GUJCET Biology

Sample Paper – 9

Duration: 60 Minutes **Maximum Marks: 40**

Instructions

- This paper contains **40** Multiple Choice Questions (Single Correct Answer), modelled on the Biology portion of **GUJCET** (Gujarat Common Entrance Test).
- Each correct answer carries **+1 mark**. There is a negative marking of -0.25 **marks** for each incorrect answer. Unanswered questions carry no penalty.
- Only **one** option is correct per question. Mark responses on the OMR sheet carefully.
- Syllabus level: **GSEB Class 11–12 Biology (NCERT aligned) — Human Physiology, Plant Physiology, Reproduction, Genetics, Ecology, Biotechnology.**
- Use of mobile phones, calculators, or any electronic device is strictly prohibited.

Q1. Which of the following functions is performed by the **large intestine (colon)**?

A. Enzymatic digestion of proteins by peptidases

B. Absorption of water and electrolytes from indigestible residues, and synthesis of vitamins K and B_{12} by commensal bacteria

C. Emulsification of dietary fats by bile salts

D. Secretion of pancreatic amylase to digest starch

Q2. Which is the **correct sequence** of blood flow after nutrient absorption from the small intestine?

A. Small intestine $\rightarrow$ hepatic vein $\rightarrow$ liver $\rightarrow$ hepatic portal vein $\rightarrow$ IVC

B. Small intestine → mesenteric artery → liver → hepatic vein → IVC

C. Small intestine → hepatic portal vein → liver → hepatic vein → inferior vena cava (IVC)

D. Small intestine → IVC → liver → hepatic portal vein → heart

Q3. Pulmonary surfactant reduces alveolar surface tension by:

A. Increasing the radius of alveoli to distribute surface forces more widely

B. Providing a rigid scaffold to keep alveoli open mechanically

C. Stimulating Clara cells to secrete additional fluid into the alveoli

D. Acting as a detergent-like molecule (dipalmitoylphosphatidylcholine, DPPC) at the air–water interface, reducing cohesive forces between water molecules

Q4. During normal quiet **inspiration**, which muscles contract to increase thoracic volume?

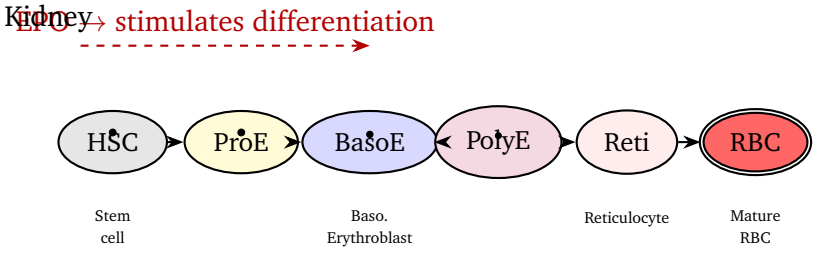
A. Diaphragm (contracts and moves downward) and external intercostal muscles (lift ribs upward and outward)

B. Internal intercostal muscles and abdominal muscles

C. Diaphragm relaxes upward while external intercostals contract

D. Only the diaphragm contracts; intercostal muscles play no role in quiet breathing

Q5. Erythropoiesis requires stimulation by erythropoietin (EPO). Which tissue is the **primary site of EPO production** in adults responding to hypoxia?



A. Liver (main EPO source in adults)

B. Kidneys (peritubular interstitial cells produce EPO in adults in response to low partial pressure of O_2)

C. Bone marrow itself produces EPO to drive its own differentiation

D. Spleen (extramedullary haematopoiesis organ)

Q6. Which sequence **correctly describes pulmonary circulation** in double circulation?

A. Left ventricle $\rightarrow$ pulmonary artery $\rightarrow$ lungs $\rightarrow$ pulmonary vein $\rightarrow$ right atrium

B. Right atrium $\rightarrow$ right ventricle $\rightarrow$ aorta $\rightarrow$ lungs $\rightarrow$ pulmonary vein $\rightarrow$ left atrium

C. Right ventricle $\rightarrow$ pulmonary artery $\rightarrow$ lungs $\rightarrow$ pulmonary vein $\rightarrow$ left atrium

D. Left ventricle $\rightarrow$ pulmonary vein $\rightarrow$ lungs $\rightarrow$ pulmonary artery $\rightarrow$ right ventricle

Q7. Which of the following is a **correct function of the spleen**?

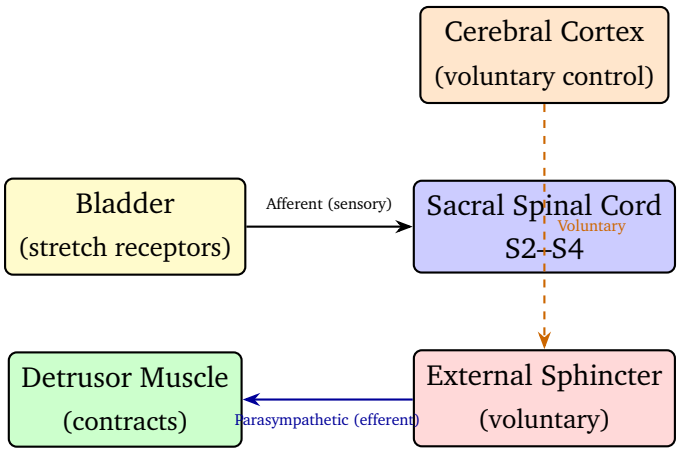
A. Production of bile for fat digestion

B. Filtration of lymph from the tissue spaces

C. Primary site of immunoglobulin synthesis under normal conditions

D. Phagocytosis of senescent (old/damaged) red blood cells, and sequestration of platelets and monocytes

Q8. The **micturition reflex** is initiated when the bladder fills. Which diagram below correctly summarises the neural arc?



A. Stretch receptors in the bladder wall detect increased volume, send signals to the sacral spinal cord, which triggers parasympathetic stimulation of the detrusor muscle causing voiding

B. Cortical signals from the cerebrum directly contract the bladder without any spinal cord involvement

C. Sympathetic stimulation of the detrusor muscle causes bladder wall contraction during micturition

D. ADH (antidiuretic hormone) acts directly on the bladder wall muscle to trigger contraction

Q9. Which statement about **Malpighian tubules** in insects is CORRECT?

A. They are connected to the midgut and excrete urea as the main nitrogenous waste

B. They are blind-ending tubules that open into the hindgut, secreting uric acid; water and ions are reabsorbed in the hindgut, producing nearly dry excreta

C. They filter haemolymph under high hydrostatic pressure, analogous to the vertebrate glomerulus

D. They produce ammonia as the main nitrogenous waste product, excreted in large volumes of water

Q10. Which of the following substances is **present in the glomerular filtrate** of a normal healthy person?

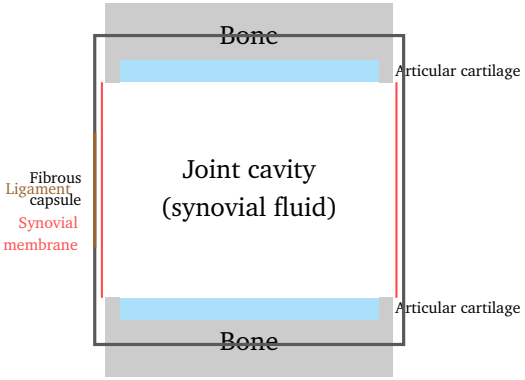
A. Haemoglobin (MW ≈68,000 Da)

B. Albumin (MW ≈69,000 Da)

C. Glucose (freely filtered and fully reabsorbed in the proximal convoluted tubule under normal blood glucose levels)

D. Immunoglobulins (antibodies, MW >150,000 Da)

Q11. A **synovial joint** is shown in cross-section below. Which structural features are found in **ALL** synovial joints?



A. Articular disc, articular cartilage, and menisci present in all types

B. Bony projections (epicondyles), bursae, and cartilaginous pads in every synovial joint

C. Fibrocartilage discs and direct bony fusion at the articulating surfaces

D. Joint cavity filled with synovial fluid, articular cartilage covering the bone ends, and a fibrous capsule lined internally by synovial membrane

Q12. How many **bones** comprise the vertebral column in an adult human?

A. 26 (7 cervical + 12 thoracic + 5 lumbar + 1 sacrum [5 fused] + 1 coccyx [4 fused])

B. 33 (counting each fused sacral and coccygeal vertebra separately)

C. 24 (excluding the sacrum and coccyx)

D. 30 (miscounting the thoracic and lumbar vertebrae)

Q13. The diagram below compares the two divisions of the **autonomic nervous system**. Which combination correctly describes the effects of the **sympathetic** nervous system?

	Sympathetic	Parasympathetic
Origin	Thoracolumbar (T1–L2)	Craniosacral (CN III,VII,IX,X; S2–S4)
Neurotransmitter	Norepinephrine	Acetylcholine
Heart rate	↑ Increases	↓ Decreases
Pupils	Dilated	Constricted

A. Decreased heart rate, increased peristalsis, constricted pupils, and bronchoconstriction

B. Increased heart rate, decreased peristalsis, dilated pupils, and bronchodilation

C. Increased digestive activity, decreased heart rate, constricted pupils, and increased salivation

D. Decreased heart rate, dilated bronchioles, increased urinary output, and miosis

Q14. Which statement about **photoreceptors** in the human retina is CORRECT?

A. Rods are concentrated at the fovea centralis and provide colour vision in bright light

B. Cones are distributed evenly throughout the retina and function best in dim (scotopic) light

C. Cones are concentrated at the fovea centralis and are responsible for colour discrimination and high-acuity daytime (photopic) vision

D. Both rods and cones contain rhodopsin as their photopigment

Q15. Excess secretion of **growth hormone (GH)** during childhood, *before* the epiphyseal plates fuse, would result in:

A. Cushing's syndrome (caused by excess cortisol, not GH)

B. Dwarfism (caused by GH deficiency, not excess)

C. Acromegaly (this condition results from excess GH in adults after plate fusion)

D. Gigantism (abnormally excessive growth of long bones due to hypersecretion of GH before epiphyseal closure)

Q16. **Melatonin** secretion by the pineal gland is best described as:

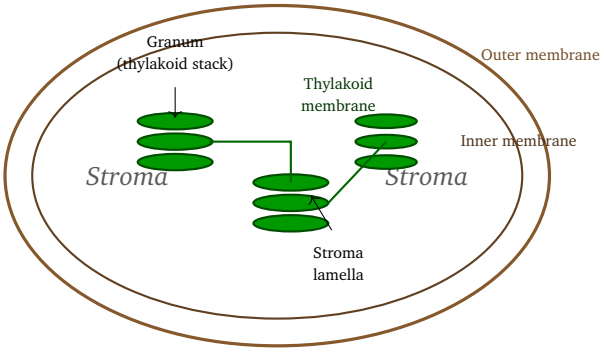
A. Highest during the night (in darkness) and is primarily involved in regulating the sleep–wake circadian rhythm

B. Constant throughout the 24-hour period, independent of light–dark cycles

C. Stimulated by bright light during the daytime to promote wakefulness and alertness

D. Primarily regulated by ACTH released from the anterior pituitary gland

Q17. In a chloroplast, where do the **light-dependent reactions** of photosynthesis occur?



A. In the stroma (the fluid matrix surrounding the grana), which is the site of the Calvin cycle

B. On the thylakoid membrane (specifically the grana thylakoids), containing photosystem I and photosystem II

C. On the outer chloroplast envelope membrane

D. In the intermembrane space between the two outer membranes of the chloroplast

Q18. The **large central vacuole** in a mature plant cell serves which primary function?

