BITSAT Biology Sample Paper – 2

Duration: 60 Minutes **Maximum Marks: 120**

Instructions

- This paper contains **40** Multiple Choice Questions (Single Correct Answer).
- Each correct answer carries **+3 marks**. Each incorrect answer carries -1 mark. Unattempted questions carry **0** marks.
- Only **one** option is correct. Choose carefully.
- Use of mobile phones, calculators, or electronic gadgets is strictly prohibited.

Q1. Which of the following organelles is present in plant cells but completely absent in typical animal cells?

(A) Mitochondrion

(B) Golgi apparatus

(C) Plastids (chloroplasts, chromoplasts, leucoplasts) and a large central vacuole

(D) Ribosome

Q2. The ribosomes found in bacteria and inside mitochondria/chloroplasts have a sedimentation coefficient of:

(A) $70\,\mathrm{S}$ (made of a $50\,\mathrm{S}$ large and $30\,\mathrm{S}$ small subunit)

(B) $80\,\mathrm{S}$ (made of $60\,\mathrm{S} + 40\,\mathrm{S}$ subunits)

(C) $50\,\mathrm{S}$ overall

(D) $60\,\mathrm{S}$ overall

Q3. Lysosomes are often called the “suicide bags” of the cell because they:

(A) Contain ribosomes for protein synthesis

(B) Carry acid hydrolases that, on membrane rupture, can digest the cell's own components (autolysis)

(C) Are the site of fatty acid β-oxidation

(D) Synthesise nuclear DNA

Q4. The centrosome of an animal cell, containing a pair of centrioles surrounded by pericentriolar material, primarily functions as:

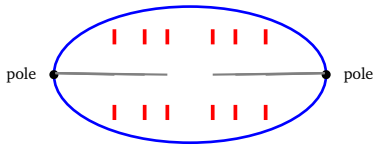
(A) The site of ATP synthesis

(B) A storage organelle for genetic information

(C) A ribosome-producing structure

(D) The microtubule-organising centre (MTOC) that nucleates spindle fibres during cell division

Q5. The figure shows a cell during mitosis where sister chromatids are visibly separating and being pulled apart by spindle fibres towards opposite poles. This phase is:



Sister chromatids pulled to opposite poles

(A) Anaphase — centromeres divide and sister chromatids are pulled to opposite poles as separate daughter chromosomes

(B) Prophase

(C) Metaphase

(D) Telophase

Q6. The fluid mosaic model of the plasma membrane (Singer & Nicolson, 1972) describes the membrane as:

(A) A rigid sandwich of lipid between protein layers

(B) A solid crystalline lattice with proteins permanently fixed

(C) A single phospholipid layer

(D) A two-dimensional fluid phospholipid bilayer with integral and peripheral proteins embedded, capable of lateral diffusion

Q7. Proteins in living organisms are built from how many standard amino acids encoded directly by the genetic code?

(A) 26

(B) 30

(C) 20 (all L-isomers except glycine, which is achiral)

(D) 50

Q8. A triglyceride (the main storage form of fat) is formed by an ester linkage between:

(A) Two glycerols and one fatty acid

(B) One glycerol molecule and three fatty acid molecules, with release of three water molecules

(C) Three glycerols and one fatty acid

(D) One amino acid and three sugars

Q9. Trypsin, a major pancreatic protease, is secreted as the inactive zymogen trypsinogen and activated in the small intestine by:

(A) Hydrochloric acid from the stomach

(B) Enterokinase (enteropeptidase) secreted by the duodenal mucosa, which cleaves an N-terminal hexapeptide

(C) Bile salts from the liver

(D) Pancreatic lipase

Q10. Vital capacity (VC) of the lungs is defined as:

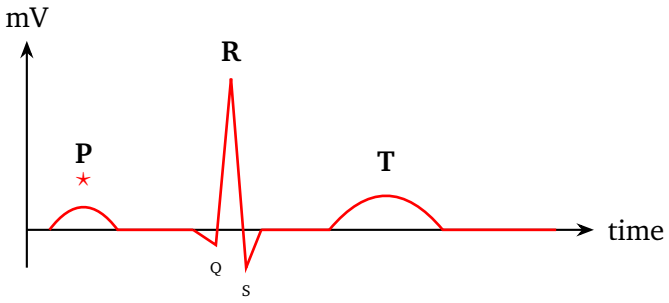
(A) Maximum volume of air exhaled after the deepest possible inspiration ($\mathrm{VC} = \mathrm{ERV} + \mathrm{TV} + \mathrm{IRV} \approx 4500\,\mathrm{mL}$ in healthy adults)

(B) Air left in the lungs after a forced expiration

(C) Air exchanged during normal breathing

(D) Maximum air inhaled forcefully

Q11. Identify the cardiac event represented by the labelled wave ($\star$) in the schematic ECG below.



(A) Ventricular repolarisation

(B) Ventricular depolarisation

(C) Atrial depolarisation, initiated by the SA node and spreading through both atria, immediately preceding atrial contraction

(D) Ventricular filling

Q12. Antidiuretic hormone (ADH, vasopressin), secreted by the posterior pituitary, primarily acts on:

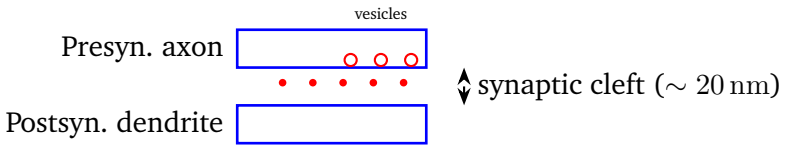
(A) The glomerulus, increasing filtration

(B) The PCT, reducing reabsorption

(C) The ascending loop of Henle, blocking sodium pumps

(D) The collecting duct (and DCT), where it inserts aquaporin-2 water channels into the apical membrane, vastly increasing water reabsorption and producing concentrated urine

Q13. The figure shows a chemical synapse between two neurons. Transmission of the nerve impulse across the synaptic cleft is mediated by:



(A) Direct electrical conduction across a gap junction

(B) Mechanical contact between cells

(C) Light photons

(D) Chemical neurotransmitters (e.g. acetylcholine, glutamate, GABA), released by vesicle exocytosis upon Ca^{2+} influx into the pre-synaptic terminal, which then bind receptors on the post-synaptic membrane

Q14. Insulin, which lowers blood glucose by promoting cellular uptake and glycogen synthesis, is secreted by:

(A) Alpha cells of pancreatic islets of Langerhans (these secrete glucagon)

(B) Acinar cells of the pancreas (these secrete digestive enzymes)

(C) Beta cells of the pancreatic islets of Langerhans

(D) Delta cells of pancreatic islets (these secrete somatostatin)

Q15. The widely accepted mechanism of phloem translocation of sucrose from source (leaves) to sink (roots, fruits) is:

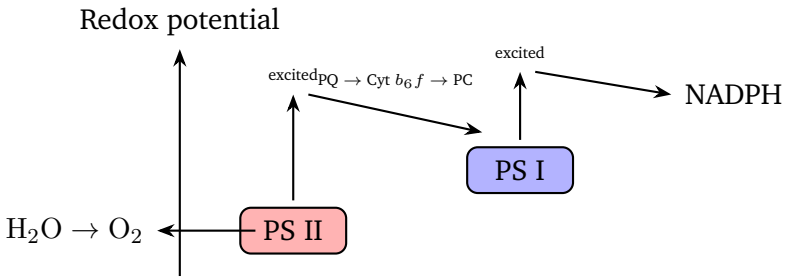
(A) The pressure-flow (mass-flow) hypothesis of Münch (1930), driven by osmotic pressure gradients between source and sink

(B) The cohesion-tension theory

(C) Root pressure

(D) Cyclosis (cytoplasmic streaming) alone

Q16. The light reactions of photosynthesis (electron transport from PS II to PS I, water splitting, ATP and NADPH formation) take place on:



(A) In the cytosol

(B) On the thylakoid membranes inside chloroplasts (with the dark reactions / Calvin cycle in the stroma)

(C) In peroxisomes

(D) On the outer chloroplast envelope

Q17. The ABO blood-group system in humans (alleles I^A, I^B, i) demonstrates:

(A) Simple Mendelian dominance only

(B) Sex linkage

(C) Multiple allelism together with codominance (I^A and I^B both expressed in AB individuals) and recessiveness of i

(D) Polygenic inheritance

Q18. Haemophilia A, in which clotting factor VIII is deficient, is inherited as:

(A) Autosomal dominant

(B) Autosomal recessive

(C) Y-linked

(D) X-linked recessive (males with the mutant X always affected; females usually carriers; daughters affected only if both X chromosomes carry the mutation)

