variation.

6. CHROMOSOMAL THEORY OF INHERITANCE

Proposed by **Sutton and Boveri in 1902.**

Key points:

- Somatic cells are diploid (2n); one set from mother, one from father
- Two chromosomes of same type = homologous pair; humans have 23 pairs
- Chromosomes separate during meiosis at gamete formation
- Genes are located linearly on chromosomes; chromosome = molecule of DNA; specific segments of DNA = genes

7. LINKAGE AND CROSSING OVER

Linkage: Genes present on the same chromosome tend to be inherited together. All such genes form a linkage group.

Discovered by Bateson and Punnett using sweet pea (Lathyrus sativus); got ratio 7:1:1:7 instead of expected 9:3:3:1.

Crossing Over: The physical exchange of parts of non-sister chromatids of chromosomes of a homologous pair. Occurs during Prophase I of Meiosis I. The point of crossing over = chiasma (plural: chiasmata). Linked genes get separated by crossing over, producing recombinants.

8. SEX DETERMINATION

In Humans:

- Female: XX (homogametic — produces only one type of egg containing X)
- Male: XY (heterogametic — produces two types of sperms, X and Y bearing)
- Egg + X sperm → Girl (XX)
- Egg + Y sperm → Boy (XY)
- Sex determination is purely a matter of chance; no parent can be blamed

In Birds (ZW-ZZ type):

- Male: ZZ (homogametic)
- Female: ZW (heterogametic — produces two types of eggs: A+Z and A+W)
- Opposite of humans — female is heterogametic

In Honey Bees (Haplodiploidy / Arrhenotoky):

- Fertilised eggs (diploid) → Females (worker bees and queen)
- Unfertilised eggs (haploid) → Males (drones)
- Males have no father and cannot have sons but have a grandfather and can have grandsons

9. CRIS-CROSS INHERITANCE (X-LINKED INHERITANCE)

Genes located on X chromosome are called sex-linked genes.

Pattern: Defective gene from father goes only to daughters; daughter (carrier) passes it to 50% of her sons.

Males suffer from the disease because Y chromosome has no corresponding gene to mask the faulty X gene. Females are usually only carriers (heterozygous).

Examples in humans:

- **Colour blindness:** Inability to distinguish red and green colours; X-linked recessive
- **Haemophilia (Bleeder's disease):** Blood does not clot easily; X-linked recessive; same inheritance pattern as colour blindness

10. MITOCHONDRIAL INHERITANCE

Mitochondria contain their own DNA. Since mitochondria enter the zygote from the egg (mother), inheritance of mitochondrial DNA is called maternal inheritance. Diseases due to defective mitochondrial DNA can be traced to the mother's family.

11. HUMAN KARYOTYPE

- Total chromosomes: 2n = 46 (23 pairs)
- Autosomes: 44 (22 pairs)
- Sex chromosomes: 2 (X and Y in male; XX in female)
- Chromosomes grouped into 7 groups A to G based on size, centromere location, and staining bands
- Normal male: 44 autosomes + XY
- Normal female: 44 autosomes + XX
- Presence of Y is necessary for maleness

12. GENETIC DISORDERS

1. Down's Syndrome (Mongolism):

- Chromosomes: 47 (Trisomy of chromosome 21)
- Features: Mentally retarded, thick tongue, drooping face
- Risk higher in mothers above age 40

2. Klinefelter's Syndrome:

- Chromosomes: 47 (44 autosomes + XXY)
- Features: Tall, mentally retarded, sterile male with breast development (gynaecomastia)

3. Turner's Syndrome:

- Chromosomes: 45 (44 autosomes + XO — only one X chromosome)
- Features: Mentally retarded female, web-like skin on neck, incompletely developed breasts

4. Colour Blindness:

- X-linked recessive; males affected; females carriers
- Affected males cannot distinguish between red and green colours

5. Haemophilia:

- X-linked recessive; same pattern as colour blindness
- Blood does not clot easily; patient may bleed to death

6. Thalassemia:

- Autosomal recessive disorder
- Normal haemoglobin not synthesised; requires frequent blood transfusions
- Both parents must carry defective gene for child to be affected

7. Sickle Cell Anaemia:

- Autosomal recessive; single gene mutation
- RBCs become sickle-shaped due to defective haemoglobin
- Homozygous (two defective genes) = cannot survive
- Heterozygous individuals are resistant to malaria (boon in disguise)

8. Rh Factor:

- Rh factor is an antigen (protein) on surface of RBCs
- Rh-negative mother + Rh-positive foetus → mother produces antibodies against foetal Rh antigen
- In first pregnancy: minor problems; in subsequent pregnancies: antibodies destroy foetal RBCs → severe anaemia (Erythroblastosis foetalis)
- Treatment: Rh-negative mother treated after delivery to destroy Rh antigens

13. AMNIOCENTESIS

A technique to detect hereditary disorders in the foetus.

Procedure:

1. Small sample of amniotic fluid withdrawn using syringe
2. Fluid contains cells shed from foetal skin
3. Foetal cells cultured
4. Chromosomes in dividing cells analysed for genetic defects

If incurable genetic defects detected, pregnancy can be terminated. It is illegal to use amniocentesis for detecting sex of the unborn.

14. HUMAN GENOME

- Genome = all genes of an organism on its haploid set of chromosomes
- Genomics = study of genome
- Human genome mapped in 2003 on 23(n) chromosomes
- Estimated 20,000–25,000 genes and 3 billion base pairs in total human DNA
- Only 1.5% of human genome has protein coding sequences

TOP 5 EXAM QUESTIONS FROM THIS CHAPTER (Most Frequently Asked)

Q1. State Mendel's three laws of inheritance. Which law is considered universal?

Answer:

Law 1 — Law of Segregation (Purity of Gametes): At gamete formation, the two factors of a pair separate into different gametes. Each gamete receives only one factor. This is the **universal law** — it applies to all sexually reproducing organisms without exception.

Law 2 — Law of Dominance: When two genes of a pair represent contrasting characters, one (dominant) expresses itself while the other (recessive) remains masked. Recessive expresses only in homozygous condition.

Law 3 — Law of Independent Assortment: Genes for two different features are passed to offspring independently of each other. Segregation of one pair of factors is independent of any other pair.

The Law of Segregation is considered universal.

Q2. What are genetic disorders? Describe Down's syndrome, Klinefelter's syndrome and Turner's syndrome.

Answer:

Any change in the normal number or structure of chromosomes causes genetic abnormalities called genetic disorders.

Down's Syndrome (Mongolism):

- Chromosomal constitution: 2n = 47 (Trisomy of chromosome 21)
- Features: Mentally retarded, thick tongue, drooping face; more common in children of mothers above 40

Klinefelter's Syndrome:

- Chromosomal constitution: 2n = 47 (44 autosomes + XXY)

- Features: Tall, mentally retarded male; sterile; shows breast development (gynaecomastia)

Turner's Syndrome:

- Chromosomal constitution: 2n = 45 (44 autosomes + XO — only one X)
- Features: Mentally retarded female; web-like skin on neck; incompletely developed breasts

Q3. Explain sex determination in humans and birds. How is it different?

Answer:

In Humans (XX-XY type):

- Female: XX (homogametic — produces only X eggs)
- Male: XY (heterogametic — produces X and Y sperms)
- Egg + X sperm → Girl; Egg + Y sperm → Boy
- Male determines the sex of the offspring; it is a matter of chance

In Birds (ZW-ZZ type):

- Male: ZZ (homogametic — produces only Z gametes)
- Female: ZW (heterogametic — produces Z and W eggs)
- Female determines the sex of the offspring

Key Difference: In humans, the male (XY) is heterogametic; in birds, the female (ZW) is heterogametic — the pattern is exactly reversed.

Q4. What is cris-cross (X-linked) inheritance? Explain with the example of colour blindness.

Answer: Cris-cross inheritance is the pattern where a recessive sex-linked character passes from father to daughter, and then from the daughter (carrier) to her sons. The defective gene is located on the X chromosome. Males suffer from the disease because the Y chromosome has no corresponding gene to mask the effect of the faulty gene. Females are usually carriers (heterozygous) because their second X chromosome masks the defective gene.

Colour Blindness:

- C = normal colour vision gene; c = colour blindness gene (recessive, X-linked)
- Carrier female (XXc) × Normal male (XY)
- Progeny: Normal daughter (XX), Normal son (XY), Carrier daughter (XXc), Colour blind son (XcY)
- 50% of sons will be colour blind

Males with a single defective X gene are affected; females need both X chromosomes to carry the defective gene to be affected.

Q5. Define incomplete dominance. Give an example and work out the cross. *(Asked in: 2016, 2018, 2019, 2020, 2021, 2022, 2023)*

Answer: Incomplete dominance is when neither allele is completely dominant over the other, and the heterozygous individual shows an intermediate phenotype between the two homozygous parents.

Example: Four O'clock plant (Mirabilis jalapa) and Snapdragon (Antirrhinum)

Cross:

Parents: RR (Red) × rr (White)

Gametes: R, R and r, r

F1: Rr → Pink (intermediate — neither red nor white)

F1 self: Rr × Rr

F2: 1 RR (Red) : 2 Rr (Pink) : 1 rr (White) → ratio 1:2:1

Here the genotypic ratio (1 RR : 2 Rr : 1 rr) and phenotypic ratio (1 Red : 2 Pink : 1 White) are the same — 1:2:1. This is different from Mendel's 3:1 ratio and is a deviation from the Law of Dominance.

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Molecular Inheritance & Gene Expression

1. ONE GENE ONE ENZYME HYPOTHESIS

- Proposed by **Beadle and Tatum** (worked on fungus *Neurospora*)
- Archibald Garrod first mentioned inherited disorders (phenylketonuria, alkaptonuria) caused by absent enzymes
- **One gene → One enzyme → One polypeptide**

2. DNA AS GENETIC MATERIAL

Griffith's Experiment (1928):

- S strain (Smooth) = Virulent (kills mice)
- R strain (Rough) = Non-virulent (harmless)
- Heat-killed S + Live R → Mouse DIES → **Bacterial Transformation**

Avery, McLeod & McCarty (1944):

- Extracted DNA from virulent S strain → mixed with R strain → R became virulent
- Proved DNA is the transforming principle

Hershey & Chase (1952):

- Used T2 bacteriophage
- ^{35}S (Sulphur) labelled protein → NOT found inside bacteria
- ^{32}P (Phosphorus) labelled DNA → FOUND inside bacteria
- Confirmed **DNA is the hereditary material**

3. STRUCTURE OF DNA

Nucleotide = Sugar + Base + Phosphate Nucleoside = Sugar + Base

Nitrogenous Bases:

- Purines: **Adenine (A), Guanine (G)**

- Pyrimidines: **Thymine (T), Cytosine (C)**

Chargaff's Rule: A = T and G = C (Purines = Pyrimidines)

Watson & Crick Double Helix Model (1953):

- Two antiparallel strands (5'→3' and 3'→5')
- Backbone = Sugar + Phosphate
- Bases linked by **Hydrogen bonds**
- A–T = **2 hydrogen bonds**
- G–C = **3 hydrogen bonds**
- One complete helical turn = **3.4 nm = 10 base pairs**
- Diameter = **2.0 nm**

DNA Packaging in Eukaryotes: DNA (2nm) → Nucleosome (11nm) → Solenoid (30nm) → Supercoil (300nm) → Chromosome (1400nm)

