

Biology — Quick Revision Sheet

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Diversity of Living Organisms

■ Living World & Classification

Taxonomic hierarchy

Species → Genus → Family → Order → Class → Phylum (Division in plants) → Kingdom. Species is the basic unit.

Binomial nomenclature

Given by Linnaeus; genus name starts with a capital, species name in small letters; italicised in print, underlined in handwriting. ICBN (plants), ICZN (animals).

Five kingdoms

Whittaker (1969): Monera, Protista, Fungi, Plantae, Animalia. Criteria: cell structure, body organisation, nutrition, reproduction, phylogeny.

Monera

Prokaryotes. Archaeobacteria (halophiles, methanogens, thermoacidophiles) live in extreme habitats; cyanobacteria (Nostoc, Anabaena) fix nitrogen; mycoplasma lack a cell wall (smallest living cells).

Protista

Unicellular eukaryotes: dinoflagellates (red tides), diatoms (silica shells, diatomaceous earth), euglenoids (pellicle), slime moulds, protozoans (amoeboid, flagellated, ciliated, sporozoans).

Fungi

Cell wall of chitin; heterotrophic. Classes: Phycomycetes (Rhizopus, Mucor), Ascomycetes (Aspergillus, Neurospora, yeast), Basidiomycetes (mushrooms, Puccinia), Deuteromycetes (imperfect fungi).

Viruses, viroids, lichens

Virus: nucleic acid + protein coat, obligate parasite (Stanley crystallised TMV; Ivanowsky discovered). Viroid: free RNA only (PSTV). Prion: infectious protein (BSE). Lichen: alga + fungus symbiosis, pollution indicator.

■ Plant Kingdom

Algae

Green (chlorophyll a, b; starch; Chlamydomonas, Spirogyra); brown (fucoxanthin; laminarin, mannitol; Laminaria, Fucus); red (phycoerythrin; floridean starch; Polysiphonia, Gelidium – agar).

Bryophytes

Amphibians of plant kingdom; gametophyte dominant; no vascular tissue; sporophyte depends on gametophyte; water needed for fertilisation. Liverworts (Marchantia), mosses (Funaria, Sphagnum – peat).

Pteridophytes

First terrestrial vascular plants (xylem, phloem); sporophyte dominant; seedless; Selaginella and Salvinia are heterosporous. Examples: Dryopteris, Pteris, Equisetum, Lycopodium.

Gymnosperms

Naked seeds; tap roots; coralloid roots (Cycas) with cyanobacteria; pollen tubes (no water for fertilisation). Cycas, Pinus, Ginkgo, Cedrus.

Angiosperms

Seeds enclosed in fruits; double fertilisation; monocots (parallel venation, fibrous roots, one cotyledon) and dicots (reticulate venation, tap roots, two cotyledons).

Life cycles

Haplontic (dominant haploid; Spirogyra, Volvox), diplontic (dominant diploid; gymnosperms, angiosperms, Fucus), haplo-diplontic (both; bryophytes, pteridophytes, Ectocarpus).

■ Animal Kingdom

Basis of classification

Symmetry (radial/bilateral), germ layers (diploblastic/triploblastic), coelom (acoelomate, pseudocoelomate, coelomate), segmentation, notochord.

Porifera, Cnidaria, Ctenophora

Sponges: cellular level, choanocytes, spongocoel (Sycon, Spongilla). Cnidaria: cnidoblasts, polyp/medusa (Hydra, Aurelia, Physalia). Ctenophora: comb plates, bioluminescence (Pleurobrachia).

Platyhelminthes & Aschelminthes

Flatworms: acoelomate, flame cells, hooks and suckers (Taenia, Fasciola). Roundworms: pseudocoelomate, complete gut, sexes separate (Ascaris, Wuchereria, Ancylostoma).

Annelida & Arthropoda

Annelida: metameric segmentation, nephridia, closed circulation (Pheretima, Hirudinaria). Arthropoda: largest phylum, jointed appendages, chitinous exoskeleton, open circulation, Malpighian tubules (Apis, Bombyx, Anopheles, Locusta, Limulus).

Mollusca & Echinodermata

Mollusca: soft body, calcareous shell, mantle, radula (Pila, Octopus, Pinctada – pearl). Echinodermata: spiny skin, water vascular system, endoskeleton of ossicles (Asterias, Echinus, Antedon).

Chordata features

Notochord, dorsal hollow nerve cord, pharyngeal gill slits, post-anal tail. Hemichordata (Balanoglossus) is now placed separately.

