BITSAT Biology Sample Paper – 4

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

Instructions

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

Q1. Peroxisomes are small membrane-bound organelles that handle hydrogen peroxide produced by their internal oxidases. The enzyme that detoxifies the H_2O_2 they generate is:

(A) Superoxide dismutase (acts on superoxide radical, not H_2O_2)

(B) Pepsin (a stomach protease, unrelated)

(C) Lysozyme (digests bacterial cell walls)

(D) Catalase, which converts $2\,H_2O_2 \rightarrow 2\,H_2O + O_2$; one of the highest turnover-number enzymes known

Q2. The principal functions of the smooth endoplasmic reticulum (SER) in mammalian cells include:

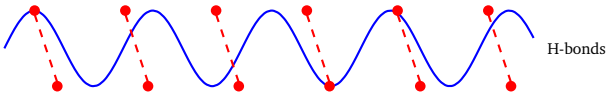
(A) Protein synthesis on attached ribosomes (this is rough ER)

(B) Storage of genetic information

(C) Lipid (phospholipid, steroid) synthesis; detoxification of drugs in hepatocytes via cytochrome P450; Ca^{2+} storage and release (sarcoplasmic reticulum of muscle)

(D) Generation of ATP by oxidative phosphorylation

Q3. The α-helix secondary structure of proteins (shown below) is stabilised by:



Backbone H-bonds every 4th residue

(A) Hydrogen bonds between the backbone $\mathrm{C}=\mathrm{O}$ of residue i and the backbone $\mathrm{N}-\mathrm{H}$ of residue $i+4$ — regular helical pitch of ~ 3.6 residues per turn ($5.4\,\text{Å}$ rise per turn)

(B) Disulfide bonds between side chains

(C) Ionic interactions between charged side chains

(D) Van der Waals forces only

Q4. Cellulose, the most abundant organic molecule on Earth and the structural polysaccharide of plant cell walls, consists of:

(A) α-1,4-linked glucose monomers, forming a branched chain

(B) Long linear β-1,4-linked glucose chains held in parallel bundles by extensive hydrogen bonding, giving great tensile strength

(C) Fructose monomers

(D) N-acetylglucosamine monomers

Q5. RNA differs from DNA in three key ways:

(A) Uses thymine, ribose sugar, single-stranded

(B) Uses adenine, deoxyribose sugar, double-stranded

(C) Contains uracil (instead of thymine), ribose (with $2'$-OH instead of $2'$-H), and is generally single-stranded

(D) Identical to DNA in every aspect except the colour

Q6. The net theoretical ATP yield from complete aerobic oxidation of one glucose molecule (glycolysis + link reaction + Krebs cycle + oxidative phosphorylation) in a eukaryotic cell is approximately:

(A) 30–32 ATP (older textbooks state 36–38, but modern estimates account for the cost of NADH transport into the mitochondrion via the malate-aspartate or glycerol-phosphate shuttle)

(B) 2 ATP only

(C) 100 ATP

(D) Zero net ATP

Q7. The pyruvate dehydrogenase complex, which oxidatively decarboxylates pyruvate to acetyl-CoA (the link reaction between glycolysis and the Krebs cycle), is located in:

(A) The cytosol

(B) The mitochondrial matrix — the same location as the Krebs cycle, so acetyl-CoA can directly enter

(C) The outer mitochondrial membrane

(D) Lysosomes

Q8. During prophase of mitosis, which of the following events occurs?

(A) Sister chromatids separate to opposite poles

(B) Chromosomes align at the metaphase plate

(C) Nuclear envelope re-forms around two daughter nuclei

(D) Chromatin condenses into visible chromosomes (each consisting of two sister chromatids joined at the centromere), the nucleolus disperses, and the mitotic spindle begins to assemble while the nuclear envelope is still intact

Q9. Salivary amylase (ptyalin) secreted by parotid, submandibular and sublingual glands begins carbohydrate digestion in the mouth by:

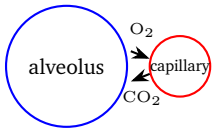
(A) Hydrolysing α-1,4 glycosidic bonds of starch into maltose, maltotriose and dextrins; optimal at salivary pH ~ 6.8; inactivated by gastric acid in stomach

(B) Digesting proteins into amino acids

(C) Breaking lipids into fatty acids

(D) Cleaving DNA into nucleotides

Q10. Gas exchange between alveoli and pulmonary capillaries occurs primarily by:



P_{O_2} alveolus $= 104$, capillary $= 40\,\text{mm Hg}$

(A) Active transport requiring ATP

(B) Simple diffusion driven by the partial-pressure gradients of O_2 and CO_2 across the very thin ($< 1\,\mu\text{m}$) alveolar-capillary respiratory membrane; equilibration is essentially complete within $0.25\,\text{s}$

(C) Endocytosis of gas molecules

(D) Osmosis only

Q11. The atrioventricular (AV) node introduces a brief delay ($\sim 0.1\,\text{s}$) before transmitting the impulse to the ventricles. The functional importance of this delay is to:

(A) Slow the heart rate permanently

(B) Prevent backflow of blood through the valves

(C) Allow time for the SA node to recover before the next beat

(D) Allow the atria to complete their contraction and fully empty blood into the ventricles before the ventricles themselves contract, optimising cardiac filling and ejection

Q12. The juxtaglomerular apparatus (JGA) of the kidney secretes which hormone in response to low blood pressure or low NaCl delivery to the macula densa?

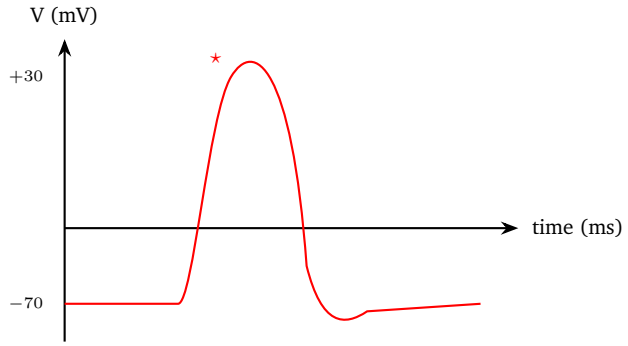
(A) Erythropoietin (this is also from kidney but from interstitial fibroblasts in response to low O_2)

(B) Aldosterone (this is from adrenal cortex, downstream of the JGA signal)

(C) Renin, an aspartic protease that cleaves angiotensinogen to angiotensin I — the trigger for the entire renin-angiotensin-aldosterone system regulating blood pressure and salt-water balance

(D) Antidiuretic hormone (from posterior pituitary)

Q13. The schematic below shows a typical neuronal action potential. The rapid upstroke (depolarisation) marked $\star$ is caused by:



(A) Slow K^+ efflux through voltage-gated potassium channels

(B) Rapid Na^+ influx through voltage-gated sodium channels, which open at the threshold potential ($\sim -55\,\mathrm{mV}$); the membrane potential briefly approaches the Na^+ equilibrium potential ($+60\,\mathrm{mV}$)

(C) Cl^- entry through ligand-gated channels

(D) Ca^{2+} entry through L-type channels (this drives the plateau in cardiac, not neuronal, APs)

Q14. Growth hormone (somatotropin), secreted by the anterior pituitary, acts on target tissues partly directly and partly through the liver-produced peptide:

(A) Insulin-like growth factor 1 (IGF-1, or somatomedin C), which mediates most of GH's anabolic effects on bone, cartilage and muscle.

