

BOTANY

+2 2nd Year (Class XII) · Study Notes

7 chapters · theory in simple words · key terms · exam Q&A

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How to use: read the box "In simple words" first, then the main points. Learn the key terms, then try each exam question yourself before reading the model answer. Diagrams named in the notes should be practised from your textbook.

Chapter 1. Sexual Reproduction in Flowering Plants

In simple words: The flower is the reproductive part of a plant. Pollen grains (made in the anther) carry the male gametes to the female part (pistil). After pollination and fertilisation, the ovule becomes the seed and the ovary becomes the fruit.

Male part: stamen

- A stamen has a filament and an **anther**. A typical anther is bilobed and **tetrasporangiate** (four microsporangia).
- Microsporangium wall layers: epidermis, endothecium, middle layers and **tapetum** (innermost, nourishes the developing pollen).
- **Microsporogenesis:** each microspore mother cell ($2n$) undergoes meiosis to form a tetrad of four microspores (n), which become pollen grains.
- A pollen grain has a hard outer wall, the **exine**, made of **sporopollenin** (the most resistant organic material known), with germ pores; and a thin inner wall, the **intine**.
- A mature pollen grain has a vegetative cell and a generative cell; the generative cell forms two male gametes.

Female part: pistil and ovule

- The pistil has stigma, style and ovary. The ovary contains ovules.
- An ovule has a stalk (funicle), integuments, a micropyle, the **nucellus** and the **embryo sac**.
- **Megasporogenesis:** the megaspore mother cell ($2n$) divides by meiosis into four megaspores; usually only one is functional.
- **Embryo sac (female gametophyte):** 7-celled and 8-nucleate — an egg apparatus (egg + two synergids) at the micropylar end, three antipodals at the other end, and a large central cell with two polar nuclei. This is the Polygonum type, the most common.

Pollination

- **Autogamy** (same flower) — cleistogamous flowers never open (Viola, Oxalis, Commelina). **Geitonogamy** (another flower on the same plant). **Xenogamy** (flower of another plant — cross-pollination).
- Agents: wind (light, dry pollen, feathery stigma — maize, grasses), water (Vallisneria, Hydrilla, Zostera) and insects and other animals (colourful, scented flowers with nectar).
- Outbreeding devices prevent self-pollination: pollen and stigma ready at different times, different positions, self-incompatibility, and unisexual flowers (papaya: male and female plants are separate).
- **Pollen–pistil interaction:** the pistil recognises compatible pollen and accepts it, or rejects incompatible pollen.

Double fertilisation

- The pollen tube enters the ovule through the micropyle and releases two male gametes into a synergid.
- One male gamete fuses with the egg → **zygote ($2n$)** — **syngamy**.
- The other fuses with the two polar nuclei → **primary endosperm nucleus ($3n$)** — **triple fusion**.
- Syngamy and triple fusion together are called **double fertilisation**, found only in flowering plants.

After fertilisation

- **Endosperm ($3n$)** develops first and nourishes the embryo. In coconut, the water is free-nuclear endosperm and the white kernel is cellular endosperm.
- **Embryo:** a dicot embryo has two cotyledons; a monocot embryo has one cotyledon called the **scutellum**.

- Seeds can be **albuminous** (endosperm remains: wheat, maize, castor) or **non-albuminous** (endosperm used up: pea, groundnut). Perisperm (left-over nucellus) is found in black pepper and beet.
- Ovary → fruit; ovule → seed. A **false fruit** develops from other parts too (apple, strawberry, cashew). **Parthenocarpic fruit** forms without fertilisation (banana — seedless).
- **Apomixis**: seeds formed without fertilisation (some grasses, Asteraceae). **Polyembryony**: more than one embryo in a seed (citrus, mango).

Exam questions

Q. What is double fertilisation?

The fusion of one male gamete with the egg (syngamy) and the second male gamete with the two polar nuclei (triple fusion) in the same embryo sac. It forms the zygote and the primary endosperm nucleus.