Vertebrate classes

Cyclostomata (jawless; Petromyzon). Chondrichthyes (cartilage; placoid scales; Scoliodon). Osteichthyes (bony; air bladder; Labeo). Amphibia (3-chambered heart; Rana). Reptilia (dry scaly skin; 3-chambered heart, crocodile 4). Aves (feathers; air sacs). Mammalia (mammary glands; hair; 4-chambered heart).

■ Morphology of Flowering Plants

Root

Regions: root cap, meristematic, elongation, maturation (root hairs). Modified: tuberous (carrot, radish, sweet potato), prop (banyan), stilt (maize, sugarcane), pneumatophores (Rhizophora).

Stem

Underground: potato (tuber), ginger (rhizome), onion (bulb), Colocasia (corm). Tendrils (cucumber, pumpkin), thorns (Citrus, Bougainvillea), phylloclade (Opuntia).

Leaf

Venation: reticulate (dicots), parallel (monocots). Phyllotaxy: alternate (mustard), opposite (Calotropis), whorled (Alstonia). Pitcher (Nepenthes), tendril (pea), spines (cactus).

Flower

Aestivation: valvate, twisted, imbricate, vexillary (pea). Placentation: marginal, axile, parietal, free central, basal. Ovary: superior (hypogynous), inferior (epigynous), half-inferior (perigynous).

Families

Fabaceae: $\% \oplus K_{(5)} C_{1+2+(2)} A_{(9)+1} G_1$. Solanaceae: $\oplus K_{(5)} C_{(5)} A_5 G_{(2)}$ (potato, tomato, brinjal). Liliaceae: $\oplus P_{(3+3)} A_{3+3} G_{(3)}$ (onion, Aloe, Asparagus).

Fruit & seed

Fruit develops from ovary; parthenocarpic fruit without fertilisation (banana). Endospermic seeds: castor, maize; non-endospermic: bean, gram, pea. Coconut water = free nuclear endosperm.

■ Anatomy of Flowering Plants

Tissues

Meristematic (apical, intercalary, lateral). Permanent: parenchyma (storage), collenchyma (pectin; support in young stems), sclerenchyma (lignin; dead). Xylem: tracheids, vessels, fibres, parenchyma. Phloem: sieve tubes, companion cells, fibres, parenchyma.

Vascular bundles

Radial (roots), conjoint (stems, leaves). Open (dicot stem: cambium present), closed (monocot). Xylem: exarch in roots, endarch in stems.

Dicot vs monocot

Dicot stem: ring of bundles, hypodermis collenchymatous. Monocot stem: scattered bundles, sclerenchymatous hypodermis, no secondary growth. Dicot root: 2–4 xylem bundles; monocot root: more than 6 (polyarch).

Secondary growth

Vascular cambium forms secondary xylem (inside) and phloem (outside); cork cambium (phellogen) forms cork (phellem) and phelloderm. Heartwood: dead, dark, resin-filled; sapwood: conducts water. Annual rings give age.

■ Structural Organisation in Animals

Animal tissues

Epithelial (squamous, cuboidal, columnar, ciliated; tight, adhering, gap junctions). Connective (areolar, adipose, cartilage, bone, blood). Muscular (skeletal, smooth, cardiac). Neural (neurons, neuroglia).

Cockroach (Periplaneta)

10 abdominal segments; mosaic vision (compound eyes); open circulation, 13-chambered heart; Malpighian tubules excrete uric acid (uricotelic); 10 pairs of spiracles.

Frog (Rana)

3-chambered heart (2 atria, 1 ventricle); skin, buccal cavity and lungs for respiration; ureotelic; tadpole shows metamorphosis; red blood cells nucleated.

Cell, Biomolecules & Plant Physiology

■ Cell: The Unit of Life

Cell theory

Schleiden and Schwann proposed it; Virchow added omnis cellula-e cellula (new cells from pre-existing cells). Robert Hooke coined "cell" (1665) from cork.

Prokaryote vs eukaryote

Prokaryote: no nuclear membrane, nucleoid, 70S ribosomes, plasmids, mesosome. Eukaryote: true nucleus, membrane-bound organelles, 80S ribosomes (70S in mitochondria and chloroplasts).

Membrane

Fluid mosaic model (Singer and Nicolson, 1972): phospholipid bilayer with proteins; selective permeability; active transport needs ATP, facilitated diffusion does not.