Excess GH in childhood causes gigantism; excess after epiphyseal closure causes acromegaly

(B) Insulin (which is from β cells of pancreas)

(C) Glucagon

(D) Thyroxine

Q15. The active uptake and accumulation of ions by root cortical cells generates a positive hydrostatic pressure inside the root xylem ($\sim$ 0.05–0.5 MPa), called root pressure. This is most evident as:

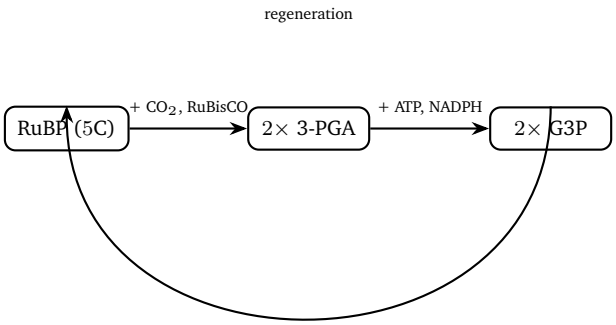
(A) Massive water transport in tall trees (root pressure is far too weak to lift water in 30-m trees; transpiration pull does this)

(B) Loss of water as vapour through stomata

(C) Bleeding of grapevines and tomato stems when cut just above ground (a related phenomenon)

(D) **Guttation** — exudation of droplets of liquid water (xylem sap) through specialised pores called hydathodes at the leaf-tip margins of grasses and many herbs, typically on cool humid mornings when root pressure builds up and transpiration is minimal

Q16. The Calvin cycle (light-independent or "dark" reactions of photosynthesis), schematised below, takes place in the chloroplast stroma. The first stable carbon-fixation product is:



(A) Glucose directly

(B) Oxaloacetate (this is the first product in C_4 plants, not the Calvin cycle proper)

(C) 3-Phosphoglycerate (3-PGA, a 3-carbon compound) — produced when RuBisCO carboxylates ribulose-1,5-bisphosphate (RuBP) with CO_2

(D) Pyruvate

Q17. In a Mendelian dihybrid cross, the F_2 phenotypic ratio (when both gene pairs assort independently and each shows simple dominance) is:

(A) $3:1$

(B) $9:3:3:1$ (the four phenotypes being two dominant : dominant-recessive : recessive-dominant : double recessive)

(C) $1:1$

(D) $1:2:1$

Q18. Crossing a true-breeding red-flowered *Mirabilis jalapa* (RR) with a true-breeding white-flowered (rr) plant produces an F_1 generation that is entirely pink-flowered. This pattern of inheritance illustrates:

(A) Incomplete dominance — neither R nor r is completely dominant; the heterozygote (Rr) shows an intermediate phenotype because the R allele produces only enough red pigment for a pale (pink) colour

(B) Complete dominance (this would give all red F_1)

(C) Codominance (both alleles would be visibly expressed, as in AB blood type)

(D) Epistasis

Q19. In eukaryotic transcription, the enzyme responsible for synthesising mRNA from protein-coding genes is:

(A) RNA polymerase I (transcribes large rRNA genes)

(B) RNA polymerase III (transcribes tRNA, $5\,S$ rRNA, some snRNAs)

(C) RNA polymerase II — transcribes all protein-coding genes; sensitive to α-amanitin (the toxin of the death-cap mushroom *Amanita phalloides*)

(D) DNA polymerase III (this is for prokaryotic DNA replication)

Q20. The theory of "inheritance of acquired characters" — e.g. that giraffes' long necks arose because ancestral giraffes stretched their necks to reach leaves, and this trait was inherited — was proposed by:

(A) Gregor Mendel

(B) Charles Darwin

(C) Alfred Russel Wallace

(D) Jean-Baptiste Lamarck (1809, in *Philosophie Zoologique*). His ideas have been discredited by modern genetics: somatic modifications acquired by an individual during life are not transmitted to offspring through the gametes

Q21. Fossils contribute to the evidence for biological evolution by:

(A) Documenting the progressive change of life forms through geological time, revealing transitional (intermediate) fossils such as *Archaeopteryx* (reptile-to-bird link with feathers + teeth + clawed wings) and showing extinct lineages no longer present in the modern biota

(B) Proving that all species are unchanged since their creation

(C) Showing that DNA is identical across all species

(D) Disproving evolution entirely

Q22. Hox genes (a subgroup of homeobox-containing genes) function in animal development by:

(A) Coding for muscle contractile proteins

(B) Specifying the identity of body segments along the antero-posterior axis during embryonic development; they encode transcription factors with a conserved homeodomain (the protein product of the

homeobox) and are arranged in clusters whose linear order on the chromosome matches their order of expression along the body axis (the colinearity principle)

(C) Producing antibodies

(D) Determining blood groups

Q23. Sertoli cells (sustentacular cells) lining the seminiferous tubules of the testis perform which key function?

(A) Secrete testosterone (this is the role of Leydig / interstitial cells)

(B) Store mature sperm before ejaculation (this is the function of the epididymis and vas deferens)

(C) Nurse the developing sperm cells — providing nutrients, forming the blood-testis barrier via tight junctions, secreting androgen-binding protein (ABP) and inhibin; bear FSH receptors and respond to FSH from the anterior pituitary

(D) Pump blood into the testes

Q24. Newly formed spermatozoa released from the seminiferous tubules are non-motile and incapable of fertilisation. They acquire motility and fertilising capacity during their ~ 12-day transit through:

(A) The vas deferens

(B) The prostate gland

(C) The ejaculatory duct

(D) The epididymis — a 6-m coiled tubule on the posterior surface of each testis, where sperm mature, are stored, and are gradually concentrated

Q25. The Leydig (interstitial) cells located between the seminiferous tubules of the testis secrete:

(A) Inhibin (this is secreted by Sertoli cells)

(B) Testosterone, the major androgen in males, under the control of luteinising hormone (LH) from the anterior pituitary; testosterone is responsible for spermatogenesis, secondary sexual characteristics and libido

(C) Oestrogen

(D) Progesterone

Q26. The mechanism of action of the male condom as a contraceptive method is:

(A) A physical (barrier) method — prevents semen (containing sperm) from entering the vagina; it is the only contraceptive that also provides protection against most sexually transmitted infections (HIV, gonorrhoea, chlamydia, hepatitis B)

(B) Suppression of spermatogenesis

(C) Hormonal suppression of ovulation

(D) Surgical sterilisation

Q27. The innermost layer of the anther wall, called the **tapetum**, is functionally critical because it:

(A) Is the outermost protective layer of the anther

(B) Carries out photosynthesis to support pollen development

(C) Provides mechanical support like sclerenchyma

(D) Surrounds the developing pollen mother cells (microsporocytes), providing them with nutrients, enzymes and the sporopollenin precursors that build the exine; tapetal cells are usually polyploid and short-lived (degenerate after pollen maturation)

Q28. Plants that bear male flowers (staminate) and female flowers (pistillate) on *separate individual plants* are termed:

(A) Monoecious (both kinds of flowers on the *same* plant, e.g. maize, cucumber)

(B) Hermaphrodite (bisexual flowers — staminate and pistillate parts in the same flower)

(C) Dioecious (Greek *di* = two, *oikos* = house) — e.g. papaya, date palm, mulberry, willow; this arrangement absolutely prevents self-pollination and enforces cross-pollination (outbreeding)

(D) Polygamous

Q29. Abscisic acid (ABA), the so-called "stress hormone" of plants, predominantly:

(A) Promotes seed and bud dormancy and triggers stomatal closure under water stress (via Ca^{2+} signalling and anion channel opening in guard cells); also accelerates leaf abscission and senescence

(B) Promotes cell elongation in stems

(C) Triggers fruit ripening

(D) Causes seed germination directly

Q30. Long-day plants (LDPs) such as spinach, wheat (winter and spring varieties), radish and *Hibiscus* flower when:

(A) Day length falls below a critical value

(B) The dark period is shorter than a critical length (equivalently, day length exceeds a critical minimum, usually 12–$14\,\mathrm{h}$); a brief flash of red light interrupting the dark period actually PROMOTES flowering in LDPs (opposite to SDPs)

(C) Day-night cycle is interrupted by drought

(D) Temperature drops below freezing

Q31. When a temperate bacteriophage (such as λ phage) infects an *E. coli* cell, it can take one of two life-cycle paths. In the **lysogenic** cycle, the phage:

(A) Immediately replicates and lyses the cell

(B) Forms a free, circular plasmid that replicates independently

(C) Destroys the bacterial chromosome

(D) Integrates its DNA into the host bacterial chromosome at a specific attachment site (*attB*) as a **prophage**; the prophage replicates passively with the host genome and is transmitted to all daughter cells until an environmental trigger (e.g. UV) induces the lytic cycle

Q32. Bryophytes (mosses, liverworts and hornworts) are botanically distinct from all other land plants in that they:

(A) Are entirely aquatic with no land adaptations

(B) Possess seeds and pollen

(C) Lack true vascular tissue (xylem and phloem); their dominant generation is the haploid gametophyte (the green "moss plant"); the sporophyte is small, dependent and short-lived; their flagellated sperm require external water to swim to the egg — restricting them to moist habitats