Q19. In Jacob and Monod's lac operon model of *E. coli*, the physiological inducer that binds the lac repressor and switches on transcription of the lac genes when lactose is available is:

(A) Glucose

(B) Allolactose — a $1,6$ isomer of lactose, produced from lactose by basal β-galactosidase activity; IPTG is its synthetic analogue used in the laboratory

(C) cAMP

(D) Tryptophan

Q20. The genetic code is described as "degenerate" because:

(A) Most amino acids are specified by more than one codon (e.g. leucine and serine each have 6 codons); only methionine and tryptophan are encoded by a single codon

(B) It changes from organism to organism

(C) Codons overlap one another

(D) Codons can be read backwards

Q21. Hugo de Vries (1901) proposed the mutation theory of evolution based on his work with:

(A) Mendel's pea plants

(B) *Oenothera lamarckiana* (the evening primrose), in which he observed sudden, large, heritable variations he called "mutations"

(C) *Drosophila melanogaster*

(D) *E. coli*

Q22. The forelimbs of humans, whales, bats and cats, although used for different functions, share the same basic skeletal plan. They are best described as:

(A) Analogous organs (similar function, different origin)

(B) Vestigial organs

(C) Atavistic structures

(D) Homologous organs (common evolutionary origin, different functions) — evidence for divergent evolution

Q23. After ovulation, the ruptured Graafian follicle transforms into the corpus luteum, which secretes mainly:

(A) Progesterone (and some oestrogen), which prepares and maintains the uterine endometrium for implantation

(B) Only FSH

(C) Only LH

(D) Testosterone

Q24. The acrosome at the tip of a mammalian sperm head contains:

(A) Mitochondria for energy supply

(B) Ribosomes for protein synthesis

(C) Hydrolytic enzymes (hyaluronidase, acrosin) which digest the zona pellucida of the ovum and permit sperm penetration

(D) DNA copies of paternal genes

Q25. Human chorionic gonadotropin (hCG), the hormone detected in urine and blood by home pregnancy tests, is secreted by:

(A) The trophoblast cells of the developing placenta; it maintains the corpus luteum (which keeps secreting progesterone) during early pregnancy

(B) The anterior pituitary

(C) The hypothalamus

(D) The ovary directly

Q26. Lactational amenorrhoea (the natural infertile period during full breastfeeding) is due to:

(A) Direct blockage of the fallopian tubes

(B) Sustained high prolactin from suckling, which suppresses hypothalamic GnRH release and hence FSH/LH secretion, preventing ovulation

(C) Continuous secretion of hCG by the placenta after delivery

(D) Permanent destruction of ovarian follicles

Q27. The outer wall of a pollen grain (exine) is exceptionally resistant to degradation by physical, chemical and biological agents. This is because it contains:

(A) Lignin

(B) Cellulose

(C) Sporopollenin — one of the most resistant organic polymers known, allowing pollen grains to be preserved as fossils for millions of years

(D) Suberin

Q28. The transfer of pollen grains from the anther to the stigma of the same flower is called:

(A) Geitonogamy

(B) Xenogamy

(C) Allogamy

(D) Autogamy (self-pollination within the same flower) — guaranteed in cleistogamous flowers that never open

Q29. The growth response in which a rosette plant (e.g. cabbage, beet) shows a sudden, dramatic elongation of the floral axis just before flowering — and which can be triggered by exogenous application of GA_3 — is called:

(A) Abscission

(B) Senescence

(C) Bolting, induced by gibberellins

(D) Vernalisation

Q30. Vernalisation is the process in which:

(A) Plants respond to day length to initiate flowering

(B) Flowering is promoted (or accelerated) by an obligatory period of low-temperature (cold) exposure — e.g. in winter wheat, biennials such as cabbage and beet

(C) Seeds germinate in response to light

(D) Roots grow towards gravity

Q31. Gram-positive bacteria retain the crystal-violet stain in the Gram-staining procedure because their cell wall has:

(A) No peptidoglycan at all

(B) An outer lipopolysaccharide membrane

(C) A capsule of polysaccharide

(D) A thick peptidoglycan layer (20–$80\,\mathrm{nm}$, sometimes constituting 90% of cell-wall mass) interwoven with teichoic acids

Q32. A mycorrhiza is best described as:

(A) A mutualistic symbiosis between a fungus and the roots of a higher plant, in which the fungus aids absorption of water and phosphorus while obtaining sugars from the plant

(B) A parasitic fungal infection of plant roots

(C) A bacterial root nodule

(D) A virus–plant association

Q33. Cnidoblasts (cells bearing nematocysts, the stinging organelles used for defence and prey capture) are a diagnostic feature of which phylum?

(A) Porifera

(B) Coelenterata (Cnidaria) — e.g. *Hydra*, jellyfish, sea anemones, corals

(C) Echinodermata

(D) Mollusca

Q34. Tuberculosis (TB) in humans is caused by:

(A) A virus

(B) A protozoan

(C) A fungus

(D) The acid-fast bacillus *Mycobacterium tuberculosis* (Koch's bacillus, identified by Robert Koch in 1882)

Q35. Vaccination (immunisation with attenuated, killed, or subunit pathogens) confers which type of immunity?

(A) Innate (natural) immunity

(B) Passive natural immunity (e.g. maternal antibodies via placenta and breast milk)

(C) Active artificial immunity — the immune system produces its own antibodies and memory cells in response to the vaccine antigen

(D) Passive artificial immunity (e.g. anti-tetanus serum)

Q36. Penicillin, the first antibiotic discovered (Fleming, 1928), acts by:

(A) Inhibiting bacterial cell-wall synthesis by blocking the transpeptidase that cross-links peptidoglycan strands — cell lysis follows

(B) Blocking protein synthesis on 70 S ribosomes

(C) Inhibiting DNA gyrase

(D) Damaging the bacterial cell membrane

Q37. In an ecosystem, the principal decomposers that mineralise dead organic matter and return nutrients to the soil are:

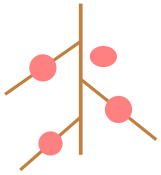
(A) Saprotrophic bacteria and fungi

(B) Green plants

(C) Herbivores

(D) Carnivores

Q38. In the figure of a leguminous root system below, the swollen pink nodules contain *Rhizobium* bacteria that fix atmospheric nitrogen. The conversion they catalyse is:



Leguminous root with *Rhizobium* nodules

(A) $N_2 \rightarrow NO_3^-$ directly in one step

(B) $N_2 + 8H^+ + 8e^- + 16ATP \rightarrow 2NH_3 + H_2 + 16ADP + 16P_i$, catalysed by the nitrogenase enzyme complex (anaerobic; protected from O_2 by leghaemoglobin)

(C) $N_2 \rightarrow N_2O$

(D) $NH_3 \rightarrow N_2$

Q39. Bt cotton is a transgenic crop that expresses an insecticidal Cry protein. The donor organism of the Bt toxin gene is:

(A) *Agrobacterium tumefaciens*

(B) *Escherichia coli*

(C) *Saccharomyces cerevisiae*

(D) *Bacillus thuringiensis* — a soil bacterium whose Cry crystal proteins are toxic to bollworms and other lepidopteran larvae but harmless to mammals

Q40. The first recombinant human insulin commercially produced and marketed (in 1982, by Eli Lilly under the trade name "Humulin") was made using:

(A) Pancreatic extract from cattle and pigs (this is animal insulin, not recombinant)

(B) Yeast cells with no genetic modification

(C) Genetically engineered *E. coli*, in which the A-chain and B-chain genes of human insulin were separately expressed and the chains then chemically combined to form mature insulin

(D) Stem-cell-derived β cells (not the original method)

Detailed Solutions

Q1.

Solution

Concept — Plant-specific organelles: Plant cells differ from animal cells in three major structural features: (i) cellulosic cell wall, (ii) plastids, and (iii) a large central vacuole.

Step 1 — Types of plastids (all derived from proplastids):

- **Chloroplasts:** green, photosynthetic, contain chlorophyll.
- **Chromoplasts:** yellow/orange/red; contain carotenoids; give colour to flowers and fruits.
- **Leucoplasts:** colourless; storage (amyloplasts store starch, elaioplasts store oils, aleuroplasts store proteins).

Step 2 — Why other options are wrong: Mitochondria, Golgi and ribosomes are present in both plant and animal cells. Plastids are uniquely plant (and algal/some protist).

Final Answer: Plastids and a large central vacuole are plant-specific $\Rightarrow$ $\boxed{\text{C}}$

Answer: (C) Go Back to Q1

Q2.

Solution

Concept — Ribosome sizes: Sedimentation coefficient (Svedberg, S) measures how fast a particle sediments in ultracentrifugation; it depends on size, shape and density (Svedberg values are NOT additive).