Organelles

Mitochondria: powerhouse, double membrane, own DNA. Golgi: packaging, secretion (Camillo Golgi). Lysosomes: hydrolytic enzymes ("suicide bags"). RER: protein synthesis; SER: lipids, steroids, detoxification. Peroxisomes: H_2O_2 breakdown.

Plastids & others

Chloroplast (chlorophyll), chromoplast (carotenoids), leucoplast (amyloplast, elaioplast, aleuroplast). Centrioles: 9+0 arrangement; cilia/flagella 9+2. Ribosomes: George Palade. Nucleolus: rRNA synthesis.

■ Cell Cycle & Cell Division

Phases

Interphase: G_1 (growth), S (DNA replication), G_2 (preparation); M phase: mitosis. G_0 = quiescent. Human cell cycle ≈ 24 h (M phase ≈ 1 h); yeast ≈ 90 min.

Mitosis

Prophase (condensation), metaphase (chromosomes at plate; best for counting), anaphase (centromere splits), telophase (nuclear envelope reforms), then cytokinesis. Equational division; growth and repair.

Meiosis I

Prophase I: leptotene, zygotene (synapsis, bivalents), pachytene (crossing over; recombination nodules), diplotene (chiasmata), diakinesis (terminalisation). Anaphase I: homologues separate.

Significance

Meiosis keeps chromosome number constant across generations and creates variation (crossing over, independent assortment). Gametes: haploid (n); meiocytes: $2n$.

■ Biomolecules

Carbohydrates

Monosaccharides (glucose, fructose), disaccharides (sucrose = glucose + fructose; maltose; lactose = glucose + galactose), polysaccharides: starch, glycogen, cellulose (β -1,4), chitin.

Proteins

Amino acids joined by peptide bonds. Structures: primary (sequence), secondary (α -helix, β -sheet), tertiary (folding), quaternary (haemoglobin: 4 chains). Collagen is the most abundant animal protein; RuBisCO the most abundant on Earth.

Lipids & nucleic acids

Lipids: fatty acid + glycerol; phospholipids (lecithin) in membranes. Nucleotide = nitrogen base + pentose + phosphate; purines A, G; pyrimidines C, T (U in RNA).

Enzymes

Lower activation energy; active site, substrate specificity. Rate rises with substrate until V_{max} ; K_m = substrate conc. at $\frac{1}{2}V_{max}$. Competitive inhibitor resembles substrate (malonate vs succinate dehydrogenase). Cofactors: prosthetic group, coenzyme (NAD, FAD), metal ions (Zn^{2+}).

Photosynthesis

Pigments & sites

Chlorophyll a (primary pigment), b, xanthophylls, carotenoids. Light reaction in grana (thylakoid membranes); dark reaction in stroma. Engelmann: action spectrum; Priestley: O_2 ; Ingenhousz: sunlight; Sachs: starch.

Light reaction

PSII (P680) splits water $\rightarrow O_2$; PSI (P700). Z-scheme gives ATP and NADPH; non-cyclic photophosphorylation (PSI + PSII) and cyclic (PSI only, ATP only). Chemiosmosis: ATP synthase in thylakoid.

Calvin cycle (C_3)

Carboxylation (RuBisCO: $RuBP + CO_2 \rightarrow 2 \times 3\text{-PGA}$), reduction, regeneration. For one glucose: 6 CO_2 , 18 ATP, 12 NADPH.

C_4 plants

Kranz anatomy; PEP carboxylase in mesophyll gives oxaloacetate (4C); Calvin cycle in bundle sheath; no photorespiration; high temperature and light (maize, sugarcane, sorghum).

Photorespiration & factors

RuBisCO binds O_2 in C_3 plants (chloroplast $\rightarrow$ peroxisome $\rightarrow$ mitochondrion); no ATP made. Blackman: limiting factors; CO_2 saturation: $C_3 \approx 450$ ppm, $C_4 \approx 360$ ppm.

Respiration in Plants

Glycolysis

Cytoplasm; glucose $\rightarrow$ 2 pyruvate; net 2 ATP + 2 NADH (Embden-Meyerhof-Parnas).

Krebs cycle

Matrix of mitochondria; acetyl CoA + oxaloacetate $\rightarrow$ citrate; per glucose: 6 NADH, 2 $FADH_2$, 2 GTP per two turns; pyruvate dehydrogenase link step gives NADH + CO_2 .

ETS & yield

Inner mitochondrial membrane; cytochrome c oxidase is the final acceptor of O_2 ; 1 NADH $\approx$ 3 ATP, 1 $FADH_2 \approx$ 2 ATP; aerobic total $\approx$ 36–38 ATP per glucose.