A. Site of protein synthesis by polyribosomes attached to the tonoplast

B. Production of cell wall polysaccharide components delivered by Golgi vesicle fusion

C. Maintenance of turgor pressure by osmotic uptake of water, contributing to cell rigidity and the structural integrity of non-woody plants

D. Energy production by oxidative phosphorylation in tonoplast-embedded enzymes

Q19. **Nuclear pores** in the nuclear envelope are important because they:

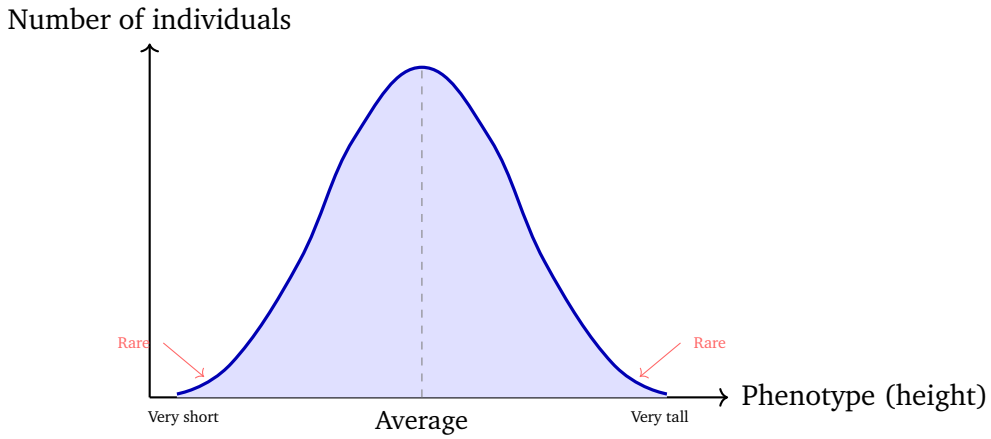
A. Allow all small molecules and ions to diffuse freely while blocking all macromolecules

B. Only permit the inward passage of nucleotides for DNA replication

C. Physically connect the nuclear lumen to the lumen of the rough endoplasmic reticulum

D. Mediate selective bidirectional transport: mRNA and tRNA exit the nucleus to the cytoplasm; ribosomal proteins and transcription factors are imported into the nucleus

Q20. **Polygenic inheritance** produces a bell-shaped (normal) distribution of phenotypes in a population, as shown below. Why does this pattern arise?



A. Multiple genes each contribute additively and independently to the trait; random assortment generates a continuous, bell-shaped range of phenotypic values

B. Each gene produces a distinct, non-overlapping phenotypic class, leading to discrete ratios like 9:3:3:1

C. All genes involved are located on the same chromosome and are completely linked, producing only two extreme phenotypes

D. The trait is controlled by a single gene with multiple alleles showing incomplete dominance, creating intermediate phenotypes

Q21. A person with **blood group AB** has the genotype I^AI^B. This is an example of **codominance** because:

A. The I^A allele is incompletely dominant over the I^B allele, producing an intermediate phenotype

B. Both the I^A and I^B alleles are fully and simultaneously expressed, producing both A and B antigens on the RBC surface without blending

C. The AB phenotype is the average (blend) of the A and B phenotypes

D. Blood group AB is caused by a single allele that happens to produce both A and B antigens simultaneously

Q22. A person with **Klinefelter syndrome (47, XXY)** would be expected to show:

A. Female external genitalia with an absent uterus and blind vaginal pouch

B. Normal male fertility with only slightly reduced testosterone levels

C. Male phenotype with small testes, azoospermia (infertility), and gynecomastia (breast tissue development)

D. Only 45 chromosomes due to monosomy of the Y chromosome

Q23. Which of the following is the **best example of pleiotropy**?

A. The ABO blood group gene controlling only the blood group antigen type on the RBC surface

B. Multiple different genes (controlling height, weight, and melanin synthesis) collectively determining overall fitness

C. The HBB gene mutation in sickle cell anaemia causing only anaemia as its sole phenotypic effect

D. The PAH gene mutation causing PKU — simultaneously producing intellectual disability, fair pigmentation, and musty-smelling urine due to phenylalanine accumulation

Q24. In eukaryotic gene expression, the **TATA box** is:

A. A promoter element located $\sim$25–30 bp upstream of the transcription start site, recognised by TBP (TATA-binding protein, a subunit of TFIID), helping recruit RNA polymerase II to initiate transcription

B. A regulatory sequence located in the 3'-UTR that controls mRNA stability and translation efficiency

C. A sequence in the 5' cap structure that promotes initial ribosome attachment to mRNA

D. A binding site for RNA polymerase I located in the nucleolus to transcribe ribosomal RNA genes

Q25. The **wobble hypothesis** (Crick, 1966) explains why:

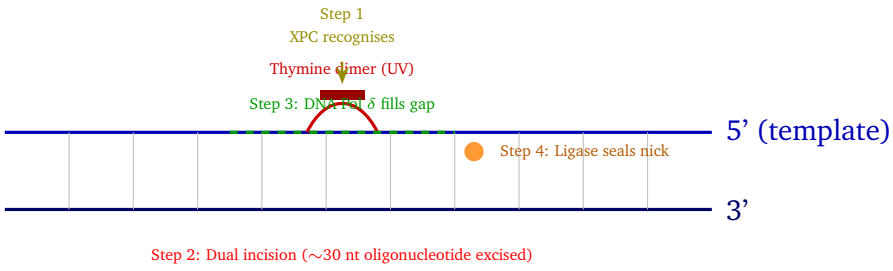
A. Multiple different amino acids can be specified by the same codon (synonymous codons)

B. One tRNA can recognise more than one codon for the same amino acid, because the third codon position (wobble position, 3' end of codon) can form non-standard base pairs with the 5' base of the anticodon

C. Some codons simultaneously code for more than one amino acid depending on context

D. The genetic code is non-overlapping and read strictly in triplets without any ambiguity

Q26. **Nucleotide Excision Repair (NER)**, summarised below, is specifically required to repair which type of DNA damage?



A. Single-nucleotide mismatches introduced by errors of DNA polymerase during replication

B. Double-strand breaks caused by ionising radiation (gamma rays or X-rays)

C. Bulky, helix-distorting lesions such as thymine dimers induced by UV radiation

D. Depurination (spontaneous loss of purine bases) from hydrolysis of the glycosidic bond

Q27. In a **short-day plant (SDP)**, flowering was inhibited by a brief flash of red light during the critical dark period. When a brief flash of **far-red light** is given immediately after, flowering is **restored**. This is because:

A. Far-red light directly activates the Pr form of phytochrome, which then triggers flowering in SDPs

B. Far-red light destroys all phytochrome molecules in the leaf, resetting the photoperiodic clock

C. Far-red light lengthens the effective dark period by slowing the plant's circadian oscillator

D. Far-red light converts Pfr back to Pr; it is Pfr that inhibits flowering in SDPs, so converting Pfr $\rightarrow$ Pr restores the long-night condition required for SDP flowering

Q28. **Vernalization** refers to:

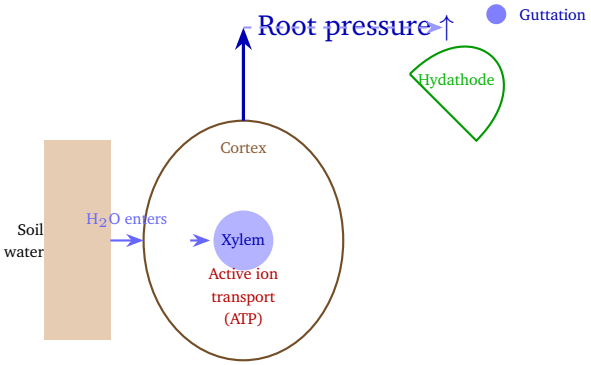
A. The promotion of flowering in certain plants (e.g., winter wheat, biennials) by prolonged exposure to low temperatures (0–10°C), allowing them to flower in the correct season

B. The inhibition of flowering triggered by continuous light exposure (photoperiod disruption)

C. The process by which seeds require cold stratification before breaking dormancy and germinating

D. The response of short-day plants to long nights that regulate the timing of their flowering

Q29. **Guttation** occurs when liquid water is exuded through hydathodes at leaf margins. The diagram below shows the mechanism. Guttation occurs when:



A. Transpiration rate is very high, forcing water out through stomata under pressure

B. Root pressure pushes xylem sap upward and out through hydathodes at leaf margins, especially when transpiration is low (e.g., at night or in high humidity)

C. Stomatal guard cells fail to close, causing excess water loss by evaporation from the mesophyll

D. Rainfall accumulates on leaf surfaces and runs off over the leaf margins

Q30. **Photorespiration** reduces the efficiency of photosynthesis in C_3 plants because:

A. It requires extra light energy in the thylakoids to split additional water molecules

B. It converts all fixed CO_2 back into inorganic carbon without generating any energy at all

C. RuBisCO uses O_2 instead of CO_2 as its substrate, producing a 2-carbon glycolate compound and consuming ATP and NADPH without any net carbon fixation or sugar production

D. It specifically inhibits the enzyme glyceraldehyde-3-phosphate dehydrogenase (G3PDH) in the Calvin cycle, blocking carbohydrate synthesis

Q31. In **Citrus** (lemon, orange), polyembryony is common because:

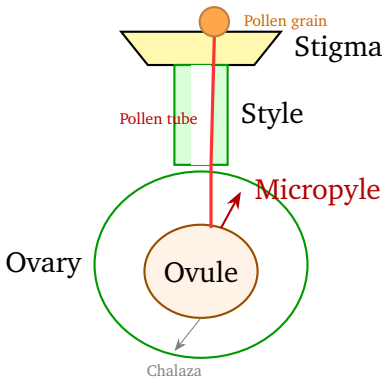
A. Multiple pollen grains simultaneously fertilize multiple ovules in the same fruit

B. The triploid endosperm divides mitotically to form additional embryos alongside the zygotic embryo

C. Gametic fusion (fertilization) occurs multiple times within the same ovule due to polyspermy

D. Additional embryos develop from the diploid somatic (nucellar) cells of the ovule wall (nucellar polyembryony), alongside the normal zygotic embryo

Q32. During **pollen tube growth**, the pollen tube enters the ovule through which structure? The diagram below illustrates the pathway.



A. Micropyle — the small opening at one end of the ovule through which the pollen tube enters to deliver the two male gametes

B. Chalaza — the basal region of the ovule opposite the micropyle

C. Funicle — the stalk that attaches the ovule to the placenta

D. Hilum — the scar left on the seed coat where the funicle was attached

Q33. **HCG (human chorionic gonadotropin)** is important in early pregnancy because:

A. It stimulates the anterior pituitary to secrete more LH and FSH to support new follicle development

B. It prevents the corpus luteum from degenerating, thereby maintaining its secretion of progesterone to sustain the endometrium until the placenta can take over this function

C. It directly stimulates endometrial cell proliferation, independent of progesterone levels

D. It promotes implantation of the blastocyst by softening and remodelling the uterine wall

Q34. The **Miller–Urey experiment (1953)** provided evidence for chemical evolution because it demonstrated that:

A. Life can spontaneously generate from organic molecules under the current oxygen-rich atmosphere

B. DNA can replicate without enzymes in the conditions of the primitive ocean

C. Organic molecules, including amino acids, can be synthesised abiotically from simple inorganic compounds (CH_4, NH_3, H_2, H_2O) under simulated primitive-earth conditions using electrical discharges

D. The first cells on Earth were photosynthetic autotrophs that produced the early oxygen atmosphere

Q35. An epiphyte (e.g., an orchid) growing on the bark of a large tree uses the tree only as a physical support and does not harm or extract nutrients from it. This interaction is **best** described as:

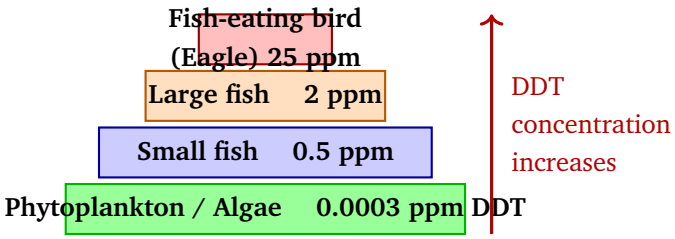
A. Mutualism $(+/+)$: both the epiphyte and the tree benefit from the association

B. Parasitism $(+/-)$: the epiphyte benefits at the tree's expense (by extracting nutrients)

C. Amensalism $(0/-)$: the epiphyte is unaffected while the tree is harmed by supporting it

D. Commensalism $(+/0)$: the epiphyte benefits from the support and elevated light position, while the tree is neither harmed nor helped

Q36. **Biological magnification (biomagnification)** of DDT is illustrated in the food chain below. Which group is **most severely affected** by DDT biomagnification?