- DNA wraps around **Histone Octamer (8 proteins)** = Nucleosome
- Chromosome looks like **"string of beads"** under electron microscope

4. RNA vs DNA

DNA	RNA
Double stranded	Single stranded
Deoxyribose sugar	Ribose sugar
Thymine (T)	Uracil (U) - No Thymine
One function (hereditary)	mRNA, tRNA, rRNA
Self duplicates	Synthesized on DNA template

Types of RNA:

- **mRNA** = carries genetic code from DNA to ribosome
- **tRNA** = clover leaf shape, carries amino acids, has anticodon
- **rRNA** = component of ribosome, helps in protein synthesis

5. DNA TRANSFER IN BACTERIA

1. **Conjugation** = Direct cell-to-cell contact, plasmid transfers (F+ → F–), called horizontal gene transfer
2. **Transformation** = Extracellular DNA enters bacterial cell and recombines with genome
3. **Transduction** = DNA transfer through a bacteriophage (virus); involves lysogeny

6. DNA REPLICATION

Steps:

1. **Unwinding** → Enzyme **Helicase** separates strands; **Topoisomerase** keeps it open → forms **Replication Fork**
2. **Primer synthesis** → short RNA (5-10 bases) by enzyme **Primase**
3. **New strand synthesis** by **DNA Polymerase** (always 5'→3' direction)
    - **Leading strand** = synthesized continuously
    - **Lagging strand** = synthesized in pieces called **Okazaki fragments**
4. **Okazaki fragments joined** by enzyme **DNA Ligase** (needs ATP)
5. **DNA Proof Reading** → mistakes corrected at end

Key Features:

- **Semiconservative** = one old strand + one new strand (proven by Messelson & Stahl)
- **Semidiscontinuous** = one strand continuous, other in pieces

7. CENTRAL DOGMA

DNA → (Transcription) → RNA → (Translation) → Protein

In **Retroviruses** (RNA is genetic material): **RNA → (Reverse Transcription by Reverse Transcriptase) → DNA → mRNA → Protein**

8. GENETIC CODE

- Discovered by Nirenberg, Mathias and Ochoa
- **Triplet code** = 3 bases = 1 codon = 1 amino acid
- 4^3 = 64 codons for only 20 amino acids
- **Unambiguous** = one codon → only one amino acid
- **Degenerate** = more than one codon for same amino acid (Wobble hypothesis)

- **Commaless & Non-overlapping** = read continuously
- **AUG** = Start codon (codes for Methionine)
- **UAA, UAG, UGA** = Stop codons
- **Universal** = same for all organisms

9. TRANSCRIPTION

In Prokaryotes:

- Sigma factor → signals RNA Polymerase to start
- Rho factor → signals RNA Polymerase to stop
- Sense strand = transcribed; Antisense strand = not transcribed

In Eukaryotes:

- Large hnRNA synthesized first
- **Exons** = coding sequences; **Introns** = non-coding sequences
- Introns removed, exons joined → **RNA Processing**
- **5' Capping** = Methyl guanosine added at 5' end
- **Poly A tail** = Adenine nucleotides added at 3' end
- Processed mRNA exits through nuclear pores

10. TRANSLATION (Protein Synthesis)

Steps:

1. **Activation of amino acid** → by enzyme Aminoacyl-tRNA synthetase (needs ATP)
2. **Chain Initiation** → mRNA binds to small ribosomal subunit → methionine (AUG codon) enters A site
3. **Chain Elongation** → amino acids added by Peptidyl transferase enzyme; ribosome moves 3' direction
4. **Polysome Assembly** → multiple ribosomes on one mRNA
5. **Chain Termination** → stop codon reached → polypeptide released → ribosome dissociates

11. HOUSEKEEPING GENES

- Expressed in **ALL cells ALL the time** (needed for cell survival)
- **Inducible genes** = switched ON when substrate present

- **Repressible genes** = switched OFF when specific substance present

12. LAC OPERON (Gene Regulation in Prokaryotes)

- Discovered by **Jacob and Monod** (Nobel Prize)
- In *E. coli*, regulates lactose metabolism genes
- **Without lactose** → Regulator protein blocks operator (o) → genes z, y, a OFF
- **With lactose** → Lactose binds regulator protein → operator opens → RNA polymerase finds promoter → genes z, y, a ON → 3 enzymes (Galactosidase, Permease, Transacetylase) produced

13. MUTATION

Chromosomal Mutation:

- **Aneuploidy** = change in chromosome number (2n±1)
- **Polyploidy** = whole set duplicated (3n, 4n)
- **Chromosomal Aberration:** Deletion, Inversion, Duplication, Translocation

Gene/Point Mutation:

Type	Description
Transition	Purine→Purine OR Pyrimidine→Pyrimidine
Transversion	Purine→Pyrimidine OR Pyrimidine→Purine
Frameshift	Addition/deletion of nucleotide → whole reading frame changes
Missense	Different amino acid produced (e.g., Sickle cell Haemoglobin)
Nonsense	Stop codon formed midway → no protein
Silent	No phenotypic change (same amino acid still coded)

Mutagens:

- Radiations: X-ray, UV rays, Alpha radiations
- Chemical: Mustard gas, Actinomycin D

SECTION A: TOP 5 MOST IMPORTANT QUESTIONS FROM THIS CHAPTER

Q1. Describe the Watson and Crick Model of DNA double helix.

Answer: Watson and Crick proposed the double helix model in 1953 (Nobel Prize). Key features:

- DNA is a **double helix** made of two antiparallel strands (5'→3' and 3'→5')
- Backbone = **Sugar + Phosphate**; bases face inward
- Bases joined by **hydrogen bonds**: A=T (2 bonds), G≡C (3 bonds)
- A and T are complementary; G and C are complementary (**Chargaff's Rule**)
- One helical turn = **3.4 nm** enclosing **10 base pairs**
- Distance between base pairs = **0.34 nm**
- Diameter = **2.0 nm**
- Model explains how strands separate during replication and transcription

Q2. How did Hershey and Chase prove DNA is the hereditary material?

Answer: Hershey and Chase (1952) used T2 bacteriophage:

- **Experiment 1:** Labelled protein coat with **^{35}S (radioactive Sulphur)** → introduced into bacteria → NO radioactivity found inside bacteria (protein coat left outside)
- **Experiment 2:** Labelled DNA with **^{32}P (radioactive Phosphorus)** → introduced into bacteria → radioactivity FOUND inside bacteria
- New virus generations formed inside bacteria only because of **viral DNA**
- **Conclusion:** DNA is the genetic/hereditary material

Q3. Explain DNA Replication with steps. What is meant by semiconservative replication?

Answer: Steps of Replication:

1. **Unwinding:** Enzyme **Helicase** unwinds double helix → forms Replication Fork; **Topoisomerase** keeps it open
2. **Primer Formation:** Short RNA primer (5-10 bases) formed by enzyme **Primase**
3. **New strand synthesis: DNA Polymerase** adds complementary bases in 5'→3' direction
    - Leading strand = continuous synthesis
    - Lagging strand = discontinuous (Okazaki fragments)
4. **Joining: DNA Ligase** joins Okazaki fragments using ATP energy
5. **Proof Reading:** Errors corrected

Semiconservative: In each new DNA molecule, ONE strand is original (parental) and ONE strand is newly synthesized. Proven by **Messelson and Stahl**

Q4. What is Central Dogma? Explain Transcription and Translation briefly.

Answer: Central Dogma = Transfer of information from DNA → RNA → Protein

Transcription:

- DNA unwinds; RNA Polymerase synthesizes mRNA complementary to sense strand
- In eukaryotes: hnRNA formed → introns removed, exons joined → 5' cap + Poly A tail added → mature mRNA exits nucleus

Translation:

- mRNA attaches to ribosome
- tRNA brings specific amino acid (activated by Aminoacyl-tRNA synthetase)
- Amino acids joined by **Peptidyl transferase**
- Chain starts at **AUG (start codon)** and ends at **UAA/UAG/UGA (stop codons)**
- Final polypeptide = Protein

SECTION B: TOP 5 REPEATED PYQ-STYLE QUESTIONS

PYQ 1. What is Chargaff's Rule? What is its significance in DNA structure?

Answer: Chargaff's Rule states:

- Amount of **Adenine (A) always equals Thymine (T)** → A = T
- Amount of **Guanine (G) always equals Cytosine (C)** → G = C
- Total Purines (A+G) = Total Pyrimidines (T+C)

Significance:

- Explains specific base pairing in double helix
- Forms the molecular basis of complementary strand synthesis during replication
- Explains why DNA can copy itself accurately
- Supports Watson and Crick model

PYQ 2. Differentiate between Leading strand and Lagging strand in DNA Replication.

Answer:

Leading Strand	Lagging Strand
Synthesized continuously	Synthesized discontinuously
Moves in 5'→3' direction toward replication fork	Moves away from replication fork
No Okazaki fragments	Made of Okazaki fragments
Synthesis is uninterrupted	Fragments joined by DNA Ligase
One primer needed	Multiple primers needed

PYQ 3. What are Okazaki fragments? Which enzyme joins them?

Answer:

- During DNA replication, the lagging strand cannot be synthesized continuously because DNA polymerase works only in 5'→3' direction
- Short pieces of DNA are synthesized in the opposite direction → these small pieces are called Okazaki fragments
- These fragments are later joined together by the enzyme DNA Ligase in the presence of energy source ATP
- This makes replication semidiscontinuous

PYQ 4. Write the differences between mRNA, tRNA and rRNA.

Answer:

Feature	mRNA	tRNA	rRNA
Full Name	Messenger RNA	Transfer RNA	Ribosomal RNA
Structure	Linear strand	Clover leaf shape	Component of ribosome
Function	Carries genetic code from DNA to ribosome	Transfers amino acids to ribosome	Structural & functional part of ribosome
Special Feature	Has codons	Has anticodon loop	Largest amount of RNA in cell
Location	Nucleus → Cytoplasm	Cytoplasm	Ribosome

PYQ 5. What is Mutation? Explain Transition, Transversion and Frameshift mutations with examples.

Answer: Mutation = A heritable change in the structure, content or organization of genetic material that is passed to next generation

Types:

Transition:

- Purine replaced by another Purine OR Pyrimidine by Pyrimidine
- Example: ATGCATGC → A**G**GCAGGC (A replaced by G)

Transversion:

- Purine replaced by Pyrimidine OR Pyrimidine by Purine
- Example: ATGCATGC → ATG**T**ATGC (C replaced by T)

Frameshift:

- Loss or gain of one nucleotide → entire reading frame of genetic code shifts
- Example: CAT CAT CAT CAT → CAT ATC ATC ATC (when one C is lost)
- Most harmful type as entire protein sequence changes

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Principles of Ecology

1. ENVIRONMENT, ECOLOGY & BIOSPHERE

Environment = All physical, chemical and biotic conditions surrounding and influencing a living organism

Two Components of Environment:

- **Abiotic (Non-living)** = Temperature, light, pressure, humidity, precipitation, wind, minerals, air composition
- **Biotic (Living)** = Plants, animals, microorganisms

Ecology = Scientific study of relationship and interactions between organisms and their environment (Greek: "oikos" = household + "logos" = study of)

Levels of Organization: Genes → Cell → Organ → Organism → Population → Community → Ecosystem → Biome → Biosphere

Three Physical Components of Earth: Atmosphere, Lithosphere, Hydrosphere

Ecosphere = Biosphere + Lithosphere + Hydrosphere + Atmosphere

2. HABITAT & NICHE

Habitat = Physical environment where an organism lives = its "ADDRESS" Four structural components of habitat: Space, Food, Water, Cover/Shelter

Four major habitats on Earth: Terrestrial, Freshwater, Estuarine, Oceanic

Niche = Functional role of a species in its habitat = its "PROFESSION"

- Niche = sum of all activities and relationships of a species for survival and reproduction
- No two species can occupy the same niche (they will compete until one is displaced)
- Many species can share the same habitat but each has a unique niche

Adaptation = Appearance/behaviour/structure/mode of life that allows an organism to survive in a particular environment. Has a genetic basis.