Step 1 — Two ribosome types:

- $70\,\mathrm{S}$**:** in prokaryotes (bacteria, archaea) and in mitochondria/chloroplasts of eukaryotes. Subunits: $50\,\mathrm{S}$ (large, $23\,\mathrm{S} + 5\,\mathrm{S}$ rRNA, ~ 34 proteins) and $30\,\mathrm{S}$ (small, $16\,\mathrm{S}$ rRNA, ~ 21 proteins).
- $80\,\mathrm{S}$**:** in eukaryotic cytoplasm. Subunits: $60\,\mathrm{S} + 40\,\mathrm{S}$.

Step 2 — Significance: The $70\,\mathrm{S}$ ribosomes in mitochondria/chloroplasts support the endosymbiotic theory — these organelles likely descended from free-living bacteria. Most ribosome-targeted antibiotics (streptomycin, tetracycline, chloramphenicol) act on $70\,\mathrm{S}$ ribosomes selectively, sparing host $80\,\mathrm{S}$ ribosomes.

Final Answer: $70\,\mathrm{S}$ $(50\,\mathrm{S} + 30\,\mathrm{S}) \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q2

Q3.

Solution

Concept — Lysosome function (Christian de Duve, 1955): Lysosomes are membrane-bound vesicles (0.1–$1.2\,\mu$m) containing ~ 40 acid hydrolases (proteases, lipases, nucleases, glycosidases) that work optimally at the internal acidic pH ~ 4.5.

Step 1 — Why "suicide bags"? If the lysosomal membrane is damaged (e.g. by silica, urate crystals, or trauma) the enzymes leak into the cytosol and digest the cell's own components — triggering autolysis and cell death.

Step 2 — Normal functions:

- Intracellular digestion of macromolecules.
- Autophagy — recycling of worn-out organelles.
- Defence: fusion with phagosomes to destroy engulfed bacteria.
- Programmed tissue remodelling (e.g. tadpole tail resorption during metamorphosis).

Step 3 — Lysosomal storage diseases: Defects in lysosomal enzymes cause genetic diseases like Tay-Sachs, Gaucher's, and Hurler syndrome — accumulation of undigested substrate in lysosomes.

Final Answer: Acid hydrolases capable of autolysis $\Rightarrow$ $\boxed{\text{B}}$

Answer: (B) Go Back to Q3

Q4.

Solution

Concept — Centrosome and microtubule organisation: The centrosome is the principal microtubule-organising centre (MTOC) of animal cells. Plant cells form spindles without centrosomes (anastral spindles).

Step 1 — Structure: Two centrioles oriented at right angles, embedded in pericentriolar material (PCM) rich in γ-tubulin ring complexes that nucleate microtubules. Each centriole is a cylinder of 9 triplet microtubules ($9+0$ arrangement).

Step 2 — Function:

- Nucleates and organises microtubule cytoskeleton during interphase.
- Duplicates in S phase; the two daughter centrosomes separate to opposite poles before mitosis, organising the spindle.
- Centrioles also form the basal bodies that template cilia and flagella.

Step 3 — Clinical: centrosome abnormalities (extra centrosomes $\rightarrow$ multipolar spindles) cause chromosomal instability and are common in cancer.

Final Answer: Microtubule-organising centre $\Rightarrow$ $\boxed{\text{D}}$

Answer: (D) Go Back to Q4

Q5.

Solution

Concept — Mitotic phases: The sequence is: Prophase → Prometaphase → Metaphase → Anaphase → Telophase, followed by cytokinesis.

Step 1 — What happens at each phase:

- Prophase: chromosomes condense; spindle starts forming; nuclear envelope intact.
- Metaphase: chromosomes align at the metaphase plate (equator); spindle complete.
- **Anaphase:** centromeres divide; sister chromatids are pulled apart by shortening kinetochore microtubules to opposite poles. Now each former chromatid is a separate chromosome. This is the shortest phase.
- Telophase: chromosomes decondense; nuclear envelopes re-form around the two clusters.

Step 2 — Anaphase A vs B:

- Anaphase A: kinetochore microtubules shorten, pulling chromatids poleward.
- Anaphase B: polar microtubules slide past each other, pushing poles further apart.

Step 3 — Key control: The spindle assembly checkpoint at the metaphase–anaphase transition ensures all chromosomes are properly attached before anaphase begins. Failure causes aneuploidy.

Final Answer: Anaphase ⇒ $\boxed{\text{A}}$

Answer: (A) Go Back to Q5

Q6.

Solution

Concept — The fluid mosaic model (Singer & Nicolson, 1972): Replaced the earlier Davson-Danielli "sandwich" model. The membrane is now understood as a dynamic, asymmetric, two-dimensional fluid.

Step 1 — Key features:

- **Bilayer:** phospholipids arranged with hydrophilic heads outside and hydrophobic tails inside.
- **Mosaic of proteins:** integral (transmembrane) and peripheral proteins are embedded.
- **Fluidity:** lipids and many proteins diffuse laterally; lipids also rotate. Cholesterol modulates fluidity (more cholesterol = less fluidity at high T; more fluid at low T).
- **Asymmetry:** inner and outer leaflets have different lipid compositions (e.g. phosphatidylserine inside).

Step 2 — Evidence for fluidity: The Frye-Edidin experiment (1970): fusion of fluorescently labelled mouse and human cell membranes showed mixing of surface proteins within 40 min, demonstrating lateral mobility.

Final Answer: Fluid bilayer with embedded mobile proteins $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q6

Q7.

Solution

Concept — The 20 standard amino acids: All proteins in all organisms are built from a set of 20 amino acids encoded by the universal genetic code: alanine, arginine, asparagine, aspartate, cysteine, glutamine, glutamate, glycine, histidine, isoleucine, leucine, lysine, methionine, phenylalanine, proline, serine, threonine, tryptophan, tyrosine, valine.

Step 1 — L versus D: All 20 standard amino acids exist as the L-isomer in proteins (except glycine, which is achiral as its R-group is H). D-amino acids occur in some bacterial cell walls and a few antibiotics.

Step 2 — The "21st and 22nd" amino acids:

- **Selenocysteine** (Sec) — encoded by UGA in special mRNA contexts.
- **Pyrrolysine** (Pyl) — encoded by UAG in certain archaea/bacteria.

These are rarely counted in introductory courses.

Final Answer: 20 standard amino acids $\Rightarrow$ C

Answer: (C) Go Back to Q7

Q8.

Solution

Concept — Triglyceride (triacylglycerol) structure: $\text{Glycerol}\,(C_3H_8O_3) + 3\,\text{Fatty acids} \xrightarrow{\text{esterification}} \text{Triglyceride} + 3\,H_2O$

Step 1 — Bond type: Each of the three hydroxyl groups of glycerol forms an **ester bond** (-COO-) with the carboxyl group of one fatty acid. Three condensation reactions release three water molecules.

Step 2 — Saturated vs unsaturated:

- Saturated fatty acids (no C=C double bonds): straight chain, pack tightly, solid at room temperature — found in animal fats (butter, lard).
- Unsaturated (one or more C=C): kinks in the chain prevent close packing, liquid at room temperature — vegetable oils.

Step 3 — Function: Triglycerides in adipose tissue store $\sim 9\,\text{kcal}\,\text{g}^{-1}$, more than twice the energy density of carbohydrates ($\sim\ 4\,\text{kcal}\,\text{g}^{-1}$) — making them the body's premier long-term energy reserve.

Final Answer: 1 glycerol $+\ 3$ fatty acids $\Rightarrow$ $\boxed{\text{B}}$

Answer: (B) Go Back to Q8

Q9.

Solution

Concept — Activation cascade of pancreatic zymogens: The pancreas releases proteases as inactive precursors into the duodenum to prevent autodigestion of the pancreas. Activation begins in the intestinal lumen.

Step 1 — Enterokinase trigger: $\text{Trypsinogen} \xrightarrow{\text{Enterokinase (from duodenal mucosa)}} \text{Trypsin} + \text{hexapeptide}$

Step 2 — Trypsin then activates other zymogens:

- Chymotrypsinogen $\rightarrow$ Chymotrypsin
- Procarboxypeptidase $\rightarrow$ Carboxypeptidase
- More trypsinogen $\rightarrow$ Trypsin (autocatalytic amplification)
- Proelastase $\rightarrow$ Elastase

Step 3 — Clinical: Premature intra-pancreatic activation of trypsinogen (e.g. alcohol abuse, gallstones blocking the duct) leads to **acute pancreatitis**, where the pancreas digests itself.

Final Answer: Enterokinase from duodenal mucosa $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q9

Q10.

Solution

Concept — Lung capacities: A capacity is the sum of two or more lung volumes.