(D) Have well-developed roots

Q33. Gymnosperms (Greek *gymnos* = naked + *sperma* = seed) are characterised by:

(A) Flowers and fruits enclosing the seeds

(B) Reproduction by spores only

(C) Naked seeds (not enclosed in a fruit wall, since the ovules are borne directly on the surface of scales of female cones); examples *Pinus*, *Cycas*, *Ginkgo biloba*, *Cedrus deodara*, *Sequoia* — the tallest and longest-lived plants on Earth

(D) Filamentous body without true roots

Q34. Typhoid fever is a serious systemic illness with sustained high fever, "rose spots" on the trunk and possible intestinal perforation. The causative organism is:

(A) *Vibrio cholerae*

(B) *Salmonella typhi*, a gram-negative bacillus transmitted via the faecal-oral route, usually through contaminated food or water; diagnosed by the Widal test or blood culture; treated with fluoroquinolones, ceftriaxone, or azithromycin

(C) *Mycobacterium tuberculosis*

(D) *Plasmodium falciparum*

Q35. An unimmunised person sustains a dirty puncture wound. The doctor administers anti-tetanus serum (ATS, a preparation of pre-formed antibodies against tetanus toxin). This provides:

(A) Active natural immunity

(B) Active artificial immunity (this requires a vaccine, not pre-formed antibodies)

(C) Passive natural immunity (this is maternal antibody transfer)

(D) Passive artificial immunity — the recipient does not make the antibodies; they are introduced fully formed. Onset is immediate but short-lived ($\sim$ 2–3 weeks) and confers no immune memory; useful for emergency post-exposure prophylaxis

Q36. Sulfonamide drugs ("sulfa" antibiotics such as sulfanilamide and sulfamethoxazole), among the earliest broad-spectrum antibacterials, act by:

(A) Competitively inhibiting bacterial dihydropteroate synthase — a key enzyme in the folate biosynthesis pathway. Sulfonamides are structural analogues of p-aminobenzoic acid (PABA), the natural substrate. Mammalian cells obtain folate from the diet, so they are unaffected (selective toxicity)

(B) Inhibiting bacterial DNA gyrase (this is the action of fluoroquinolones)

(C) Inhibiting peptidoglycan synthesis (this is the action of β-lactams)

(D) Inhibiting the bacterial $50\,\mathrm{S}$ ribosomal subunit (this is the action of macrolides like erythromycin)

Q37. In the global carbon cycle, the LARGEST active reservoir of carbon (i.e. that exchanges with the atmosphere on geological-to-biological timescales) is:

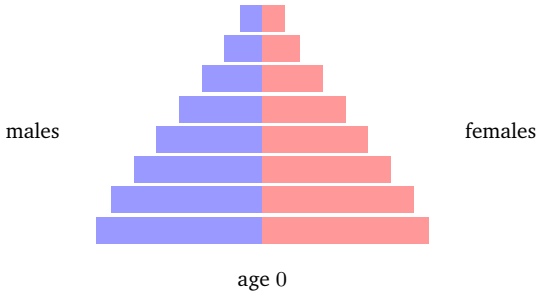
(A) Living biomass (forests, oceans plankton)

(B) The oceans, which hold $\sim 38{,}000$ gigatonnes of carbon as dissolved CO_2, bicarbonate (HCO_3^-) and carbonate (CO_3^{2-}) — about $50\times$ the atmospheric pool. Sedimentary rocks are by far the largest *total* reservoir but exchange much more slowly

(C) The atmosphere

(D) Polar ice caps

Q38. The population age pyramid shown below (broad base, narrowing top) represents:



(A) A declining (contracting) population

(B) A stable, stationary population

(C) An expanding (growing) population — with a high proportion of young individuals (high birth rate) and a decreasing proportion at older ages (high mortality); typical of many developing countries

(D) A population at zero population growth

Q39. pBR322 — one of the earliest and most widely used *E. coli* plasmid cloning vectors — has which essential features?

(A) An origin of replication (*ori*) allowing autonomous replication inside *E. coli*; two selectable antibiotic-resistance genes (ampicillin resistance amp^R and tetracycline resistance tet^R); and unique restriction

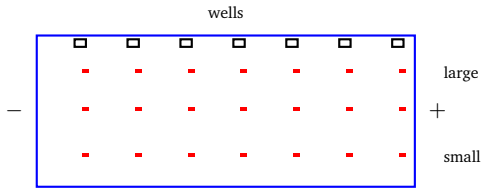
sites within the antibiotic-resistance genes that allow insertional inactivation for screening recombinant clones (blue-white-style selection)

(B) A complete chromosomal centromere

(C) Telomeres for linear replication

(D) A nuclear localisation signal for eukaryotic targeting

Q40. Agarose gel electrophoresis, shown below, separates DNA fragments by:



(A) Their chemical composition (sequence)

(B) Hydrogen bonding pattern

(C) Density only

(D) Their size (length) — DNA being negatively charged migrates toward the anode (+) through the agarose gel matrix; smaller fragments encounter less resistance and travel faster, so they move farther from the well, giving a size-ordered ladder of bands typically visualised with ethidium bromide under UV light

Detailed Solutions

Q1.

Solution

Concept — Peroxisomes and catalase: Peroxisomes are small (0.1–$1.0\,\mu$m) single-membrane organelles found in nearly all eukaryotic cells, discovered by Christian de Duve (1965). They carry out oxidative metabolism using molecular O_2.

Step 1 — Why H_2O_2 is generated: Peroxisomal oxidases use O_2 to oxidise substrates (very-long-chain fatty acids, D-amino acids, uric acid), producing hydrogen peroxide as a by-product. H_2O_2 is toxic — a powerful oxidant that damages DNA and proteins.

Step 2 — Catalase: The enzyme catalase converts: $2\,H_2O_2 \rightarrow 2\,H_2O + O_2$. It is one of the fastest enzymes known — a single molecule can decompose millions of H_2O_2 molecules per second.

Step 3 — Other peroxisomal functions: β-oxidation of very-long-chain fatty acids (> 22 carbons), bile acid synthesis, plasmalogen synthesis, and (in plants) the glyoxylate cycle. Defects cause Zellweger syndrome and adrenoleukodystrophy.

Final Answer: Catalase $\Rightarrow$ $\boxed{\text{D}}$

Answer: (D) Go Back to Q1

Q2.

Solution

Concept — Smooth ER (SER) functions: The ER is a continuous membrane network with two morphologically and functionally distinct regions: rough ER (RER, studded with ribosomes) and smooth ER (no ribosomes).

Step 1 — SER functions:

- **Lipid synthesis:** phospholipids, cholesterol, steroid hormones (in adrenal cortex, gonads).
- **Drug detoxification:** in hepatocytes, cytochrome P450 enzymes embedded in SER membranes hydroxylate lipophilic toxins (alcohol, barbiturates) for excretion. Chronic alcohol use causes SER proliferation in liver cells.
- **Ca^{2+} storage:** the sarcoplasmic reticulum (SR), a specialised SER in muscle, stores Ca^{2+} released during excitation-contraction coupling.
- **Carbohydrate metabolism:** glucose-6-phosphatase (last step of gluconeo-

genesis) is in SER.

Final Answer: Lipid synthesis, detoxification, Ca^{2+} storage $\Rightarrow$ C

Answer: (C) Go Back to Q2

Q3.

Solution

Concept — α-helix — the most common protein secondary structure: Predicted by Pauling, Corey & Branson (1951). A right-handed helix with 3.6 residues per turn and 5.4 Å rise per turn (each residue rises 1.5 Å).

Step 1 — Stabilising bonds: Hydrogen bonds form between the backbone carbonyl oxygen ($C=O$) of residue i and the backbone amide hydrogen ($N-H$) of residue $i+4$. These H-bonds run parallel to the helix axis.

Step 2 — Side chains: Side chains (R groups) point outward from the helix, away from the backbone. The amino acid composition of the helix determines its solubility and interaction partners.

Step 3 — Distinguish from β-sheet: β-sheets are stabilised by H-bonds *between adjacent strands* (not within a strand). They can be parallel or anti-parallel.

Step 4 — Helix-breaking residues: Proline (rigid ring restricts ϕ angle) and glycine (very flexible) tend to disrupt or terminate α-helices.

Final Answer: Backbone H-bonds between i and $i+4$ residues $\Rightarrow$ A

Answer: (A) Go Back to Q3

Q4.