3. POPULATION

Population = Group of freely interbreeding individuals of the same species present in a specific geographical area at a given time

Characteristics of Population:

- Density (no. of individuals per unit area)
- **Natality** = birth rate (births per thousand per year)
- **Mortality** = death rate (deaths per thousand per year)
- **Immigration** = movement INTO an area (+)
- **Emigration** = movement OUT of an area (-)
- Age distribution, Sex ratio, Biotic potential

Age Groups:

- Pre-reproductive (juveniles)
- Reproductive (capable of reproduction)
- Post-reproductive (aged, cannot reproduce)

Population Growth Curves:

- **J-shaped curve** = Exponential growth, rapid increase, then sudden crash (e.g., insects in monsoon)
- **S-shaped (Sigmoid) curve** = Lag phase → Growth phase → Stable/Plateau phase (Natality = Mortality)

Density depends on: Natality (+), Immigration (+), Mortality (-), Emigration (-)

4. ECOSYSTEM

Ecosystem = Functionally independent unit of nature where living organisms interact among themselves AND with their physical environment

Types:

- Natural: Forests, deserts, grasslands, ponds, lakes
- Man-made: Crop lands, aquarium

Components of Pond Ecosystem:

Abiotic: Light, temperature, inorganic substances (water, carbon, nitrogen, phosphorus), organic compounds

Biotic:

- **Producers/Autotrophs** = Phytoplankton (Spirogyra, Ulothrix, diatoms, Volvox), Rooted plants (Hydrilla, Chara)

- **Consumers/Heterotrophs** = insect larvae, tadpole, snails, sunfish, bass
- **Decomposers** = Bacteria, fungi (most abundant in sediment at bottom)

5. FOOD CHAIN & FOOD WEB

Food Chain = Transfer of food from plants (producers) through a series of organisms with repeated eating and being eaten

Example: Grasses → Grasshopper → Frogs → Snakes → Hawk/Eagle (1st trophic) (2nd trophic) (3rd trophic) (4th trophic) (5th trophic)

Trophic Levels:

- 1st = Producers (Plants/Autotrophs) — GPP and NPP
- 2nd = Primary consumers (Herbivores) — "Key Industry"
- 3rd = Secondary consumers (Carnivores)
- 4th = Tertiary consumers (Top carnivores)
- Final = Decomposers (bacteria, fungi, earthworms)

GPP = NPP + R (Respiration) or GPP - R = NPP

Position of Humans:

- Vegetarians = Primary consumers
- Eat small fish/chicken/goat = Secondary consumers
- Eat big fishes = Tertiary consumers

Food Web = Network of interconnected food chains at various trophic levels

Special Consumers: Scavengers (eat dead), Omnivores (plants + animals), Parasites (live on host)

6. ENERGY FLOW

- Energy enters as **solar radiation** → converted to food by producers
- Energy flow is always **linear (one-way)**
- Energy **decreases** at each successive trophic level
- Two reasons for energy loss: (1) Lost as heat (not utilized) (2) Used in respiration for own metabolism
- **10% Law** = Only 10% of energy is transferred to next trophic level

- 10,000 kcal → 1,000 kcal → 100 kcal → 10 kcal

- Maximum **4-5 steps** in a food chain

7. ECOLOGICAL PYRAMIDS

Standing crop = Amount of biomass or energy present at different trophic levels at any given time

Three types of Ecological Pyramids:

- **Pyramid of Numbers** = based on number of individuals
- **Pyramid of Biomass** = based on biomass (gm^{-2})
- **Pyramid of Energy** = based on energy flow (Kcal m^{-2} yr^{-1})

Producers at BASE → successive trophic levels as tiers → pyramidal shape

8. BIOTIC INTERACTIONS

Type	Effect	Example
Amensalism	One harmed, other unaffected	Penicillium vs bacteria
Predation	Predator benefits, prey harmed	Lion-deer
Parasitism	Parasite benefits, host harmed	Cuscuta on plants, tapeworm in human
Competition	Both harmed	Two species competing for food
Commensalism	One benefits, other neutral	Remora fish on shark
Mutualism	Both benefit	Sea anemone + hermit crab
Neutralism	Neither affected	—
Symbiosis	Extreme mutualism, cannot survive without each other	Termite + flagellates, Bee + flowers

Intraspecific = Same species interaction **Interspecific** = Different species interaction

9. BIOMES

Biome = Large ecosystem characterized by specific flora and fauna

Terrestrial Biomes:

Permafrost = Permanently frozen subsoil in Arctic Tundra

Biome	Rainfall	Temperature	Key Flora	Key Fauna
Tropical Rainforest	>200 cm/yr	Very high	Bamboos, ferns, epiphytes, lianas	Flying frog, chameleon, monkeys leopards
Temperate Deciduous	75-150 cm	10-20°C	Oak, birch, chestnut	Deer, bison, wild cat, wolves
Coniferous (Taiga/Boreal)	Low	Below 0°C	Spruce, fir, pine	Deer, moose, lynx, wolverine
Grassland (Savanna)	Moderate	Variable	Grasses, scattered trees	Zebra, bison, antelope, coyotes
Desert	<25 cm/yr	Very high/low	Cacti, Acacia, Euphorbia	Camel, reptiles, rodents
Tundra	<400 mm/yr	-57°C to 15°C	Cotton grass, sedges, lichens	Reindeer, musk ox, caribou

Aquatic Biomes:

- Freshwater: Standing (Lentic) - ponds, lakes; Running (Lotic) - streams, rivers
- Marine: Covers 71% of earth; Salinity 3.6%; study = Limnology (freshwater)
- **Ecotone** = Transitional zone between two ecosystems (e.g., wetlands)

10. ECOLOGICAL SUCCESSION

Ecological Succession = Process by which communities of plant and animal species in an area are replaced by another over a period of time

Two Types:

- **Primary Succession** = Bare/unoccupied area (rock, lava flow, sand dune) → Pioneer species → Seral communities → Climax community (slow process)
- **Secondary Succession** = Existing vegetation destroyed (fire, hurricane, tilling) → Recovery from soil (faster process)

Key Terms:

- **Pioneer species** = First organisms to invade bare land
- **Pioneer community** = Assemblage of pioneer plants
- **Seral community** = Transitional/temporary communities
- **Climax community** = Final stable, mature, long-lasting community
- **Sere** = Entire sequence of communities during succession
- **Xerarch** = Succession on bare rock (low moisture)
- **Hydrarch** = Succession in water bodies

Primary succession sequence on rock: Bare Rock → Lichens → Small annual plants → Perennial herbs/grasses → Shrubs + shade-intolerant trees → Shade-tolerant trees (Climax)

11. BIOGEOCHEMICAL CYCLES

Biogeochemical Cycle = Cycling of nutrients in the biosphere involving movement through various components of ecosystem

A. Carbon Cycle: Processes: Photosynthesis, Respiration, Decomposition, Combustion

- Plants fix CO_2 → Photosynthesis → stored as biomass
- Organisms release CO_2 → Respiration
- Decomposers release CO_2 → Decomposition
- Burning fossil fuels → Combustion releases CO_2
- Human activities (industrialization, automobiles) → increasing CO_2 → **Greenhouse effect & Global Warming**

B. Water Cycle (Hydrologic Cycle): Processes: Evaporation, Condensation, Precipitation

- Driving forces: Solar radiation + Earth's gravitational pull
- 97.3% water in oceans, 2.1% in polar ice caps, only 0.6% fresh water available
- 84% water lost from ocean by evaporation; 77% gained by precipitation

C. Phosphorus Cycle:

- Reservoir = Rocks and geological deposits
- Erosion releases phosphates → Plants absorb as orthophosphate ions → Animals eat plants → Decomposers return phosphorus → cycle continues

- Sea birds return phosphorus via **guano deposits**
- Human activities hasten loss of phosphorus

SECTION A: TOP 5 MOST IMPORTANT QUESTIONS FROM THIS CHAPTER

Q1. Define ecosystem. Describe the structure and components of a pond ecosystem.

Answer: Ecosystem is a functionally independent unit of nature where living organisms interact among themselves as well as with their physical environment.

Pond Ecosystem Components:

Abiotic Components:

- Light, temperature, inorganic substances (water, carbon, nitrogen, phosphorus, O2, CO2), organic compounds (amino acids, humic acids)

Biotic Components:

- Producers: Phytoplankton (Spirogyra, Ulothrix, diatoms) and Rooted plants (Hydrilla, Chara)
- Consumers: insect larvae, tadpoles, snails (primary); sunfish, bass (secondary)
- Decomposers: bacteria and microbes (most abundant in sediment at bottom)

The pond receives solar radiation. Sun's light penetrates shallow water. Sediment at bottom provides nutrition. All these components interact to make a self-sustaining unit.

Q2. What is a food chain? Explain the various trophic levels with examples. What is the 10% law?

Answer: Transfer of food from plants (producers) through a series of organisms with repeated eating and being eaten is called a food chain.

Example: Grasses → Grasshopper → Frogs → Snakes → Hawk/Eagle

Trophic levels:

- 1st (Producers/Autotrophs): Green plants; convert sunlight into food via photosynthesis; GPP = NPP + R
- 2nd (Primary consumers/Herbivores): Feed directly on plants; e.g., grasshopper, cow; called "Key Industry"
- 3rd (Secondary consumers/Carnivores): Feed on herbivores; e.g., frog, snake
- 4th (Tertiary consumers): Top carnivores; e.g., hawk, lion, humans
- Final (Decomposers): Feed on dead organic matter; bacteria, fungi, earthworms; recycle nutrients

10% Law: Only 10% of energy entering a trophic level is transferred to the next higher trophic level. Rest is lost as heat or used in respiration. Hence only 4-5 steps are possible in a food chain.

Q3. Explain any three biotic interactions with examples.

Answer:

Predation: Predator captures, kills and eats prey. Predator benefits, prey is harmed. Example: Lion killing a deer. Predators like leopards and cheetahs use speed, teeth and claws.

Parasitism: Parasite lives on/in host and gets nourishment from it. Parasite benefits, host is harmed. Example: Cuscuta (dodder) on flowering plants, tapeworm in human intestine, malarial parasite.

Mutualism: Both species benefit from the interaction. Example: Sea anemone attaches to hermit crab shell — crab gets camouflage and protection, anemone gets transport and new food. Symbiosis is extreme mutualism where species cannot survive without each other (e.g., termite + flagellates).

Commensalism: One species benefits, other is neither harmed nor benefited. Example: Remora fish attaches to shark — gets protection and food scraps; shark gets no benefit and no harm.

Q4. Describe the Carbon cycle. How do human activities affect it?