Step 1 — Vital capacity (VC):

$$\text{VC} = \text{IRV} + \text{TV} + \text{ERV}$$

$= 3000 + 500 + 1100 = 4600\,\text{mL}$ (typical healthy adult).

Step 2 — Other capacities:

- Inspiratory capacity (IC) $= \text{TV} + \text{IRV} \approx 3500\,\text{mL}$.
- Functional residual capacity (FRC) $= \text{ERV} + \text{RV} \approx 2300\,\text{mL}$.
- Total lung capacity (TLC) $= \text{VC} + \text{RV} \approx 5800\,\text{mL}$.

Step 3 — Clinical use: VC measured by spirometry. Reduced VC indicates restrictive lung disease (e.g. pulmonary fibrosis); FEV_1/FVC ratio diagnoses obstructive disease (asthma, COPD).

Final Answer: $\text{VC} = \text{IRV} + \text{TV} + \text{ERV} \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q10

Q11.

Solution

Concept — ECG wave components: An ECG records the summed electrical activity of cardiac muscle, picked up by electrodes on the body surface.

Step 1 — Each wave corresponds to:

- **P wave:** atrial depolarisation (impulse spreading from SA node through both atria). Atrial contraction follows immediately.
- **QRS complex:** ventricular depolarisation. Large amplitude because ventricular muscle mass is much greater than atrial. Atrial repolarisation is hidden inside QRS.
- **T wave:** ventricular repolarisation.
- P–R interval: AV nodal delay (~ 0.12–0.20 s) allowing atria to fully empty into ventricles before ventricular contraction.

Step 2 — Diagnostic value:

- Absent P waves with irregular QRS $=$ atrial fibrillation.
- Wide QRS > 0.12 s $=$ bundle-branch block.
- ST-segment elevation $=$ acute myocardial infarction.
- T-wave inversion $=$ ischaemia.

Final Answer: P wave $=$ atrial depolarisation $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q11

Q12.

Solution

Concept — ADH (vasopressin) action: Synthesised by hypothalamic neurons (supraoptic and paraventricular nuclei), transported down axons, stored in and released from the *posterior pituitary* (neurohypophysis).

Step 1 — Stimulus for release:

- Increased plasma osmolality (detected by hypothalamic osmoreceptors).
- Decreased blood volume / pressure (detected by baroreceptors).

Step 2 — Cellular action: ADH binds V_2 receptors on the basolateral membrane of collecting-duct principal cells $\rightarrow$ activates adenylyl cyclase $\rightarrow$ raises cAMP $\rightarrow$ PKA phosphorylates aquaporin-2 (AQP2) $\rightarrow$ insertion of AQP2 water channels into the apical (luminal) membrane $\rightarrow$ water moves osmotically from the dilute tubular fluid into the hypertonic medullary interstitium $\rightarrow$ concentrated urine.

Step 3 — Pathology:

- ADH deficiency $\Rightarrow$ central diabetes insipidus (large volumes of dilute urine, severe thirst).
- ADH-receptor defect $\Rightarrow$ nephrogenic diabetes insipidus.
- Excess ADH (SIADH) $\Rightarrow$ water retention and hyponatraemia.

Final Answer: Collecting duct (and DCT), insertion of aquaporin-2 $\Rightarrow$ $\boxed{\text{D}}$

Answer: (D) Go Back to Q12

Q13.

Solution

Concept — Chemical synapse: The vast majority of synapses in the vertebrate nervous system are chemical (electrical gap-junction synapses are rare exceptions, found e.g. in cardiac pacemaker tissue and a few neuronal circuits).

Step 1 — Sequence of events at a chemical synapse:

(a) Action potential arrives at pre-synaptic terminal.
(b) Voltage-gated Ca^{2+} channels open; Ca^{2+} enters the terminal.
(c) Ca^{2+} triggers fusion of synaptic vesicles with the pre-synaptic membrane.
(d) Neurotransmitter (ACh, glutamate, GABA, dopamine, serotonin, etc.) is released into the cleft.
(e) NT diffuses across the cleft ($\sim 20\,\text{nm}$) and binds receptors on the post-synaptic membrane.
(f) Receptor activation opens ion channels (ionotropic) or activates G proteins (metabotropic), generating EPSP or IPSP.
(g) NT is removed by reuptake (e.g. dopamine transporter), enzymatic breakdown (e.g. AChE for ACh), or diffusion.

Step 2 — Pharmacology:

- SSRIs (Prozac): block serotonin reuptake $\rightarrow$ more serotonin in cleft.
- Curare: blocks nicotinic ACh receptors at the NMJ $\rightarrow$ paralysis.
- Botulinum toxin: prevents ACh vesicle release.

Final Answer: Chemical neurotransmitters $\Rightarrow$ $\boxed{\text{D}}$

Answer: (D) Go Back to Q13

Q14.

Solution

Concept — Pancreatic endocrine cells (Islets of Langerhans): $\sim$ 1–2 million islets scattered throughout the pancreas; each contains four major cell types.

Step 1 — Hormones and cells:

- α **cells ($\sim$ 20%):** glucagon (raises blood glucose by promoting hepatic glycogenolysis and gluconeogenesis).
- β **cells ($\sim$ 70%): insulin** (lowers blood glucose; promotes glucose uptake into muscle/adipose, glycogen synthesis in liver/muscle).
- δ **cells ($\sim$ 5–10%):** somatostatin (inhibits both insulin and glucagon secretion).
- PP cells: pancreatic polypeptide.

Step 2 — Insulin action signal: Insulin binds receptor tyrosine kinase $\rightarrow$ recruits GLUT4 transporters to muscle/fat cell membranes $\rightarrow$ glucose enters cells $\rightarrow$ blood glucose falls.

Step 3 — Diabetes:

- Type 1: autoimmune destruction of β cells $\Rightarrow$ absolute insulin deficiency.
- Type 2: peripheral insulin resistance with relative deficiency.

Final Answer: β cells of pancreatic islets $\Rightarrow$ $\boxed{\text{C}}$

Answer: (C) Go Back to Q14

Q15.

Solution

Concept — Münch's pressure-flow (mass-flow) hypothesis (1930): The currently accepted mechanism of long-distance phloem transport.

Step 1 — The model:

(a) At the source (mature leaf): sucrose is actively loaded into the phloem sieve elements (via companion cells, often via apoplastic loading using H^+/sucrose symporters).
(b) Loading raises the solute concentration $\rightarrow$ water enters the sieve element from neighbouring xylem by osmosis $\rightarrow$ high turgor pressure builds at the source.
(c) At the sink (root, fruit, growing tissue): sucrose is unloaded $\rightarrow$ water leaves the sieve element by osmosis $\rightarrow$ low pressure at the sink.
(d) This pressure difference drives bulk flow of phloem sap (sucrose, amino acids, hormones, mRNAs) from source to sink.

Step 2 — Key features:

- Direction is bidirectional in the plant overall, but a single sieve tube transports in one direction at a time — from source to sink.
- Velocity: ~ 0.5–$1\,\mathrm{m\,h^{-1}}$ in most species.
- Energy requirement: only at loading and unloading (active transport); the bulk flow itself is passive.

Step 3 — Why other options are wrong:

- Cohesion-tension: drives *xylem* water transport, not phloem.
- Root pressure: a minor xylem mechanism, important only at night.
- Cyclosis: cytoplasmic streaming inside cells; cannot drive long-distance transport.

Final Answer: Pressure-flow hypothesis (Münch) $\Rightarrow$ A

Answer: (A) Go Back to Q15

Q16.

Solution

Concept — Site of the light reactions: Within the chloroplast, two compartments host two phases of photosynthesis.

Step 1 — Thylakoid membranes (light reactions / photochemical phase):

- Photosystems II and I (PSII, PSI) are embedded in the thylakoid membrane.
- Light excitation of chlorophyll-a in PSII drives water splitting (oxygen evolution at the lumen side): $2H_2O \rightarrow 4H^+ + 4e^- + O_2$.
- Electrons flow PSII $\rightarrow$ plastoquinone $\rightarrow$ cytochrome b_6f complex $\rightarrow$ plastocyanin $\rightarrow$ PSI $\rightarrow$ ferredoxin $\rightarrow$ $NADP^+$ reductase $\rightarrow$ NADPH.
- Proton gradient across the thylakoid membrane (high H^+ in lumen) drives ATP synthase, producing ATP (photophosphorylation).

Step 2 — Stroma (dark reactions / biosynthetic phase): The Calvin cycle takes place in the stroma, using NADPH and ATP from the light reactions to fix CO_2 into 3-phosphoglycerate $\rightarrow$ G3P $\rightarrow$ glucose.

Step 3 — Z scheme: The energy diagram of the two excitations (PSII $\rightarrow$ PSI) traces a Z shape on a redox-potential axis — hence "Z scheme".

