# UP Board 12 Biology (348- GM) Question Paper with Solutions

| Time Allowed : 3 hours | Maximum Marks : 70 | Total questions : 33 |
|---|---|---|

## General Instructions

**Read the following instructions very carefully and strictly follow them:**

1. **All questions are compulsory.**
2. **Illustrate your answers with labeled diagrams, wherever necessary.**
3. **Marks allotted to each question are mentioned against it.**

## Multiple Choice Type Questions

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**1. (a) The cells of endosperm are:**

(1) Haploid

(2) Diploid

(3) Triploid

(4) Tetraploid

**Correct Answer:** (3) Triploid

**Solution:**

In flowering plants (angiosperms), endosperm forms after double fertilization when one sperm fuses with two polar nuclei.

This produces a primary endosperm nucleus with three haploid sets of chromosomes (3n), so endosperm cells are triploid.

> **Quick Tip**
>
> Double fertilization gives two products: zygote (2n) and endosperm (3n).

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**1. (b) The number of chromosomes in male drone of honeybee is:**

(1) 32

(2) 64

(3) 8

(4) 16

**Correct Answer:** (4) 16

**Solution:**

Drones arise by parthenogenesis and are haploid.

In honeybees, females (workers/queen) are diploid with 2n = 32, so males have n = 16 chromosomes.

> **Quick Tip**
>
> Haplodiploidy rule: males haploid (n=16), females diploid (2n=32).

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**1. (c) The genetic substance of virus is:**

(1) DNA or RNA

(2) only RNA

(3) only DNA

(4) None of these

**Correct Answer:** (1) DNA or RNA

**Solution:**

Viruses contain a single type of nucleic acid as genetic material—either DNA or RNA, not both.

Examples: T4 bacteriophage (DNA virus); influenza and HIV (RNA viruses).

> **Quick Tip**
>
> Think "either–or": a virus carries one nucleic acid—DNA or RNA.

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**1. (d) Congenital metabolic disorder is:**

(1) Phenylketonuria

(2) Colourblindness

(3) Haemophilia

(4) Anaemia

**Correct Answer:** (1) Phenylketonuria

**Solution:**

Phenylketonuria (PKU) is an inborn error of metabolism due to deficiency of phenylalanine hydroxylase, causing toxic accumulation of phenylalanine.

Colourblindness and haemophilia are X-linked genetic disorders but not primarily metabolic; anaemia is a condition with many causes, not a specific congenital metabolic defect.

> **Quick Tip**
>
> "Inborn error of metabolism" usually points to enzyme deficiency disorders such as PKU.

## Very Short Answer Type Questions

**2. (a) Write the zoological name of the causative agent of Filaria disease.**

**Solution:**

Lymphatic filariasis is primarily caused by the nematode *Wuchereria bancrofti*. In some regions, related species *Brugia malayi* and *Brugia timori* also infect humans. Adult worms lodge in lymphatic vessels, producing inflammation and obstruction that can lead to lymphoedema and elephantiasis if untreated or recurrently infected.

> **Quick Tip**
>
> Remember: *Wuchereria bancrofti* is the most common human filarial worm worldwide.

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**2. (b) Write any one difference between DNA and RNA.**

**Solution:**

Key difference: DNA contains the sugar deoxyribose and the base thymine (T), while RNA contains ribose and uracil (U) instead of thymine. Consequently, DNA is generally double-stranded and stable for long-term genetic storage; RNA is usually single-stranded, less stable, and primarily functions in protein synthesis.

> **Quick Tip**
>
> Sugar-base pair: Deoxyribose+Thymine (DNA) vs Ribose+Uracil (RNA).

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**2. (c) Name any two biodiversity hot spots.**

**Solution:**

Two well-known biodiversity hotspots are the Western Ghats–Sri Lanka hotspot and the Himalaya hotspot. Both regions show exceptional plant endemism and face significant habitat loss, which is why they qualify as hotspots. Conservation here protects disproportionately high numbers of species relative to area conserved.

**Quick Tip**

A "hotspot" needs high endemism and heavy threat—both criteria must be met.