A. Top predators (such as fish-eating birds like eagles and ospreys), because persistent fat-soluble toxins accumulate and concentrate at each successive trophic level, reaching the highest concentrations at the apex

B. Primary producers, because they absorb DDT directly from the water over the longest time period

C. Herbivores at the second trophic level, because they consume the greatest total biomass

D. Decomposers, because they process all dead organisms from every trophic level and accumulate all toxins

Q37. In a **biosphere reserve**, which zone permits sustainable human settlement, traditional community practices, and ecotourism?

A. Core zone (strictly protected, no human habitation or extractive use allowed)

B. Transition zone (cooperation zone), where local communities live and carry out sustainable resource use, agriculture, and traditional practices

C. Buffer zone, which has absolutely no human activity whatsoever

D. Central nucleus zone, which is equivalent to the outer transition zone

Q38. In **hydrarch succession**, what is the CORRECT sequence of stages from open water to a climax forest?

A. Rooted floating stage $\rightarrow$ marsh meadow $\rightarrow$ phytoplankton $\rightarrow$ shrubland $\rightarrow$ forest

B. Phytoplankton $\rightarrow$ marsh meadow $\rightarrow$ rooted submerged plants $\rightarrow$ shrubland $\rightarrow$ forest

C. Phytoplankton $\rightarrow$ rooted submerged plants $\rightarrow$ floating plants $\rightarrow$ reed-swamp $\rightarrow$ marsh meadow $\rightarrow$ shrubland $\rightarrow$ climax forest

D. Reed-swamp → phytoplankton → floating plants → meadow → forest

Q39. Recombinant **human insulin (Humulin)** is produced by:

A. Extracting insulin directly from human pancreatic islets of Langerhans and purifying it

B. Chemically synthesising all 51 amino acids of insulin in an automated solid-phase peptide synthesiser

C. Cloning the pig insulin gene and introducing a single amino acid change to match the human sequence

D. Introducing separate DNA sequences coding for the A chain (21 aa) and B chain (30 aa) of human insulin into *E. coli*, expressing each chain separately, then chemically combining them with correct disulfide bond formation to produce functional insulin

Q40. The **hybridoma technique** for producing monoclonal antibodies (Köhler and Milstein, 1975) involves:

A. Fusing immune B lymphocytes from an immunised animal with immortal myeloma cells to create hybridoma cells that are both immortal and capable of producing a single, specific antibody indefinitely

B. Immunising a mouse repeatedly and collecting blood serum containing a mixture of antibodies against the antigen (polyclonal antisera)

C. Cloning the antibody-coding gene from a single B cell and expressing it as a recombinant protein in bacteria

D. Fusing T-lymphocytes with myeloma cells to produce hybridomas that secrete cytokines and antigen-specific antibodies

Detailed Solutions

Q1.

Solution

Concept — Functions of the Large Intestine (Colon)

The large intestine does NOT perform enzymatic digestion of proteins, carbohydrates, or fats. Its primary roles are: (1) absorption of water and electrolytes (Na^+, Cl^-) from the liquid chyme received from the ileum, converting it into semi-solid faeces; and (2) harbouring commensal bacteria (*Bacteroides*, *E. coli*, *Lactobacillus*) that synthesise vitamin K (essential for clotting) and some B vitamins (B_{12}, biotin, folate).

Step 1 — Water Absorption:

The colon reabsorbs $\sim$1.3–1.5 L of water per day from the $\sim$1.5 L of chyme that enters from the ileum, producing $\sim$100–200 g of faeces daily.

Step 2 — Commensal Bacteria:

These bacteria ferment undigested dietary fibre, producing short-chain fatty acids (butyrate, propionate) and gas (CO_2, CH_4, H_2). They also synthesise vitamin K_2 (menaquinone) and B vitamins that can be absorbed across the colon wall.

Why other options are wrong:

Option A: Protein digestion by peptidases occurs in the stomach and small intestine (PCT and duodenum), not the colon.

Option C: Bile salt emulsification of fats occurs in the duodenum and jejunum of the small intestine.

Option D: Pancreatic amylase is secreted into the duodenum; it is not secreted by the large intestine.

Answer: (B) ← Go back to Q1

Q2.

Solution

Concept — Hepatic Portal Circulation after Nutrient Absorption

After nutrients (glucose, amino acids, fatty acids, vitamins) are absorbed by intestinal villi, they enter capillaries of the intestinal wall. These capillaries drain into the **hepatic portal vein** (formed by the superior mesenteric and splenic veins), which carries nutrient-rich blood directly to the liver for first-pass metabolism. After the liver processes the nutrients, blood exits via the **hepatic veins** into the **inferior vena cava (IVC)**, then to the right side of the heart.

Step 1 — Portal Vein:

Small intestine $\rightarrow$ intestinal capillaries $\rightarrow$ superior mesenteric vein $\rightarrow$ hepatic portal vein $\rightarrow$ liver sinusoids (hepatocytes process glucose, amino acids, toxins).

Step 2 — Hepatic Vein and IVC:
Liver → hepatic veins (3) → IVC → right atrium → pulmonary circulation → systemic distribution.

Why other options are wrong:
Option A: Reverses the direction — blood goes TO the portal vein first, not away from the liver through the hepatic vein first.
Option B: The mesenteric artery brings oxygenated blood TO the intestines; it does not carry absorbed nutrients away from the intestines.
Option D: IVC carries blood to the heart, not to the liver; the sequence described is anatomically impossible.

Answer: (C) ← Go back to Q2

Q3.

Solution

Concept — Pulmonary Surfactant and Alveolar Surface Tension
Pulmonary surfactant is a complex mixture of phospholipids (∼80%), proteins (SP-A, SP-B, SP-C, SP-D), and neutral lipids. The main active component is **dipalmitoylphosphatidylcholine (DPPC)**, produced by **type II pneumocytes**. At the alveolar air–water interface, DPPC molecules orient with their hydrophobic tails pointing into the air and their hydrophilic heads in the fluid layer, disrupting the cohesive forces (hydrogen bonds) between water molecules and thereby reducing surface tension.

Step 1 — Why Surface Tension Matters:
Without surfactant, surface tension at the alveolar air–water interface would cause alveoli to collapse (atelectasis) on each expiration. Surfactant reduces surface tension from ∼70 mN/m (pure water) to ∼1–5 mN/m, stabilising alveoli. Lack of surfactant in premature infants causes Neonatal Respiratory Distress Syndrome (NRDS / hyaline membrane disease).

Step 2 — Deficiency:
Surfactant production begins at ∼24–28 weeks gestation; premature infants born before this stage have insufficient surfactant, requiring exogenous surfactant therapy.

Why other options are wrong:
Option A: Increasing alveolar radius reduces surface tension (Law of Laplace: $P = 2T/r$), but surfactant works by reducing T directly, not by increasing r.
Option B: Surfactant is a fluid film, not a rigid scaffold; alveoli are not held open mechanically.
Option C: Clara (Club) cells secrete surfactant proteins in small airways, but the main surfactant-secreting cells of alveoli are type II pneumocytes; Clara cells do

not add fluid to the alveoli to reduce surface tension.

Answer: (D) ← Go back to Q3

Q4.

Solution

Concept — Mechanics of Normal Quiet Inspiration

Breathing involves changes in thoracic volume driven by skeletal muscle contraction. During **inspiration** (an active process), two muscle groups contract simultaneously: (1) the **diaphragm** (dome-shaped sheet of muscle at the base of the thorax) contracts and flattens, moving inferiorly; and (2) the **external intercostal muscles** contract, elevating the ribs upward and outward (pump-handle and bucket-handle movements). Both actions increase thoracic volume in all dimensions (vertical, anterior-posterior, transverse), reducing intrapulmonary pressure below atmospheric ($\sim$758 mmHg vs 760 mmHg), causing air to flow in.

Step 1 — Diaphragm:

Contracts and descends $\sim$1.5 cm in quiet breathing (up to 10 cm in forced inspiration), increasing vertical thoracic dimension. Contributes $\sim$75% of tidal volume.

Step 2 — External Intercostals:

Fibres run obliquely downward and forward; contraction lifts ribs and sternum outward/upward, increasing lateral and anteroposterior dimensions.

Why other options are wrong:

Option B: Internal intercostals and abdominal muscles are *expiratory* muscles (used in forced expiration), not inspiratory.

Option C: The diaphragm contracts (moves downward) during inspiration; it relaxes and moves upward during passive expiration. The description is reversed.

Option D: Both the diaphragm and external intercostals contribute to quiet inspiration; the diaphragm alone cannot achieve normal tidal breathing efficiently.

Answer: (A) ← Go back to Q4

Q5.

Solution

Concept — Erythropoietin (EPO) Production and Erythropoiesis

Erythropoiesis is the production of red blood cells from multipotent haematopoietic stem cells in the red bone marrow. This process is driven by **erythropoietin (EPO)**, a glycoprotein hormone produced primarily by **peritubular interstitial cells (fibroblast-like cells) of the renal cortex** in adults. When pO_2 drops (hypoxia — e.g., at high altitude, haemorrhage, anaemia), these kidney cells detect low oxygen delivery via HIF-1α (hypoxia-inducible factor) and secrete EPO into

the blood. EPO then stimulates stem cells in the bone marrow to proliferate and differentiate into erythrocytes.

Step 1 — Developmental Note:
In the fetus (especially before 20 weeks gestation), the *liver* is the primary EPO source (hepatocytes). After birth, this role transfers to the kidneys ($\sim$90% renal, $\sim$10% hepatic in adults). This is why chronic kidney disease causes normocytic normochromic anaemia.

Step 2 — Stages of Erythropoiesis:
HSC $\rightarrow$ proerythroblast $\rightarrow$ basophilic erythroblast (haemoglobin synthesis begins) $\rightarrow$ polychromatophilic erythroblast $\rightarrow$ orthochromatophilic erythroblast (nucleus extruded) $\rightarrow$ reticulocyte $\rightarrow$ mature RBC (biconcave disc, no nucleus, no mitochondria).

Why other options are wrong:
Option A: The liver is the main EPO source in the fetus, not in adults; in adults the kidney dominates ($\sim$90%).
Option C: The bone marrow is the site of erythropoiesis (where stem cells respond to EPO), not the site of EPO production.
Option D: The spleen performs extramedullary erythropoiesis in disease states (e.g., thalassaemia), but is not the normal EPO-secreting organ.

Answer: (B) ← Go back to Q5

Q6.

Solution

Concept — Double Circulation: Pulmonary Circuit
Mammals (including humans) have **double circulation**: the pulmonary circuit (right side of heart $\rightarrow$ lungs $\rightarrow$ left side of heart) and the systemic circuit (left side $\rightarrow$ body $\rightarrow$ right side). In the **pulmonary circuit**: deoxygenated blood from the right ventricle is pumped via the **pulmonary artery** to the lungs, where CO_2 is released and O_2 is absorbed. Oxygenated blood returns via the **pulmonary veins** (4 veins) to the **left atrium**, then passes to the left ventricle for systemic circulation.

Key memory point: Pulmonary arteries carry deoxygenated blood (exception to the rule that arteries carry oxygenated blood); pulmonary veins carry oxygenated blood (exception to the rule that veins carry deoxygenated blood).

Correct sequence: Right ventricle $\rightarrow$ pulmonary artery $\rightarrow$ lung capillaries $\rightarrow$ pulmonary vein $\rightarrow$ left atrium.