Final Answer: Thylakoid membranes inside chloroplasts $\Rightarrow$ $\boxed{\text{B}}$

Answer: (B) Go Back to Q16

Q17.

Solution

Concept — ABO blood-group genetics: The ABO locus on chromosome 9 has three alleles: I^A, I^B, i.

Step 1 — Allele relationships:

- I^A and I^B are **codominant** with each other (both expressed when together).
- i is recessive to both I^A and I^B.
- This is also an example of **multiple allelism** — 3 alleles at one locus in the population (though each individual still carries only 2).

Step 2 — Genotype-phenotype:

Genotype	Phenotype (blood group)
I^AI^A or I^Ai	A
I^BI^B or I^Bi	B
I^AI^B	AB (both A and B antigens on RBC; codominance)
ii	O (no antigen)

Step 3 — Biochemistry: The ABO gene encodes a glycosyltransferase. The I^A allele adds N-acetylgalactosamine and the I^B allele adds galactose to a common precursor (H antigen) on RBCs. The i allele encodes an inactive enzyme.

Step 4 — Transfusion: Anti-A and anti-B antibodies are naturally present against missing antigens. Mismatched transfusion $\rightarrow$ haemolysis. AB are universal recipients; O^- are universal donors.

Final Answer: Multiple alleles with codominance and recessiveness $\Rightarrow$ $\boxed{C}$

Answer: (C) Go Back to Q17

Q18.

Solution

Concept — X-linked recessive inheritance: The gene for factor VIII is on the X chromosome. The mutant allele is recessive.

Step 1 — Inheritance pattern:

- **Males** have only one X chromosome (XY). A single defective X means they are affected (no other X to mask it). All affected males in haemophilia are hemizygous.
- **Females** have two X chromosomes (XX). Heterozygotes (carriers) are usually unaffected because the normal allele on the other X provides enough factor VIII. Affected females need defective alleles on *both* X chromosomes — much rarer.

Step 2 — Carrier consequences: A carrier mother (X^HX^h) crossed with a normal father (X^HY) gives:

- $1/4$ X^HX^H (normal daughter)
- $1/4$ X^HX^h (carrier daughter)
- $1/4$ X^HY (normal son)
- $1/4$ X^hY (affected son)

So 50% of sons are affected; 50% of daughters are carriers.

Step 3 — Royal family example: Queen Victoria was a carrier; haemophilia spread to several royal lines of Europe (Russia, Spain, Prussia) through her descendants.

Final Answer: X-linked recessive $\Rightarrow$ $\boxed{\text{D}}$

Answer: (D) Go Back to Q18

Q19.

Solution

Concept — Jacob–Monod lac operon (1961): The first model of prokaryotic gene regulation. The lac operon contains a promoter, operator, and three structural genes: *lacZ* (β-galactosidase), *lacY* (permease), and *lacA* (transacetylase).

Step 1 — Repressor and inducer:

- LacI gene (regulator) produces the lac repressor protein constitutively.
- In the absence of lactose: repressor binds the operator, RNA polymerase cannot transcribe lac genes. Operon is OFF.
- In the presence of lactose: a tiny amount of lactose is converted by basal β-galactosidase to **allolactose** (a 1,6 isomer). Allolactose binds the repressor, causing a conformational change so it can no longer bind the operator. RNA polymerase transcribes lac genes. Operon is ON.

Step 2 — Catabolite repression (CAP/cAMP): Even when lactose is present, glucose suppresses lac operon transcription via the catabolite activator protein (CAP). Only when glucose is low (cAMP high), does CAP-cAMP bind upstream of the lac promoter and boost transcription.

Step 3 — IPTG: IPTG (isopropyl-β-D-thiogalactoside) is a non-metabolisable allolactose analogue, used in molecular biology to induce lac promoter constructs.

Final Answer: Allolactose is the physiological inducer $\Rightarrow$ $\boxed{\text{B}}$

Answer: (B) Go Back to Q19

Q20.

Solution

Concept — Degeneracy of the genetic code: Of the 64 codons (4^3): 61 encode amino acids; 3 are stop codons (UAA, UAG, UGA). Since there are only 20 amino acids, most are specified by more than one codon — this redundancy is degeneracy.

Step 1 — Distribution:

- Leucine, serine, arginine: 6 codons each.
- Alanine, glycine, proline, threonine, valine: 4 codons each.
- Most others: 2 codons.
- **Only methionine (AUG) and tryptophan (UGG) have a single codon.**

Step 2 — The wobble hypothesis (Crick, 1966): The third codon position often allows non-standard base pairing, so a single tRNA can decode several synonymous codons. This explains how ~ 45 tRNAs (in many organisms) can decode all 61 sense codons.

Step 3 — Biological significance: Degeneracy protects against the deleterious effects of point mutations — a base change at the third position often produces a synonymous mutation that doesn't alter the encoded amino acid.

Other properties of the genetic code: universal, non-overlapping, read in $5' \to 3'$ direction, comma-less.

Final Answer: Most amino acids have more than one codon $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q20

Q21.

Solution

Concept — Hugo de Vries and the mutation theory (1901): While conducting hybridisation experiments on the evening primrose *Oenothera lamarckiana*, de Vries observed sudden, large, heritable variations appearing without any intermediate forms — he called these "mutations" and proposed that evolution proceeds in such discontinuous jumps (saltations).

Step 1 — Contrast with Darwinian gradualism:

- **Darwin (1859):** evolution occurs through gradual accumulation of small, continuous variations selected by natural selection.
- **de Vries:** evolution occurs through sudden, large mutations that are directly heritable and provide raw material for evolution; natural selection plays a secondary role.

Step 2 — Re-interpretation: The variations de Vries observed in *Oenothera* were later found to be due to chromosomal translocations and aneuploidy, not gene mutations in the modern sense. Nonetheless, his work introduced "mutation" as a foundational concept and laid the groundwork for the Modern Synthesis (Dobzhansky, Mayr, Huxley) that united Mendelian genetics with Darwinian evolution.

Step 3 — Subsequent landmarks: T. H. Morgan's work on *Drosophila* ($\sim$ 1910 onwards) confirmed that mutations arose continually at all loci, providing the heritable variation Darwin had postulated but could not explain.

Final Answer: *Oenothera lamarckiana* $\Rightarrow$ $\boxed{\text{B}}$

Answer: (B) Go Back to Q21

Q22.

Solution

Concept — Homology vs analogy:

- **Homologous organs:** same basic structural plan (anatomy, embryonic origin), different functions; evidence of common ancestry and *divergent* evolution.
- **Analogous organs:** different structures, similar function; evidence of *convergent* evolution under similar selective pressures.

Step 1 — Forelimb pattern (the classic homology): Human arm, whale flipper, bat wing, cat foreleg: all share the same skeletal arrangement — one humerus, then radius+ulna, then carpals, metacarpals, phalanges (the pentadactyl limb pattern). Yet the functions are radically different: manipulation, swimming, flying, running.

Step 2 — Classic analogy examples:

- Wings of insects, birds, and bats — all enable flight but built from different embryonic tissues: insect wing is a cuticular outgrowth, bird wing is a feathered forelimb, bat wing is a skin membrane over forelimb bones.
- Eyes of vertebrates and octopuses — both image-forming, but completely different embryological origin and structure (vertebrate retina is inverted, cephalopod retina is non-inverted).

Step 3 — Vestigial organs: Reduced, non-functional structures inherited from ancestors (e.g. human vermiform appendix, whale pelvic bones, snake hind-limb buds). These are evidence of evolution in their own right, but the four forelimbs described are functional homologous structures, not vestigial.

Final Answer: Homologous organs (divergent evolution) $\Rightarrow$ $\boxed{\text{D}}$

Answer: (D) Go Back to Q22

Q23.

Solution

Concept — Corpus luteum ("yellow body"): After ovulation, the cells of the ruptured Graafian follicle undergo luteinisation (driven by the LH surge), proliferate, accumulate yellow lipid pigments (lutein), and form an endocrine structure — the corpus luteum.

Step 1 — Hormone output:

- **Progesterone (dominant):** maintains the uterine endometrium in a thickened secretory state, ready for implantation; suppresses uterine contractions; thickens cervical mucus.
- Oestrogen (in smaller amounts).
- Inhibin (suppresses FSH).

Step 2 — Two fates of the corpus luteum:

- **If pregnancy occurs:** the developing trophoblast secretes hCG, which acts like LH on the corpus luteum, maintaining it for $\sim$ 10–12 weeks until the placenta takes over progesterone production.
- **If no pregnancy:** corpus luteum regresses by day ~ 26, progesterone falls, the endometrium sheds (menstruation), and a new cycle begins.