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**2. (d) What is the function of Sertoli cells in human testis?**

**Solution:**

Sertoli cells support and nourish developing sperm, form the blood–testis barrier, phagocytose residual cytoplasm, and secrete androgen-binding protein to concentrate testosterone for spermatogenesis. They also release inhibin to regulate FSH. Collectively, they create a protected microenvironment essential for orderly germ cell maturation.

**Quick Tip**

Think "support cells": barrier, nourishment, hormonal regulation, and debris cleanup.

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**2. (e) Which enzyme breaks DNA molecule?**

**Solution:**

Deoxyribonucleases (DNases) break DNA by hydrolyzing phosphodiester bonds. Endonucleases cut within the strand, while exonucleases remove nucleotides from ends. In genetics labs, *restriction endonucleases* are specific DNases that cleave DNA at defined recognition sequences, generating fragments useful for cloning and analysis.

**Quick Tip**

General enzyme: DNase; sequence-specific cutters: restriction endonucleases.

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## Short Answer Type Questions I

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**3. (a) Write the names of four nucleotide units of DNA.**

**Solution:**

DNA is a polymer of four deoxyribonucleotides, each composed of a deoxyribose sugar, a phosphate group, and a nitrogenous base. The four bases are adenine (A), thymine (T), guanine (G), and cytosine (C); therefore the nucleotide units are dAMP, dTMP, dGMP, and dCMP (monophosphate forms). In the double helix, A pairs specifically with T via two hydrogen bonds, and G pairs with C via three hydrogen bonds, maintaining uniform helix width and complementarity. The linear order of these nucleotides encodes genetic information, while base pairing enables accurate replication and repair through template-directed synthesis.

**Quick Tip**

Remember the pairing rule: A–T (2 H-bonds) and G–C (3 H-bonds).

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**3. (b) Describe the food chain with diagram.**

**Solution:**

A food chain shows linear energy flow across trophic levels. It begins with producers (green plants/algae) that fix solar energy, followed by primary consumers (herbivores), secondary consumers (small carnivores), and tertiary consumers (top predators). Decomposers recycle nutrients back to the environment. A typical terrestrial chain is:

**Grass** $\rightarrow$ **Grasshopper** $\rightarrow$ **Frog** $\rightarrow$ **Snake** $\rightarrow$ **Hawk**. Energy diminishes at each step due to metabolic losses (10% transfer), explaining shorter chains and fewer top predators. Food chains interconnect to form food webs, which provide ecosystem stability by offering alternative energy pathways when one population fluctuates.

**Quick Tip**

Only about 10% of energy transfers to the next trophic level—hence short chains.

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**3. (c) What do you mean by Central Dogma of Molecular Biology?**

**Solution:**

The Central Dogma explains the directional flow of genetic information: DNA stores hereditary information, which is copied into RNA by transcription, and RNA guides protein synthesis by translation—summarized as **DNA** $\rightarrow$ **RNA** $\rightarrow$ **Protein**. Proteins then perform structural and catalytic roles determining phenotype. DNA replicates semi-conservatively to pass information to daughter cells. Exceptions refine, not violate, the dogma: reverse transcription in retroviruses (RNA $\rightarrow$ DNA), and RNA-dependent RNA replication in some RNA viruses. Nevertheless, information does not flow from protein back to nucleic acids, preserving genetic instructions in nucleic acid sequences.

> **Quick Tip**
>
> Core sequence: Replication $\rightarrow$ Transcription $\rightarrow$ Translation; remember reverse transcription as an exception.

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**3. (d) Write the name of any one disease caused by mosquitoes and describe its control measures.**

**Solution:**

**Malaria** (caused by *Plasmodium* spp., transmitted by female *Anopheles*) is a major mosquito-borne disease. Control measures target both vector and parasite: eliminate breeding sites by draining stagnant water; use larvicides or larvivorous fish; deploy insecticide-treated bed nets and indoor residual sprays; install window screens, wear protective clothing, and apply repellents; ensure prompt diagnosis (rapid tests/microscopy) and complete treatment with ACTs; chemoprophylaxis for travellers; and community education plus surveillance to detect outbreaks early. Integrated vector management combining environmental, biological, and chemical methods is most effective and sustainable.

> **Quick Tip**
>
> Break transmission at two points: prevent mosquito bites and treat human carriers quickly.