Solution

Concept — Cellulose structure: The most abundant biopolymer on Earth ($\sim 1.5 \times 10^{12}$ tonnes produced annually by plants).

Step 1 — Chemistry: Linear chains of D-glucose connected by β-1,4 glycosidic bonds. The β-linkage forces every other glucose to flip 180°, producing a perfectly straight, ribbon-like chain.

Step 2 — Why so strong? ~ 36 such linear chains lie side-by-side, held together by extensive inter- and intra-chain hydrogen bonding $\Rightarrow$ microfibrils. Microfibrils have tensile strength comparable to steel by weight.

Step 3 — Why we cannot digest it: Humans lack cellulase. Only certain bacteria (in ruminant rumen, termite gut, herbivore caecum), fungi and protozoa can hydrolyse β-1,4 links. Dietary cellulose passes through as "fibre".

Step 4 — Compare with starch: Starch (amylose) is α-1,4-linked $\rightarrow$ chain coils helically, easily hydrolysed by amylase. The single bond-angle difference between α and β has profound biological consequences.

Final Answer: Linear β-1,4 glucose chains held in bundles by H-bonds $\Rightarrow$ B

Answer: (B) Go Back to Q4

Q5.

Solution

Concept — Three structural differences between RNA and DNA:

Step 1 — The sugar:

- DNA: 2′-deoxyribose (a hydrogen at $C2'$).
- RNA: ribose (a hydroxyl, 2′-OH).
- The extra 2′-OH makes RNA much more chemically reactive and prone to hydrolysis (RNA half-life is short).

Step 2 — The bases:

- DNA: A, T, G, C.
- RNA: A, U (**uracil** replaces thymine), G, C.
- Uracil is unmethylated; thymine is 5-methyluracil.

Step 3 — The strand:

- DNA: usually double-stranded helix.
- RNA: usually single-stranded; can fold back on itself to form secondary structures (hairpins, loops). Exception: some viruses have dsRNA (reoviruses) or ssDNA (parvoviruses).

Step 4 — Function:

- DNA: long-term hereditary storage; very stable.
- RNA: short-term messenger (mRNA), structural and catalytic (rRNA, ribozymes), adaptor (tRNA), regulatory (miRNA, lncRNA).

Final Answer: Uracil, ribose, single-stranded $\Rightarrow$ C

Answer: (C) Go Back to Q5

Q6.

Solution

Concept — ATP yield from glucose oxidation:

Step 1 — Stage-by-stage breakdown:

Stage	Direct ATP/GTP	NADH/$FADH_2$
Glycolysis (cytosol)	$+2$ ATP	2 NADH
Link reaction $\times 2$	0	2 NADH
Krebs cycle $\times 2$	$+2$ GTP	6 NADH + 2 $FADH_2$
TOTAL	4 ATP/GTP	10 NADH + 2 $FADH_2$

Step 2 — Yield from ETC + oxidative phosphorylation:

- Each NADH (matrix) $\rightarrow\sim 2.5$ ATP (modern stoichiometry).
- Each $FADH_2$ $\rightarrow\sim 1.5$ ATP.
- Cytosolic NADH from glycolysis $\rightarrow$ 1.5 ATP via glycerol-phosphate shuttle, or ~ 2.5 via malate-aspartate shuttle.

Step 3 — Total (typical): $4 + 10 \times 2.5 + 2 \times 1.5-$ shuttle losses $\approx$ **30** to **32** ATP per glucose.

Step 4 — Older value of 36–38: Old textbooks assumed exact stoichiometric H^+/ATP coupling and no shuttle losses. The modern, lower value accounts for the proton-motive cost of importing P_i and ADP and exporting ATP.

Final Answer: $\sim$ 30–32 ATP per glucose $\Rightarrow$ $\boxed{\text{A}}$

Answer: (A) Go Back to Q6

Q7.

Solution

Concept — The link reaction (oxidative decarboxylation of pyruvate): After glycolysis in the cytosol, pyruvate enters the mitochondrion via the pyruvate carrier (MPC) in the inner membrane. The pyruvate dehydrogenase complex (PDH) then catalyses:

$$\text{Pyruvate} + \text{NAD}^+ + \text{CoA} - \text{SH} \rightarrow \text{Acetyl-CoA} + \text{NADH} + \text{CO}_2$$

Step 1 — The complex: PDH is a huge multi-enzyme complex of 3 subunits (E1, E2, E3) using 5 cofactors: thiamine pyrophosphate (TPP, from vitamin B_1), lipoic

acid, CoA (vit. B_5), FAD (B_2) and NAD^+ (B_3). Vitamin B_1 deficiency $\rightarrow$ beriberi.

Step 2 — Location: PDH is located in the **mitochondrial matrix** — the same compartment as the Krebs cycle enzymes, allowing direct hand-off of acetyl-CoA.

Step 3 — Regulation: Inhibited by high ATP, NADH and acetyl-CoA (product inhibition); activated by Ca^{2+} (during muscle contraction signal). PDH kinase (inhibitor) and phosphatase (activator) provide reversible phosphorylation control.

Final Answer: Mitochondrial matrix $\Rightarrow$ B

Answer: (B) Go Back to Q7

Q8.

Solution

Concept — Prophase events in mitosis: The longest phase of mitosis (early prophase + prometaphase). Several major changes prepare the cell for chromosome separation.

Step 1 — Hallmark events:

- **Chromatin condensation:** interphase chromatin (loose 10 nm fibre) compacts into visible chromosomes through cohesin loading and condensin action. Each chromosome already consists of two sister chromatids joined at the centromere (DNA was replicated in S phase).
- **Nucleolus dispersal:** rRNA synthesis halts; the nucleolus disassembles.
- **Centrosome separation:** duplicated centrosomes move to opposite poles, organising microtubules into the bipolar mitotic spindle.
- Nuclear envelope is still intact at this point (it breaks down at the end of prophase / start of prometaphase in animal cells).

Step 2 — Sequence after prophase: Prometaphase (nuclear envelope breakdown, kinetochore attachment) $\rightarrow$ metaphase (alignment) $\rightarrow$ anaphase (separation) $\rightarrow$ telophase (decondensation).

Final Answer: Chromosome condensation, spindle formation, nucleolar dispersal $\Rightarrow$ D

Answer: (D) Go Back to Q8

Q9.

Solution

Concept — Salivary amylase (ptyalin): Carbohydrate digestion begins in the mouth, not in the stomach. Three pairs of salivary glands (parotid, submandibular, sublingual) secrete ~ 1–$1.5\,\mathrm{L}$ of saliva daily.

Step 1 — Substrate specificity: α-amylase hydrolyses α-1,4 glycosidic bonds within starch and glycogen. It cannot cleave α-1,6 branch points or β-bonds (so cellulose is untouched). $\mathrm{Starch} + \mathrm{H_2O} \rightarrow \mathrm{Maltose} + \mathrm{Maltotriose} + \alpha$-limit dextrins.

Step 2 — Conditions: Optimum pH ~ 6.8 (mildly alkaline saliva). Inactivated in stomach as pH drops to ~ 2, so digestion resumes only when chyme enters the duodenum and is neutralised — where pancreatic amylase continues the work.

Step 3 — Why "begins"? Food spends only a few seconds chewing in the mouth, so most starch digestion actually occurs in the small intestine. The completed end-products of carbohydrate digestion (monosaccharides — glucose, galactose, fructose) are absorbed in the jejunum.

Final Answer: Hydrolyses α-1,4 bonds of starch $\rightarrow$ maltose, dextrins $\Rightarrow$ $\boxed{\text{A}}$

Answer: (A) Go Back to Q9

Q10.

Solution

Concept — Pulmonary gas exchange by passive diffusion: The respiratory zone of the lung (respiratory bronchioles + alveolar ducts + alveoli) provides a vast surface area ($\sim 70\,\mathrm{m^2}$ in adults — the size of half a tennis court) packed into a small thoracic cavity.

Step 1 — The respiratory membrane: Comprises five layers but totals only 0.2–$0.6\,\mu\mathrm{m}$ thick:

- Layer of alveolar fluid + surfactant
- Alveolar epithelium (Type I pneumocytes)
- Basement membrane (epithelial)
- Basement membrane (capillary)
- Capillary endothelium

Step 2 — Partial pressure gradients drive diffusion:

- P_{O_2}: alveolus 104 mm Hg $\rightarrow$ deoxygenated capillary 40 mm Hg $\Rightarrow$ $\mathrm{O_2}$ diffuses into blood.