Step 3 — Clinical: Progesterone supplementation is used to support pregnancy in cases of corpus luteum insufficiency or after IVF.

Final Answer: Progesterone (and some oestrogen) $\Rightarrow$ $\boxed{\text{A}}$

Answer: (A) Go Back to Q23

Q24.

Solution

Concept — Sperm structure and the acrosome: A mature sperm has three regions: head (nucleus + acrosome), middle piece (mitochondrial sheath), and tail (flagellum with $9 + 2$ axoneme).

Step 1 — The acrosomal cap: A specialised Golgi-derived membrane-bound vesicle covering the anterior $2/3$ of the sperm head. It contains digestive enzymes — the most important being:

- **Hyaluronidase:** dissolves hyaluronic acid in the cumulus oophorus surrounding the ovum.
- **Acrosin (a protease):** digests the glycoprotein layer of the zona pellucida.

Step 2 — The acrosomal reaction: When the sperm contacts the zona pellucida, the acrosomal membrane fuses with the plasma membrane and the contents are released by exocytosis. This permits the sperm to penetrate the zona and reach the ovum's plasma membrane.

Step 3 — Once one sperm enters: Cortical granules release their contents (cortical reaction), inactivating ZP3 glycoproteins and hardening the zona — the "slow block to polyspermy" that prevents additional sperm entry. A faster electrical block also exists momentarily.

Final Answer: Hydrolytic enzymes for zona pellucida penetration $\Rightarrow$ $\boxed{\text{C}}$

Answer: (C) Go Back to Q24

Q25.

Solution

Concept — Human chorionic gonadotropin (hCG): A glycoprotein hormone secreted by the trophoblast cells (specifically the syncytiotrophoblast) of the developing embryo and placenta, beginning soon after implantation ($\sim$ 6–8 days post-fertilisation).

Step 1 — Function of hCG: hCG has structural and functional similarity to LH (both bind the LH/hCG receptor). It maintains the corpus luteum (rescuing it from regression), so progesterone secretion continues and the endometrium is preserved. Without hCG, the corpus luteum would regress, progesterone would fall, and the endometrium would shed — losing the pregnancy.

Step 2 — hCG and pregnancy diagnosis:

- Detected in maternal blood within 1–2 days of implantation; in urine $\sim$ 2 weeks after conception.
- Home pregnancy tests use anti-hCG antibodies (monoclonal, against the β-subunit, which is unique to hCG; the α-subunit is shared with FSH, LH, TSH).
- hCG levels approximately double every 48 hours in normal early pregnancy and peak at $\sim$ 8–11 weeks.

Step 3 — Clinical use beyond pregnancy testing:

- Tumour marker for choriocarcinoma and some germ-cell tumours.
- Therapeutic use in male hypogonadism, cryptorchidism, and as ovulation trigger in IVF (mimicking the LH surge).

Final Answer: Trophoblast cells of the developing placenta $\Rightarrow$ $\boxed{\text{A}}$

Answer: (A) Go Back to Q25

Q26.

Solution

Concept — Lactational amenorrhoea method (LAM): A natural contraceptive period during exclusive breastfeeding, lasting up to 6 months postpartum if specific criteria are met.

Step 1 — Hormonal mechanism:

- Suckling stimulates afferent neural signals to the hypothalamus.
- Prolactin secretion from the anterior pituitary rises strongly.
- High prolactin inhibits the pulsatile release of GnRH from the hypothalamus.
- Without GnRH pulses, FSH and LH secretion from the anterior pituitary drops.
- Without FSH/LH, ovarian follicles do not mature, no LH surge, no ovulation, no menstruation.

Step 2 — Conditions for effective LAM ($\sim 98\%$ effective when all met):

- Exclusive (or near-exclusive) breastfeeding day and night.
- Infant under 6 months old.
- Mother is still amenorrhoeic.

Step 3 — Why it's reliable but not perfect: Once any of the three conditions is broken (e.g. supplemental feeding reduces nipple stimulation), prolactin levels drop and ovulation can resume — often before the first postpartum menstruation. Hence return of fertility can precede the return of menstruation.

Final Answer: High prolactin suppresses GnRH $\Rightarrow$ $\boxed{\text{B}}$

Answer: (B) Go Back to Q26

Q27.

Solution

Concept — Pollen wall structure: A pollen grain has two distinct walls:

- **Exine (outer):** hard, ornamented, contains **sporopollenin**.
- **Intine (inner):** thin, made of cellulose and pectin; gives rise to the pollen tube during germination.

Step 1 — Properties of sporopollenin:

- One of the most chemically inert organic compounds known.
- Resistant to strong acids, alkalis, and high temperatures.
- Resistant to enzymatic degradation — which is why pollen grains are preserved in sediments for millions of years.

Step 2 — Use in palaeontology: The science of palynology (study of pollen and spores in sediments) relies on sporopollenin's preservation. Pollen analysis of lake and bog sediments reconstructs ancient vegetation and climates over millions of years.

Step 3 — Germ pores: The exine has thin, sporopollenin-free regions called **germ pores** (apertures), through which the pollen tube emerges during germination on the stigma.

Final Answer: Sporopollenin (exine) $\Rightarrow$ $\boxed{\text{C}}$

Answer: (C) Go Back to Q27

Q28.

Solution

Concept — Types of pollination:

- **Autogamy:** pollen from anther to stigma of *the same* flower (self-pollination within one flower).
- **Geitonogamy:** pollen from anther of one flower to stigma of another flower *on the same plant* (functionally self, genetically self).
- **Xenogamy:** pollen from one plant to stigma of another plant of same species (true cross-pollination, allogamy).
- Allogamy is an umbrella term for cross-pollination (geitonogamy + xenogamy).

Step 1 — Two ways autogamy occurs:

- **Chasmogamous flowers** (most flowers): open, expose anthers and stigma. Autogamy requires the synchronous maturation of anther and stigma.
- **Cleistogamous flowers** (e.g. *Commelina*, *Viola*, peanut): the flower never opens; pollination occurs inside the closed bud and is *always* autogamous. Cleistogamy guarantees seed-set but eliminates genetic recombination.

Step 2 — Advantages/disadvantages of autogamy:

- Advantages: assured pollination, no need for pollinators, no loss of pollen.
- Disadvantages: no genetic variation; inbreeding depression over generations.

Final Answer: Autogamy (self-pollination within the same flower) $\Rightarrow$ $\boxed{\text{D}}$

Answer: (D) Go Back to Q28

Q29.

Solution

Concept — Bolting and gibberellins: Bolting is the sudden, rapid elongation of the stem (internode) just before flowering in plants that normally grow as rosettes (very short internodes, leaves clustered near the ground).

Step 1 — Examples:

- Cabbage (*Brassica oleracea*), beet, spinach, lettuce, carrot — all biennials that form a rosette in their first year and bolt to flower in their second year.

Step 2 — Hormonal trigger:

- Endogenous gibberellin levels rise sharply just before bolting.
- Application of exogenous GA_3 (gibberellic acid) can induce bolting prematurely, even without the normal trigger of low temperature (vernalisation) or long days.
- Gibberellins stimulate cell elongation in the internodal regions $\Rightarrow$ rapid stem extension.

Step 3 — Practical use:

- In sugarcane: GA spray promotes stem elongation $\Rightarrow$ higher cane yield.
- In seedless grape: GA induces longer internodes $\Rightarrow$ less crowded bunches and larger berries.
- In barley brewing: GA promotes α-amylase production $\Rightarrow$ malting.

Final Answer: Bolting — gibberellin-induced stem elongation $\Rightarrow$ $\boxed{C}$

Answer: (C) Go Back to Q29

Q30.

Solution

Concept — Vernalisation: The term "vernalisation" (from Latin *vernus*, of spring) was introduced by Lysenko (1928) for the artificial promotion of flowering by pre-treating seeds with low temperature.

Step 1 — Definition: The promotion (or qualitative requirement) of flowering by an obligatory period of low-temperature exposure ($\sim$ 1–7°C for several weeks).

Step 2 — Examples:

- Winter wheat: must be sown in autumn so the seedling experiences winter cold; if sown in spring, it remains vegetative and does not flower in time. Vernalisation of seeds before spring sowing allows the same effect.
- Biennials — cabbage, beet, carrot, turnip: spend the first year as a rosette (cold winter), then bolt and flower in the second year.

Step 3 — Mechanism: At the molecular level (well-studied in *Arabidopsis*), cold causes silencing of *FLOWERING LOCUS C* (*FLC*, a floral repressor) through Polycomb-mediated chromatin changes (epigenetic memory of winter). Once silenced, the plant can express *FT* (florigen) under long days and proceed to flowering.