Why other options are wrong:
Option A: This incorrectly starts from the left ventricle (systemic circuit side) and

sends blood to pulmonary artery; also returns to right atrium, which is backward.
Option B: Pulmonary circuit does not use the aorta — the aorta is the systemic artery from the left ventricle.
Option D: Veins and arteries are reversed — pulmonary veins carry blood *from* lungs *to* left atrium, not the other way.

Answer: (C) ← Go back to Q6

Q7.

Solution

Concept — Functions of the Spleen

The spleen is the **largest lymphoid organ** (weight ∼150 g). It is located in the upper left abdomen. Its major functions include: (1) **RBC graveyard**: macrophages in the splenic sinusoids (red pulp) phagocytose senescent (old, rigid, damaged) RBCs after ∼120 days; iron is recycled for new haem synthesis; (2) **Platelet reservoir**: stores ∼30% of total body platelets; (3) **Immune function**: white pulp contains lymphocytes (B cells in germinal centres, T cells in periarteriolar lymphoid sheaths) that respond to blood-borne antigens; (4) **Monocyte reservoir**: stores ∼50% of total body monocytes.

Step 1 — Red Pulp vs White Pulp:

Red pulp = sinusoids + splenic cords (Billroth cords) for RBC and platelet phagocytosis.
White pulp = lymphoid tissue surrounding central arterioles, site of immune response.

Step 2 — Fetal Haematopoiesis:

In fetal life, the spleen performs erythropoiesis (extramedullary haematopoiesis) until the bone marrow takes over.

Why other options are wrong:

Option A: Bile is produced by the *liver* and stored in the *gallbladder*; the spleen has no role in fat digestion.
Option B: Lymph node filtration of lymph is performed by lymph nodes, not the spleen (the spleen filters blood, not lymph).
Option C: Immunoglobulin synthesis occurs in *plasma cells* (derived from B cells) in lymph nodes, bone marrow, and mucosal tissues; the spleen can also host plasma cells but is not the primary antibody factory under normal conditions.

Answer: (D) ← Go back to Q7

Q8.

Solution

Concept — Micturition Reflex Arc

The **micturition (voiding) reflex** is a spinal cord–mediated autonomic reflex with voluntary override. When the bladder fills to ∼300–400 mL, **stretch receptors** in the detrusor muscle wall are activated. Sensory (afferent) signals travel via pelvic nerves to the **sacral spinal cord (S2–S4)**. The sacral micturition centre integrates these signals and sends **parasympathetic efferent** signals (via pelvic nerves) back to the detrusor muscle, causing its contraction. Simultaneously, the **internal urethral sphincter** (smooth muscle, autonomic control) relaxes. The **external urethral sphincter** (skeletal muscle) is under voluntary somatic control from the cerebral cortex via the pudendal nerve, allowing conscious control over voiding timing.

Step 1 — Bladder Filling (Storage Phase):

Sympathetic stimulation (hypogastric nerve, T11–L2) inhibits detrusor contraction and increases internal sphincter tone during filling.

Step 2 — Voiding Reflex:

Stretch receptors activated → afferent pelvic nerve → sacral cord S2–S4 → parasympathetic efferent → detrusor contracts + internal sphincter relaxes → void (if external sphincter also relaxed voluntarily).

Why other options are wrong:

Option B: The cerebral cortex modulates (facilitates or inhibits) micturition but does not directly contract the bladder without the sacral spinal cord reflex arc.

Option C: Sympathetic stimulation *inhibits* detrusor contraction (promotes storage); parasympathetic stimulation drives contraction.

Option D: ADH (vasopressin) acts on the kidney collecting duct to increase water reabsorption; it does not act on bladder smooth muscle to cause micturition.

Answer: (A) ← Go back to Q8

Q9.

Solution

Concept — Malpighian Tubules: Insect Excretory Organs

Malpighian tubules are the principal excretory organs of insects (class Insecta) and some arachnids. They are long, blind-ending, tubular outgrowths that arise at the junction of the midgut and hindgut and open into the hindgut (ileum). Unlike vertebrate nephrons, Malpighian tubules do NOT filter haemolymph under hydrostatic pressure. Instead, **ions (K^+, Na^+) are actively secreted** into the tubule lumen; water, nitrogenous waste (mainly **uric acid**), and other solutes follow osmotically. As the fluid passes through the hindgut and rectum, water and valuable ions are reabsorbed, producing a nearly dry, semi-solid excreta of uric acid. This is

why insects are **uricotelic** and adapted to conserve water — crucial for terrestrial existence.

Step 1 — Mechanism:
Haemolymph → K^+/Na^+ secreted into tubule lumen (active transport) → water + uric acid follow osmotically → fluid enters hindgut → ions and water reabsorbed in rectum → dry uric acid crystals excreted.

Step 2 — Comparison to Nephron:
The nephron uses high hydrostatic pressure (Starling forces at glomerulus) to filter; Malpighian tubules use active secretion — no pressure-driven filtration.

Why other options are wrong:
Option A: Malpighian tubules open into the *hindgut*, not the midgut; they excrete uric acid, not urea.
Option C: Malpighian tubules secrete substances via active transport (not ultrafiltration under pressure). There is no glomerulus-equivalent.
Option D: Ammonia is the main waste of aquatic invertebrates (ammonotelic); insects are uricotelic (excrete uric acid), which requires minimal water for excretion.

Answer: (B) ← Go back to Q9

Q10.

Solution

Concept — Glomerular Filtrate Composition
The **glomerular filtrate** (ultrafiltrate) is formed at the renal corpuscle by ultrafiltration of blood plasma across the filtration barrier (fenestrated glomerular capillary endothelium + basement membrane + podocyte filtration slits). The filtration barrier is a **size-selective** and **charge-selective** barrier. Molecules with MW $<$68,000 Da and/or small enough to pass through the $\sim$8 nm pores are filtered. Small molecules freely filtered include: water, urea, glucose, amino acids, uric acid, creatinine, Na^+, K^+, Cl^-, HCO_3^-.

Step 1 — Glucose in Filtrate:
Glucose (MW 180 Da) is freely filtered, so it *appears in the filtrate*. However, under normal blood glucose ($<$180 mg/dL), all filtered glucose is completely reabsorbed in the **proximal convoluted tubule (PCT)** by SGLT1/SGLT2 (Na^+-glucose co-transporters). Thus, no glucose normally appears in urine — but it IS present in the filtrate.

Step 2 — Macromolecules Excluded:
Haemoglobin (MW $\approx$68,000 Da) is marginally excluded; free haemoglobin in plasma (haemoglobinuria) only occurs in haemolysis. Albumin (69,000 Da), im-

munoglobulins (>150,000 Da) — all excluded by size and charge (the basement membrane bears negative charge that repels anionic proteins).

Why other options are wrong:
Option A: Haemoglobin is too large (∼68,000 Da) and is normally inside RBCs; it is not present in the plasma in significant amounts, and is not filtered under normal conditions.
Option B: Albumin (∼69,000 Da) is excluded by the size and charge barrier of the glomerular filtration membrane; its presence in urine (albuminuria) indicates glomerular disease.
Option D: Immunoglobulins (150,000–900,000 Da) are far too large to pass through the filtration barrier.

Answer: (C) ← Go back to Q**10**

Q11.

Solution

Concept — Universal Features of Synovial Joints
Synovial joints (diarthroses) are the most mobile type of joint in the body. All synovial joints share three universal structural features: (1) **Joint cavity**: a fluid-filled space between the two articulating bones, enclosed by the joint capsule; (2) **Articular cartilage**: hyaline cartilage covering the articulating surfaces of each bone, providing a smooth, low-friction surface; (3) **Fibrous joint capsule** with an inner **synovial membrane** (synovium): the outer layer is dense irregular connective tissue (fibrous capsule); the inner synovial membrane secretes **synovial fluid** (hyaluronate-rich, lubricating, shock-absorbing, supplies nutrients to avascular cartilage). Ligaments (thickenings of the capsule or separate bands) reinforce the joint.

Step 1 — Types of Synovial Joints:
Ball-and-socket (hip, shoulder), hinge (knee, elbow), pivot (atlas-axis), gliding (intercarpal), condyloid (wrist), saddle (thumb carpometacarpal). All have the three universal features.

Step 2 — Optional Structures:
Articular discs/menisci and bursae are present in *some* synovial joints (e.g., knee) but NOT all.

Why other options are wrong:
Option A: Articular discs (e.g., temporomandibular joint) and menisci (e.g., knee) are found only in *certain* synovial joints, not all.
Option B: Bursae (fluid-filled sacs near some joints) and cartilaginous pads are not universal features of all synovial joints.
Option C: Fibrocartilage discs are found only in some joints (e.g., TMJ, stern-

oclavicular); direct bony fusion is characteristic of fibrous joints (synostosis), not synovial joints.

Answer: (D) ← Go back to Q11

Q12.

Solution

Concept — Vertebral Column: Bone Count in Adults

The adult human vertebral column consists of **26 bones** when counted as functional units: **7 cervical** vertebrae (C1 atlas, C2 axis, C3–C7) + **12 thoracic** (T1–T12) + **5 lumbar** (L1–L5) + **1 sacrum** (5 sacral vertebrae fused into one bone in adults, fusion complete by ∼25–30 years) + **1 coccyx** (4 rudimentary vertebrae fused into one bone). Total = 7 + 12 + 5 + 1 + 1 = **26 bones**.

Step 1 — Developmental Note (Confusion Source):

At birth and in childhood, the sacral region has 5 separate vertebrae (S1–S5) and the coccygeal region has 3–5 separate vertebrae. In adults, they fuse to form single composite bones. The number 33 (option B) counts all individual segments before fusion.

Step 2 — Axial vs Appendicular:

The vertebral column is part of the **axial skeleton**, along with the skull (22 bones in adults after suture fusion), sternum (3 parts — manubrium, body, xiphoid process), and 12 pairs of ribs (24 bones).

Why other options are wrong:

Option B: 33 counts each sacral and coccygeal segment individually before fusion — this is the embryological/childhood count, not the adult count.

Option C: 24 incorrectly excludes the sacrum and coccyx, which are integral parts of the vertebral column.

Option D: 30 is an incorrect count resulting from errors in tallying thoracic or lumbar vertebrae; no standard anatomical count gives 30.

Answer: (A) ← Go back to Q12

Q13.

Solution

Concept — Sympathetic Nervous System: Fight-or-Flight Effects

The **autonomic nervous system (ANS)** has two divisions with opposing effects on most organs. The **sympathetic division** (origin: thoracolumbar T1–L2; neurotransmitter: **norepinephrine** at neuroeffector junction; **acetylcholine** at ganglia) mediates the "fight-or-flight" response: preparation for rapid physical activity, stress, or emergency. Its effects include: **increased heart rate** (chronotropy)

and contractility, **bronchodilation** (increased airway diameter for more O_2 intake), **decreased GI peristalsis** (blood diverted away from gut), **pupil dilation** (mydriasis), increased sweating, vasodilation in skeletal muscles, vasoconstriction in skin and viscera, glycogenolysis.

Step 1 — Sympathetic Receptors:
Heart: β_1 adrenoreceptors $\rightarrow$ increased rate and force.
Bronchi: β_2 receptors $\rightarrow$ relaxation of smooth muscle $\rightarrow$ dilation.
Pupils: α_1 receptors on iris dilator muscle $\rightarrow$ dilation.
GI: α_2 and β_2 receptors $\rightarrow$ decreased motility.

Step 2 — Contrast with Parasympathetic:
Parasympathetic (craniosacral, ACh) produces opposite effects: decreased HR, bronchoconstriction, increased peristalsis ("rest and digest"), pupil constriction (miosis).