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**3. (e) What is Bioinformatics?**

**Solution:**

Bioinformatics is the interdisciplinary field that develops and applies computational tools to store, analyze, and interpret biological data, especially large-scale datasets like DNA/RNA sequences, protein structures, and expression profiles. It integrates biology, computer science, mathematics, and statistics. Key tasks include sequence alignment, genome assembly/annotation, phylogenetics, motif discovery, protein structure prediction, and systems biology network analysis. Applications span drug target identification, personalized medicine, disease variant discovery, metagenomics, and agriculture. Databases (e.g., GenBank, UniProt) and algorithms (BLAST, Hidden Markov Models) enable efficient querying and biological inference from high-throughput experiments.

**Quick Tip**

Think "biology + computing": databases + algorithms turn big bio-data into insight.

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## Short Answer Type Questions II

**4. (a) Describe the role of animals in pollination.**

**Solution:**

Animals act as biotic pollinators by transferring pollen from anthers to stigmas while seeking nectar, pollen, oils, or shelter. Bees, butterflies, moths, birds (e.g., hummingbirds, sunbirds), bats, beetles, and flies exhibit flower constancy, increasing pollination efficiency. Flowers coevolve traits that suit vectors: bright colors and landing platforms for bees/butterflies; tubular, odorless, nectar-rich corollas for birds; night-blooming, pale, strongly scented flowers for bats/moths; carrion-like odors for flies/beetles. Many species provide rewards (nectar, pollen) or deceit (mimicry). Animal pollination promotes cross-pollination, enhancing genetic diversity, fruit/seed set, and yield quality in crops (e.g., apple, almond, cacao). Structural adaptations like sticky/spiny pollen, brushy body hairs, and specialized mouthparts aid pollen pickup and deposition. Mutualism can be highly specific (fig–fig wasp, yucca–yucca moth) or generalized. Habitat loss and pesticides threaten pollinators, making conservation crucial for ecosystem services and food security.

Quick Tip

Match the pollinator to the flower trait: bees—bright + scented; birds—red tubular; bats—night-blooming + strong odor.

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**4. (b) Draw a neat labelled diagram of a dicotyledonous embryo.**

**Solution:**

A dicot embryo (e.g., bean) has: **(1) Plumule**—the embryonic shoot with future leaves; **(2) Epicotyl**—stem region above the cotyledons; **(3) Hypocotyl**—stem region below the cotyledons; **(4) Radicle**—embryonic root that forms the primary root; **(5) Two fleshy cotyledons**—food-storage leaves; and **(6) Embryonal axis** connecting radicle–hypocotyl–epicotyl–plumule. The **cotyledons** store proteins/oils and nourish the seedling until photosynthesis begins. During germination, the **radicle** emerges first, followed by **hypocotyl/epicotyl** growth depending on epigeal or hypogeal germination. To sketch: draw two large cotyledons flanking the axis; label plumule at top, epicotyl just below, hypocotyl leading down to a pointed radicle; indicate the micropylar end near radicle. Clean, minimal lines with arrows to each part suffice for scoring when a physical diagram is required.

Quick Tip

Remember the order along the axis (top$\rightarrow$bottom): plumule $\rightarrow$ epicotyl $\rightarrow$ cotyledons (lateral) $\rightarrow$ hypocotyl $\rightarrow$ radicle.

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**4. (c) What is incomplete dominance? Explain with examples.**

**Solution:**

Incomplete dominance is a non-Mendelian inheritance pattern in which the heterozygote shows an intermediate phenotype between the two homozygotes because neither allele is completely dominant. The classic case is *Mirabilis jalapa* (four-o'clock): RR = red, rr = white, while Rr is pink; selfing $F_1$ yields a 1 red : 2 pink : 1 white phenotypic and genotypic ratio in $F_2$. Another example is **snapdragon** (*Antirrhinum*) flower color with the same ratios.

In animals, Andalusian fowl feather color (black $\times$ white $\Rightarrow$ blue heterozygotes) and some coat-color dilutions reflect similar dosage effects. Molecularly, one functional allele produces insufficient product to reach the homozygous dominant phenotype (haploinsufficiency), so the heterozygote's trait is quantitatively intermediate. Importantly, alleles are not blending irreversibly; segregation in $F_2$ restores parental phenotypes, preserving particulate inheritance.