RQ & fermentation

$RQ = \frac{CO_2 \text{ released}}{O_2 \text{ consumed}}$: carbohydrates 1, fats $\approx$ 0.7, proteins $\approx$ 0.9; anaerobic ∞ . Fermentation: yeast $\rightarrow$ ethanol + CO_2 ; muscle $\rightarrow$ lactic acid.

Mineral Nutrition & Transport

Essential elements

Macro (C, H, O, N, P, K, Ca, Mg, S); micro (Fe, Mn, Cu, Zn, B, Mo, Cl, Ni). Mobile elements (N, P, K, Mg): deficiency in old leaves; immobile (Ca, S, Fe): young leaves. Mo: nitrogenase, nitrate reductase; Mg: chlorophyll; Fe: chlorosis.

Nitrogen fixation

Symbiotic: Rhizobium in legume root nodules (nitrogenase, leghaemoglobin protects it from O_2); free-living: Azotobacter, Azospirillum, Anabaena. Nitrification: $NH_3 \rightarrow NO_2^-$ (Nitrosomonas) $\rightarrow NO_3^-$ (Nitrobacter).

Water relations

$\Psi_w = \Psi_s + \Psi_p$; pure water $\Psi_w = 0$; water moves from higher to lower Ψ_w . Plasmolysis in hypertonic solution. Imbibition: seeds, resins.

Water & food transport

Ascent of sap: cohesion–tension (transpiration pull) theory (Dixon and Joly); root pressure. Stomata: guard cells open with K^+ influx. Phloem: mass (pressure) flow hypothesis (Münch), source to sink.

Plant Growth & Development

Plant hormones

Auxin (IAA): apical dominance, rooting, parthenocarp, weed killer 2,4-D. Gibberellin: stem elongation, bolting, malting. Cytokinin: cell division, delays senescence (Skoog, Miller; kinetin). Ethylene: ripening, only gaseous hormone. ABA: stress hormone, stomatal closure, seed dormancy.

Photoperiodism

Short-day plants (Xanthium, rice), long-day (wheat, spinach), day-neutral (tomato, cotton). Critical dark period matters; phytochrome (Pr $\rightleftharpoons$ Pfr) is the receptor. Vernalisation: cold treatment promotes flowering.

Growth phases

Meristematic, elongation, maturation. Growth curve is sigmoid. Arithmetic growth: $L_t = L_0 + rt$; geometric: $W_t = W_0 e^{rt}$.

Reproduction

Sexual Reproduction in Flowering Plants

Male gametophyte

Anther: 4 microsporangia; tapetum nourishes pollen; microspore mother cell $\rightarrow$ 4 pollen grains (meiosis). Pollen: exine of sporopollenin, intine; at shedding 2-celled (vegetative + generative).

Female gametophyte

Megaspore mother cell $\rightarrow$ 4 megaspores, 1 functional; 3 mitoses $\rightarrow$ 8 nuclei, 7 cells: egg apparatus (egg + 2 synergids), 3 antipodals, central cell (2 polar nuclei).

Pollination

Autogamy, geitonogamy, xenogamy (only xenogamy brings genetic variation). Agents: wind (light pollen, feathery stigma: grasses), water (Vallisneria, Zostera), insects (colourful, scented). Bagging and emasculation in breeding.

Double fertilisation

Syngamy: sperm + egg $\rightarrow$ zygote (2n); triple fusion: sperm + 2 polar nuclei $\rightarrow$ PEN (3n) $\rightarrow$ endosperm. Unique to angiosperms (Nawaschin, Guignard). Zygote $\rightarrow$ embryo; ovule $\rightarrow$ seed; ovary $\rightarrow$ fruit.

Special modes

Apomixis: seeds without fertilisation (hybrid seed fixation). Polyembryony: citrus, mango. Parthenocarp: banana, grape. Seed dormancy and viability: Lupinus 10,000 yr; date palm 2000 yr.

Human Physiology

■ Digestion & Absorption

Digestive enzymes

Saliva: amylase (starch → maltose). Stomach: pepsin (needs HCl), rennin in infants. Pancreas: trypsinogen, chymotrypsinogen, amylase, lipase. Bile (liver, no enzymes): emulsifies fats. Intestine: maltase, lactase, sucrase, enterokinase.

GI hormones

Gastrin (gastric juice), secretin (pancreatic bicarbonate), CCK (gall bladder, pancreatic enzymes), GIP (inhibits gastric secretion).