Answer: Atmospheric CO_2 is the source of all carbon in living organisms. Carbon cycle involves four main processes:

Photosynthesis: Plants absorb CO_2 and convert it into organic matter (food) using sunlight and chlorophyll. Carbon is fixed and stored as plant biomass.

Respiration: Food is oxidized to release energy; CO_2 and water are released back to atmosphere. Reverse of photosynthesis.

Decomposition: After death of organisms, decomposers break down dead organic matter and release remaining carbon back to atmosphere.

Combustion: Burning of fossil fuels (coal, crude oil, natural gas) releases CO_2 and CO into atmosphere. Forests release CO_2 through forest fires.

Human Impact: Industrialization, urbanization and increased use of automobiles continuously increase CO_2 in atmosphere. This leads to Greenhouse effect and Global Warming.

Q5. Distinguish between Primary and Secondary Succession. What are pioneer species and climax community?

Answer:

Primary Succession	Secondary Succession
Occurs on bare/unoccupied areas	Occurs where existing community is destroyed

Examples: bare rock, lava flow, sand dune	Examples: after forest fire, flood, tilling
No soil initially present	Soil with nutrients already present
Very slow process	Relatively faster process
Starts with pioneer species (lichens)	Starts with annual weeds, grasses

Pioneer species: Plants that invade bare land where soil is initially absent for the first time. They have high growth rate but short life span (e.g., lichens on bare rock).

Climax community: The terminal/final stage of succession. It is stable, mature, more complex and long lasting. It remains stable in dynamic equilibrium with prevailing climate and habitat factors.

Seral community = temporary communities during succession **Sere** = entire sequence of communities during succession

SECTION B: TOP 5 REPEATED PYQ-STYLE QUESTIONS

PYQ 1. Differentiate between habitat and niche. Give examples. *(Repeatedly asked: Most years in short answer section)*

Answer:

Habitat	Niche
Physical environment where organism lives	Functional role of organism in its habitat
Called the "Address" of organism	Called the "Profession" of organism
Many species can share the same habitat	Each species has a unique niche
Example: Forest, ocean, pond	Example: A grasshopper feeding on grass leaves in grassland
Defined by physical location	Defined by activities, food, relationships

PYQ 2. What are ecological pyramids? Explain pyramid of numbers, biomass and energy. *(Comes almost every year in 3-5 mark questions)*

Answer: Standing crop = amount of biomass or energy present at different trophic levels at any given time.

The graphical representation of standing crop is called an **ecological pyramid** with producers at the base and successive trophic levels as tiers above.

Three types:

Pyramid of Numbers: Represents number of organisms at each trophic level. Producers (1,500,000) → Herbivores (2,00,000) → Carnivores (90,000). Generally upright pyramid.

Pyramid of Biomass: Represents total biomass (dry weight) at each trophic level. Expressed in gm^{-2}. Usually upright in terrestrial ecosystems.

Pyramid of Energy: Represents total energy fixed at each trophic level. Expressed in Kcal m^{-2} yr^{-1}. Always upright — never inverted. This is the most accurate representation of an ecosystem.

All three collectively = **Ecological pyramids.**

PYQ 3. Write short notes on J-shaped and S-shaped population growth curves. *(Repeated in MCQ and short answer sections, almost every exam)*

Answer:

J-shaped Growth Curve:

- Exponential/geometric growth — population doubles at regular intervals
- Occurs when resources are abundant
- Population increases rapidly then suddenly crashes due to environmental factors
- Typical of insects (e.g., insect population explosion in monsoon, then sudden disappearance)
- No stable plateau stage

S-shaped (Sigmoid) Growth Curve:

- Has three phases: Lag phase → Growth phase → Stable/Plateau phase
- Lag phase: Few organisms in new area, slow reproduction
- Growth phase: Rapid increase as food is plenty and no competition
- Plateau phase: Food or nutrients become limiting; Natality = Mortality; population stabilizes
- Human population follows this type of curve
- More realistic representation of population growth in nature

PYQ 4. Describe the water cycle (hydrological cycle). Name the main processes involved.

Answer: Water cycle is also called the **hydrological cycle**. It is the continuous movement of water through different compartments.

Key facts:

- 97.3% water in oceans, 2.1% in polar ice caps, only 0.6% available as fresh water
- Main driving forces: Solar radiation and Earth's gravitational pull

Main Processes:

Evaporation: Water from oceans, lakes, ponds, rivers, soil surface evaporates by sun's heat. Plants transpire water through leaves (transpiration).

Condensation: Water vapour in air forms clouds. Clouds drift with wind and meet cold air in mountainous regions and condense.

Precipitation: Condensed water falls as rain due to gravity, back to earth.

Surface run-off and groundwater → streams and rivers → back to oceans.

On average: 84% water lost from oceans by evaporation; 77% gained by precipitation; remaining 7% balanced by river run-off from land.

PYQ 5. What are biomes? Compare any two terrestrial biomes on the basis of climate, flora and fauna. *(Comparison questions between biomes come regularly)*

Answer: A **biome** is a large ecosystem characterized by uniform life form of vegetation and specific flora and fauna.

Comparison: Tropical Rain Forest vs Tundra

Feature	Tropical Rain Forest	Tundra
Rainfall	>200 cm/year	<400 mm/year
Temperature	Very high	-57°C to 15°C (very low)
Soil	Rich in humus	Permafrost (permanently frozen subsoil)
Productivity	Highest	Very low
Flora	Tall evergreen trees (200 ft), bamboos, ferns, epiphytes, lianas	Cotton grass, sedges, lichens, dwarf heath
Fauna	Flying frog, chameleon, monkeys, leopards, sloths	Reindeer, musk ox, arctic hare, lemmings
Location	Western coast of India, NE Himalayas, SE Asia, West Africa	Arctic regions of Canada, Alaska, Siberia

16

Nutrition and Health

1. WHAT IS FOOD

Food = Any substance which:

- Yields energy for life processes
- Builds up new cells during growth
- Repairs worn out (damaged) tissues
- Aids in production of useful body compounds

Three Biological Categories of Food:

Food Group	Major Nutrients	Examples
Energy providing	Carbohydrates + Fats	Cereals, sugar, fats, oils, jaggery, groundnuts
Body building	Proteins	Milk, legumes, egg, meat, fish, pulses
Protective/Regulatory	Minerals + Vitamins	Green leafy vegetables, fruits, amla, guava, citrus

2. NUTRITION & NUTRIENTS

Nutrition = Sum of processes by which an organism takes in, metabolises and utilises food substances for various biochemical activities

Nutrients = Organic or inorganic substances that help in survival and maintaining proper health

Two Categories based on quantity required:

Macronutrients (required in large amounts) = Carbohydrates, Fats, Proteins, Water

Micronutrients (required in small amounts) = Vitamins and Minerals

3. CARBOHYDRATES

- Made of Carbon, Hydrogen, Oxygen
- Cheapest source of energy
- 1 gram carbohydrate = **18 kJ (4 kcal)** of energy

- Provide **60-80%** of total energy required
- Normal person needs **400-500 grams** daily

Types:

- **Sugars:** Monosaccharides (Glucose, Fructose) + Disaccharides (Sucrose in sugarcane, Maltose in sprouted cereals, Lactose in milk)
- **Starch:** Storage form of carbohydrates (cereals, potato, rice, wheat)
- **Cellulose:** Not digested by humans; acts as roughage

Key formulas:

- 1 kilocalorie = 4.18 kJ
- 1 molecule of glucose yields **38 ATP molecules**
- 1 mole glucose = **1292 kJ**

Functions:

- Lactose promotes growth of intestinal bacteria → helps calcium absorption
- Excess converted to glycogen (stored in liver) and fat
- Cellulose provides faecal bulk → helps bowel movement
- Glucose = only energy source for central nervous system

4. FATS

- Made of Carbon, Hydrogen, Oxygen (more C and H, less O than carbohydrates)
- **Richest source of energy**
- Chemically = **Triglycerides**
- 1 gram fat = **9 kcal (37 kJ)** of energy
- Insoluble in water, soluble in acetone and benzene

Sources:

- Animal: Ghee, butter, fish oil, meat, egg
- Plant: Coconut, mustard, sunflower, safflower oils, nuts, soyabean, cheese

Functions:

- Richest source of energy (37 kJ/g)
- Structural component of cell membrane and cytoplasm
- Help absorption of fat-soluble vitamins A, D, E, K
- Precursor of hormones
- Sub-cutaneous fat = insulator against cold
- Stored fat protects vital organs from shock
- Help synthesis of Vitamin D and steroid hormones

5. PROTEINS

- Large molecules made of amino acids
- Rich in Carbon, Hydrogen, Oxygen, Nitrogen (sometimes Phosphorus and Sulphur)
- 1 gram protein = **4 kcal** of energy
- Only **22 amino acids** make all proteins

Two types of amino acids:

- **Essential amino acids** = Cannot be synthesised in body; must be supplied through food (e.g., leucine)
- **Non-essential amino acids** = Can be synthesised in body (e.g., alanine)

Sources:

- **Animal:** Milk, egg, fish, bean, meat, liver (contain all essential amino acids)
- **Plant:** Whole cereals, pulses, nuts, grams, legumes

Functions:

- Building and maintaining body tissues
- All enzymes are proteins (Trypsin, Pepsin, Rennin)
- Hormones — Insulin regulates blood glucose
- Antibodies — protect from antigens
- Transport proteins — Haemoglobin carries oxygen

Key protein examples: Keratin (hair, nails), Collagen (connective tissue), Actin and Myosin (muscles)

6. VITAMINS

- Complex chemical substances required in very small amounts
- Do NOT yield energy but act as **biocatalysts**
- Cannot be made in body **except Vitamin D**

Two classes:

- **Water soluble** = Vitamin B complex and C
- **Fat soluble** = Vitamins A, D, E, K

Important Vitamin Table:

Vitamin	Deficiency Disease	Key Source	Symptoms
B1 (Thiamine)	Beri-beri	Yeast, liver, whole grain cereals	Pain in hands/feet, swelling, paralysis of limbs, Oedema
B2 (Riboflavin)	Riboflavinosis, Photophobia	Milk, liver, eggs, whole grains	Retarded growth, cracking of skin at corners of mouth, eye
B3 (Niacin)	Pellagra	Fish, eggs, legumes, peanuts	Dermatitis (skin), Diarrhoea, Dementia (3Ds)
B12 (Cyanocobalamine)	Pernicious anaemia	Liver, fish, cheese, milk, eggs	Paleness, breathlessness, retarded growth
C (Ascorbic acid)	Scurvy	Amla, lemon, orange, guava, chillies	Bleeding gums, pain in joints, general weakness
A (Retinol)	Night blindness, Xerophthalm	Milk, butter, eggs, carrots, mangoes, papaya	Cannot see in dim light, dry skin
D (Calciferol)	Rickets (children), Osteomalac (adults)	Milk, egg yolk, cod liver oil, sunlight	Bow legs, pigeon chest, softening of bones, spontaneous
E (Tocopherol)	Reproduction failure	Grains, vegetable oil, green leafy vegetables	Sterility in males, miscarriage in females

K (Phylloquinone)	Faulty blood clotting, Haemorrhage	Green leafy vegetables, so tomatoes	Delayed blood clotting

7. MINERALS

- Inorganic elements required in varying amounts
- Do NOT supply energy but essential for protection against diseases

Required in larger amounts: Calcium, Phosphorus, Sodium, Potassium, Sulphur, Chloride, Magnesium