Q. Why is the pollen grain wall so resistant?

Its exine is made of sporopollenin, which withstands high temperature, strong acids and alkalis, and is not broken down by any known enzyme. That is why pollen survives as fossils.

Q. What is the ploidy of the endosperm? Why?

Triploid ($3n$), because it forms from the fusion of one male gamete (n) with two polar nuclei ($n + n$).

Q. Distinguish between geitonogamy and xenogamy.

In geitonogamy pollen reaches the stigma of another flower on the same plant (genetically like self-pollination). In xenogamy pollen comes from a different plant, giving genetic variation.

Chapter 2. Principles of Inheritance and Variation

In simple words: Offspring resemble their parents because genes are passed on in a regular way. Mendel worked out the basic rules by crossing pea plants. Later, scientists showed that genes lie on chromosomes and that changes in genes or chromosomes cause variation and genetic disorders.

Mendel's experiments

- Gregor Mendel worked on the garden pea (*Pisum sativum*) for about 7 years (1856–1863) and studied **7 pairs of contrasting characters** (e.g. tall/dwarf, round/wrinkled seed, yellow/green seed).
- Peas suit genetics: many clear contrasting traits, self-pollination, easy cross-pollination, short life and many seeds.

Monohybrid cross

- Tall (TT) × dwarf (tt) → F₁ all tall (Tt). Selfing F₁ → F₂ phenotypic ratio **3 : 1** (tall : dwarf) and genotypic ratio **1 : 2 : 1** (TT : Tt : tt).
- Law of dominance:** in a heterozygote, only the dominant trait shows.
- Law of segregation:** the two alleles of a gene separate during gamete formation, so each gamete gets only one allele.
- Test cross:** crossing an F₁ or unknown dominant plant with a homozygous recessive. A 1 : 1 result shows the plant was heterozygous.

Exceptions to dominance

Incomplete dominance	F ₁ shows an intermediate trait. Snapdragon / <i>Mirabilis</i> : red × white → pink; F ₂ ratio 1 red : 2 pink : 1 white.
Co-dominance	Both alleles show fully. ABO blood group: I ^A and I ^B are co-dominant, giving group AB; i is recessive.
Multiple alleles	More than two alleles of one gene in a population. ABO blood group has three: I ^A , I ^B , i.
Pleiotropy	One gene affects many traits. Example: phenylketonuria.

Dihybrid cross

- Round yellow (RRYY) × wrinkled green (rryy) → F₁ all round yellow. F₂ phenotypic ratio **9 : 3 : 3 : 1**.
- Law of independent assortment:** alleles of different genes separate independently of each other during gamete formation.

Chromosomal theory and linkage

- Sutton and Boveri** proposed that chromosomes carry genes and their behaviour in meiosis explains Mendel's laws.
- Morgan** worked on fruit flies (*Drosophila*). Genes on the same chromosome tend to be inherited together (**linkage**); crossing over creates new combinations (**recombination**). Sturtevant used recombination frequency to map genes.

Sex determination

- Humans: XX female, XY male — the father decides the sex of the child.
- Grasshopper: XX female, XO male. Birds: ZW female, ZZ male. Honey bee: males develop from unfertilised eggs (haploid, n = 16); females from fertilised eggs (diploid) — haplodiploidy.

Mutation and genetic disorders

- **Mutation:** a sudden change in DNA. Point mutation in sickle-cell anaemia: glutamic acid is replaced by valine at the 6th position of the β -globin chain (GAG $\rightarrow$ GUG).
- **Pedigree analysis** follows a trait through generations of a family.