Why other options are wrong:
Option A: Decreased heart rate and constricted pupils are parasympathetic effects, not sympathetic.
Option C: Increased digestion and decreased heart rate are parasympathetic ("rest and digest") features.
Option D: Decreased heart rate and increased urinary output are parasympathetic effects; dilation of bronchioles is sympathetic but combined here with parasympathetic effects, making this a mixed/incorrect combination.

Answer: (B) ← Go back to Q13

Q14.

Solution

Concept — Retinal Photoreceptors: Rods vs Cones
The retina contains two types of photoreceptor cells: **rods** and **cones**.
Rods: ∼120 million; distributed throughout the retina (but absent at the fovea and optic disc); contain **rhodopsin** (visual purple, peak sensitivity ∼498 nm); function in **dim/scotopic light**; detect only black, white, and grey; highly sensitive (single photon threshold); provide peripheral and low-light vision.
Cones: ∼6 million; densely concentrated at the **fovea centralis** (centre of the macula lutea); contain three types of iodopsin-related photopigments (S-cones/blue, M-cones/green, L-cones/red); function in **bright/photopic light**; responsible for **colour vision** and **high visual acuity** (sharpest image formation at fovea, 1:1 cone-to-ganglion cell ratio).

Step 1 — Fovea and Acuity:
The fovea has no rods; only cones (both M and L, minimal S). Each cone in the fovea synapses with a single midget bipolar cell and a single midget ganglion cell

— a 1:1:1 pathway providing maximum acuity.

Step 2 — Blind Spot:
The optic disc (where optic nerve exits) has no photoreceptors (neither rods nor cones).

Why other options are wrong:
Option A: Rods are concentrated in the *peripheral* retina and provide black-and-white vision, not colour vision; they are *absent* at the fovea.
Option B: Cones are concentrated at the fovea (not evenly distributed) and function in bright, not dim, light.
Option D: Rods contain *rhodopsin*; cones contain *iodopsins* (photopsins) — different photopigments. Not all photoreceptors use rhodopsin.

Answer: (C) ← Go back to Q14

Q15.

Solution

Concept — Growth Hormone Excess: Gigantism vs Acromegaly
Growth hormone (GH), produced by somatotroph cells of the anterior pituitary, promotes: linear bone growth (via IGF-1/somatomedin C from the liver, acting on epiphyseal growth plates), protein synthesis, lipolysis, and inhibition of glucose uptake (anti-insulin effect).

Effect of excess GH depends on timing relative to epiphyseal plate fusion:
• **Before plate fusion (childhood/adolescence)**: Excess GH causes **Gigantism** — uniform, excessive growth of all bones, especially long bones (femur, tibia, humerus). Patient grows very tall (>210 cm). Features: tall stature, normal proportions in early stages, later features of acromegaly if untreated.
• **After plate fusion (adulthood)**: Excess GH causes **Acromegaly** — growth plates are closed, so long bones cannot grow longer. Instead, bones grow thicker in acral regions (hands, feet, jaw = prognathism, frontal bossing, macroglossia, carpal tunnel syndrome, organomegaly).

Why other options are wrong:
Option A: Cushing's syndrome results from excess *cortisol* (adrenal glucocorticoid), not GH. Features: moon face, buffalo hump, central obesity, striae, hypertension.
Option B: Dwarfism (particularly pituitary dwarfism) is caused by GH *deficiency* before puberty, resulting in proportionate short stature.
Option C: Acromegaly occurs in *adults* when excess GH is secreted *after* epiphyseal plate closure, so long bone lengthening is no longer possible.

Answer: (D) ← Go back to Q15

Q16.

Solution

Concept — Melatonin: Pineal Gland and Circadian Rhythm

Melatonin (N-acetyl-5-methoxytryptamine) is synthesised from serotonin (derived from tryptophan) in the **pineal gland** (epiphysis cerebri). Melatonin secretion is controlled by the **suprachiasmatic nucleus (SCN)** of the hypothalamus, the master circadian pacemaker. The SCN receives light information from the retina via the retinohypothalamic tract: **light inhibits melatonin secretion**; **darkness stimulates it**. Thus melatonin is secreted at high levels **at night (in darkness)**, peaking at ∼2–4 AM, and suppressed during daytime.

Step 1 — Functions:

(1) Regulates the **sleep–wake circadian rhythm** (promotes sleepiness at night, signals time-of-night to the body); (2) Signals **seasonal reproductive changes** in photoperiod-sensitive mammals (long nights/high melatonin → gonadal regression in some species); (3) Acts as an **antioxidant** (scavenges free radicals).

Step 2 — Medical Application:

Exogenous melatonin (0.5–5 mg) is used for jet lag, shift-work disorders, and insomnia. Blue light (460–480 nm) from screens maximally suppresses melatonin, disrupting sleep.

Why other options are wrong:

Option B: Melatonin secretion is strongly dependent on light–dark cycles, not constant; it is a prime example of a circadian hormone.

Option C: Bright light *suppresses* melatonin (rather than stimulating it); daytime light exposure keeps melatonin levels low.

Option D: Melatonin production is regulated by the SCN/light pathway, not by ACTH. ACTH controls cortisol from the adrenal cortex.

Answer: (A) ← Go back to Q16

Q17.

Solution

Concept — Chloroplast Ultrastructure and Site of Light Reactions

The **chloroplast** has: outer membrane (freely permeable), inner membrane (selectively permeable, contains transport proteins), and internal membranes (**thylakoids**). The thylakoids are arranged in interconnected stacks called **grana** (singular: granum). Individual thylakoids in adjacent grana are connected by **stroma lamellae** (intergranal thylakoids). The space inside each thylakoid is the **thylakoid lumen**. The fluid surrounding the thylakoids (inside the inner membrane) is the **stroma**.

Light-Dependent Reactions (occur on the thylakoid membrane):

Photosystem II (P680), Photosystem I (P700), the electron transport chain (plastoquinone, cytochrome b_6f complex, plastocyanin), and ATP synthase (CF_0CF_1) are all **embedded in the thylakoid membrane**. Products: ATP (via photophosphorylation) + NADPH + O_2 (from water splitting).

Calvin Cycle / Light-Independent Reactions (occur in the stroma):
RuBisCO and all Calvin cycle enzymes are dissolved in the stroma. They use ATP + NADPH from thylakoids to fix CO_2 into G3P.

Why other options are wrong:
Option A: The stroma is the site of the *Calvin cycle* (light-independent reactions), not the light reactions.
Option C: The outer chloroplast envelope membrane is simply a permeable barrier; no photosynthetic reactions occur there.
Option D: The intermembrane space (between outer and inner membranes) contains no photosynthetic machinery; it is metabolically relatively inactive compared to the thylakoid/stroma compartments.

Answer: (B) ← Go back to Q17

Q18.

Solution

Concept — Plant Central Vacuole: Turgor Pressure and Cell Rigidity
Mature plant cells contain a **large central vacuole** (occupying up to 90% of cell volume) bounded by the **tonoplast** membrane. The vacuole contains cell sap — a solution of inorganic ions, sugars, amino acids, organic acids, pigments (anthocyanins), secondary metabolites, and water. Because cell sap has a higher solute concentration (lower water potential Ψ) than the surrounding cytoplasm and extracellular fluid, water enters the vacuole by osmosis, creating **turgor pressure** against the rigid cell wall. This turgor pressure is what makes non-woody plants (herbs, leaves) firm and erect. Loss of turgor = wilting.

Step 1 — Turgor and Wall Pressure:
Water potential equation: $\Psi = \Psi_s + \Psi_p$ (solute potential + pressure potential). In a turgid cell, $\Psi_p > 0$ (positive pressure) acts as a tensile force on the cell wall. The cell wall's **wall pressure** (Ψ_p in the positive direction) balances the osmotic inflow.

Step 2 — Additional Vacuole Functions:
Storage (ions, sugars, amino acids, pigments), sequestration of toxic compounds, lytic function (in senescence — vacuole enzymes degrade cellular components).

Why other options are wrong:
Option A: Protein synthesis occurs on ribosomes (in the cytoplasm, rough ER), not

in the vacuole.
Option B: Cell wall components are assembled by the Golgi apparatus in vesicles that fuse with the plasma membrane, not by the vacuole.
Option D: Oxidative phosphorylation (ATP production via electron transport chain) occurs on the *inner mitochondrial membrane*, not in the vacuole.

Answer: (C) ← Go back to Q18

Q19.

Solution

Concept — Nuclear Pores: Selective Bidirectional Transport
The **nuclear envelope** consists of two concentric phospholipid bilayers (outer membrane continuous with rough ER; inner membrane associated with nuclear lamina). **Nuclear pore complexes (NPCs)** are large protein assemblies (∼125 MDa in vertebrates, containing ∼30 different nucleoporin proteins) embedded in the nuclear envelope. There are ∼3,000–5,000 NPCs per nucleus. NPCs allow **selective bidirectional nucleocytoplasmic transport**:

Export from nucleus to cytoplasm: mRNA (as mRNP complexes), tRNA (after aminoacylation), rRNA and pre-assembled ribosomal subunits, snRNAs.
Import into nucleus from cytoplasm: Ribosomal proteins (for assembly in the nucleolus), transcription factors, DNA/RNA polymerases, histones, NTPs (nucleotide building blocks). Import is mediated by **importins** (recognise nuclear localisation signals, NLS), and export by **exportins** (recognise nuclear export signals, NES). Energy for active transport is provided by the RanGTP/GDP cycle.

Why other options are wrong:
Option A: NPCs are not freely permeable to all small molecules; they are selectively permeable. Very small molecules (<40 kDa) may diffuse passively, but larger molecules require active, signal-mediated transport.
Option B: NPCs allow the import of a wide range of proteins and complexes, not just nucleotides.
Option C: The nuclear envelope is continuous with the rough ER membrane, but nuclear pores do not connect the nuclear lumen to the ER lumen — pores open to the cytoplasm.

Answer: (D) ← Go back to Q19

Q20.

Solution

Concept — Polygenic Inheritance and Continuous Variation
Polygenic traits (quantitative traits) are controlled by two or more genes (loci), each contributing additively and independently to the phenotype. Classic exam-

ples: human skin colour (MYO5A, OCA2, TYRP1, SLC45A2, SLC24A5 genes), height (∼700+ genes), intelligence, weight. When each gene contributes an equal, additive, and independent increment to the phenotype, the phenotypic distribution in a population follows a **binomial distribution**, which approximates a **normal (Gaussian, bell-shaped) distribution** as the number of contributing loci increases. The **central limit theorem** explains why: the sum of many independent random variables tends toward a normal distribution.

Step 1 — Example (2 genes, each 2 alleles):
With 2 polygenes (A/a and B/b), genotypic classes: AABB (4 doses, darkest) through aabb (0 doses, lightest). 5 phenotypic classes (0,1,2,3,4 contributing alleles) in ratio 1:4:6:4:1 — already approximating a bell curve. With more genes, the curve smooths out into continuous variation.

Step 2 — Environmental Modulation:
Environmental factors (nutrition, hormones, sunlight) further widen the distribution and blur class boundaries, producing the smooth bell curve seen in populations.

Why other options are wrong:
Option B: Discrete phenotypic ratios (e.g., 9:3:3:1, 3:1) arise from *oligogenic* traits with clear dominance — the opposite of polygenic continuous variation.
Option C: Complete linkage eliminates independent assortment, producing only parental phenotypic combinations — not a bell curve distribution.
Option D: A single gene with multiple alleles and incomplete dominance produces a *few* distinct or graded phenotypic classes, not the broad normal distribution of a true polygenic trait.

Answer: (A) ← Go back to Q**20**

Q21.

Solution

Concept — Codominance in ABO Blood Groups
Codominance is a pattern of inheritance where **both alleles in a heterozygote are fully and simultaneously expressed** as separate phenotypic products, with neither allele dominant over the other. In the ABO blood group system (chromosome 9, glycosyltransferase gene), the I^A allele encodes the enzyme that adds N-acetylgalactosamine to the H antigen (producing the A antigen), and the I^B allele encodes the enzyme that adds galactose (producing the B antigen). In the I^AI^B heterozygote, BOTH enzymes are produced, so **BOTH A and B antigens are expressed on the RBC surface simultaneously** — giving blood group AB. This is codominance: both products are independently made without blending.