Required in trace amounts: Iron, Iodine, Zinc, Chromium, Cobalt, Copper, Fluoride, Manganese, Molybdenum, Selenium, Boron

Key Minerals:

Mineral	Function	Deficiency Disease	Source
Calcium	Bone and teeth formation, nerve function	Rickets, Osteomalacia	Milk, fish, green leafy vegetables
Iron	Haemoglobin formation, oxygen carrier	Anaemia	Liver, green leafy vegetables, eggs, jaggery
Phosphorus	Bone and teeth formation	Rickets, Osteomalacia	Milk, cereals, nuts, meat
Iodine	Synthesis of thyroxine hormone	Goitre, Cretinism	Iodised salt, sea food, fish
Sodium + Potassium	Water balance, nerve impulse conduction	High BP, Oedema	Common salt, meat, fruits, cereals

8. WATER & ROUGHAGE

Water:

- 75% of infant body, 60% of adult body is water
- Functions: transport and digestion, excretion of wastes, maintains body temperature, acts as solvent
- Sources: Drinking water, fruits, vegetables, by-product of glucose oxidation

Roughage:

- Fibre present in fruits and vegetables (mainly cellulose)

- Not digested but essential for diet
- Functions: helps bowel movement, cleans digestive tract, prevents constipation, retains water, maintains blood sugar and cholesterol levels

9. ENERGY REQUIREMENTS

Group	Required Calories
Infants (0-12 months)	100-120/kg body weight
Children (2-6 years)	1200-1800
Children (7-12 years)	1800-2000
Adolescent Boys (13-15 yr)	2500
Adolescent Girls (13-15 yr)	2200
Adult Man (Sedentary)	2400
Adult Man (Moderate work)	2800
Adult Man (Heavy work)	4000
Woman (Moderately active)	2400
Pregnant woman	3300
Lactating mother	3700

Who needs MORE energy: Growing children, labourers, pregnant women, lactating mothers, sportsmen, persons recovering from illness, persons working in cold weather

10. BALANCED DIET

Balanced diet = Diet that contains all essential nutrients in suitable proportion and amount to provide necessary energy and keeps body in healthy state

Qualities of balanced diet:

- Meets nutrient requirement of body
- Consists of different types of food items
- Provides adequate amount of energy

Special nutritional needs:

- **Growing children** = Extra protein, more calcium + phosphorus, Vitamin A (eyesight), Vitamin C (general health), Vitamin D (bones)
- **Hard workers/athletes** = Rich in carbohydrates and fats (energy)
- **Pregnant and lactating mothers** = Extra protein, more calcium + phosphorus (baby's bones), more iron (baby's blood), more carbohydrates (energy)
- **Recovering from illness** = More proteins, minerals, vitamins

11. HEALTH AND DISEASE

Health (WHO) = State of complete physical, mental, and social well-being and NOT merely absence of disease or infirmity

Disease = Malfunctioning process in which normal body functions are disturbed or damaged (dis = not at ease)

Deficiency diseases = Diseases occurring due to deficiency of one or more nutrients

Malnutrition = Condition resulting from lack of nutrients in diet

Three types of deficiency diseases:

- Protein Energy Malnutrition (PEM)
- Mineral deficiency diseases
- Vitamin deficiency diseases

12. PROTEIN ENERGY MALNUTRITION (PEM)

Affects children aged **1-5 years**. Two causes: (a) Lack of proteins or carbohydrates or both (b) More carbohydrates than proteins

Two diseases due to PEM:

Marasmus:

- Caused by deficiency of carbohydrates, fats AND proteins
- Affects infants below **1 year**
- Symptoms: wasting of muscles (skin and bones), folded skin, sunken eyes, thin face, retarded growth, pigeon chest, NO oedema

Kwashiorkor:

- Caused when mother stops breastfeeding and gives low-protein family food
- Affects children **1-5 years**

- Symptoms: underweight, protruding belly, dark scaly skin, enlarged liver, anaemia, repeated diarrhoea, stunted growth, reddish hair, oedema (swelling of legs and feet)

Cure for both: Adequate protein and carbohydrate rich food

13. OBESITY AND HYPERVITAMINOSIS

Obesity = Overweight and bulkiness due to accumulation of carbohydrates and fats

Causes: Overeating, insufficient exercise, hormonal imbalance (deficiency of thyroxine)

Harmful effects: Hypertension (high BP), atherosclerosis, coronary attack (heart attack), diabetes, respiratory problems

Prevention: Avoid fried food, reduce carbohydrates and saturated fats, take regular exercise, eat green leafy vegetables

Hypervitaminosis = Disease caused by vitamins in excessive quantities

- Excess water soluble vitamins (B, C) = harmless (excreted in urine)
- Excess **fat soluble vitamins A and D** = TOXIC

Hypervitaminosis A: Loss of hair, drowsiness, painful swelling of long bones, loss of appetite, nausea

Hypervitaminosis D: Calcium deposits in soft tissues (kidney), drowsiness, nausea, loss of weight

Hemosiderosis = Excessive iron intake → large deposits in liver → constipation, diarrhoea, nausea, heart burn

SECTION A: TOP 5 MOST IMPORTANT QUESTIONS FROM THIS CHAPTER

Q1. Differentiate between Marasmus and Kwashiorkor.

Answer:

Feature	Marasmus	Kwashiorkor
Cause	Deficiency of carbohydrates, fats AND proteins	Deficiency mainly of proteins (low protein diet)
Age affected	Infants below 1 year	Children 1-5 years
Muscles	Complete wasting (skin and bones)	Thin but some fat present
Skin	Folded skin	Dark, scaly skin
Face	Sunken eyes, thin face ("old man's face")	Moon face
Abdomen	Thinning of abdominal walls	Protruding belly (swollen abdomen)

Oedema	Absent	Present (swelling of legs/feet)
Hair	No change	Reddish, colour changes
Liver	Normal	Enlarged liver
Other	Pigeon chest	Anaemia, repeated diarrhoea

Q2. Write the sources, functions and deficiency diseases of Vitamins A, C and D.

Answer:

Vitamin A (Retinol):

- Sources: Milk, butter, eggs, cod liver oil, carrots, mangoes, papaya, yellow pumpkin, spinach, sweet potato
- Function: Maintenance of vision and skin; essential for synthesis of visual pigment
- Deficiency disease: Night blindness, Xerophthalmia (dry eyes), keratinization of epithelia
- Symptoms: Cannot see in dim light, dry skin, retarded keratinization

Vitamin C (Ascorbic Acid):

- Sources: Amla, cabbage, tomatoes, lemon, orange, mangoes, chillies, guava, pineapple, sprouted grams
- Function: Resistance to infections; keeping teeth, gums and joints healthy; healing cuts and wounds; maintenance of connective tissue
- Deficiency disease: Scurvy
- Symptoms: Bleeding gums, pain in joints, general weakness

Vitamin D (Calciferol):

- Sources: Milk, cheese, egg yolk, cod liver oil, fish, butter, exposure to sunlight
- Function: Keeps teeth and bones healthy; absorption of calcium and phosphorus
- Deficiency disease: Rickets in children, Osteomalacia in adults
- Symptoms: Bow legs, pigeon chest, softening of bones, spontaneous fracture in adults

Q3. What is a balanced diet? State the special nutritional needs of a pregnant and lactating mother.

Answer: A balanced diet is one that contains all essential nutrients in suitable proportion and amount to provide necessary energy and keeps the body in a healthy state.

Special nutritional needs of pregnant and lactating mothers:

Pregnant woman:

- Extra protein for tissue growth (of mother and baby)
- More calcium and phosphorus to form bones of the baby
- More iron for making sufficient blood for the baby
- More carbohydrates for extra energy required for all building processes linked with embryo
- Caloric requirement = 3300 cal/day (much more than normal woman's 2400)

Lactating mother:

- More proteins for milk production and to care for additional requirements
- More calcium for milk formation
- More vitamins for healthy milk
- Caloric requirement = 3700 cal/day (highest requirement)

Both need a diet that is protein-rich, calcium-rich and has high iron content to meet the special demands of growth of the baby and milk production.

Q4. What are minerals? Describe the functions and deficiency diseases of Iron, Iodine and Calcium.

Answer: Minerals are micronutrients required in varying amounts for proper functioning, normal growth and keeping good health. They are inorganic elements occurring in the form of their salts. They do not supply energy but are essential for protection against diseases.

Iron:

- Function: Formation of haemoglobin; acts as carrier of oxygen in blood
- Sources: Liver, green leafy vegetables, eggs, spinach, groundnuts, cereals, jaggery
- Deficiency disease: Anaemia (reduction of red blood cells, reduced oxygen carrying capacity)
- Symptoms: Pale appearance, tiredness, loss of appetite, loss of weight

Iodine:

- Function: Metabolic control through hormone thyroxine; controls growth and mental ability
- Sources: Iodised salt, sea food, fish, green leafy vegetables
- Deficiency disease: Goitre (enlargement of thyroid gland); Cretinism

- Symptoms: Enlargement of thyroid gland, retarding of physical and mental growth, stunted growth, protruding eyes, irregular heart beat, low intelligence

Calcium:

- Function: Formation of bones and teeth; necessary for nerve, teeth and muscles; helps blood clotting; regulates heart beat
- Sources: Milk and milk products, fish, meat, beans, green leafy vegetables, broccoli, tapioca, cereals
- Deficiency disease: Rickets (children), Osteomalacia (adults)
- Symptoms: Softening of bones, deformities, bow legs, pigeon chest, loss of teeth enamel, spontaneous frctures

Q5. What is obesity? What are its causes, harmful effects and methods of prevention?

Answer:

Obesity = The overweight and bulkiness of a person's body due to accumulation of carbohydrate and fat is called obesity. It occurs when a person continues to eat more food than required.

Causes:

- Overeating
- Insufficient exercise
- Hormonal imbalance (deficiency of thyroxine) or other metabolic disturbances

Harmful effects: An obese person tends to have high cholesterol deposited in blood arteries leading to: Hypertension (high blood pressure), Atherosclerosis (hardening of arteries), Coronary attack (heart attack), Diabetes, Respiratory problems

Methods to prevent obesity:

- Avoid fried food
- Do not take carbohydrate-rich foods
- Avoid saturated fats (ghee, vanaspati); take unsaturated fats (oils) in small quantity
- Take regular physical exercise
- Eat green leafy vegetables (adds roughage)
- If hormonal imbalance, consult physician

SECTION B: TOP 5 REPEATED PYQ-STYLE QUESTIONS

PYQ 1. Differentiate between Water-soluble and Fat-soluble vitamins. Give examples and effects of excessive intake. *(2018, 2019, 2020, 2022, 2023)*

Answer:

Feature	Water Soluble Vitamins	Fat Soluble Vitamins
Examples	Vitamin B complex, Vitamin C	Vitamins A, D, E, K
Solubility	Dissolve in water	Dissolve in fats/oils
Storage in body	Not stored, excreted in urine	Stored in liver and fatty tissues
Effect of excess intake	No harm — excreted through urine	Toxic (poisonous) — cause Hypervitaminosis
Deficiency	Develops quickly (not stored)	Develops slowly (stored)

Hypervitaminosis A (excess Vitamin A): Loss of hair, drowsiness, painful swelling of long bones, loss of appetite, nausea, vomiting.

Hypervitaminosis D (excess Vitamin D): Deposition of calcium in soft tissues like kidney, drowsiness, nausea, loss of weight.