> **Quick Tip**
>
> Key clue: $F_2$ shows 1:2:1 phenotype ratio—hallmark of incomplete dominance.

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**4. (d) How do biofertilizers increase the fertility of the soil?**

**Solution:**

Biofertilizers are living microorganisms that enhance nutrient availability and soil health. **Nitrogen fixers** like *Rhizobium* (legume nodules), *Azotobacter*, and *Azospirillum* convert atmospheric $N_2$ into ammonia, increasing plant-accessible nitrogen. **Phosphate-solubilizing microbes** (PSB) such as *Pseudomonas* and *Bacillus* release organic acids and phosphatases that mobilize insoluble phosphates. **Mycorrhizal fungi** (AMF) extend hyphal networks, improving uptake of P, Zn, and water, and enhancing drought tolerance. **Potassium- and zinc-solubilizers** mobilize micronutrients; **cyanobacteria** and *Azolla* enrich paddy fields. Many strains produce phytohormones (IAA, gibberellins), siderophores that chelate iron, and antibiotics that suppress pathogens, thereby improving root growth and disease resistance. Over time, biofertilizers increase soil organic matter, aggregate stability, and microbial diversity, reducing dependence on chemical fertilizers, lowering input costs, and mitigating environmental impacts. Proper carrier formulation, seed/soil inoculation, and moisture ensure field success.

> **Quick Tip**
>
> Think "3 Ms": **M**obilize nutrients, **M**ake nitrogen, and **M**ycorrhiza for better roots.

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**5. (a) Write a note on Hardy–Weinberg principle.**

**Solution:**

The Hardy–Weinberg principle states that in a large, randomly mating population with no mutation, migration, selection, or genetic drift, allele and genotype frequencies remain constant across generations. For a locus with two alleles $A$ and $a$, if their frequencies are $p$ and $q$ ($p + q = 1$), the genotype frequencies are $p^2$(AA), $2pq$(Aa), and $q^2$(aa), so $p^2 + 2pq + q^2 = 1$. It provides a null model to detect microevolution: any significant deviation indicates forces like selection or gene flow. It is widely used to estimate carrier frequency of recessive disorders (e.g., if disease incidence $q^2 = 1/10{,}000$, then $q = 0.01$ and carriers $2pq \approx 2(0.99)(0.01) = 0.0198$). In real populations, partial deviations occur, but the model remains a powerful baseline for population genetics and public-health screening.

> **Quick Tip**
>
> Remember the two equations: $p + q = 1$ and $p^2 + 2pq + q^2 = 1$ under five assumptions (no **M**MSDS: mutation, migration, selection, drift; random mating).

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**5. (b) Describe emasculation.**

**Solution:**

Emasculation is the removal of anthers from a bisexual flower bud of the female parent to prevent self-pollination during artificial hybridization.

**Steps:** Select flowers just before anther dehiscence; carefully cut or pluck anthers using fine forceps/scissors without injuring the stigma/style; immediately **bag** the emasculated flower with butter paper/polythene to exclude foreign pollen; **tag** with date and cross details. When the stigma becomes receptive, dust desired pollen collected from the chosen male parent and rebag until fruit set. Heat treatment or genetic male sterility can substitute mechanical emasculation in small or tiny flowers (e.g., cereals).

**Purpose:** Ensures controlled cross, maintains pedigree purity, and enables breeding for desirable traits like yield, disease resistance, or quality.

> **Quick Tip**
>
> Mnemonic: **E-B-P**: Emasculate $\rightarrow$ Bag $\rightarrow$ Pollinate (then rebag and tag).

**5. (c) Write a note on linkage.**

**Solution:**

Linkage is the tendency of genes located on the same chromosome to be inherited together because they are physically close and do not assort independently. First noticed by Bateson and Punnett; explained by T.H. Morgan using *Drosophila*. **Complete linkage** (rare) shows parental combinations only; **incomplete linkage** (common) allows some recombinants due to crossing over. The **recombination frequency** (0–50%) reflects the distance between loci and is used by Sturtevant to construct genetic maps (1 map unit = 1% recombination). Genes on a chromosome form a **linkage group** equal to the haploid chromosome number.

Example: grey body–normal wing genes in *Drosophila* show strong linkage, producing mostly parental phenotypes with few recombinants. Linkage analysis underpins mapping of disease genes and marker-assisted selection in crops.