Absorption & disorders

Villi absorb in the small intestine; fatty acids go as chylomicrons into lacteals. Dental formula (adult): $\frac{2123}{2123} = 32$ teeth. Jaundice (bile pigments), PEM (kwashiorkor, marasmus), constipation.

■ Breathing & Gas Exchange

Lung volumes

TV ≈ 500 mL; IRV 2500–3000 mL; ERV 1000–1100 mL; RV 1100–1200 mL. Vital capacity = TV + IRV + ERV ≈ 3500–4500 mL; TLC ≈ 5000–6000 mL.

Transport

O₂: 97% bound to haemoglobin (1 g Hb binds 1.34 mL O₂), 3% dissolved. CO₂: ≈70% as bicarbonate (carbonic anhydrase in RBC), 20–25% carbamino-haemoglobin, 7% dissolved.

Control & disorders

Rhythm centre in medulla; pneumotaxic centre in pons. Asthma, emphysema (alveolar damage; smoking), occupational: silicosis, asbestosis. Right shift of the O₂ curve: ↑ pCO₂, ↑ H⁺, ↑ temperature.

■ Body Fluids & Circulation

Blood

Plasma 55%; RBC (5–5.5 million/mm³; no nucleus; life 120 days), WBC (neutrophils most, basophils least), platelets (1.5–3.5 lakh). Blood groups: A, B, AB (universal recipient), O (universal donor). Rh incompatibility: Rh[−] mother, Rh⁺ foetus (erythroblastosis fetalis).

Heart

4 chambers; SA node (pacemaker) → AV node → bundle of His → Purkinje fibres. Cardiac cycle 0.8 s; cardiac output = stroke volume × heart rate ≈ 70 mL × 72 = 5 L/min.

ECG

P wave: atrial depolarisation; QRS: ventricular depolarisation (start of systole); T wave: ventricular repolarisation. Normal BP 120/80 mm Hg; hypertension ≥ 140/90.

Lymph & disorders

Lymph returns fluids and absorbs fats; double circulation (pulmonary + systemic); hepatic portal system. Coronary artery disease (atherosclerosis), angina, heart failure ≠ cardiac arrest.

■ Excretion

Nephron

Glomerulus + Bowman's capsule (Malpighian body), PCT, loop of Henle, DCT, collecting duct. Cortical nephrons (short loop) vs juxtamedullary (long loop). GFR ≈ 125 mL/min ≈ 180 L/day; urine ≈ 1–1.5 L/day.

Regulation

Countercurrent mechanism concentrates urine. ADH: water reabsorption (deficiency → diabetes insipidus). RAAS: juxtaglomerular cells release renin → angiotensin II → aldosterone. ANF opposes it.

Disorders

Uremia → haemodialysis; renal calculi (stones); glomerulonephritis. Ammonotelic (fish), ureotelic (mammals, frog), uricotelic (birds, reptiles, insects).

■ Locomotion & Movement

Muscle contraction

Sliding filament theory (Huxley): actin slides over myosin; Ca²⁺ binds troponin; ATP for cross-bridges; sarcomere: Z to Z; I band shortens, A band constant. Red fibres (myoglobin) are slow, aerobic.

Skeleton

Adult 206 bones: skull 29, vertebral column 26, ribs 24 (12 pairs), sternum 1, limbs 118 (girdles + limbs). Joints: fibrous, cartilaginous, synovial (ball and socket, hinge, pivot, gliding, saddle).

Disorders

Myasthenia gravis (autoimmune; neuromuscular), tetany (low Ca²⁺), osteoporosis (old age, low oestrogen), arthritis, gout (uric acid crystals), muscular dystrophy.

■ Neural Control & Coordination

Neuron & impulse

Resting potential ≈ −70 mV (K⁺ leak channels; Na⁺/K⁺ pump 3 Na⁺ out, 2 K⁺ in). Action potential: depolarisation (Na⁺ in) then repolarisation (K⁺ out). Saltatory conduction in myelinated fibres is faster.

Synapse

Chemical synapse (acetylcholine, dopamine, serotonin) is one-way; electrical synapse is faster, two-way (gap junctions). Reflex arc: receptor → sensory neuron → spinal cord → motor neuron → effector.

Brain

Forebrain: cerebrum (intelligence, memory), thalamus (relay), hypothalamus (thermoregulation, hunger). Midbrain: corpora quadrigemina. Hindbrain: cerebellum (balance), pons, medulla (heart rate, respiration). Corpus callosum joins hemispheres.