Step 1 — Contrast with Incomplete Dominance:

In incomplete dominance (e.g., red $\times$ white flowers $\rightarrow$ pink), neither allele is fully expressed; instead a blended, intermediate phenotype results. In codominance (AB blood), the phenotype is *additive* (both products present), not intermediate.

Step 2 — Contrast with Dominance:
In simple dominance (I^Ai or I^Bi), only one allele's product is expressed phenotypically (A or B antigen); the i allele contributes nothing (encodes no functional glycosyltransferase).

Why other options are wrong:
Option A: Incomplete dominance produces a blended/intermediate phenotype; in AB blood there is no blending — both A and B antigens are fully expressed.
Option C: The AB phenotype is not the average of A and B; it is the expression of both simultaneously.
Option D: Blood group AB requires two distinct alleles (I^A and I^B), not a single allele producing both antigens.

Answer: (B) ← Go back to Q21

Q22.

Solution

Concept — Klinefelter Syndrome (47, XXY)
Klinefelter syndrome (47, XXY) is the most common sex chromosome aneuploidy in males ($\sim$1 in 600 male births). It arises from **non-disjunction** during meiosis I (most commonly in the mother, producing an XX egg) or meiosis II, resulting in an extra X chromosome. The **extra X chromosome is inactivated** (forming one Barr body), but X-inactivation is incomplete. Key clinical features: **male phenotype** (XY sex-determining gene SRY on Y determines male development); **small testes** (testicular atrophy/hyalinisation of seminiferous tubules, Sertoli cell-only syndrome); **azoospermia** (absent sperm $\rightarrow$ infertility in $>$95%); **gynaecomastia** (breast tissue due to relative oestrogen excess); tall stature; reduced facial and body hair; learning/social difficulties (not intellectual disability in most cases); low testosterone with elevated FSH and LH.

Step 1 — Diagnosis:
Karyotype: 47, XXY. Barr body present (1 Barr body = number of X chromosomes minus 1). Elevated FSH (loss of negative feedback from seminiferous tubules).

Step 2 — Management:
Testosterone replacement therapy from puberty onwards to promote secondary sexual characteristics. Assisted reproduction (testicular sperm extraction) may be possible in some cases.

Why other options are wrong:

Option A: Female external genitalia with absent uterus describes Androgen Insensitivity Syndrome (AIS) — 46,XY individuals who cannot respond to androgens.
Option B: Klinefelter males have significantly impaired fertility (>95% azoospermic) and reduced testosterone, not normal fertility.
Option D: Klinefelter syndrome has 47 chromosomes (trisomy for sex chromosomes), not 45.

Answer: (C) ← Go back to Q22

Q23.

Solution

Concept — Pleiotropy: One Gene, Multiple Phenotypic Effects
Pleiotropy is the phenomenon where a single gene mutation affects two or more seemingly unrelated phenotypic traits. This occurs because: (1) the gene product (enzyme/protein) participates in multiple metabolic pathways; (2) the product is expressed in multiple tissues at different stages of development.

PKU as a pleiotropic example:
Phenylketonuria (PKU) is caused by mutations in the **PAH gene** (chromosome 12q23.2), encoding phenylalanine hydroxylase (PAH), which converts phenylalanine → tyrosine. When PAH is absent/deficient: phenylalanine accumulates in blood and brain. This one genetic defect simultaneously produces: (1) **Intellectual disability and seizures** (phenylalanine is neurotoxic, disrupts myelin synthesis and neurotransmitter production); (2) **Fair hair and light skin** (phenylalanine accumulation competitively inhibits tyrosinase, reducing melanin synthesis from tyrosine); (3) **Musty/mousy urine odour** (accumulation of phenylpyruvate, phenylacetate, phenyllactate excreted in urine); (4) **Low levels of dopamine, norepinephrine, serotonin** (all derived from tyrosine/tryptophan pathways).

Why other options are wrong:
Option A: If the ABO gene affects *only* the blood group antigen, that is not pleiotropy (recent research links ABO to disease susceptibility, but classically it is a single-trait gene).
Option B: Multiple genes affecting fitness is *polygenic* inheritance, the opposite of pleiotropy.
Option C: Sickle cell anaemia actually *is* pleiotropic (one HBB mutation causes anaemia, vaso-occlusive crises, organ damage, splenic sequestration, avascular necrosis, etc.), but the option states "causing anaemia alone," making it incorrect.

Answer: (D) ← Go back to Q23

Q24.

Solution

Concept — TATA Box: Eukaryotic Core Promoter Element

In eukaryotic protein-coding genes transcribed by **RNA polymerase II**, the **TATA box** (consensus sequence: 5'-TATAAA-3') is a **core promoter element** located approximately -25 to -30 nucleotides **upstream** of the transcription start site (TSS, defined as $+1$). The TATA box is recognised by **TBP (TATA-binding protein)**, which is a subunit of the general transcription factor **TFIID**. TBP binds the minor groove of the TATA box and induces a sharp bend ($\sim$80°) in the DNA. TBP binding nucleates the assembly of the pre-initiation complex (PIC): TFIIA, TFIIB, RNA Pol II (with TFIIF), TFIIE, TFIIH. TFIIH has helicase activity to unwind DNA at the TSS, enabling transcription initiation.

Step 1 — Prokaryotic Analogue:

In prokaryotes, the σ (sigma) factor of RNA polymerase recognises the **–10 sequence (Pribnow box: TATAAT)** and **–35 sequence (TTGACA)** in the promoter. The function is analogous to the TATA box but the molecular machinery is simpler.

Step 2 — Genes Without TATA Box:

Housekeeping genes often lack a TATA box and instead use initiator elements (Inr) or downstream core elements (DCE). They tend to have CpG islands in their promoters.

Why other options are wrong:

Option B: The 3'-UTR contains AU-rich elements (AREs) that regulate mRNA stability, not the TATA box.

Option C: The 5' cap (7-methylguanosine) is recognised by the eIF4F complex for ribosome recruitment, a post-transcriptional event unrelated to the TATA box.

Option D: RNA polymerase I transcribes rRNA genes in the *nucleolus*; it uses a different core promoter element (UCE and core element), not the TATA box.

Answer: (A) ← Go back to Q24

Q25.

Solution

Concept — Wobble Hypothesis: Degeneracy of the Genetic Code

Francis Crick proposed the **wobble hypothesis** (1966) to explain how the genetic code can be **degenerate** (multiple codons specify the same amino acid) without requiring a separate tRNA for each of the 61 sense codons. In Watson–Crick base pairing, the **first two positions of the codon** (5'–3') pair strictly with the **last two positions of the anticodon** (3'–5'). However, the **third codon position** (3' end of codon) and the **first anticodon position** (5' end of anticodon, the "wobble position") can form **non-standard (wobble) base pairs**: G can pair with U (in addition to C); inosine (I, hypoxanthine nucleoside found in anticodon position 1)

can pair with U, C, or A. Thus, one tRNA (with a single anticodon) can recognise **2–3 different codons** for the same amino acid.

Step 1 — Example:
Alanine codons: GCU, GCC, GCA, GCG — all share the same first two bases (GC). A single $tRNA^{Ala}$ with anticodon 3'-CGI-5' (I = inosine) can recognise GCU, GCC, and GCA (I pairs with U, C, or A at the wobble position).

Step 2 — Implication for Codon Count:
Because of wobble, organisms need fewer than 61 different tRNA species to read all 61 sense codons (humans have ∼45 different tRNA anticodon sequences).

Why other options are wrong:
Option A: The wobble hypothesis explains why one tRNA can recognise multiple *synonymous* codons (same amino acid), not why multiple amino acids can be specified by the same codon.
Option C: The genetic code is non-ambiguous — each codon specifies only one amino acid. The wobble hypothesis does not violate this.
Option D: The non-overlapping, triplet-reading nature of the genetic code was established by Crick's frameshift experiments and is a separate concept from wobble.

Answer: (B) ← Go back to Q25

Q26.

Solution

Concept — Nucleotide Excision Repair (NER): UV-Induced Thymine Dimers
NER is the primary repair pathway for **bulky, helix-distorting DNA lesions** that cannot be repaired by base excision repair (BER). The main substrates are: **cyclobutane pyrimidine dimers (CPDs)** and **6-4 photoproducts** — both formed when adjacent thymine (or cytosine) bases are covalently cross-linked by **UV radiation (254–320 nm)**. These lesions distort the DNA double helix and block RNA polymerase (transcription) and DNA polymerase (replication).

NER Steps:
Step 1 — Recognition: XPC–RAD23B (global genome NER) or stalled RNA Pol II (transcription-coupled NER, TC-NER) recognises the distortion.
Step 2 — Verification and opening: TFIIH (with XPB and XPD helicases) unwinds ∼25–30 nt around the lesion; XPA and RPA verify the damage.
Step 3 — Dual incision: XPG cleaves 3' of the lesion; XPF–ERCC1 cleaves 5'; a ∼25–30 nt single-stranded oligonucleotide containing the lesion is excised.
Step 4 — Gap filling: DNA polymerase δ or ε (with PCNA) fills the gap using the complementary strand as template.
Step 5 — Ligation: DNA ligase I or ligase III/XRCC1 seals the nick.
Defect: Inherited NER defects cause **Xeroderma pigmentosum (XP)** — extreme

UV sensitivity, predisposition to skin cancer.

Why other options are wrong:
Option A: Single-nucleotide mismatches from replication errors are repaired by **Mismatch Repair (MMR)**, using MutS and MutL homologues.
Option B: Double-strand breaks from ionising radiation are repaired by **Non-Homologous End Joining (NHEJ)** or **Homologous Recombination (HR)**.
Option D: Depurination (loss of purine base, creating an apurinic/abasic site) is repaired by **Base Excision Repair (BER)**, using AP endonuclease.

Answer: (C) ← Go back to Q**26**

Q27.

Solution

Concept — Phytochrome and Photoperiodism: SDP Far-Red Reversal
Phytochrome is a photoreversible chromoprotein existing in two interconvertible forms: **Pr** (absorbs red light, 660 nm → converts to Pfr) and **Pfr** (absorbs far-red light, 730 nm → converts to Pr). **Pfr is the physiologically active form** that causes photomorphogenic responses. In darkness, Pfr slowly reverts to Pr (dark reversion).

SDP (Short-Day Plants) require a **critical minimum dark period** (long night) for flowering. **Pfr inhibits flowering in SDPs**: if Pfr is present during the dark period (i.e., red light interrupts the dark period → Pr → Pfr), flowering is prevented.

The experiment described:
Red flash during dark period → Pr → Pfr → Pfr inhibits SDP flowering (flowering blocked).
Then far-red flash immediately after → Pfr → Pr → Pfr is eliminated → SDP "sees" an uninterrupted long night → flowering **restored**.

This demonstrates: (1) It is Pfr that suppresses SDP flowering; (2) Far-red undoes the red-light effect by converting Pfr back to Pr; (3) This reversibility confirms the phytochrome system.

Why other options are wrong:
Option A: Far-red light converts Pfr → Pr (not activating Pr; Pr is simply the inactive form). Pr alone does not trigger SDP flowering.
Option B: Far-red light does not destroy phytochrome; it photochemically converts Pfr to Pr. Phytochrome protein is stable.
Option C: Far-red light has no known direct effect on the circadian clock speed; it acts purely through phytochrome photochemistry.

Answer: (D) ← Go back to Q**27**

Q28.

Solution

Concept — Vernalization: Cold-Induced Promotion of Flowering

Vernalization (from Latin *vernus* = of spring) is the phenomenon by which exposure to **prolonged low temperatures** (0–10°C, typically 4–8 weeks) promotes or enables subsequent flowering in certain plants that would otherwise remain vegetative. It is a requirement of **biennials** (e.g., carrot *Daucus carota*, henbane *Hyoscyamus niger*) and **winter annual cereals** (e.g., winter wheat *Triticum aestivum*, winter rye *Secale cereale*). These plants need to sense winter before they can flower the following spring.