Haemophilia	Sex-linked recessive; blood does not clot properly. Women are usually carriers; mostly sons are affected.
Colour blindness	Sex-linked recessive; cannot tell red from green.
Sickle-cell anaemia	Autosomal recessive; RBCs become sickle-shaped at low oxygen.
Phenylketonuria	Autosomal recessive; phenylalanine cannot be converted, leading to mental retardation.
Thalassaemia	Autosomal recessive; reduced synthesis of globin chains, leading to anaemia.
Down's syndrome	Trisomy of chromosome 21 (47 chromosomes); short stature, mental retardation.
Klinefelter's syndrome	47, XXY male; sterile, some female features.
Turner's syndrome	45, XO female; sterile, rudimentary ovaries.

Exam questions

Q. State Mendel's law of segregation.

The two alleles of a gene separate during gamete formation, so that each gamete receives only one allele of each gene.

Q. Why is the F_2 ratio of a snapdragon flower-colour cross 1 : 2 : 1?

Because red and white show incomplete dominance. The heterozygote (Rr) is pink, so each genotype has its own phenotype: 1 red : 2 pink : 1 white.

Q. Why is haemophilia more common in males?

The gene is on the X chromosome and is recessive. Males have only one X, so one faulty allele causes the disease; females need two faulty alleles and are usually only carriers.

Q. What is a test cross?

A cross between an individual with the dominant phenotype and a homozygous recessive individual, done to find out whether the first one is homozygous or heterozygous.

Chapter 3. Molecular Basis of Inheritance

In simple words: DNA is the genetic material. Its double helix copies itself before cell division (replication). Genes in DNA are copied into RNA (transcription), and RNA is read in groups of three bases (codons) to build proteins (translation).

Structure of DNA

- DNA is a polymer of nucleotides. Each nucleotide = a nitrogen base + deoxyribose sugar + phosphate.
- Bases: purines — adenine (A), guanine (G); pyrimidines — cytosine (C), thymine (T). RNA has uracil (U) instead of thymine.
- **Watson and Crick (1953)** proposed the double helix, based on X-ray pictures by Wilkins and Franklin. The two strands are **antiparallel** and held by hydrogen bonds: A=T (two bonds), G≡C (three bonds).
- **Chargaff's rule:** in double-stranded DNA, A = T and G = C, so purines = pyrimidines.
- One turn of the helix is 3.4 nm long with about 10 base pairs (0.34 nm between pairs).
- In eukaryotes DNA is wound around histone proteins to form **nucleosomes** (about 200 bp each) — "beads on a string".

DNA is the genetic material

- **Griffith (1928):** a "transforming principle" from heat-killed virulent (S) *Streptococcus pneumoniae* changed harmless R bacteria into virulent ones.
- **Avery, MacLeod and McCarty:** showed the transforming principle is DNA.
- **Hershey and Chase (1952):** using bacteriophages with radioactive ^{32}P (DNA) and ^{35}S (protein), showed that DNA, not protein, enters bacteria — proof that DNA is the genetic material.
- RNA is the genetic material in some viruses (e.g. TMV). RNA was probably the first genetic material, but DNA is more stable.

Replication

- **Semi-conservative:** each new DNA molecule has one old strand and one new strand. Proved by **Meselson and Stahl (1958)** using heavy nitrogen (^{15}N) in *E. coli*.
- Main enzyme: **DNA polymerase** (works only 5' → 3'). Replication occurs at the replication fork; the leading strand is continuous, the lagging strand is made in short **Okazaki fragments** joined by **DNA ligase**.

Transcription

- Copying DNA into RNA by **RNA polymerase**. A transcription unit has a promoter, the structural gene and a terminator.
- In eukaryotes the first RNA (hnRNA) is processed: **splicing** removes introns and joins exons, a cap (methyl guanosine) is added at the 5' end and a poly-A tail at the 3' end.
- Types of RNA: mRNA (carries the code), tRNA (brings amino acids, has the anticodon), rRNA (structural and catalytic part of ribosomes).

Genetic code and translation

- The code is a **triplet**: 64 codons; 61 code for amino acids; 3 are stop codons (UAA, UAG, UGA). **AUG** is the start codon (methionine).
- The code is **universal** (nearly), **degenerate** (one amino acid can have several codons), **unambiguous** and read without commas.
- **Translation** happens on ribosomes: initiation, elongation (peptide bonds formed) and termination.