Conclusion: Both deficiency AND excess of nutrients are harmful to the body.

PYQ 2. What are macronutrients and micronutrients? Give two examples of each and their functions. *(Almost every NIOS exam, 2017-2024)*

Answer:

Macronutrients = Nutrients required in large amounts by the body. Examples and functions:

- **Carbohydrates:** Primary and cheapest source of energy (18 kJ/gram); glucose is only energy source for nervous system; provides 60-80% of total energy
- **Fats:** Richest source of energy (37 kJ/gram); structural component of cell membrane; help absorption of fat-soluble vitamins A, D, E, K
- **Proteins:** Growth and repair of tissues; synthesis of enzymes, hormones and antibodies; 4 kcal per gram
- **Water:** Transport of food; excretion of wastes; maintains body temperature; acts as solvent

Micronutrients = Nutrients required in small (trace) amounts by the body. Examples and functions:

- **Vitamins:** Act as biocatalysts (do not provide energy); essential for good health; protect from diseases; Vitamin C prevents scurvy, Vitamin D prevents rickets

- **Minerals:** Essential for development of bone and teeth (calcium, phosphorus); iron is major component of haemoglobin; iodine needed for thyroxine synthesis

PYQ 3. Describe the symptoms, causes and cure of (a) Goitre (b) Anaemia. *(Repeated in almost all NIOS board exams — Goitre and Anaemia questions come together)*

Answer:

GOITRE:

- Cause: Deficiency of iodine → insufficient synthesis of thyroxine → thyroid gland enlarges and swells
- Symptoms: Enlargement of thyroid gland (visible swelling in neck), protruding eyes, stunted growth, puffy appearance, irregular heart beat, low intelligence; iodine deficiency also causes Cretinism (stunted growth, retarded mental growth, delayed puberty, low metabolic rate)
- Cure: Use of iodised table salt; eating sea food and fish

ANAEMIA:

- Cause: Deficiency of iron → less haemoglobin formation → reduction of red blood cells → reduced oxygen carrying capacity of blood
- Symptoms: Pale appearance, tires easily, loss of appetite, loss of weight, breathlessness
- Cure: Eating food rich in iron and Vitamin B12 — eggs, meat, liver, milk, green leafy vegetables (spinach), fruits (apple, banana, guava); iron tablets and tonics can supplement

PYQ 4. Name the deficiency disease, symptoms and food sources for Vitamin B1, B3 and B12. *(Vitamin B group questions repeat every 1-2 years)*

Answer:

Vitamin B1 (Thiamine):

- Deficiency disease: Beri-beri
- Symptoms: Pain in hands and feet, swelling of body, paralysis of limbs, Oedema (accumulation of fluid in tissues)
- Food sources: Yeast, liver, milk, cheese, leafy vegetables, meat, whole grain cereals

Vitamin B3 (Niacin):

- Deficiency disease: Pellagra
- Symptoms: 3 Ds — Dermatitis (bad/scaly skin), Diarrhoea (loose motions), Dementia (mental disorder)
- Food sources: Fish, eggs, meat, legumes, whole grains, leafy vegetables, peanuts, bean, tomato, potato

Vitamin B12 (Cyanocobalamine):

- Deficiency disease: Pernicious anaemia
- Symptoms: Paleness of skin, breathlessness, retarded growth
- Food sources: Liver, fish, cheese, milk, eggs, meat
- Functions: Blood formation, nervous tissue metabolism, nucleic acid synthesis

PYQ 5. What is PEM? Distinguish between Kwashiorkor and Marasmus. What are the causes and cure? *(Most repeated question — appears almost EVERY year in NIOS biology exams)*

Answer: PEM (Protein Energy Malnutrition) = Condition that occurs in children (1-5 years) when required amount of proteins for growth and development is not available.

Two causes of PEM: (a) Lack of proteins or carbohydrates or both in the diet (b) More intake of carbohydrates than proteins

Distinction:

Feature	Kwashiorkor	Marasmus
Deficiency	Mainly protein deficiency	Carbohydrates, fats AND proteins all deficient
Age	1-5 years (after weaning)	Below 1 year
Body weight	Underweight	Severely underweight (skin and bones)
Oedema	Present (swelling of legs/feet)	Absent
Skin	Dark and scaly	Folded skin
Hair	Reddish	No change
Abdomen	Protruding belly (swollen)	Thinned abdominal walls
Liver	Enlarged	Normal
Face	Moon face	Sunken eyes, old man face

Cure for both: Adequate protein and carbohydrate rich food should be given. Foods recommended: Milk, eggs, pulses, dal, rice, meat, fish — high protein and calorie diet

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Biotechnology

1. WHAT IS BIOTECHNOLOGY?

Biotechnology = Bios (biology) + Technology (application)

It is the industrial application of living organisms and their biological processes (biochemistry, microbiology, genetic engineering) for the benefit of mankind.

Applications: Health/Medicine, Environment, Agriculture, Industry

2. INDUSTRIAL MICROORGANISMS & PRODUCTS

Microorganisms used: Yeasts (fungi), Moulds (fungi), Bacteria, Actinomycetes

Products: Alcohol-containing beverages, Yoghurt, Proteins, Antibiotics, Vitamins, Steroids, Enzymes, Biogas

3. FERMENTATION & ALCOHOL PRODUCTION

Fermentation: Carbohydrates (sugar) → Alcohol + CO_2 + ATP (by yeast enzymes)

Yeast used: *Saccharomyces cerevisiae* (Brewer's yeast)

- Wine → from grapes
- Beer → from barley malt
- Fermentation done in large tanks called **Bioreactors**

Steps of Fermentation:

1. Sterilise fermenter + nutrient medium (autoclave)
2. Select correct yeast strain
3. Inoculate yeast by:
    - **Support growth system** (yeast on surface)
    - **Suspended growth system** (cells suspended in liquid)
4. Maintain temperature, pH, O_2, CO_2
5. Stir and ferment

6. Sugar fermented by yeast enzymes
7. Remove fermented product

Alcohols produced: Ethyl alcohol, Butanol, Glycerol

Also produced: Lactic acid, Acetic acid (vinegar) by bacteria

4. YOGHURT & CHEESE MAKING

- Milk curdled by **Lactobacillus** bacteria → releases milk-curdling enzymes
- Commercial scale uses **Rennet tablets** (Rennin enzyme from calf stomach)
- **Casein** (milk protein) separates from **whey** (liquid)
- *Lactobacillus* converts **lactose** → **lactic acid** → lowers pH → souring → preservation
- Butter made by churning sour milk
- Starter culture: *Streptococcus cremosis* + *Leuconostoc*

Product	Microorganism
Yoghurt	*Streptococcus thermophilus* + *Lactobacillus bulgarians*
Butter	*Lactococcus lactis*

5. ANTIBIOTICS

- Discovered by **Alexander Fleming (1928)**
- Term "antibiotic" coined by **Selman Waksman (1942)**
- **Definition:** Substance produced by microorganism that inhibits growth of another microorganism
- Molecular weight < 2000 Da, NOT enzymes
- Interferes with **vital metabolic processes** of pathogenic bacteria

Types:

- **Broad spectrum:** Chloramphenicol, Erythromycin, Tetracycline (from *Streptomyces*)
- **Narrow spectrum:** Streptomycin, Penicillin

Drawbacks: Allergic reactions, Bacteria develop resistance (mutation)

Antibiotic	Source
Penicillin	*Penicillium chrysogenum*
Streptomycin	*S. griseus*
Tetracyclin	*Streptomyces sp*
Chloramphenicol	*S. venezuelae*
Cephalosporin	*Cephalosporium acremonium*

6. VACCINATION

- **Edward Jenner (1790):** Observed milkmaids didn't get smallpox → discovered vaccination
- **Vaccine** (latin: *vacca* = cow) = weakened/attenuated germs introduced into body

Generations of Vaccines:

- **1st Generation:** From attenuated (weakened) bacteria
- **2nd Generation:** By Genetic Engineering / Recombinant DNA technology (Hepatitis B, Herpes)
- **3rd Generation:** Synthesised from chemicals

7. PRODUCTION OF VITAMINS

- **Vitamin C** = first vitamin produced by fermentation (by bacteria)
- **B_{12}** (cyanocobalamin) = from liver extract, fermentation by propionic bacteria
- **B_2** (Riboflavin) = yield enhanced 100-300 fold by using microbes

8. BIOGAS PRODUCTION

- Primary source: **Cowdung** (contains lignocellulose)
- Energy from **Methane (CH_4)**
- Produced by **Methanogenic bacteria** anaerobically

Conditions required:

1. Anaerobic environment (no free oxygen)
2. pH: 6.8 to 7.6
3. Methanogenic bacteria

Byproduct: Slurry = excellent manure

Advantages: Fuel for cooking/lighting, Cheaper than LPG, Slurry as soil conditioner

9. GENETIC ENGINEERING

Definition: Construction and utilisation of new DNA molecules engineered by Recombinant DNA technology

Recombinant DNA: Cutting original DNA + inserting different DNA segment with desired characters

Two Key Discoveries:

1. **Plasmids** – extra chromosomal DNA in bacteria (vector for foreign DNA)
2. **Restriction enzymes** – cut DNA at specific sites

5 Tools of rDNA Technology:

1. Cell culture
2. Restriction endonuclease ("molecular scissors") – cuts at 4-6 base sequences, creates **sticky ends**
3. Plasmids (clonal vectors)
4. DNA Ligase ("molecular glue") – joins DNA fragments
5. Host bacteria

Steps: Select enzyme → Get cell culture → Cut DNA → Cut plasmid → Ligase joins → Recombinant plasmid → Insert into bacteria → Bacteria divide → Clone → DNA library

10. APPLICATIONS OF GENETIC ENGINEERING

Proteins produced:

Protein	Used for
Insulin	Diabetes mellitus
Growth hormone	Pituitary dwarfism
Erythropoietin	Anaemia
Interferons	Viral infections
Clotting factor VIII	Haemophilia A
Monoclonal antibodies	Infectious diseases

Enzymes produced:

Enzyme	Use
Proteases	Detergents, meat tenderisers
Amylases	Beer, bread, textiles
Glucoisomerases	Corn syrup for soft drinks

- First commercial success of rDNA: **Human Insulin (1982)**
- Bioengineered vaccines for: **Rabies, Hepatitis B**

11. TRANSGENIC ORGANISMS

- **Transgene** = foreign gene inserted into an organism
- **Transgenic** = organism carrying foreign gene

Methods to produce transgenics:

1. **Microinjection** of foreign DNA into pronuclei of fertilised eggs
2. **Retroviral vector method** – retrovirus carries foreign DNA into early embryo

Transgenic Plants: Using *Agrobacterium tumefaciens* (Ti plasmid)

- Examples: BT cotton (worm resistant), Drought-tolerant corn & soyabean

Transgenic Animals:

- **Mice:** rat growth hormone gene → bigger mice
- **Goats:** produce tPA (dissolves blood clots) in milk
- **Chinese hamster:** Blood clotting factor VIII for haemophilia A

12. BIOREMEDIATION

- Using **genetically engineered bacteria** to clean environmental pollutants
- Bacteria break down **toxic pollutants** → **harmless compounds**
- Mercury-resistant bacteria convert metallic mercury → non-toxic compound

13. GENE THERAPY

Definition: Technique where a patient is given **healthy genes** to replace defective ones

Single Gene Disorders:

Disease	Defect	Symptoms
SCID	Absence of adenosine deaminase	Loss of immunity
Haemophilia	Absence of clotting factor VIII	Chronic bleeding
Sickle Cell Anaemia	Defective β chain of Hb	Organ damage
PKU	Accumulation of phenylalanine	Mental retardation

Two Approaches:

1. **Somatic gene therapy** (body cells) – correction NOT passed to offspring
2. **Germ-line gene therapy** (sex cells) – NOT currently practised

Three Types of Somatic Gene Therapy:

- **(a) Ex-vivo** – cells taken out, corrected outside, put back
- **(b) In-vivo** – direct delivery via **Adenovirus** into tissues
- **(c) Antisense** – prevents over-expression of a gene; mRNA blocked

Limitations of Gene Therapy:

- Cannot pass correction to offspring
- Random DNA integration may cause cancer
- Expensive and time-consuming
- Limited to single-gene defect diseases

TOP 5 MOST IMPORTANT Q&A FROM THE CHAPTER (100% Exam Guaranteed)

Q1. What is fermentation? Write the equation and explain the steps of alcohol production.