Step 4 — Devernalisation: Brief exposure to high temperature ($\sim$ 30°C) immediately after the cold treatment can reverse vernalisation — showing that the cold-induced state must be stabilised over time.

Final Answer: Promotion of flowering by cold exposure $\Rightarrow$ $\boxed{\text{B}}$

Answer: (B) Go Back to Q30

Q31.

Solution

Concept — Gram staining (Hans Christian Gram, 1884): The Gram stain is the most widely used differential stain in bacteriology. Bacteria are stained with crystal violet, fixed with iodine (forming the CV-I complex), decolourised with alcohol/acetone, and counter-stained with safranin.

Step 1 — The two outcomes:

- **Gram-positive:** retain crystal violet $\rightarrow$ appear purple/violet under microscope. The thick peptidoglycan layer (20–80 nm, 40–80% of cell-wall dry weight) traps the CV-I complex during decolourisation. Examples: *Staphylococcus aureus*, *Streptococcus*, *Bacillus*, *Clostridium*, *Mycobacterium*.
- **Gram-negative:** crystal violet is washed out $\rightarrow$ counter-stained pink by safranin. They have a thin peptidoglycan layer ($\sim$ 5–10 nm) covered by an outer lipopolysaccharide (LPS) membrane. Examples: *E. coli*, *Salmonella*, *Pseudomonas*, *Neisseria*.

Step 2 — Why it matters clinically:

- Different antibiotics target different cell-wall types:
  - Penicillins, vancomycin: more effective against gram-positives.
  - Aminoglycosides, polymyxins: more effective against gram-negatives.
- LPS of gram-negatives is an **endotoxin** — can cause severe systemic illness (septic shock).
- Gram stain is the first rapid bacteriological test on a clinical sample (sputum, blood culture, CSF), often guiding initial empirical antibiotic choice.

Final Answer: Thick peptidoglycan layer with teichoic acids $\Rightarrow$ $\boxed{\text{D}}$

Answer: (D) Go Back to Q31

Q32.

Solution

Concept — Mycorrhiza (= "fungus root"): A mutualistic association between certain fungi and the roots of $\sim 90\%$ of land plants. The association is so widespread that most natural plants depend on it for normal nutrition.

Step 1 — The mutualism:

- **Fungus benefits:** receives photosynthetically fixed sugars (sucrose, glucose) from the plant.
- **Plant benefits:** the fungal hyphae, much finer and more extensive than root hairs, vastly increase the volume of soil exploited, dramatically improving uptake of water and especially phosphorus (often the limiting nutrient in soils). Mycorrhizal hyphae also enhance uptake of trace elements (Zn, Cu) and confer some protection from soil pathogens.

Step 2 — Two main types:

- **Ectomycorrhiza (sheathing):** fungal hyphae form a sheath around the root surface and penetrate only the intercellular spaces of the cortex (forming a Hartig net). Common in forest trees (pine, oak, beech). Fungi: Basidiomycetes mostly.
- **Endomycorrhiza (arbuscular, AM):** hyphae penetrate *into* root cortical cells, forming branched arbuscules (the exchange interface). The most common type, found in most herbaceous and crop plants. Fungi: Glomeromycota.

Step 3 — Importance: Crop yield in many soils depends on mycorrhizal colonisation. Excessive phosphate fertilisation can suppress mycorrhization. Biofertilisers based on mycorrhizal inoculants are used in modern sustainable agriculture.

Final Answer: Mutualistic symbiosis between fungus and plant roots $\Rightarrow$ $\boxed{\text{A}}$

Answer: (A) Go Back to Q32

Q33.

Solution

Concept — Phylum Coelenterata (Cnidaria): The name "Cnidaria" itself derives from *cnidae* (nematocysts) — the defining synapomorphy of the phylum.

Step 1 — Cnidocytes (nematocyst-bearing cells):

- Specialised cells on the tentacles and body surface.
- Each contains a **nematocyst** — a coiled, harpoon-like thread inside a fluid-filled capsule, often loaded with toxin.
- A small projection (cnidocil) acts as the trigger. Mechanical or chemical stimulation $\rightarrow$ rapid eversion of the thread within microseconds, injecting toxin into prey or attacker.

Step 2 — Other diagnostic features of Cnidaria:

- Tissue level of organisation (no true organs).
- Radial symmetry.
- Diploblastic (ectoderm + endoderm, with mesoglea between).
- Two body forms: polyp (sessile, e.g. *Hydra*, sea anemone) and medusa (free-swimming, e.g. jellyfish). Many show alternation of generations (e.g. *Obelia*).
- Single opening serves as both mouth and anus.

Step 3 — Notable members: *Hydra* (freshwater polyp), *Aurelia* (jellyfish), *Physalia* (Portuguese man-of-war — siphonophore), *Adamsia* (sea anemone), coral animals (form coral reefs).

Final Answer: Coelenterata (Cnidaria) $\Rightarrow$ $\boxed{\text{B}}$

Answer: (B) Go Back to Q33

Q34.

Solution

Concept — Tuberculosis (TB): A chronic bacterial infection, primarily of the lungs (pulmonary TB), though it can affect any organ (extrapulmonary TB — lymph nodes, bones, kidneys, meninges).

Step 1 — The pathogen: *Mycobacterium tuberculosis* — a slow-growing, aerobic, acid-fast bacillus identified by Robert Koch on 24 March 1882 (now celebrated as World TB Day).

Special features:

- Lipid-rich cell wall (mycolic acids) makes the bacillus "acid-fast" — it resists decolourisation by acid alcohol after staining with carbol fuchsin (Ziehl-Neelsen stain).
- Generation time: ~ 24 hours (compared with ~ 20 minutes for *E. coli*).
- Spreads by inhalation of aerosolised droplets from coughing/sneezing of infectious patients.

Step 2 — Pathology: Infection $\rightarrow$ engulfment by alveolar macrophages, which often cannot kill the bacteria $\rightarrow$ formation of granulomas (tubercles) containing macrophages, T cells, and central caseous necrosis. Most healthy individuals contain the infection (latent TB); 5–10% progress to active TB (productive cough, fever, night sweats, weight loss, haemoptysis).

Step 3 — Diagnosis and treatment:

- Tuberculin (Mantoux) skin test; Interferon-gamma release assays.
- Sputum smear (acid-fast stain), culture, GeneXpert PCR.
- Treatment: 6-month multi-drug regimen — isoniazid, rifampicin, pyrazinamide, ethambutol. Multi-drug resistance (MDR-TB) is a growing global challenge.
- Prevention: BCG vaccine (live attenuated *M. bovis*), now part of routine childhood immunisation in many countries.

Final Answer: *Mycobacterium tuberculosis* $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q34

Q35.

Solution

Concept — Types of immunity:

Type	Example
Innate (natural)	Skin, gastric acid, complement, NK cells
Active natural	Acquired by recovery from natural infection
Active artificial	Vaccination (immunisation)
Passive natural	Maternal IgG via placenta; IgA via breast milk
Passive artificial	Anti-tetanus serum, antivenom, monoclonal antibodies

Step 1 — How vaccination produces active immunity: A vaccine introduces antigens (attenuated/killed pathogen, subunit protein, conjugate, mRNA) that the recipient's own immune system recognises as foreign. The immune system mounts a primary response: B cells produce specific antibodies, T cells develop, and crucially, **memory B and T cells** are formed. On later exposure to the actual pathogen, the secondary response is faster, stronger, and effective at preventing disease.

Step 2 — Distinguishing features:

- Active immunity: slow onset (weeks), long-lasting (years to lifelong), requires the recipient's own immune system, generates memory.
- Passive immunity: rapid onset (immediate), short-lasting (weeks to months), no memory generated, no immune system response needed.

Step 3 — Types of vaccines:

- Live attenuated: BCG, MMR, oral polio, yellow fever.
- Inactivated: rabies, hepatitis A, salk polio.
- Subunit/recombinant: hepatitis B, HPV.
- Toxoid: tetanus, diphtheria.
- mRNA: SARS-CoV-2 (a recent breakthrough).

Final Answer: Active artificial immunity $\Rightarrow$ C

Answer: (C) Go Back to Q35

Q36.

Solution

Concept — Penicillin and bacterial cell-wall synthesis: Penicillin was discovered serendipitously by Alexander Fleming in 1928 when he noticed that a contaminating *Penicillium notatum* mould had killed nearby *Staphylococcus* colonies on a Petri dish. Howard Florey and Ernst Chain later purified penicillin and made it medically useful (1940s), winning the Nobel Prize with Fleming in 1945.