Gene regulation: the lac operon

- Proposed by **Jacob and Monod** in *E. coli*. Genes: *i* (regulator, makes the repressor), and structural genes *z* (β -galactosidase), *y* (permease) and *a* (transacetylase).
- Without lactose, the repressor binds the operator and blocks transcription. When lactose (the **inducer**) is present, it binds the repressor and frees the operator, so the genes are transcribed. This is **negative regulation**.

Human Genome Project and DNA fingerprinting

- The Human Genome Project (1990–2003) found the human genome has about **3×10^9 bp** and about 20 000–25 000 genes. Less than 2% of the genome codes for proteins.
- DNA fingerprinting** (Alec Jeffreys) compares repetitive DNA (VNTRs) between people. Used in forensic cases, paternity disputes and studying populations.

Exam questions

Q. What is meant by semi-conservative replication? Who proved it?

Each daughter DNA keeps one strand of the parent molecule and makes one new strand. Meselson and Stahl proved it using ^{15}N -labelled *E. coli*.

Q. What are Okazaki fragments?

Short pieces of DNA made on the lagging strand during replication, because DNA polymerase works only in the $5' \rightarrow 3'$ direction. DNA ligase joins them.

Q. Name the three stop codons and the start codon.

Stop codons: UAA, UAG and UGA. Start codon: AUG, which also codes for methionine.

Q. How did Hershey and Chase prove DNA is the genetic material?

Phages with ^{32}P -labelled DNA passed the radioactivity into bacteria, while ^{35}S -labelled protein stayed outside. So DNA, not protein, carries the hereditary information.

Chapter 4. Microbes in Human Welfare

In simple words: Microbes are not only germs — many are very useful. They give us curd, bread and cheese, antibiotics and enzymes, clean sewage, make biogas, and help farmers as biofertilisers and biocontrol agents.

In household products

- **Lactobacillus** (lactic acid bacteria, LAB) turns milk into curd and increases its vitamin B₁₂.
- Dough for bread, dosa and idli is fermented by bacteria and yeast; **Saccharomyces cerevisiae** (baker's yeast) makes bread rise with CO₂.
- **Propionibacterium sharmanii** makes the large holes in Swiss cheese; Roquefort cheese is ripened by fungi.

In industrial products

- Alcoholic drinks: yeast (*S. cerevisiae* — brewer's yeast). Wine and beer are not distilled; whisky, brandy and rum are distilled.
- **Antibiotics:** penicillin was the first, discovered by **Alexander Fleming** from *Penicillium notatum*. Its full value was shown by Chain and Florey.

Citric acid	<i>Aspergillus niger</i> (fungus).
Acetic acid	<i>Acetobacter aceti</i> (bacterium).
Butyric acid	<i>Clostridium butylicum</i> (bacterium).
Lactic acid	<i>Lactobacillus</i> (bacterium).
Streptokinase	<i>Streptococcus</i> ; a "clot buster" that removes clots in blood vessels of heart-attack patients.
Cyclosporin A	<i>Trichoderma polysporum</i> ; immunosuppressant used in organ transplants.
Statins	<i>Monascus purpureus</i> (yeast); lower blood cholesterol.
Lipases	Used in detergents to remove oily stains.

- Pectinases and proteases are used to clear fruit juices.

In sewage treatment

- **Primary treatment:** physical removal of floating debris and grit by filtration and sedimentation.
- **Secondary (biological) treatment:** aeration lets aerobic microbes form **flocs** and use up organic matter, reducing **BOD** (biochemical oxygen demand). The settled sludge (activated sludge) is digested by anaerobic bacteria, producing biogas.
- High BOD means the water is heavily polluted with organic matter.

Biogas

- Mainly **methane** with CO₂ and H₂. Made by **methanogens** such as *Methanobacterium*, which also live in the rumen of cattle.
- Cattle dung (gobar) is used in biogas plants; technology developed in India by IARI and KVIC.