Ans. Fermentation is the process by which carbohydrates (sugars) are converted into alcohol and CO_2 by the action of yeast enzymes.

Equation: Glucose → (Yeast enzyme) → Ethyl alcohol + Carbon dioxide + ATP

Steps:

1. Sterilise fermenter and nutrient medium by autoclaving
2. Select correct yeast strain (*Saccharomyces cerevisiae*)

3. Inoculate yeast (support growth or suspended growth system)
4. Maintain temperature, pH, O_2, CO_2
5. Stir and allow fermentation
6. Sugar fermented by yeast enzymes
7. Remove fermented product (wine/beer)

Q2. What is Recombinant DNA technology? Write the tools and steps involved.

Ans. Recombinant DNA technology is a "cut and paste" technique where specific DNA sequences are cut from one organism and inserted into the plasmid of bacteria.

5 Tools:

1. Cell culture
2. Restriction endonuclease (molecular scissors)
3. Plasmids
4. DNA Ligase (molecular glue)
5. Host bacteria

Steps:

1. Select restriction enzyme
2. Get cell culture with required gene
3. Restriction enzyme cuts the gene → restriction fragment with sticky ends
4. Same enzyme cuts plasmid DNA
5. Ligase joins gene fragment into plasmid → Recombinant plasmid
6. Insert into bacteria
7. Bacteria divide → millions of clones in <10 hours
8. Stored in DNA library

Q3. Define Gene Therapy. Explain its types with limitations.

Ans. Gene therapy is a technique in which a patient is given healthy genes to replace defective ones, or to enhance gene action.

Types:

- **Somatic gene therapy** – applied to body cells; 3 subtypes:
  - Ex-vivo (cells corrected outside body, returned back)
  - In-vivo (direct delivery via adenovirus)
  - Antisense (blocks over-expressed gene)
- **Germ-line gene therapy** – on sex cells; not currently practised

Limitations:

- Cannot pass correction to offspring
- Risk of random DNA integration causing cancer
- Very expensive and time-consuming
- Only for known single-gene defects

Q4. What are antibiotics? Differentiate between broad spectrum and narrow spectrum antibiotics with examples.

Ans. Antibiotics are substances produced by microorganisms (bacteria/fungi) that inhibit the growth of other microorganisms. They have molecular weight <2000 Da and are not enzymes.

Broad Spectrum: Effective against many pathogens

- Examples: Chloramphenicol, Erythromycin, Tetracycline (from *Streptomyces*)

Narrow Spectrum: Effective against only a few pathogens

- Examples: Streptomycin, Penicillin

Q5. What are transgenic organisms? How are transgenic plants produced using *Agrobacterium tumefaciens*?

Ans. Transgenic organisms are genetically engineered organisms that carry foreign genes (transgenes) in their genome.

Production of transgenic plants using *Agrobacterium tumefaciens*:

- *A. tumefaciens* is a soil bacterium with a natural genetic engineering system
- It contains a **Ti plasmid** which can integrate into plant cell DNA
- Gall-forming genes in Ti plasmid are **removed and replaced** with desired genes

- Modified plasmid is used to infect plant protoplasts
- Foreign genes integrate into plant chromosome and are expressed
- Plant is regenerated with the new trait (e.g., BT cotton, drought-tolerant soyabean)

TOP 5 PYQs (Repeated in Exams - From Previous Years)

PYQ 1. Define biotechnology and list any four applications of it. *(Asked in: NIOS Board Exam 2018, 2020, 2022)*

Ans. Biotechnology is the industrial application of living organisms and their biological processes such as biochemistry, microbiology, and genetic engineering to make best use of microorganisms for the benefit of mankind.

Four Applications:

1. **Health:** Development of vaccines, antibiotics, gene therapy
2. **Environment:** Bioremediation to clean up pollutants
3. **Agriculture:** Transgenic crops with disease resistance, herbicide tolerance
4. **Industry:** Production of food additives, enzymes, alcohol, cheese, yoghurt

PYQ 2. What is biogas? How is it produced? Mention its advantages. *(Asked in: NIOS Board Exam 2016, 2019, 2021)*

Ans. Biogas is a fuel made from organic waste (cowdung, faeces) by the action of methanogenic bacteria. It is mainly composed of **Methane (CH_4)**.

Production:

- Cowdung/faeces collected and put in **biogas digester (fermenter)**
- **Methanogenic bacteria** act on it **anaerobically**
- CH_4 and CO_2 are produced
- Residual material = **slurry** (excellent manure)

Conditions: Anaerobic environment, pH 6.8–7.6, methanogenic bacteria

Advantages:

1. Used as fuel for cooking and lighting
2. Slurry acts as soil conditioner/manure
3. Much cheaper than LPG

PYQ 3. Describe the role of restriction enzymes and DNA ligase in recombinant DNA technology. *(Asked in: NIOS Board Exam 2017, 2019, 2023)*

Ans.

Restriction Endonuclease (Molecular Scissors):

- Enzymes found in bacteria
- Recognise specific DNA sequences (4–6 bases) and cut them
- Create **sticky ends** (single-stranded overhangs)
- Different restriction enzymes cut at different specific sequences
- Used to isolate specific genes from the DNA

DNA Ligase (Molecular Glue):

- Called "joining enzyme"
- Joins two DNA fragments that have matching sticky ends
- Seals the recombinant DNA by forming covalent bonds
- Without ligase, the foreign gene cannot be permanently inserted into the plasmid

PYQ 4. What is gene therapy? Distinguish between somatic and germ-line gene therapy. *(Asked in: NIOS Board Exam 2015, 2018, 2021, 2022)*

Ans. Gene therapy is the replacement or alteration of defective genes by giving a patient healthy functional genes.

Feature	Somatic Gene Therapy	Germ-line Gene Therapy
Target cells	Body (somatic) cells	Sex cells (gametes/zygote)
Inheritance	Correction NOT passed to offspring	Correction passed to future generations
Current status	Being practised (early stages)	NOT currently practised
Example	Ex-vivo, In-vivo, Antisense therapy	Theoretically possible only

PYQ 5. What are transgenic animals? Give two examples and explain how they are useful. *(Asked in: NIOS Board Exam 2016, 2019, 2020, 2023)*

Ans. Transgenic animals are animals that carry foreign genes (transgenes) artificially inserted into their genome through genetic engineering.

Examples and Uses:

1. **Transgenic Mice:** Rat growth hormone gene inserted → mice grew larger than normal. Used in research to study gene expression and growth.
2. **Transgenic Goats:** Human gene for tPA (tissue plasminogen activator) inserted. Goat milk contains tPA which dissolves blood clots → very useful for **heart attack and stroke patients**.
3. **Chinese Hamster:** Blood clotting factor VIII gene inserted → produces this factor to treat **Haemophilia A** patients without the risk of HIV transmission from human blood.

General Uses:

- Better yield in agriculture and livestock
- Production of valuable medical proteins
- Study of biological processes like gene expression

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Immunobiology: An Introduction

1. IMMUNITY - DEFINITION

Immunity = "The capacity of the body to recognize materials as foreign to itself and to neutralize, eliminate or metabolize them with or without injury to its own tissues."

Immunobiology = Study of organization and functioning of the immune system.

Father of Immunobiology = Edward Jenner (1749–1823)

- Observed milkmaids who recovered from cowpox never got smallpox
- Introduced vaccination in **1796** using cowpox to protect against smallpox
- Term **"Vaccine"** from Latin word **"Vacca"** = cow

Self vs Non-Self:

- Self = body's own tissues
- Non-Self = foreign substances (pathogens, viruses, etc.)
- Immune system distinguishes between the two and responds to non-self

2. DEFENCE MECHANISMS IN THE BODY (4 Types)

1. **Immunity** – defend body from infections
2. **Metabolic defence** – metabolize and detoxify foreign chemicals
3. **Haemostasis** – stoppage of bleeding, prevent blood loss
4. **Resistance to stress** – through release of hormones

Immunological defence is the MOST IMPORTANT. It serves 3 functions:

1. Defence against microorganisms
2. **Surveillance** – recognition and destruction of mutant cells
3. **Homeostasis** – removal of damaged/non-functional cells

3. IMMUNE SYSTEM - ORGANS & CELLS

Lymphoid Organs:

Primary (Central) Lymphoid Organs:

- Thymus
- Bone Marrow

Secondary (Peripheral) Lymphoid Organs:

- Spleen, Tonsils, Lymph nodes, Peyer's patches, MALT (Mucosa-Associated Lymphoid Tissue)

Cells of Immune System:

Origin: All from **Hemopoietic stem cells** of Bone Marrow

Stem cells produce:

- Erythrocytes (RBC)
- Thrombocytes (platelets)
- Granulocytes
- Monocytes (WBC)
- Lymphocytes

(a) B-CELLS (B-Lymphocytes)

- **"B"** = Bursa of Fabricius (in birds)
- Mature in **Bone Marrow**
- In mammals, B-cell lineage begins in **foetal liver** (8th week of gestation)

Functions:

1. Initiate antibody-mediated immune response
2. Transform into **plasma cells** which secrete antibodies

Key Facts:

- Display **immunoglobulin** on cell membrane as antigen receptor
- Activated B-cells → Plasma cells → produce antibodies
- Some B-cells become **memory cells** for future antigen exposure
- Plasma cells produce thousands of antibody molecules per second before dying in ~1 day

(b) T-CELLS (T-Lymphocytes)

- **"T"** = Thymus (where they mature)
- Leave bone marrow immature → mature in **Thymus** → migrate to peripheral lymphoid organs

Functions:

1. Regulate immune response
2. Mediate **Cell-Mediated Immune (CMI)** response
3. Induce B-cells to produce antibody

Three Types of T-cells:

T-cell Type	Symbol	Function
Helper T-cells	TH	Promote B-cell response → antibody production; activate other T-cells
Cytotoxic T-cells	TC	Kill virus-infected cells and tumour cells
Suppressor T-cells	TS	Suppress Helper T-cells and B-cells; regulate immune activity

T-cells mediate two functions: **Effector** and **Regulatory**

4. ANTIGEN & ANTIBODY

Antigen:

Definition: Any foreign molecule that can trigger a specific immune response.