Step 1 — Mechanism of action: Penicillins (and all β-lactam antibiotics: cephalosporins, carbapenems, monobactams) share a β-lactam ring that is a structural analogue of the D-Ala-D-Ala dipeptide. They:

- Bind irreversibly to penicillin-binding proteins (PBPs), particularly the transpeptidases that cross-link adjacent peptidoglycan strands.
- Block cross-linking $\Rightarrow$ weakened cell wall.
- Autolysins continue to degrade peptidoglycan as part of normal growth, but no new cross-linking forms $\Rightarrow$ osmotic lysis of the bacterium.

Step 2 — Selective toxicity: Eukaryotic cells lack peptidoglycan altogether, so penicillin is harmless to human cells — an excellent example of selective toxicity, a principle articulated by Paul Ehrlich ("the magic bullet").

Step 3 — Resistance:

- Bacteria produce β-lactamases that hydrolyse the ring (combated by adding clavulanic acid, a β-lactamase inhibitor).
- Altered PBPs (e.g. PBP2a in MRSA) reduce penicillin binding.

Final Answer: Inhibits transpeptidase $\rightarrow$ blocks peptidoglycan cross-linking $\Rightarrow$ $\boxed{\text{A}}$

Answer: (A) Go Back to Q36

Q37.

Solution

Concept — Decomposers in an ecosystem: Decomposers (also called saprotrophs or saprobes) break down dead organic matter and waste products into simpler inorganic substances, releasing nutrients back to the soil and atmosphere. They close the loop of nutrient cycling and prevent indefinite accumulation of organic waste.

Step 1 — Major decomposer groups:

- **Saprotrophic fungi:** most efficient decomposers of cellulose, hemicellulose, and lignin; key in forest ecosystems where wood needs to be broken down. Examples: *Aspergillus*, *Rhizopus*, mushrooms, bracket fungi.
- **Saprotrophic bacteria:** decompose proteins, fats, sugars; vital in nutrient mineralisation. Examples: many *Bacillus*, *Pseudomonas*.

Step 2 — Decomposition process:

(a) **Fragmentation:** earthworms, mites, beetles physically break dead matter into smaller pieces.
(b) **Leaching:** water-soluble nutrients percolate into soil.
(c) **Catabolism:** extracellular enzymes from microbes degrade polymers into monomers.
(d) **Humification:** formation of dark, amorphous humus — resistant, nutrient-rich soil component.
(e) **Mineralisation:** final release of inorganic ions (CO_2, NH_4^+, $H_2PO_4^-$).

Step 3 — Why options B, C, D are wrong: Green plants are producers (autotrophs). Herbivores and carnivores are consumers. Decomposers form a fundamentally separate trophic category.

Final Answer: Saprotrophic bacteria and fungi $\Rightarrow$ $\boxed{\text{A}}$

Answer: (A) Go Back to Q37

Q38.

Solution

Concept — Symbiotic nitrogen fixation: *Rhizobium* (and related genera — *Bradyrhizobium*, *Sinorhizobium*) form root nodules with leguminous plants in a tightly regulated mutualism.

Step 1 — Establishment of nodulation:

(a) Plant root exudes flavonoids that attract free-living rhizobia in soil.
(b) Bacterial Nod factors trigger root-hair curling.
(c) Bacteria enter via infection threads into cortical cells.
(d) Cortical cells divide $\rightarrow$ nodule formation.
(e) Bacteria differentiate into nitrogen-fixing bacteroids inside the cytoplasm.

Step 2 — The biochemistry: Nitrogenase catalyses:

$$N_2 + 8H^+ + 8e^- + 16\,ATP \longrightarrow 2NH_3 + H_2 + 16\,ADP + 16\,P_i$$

This is energetically very expensive (16 ATPs per N_2 fixed), supplied by the plant from photosynthesis. The reduction proceeds through bound intermediates: $N_2 \rightarrow N_2H_2 \rightarrow N_2H_4 \rightarrow NH_3$.

Step 3 — Oxygen problem: Nitrogenase is irreversibly inactivated by O_2. The plant solves this by producing **leghaemoglobin** (an oxygen-binding protein, giving nodules their pink colour), which scavenges free O_2 to keep nitrogenase functional while still supplying bacteroids with O_2 for respiration via tightly controlled flow.

Step 4 — Why legumes are important:

- Improve soil nitrogen $\Rightarrow$ used in crop rotation (e.g. pulses after cereals).
- Reduce need for synthetic nitrogen fertiliser (Haber-Bosch).
- Global symbiotic N_2 fixation: $\sim$ 50–70 million tonnes per year.

Final Answer: $N_2 + H^+ + e^- \rightarrow NH_3$ by nitrogenase (anaerobic) $\Rightarrow$ $\boxed{B}$

Answer: (B) Go Back to Q38

Q39.

Solution

Concept — Bt cotton — transgenic crop: Bt cotton is a genetically modified cotton variety that contains the *cry* gene(s) from the soil bacterium *Bacillus thuringiensis*, enabling the plant to produce its own insecticidal protein.

Step 1 — The Bt bacterium and toxin: *B. thuringiensis* is a gram-positive bacterium that, during sporulation, produces protein crystals (Cry proteins, δ-endotoxins) toxic to specific groups of insects.

- **Cry I:** toxic to lepidopteran larvae (caterpillars, e.g. bollworm).
- **Cry II:** also lepidopteran-toxic.
- **Cry III:** toxic to coleopterans (beetles).
- **Cry IV/V:** dipteran (flies, mosquitoes).

Step 2 — Mechanism of toxicity:

(a) Insect larva ingests Bt-containing plant tissue.
(b) In the alkaline midgut, the inactive protoxin is solubilised and proteolytically cleaved to the active toxin core.
(c) Active toxin binds specific cadherin receptors on midgut epithelial cells.
(d) Forms ion-channel pores in the cell membrane $\rightarrow$ midgut cells lyse $\rightarrow$ insect stops feeding and dies in 1–3 days.

Step 3 — Why specifically lepidopteran-selective: The cadherin receptors exist only on certain insect midgut cells. Mammals (acidic stomach pH, different gut receptors) are not affected — Bt protein is degraded by gastric acid and digestive enzymes.

Step 4 — Cultivation in India: Bt cotton was approved in India in 2002 and is the only commercially cultivated GM crop in the country. It has substantially reduced insecticide use against bollworm, though concerns about resistance evolution and secondary-pest outbreaks remain.

Final Answer: *Bacillus thuringiensis* $\Rightarrow$ $\boxed{\text{D}}$

Answer: (D) Go Back to Q39

Q40.

Solution

Concept — Humulin — the first recombinant human insulin: Approved by the US FDA in October 1982, Humulin (manufactured by Eli Lilly in collaboration with Genentech) was the first medicine produced by recombinant DNA technology and approved for human use — a landmark of the biotech industry.

Step 1 — The two-chain strategy used: Native human insulin is a 51-amino-acid hormone consisting of two chains (A $= 21$ residues, B $= 30$ residues) linked by two interchain disulfide bonds. To produce it in *E. coli*:

(a) Two synthetic genes were chemically synthesised: one encoding the A-chain and one encoding the B-chain.
(b) Each gene was cloned into a separate *E. coli* plasmid downstream of the lac promoter and fused to the β-*galactosidase* coding sequence (producing a fusion protein that protected the small insulin chain from bacterial proteases).
(c) Two cultures of *E. coli* were grown, one expressing the A-chain fusion and the other the B-chain fusion.
(d) Each chain was cleaved from the β-galactosidase carrier (using cyanogen bromide at methionine residues).
(e) The two purified chains were then chemically combined under controlled oxidation to form the correct interchain disulfide bonds and yield mature, biologically active insulin.

Solution

Step 2 — Why this was a breakthrough:

- Before 1982: diabetics relied on insulin extracted from pig and cow pancreases (animal insulin), which differed slightly from human insulin and caused immunological reactions in some patients. Supply was limited by abattoir output.
- Recombinant Humulin: identical to human insulin, unlimited supply, no animal allergens.

Step 3 — Modern method (Humulin today): The modern process uses a single proinsulin gene (A-C-B with the C-peptide connector) expressed as a single recombinant protein in *E. coli* or yeast; the C-peptide is then enzymatically removed to give mature insulin — closer to the natural biosynthesis pathway.

Final Answer: Genetically engineered *E. coli* with separate A and B chain expression, then chemical combination $\Rightarrow$ C

Answer: (C) Go Back to Q40

Answer Key

Q	Ans	Q	Ans	Q	Ans	Q	Ans	Q	Ans
1	C	2	A	3	B	4	D	5	A
6	D	7	C	8	B	9	B	10	A
11	C	12	D	13	D	14	C	15	A
16	B	17	C	18	D	19	B	20	A
21	B	22	D	23	A	24	C	25	A
26	B	27	C	28	D	29	C	30	B
31	D	32	A	33	B	34	D	35	C
36	A	37	A	38	B	39	D	40	C