Biocontrol and biofertilisers

- Biocontrol agents: ladybird beetles (eat aphids), dragonflies (eat mosquitoes), **Bacillus thuringiensis** (kills caterpillars), **Trichoderma** (fungus controlling plant pathogens), **baculoviruses**

(Nucleopolyhedrovirus — narrow-spectrum insecticide).

- Biofertilisers: **Rhizobium** (root nodules of legumes, fixes N_2), Azotobacter and Azospirillum (free-living), **mycorrhiza** (fungi such as Glomus with plant roots, help absorb phosphorus), **cyanobacteria** (Anabaena, Nostoc, Oscillatoria — important in paddy fields).

Exam questions

Q. What is BOD? Why is it important?

Biochemical oxygen demand is the amount of oxygen used up if all the organic matter in one litre of water were oxidised by bacteria. Higher BOD means more polluted water, so it measures the strength of sewage.

Q. Why are cyanobacteria useful in paddy fields?

Cyanobacteria such as Anabaena and Nostoc fix atmospheric nitrogen and add organic matter, increasing soil fertility for rice.

Q. Name a microbe used for making (a) citric acid and (b) statins.

(a) Aspergillus niger. (b) Monascus purpureus.

Q. What are methanogens?

Anaerobic bacteria (e.g. Methanobacterium) that produce methane from cellulose-rich material. They are used in biogas plants and live in the rumen of cattle.

Chapter 5. Organisms and Populations

In simple words: Ecology studies how living things interact with each other and with their surroundings. A population is a group of the same species in an area. It grows or shrinks depending on births, deaths and movement, and different species affect each other in many ways.

Organism and its environment

- Major abiotic factors: **temperature, water, light** and **soil**.
- **Eurythermal** organisms tolerate a wide range of temperature; **stenothermal** ones a narrow range. Similarly, euryhaline and stenohaline for salt.
- Responses to stress: **regulate** (keep internal conditions constant — birds and mammals), **conform** (body follows the surroundings — most animals and plants), **migrate** (Siberian birds come to Chilika lake in Odisha in winter), or **suspend** activity (hibernation, aestivation, diapause, seed dormancy).

Adaptations

- Desert plants: thick cuticle, sunken stomata, CAM photosynthesis (stomata open at night), leaves reduced to spines (Opuntia).
- Kangaroo rat meets its water needs by oxidising fats (metabolic water) and makes very concentrated urine.
- **Allen's rule:** mammals in cold climates have shorter ears and limbs to reduce heat loss.
- At high altitude, the body makes more RBCs and raises breathing rate (altitude sickness at first).

Population attributes

- Birth rate (natality), death rate (mortality), sex ratio and **age pyramids** (expanding/triangular = growing, bell-shaped = stable, urn-shaped = declining).
- Population size changes by: natality (+), immigration (+), mortality (−), emigration (−).

Population growth

- **Exponential growth:** $dN/dt = rN$, gives a **J-shaped** curve when resources are unlimited.
- **Logistic growth:** $dN/dt = rN (K - N)/K$, gives an **S-shaped (sigmoid)** curve. **K** is the **carrying capacity** — the maximum population the environment can support. This model is more realistic.
- r = intrinsic rate of natural increase.

Population interactions

Mutualism (+ +)	Both benefit. Lichens (fungus + alga); mycorrhiza; fig and fig wasp; orchid Ophrys and bee.
Competition (− −)	Both are harmed. Gause's competitive exclusion principle: two closely related species competing for the same resource cannot live together forever.
Predation (+ −)	One eats the other; keeps prey populations in check. Example: tiger and deer.
Parasitism (+ −)	Parasite benefits, host is harmed. Example: Cuscuta on plants (no chlorophyll), lice, tapeworm. Brood parasitism: the cuckoo lays eggs in the crow's nest.
Commensalism (+ 0)	One benefits, the other is unaffected. Orchid growing on a mango branch; barnacles on a whale; cattle egret and grazing cattle.
Amensalism (− 0)	One is harmed, the other is unaffected. Example: Penicillium inhibiting bacteria.