> Quick Tip
>
> Closer genes $\rightarrow$ stronger linkage $\rightarrow$ fewer recombinants; 1% recombination = 1 cM (map unit).

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**5. (d) Draw a labelled diagram of sectional view of female ovary.**

**Solution:**

In section, an ovary shows: **Germinal epithelium** (outer single layer) over a thin **tunica albuginea**; beneath lies the **cortex** with stroma and follicles at different stages—**primordial** (oocyte with simple squamous cells), **primary** (granulosa cuboidal), **secondary** (multiple granulosa layers), and **tertiary/Graafian** follicle with fluid-filled **antrum**, **oocyte** surrounded by **zona pellucida** and **corona radiata**, and outer **theca interna/externa**. After ovulation, the follicle becomes **corpus luteum**; later, **corpus albicans**. The central **medulla** contains loose connective tissue with blood vessels and nerves; the **hilum** is the vascular entry.

**To sketch:** outline ovary; shade cortex vs medulla; draw follicles at stages with labels—zona pellucida, granulosa, theca, antrum, corpus luteum—and indicate germinal epithelium and hilum.

Quick Tip

Label from outside in: germinal epithelium → tunica → cortex (follicles) → medulla; show a Graafian follicle with antrum and corona radiata.

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**6. (a) Describe the role of microbes in biogas production.**

**Solution:**

Biogas is produced in anaerobic digesters where mixed microbial consortia decompose organic wastes (cow dung, sewage, crop residues). The process occurs in stages: **hydrolytic bacteria** break complex polymers (cellulose, proteins, lipids) into monomers; **acidogenic** and **acetogenic bacteria** convert these into volatile fatty acids, alcohols, $H_2$, and $CO_2$; finally, **methanogenic archaea** (e.g., *Methanobacterium*, *Methanococcus*) reduce acetate and $CO_2/H_2$ to methane. Optimal mesophilic conditions (30–40°C), neutral pH, and proper C:N ratio enhance yields. The resulting gas contains ∼55–70% $CH_4$, ∼30–45% $CO_2$, and traces of $H_2S$; it is usable for cooking and electricity. The digested slurry is pathogen-reduced, nutrient-rich manure, closing a circular bioeconomy loop and reducing greenhouse emissions from unmanaged waste.

Quick Tip

Remember the sequence: Hydrolysis → Acidogenesis/Acetogenesis → Methanogenesis (by archaea).

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**6. (b) Explain the DNA fingerprinting and its uses.**

**Solution:**

DNA fingerprinting exploits polymorphic loci (VNTRs/STRs) that vary greatly between individuals. Typical workflow: collect biological samples; extract DNA; amplify selected STR markers by PCR (earlier, RFLP–Southern blot with VNTR probes); separate fragments by gel/capillary electrophoresis; generate a multi-locus allele profile and compute match statistics. Because alleles at multiple STR loci are inherited independently, the combined probability of two unrelated people sharing a profile is extremely low. **Uses:** forensic identification from crime-scene traces; paternity/maternity testing and kinship analysis; identification of missing persons and disaster victims; detection of sample mix-ups in hospitals/IVF; wildlife forensics and tracking illegal trade; population genetics; and verifying pedigree in plant/animal breeding. Chain of custody and contamination control are critical for evidentiary reliability.

> **Quick Tip**
>
> Multiple STR loci $\rightarrow$ unique profile; more loci tested  lower random match probability.

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**6. (c) Write a note on Australopithecines.**

**Solution:**

Australopithecines were early hominins that lived in Africa ∼4.2–1.9 million years ago. They were **bipedal**, with pelvis and limb bones adapted for upright walking, yet retained some arboreal traits. Brain size was modest (about 400–550 cc), facial prognathism present, and teeth showed reduced canines with thick-enameled molars suited to mixed diets. Important species include *A. afarensis* (e.g., "Lucy") and *A. africanus*; robust forms formerly grouped as *Australopithecus* are now often placed in *Paranthropus*. They inhabited savannah–woodland mosaics, likely used simple tools, and show sexual dimorphism. Phylogenetically, gracile australopithecines are considered close ancestors of the genus *Homo*. Their fossils provide key evidence for the sequence "bipedalism before big brains" in human evolution and illuminate ecological pressures that shaped later hominin adaptations.