Eye & ear

Eye: rods (dim light; rhodopsin), cones (colour; fovea, 3 types), blind spot, aqueous/vitreous humour. Ear: organ of Corti (cochlea) for hearing; vestibular apparatus (semicircular canals) for balance; ossicles: malleus, incus, stapes.

■ Chemical Coordination

Hypothalamus & pituitary

Hypothalamus: releasing and inhibiting hormones. Anterior pituitary: GH, PRL, TSH, ACTH, LH, FSH. Posterior: oxytocin, vasopressin (ADH) stored (made in hypothalamus). GH excess: gigantism/acromegaly; deficiency: dwarfism.

Thyroid, parathyroid, thymus

Thyroid: T₃, T₄ (iodine; goitre, cretinism), calcitonin (↓ Ca²⁺). Parathyroid: PTH (↑ Ca²⁺). Thymus: thymosin (T-cell differentiation; degenerates with age).

Adrenal & pancreas

Cortex: cortisol, aldosterone; Addison's (deficiency), Cushing's (excess). Medulla: adrenaline, noradrenaline ("fight or flight"). Pancreas: α cells glucagon ($\uparrow$ glucose), β cells insulin ($\downarrow$ glucose); diabetes mellitus.

Gonads & others

Testis: testosterone (Leydig cells). Ovary: oestrogen, progesterone. Pineal: melatonin (circadian rhythm). Heart: ANF; kidney: erythropoietin; GI hormones. Hormone action: peptide (cAMP, membrane receptor) vs steroid (intracellular receptor).

Human Reproduction

Gametogenesis

Spermatogenesis: spermatogonia $\rightarrow$ primary spermatocyte ($2n$) $\rightarrow$ secondary (n) $\rightarrow$ spermatids $\rightarrow$ sperms (spermiogenesis); GnRH, LH (Leydig), FSH (Sertoli). Oogenesis: begins in foetal life; primary oocyte arrested in prophase I until puberty; secondary oocyte arrested in metaphase II until fertilisation.

Menstrual cycle

$\approx$ 28 days; menstrual phase (1–5), follicular/proliferative, ovulation $\approx$ day 14 (LH surge), luteal/secretory (corpus luteum $\rightarrow$ progesterone). Menopause $\approx$ 50 years.

Fertilisation & pregnancy

Fertilisation in ampulla of the oviduct; cleavage $\rightarrow$ morula $\rightarrow$ blastocyst; trophoblast implants in the endometrium; placenta secretes hCG, hPL, oestrogen, progesterone; gestation $\approx$ 9 months; oxytocin for parturition; colostrum (IgA).

Reproductive Health

Contraception

Natural (periodic abstinence, coitus interruptus, lactational amenorrhoea); barrier (condoms, diaphragm, cervical caps); IUDs (Cu-T, Multiload 375, LNG-20, Lippes loop); oral pills (Saheli); surgical (vasectomy, tubectomy).

MTP & STDs

MTP legal in India (1971): up to 12 weeks (safest). STDs: gonorrhoea, syphilis, chlamydia, genital herpes, trichomoniasis, genital warts, hepatitis-B, HIV/AIDS. Amniocentesis banned for sex determination.

ART

IVF (in vitro fertilisation; embryo transfer at 8 blastomeres $\rightarrow$ ET; more than 8 $\rightarrow$ IUT), ZIFT (zygote intrafallopian transfer), GIFT (gamete intrafallopian), ICSI (sperm injected into ovum), AI/IUI (artificial/intra-uterine insemination).

Human Health & Disease

Common diseases

Typhoid: Salmonella typhi (Widal test). Pneumonia: Streptococcus/Haemophilus. Malaria: Plasmodium (female Anopheles; sporozoite; haemozoin $\rightarrow$ fever). Amoebiasis: Entamoeba (housefly). Filariasis: Wuchereria (Culex). Ascariasis. Ringworm: Trichophyton. Common cold: Rhinovirus.

Immunity

Innate (barriers, phagocytes, interferons) and acquired (primary and secondary response; memory). B-cells make antibodies (IgG, IgM, IgA, IgE: allergy); T-cells: cell-mediated; helper T cells. Active (vaccine) vs passive (antibodies, antivenom, colostrum).

HIV/AIDS

Retrovirus (ssRNA); reverse transcriptase makes cDNA; infects helper T cells (CD4) and macrophages; ELISA test; transmitted by sexual contact, blood, mother to child, needles.