Exam questions

Q. Distinguish between exponential and logistic growth.

Exponential growth happens when resources are unlimited and gives a J-shaped curve. Logistic growth happens when resources are limited; growth slows as the population nears the carrying capacity (K), giving an S-shaped curve.

Q. What is brood parasitism? Give an example.

A parasite bird lays its eggs in the nest of a host bird, which then raises the young. The cuckoo (koel) lays its eggs in the crow's nest.

Q. State Gause's competitive exclusion principle.

Two closely related species competing for the same limited resource cannot coexist indefinitely; the competitively weaker one is eventually eliminated.

Chapter 6. Ecosystem

In simple words: An ecosystem is a living community together with its physical surroundings, working as one unit. Energy enters as sunlight, flows one way through food chains, and is lost as heat at each step, while nutrients are recycled.

Structure and function

- Components: **producers** (green plants), **consumers** (herbivores, carnivores), **decomposers** (bacteria, fungi) and the abiotic environment.
- **Stratification:** vertical layering of plants in a forest — trees on top, then shrubs, then herbs and grasses.

Productivity

- **Gross primary productivity (GPP):** the rate of production of organic matter by photosynthesis.
- **Net primary productivity (NPP) = GPP – R** (respiration losses). NPP is the food available to consumers.
- Secondary productivity is the rate at which consumers form new organic matter.

Decomposition

- Steps: **fragmentation** (by detritivores like earthworms), **leaching** (soluble nutrients go into the soil), **catabolism** (by bacterial and fungal enzymes), **humification** (forming dark humus) and **mineralisation** (release of inorganic nutrients).
- Decomposition is faster in warm, moist conditions and with detritus rich in nitrogen and sugars; slower with lignin and chitin.

Energy flow

- Only a small part (about 2–10%) of incident sunlight (photosynthetically active radiation, PAR) is captured by plants.
- **10 percent law (Lindeman):** only about 10% of the energy at one trophic level is passed to the next. So food chains are short (usually 3–4 levels).
- **Grazing food chain** starts from green plants; **detritus food chain** starts from dead organic matter and carries more energy in many ecosystems (e.g. forests).
- Food chains interconnect to form a **food web**.

Ecological pyramids

- **Pyramid of numbers:** upright in grassland; inverted for a tree (one tree supports many insects).
- **Pyramid of biomass:** usually upright; **inverted in the sea** (small phytoplankton biomass supports larger fish biomass).
- **Pyramid of energy:** always upright, because energy is lost at every level.

Ecological succession

- Gradual, predictable change in a community until a stable **climax community** forms.
- **Primary succession:** starts on bare areas with no soil (bare rock, new lava). On rock, **lichens** are pioneers; they release acids that break the rock into soil. It is slow.
- **Secondary succession:** starts where the community was destroyed but soil remains (abandoned farm, burnt forest). It is faster.
- Hydrarch succession begins in water; xerarch succession begins in dry areas; both lead to a mesic (medium-moisture) climax.

Nutrient cycles

- **Carbon cycle:** gaseous cycle; about 71% of carbon is dissolved in the oceans. Burning fossil fuels and deforestation add CO₂ to the air.
- **Phosphorus cycle:** sedimentary cycle; rocks are the main reservoir; there is no significant exchange with the atmosphere.

Exam questions

Q. Why is the pyramid of energy always upright?

At each trophic level some energy is lost as heat and in life activities, so less energy is available at every higher level. Energy can never increase going up.

Q. Distinguish between primary and secondary succession.

Primary succession starts on a bare area with no soil, such as bare rock, and is very slow. Secondary succession starts where soil is already present after the earlier community was destroyed, and is faster.