Molecular Mechanism (in *Arabidopsis*):

During cold, the transcription factor **FLC (Flowering Locus C)**, a repressor of flowering, is epigenetically silenced by Polycomb Repressive Complex 2 (PRC2) — which methylates histone H3 at Lys27 (H3K27me3) at the FLC locus. This silencing is **epigenetic memory** of winter: it persists even after temperatures rise in spring, allowing flowering pathways (FT gene activation) to proceed.

Step 2 — Applied Significance:

Artificially vernalizing seeds or seedlings (e.g., by storing at ∼4°C) can induce early flowering in crop plants, useful in agricultural breeding programmes.

Why other options are wrong:

Option B: Inhibition of flowering by continuous light is *photoperiodism*-related (for SDPs), not vernalization.

Option C: Cold stratification of seeds breaks seed dormancy and is required for germination in some species — this is a separate phenomenon from vernalization, which promotes flowering, not germination.

Option D: The response of SDPs to long nights is *photoperiodism*, not vernalization. Vernalization involves temperature, not day length.

Answer: (A) ← Go back to Q28

Q29.

Solution

Concept — Root Pressure and Guttation

Root pressure is a positive hydrostatic pressure that develops in the xylem of plant roots when active mineral ion uptake by root cortical cells creates a low water potential in the xylem, drawing water in from the soil by osmosis. This generates an upward push on xylem sap. Root pressure is most prominent at night and in conditions of **low transpiration** (high humidity, cool temperatures, darkness — when stomata are closed), because during active transpiration, the tension (negative pressure) in xylem overwhelms root pressure.

Guttation: When root pressure forces xylem sap upward faster than it can exit

through stomata (which are closed at night), the sap exits through specialised pores called **hydathodes** at the margins and tips of leaves, producing droplets of water (and dissolved salts/solutes) on the leaf surface. This is **guttation** — not pure water but a dilute xylem exudate.

Step 1 — Distinction from Dew:
Guttation droplets form from the *inside* of the leaf (through hydathodes), whereas dew condenses from atmospheric moisture on the leaf surface. Guttation droplets may contain minerals and amino acids; dew is pure water condensate.

Step 2 — Guttation vs Transpiration:
Transpiration is evaporation from stomata during the day (passive, driven by the vapour pressure gradient). Guttation is exudation through hydathodes at night (driven by active root pressure).

Why other options are wrong:
Option A: High transpiration causes water to exit as vapour through stomata (not as liquid through hydathodes); high transpiration actually *reduces* root pressure by pulling water up via tension.
Option C: When guard cells fail to close, excess water is lost as vapour (transpiration), not as liquid droplets from hydathodes.
Option D: Surface water from rainfall dripping off leaves is a physical phenomenon, not guttation; guttation produces liquid from the vascular system inside the plant.

Answer: (B) ← Go back to Q29

Q30.

Solution

Concept — Photorespiration: RuBisCO Oxygenase Activity
RuBisCO (ribulose-1,5-bisphosphate carboxylase/oxygenase) is the key carbon-fixing enzyme of the Calvin cycle. It has two competing activities: **carboxylase** (CO_2 + RuBP $\rightarrow$ 2×3-PGA, net carbon fixation) and **oxygenase** (O_2 + RuBP $\rightarrow$ 3-PGA + 2-phosphoglycolate, a 2-carbon compound). When CO_2 concentration is low relative to O_2 (hot, dry conditions when stomata close to conserve water, or bright light when CO_2 is depleted), **photorespiration** dominates.

The photorespiratory pathway (C2 cycle):
2-Phosphoglycolate $\rightarrow$ glycolate (exported to peroxisome) $\rightarrow$ glyoxylate $\rightarrow$ glycine (exported to mitochondrion) $\rightarrow$ serine (releasing 1 CO_2 and 1 NH_3) $\rightarrow$ hydroxypyruvate $\rightarrow$ glycerate (returned to chloroplast). This cycle: (1) **consumes ATP and NADPH** (same energy currency used in the Calvin cycle); (2) **releases already-fixed CO_2** (wasteful); (3) produces no net sugar. Net effect: up to **25% loss** of photosynthetically fixed carbon in C_3 plants.

Why C_4 and CAM plants avoid it:
C_4 plants concentrate CO_2 at RuBisCO in bundle sheath cells (via C_4 dicarboxylate shuttle), maintaining high CO_2/O_2 ratio. CAM plants open stomata at night, fixing CO_2 into malic acid for daytime release at RuBisCO.

Why other options are wrong:
Option A: Photorespiration does not require extra light energy for water splitting (photolysis); it wastes energy already produced, but water splitting is a normal light reaction, unrelated to oxygenase activity.
Option B: Photorespiration does not convert *all* CO_2 back; it partially oxidises carbon and releases some CO_2, but does not generate ATP in the process (unlike mitochondrial respiration).
Option D: G3PDH (GAPDH) is not specifically inhibited by photorespiration; the problem is RuBisCO choosing O_2 over CO_2 as its substrate.

Answer: (C) ← Go back to Q**30**

Q31.

Solution

Concept — Polyembryony in Citrus: Nucellar Embryony
Polyembryony is the development of more than one embryo in a single seed. In **Citrus** species (lemon, orange, grapefruit, mandarin), polyembryony is particularly common and is primarily of the **nucellar** type (also called sporophytic polyembryony or adventitious embryony). The **nucellus** is the diploid (2n) maternal tissue surrounding the embryo sac (megagametophyte) within the ovule. In polyembryonic Citrus ovules, **somatic cells of the nucellus** are stimulated (by fertilisation signals) to proliferate and develop directly into embryos without meiosis or fertilisation. These **nucellar embryos** are **genetically identical to the mother plant** (clones) and are diploid. In addition, a normal zygotic embryo may develop from the fertilised egg. The seed may thus contain multiple embryos — one zygotic (sexually derived) and several nucellar (asexually derived). This property is exploited horticulturally to produce true-to-type rootstocks.

Step 1 — Other Types of Polyembryony:
Cleavage polyembryony: zygote splits into multiple embryos (e.g., armadillos in animals, Orchis in some plants).
Synergid polyembryony: synergid cells develop into embryos.
Endosperm polyembryony: endosperm-derived embryos (rare).

Step 2 — Practical Significance:
Nucellar seedlings from polyembryonic Citrus seeds are disease-free, genetically uniform, and juvenile — used as rootstocks in commercial citrus cultivation.

Why other options are wrong:

Option A: Polyembryony within a single seed is not caused by multiple pollen grains fertilising multiple ovules — each ovule produces one fruit unit; multiple ovules per ovary produce multiple seeds, not polyembryony.
Option B: Triploid endosperm (3n) results from double fertilisation (second male gamete + two polar nuclei); the endosperm nucleus does not normally develop into embryos.
Option C: Polyspermy (multiple sperm fertilising one egg) does not normally occur in angiosperms; only two male gametes participate in double fertilisation.

Answer: (D) ← Go back to Q31

Q32.

Solution

Concept — Pollen Tube Growth and Micropyle
After a **pollen grain** (male gametophyte) lands on the **stigma** (compatible, based on self-incompatibility recognition), it germinates and produces a **pollen tube** that grows through the style to reach the ovule. The pollen tube grows by tip growth, directed by **chemotropic cues**: a Ca^{2+} gradient in the style, γ-aminobutyric acid (GABA) gradient, and peptide attractants (LURE peptides in many species) secreted by the synergid cells of the embryo sac. The pollen tube enters the ovule through the **micropyle** — a small pore in the integuments at one end of the ovule (this is called **porogamy**, the most common mode). Upon reaching the embryo sac, the pollen tube ruptures (triggered by synergid cell calcium burst) and releases two male gametes. Double fertilisation: one male gamete + egg cell = zygote (2n); one male gamete + two polar nuclei = primary endosperm nucleus (3n).

Step 1 — Ovule Structure:
Ovule parts: funicle (stalk), hilum (junction of funicle and ovule), chalaza (basal region, where integuments originate), integuments (outer and inner, forming the seed coat/testa), nucellus (nutritive tissue), embryo sac (with egg, synergids, central cell/polar nuclei, antipodal cells), micropyle (opening through integuments at the opposite end from the chalaza).

Step 2 — Other Modes:
Chalazogamy: pollen tube enters through the chalaza (e.g., walnut, birch).
Mesogamy: pollen tube enters through the integuments (rare).

Why other options are wrong:
Option B: The chalaza is the opposite end of the ovule from the micropyle; pollen tubes enter the micropyle end in most angiosperms (porogamy).
Option C: The funicle is the stalk attaching the ovule to the placenta (ovary wall); pollen tubes grow through the style, not down the funicle.

Option D: The hilum is the scar on the seed coat where the funicle was attached after seed maturation; it is a post-fertilisation structure, not the pollen tube entry point.

Answer: (A) ← Go back to Q32

Q33.

Solution

Concept — HCG: Maintaining the Corpus Luteum in Early Pregnancy

Human chorionic gonadotropin (HCG) is a glycoprotein hormone (α–β heterodimer; β-HCG is pregnancy-specific) secreted by the **syncytiotrophoblast** (outer layer of the blastocyst and early placenta) beginning around day 8–10 after fertilisation (i.e., just after implantation). Structurally, HCG is similar to **LH** (luteinising hormone) and binds the same receptor (LH/HCG receptor = LHCGR) on the corpus luteum. In a normal non-pregnant cycle, the corpus luteum (formed from the ruptured Graafian follicle after ovulation) begins to regress (luteolysis) $\sim$14 days after ovulation. **HCG prevents this regression** by continually stimulating the corpus luteum's LH receptor, maintaining its secretion of **progesterone and oestrogen** until the placenta (by $\sim$8–10 weeks, the "luteo-placental shift") can produce these hormones independently.

Step 1 — HCG as Pregnancy Test Basis:

HCG peaks at $\sim$8–10 weeks of gestation ($\sim$100,000 IU/L) then declines. Urinary or serum HCG (β-subunit) is detected by pregnancy tests (immunoassay, ELISA, lateral flow immunoassay).

Step 2 — Progesterone Role:

Progesterone (from corpus luteum $\rightarrow$ then placenta) maintains the endometrium, inhibits uterine contractions, promotes decidualisation, and suppresses the maternal immune response to the semi-allogeneic embryo.

Why other options are wrong:

Option A: HCG does not stimulate the anterior pituitary; rather, during pregnancy, rising oestrogen and progesterone suppress FSH and LH secretion, preventing further follicle development.

Option C: The endometrium is maintained by *progesterone* (secreted by the corpus luteum in response to HCG); HCG itself does not directly proliferate the endometrium.

Option D: Implantation is facilitated by progesterone (secreted by corpus luteum under HCG stimulation) and by proteases from the trophoblast, not directly by HCG itself.

Answer: (B) ← Go back to Q33

Q34.

Solution

Concept — Miller–Urey Experiment: Abiotic Synthesis of Organic Molecules

In 1953, Stanley Miller (a graduate student under Harold Urey at the University of Chicago) designed an apparatus to test the Oparin–Haldane hypothesis of **chemical evolution**: that the Earth's primitive (reducing) atmosphere contained simple inorganic gases, and that energy sources could drive the abiotic synthesis of organic molecules — the first step toward life.

Experimental Setup:

A sealed glass apparatus contained: **CH_4 (methane), NH_3 (ammonia), H_2 (hydrogen)**, and **H_2O vapour** (simulating the reducing atmosphere) + a flask of boiling water (simulating the primitive ocean). **Electrical sparks** (simulating lightning) were passed through the gas mixture.

Results after ∼1 week:

∼10–15% of the carbon was converted to organic compounds, including **amino acids** (glycine, alanine, aspartate, glutamate), HCN, formaldehyde, aldehydes, and carboxylic acids. This was the first laboratory demonstration that **amino acids — the building blocks of proteins — can form abiotically** under simulated prebiotic conditions.