- P_{CO_2}: deoxygenated blood 45 mm Hg $\rightarrow$ alveolus 40 mm Hg $\Rightarrow$ CO_2 diffuses out.
- No ATP required — pure passive diffusion (Fick's law).

Step 3 — Time course: RBCs traverse the pulmonary capillary in ~ 0.75 s at rest; gas equilibration is complete within the first ~ 0.25 s, leaving a large safety reserve during exercise (when transit time shortens).

Final Answer: Simple diffusion driven by partial-pressure gradients $\Rightarrow$ $\boxed{\text{B}}$

Answer: (B) Go Back to Q10

Q11.

Solution

Concept — The atrioventricular nodal delay: The AV node, located in the lower interatrial septum near the tricuspid valve, conducts impulses much more slowly than the rest of the conducting system (only $\sim 0.05\,\mathrm{m\,s^{-1}}$ vs $\sim 4\,\mathrm{m\,s^{-1}}$ in the Purkinje fibres).

Step 1 — The delay: SA-node impulse reaches the AV node in $\sim 30\,\mathrm{ms}$, then dwells in the AV node for $\sim 100\,\mathrm{ms}$ before being passed to the bundle of His. This $\sim 0.1\,\mathrm{s}$ delay corresponds to the PR segment on the ECG.

Step 2 — Functional role: The delay gives the atria enough time to:

- Complete their contraction.
- Eject the final $\sim 20\%$ of ventricular filling (atrial kick).
- Reach end-diastolic volume before ventricles begin to contract.

If the AV node did not delay, atria and ventricles would contract simultaneously $\Rightarrow$ poor filling and ejection efficiency.

Step 3 — Protection: The AV node also acts as a gatekeeper: in atrial fibrillation, it filters out most of the chaotic atrial impulses, protecting the ventricles from racing at 400–600 bpm.

Final Answer: Allows atrial contraction to complete before ventricular contraction $\Rightarrow$ $\boxed{\text{D}}$

Answer: (D) Go Back to Q11

Q12.

Solution

Concept — The juxtaglomerular apparatus (JGA): A specialised structure at the vascular pole of each nephron, formed at the meeting of the afferent arteriole and the distal convoluted tubule.

Step 1 — Three components:

- **Juxtaglomerular (JG) cells:** modified smooth muscle cells in the wall of the afferent arteriole; contain renin granules.
- **Macula densa:** specialised epithelial cells in the wall of the DCT that sense tubular NaCl concentration.
- **Lacis (extraglomerular mesangial) cells:** connect the above.

Step 2 — Stimuli for renin release:

- Decreased renal perfusion pressure (sensed by JG cells as baroreceptors).
- Decreased NaCl at the macula densa (signals low GFR/dehydration).
- Sympathetic stimulation (via β_1 receptors on JG cells).

Step 3 — The renin-angiotensin-aldosterone system (RAAS):

(a) JG cells release renin into blood.
(b) Renin cleaves circulating angiotensinogen (from liver) to angiotensin I.
(c) ACE (Angiotensin-Converting Enzyme, in lung capillaries) converts angiotensin I to angiotensin II.
(d) Angiotensin II: powerful vasoconstrictor; stimulates aldosterone release from adrenal cortex; thirst; ADH release.
(e) Aldosterone: promotes Na^+ (and water) reabsorption in DCT/collecting duct $\rightarrow$ raises blood volume and BP.

Step 4 — Pharmacology: ACE inhibitors (enalapril, ramipril), angiotensin-receptor blockers (losartan), direct renin inhibitors (aliskiren) are mainstays of hypertension treatment.

Final Answer: Renin $\Rightarrow$ C

Answer: (C) Go Back to Q12

Q13.

Solution

Concept — The neuronal action potential and voltage-gated Na^+ channels: Hodgkin and Huxley (1952, Nobel 1963) elucidated the ionic basis using voltage clamp on squid giant axon.

Step 1 — Resting state (~ -70 mV): Membrane more permeable to K^+ (leak channels open) than to Na^+ (most Na^+ channels closed). Na^+/K^+ ATPase maintains gradients ($[Na^+]_{out} = 145$, $[Na^+]_{in} = 10$ mM; $[K^+]_{in} = 140$, $[K^+]_{out} = 4$ mM).

Step 2 — Depolarisation phase (the upstroke $\star$): At threshold (~ -55 mV), voltage-gated Na^+ channels open rapidly. Na^+ rushes IN down its steep electrochemical gradient $\rightarrow$ membrane potential reverses, briefly reaching $+30$ to $+40$ mV (approaching but not reaching $E_{Na} = +60$ mV because Na^+ channels inactivate before equilibrium).

Step 3 — Repolarisation: Na^+ channels inactivate (a second gate closes). Voltage-gated K^+ channels (delayed-rectifier) open, K^+ flows OUT, returning membrane to negative potential. Brief hyperpolarisation (afterhyperpolarisation) as K^+ channels close slowly.

Step 4 — Refractory period:

- Absolute: Na^+ channels inactivated; no AP can be fired.
- Relative: a stronger-than-normal stimulus can fire an AP.

Ensures unidirectional propagation and limits maximum firing frequency.

Step 5 — Pharmacology: Tetrodotoxin (puffer fish), saxitoxin (red tide) block voltage-gated Na^+ channels $\rightarrow$ paralysis. Local anaesthetics (lidocaine) also act on Na^+ channels in a use-dependent fashion.

Final Answer: Rapid Na^+ influx through voltage-gated channels $\Rightarrow$ $\boxed{\text{B}}$

Answer: (B) Go Back to Q13

Q14.

Solution

Concept — Growth hormone (GH) and its mediator IGF-1: GH (somatotropin) is a 191-amino-acid peptide hormone secreted in pulsatile fashion by somatotrophs of the anterior pituitary, mostly during sleep and exercise.

Step 1 — Direct vs indirect actions:

- **Direct actions of GH:** promotes lipolysis in adipose tissue; antagonises insulin (diabetogenic effect); stimulates IGF-1 production in liver.
- **Indirect actions via IGF-1 (somatomedin C):** insulin-like growth factor 1, a 70-amino-acid peptide produced mainly by hepatocytes. IGF-1 mediates most growth-promoting effects — stimulates chondrocyte proliferation at epiphyseal plates, increases bone matrix synthesis, stimulates muscle protein synthesis.

Step 2 — Regulation: GHRH (from hypothalamus) stimulates GH; somatostatin inhibits. Negative feedback from IGF-1 on hypothalamus and pituitary.

Step 3 — Clinical disorders:

- Excess GH in childhood (before epiphyseal closure): **gigantism** — excessive linear growth.
- Excess GH in adulthood: **acromegaly** — enlarged hands, feet, jaw, brow ridges, organ enlargement, glucose intolerance.
- Deficiency in childhood: **dwarfism** (pituitary type) — proportionate short stature.

Final Answer: IGF-1 (somatomedin C) $\Rightarrow$ A

Answer: (A) Go Back to Q14

Q15.

Solution

Concept — Root pressure and guttation: Root pressure is the positive hydrostatic pressure generated in the root xylem by active ion uptake by root cortical cells, which lowers root water potential and draws water in osmotically.

Step 1 — Mechanism:

- Endodermal cells actively pump ions (K^+, Na^+, NO_3^-) into the xylem against their concentration gradients.

- Water follows osmotically.
- Pressure builds up to ~ 0.05–$0.5\,\mathrm{MPa}$.

Step 2 — When is root pressure significant?

- Cool, humid nights when transpiration is minimal — water continues to enter roots but cannot evaporate through stomata.
- Causes **guttation**: liquid water exudes from hydathodes (special pores at leaf tips and margins of grasses, strawberry, nasturtium); these are unmodified water-secreting stomata.
- Should not be confused with dew (water condensing on plant surfaces from humid air) — guttation droplets contain dissolved salts and sugars.

Step 3 — Why root pressure cannot lift water in tall trees: $0.5\,\mathrm{MPa}$ can lift water only $\sim 5\,\mathrm{m}$. Tall trees (30–$100\,\mathrm{m}$) rely on transpiration pull (cohesion-tension theory), which can generate negative pressures up to $-3\,\mathrm{MPa}$.