Q. Why does the pyramid of biomass in the sea appear inverted?

The small biomass of phytoplankton at any one time supports a larger biomass of zooplankton and fish, because phytoplankton multiply very quickly.

Q. What is NPP?

Net primary productivity: the organic matter left after producers use some for respiration ($NPP = GPP - R$). It is the food available to herbivores and decomposers.

Chapter 7. Biodiversity and Conservation

In simple words: Biodiversity is the variety of life — genes, species and ecosystems. India is one of the world's richest countries in biodiversity, but habitat loss and other human activities are causing species to disappear. Conservation protects them.

Levels of biodiversity

- **Genetic diversity:** variation within a species, e.g. the medicinal plant *Rauwolfia vomitoria* in the Himalayas; India has more than 50 000 strains of rice and about 1000 varieties of mango.
- **Species diversity:** the number of species, e.g. the Western Ghats have more amphibian species than the Eastern Ghats.
- **Ecological diversity:** variety of ecosystems — deserts, rain forests, mangroves, coral reefs, wetlands, estuaries, alpine meadows.

Biodiversity on Earth and in India

- About 1.5 million species have been described; estimates of the total range up to about 7 million (Robert May's estimate).
- More than 70% of all recorded species are animals; insects are the largest group.
- India has only 2.4% of the world's land area but about **8.1%** of global species diversity — it is one of the 12 **mega-diversity** countries.

Patterns of biodiversity

- Diversity generally **decreases from the equator to the poles**. Tropical regions are richer because they have remained relatively undisturbed for millions of years, have stable climates and receive more solar energy.
- **Species–area relationship (Alexander von Humboldt):** species richness increases with area, up to a limit. $\log S = \log C + Z \log A$; Z is usually 0.1–0.2.
- **Rivet popper hypothesis (Paul Ehrlich):** each species is like a rivet in an aeroplane; losing more and more species weakens the ecosystem.

Loss of biodiversity

- Recent extinctions: dodo (Mauritius), quagga (Africa), thylacine (Australia), Steller's sea cow (Russia), and three subspecies of tiger (Bali, Javan, Caspian).
- Causes — the **"Evil Quartet"**: habitat loss and fragmentation (the main cause), over-exploitation, alien species invasion (Parthenium, Lantana, water hyacinth; Nile perch in Lake Victoria), and co-extinctions (a host and its parasite die out together).

Conservation

- Reasons to conserve: narrowly utilitarian (food, medicines, timber), broadly utilitarian (ecosystem services — the Amazon forest produces a large share of Earth's oxygen; pollination) and ethical.
- **In situ conservation** (in natural habitat): national parks, wildlife sanctuaries, biosphere reserves, sacred groves (Khasi and Jaintia hills, Western Ghats, Aravalli), and **biodiversity hotspots** (India has Western Ghats and Sri Lanka, Indo-Burma and the Himalaya).
- **Ex situ conservation** (outside natural habitat): zoos, botanical gardens, wildlife safari parks, seed banks, cryopreservation of gametes, tissue culture.
- **Earth Summit (Rio de Janeiro, 1992):** the Convention on Biological Diversity. **World Summit on Sustainable Development (Johannesburg, 2002).**

Exam questions

Q. What is the "Evil Quartet"?

The four main causes of biodiversity loss: habitat loss and fragmentation, over-exploitation, alien species invasion, and co-extinctions.

Q. Why are tropical regions richer in species?

They have stayed relatively undisturbed for millions of years, have a stable, predictable climate, and receive more solar energy, which supports higher productivity.

Q. Distinguish between in situ and ex situ conservation.

In situ conservation protects species in their natural habitat (national parks, sanctuaries, biosphere reserves). Ex situ conservation protects them outside their habitat (zoos, botanical gardens, seed banks).

Q. Explain the rivet popper hypothesis.

Paul Ehrlich compared an ecosystem to an aeroplane and species to its rivets. Losing a few rivets may not matter, but as more are lost the plane — like the ecosystem — becomes dangerously weak.