Significance: Supported the concept that the "primordial soup" (Oparin's idea) could contain the necessary organic precursors for life without requiring a pre-existing biological system.

Why other options are wrong:

Option A: The experiment used a *reducing* atmosphere (no O_2); modern atmosphere is oxidising (21% O_2). Spontaneous generation of life does not occur under current conditions.

Option B: The Miller–Urey experiment produced amino acids, not nucleic acids; DNA replication without enzymes was not demonstrated.

Option D: The first cells are thought to have been *heterotrophic* anaerobes; photosynthetic autotrophs evolved later and produced atmospheric O_2 (Great Oxidation Event, ∼2.4 billion years ago).

Answer: (C) ← Go back to Q34

Q35.

Solution

Concept — Commensalism: Epiphytes on Trees

Ecological interactions between species are classified by the effect on each participant: mutualism (+/+), commensalism (+/0), amensalism (0/−), parasitism (+/−), competition (−/−), predation (+/−).

Commensalism (+/0): One organism benefits while the other is **neither harmed nor helped**. Examples: **epiphytes** (orchids, bromeliads, ferns) growing on tree bark — the epiphyte gains a *physical support* above the forest floor (access to better light, rainfall) without drawing nutrients from the tree, so the tree is unaffected; **remora fish** clinging to sharks (eat scraps, the shark is not harmed); **cattle egrets** following large mammals (eat disturbed insects, the mammal is unaffected).

Step 1 — Epiphytes vs Parasitic Plants:
Epiphytes are not parasites — they do NOT tap into the tree's vascular system. They are rooted on bark and absorb water and minerals from rain, dust, and air (epiphytes have specialised absorptive root structures, e.g., orchid velamen). Contrast with *Cuscuta* (dodder, a holoparasite) or *Loranthus* (mistletoe, hemiparasite) — these DO extract nutrients from the host (+/−).

Step 2 — Is it truly 0 for the tree?
In strict ecological terms, a very heavy load of epiphytes *could* increase the risk of branch breakage (slight harm), making it borderline commensalism/parasitism in extreme cases. However, classically and for examination purposes, epiphytes are the canonical example of commensalism.

Why other options are wrong:
Option A: Mutualism requires both species to benefit; the tree receives no benefit from the orchid.
Option B: Parasitism requires the host (tree) to be harmed; epiphytes do not harm the tree by extracting nutrients.
Option C: Amensalism requires one species to be harmed (the "0" species is unaffected while the "−" species is harmed); here the epiphyte benefits (+), not harmed (−).

Answer: (D) ← Go back to Q35

Q36.

Solution

Concept — Biological Magnification (Biomagnification) of Persistent Organic Pollutants
Biomagnification (biological magnification) is the progressive increase in the concentration of a **persistent, lipophilic (fat-soluble)** pollutant (DDT, PCBs, dioxins, methylmercury) at successive trophic levels in a food chain. It occurs because: (1) the pollutant is not metabolised or excreted (persistent); (2) it dissolves and accumulates in adipose tissue (bioaccumulation within an organism); (3) predators must consume large quantities of prey — the total body burden of toxin from all prey consumed is concentrated in the predator's smaller biomass.

DDT in Aquatic Food Chains — Classic Example:

Plankton/algae: 0.0003 ppm → small fish: ∼0.5 ppm (>1,000× increase) → large fish: ∼2 ppm → fish-eating birds (ospreys, eagles, pelicans): 25 ppm (∼80,000× the water concentration). **Effect on top predators:** DDT and its metabolite DDE inhibit Ca^{2+}-ATPase in avian eggshell glands, causing **eggshell thinning** and egg breakage during incubation, leading to dramatic population declines of peregrine falcon, bald eagle, osprey, brown pelican. This was documented by Rachel Carson in *Silent Spring* (1962) and led to the 1972 ban of DDT in the USA.

Why other options are wrong:
Option B: Primary producers (algae) have the *lowest* DDT concentrations (they absorb from water but also grow rapidly, diluting the toxin); top predators have the highest.
Option C: Herbivores (second trophic level) accumulate more DDT than producers but far less than top predators.
Option D: Decomposers process dead organisms and recycle nutrients, but their body burden of fat-soluble persistent pollutants is lower than that of top predators, because they are not at the top of a food chain where toxins concentrate.

Answer: (A) ← Go back to Q36

Q37.

Solution

Concept — Biosphere Reserve Zonation: UNESCO MAB Programme
Biosphere Reserves are designated under the **UNESCO Man and the Biosphere (MAB) programme** (launched 1971). They have a **tripartite (three-zone) structure**:

1. Core Zone (Strictly Protected Area):
Innermost zone. **No human disturbance or extractive use**. Only non-invasive scientific research and monitoring permitted. Maximum conservation of biodiversity, ecosystems, and genetic resources. Example: national park/sanctuary core area.

2. Buffer Zone:
Surrounds the core zone. **Limited activities**: ecological research, education, low-impact tourism. No permanent human settlement or extraction. Acts as a shock-absorber protecting the core from disturbance. Not "no human activity whatsoever" — some scientific activity is allowed.

3. Transition Zone (Cooperation Zone/Area of Cooperation):
Outermost zone. **Sustainable human use**: local communities live here, carrying out traditional land use, sustainable farming, forestry, fishing, ecotourism, and educational activities. Human settlements, villages, and compatible development are found here. This is the zone that integrates conservation with human livelihood

needs.

India's Biosphere Reserves: 18 biosphere reserves, of which 12 are UNESCO MAB sites (Nilgiri, Gulf of Mannar, Sundarban, Nanda Devi, Nokrek, Panchmarhi, Simlipal, Pachmarhi, etc.).

Why other options are wrong:
Option A: The core zone prohibits human settlement and extractive activities; it is the most strictly protected zone.
Option C: The buffer zone does allow some human activity (research, controlled tourism, education) — it is not a "no human activity" zone.
Option D: There is no "central nucleus" zone separate from the transition zone; this is a fabricated term mixing zone names.

Answer: (B) ← Go back to Q37

Q38.

Solution

Concept — Hydrarch Succession: Aquatic to Terrestrial Climax
Ecological succession is the sequential, directional change in community composition over time in a given area. **Hydrarch succession** (hydrosere) begins in an **aquatic environment** (open pond, lake) and progresses toward a **terrestrial climax forest** as organic matter accumulates and the pond gradually fills in (by sedimentation and organic deposition). The seral stages in order are:

Stage 1 — Phytoplankton stage: Open water colonised by free-floating algae/phytoplankton (pioneers). Minimal organic matter.
Stage 2 — Submerged plant stage: Rooted submerged macrophytes (Hydrilla, Potamogeton, Elodea) colonise as sediment accumulates.
Stage 3 — Floating plant stage: Plants with floating leaves (Nymphaea/water lily, Lotus, Trapa) colonise. More organic matter, shallower water.
Stage 4 — Reed-swamp (emergent plant) stage: Emergent macrophytes (Typha/cattail, Phragmites/common reed, Scirpus) colonise as the pond becomes shallower. Much organic accumulation.
Stage 5 — Marsh meadow stage: Sedges, grasses, and herbs colonise as the area becomes wet land.
Stage 6 — Woodland/shrubland stage: Shrubs and trees begin to colonise.
Stage 7 — Climax forest: Stable, self-sustaining forest community.

Why other options are wrong:
Option A: Rooted floating stage cannot precede phytoplankton; phytoplankton are always first (pioneer in open water).
Option B: Marsh meadow cannot precede rooted submerged plants; submerged plants colonise first, then floating, then emergent.

Option D: Reed-swamp stage occurs after floating plants; phytoplankton must precede all other stages.

Answer: (C) ← Go back to Q38

Q39.

Solution

Concept — Recombinant Human Insulin Production (Humulin)

Recombinant human insulin was the **first recombinant pharmaceutical protein approved for clinical use** (Eli Lilly's Humulin, FDA approved 1982). Human insulin consists of two polypeptide chains: **A chain** (21 amino acids) and **B chain** (30 amino acids), linked by two inter-chain disulfide bonds (A7–B7 and A20–B19) and one intra-chain bond (A6–A11).

Production method (original Genentech/Eli Lilly process):

Step 1: Synthetic genes encoding the human insulin A chain and B chain separately (with ATG start codons and stop codons, codon-optimised for *E. coli*) were constructed by chemical synthesis.

Step 2: Each gene was cloned into a separate plasmid vector (fused to the β-galactosidase gene for expression) and transformed into separate *E. coli* strains.

Step 3: Each chain was expressed separately, extracted, and purified (after cleaving from β-galactosidase with cyanogen bromide at the methionine junction).

Step 4: Purified A and B chains were combined *in vitro* under controlled oxidising conditions to form the correct three disulfide bonds, yielding functional human insulin.

Modern alternative: Expression of proinsulin (A-C-B chain) in yeast (*Saccharomyces cerevisiae* or *Pichia pastoris*), then enzymatic removal of the C-peptide.

Why other options are wrong:

Option A: Extracting insulin from human pancreases is ethically and practically impossible at scale; animal (pork/beef) pancreatic insulin was used before 1982.

Option B: Chemical peptide synthesis of all 51 amino acids is technically possible but prohibitively expensive at pharmaceutical scale, and does not constitute "recombinant" insulin.

Option C: Modifying pig insulin (porcine insulin differs from human insulin by only one amino acid: B30 Ala vs Thr) by chemical semi-synthesis was done (Novo Nordisk's "Actrapid"), but true recombinant insulin uses human gene sequences in *E. coli*, not pig genes.

Answer: (D) ← Go back to Q39

Q40.

Solution

Concept — Hybridoma Technique for Monoclonal Antibody Production

Monoclonal antibodies (mAbs) are identical antibodies produced by a single B-cell clone, all recognising the same **epitope** (specific antigen determinant). The **hybridoma technique** (Köhler and Milstein, 1975; Nobel Prize 1984) solves two problems: B lymphocytes (which produce specific antibodies) are *mortal* (die in culture after a few divisions); myeloma cells (antibody-secreting B-cell tumours) are *immortal* but do not produce a desired specific antibody.

Step 1 — Immunisation: Mouse is immunised with the target antigen; B lymphocytes in the spleen are producing specific antibodies.

Step 2 — Fusion: Spleen B lymphocytes are fused with **myeloma cells** (HAT-sensitive, $HGPRT^-$, do not secrete antibody — e.g., SP2/0 or NS0 cells) using **polyethylene glycol (PEG)** as a fusogen. This creates **hybridoma cells** that are: (a) *immortal* (from myeloma parent) and (b) *produce the specific antibody* (from B lymphocyte parent).

Step 3 — Selection: Culture in **HAT medium** (hypoxanthine-aminopterin-thymidine): unfused myeloma cells ($HGPRT^-$) die; unfused B cells die (mortal); only hybridomas survive.

Step 4 — Screening and Cloning: Hybridomas screened by ELISA for antibody specificity; positive clones are single-cell-cloned and expanded. mAbs collected from culture supernatant or mouse ascites.

Applications: Diagnostics (pregnancy tests, ELISA kits, flow cytometry), therapeutics (trastuzumab/Herceptin for $HER2^+$ breast cancer, rituximab for $CD20^+$ lymphomas, infliximab for TNF-α-mediated inflammation).

Why other options are wrong:

Option B: Collecting serum from repeatedly immunised animals gives *polyclonal* antiserum (mixture of antibodies from many different B-cell clones recognising multiple epitopes) — not monoclonal.

Option C: Cloning an antibody gene from a single B cell and expressing it in bacteria is the basis of *recombinant antibody technology* (a more modern approach), not the classical hybridoma technique.

Option D: T lymphocytes do not produce antibodies; hybridomas are made from B lymphocytes (antibody-secreting cells), not T cells.

Answer: (A) ← Go back to Q**40**

Answer Key

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