> **Quick Tip**
>
> Think "upright first": bipedal gait evolved well before major brain expansion in *Homo*.

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**6. (d) What is mutualism? Explain it with suitable example.**

**Solution:**

**Mutualism** is an interspecific interaction in which both partners gain a net fitness benefit; it may be *obligate* (species cannot survive/reproduce without the partner) or *facultative*.

Classic example: the **fig–fig wasp** system. Female wasps enter fig inflorescences (syconia), pollinate the flowers while laying eggs; larvae develop inside some ovules, and new adults carry pollen to another fig, ensuring plant reproduction. Both species are coevolved and often species-specific, illustrating obligate mutualism. Other examples include lichen (alga–fungus), mycorrhiza (plant–fungus enhancing nutrient uptake), and ruminants with gut microbes digesting cellulose. Mutualisms increase resource acquisition, reproductive success, and resilience but can collapse under habitat loss or partner decline, affecting ecosystem services such as pollination and nutrient cycling.

**Quick Tip**

Definition first; then pair a *specific*, coevolved example—fig tree $\leftrightarrow$ fig wasp.

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## Long Answer Type Questions

**7. Describe in detail how microbes can be used to decrease the use of chemical fertilizers and pesticides.**

**Solution:**

Microbes reduce dependence on agrochemicals by **fixing nutrients**, **mobilizing locked minerals**, and **protecting plants from pests**—thus replacing synthetic fertilizers and pesticides.

**1) Biofertilizers (nutrient input).**

*Rhizobium* in legume root nodules, and free-living/associative *Azotobacter*, *Azospirillum*, and cyanobacteria (*Anabaena*, *Nostoc*, *Azolla–Anabaena*) convert atmospheric $N_2$ to ammonium, raising soil N without urea. Arbuscular mycorrhizal fungi (AMF) extend hyphal networks, enhancing uptake of P, Zn, Cu and water, improving drought tolerance and fertilizer-use efficiency. Phosphate-solubilizing bacteria/fungi (*Pseudomonas*, *Bacillus*, *Aspergillus*) secrete organic acids and phosphatases to release insoluble Ca-, Fe-, or Al-phosphates; potassium and zinc solubilizers mobilize K and micronutrients. Many rhizobacteria produce phytohormones (IAA, gibberellins), siderophores that chelate Fe, and ACC deaminase that lowers ethylene—stimulating root growth and nutrient capture.

**2) Biopesticides (pest suppression).**

*Bacillus thuringiensis* (Bt) produces Cry proteins toxic to specific insect larvae; spores/formulations or Bt-transgenic crops reduce chemical insecticides. *Trichoderma* spp. control soil-borne fungi by mycoparasitism, antibiotics, and induced systemic resistance. *Pseudomonas fluorescens* suppresses pathogens through siderophores and antimicrobial metabolites. *Nuclear polyhedrosis viruses* (NPVs) specifically kill lepidopteran pests; *Beauveria* and *Metarhizium* are entomopathogenic fungi used as sprays.

**3) Integrated benefits.**

Compost/biogas slurry inoculated with microbes adds organic matter, improves aggregation and water holding, and releases nutrients slowly, cutting fertilizer doses. Microbial consortia in Integrated Nutrient and Pest Management (INM/IPM) maintain yields, lower input cost, and minimize residues. Field success needs quality carriers, correct inoculation (seedling dip/seed coat/soil drench), adequate moisture, and crop–microbe matching.

**Outcome:** sustained soil fertility, reduced chemical load, and resilient agroecosystems.

> Quick Tip
>
> Remember "**3 Ms**": **M**ake N (fixers), **M**obilize P/K (solubilizers, AMF), and **M**anage pests (Bt, *Trichoderma*, NPVs).

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**OR**

**7. Mention in brief the contribution of biotechnology in human welfare.**

**Solution:**

Biotechnology benefits society through **healthcare**, **food and agriculture**, **industry**, and **environment**.