Most antigens are: Proteins or large polysaccharides

Requirements to be an antigen:

1. Must be foreign to the host
2. Molecular weight ≥ 10,000 Dalton
3. Must possess chemical complexity

Key Terms:

- **Epitope** = Part of antigen that contacts antibody (= Antigenic determinant)
- **Paratope** = Part of antibody that contacts antigen
- **Immunogen** = molecule that provokes immune response

Antibody (Immunoglobulin):

Definition: Protein molecule produced in animals in response to an antigen.

Structure:

- 4 polypeptide chains: **2 Heavy chains + 2 Light chains**
- **Fc portion** (stem) = constant region (same for all antibodies of same class)
- **Antigen binding sites** (prongs) = variable region (differs between antibodies)

5 Classes of Immunoglobulins:

Class	Special Note
IgG	Highest concentration (~75% of total Ig in humans)
IgM	First produced in immune response
IgA	Found in secretions
IgE	Involved in allergy
IgD	Found on B-cell surface

- Antibodies produced by **plasma cells** (differentiated B-cells)
- Travel through blood → reach antigens → combine → direct attack by phagocytic cells

5. TYPES OF IMMUNE RESPONSES

A. Non-Specific Immune Response:

- Does NOT recognize specific identity of foreign substance
- Examples: Phagocytosis by macrophages, Complement proteins

B. Specific Immune Response (Adaptive):

Two types:

(a) Cell-Mediated Immune (CMI) Response:

- Mediated by **Cytotoxic T-cells** and natural killer cells
- Defence against: intracellular viruses and cancer cells

(b) Humoral (Antibody-Mediated) Immune Response:

- Mediated by **antibodies** secreted by plasma cells (from activated B-cells)
- Defence against: bacteria and viruses

Differences:

Cell-Mediated	Humoral
Kills intracellular organisms	Antibodies bind specific antigens
Destroys tumour cells	Causes clumping, neutralisation, lysis
Rejects graft tissue	Facilitates phagocytosis
Delayed hypersensitivity	—

Both types facilitated by **Helper T-cells** and inhibited by **Suppressor T-cells**

6. TYPES OF IMMUNITY

A. Natural / Innate Immunity (from birth)

Three components:

1. **Physical Barriers** (1st line of defence)
2. **Phagocytic Cells**
3. **Complement System**

Physical Barriers:

- **Skin** = outer layer of keratin (impermeable); sebaceous glands produce lactic acid → kills pathogens
- **Epithelial lining** = respiratory/alimentary/urogenital tracts; cilia expel pathogens; mucus lining
- **Body secretions** = sweat, tears, HCl in gastric juice, spermine in seminal fluid

Phagocytic Cells:

- Engulf and destroy microorganisms = **Phagocytosis** (literally "cell eating")
- Two types: **Microphages** (WBCs) and **Macrophages** (liver and spleen)
- Contain digestive enzymes
- Link between innate and acquired immunity

Complement System:

- Group of at least **20 proteins**
- Most pivotal component = **C3**
- Can act as **opsonin** (e.g. C3b) → enhances phagocytosis
- Can kill microbes by making membrane leaky

B. Acquired Immunity (developed during lifetime)

Mediated by **lymphocytes**; characterized by **antigen specificity** and **memory**

(i) Actively Acquired Immunity – body produces its own antibodies:

- By infection (natural) OR by vaccination (artificial)
- Some diseases give lifetime immunity (smallpox, mumps, diphtheria)
- Some give short immunity (common cold, influenza)

(ii) Passively Acquired Immunity – antibodies transferred from another:

- IgG from mother to foetus across **placenta**
- Antibodies from **breast milk** to infant
- Pooled human immunoglobulin (for measles, hepatitis

7. VACCINATION (Active Immunization)

Objective: Introduce attenuated germs → body generates **memory cells** → rapid response on re-exposure

Three Types of Vaccines:

Type	Examples
Killed organisms	Typhoid, Cholera, Pertussis (whooping cough), Rabies, Polio
Live attenuated (weakened)	BCG, Rubella, Measles, Polio
Toxoid vaccines	Diphtheria, Tetanus

Toxoid = chemically/physically modified toxin → no longer harmful but retains immunogenicity

Important Vaccines:

- **BCG** = Bacillo Calmette Guerin → Tuberculosis vaccine
- **DPT** = Diphtheria + Pertussis + Tetanus (Triple vaccine)

- **MMR** = Measles + Mumps + Rubella
- **Polysaccharide vaccines** = Influenza, Meningitis, Pneumonia

Vaccines of future: Malaria, Leprosy, Anthrax, AIDS

TOP 5 MOST IMPORTANT Q&A FROM THE CHAPTER (100% Exam Guaranteed)

Q1. Define immunity. What are the four defence mechanisms in the human body?

Ans. Immunity is defined as the capacity of the body to recognize materials as foreign to itself and to neutralize, eliminate or metabolize them with or without injury to its own tissues.

Four defence mechanisms:

1. Immunity – defends body from infections
2. Metabolic defence – detoxifies foreign chemicals
3. Haemostasis – stoppage of bleeding to prevent blood loss
4. Resistance to stress – through release of hormones

Immunological defence is the most important and serves three functions: defence against microorganisms, surveillance (destruction of mutant cells), and homeostasis (removal of damaged cells).

Q2. Differentiate between B-cells and T-cells.

Ans.

Feature	B-cells	T-cells
Origin	Mature in Bone Marrow	Mature in Thymus
"B" stands for	Bursa of Fabricius	—
"T" stands for	—	Thymus
Function	Antibody-mediated immunity	Cell-mediated immunity
Products	Transform into plasma cells → produce antibodies	TH, TC, TS subtypes
Main role	Humoral immune response	Regulate + effector immune response
Memory cells	Form B-memory cells	Form T-memory cells

Q3. What is an antigen? What are the requirements for a substance to act as an antigen?

Ans. An antigen is any foreign molecule that can trigger a specific immune response. Most antigens are proteins or large polysaccharides.

Requirements to be an antigen:

1. It must be foreign (non-self) to the host
2. Molecular weight must be 10,000 Dalton or more
3. It must possess chemical complexity

Key terms: Epitope = part of antigen that contacts antibody (antigenic determinant). Paratope = part of antibody that contacts antigen.

Q4. Describe the structure of an antibody. Name the five classes of immunoglobulins.

Ans. Antibody (immunoglobulin) is a protein molecule produced in response to an antigen. Each antibody molecule has four polypeptide chains: 2 heavy chains and 2 light chains.

Structure:

- Fc portion (stem) = lower half of two heavy chains; constant region; same for all antibodies of same class
- Antigen-binding sites (two prongs) = variable region; differs between antibodies

Five classes: IgG (highest concentration, ~75%), IgM, IgA, IgE, IgD

Antibodies are produced by plasma cells (differentiated B-cells). They travel through blood and combine with antigens, directing phagocytic cells to eliminate them.

Q5. Distinguish between Cell-Mediated and Humoral Immune Responses. What are the types of vaccines?

Ans.

Cell-Mediated	Humoral (Antibody-Mediated)
Mediated by T-cells (Cytotoxic)	Mediated by antibodies from plasma cells
Kills intracellular organisms	Antibodies bind specific antigens
Destroys tumour cells	Causes clumping, neutralisation of toxins
Rejects graft tissue	Facilitates phagocytosis
Defence against viruses and cancer	Defence against bacteria and viruses

Three Types of Vaccines:

1. Killed organism vaccines – Typhoid, Cholera, Rabies
2. Live attenuated vaccines – BCG, Rubella, Measles
3. Toxoid vaccines – Diphtheria, Tetanus

TOP 5 PYQs (Repeated in Exams - With Years)

PYQ 1. What is immunity? Distinguish between innate and acquired immunity. *(Asked in: NIOS Board Exam 2016, 2018, 2020, 2022)*

Ans. Immunity is the capacity of the body to recognize foreign materials and neutralize or eliminate them.

Innate (Natural) Immunity	Acquired Immunity
Present from birth (genetic)	Developed during lifetime
Non-specific	Specific (antigen-specific)
No memory	Has immunological memory
Physical barriers, phagocytes, complement	Lymphocytes (B and T cells)
Fast acting	Slower, but stronger on re-exposure
Examples: skin, mucus, phagocytosis	Examples: vaccination, antibody production

PYQ 2. What are the types of vaccines? Explain with examples. What is a toxoid? *(Asked in: NIOS Board Exam 2015, 2017, 2019, 2021, 2023)*

Ans.

Three types of vaccines:

1. **Killed organisms as vaccines:** The pathogens are killed but still trigger immune response. Examples: Typhoid, Cholera, Pertussis (whooping cough), Rabies, Poliomyelitis.
2. **Live attenuated organisms as vaccines:** Weakened (attenuated) live pathogens used. They mimic natural infection without causing disease. Examples: BCG (tuberculosis), Rubella, Measles, Polio.
3. **Toxoid vaccines:** Modified toxins used. Toxoid = chemically or physically modified toxin that is no longer harmful but retains immunogenicity. Examples: Diphtheria, Tetanus.

BCG = Bacillo Calmette Guerin (TB vaccine) **DPT** = Diphtheria + Pertussis + Tetanus (triple vaccine) **MMR** = Measles + Mumps + Rubella

PYQ 3. Describe the structure and function of antibodies. Name the types of immunoglobulins. *(Asked in: NIOS Board Exam 2016, 2019, 2022)*

Ans. Antibody is a protein molecule (immunoglobulin) produced in response to an antigen. It is produced by plasma cells (activated B-cells).

Structure:

- 4 polypeptide chains: 2 heavy + 2 light chains
- Fc portion (stem) = constant region
- Antigen-binding sites = variable region (specific to each antigen)

5 Classes: IgG, IgM, IgA, IgE, IgD

- IgG = most abundant (75% of total immunoglobulins)

Function: Antibodies travel through blood, bind to specific antigens, direct phagocytic attack, cause agglutination (clumping), neutralise toxins, and lead to lysis of bacteria and viruses.

PYQ 4. What is phagocytosis? Describe the role of phagocytic cells in immunity. *(Asked in: NIOS Board Exam 2017, 2020, 2023)*

Ans. Phagocytosis is the process of engulfment and destruction of microorganisms and foreign particles by specialised cells called phagocytes. The word literally means "eating by the cell."

Two major phagocytic cells:

- **Microphages** – certain white blood cells (WBCs)
- **Macrophages** – found in liver and spleen

Important features of phagocytic cells:

1. They rapidly engulf foreign agents on contact
2. They contain digestive enzymes to break down engulfed material
3. They are an important link between innate and acquired immunity

When microorganisms enter the body, phagocytic cells (circulating in blood or fixed in tissues) rapidly engulf and destroy them as part of the innate immune defence.

PYQ 5. What are the functions of T-lymphocytes? Differentiate between Helper T-cells, Cytotoxic T-cells and Suppressor T-cells. *(Asked in: NIOS Board Exam 2015, 2018, 2021, 2022)*

Ans. Main functions of T-cells:

1. Regulate immune response

2. Mediate cell-mediated immune (CMI) response
3. Induce B-cells to produce antibody

Three types of T-cells:

Type	Symbol	Function
Helper T-cells	TH	Promote B-cell response → antibody production; activate other T-cells
Cytotoxic T-cells	TC	Kill virus-infected cells and tumour cells directly
Suppressor T-cells	TS	Suppress Helper T-cells and B-cells; regulate/limit immune activity

T-cells mature in the Thymus and then migrate to peripheral lymphoid organs. They are differentiated by specific surface molecules called T-cell receptors. Both B-cells and T-cells work in cooperation.