Final Answer: Guttation $\Rightarrow$ $\boxed{\mathrm{D}}$

Answer: (D) Go Back to Q15

Q16.

Solution

Concept — Calvin cycle: the dark reactions: Discovered by Melvin Calvin (1947–1957, Nobel 1961) using $^{14}CO_2$ pulse-chase in *Chlorella*. Takes place in the chloroplast stroma.

Step 1 — Three phases:

(a) **Carbon fixation:** RuBisCO (ribulose-1,5-bisphosphate carboxylase/oxygenase) attaches CO_2 to RuBP (a 5C sugar), producing an unstable 6C intermediate that immediately splits into two molecules of 3-PGA (3-phosphoglycerate, 3C). **3-PGA is the first stable product.**

(b) **Reduction:** 3-PGA + ATP + NADPH (from light reactions) $\rightarrow$ G3P (glyceraldehyde-3-phosphate, the actual "sugar").

(c) **Regeneration of RuBP:** 5 out of every 6 G3P molecules cycle through a complex series of reactions (involving transketolase, aldolase, phosphatases) to regenerate three RuBP molecules; 1 G3P exits as net product to be used for glucose, sucrose, starch synthesis.

Step 2 — Stoichiometry: To make ONE net G3P molecule, the cycle must turn three times, consuming 9 ATP and 6 NADPH and fixing $3\,CO_2$.

Step 3 — RuBisCO — the most abundant protein on Earth: Slow (3 catalytic events per second), inefficient (also reacts with O_2, causing photorespiration), and abundant (up to 50% of leaf protein). C_4 and CAM plants evolved to overcome the photorespiration problem by concentrating CO_2 around RuBisCO.

Final Answer: 3-Phosphoglycerate (3-PGA) $\Rightarrow$ C

Answer: (C) Go Back to Q16

Q17.

Solution

Concept — Mendel's dihybrid cross and law of independent assortment: Mendel crossed two true-breeding pea plants differing in two characters: round-yellow seeds (RRYY) $\times$ wrinkled-green (rryy).

Step 1 — F_1: All offspring are RrYy — phenotype: round and yellow (both dominant traits expressed). All identical heterozygotes.

Step 2 — F_2 Punnett square (16 boxes): F_1 self-cross. Independent assortment means each F_1 produces four equally likely gametes: RY, Ry, rY, ry. The 4×4 Punnett square gives $9:3:3:1$ phenotypic ratio:

- 9 Round Yellow (R_Y_)
- 3 Round green (R_yy)
- 3 wrinkled Yellow (rrY_)
- 1 wrinkled green (rryy)

Step 3 — Why this ratio? The two genes are unlinked (or far enough apart on the same chromosome) so they assort independently during meiosis. The probability of being R_Y_ $= 3/4 \times 3/4 = 9/16$, and so on.

Step 4 — Modifications: If genes are linked (close on the same chromosome), recombination frequency $< 50\%$ alters the ratio. Sutton (1903) and Boveri linked Mendel's laws to chromosome behaviour.

Final Answer: $9:3:3:1 \Rightarrow$ B

Answer: (B) Go Back to Q17

Q18.

Solution

Concept — Incomplete (partial) dominance: A pattern of inheritance where the heterozygote shows a phenotype that is intermediate between the two homozygotes — because the dominant allele's gene product is insufficient on its own to produce the full dominant phenotype.

Step 1 — The classic example: Correns (1900) crossed red-flowered *Mirabilis jalapa* (RR, "four o'clock plant") with white-flowered (rr):

- F_1: all Rr $\rightarrow$ **pink** (intermediate)
- F_2 from F_1 self-cross: 1 RR (red) : 2 Rr (pink) : 1 rr (white) — phenotypic ratio $1:2:1$ (identical to the genotypic ratio because each genotype has a unique phenotype).

Step 2 — Molecular explanation: The R allele produces a functional enzyme that converts a colourless precursor to red pigment. One copy of R (Rr) makes only half the enzyme, resulting in partial pigment production $\rightarrow$ pink colour. Two copies of R (RR) make enough enzyme for full red colour.

Step 3 — Distinguish from codominance:

- Incomplete dominance: heterozygote is intermediate (pink between red and white).
- Codominance: both alleles fully expressed simultaneously (AB blood type, with both A and B antigens on RBC).

Step 4 — Other examples of incomplete dominance: Snapdragon (*Antirrhinum*) flower colour; sickle-cell trait heterozygotes (intermediate sickling); tail length in Manx cats; pigeon feather colour.

Final Answer: Incomplete dominance $\Rightarrow$ $\boxed{\text{A}}$

Answer: (A) Go Back to Q18

Q19.

Solution

Concept — Three eukaryotic RNA polymerases: Unlike bacteria (which have a single RNA polymerase), eukaryotes have three distinct, specialised nuclear RNA polymerases, plus a fourth in plants.

Step 1 — Pol I, II, III:

Polymerase	Transcribes	Sensitivity to α-amanitin
RNA pol I	$45\,\mathrm{S}$ pre-rRNA (28S + 18S + 5.8S)	Insensitive
RNA pol II	All mRNA, most snRNA, miRNA	Very sensitive
RNA pol III	tRNA, 5S rRNA, 7SL RNA	Moderate

Step 2 — Why RNA Pol II is special:

- Largest subunit has a unique C-terminal domain (CTD) with a tandem repeat of YSPTSPS (52 repeats in human Pol II). Phosphorylation of the CTD by CDK7/CDK9 couples transcription with mRNA processing (capping, splicing, polyadenylation).
- Requires general transcription factors (TFIIA, B, D, E, F, H) to assemble the pre-initiation complex at the promoter (TATA box, -25 position).

Step 3 — α-Amanitin: The toxin of the death-cap mushroom *Amanita phalloides* binds the bridge helix of RNA Pol II, blocking translocation. Ingestion causes severe liver failure (no mRNA $\rightarrow$ no protein synthesis $\rightarrow$ hepatic necrosis); the antidote silibinin from milk thistle helps if given early.

Final Answer: RNA polymerase II $\Rightarrow$ $\boxed{\text{C}}$

Answer: (C) Go Back to Q19

Q20.

Solution

Concept — Lamarckism — a pre-Darwinian theory: French naturalist Jean-Baptiste Lamarck (1744–1829) was the first scientist to propose a coherent theory of biological evolution (in *Philosophie Zoologique*, 1809), pre-dating Darwin by 50 years.

Step 1 — Two postulates of Lamarckism:

(a) **Use and disuse:** Organs used extensively become stronger and larger; organs not used wither away.

(b) **Inheritance of acquired characters:** These changes during the organism's lifetime are transmitted to its offspring.

Step 2 — The classic example: Giraffe necks. Lamarck argued that ancestral short-necked giraffes stretched to reach high foliage; this lengthened their necks; the elongated necks were passed to offspring; over generations, necks became progressively longer.

Step 3 — Why Lamarckism is rejected by modern biology:

- Weismann's germ-plasm theory: the germ line is sequestered from somatic modifications.
- Modern genetics: changes in somatic cells are not transmitted through gametes (with rare exceptions like transgenerational epigenetic effects, which are not Lamarckian per se).
- Mendel and Mendel's heirs: heredity follows discrete particulate inheritance.

Step 4 — Some modern reappraisal: Epigenetic inheritance (DNA methylation, histone modifications) can sometimes transmit acquired patterns through one or a few generations — but the underlying DNA sequence is unaltered. This is sometimes loosely called "soft inheritance".

Final Answer: Lamarck $\Rightarrow$ $\boxed{\text{D}}$

Answer: (D) Go Back to Q20

Q21.

Solution

Concept — Fossils as evolutionary evidence: Palaeontology provides the only direct historical record of life on Earth.

Step 1 — What fossils show:

- Progressive change in life forms through geological time.
- Extinct organisms with no modern descendants (trilobites, dinosaurs, ammonites).
- **Transitional fossils** linking major taxonomic groups.

Step 2 — Famous transitional fossils:

- *Archaeopteryx* ($\sim$ 150 Mya): reptile-bird intermediate with feathers, teeth, clawed wings, long bony tail.