**Healthcare:** Recombinant DNA enables human insulin, growth hormone, clotting factors, erythropoietin, and monoclonal antibodies for cancer/autoimmune diseases. Vaccines—from recombinant Hepatitis B to mRNA platforms—provide rapid, scalable immunization. Gene therapy and genome editing (CRISPR) correct or palliate genetic disorders; pharmacogenomics customizes therapy. Diagnostics like PCR/RT-PCR, qPCR, and ELISA deliver sensitive detection of pathogens, while DNA fingerprinting supports forensics and

kinship analysis.
**Agriculture:** Tissue culture produces disease-free, uniform planting material; marker-assisted selection accelerates breeding. Transgenic crops (Bt cotton, herbicide-tolerant soybean, Golden Rice in development) provide pest resistance, quality traits, and yield stability; microbial biofertilizers and biopesticides reduce chemical inputs.
**Industry & environment:** Enzymes (amylases, proteases, lipases) from microbes run eco-friendly processes in detergents, textiles, leather, and food. Fermentation yields antibiotics (penicillin), vitamins, organic acids (citric acid), and biofuels (ethanol, biogas). Bioremediation uses microbes/plants to detoxify pollutants, treat sewage, and recover metals.
**Societal safeguards:** Biosafety guidelines, ethical review, and regulatory frameworks govern GM release, clinical trials, and data privacy.
**Overall impact:** greater health security, sustainable food systems, cleaner industry, and green energy—improving quality of life and economic resilience.

> **Quick Tip**
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> Think "**H-A-I-E**": Health, Agriculture, Industry, Environment—the four pillars of biotech for human welfare.

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**8. Explain the salient features of Human Genome.**

**Solution:**

The human genome comprises $\sim 3.2 \times 10^9$ base pairs across 23 chromosome pairs and mitochondrial DNA. **Gene count:** about 20,000–21,000 protein-coding genes—far fewer than once expected—plus thousands of noncoding RNA genes (rRNA, tRNA, miRNA, lncRNA). **Coding fraction:** exons make only $\sim 1.5\%$ of the genome; the rest includes introns, regulatory sequences (promoters, enhancers, silencers), repetitive elements, and structural DNA. **Repetitive DNA:** transposable elements (LINEs, SINEs—Alu), segmental duplications, and microsatellites contribute to genome size, variability, and evolution.
**Variation:** individuals differ at $\sim 1$ in 1,000 bases (millions of SNPs), small indels, and larger CNVs; such polymorphisms underlie traits, disease risk, and forensic identification.
**Gene density** and GC content vary by chromosome; chromosome 19 is gene-rich, 13/18/Y gene-poor. **Mitochondrial genome** (16.6 kb) is maternally inherited, encodes 13 OXPHOS

proteins, 22 tRNAs, and 2 rRNAs. **Functional organization:** alternative splicing, RNA editing, and epigenetic marks (DNA methylation, histone modifications) expand proteomic diversity and regulate gene expression in a cell-type specific manner. **Medical insights:** catalogues like HapMap/1000 Genomes support association studies; reference assemblies (GRCh38, T2T-CHM13) and pangenomes improve completeness and representation.
Overall, the genome is **modular, dynamic, and highly regulated**, with modest gene number but complex control networks producing human phenotypic diversity.

**Quick Tip**

Only $\sim$ 1.5% of our genome codes proteins; variation (SNPs/CNVs) and regulation drive diversity and disease risk.

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**OR**

**8. Describe different Assisted Reproductive Technologies (ART).**

**Solution:**

ARTs help infertile couples conceive by manipulating gametes/embryos.

**Ovulation induction & IUI:** Drugs (clomiphene, gonadotropins) stimulate follicular development; processed motile sperm are placed into the uterus at ovulation—useful for mild male factor or cervical issues.

**IVF-ET (In Vitro Fertilization–Embryo Transfer):** Ovaries are hyperstimulated; oocytes retrieved transvaginally; fertilized with sperm *in vitro*; embryos cultured to day 3–5 and transferred to uterus.

**ICSI (Intracytoplasmic Sperm Injection):** A single sperm is injected into an oocyte—key for severe oligo/astheno/teratozoospermia or obstructive azoospermia.

**GIFT/ZIFT:** Gametes or zygotes are placed in the fallopian tube (laparoscopic)—now less common.

**Third-party options: Donor sperm** or **donor oocytes** for gamete defects; **gestational surrogacy** when uterus is absent or pregnancy contraindicated.