Cancer & drugs

Cancer: loss of contact inhibition; oncogenes; carcinoma (epithelial), sarcoma (connective), leukaemia, lymphoma; biopsy, CT, MRI; chemotherapy. Opioids (heroin, morphine), cannabinoids (marijuana), coca alkaloids (cocaine), nicotine, alcohol.

Genetics & Evolution

Principles of Inheritance

Mendel's laws

Dominance; segregation (purity of gametes); independent assortment. Monohybrid F_2 : 3:1 (phenotype), 1:2:1 (genotype). Dihybrid: 9:3:3:1. Test cross: 1:1 (monohybrid), 1:1:1:1 (dihybrid).

Deviations

Incomplete dominance (Mirabilis, snapdragon): 1:2:1. Codominance and multiple alleles: ABO (I^A , I^B codominant over i). Pleiotropy: sickle cell. Polygenic: skin colour, height.

Linkage & sex determination

Morgan (Drosophila): linked genes show less recombination. XX-XY (humans, Drosophila), XX-XO (grasshopper), ZZ-ZW (birds). In humans sex is determined by the sperm.

Genetic disorders

Autosomal recessive: sickle cell (Glu $\rightarrow$ Val, 6th position of β -globin), thalassemia, phenylketonuria. X-linked recessive: haemophilia, colour blindness. Chromosomal: Down (trisomy 21), Klinefelter (XXY), Turner (XO).

Molecular Basis of Inheritance

DNA structure

Watson-Crick double helix; antiparallel; A=T (2 H-bonds), G=C (3); pitch 3.4 nm, 10 bp per turn, 0.34 nm per bp. Chargaff: A = T, G = C. Nucleosome: DNA on 8 histones (H2A, H2B, H3, H4 $\times$ 2); histones are basic.

Genetic material

Griffith (transformation, Streptococcus); Avery, MacLeod, McCarty (DNA is the transforming principle); Hershey-Chase (bacteriophage, ^{32}P DNA; ^{35}S protein).

Replication

Semi-conservative (Meselson-Stahl, ^{15}N). 5' $\rightarrow$ 3' synthesis; leading strand continuous, lagging strand as Okazaki fragments (DNA ligase). Origin of replication; DNA polymerase III; primase.

Transcription

RNA polymerase (3 types in eukaryotes: I rRNA, II mRNA, III tRNA); template strand 3' $\rightarrow$ 5'. Processing of hnRNA: splicing (introns removed), capping (5'), tailing (poly-A at 3').

Genetic code

Triplet; 64 codons: 61 sense, 3 stop (UAA, UAG, UGA); AUG start (Met); degenerate, unambiguous, universal, non-overlapping, comma-less. Khorana, Nirenberg, Ochoa.

Translation & lac operon

Ribosome (large + small subunit), tRNA with anticodon, peptidyl transferase (a ribozyme). Lac operon (Jacob and Monod): repressor binds operator; lactose/allolactose (inducer) lifts repression; z, y, a genes: β -galactosidase, permease, transacetylase.

HGP & fingerprinting

Human Genome Project (1990–2003): $\approx 3 \times 10^9$ bp, $\approx 30,000$ genes, chromosome 1 has most genes; SNPs; bioinformatics. DNA fingerprinting (Alec Jeffreys): VNTR polymorphism; uses RFLP, electrophoresis, Southern blot.

■ Evolution

Origin of life

Oparin–Haldane: chemical evolution in the primitive atmosphere; Miller (1953): CH_4 , NH_3 , H_2 , water vapour at 800°C with sparks $\rightarrow$ amino acids. Earliest cells: anaerobic, heterotrophic.

Evidences

Homologous organs (divergent evolution; forelimbs of vertebrates), analogous organs (convergent; wings of bird and insect), vestigial organs, fossils, biogeography, industrial melanism (Biston betularia).

Theories

Lamarck: use and disuse. Darwin: natural selection, struggle for existence, variations, fitness. De Vries: mutation theory (saltation). Adaptive radiation: Darwin's finches, Australian marsupials.

Hardy–Weinberg

$p + q = 1$; $p^2 + 2pq + q^2 = 1$; allele frequency stays constant unless: mutation, gene flow, genetic drift, non-random mating, selection. Founder effect; bottleneck.

Human evolution

Dryopithecus (ape-like) $\rightarrow$ Ramapithecus (man-like) $\rightarrow$ Australopithecus $\rightarrow$ Homo habilis (≈ 650 – 800 cc) $\rightarrow$ H. erectus (≈ 900 cc) $\rightarrow$ Neanderthal (≈ 1400 cc) $\rightarrow$ H. sapiens (≈ 1350 cc).