- *Tiktaalik* (~ 375 Mya): fish-tetrapod intermediate with wrist bones, neck.
- *Ambulocetus* (~ 49 Mya): land mammal $\rightarrow$ whale intermediate.
- *Australopithecus afarensis* ("Lucy", ~ 3.2 Mya): ape-human intermediate, bipedal but small brained.

Step 3 — Dating methods: Stratigraphy (relative dating by rock layer); radiometric dating (absolute, using $^{14}\mathrm{C}$, $^{40}\mathrm{K}/^{40}\mathrm{Ar}$, $^{238}\mathrm{U}/^{206}\mathrm{Pb}$).

Final Answer: Document progressive change and transitional forms $\Rightarrow$ A

Answer: (A) Go Back to Q21

Q22.

Solution

Concept — Hox genes and the homeobox: A landmark discovery in evolutionary developmental biology ("evo-devo"). First identified in *Drosophila* mutants by Edward Lewis (1978, Nobel 1995).

Step 1 — Structure: Hox genes contain a 180-bp DNA segment called the **homeobox**, which encodes a 60-amino-acid **homeodomain** — a helix-turn-helix DNA-binding motif. Hox proteins are transcription factors that switch on or off cohorts of downstream developmental target genes.

Step 2 — Function: Specify positional identity along the antero-posterior body axis of bilateral animals. Mutations cause **homeotic transformations** — one body part is replaced by another:

- *Antennapedia* mutation in fly: legs grow where antennae should be.
- *Bithorax* mutation: a second pair of wings replaces the halteres.

Step 3 — Colinearity: The linear order of Hox genes on the chromosome matches their order of expression along the body axis (anterior genes at one end of the cluster, posterior genes at the other). This is among the most striking and conserved features of animal genome organisation.

Step 4 — Conservation across animals: Hox cluster organisation is essentially preserved from fly to mouse to human (four clusters in mammals: *HoxA, B, C, D*). Mouse Hox genes can substitute functionally for fly counterparts — demonstrating deep evolutionary conservation over > 500 million years.

Final Answer: Specify antero-posterior body axis $\Rightarrow$ B

Answer: (B) Go Back to Q22

Q23.

Solution

Concept — Sertoli cells (sustentacular cells): Identified by Italian histologist Enrico Sertoli (1865). Tall columnar cells lining the seminiferous tubules; their cytoplasm spans the entire thickness of the seminiferous epithelium from basement membrane to lumen.

Step 1 — Key functions:

- **Nurse cells:** provide nutrients (lactate, amino acids), growth factors, and physical support to developing spermatogenic cells from spermatogonia through to mature spermatids.
- **Blood-testis barrier:** adjacent Sertoli cells form tight junctions, creating an immunologically privileged microenvironment for meiotic and post-meiotic germ cells. This is essential because sperm cell-surface antigens (haploid) are recognised as foreign by the body's own immune system.
- **Secrete androgen-binding protein (ABP):** concentrates testosterone in the seminiferous tubules.
- **Secrete inhibin:** feedback inhibits FSH release from anterior pituitary.
- **Phagocytosis:** remove residual bodies (excess cytoplasm) shed by maturing sperm.

Step 2 — Hormonal control: Sertoli cells bear FSH receptors and respond to FSH from anterior pituitary. (Leydig cells respond to LH and produce testosterone.)

Step 3 — Differentiate from Leydig:

- Sertoli: *inside* tubules, nurse cells, respond to FSH.
- Leydig: *between* tubules (interstitial), make testosterone, respond to LH.

Final Answer: Nurse developing sperm; form blood-testis barrier; respond to FSH $\Rightarrow$ C

Answer: (C) Go Back to Q23

Q24.

Solution

Concept — Epididymis — where sperm grow up: A single highly convoluted tubule ($\sim 6\,\mathrm{m}$ long, packed into the posterior testis) where spermatozoa undergo functional maturation.

Step 1 — Three regions:

- Head (caput): receives sperm from rete testis via efferent ductules.
- Body (corpus): the middle long section.
- Tail (cauda): main storage site of mature sperm; transitions into the vas deferens.

Step 2 — What happens in the epididymis (~ 12 days transit):

- Sperm acquire forward motility (they were immotile when leaving the testis).
- Acquire ability to fertilise the egg (though final "capacitation" occurs in the female tract).
- Membrane remodelling and removal of cytoplasmic droplet.
- Concentration of sperm by reabsorption of fluid (luminal contents become viscous).

Step 3 — Pathology: Epididymitis (infection) is common; usually caused by retrograde ascent of urinary pathogens (*E. coli*, *N. gonorrhoeae*, *C. trachomatis*).

Final Answer: Epididymis $\Rightarrow$ $\boxed{\text{D}}$

Answer: (D) Go Back to Q24

Q25.

Solution

Concept — Leydig (interstitial) cells: Discovered by Franz Leydig (1850). Polygonal cells in the loose connective tissue between seminiferous tubules, in clusters around blood vessels.

Step 1 — Function: Synthesise and secrete **testosterone**, the major male androgen, from cholesterol precursor through the steroidogenic pathway (cholesterol $\rightarrow$ pregnenolone $\rightarrow$ progesterone $\rightarrow$ 17α-hydroxyprogesterone $\rightarrow$ androstenedione $\rightarrow$ testosterone).

Step 2 — Control: Stimulated by LH (luteinising hormone, also called Interstitial Cell-Stimulating Hormone or ICSH in males) from the anterior pituitary.

Step 3 — Testosterone actions:

- Foetal: differentiation of male internal and external genitalia.
- Puberty: secondary sexual characteristics (facial/body hair, deep voice, muscle mass, growth spurt).

- Adult: maintains spermatogenesis (alongside FSH and ABP), libido, anabolic effects on muscle and bone.

Step 4 — Negative feedback: Testosterone feeds back negatively on hypothalamus (reducing GnRH) and pituitary (reducing LH).

Final Answer: Testosterone $\Rightarrow$ $\boxed{\text{B}}$

Answer: (B) Go Back to Q25

Q26.

Solution

Concept — Condom — the only "dual-protection" contraceptive: A thin sheath (latex, polyurethane, or polyisoprene) covering the penis (male condom) or lining the vagina (female condom).

Step 1 — Mechanism: Barrier method: physically prevents semen (containing $\sim$ 200–400 million sperm) from entering the vagina and reaching the cervix.

Step 2 — Efficacy:

- Perfect use: $\sim 98\%$ effective.
- Typical use: $\sim 85\%$ (failures due to breakage, slippage, late application).

Step 3 — Dual protection: Unique among contraceptives in also providing significant protection against sexually transmitted infections (STIs):

- HIV (latex highly impermeable).
- Gonorrhoea, chlamydia, syphilis.
- Hepatitis B.
- Some protection against HPV and HSV.

This makes condoms a cornerstone of public health, especially in HIV/AIDS prevention.

Step 4 — No hormonal or systemic effects, no significant side effects (apart from rare latex allergy).

Final Answer: Barrier method $\Rightarrow$ $\boxed{\text{A}}$

Answer: (A) Go Back to Q26

Q27.

Solution

Concept — Tapetum — the nurse layer of the anther: The innermost of four wall layers of a typical anther locule (epidermis → endothecium → middle layer(s) → tapetum). The tapetum directly surrounds the pollen mother cells.

Step 1 — Critical functions:

- **Nourishment:** secretes nutrients, callase enzymes (which dissolve the callose wall around developing microspores), and the substrates for pollen exine wall formation.
- **Sporopollenin supply:** the tapetum synthesises and exports sporopollenin — an extraordinarily resistant biopolymer that builds the outer pollen wall (exine). This is why pollen and spores can survive for millions of years (fossil pollen of *Ginkgo* > 200 million years old).
- **Pollen-coat lipids and proteins:** deposited on the exine surface from tapetal cell debris, providing recognition signals at the stigma.

Step 2 — Tapetal types:

- Secretory (parietal) tapetum: cells remain in their original position and secrete materials.
- Amoeboid (periplasmodial) tapetum: cell walls break down; cytoplasm extends among the developing microspores.

Step 3 — Tapetal cells: Cytologically distinct — often polyploid (through endomitosis), bi- or multi-nucleate. They have very dense cytoplasm with abundant ER and ribosomes. After pollen maturation, the tapetum degenerates by programmed cell death.

Step 4 — Defective tapetum → male sterility: Pollen development fails. This phenomenon (cytoplasmic male sterility, CMS) is exploited commercially in hybrid seed production (maize, rice, sunflower).