**Add-ons:** Preimplantation genetic testing (PGT-A/PGT-M) screens embryos for aneuploidy or single-gene disorders; cryopreservation (vitrification) stores gametes/embryos; time-lapse imaging and embryo scoring optimize selection.

**Success factors:** maternal age, ovarian reserve, embryo quality, uterine receptivity; risks include ovarian hyperstimulation syndrome, multiple pregnancy (mitigated by single-embryo transfer), and procedural complications. Ethical/legal oversight ensures consent, donor anonymity rules, and rights of the child. ARTs thus provide effective, evidence-based routes to parenthood while allowing genetic disease avoidance.

> **Quick Tip**
>
> Match method to need: IUI (mild male/cervical), IVF (tubal/idiopathic), ICSI (severe male factor), PGT (genetic disease risk).

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**9. Describe Mendelian disorder in detail.**

**Solution:**

Mendelian disorders are single-gene defects that segregate according to Mendel's laws. They may be **autosomal dominant** (one mutant allele sufficient; vertical inheritance; equal in sexes—e.g., Huntington disease, familial hypercholesterolemia), **autosomal recessive** (two mutant alleles required; often skips generations; consanguinity risk—e.g., cystic fibrosis, phenylketonuria, sickle-cell anemia), **X-linked recessive** (males affected; carrier mothers transmit to sons—e.g., haemophilia A/B, Duchenne muscular dystrophy), **X-linked dominant** (rare; affected fathers transmit to all daughters—e.g., Rett syndrome), and **Y-linked** (holandric traits affecting males only).

**Pedigree clues:** Dominant shows no skipping; recessive clusters among siblings; X-linked recessive shows no male-to-male transmission.

**Molecular basis:** mutations include missense, nonsense, frameshift, splice-site, or copy-number changes affecting protein function; penetrance and expressivity modify phenotype.

**Diagnosis:** family history and pedigree analysis, biochemical assays, molecular testing (targeted mutation, gene panels, exome sequencing), and prenatal options (CVS, amniocentesis).

**Management:** supportive or causal—dietary restriction in PKU, enzyme replacement in

Gaucher disease, factor replacement in haemophilia, and emerging gene therapies.
**Counseling:** recurrence risks predictable (e.g., 25% for autosomal recessive when both parents are carriers). Newborn screening and carrier testing reduce disease burden.
Mendelian disorders thus illuminate gene–phenotype relationships and remain central to medical genetics.

**Quick Tip**

Start by classifying inheritance (AD/AR/XR/XD/Y). Then apply pedigree rules: dominance = vertical; recessive = skips; XR = no father→son transmission.

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**OR**

**9. Define ecosystem. Describe its biotic and abiotic components with diagrams.**

**Solution:**

An **ecosystem** is a functional unit where living organisms (community) interact with each other and with their physical environment, exchanging matter and energy. It includes **abiotic components**—light, temperature, water, soil, air, nutrients—and **biotic components** organized across trophic levels.

**Abiotic:** Solar radiation drives photosynthesis and climate; temperature and moisture regulate distribution and productivity; soil texture, pH, and mineral pools influence plant communities; gases ($O_2$, $CO_2$) and dissolved nutrients govern metabolism; disturbances (fire, floods) reset succession.

**Biotic: Producers** (green plants, algae, phytoplankton) fix energy; **consumers**—primary (herbivores), secondary (small carnivores), tertiary (top predators)—transfer energy; **decomposers/detritivores** (bacteria, fungi, earthworms) recycle nutrients by breaking down litter and dead biomass.

**Energy flow & cycles:** Energy moves unidirectionally (10% law) through food chains/webs; matter cycles via biogeochemical cycles (C, N, P, water).

**How to sketch:** Draw a box for *ecosystem*; left: sun → arrow to producers (trees/grass); arrows upward to herbivores → carnivores; a downward arrow from all boxes to decomposers; curved arrows show nutrient recycling; beneath, annotate abiotic factors (light, water, soil, temperature).

Ecosystems range from ponds and forests to agroecosystems and microhabitats; despite scale differences, structure–function principles remain consistent.

**Quick Tip**

Diagram rule: Sun → Producers → Consumers; decomposers return nutrients; surround with abiotic factors (light, water, soil, temperature).

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