Biotechnology, Ecology & Environment

■ Biotechnology

Tools

Restriction endonucleases (EcoRI cuts $\text{G}\downarrow\text{AATTC}$; palindromic; sticky ends), ligase, vectors (pBR322: ori, amp^R , tet^R , rop; Ti plasmid for plants), competent host (CaCl_2 heat shock).

PCR & electrophoresis

PCR: denaturation 94°C , annealing (primers) 54°C , extension 72°C with Taq polymerase (Thermus aquaticus). Gel electrophoresis: DNA is negative, moves to anode; ethidium bromide + UV shows bands.

Applications

Bt cotton (Cry genes from Bacillus thuringiensis; Cry1Ac vs bollworm). RNAi (Meloidogyne in tobacco). Humulin: E. coli, A and B chains (Eli Lilly, 1983). Gene therapy: first for ADA deficiency (1990). Golden rice: vitamin A.

Bioethics

GEAC (Genetic Engineering Approval Committee) decides safety; biopiracy (patents on Basmati, neem, turmeric); transgenic animals, molecular diagnosis (ELISA, PCR).

■ Microbes & Food Production

Microbes in welfare

Curd: Lactobacillus (LAB); bread: Saccharomyces; Swiss cheese: Propionibacterium (CO_2 holes); acetic acid: Acetobacter aceti; butyric: Clostridium butylicum; citric: Aspergillus niger; lactic: Lactobacillus.

Bioactive molecules

Penicillin (Penicillium notatum; Fleming, Chain, Florey); cyclosporin A (Trichoderma polysporum; immunosuppressant); statins (Monascus purpureus; cholesterol); streptokinase (Streptococcus; clot buster).

Sewage & biogas

Primary (physical) and secondary (biological; flocs) treatment; BOD reduced. Biogas: Methanobacterium (methanogens) on cattle dung; mainly CH_4 (IARI, KVIC).

Biocontrol & biofertilisers

Bacillus thuringiensis, Trichoderma, Baculovirus (Nucleopolyhedrovirus) for pests. Biofertilisers: Rhizobium, Azospirillum, Azotobacter, Anabaena, Nostoc, mycorrhiza (Glomus; phosphate uptake).

Food production

Tissue culture: totipotency; meristem culture gives virus-free plants; somatic hybrids (protoplast fusion; pomato). SCP: Spirulina. Apiculture; dairy: Jersey, Holstein; fisheries; MOET. Green revolution: Norman Borlaug.

■ Ecology

Population

Growth: exponential $\frac{dN}{dt} = rN$; logistic $\frac{dN}{dt} = rN \left(\frac{K - N}{K} \right)$. Natality, mortality, immigration, emigration. Age pyramids: expanding, stable, declining.

Interactions

Mutualism (+ +; lichen, mycorrhiza), competition (– –; Gause's principle), predation (+ –), parasitism (+ –), commensalism (+ 0; orchid on mango), amensalism (– 0).

Ecosystem

GPP – respiration = NPP; Lindeman's 10% law; grazing food chain vs detritus food chain; pyramids of number, biomass (can be inverted in sea), energy (always upright). Decomposition: fragmentation $\rightarrow$ leaching $\rightarrow$ catabolism $\rightarrow$ humification $\rightarrow$ mineralisation.

Succession & cycles

Primary (lithosere, hydrosere: bare rock / water), secondary (faster). Climax community. Carbon cycle ($\approx 4 \times 10^{13}$ kg/yr fixed), phosphorus (no gaseous phase), nitrogen cycle.

■ Biodiversity & Environmental Issues

Biodiversity

Genetic, species, ecological. Species–area: $\log S = \log C + Z \log A$ ($Z \approx 0.1$ – 0.2). Hotspots: 34 worldwide; India: Western Ghats–Sri Lanka, Indo-Burma, Himalaya. Latitudinal gradient: richest in tropics.

Extinction & conservation

"Evil quartet": habitat loss, over-exploitation, alien species invasion, co-extinctions. In situ: national parks, sanctuaries, biosphere reserves, sacred groves. Ex situ: zoos, botanical gardens, gene banks, cryopreservation.

Pollution & protocols

Electrostatic precipitator removes particulates (99%); catalytic converter ($\text{CO} \rightarrow \text{CO}_2$; unleaded petrol). Montreal (1987, ozone), Kyoto (1997, greenhouse gases). Eutrophication, biomagnification (DDT), Ramsar, Chipko, Joint Forest Management.