Final Answer: Nourishes microspores and supplies sporopollenin $\Rightarrow$ D

Answer: (D) Go Back to Q27

Q28.

Solution

Concept — Sexual systems in flowering plants: Flowering plants exhibit remarkable diversity in the spatial distribution of male and female reproductive organs.

Step 1 — Terminology:

- **Bisexual (hermaphrodite/perfect) flower:** both stamens and pistils in the same flower (rose, lily, pea, tomato). The most common condition.
- **Unisexual flowers:** either staminate (male) or pistillate (female), not both.
- **Monoecious plant:** both unisexual flower types on the SAME individual (maize, cucumber, castor, coconut). Greek *mono* = one + *oikos* = house.
- **Dioecious plant:** the two unisexual flower types on SEPARATE individual plants (papaya, date palm, mulberry, willow, marijuana, kiwi fruit). Greek *di* = two + *oikos* = house.

Step 2 — Reproductive implications of dioecy:

- Enforces cross-pollination (no possibility of selfing) $\rightarrow$ promotes genetic diversity.
- Requires reliable pollen transfer between separate plants (wind or insect vectors).
- In agriculture: orchard managers must plant both male and female trees in proper ratios (e.g. for papaya, date palm) or use grafting.

Step 3 — Sex determination: In some dioecious plants (e.g. *Silene latifolia*, *Cannabis sativa*), there are heteromorphic sex chromosomes (XY system); in others (e.g. *Asparagus*), sex is determined by single genes.

Step 4 — Evolutionary significance: Dioecy has evolved independently many times from hermaphroditism, often via gynodioecy or monoecy intermediates.

Final Answer: Dioecious $\Rightarrow$ $\boxed{\text{C}}$

Answer: (C) Go Back to Q28

Q29.

Solution

Concept — Abscisic acid (ABA) — the plant "stress hormone": A sesquiterpenoid (15-carbon) hormone discovered in 1963. Despite its name (originally thought to cause abscission), its main role is in stress responses and dormancy.

Step 1 — Major physiological effects:

- **Seed dormancy and germination control:** accumulates in maturing seeds; prevents premature germination. ABA must be degraded or leached before germination can occur; some seeds break dormancy after gibberellin/ABA balance shifts.
- **Bud dormancy:** promotes dormancy of axillary and apical buds before winter.
- **Stomatal closure under drought:** ABA produced in water-stressed leaves (or arriving via xylem from roots) binds PYR/PYL/RCAR receptors in guard cells $\rightarrow$ activates SnRK2 kinases $\rightarrow$ activates anion (SLAC1) channels $\rightarrow$ K^+ efflux follows $\rightarrow$ guard cells lose turgor $\rightarrow$ stomata close $\rightarrow$ water conserved.
- Inhibits shoot growth (counteracts gibberellin and auxin).
- Promotes leaf senescence and abscission (especially of older, stressed leaves).

Step 2 — ABA and the "triple stress responses": ABA mediates plant responses to drought, salinity, and cold — the three most important abiotic stresses for crops. Engineering ABA pathways is a major focus of drought-resistant crop development.

Step 3 — Biosynthesis: Made from carotenoid precursors in plastids; key enzyme is NCED (nine-cis-epoxycarotenoid dioxygenase).

Final Answer: Promotes dormancy and stomatal closure under stress $\Rightarrow$ $\boxed{\text{A}}$

Answer: (A) Go Back to Q29

Q30.

Solution

Concept — Long-day plants (LDPs) and photoperiodism: Garner and Allard (1920) discovered that flowering in many plants is triggered by day length (photoperiod), not by total light or warmth.

Step 1 — Three photoperiodic classes:

- **Long-day plants (LDPs):** flower when day length EXCEEDS a critical value (or, more precisely, when night is shorter than a critical length). Examples: spinach, lettuce, radish, wheat (spring), barley, *Hyoscyamus niger*, *Hibiscus*.
- **Short-day plants (SDPs):** flower when day length is LESS than a critical value (night longer than critical length). Examples: *Chrysanthemum*, rice, soybean, cotton, *Xanthium*, tobacco.
- **Day-neutral plants (DNPs):** flowering independent of photoperiod (controlled by age, growth, or other cues). Examples: tomato, cucumber, sunflower, pea, maize.

Step 2 — Night length matters, not day length: Experiments showed that what is actually measured is the DARK period. A brief flash of red light during the long dark period:

- INHIBITS flowering in SDPs (treats them as if days were long).
- PROMOTES flowering in LDPs (treats them as if nights were short).

A subsequent far-red flash reverses the effect — implicating phytochrome.

Step 3 — Leaves are the sensors: Even a single inductive photoperiodic cycle, applied to just one leaf, can induce flowering of the whole plant. The shoot apical meristem becomes the responder. The mobile flowering signal ("florigen") was molecularly identified as the FT (FLOWERING LOCUS T) protein.

Step 4 — Adaptive value: Allows plants to time flowering with seasons (predictable astronomical signal), ensuring favourable conditions for fertilisation, fruit set and seed dispersal.

Final Answer: Flower when day length exceeds (or night is shorter than) a critical value $\Rightarrow$ $\boxed{\text{B}}$

Answer: (B) Go Back to Q30

Q31.

Solution

Concept — The lambda (λ) bacteriophage life cycle: A classic temperate phage of *E. coli*. Pioneered by André Lwoff and François Jacob (Nobel 1965). Decision between lytic and lysogenic cycles is one of the cleanest examples of a developmental switch.

Step 1 — Lytic cycle (briefly): Phage DNA enters $\rightarrow$ takes over host machinery $\rightarrow$ many phage copies produced $\rightarrow$ host cell lyses $\rightarrow$ phages released. Done in $\sim$ 20–40 min.

Step 2 — Lysogenic cycle:

(a) Phage DNA enters host cell.
(b) Phage integrase catalyses site-specific recombination, integrating the phage genome at the *attB* site of the bacterial chromosome (between the *gal* and *bio* operons in λ case). The integrated phage DNA is now called a **prophage**.
(c) The prophage replicates passively with the host chromosome at every cell division and is transmitted to all daughter cells.
(d) Most phage genes are silenced by the phage repressor (CI in λ); only a few are expressed.
(e) The bacterium is now a **lysogen** — carries the prophage but is not killed.

Step 3 — Induction: Environmental stress (UV radiation, DNA damage) activates the SOS response in *E. coli*; RecA cleaves the CI repressor; the prophage excises and enters the lytic cycle.

Step 4 — Importance of lysogeny:

- Source of horizontal gene transfer (carrying bacterial genes between hosts: "specialised transduction").
- Some bacterial toxins (cholera toxin, diphtheria toxin, Shiga toxin) are encoded on prophages.
- Useful tools for molecular biology (cloning vectors, site-specific recombination systems like Cre/loxP).

Final Answer: Integrates as prophage into bacterial chromosome $\Rightarrow$ $\boxed{\text{D}}$

Answer: (D) Go Back to Q31

Q32.

Solution

Concept — Bryophytes — "the amphibians of the plant kingdom": The most primitive of land plants. Comprise mosses (Bryophyta sensu stricto), liverworts (Marchantiophyta) and hornworts (Anthocerotophyta).

Step 1 — Diagnostic features:

- No true vascular tissue — no xylem or phloem; water and nutrients move by diffusion and capillary action through thin-walled cells.
- No true roots — rhizoids (filamentous, sometimes multicellular) anchor and absorb water.
- No flowers, no seeds.
- Reproduction by spores; flagellated sperm need a film of water to swim to the archegonium (female organ) where the egg is fertilised.
- Confined to moist habitats (banks of streams, damp forest floor, north-facing rocks). Some are desiccation-tolerant.

Step 2 — Dominant gametophyte generation: This is the unique feature: in bryophytes, the green, photosynthetic "moss plant" you see is the haploid gametophyte (n). It produces gametes by mitosis in archegonia (eggs) and antheridia (sperm). Compare with all other land plants, where the diploid sporophyte dominates.

Step 3 — Sporophyte stage: After fertilisation, the diploid zygote develops on top of the gametophyte into a small, slender stalked structure (the sporophyte: foot + seta + capsule), permanently attached to and nutritionally dependent on the gametophyte. The capsule produces haploid spores by meiosis. Spores germinate to give new gametophytes.

Step 4 — Economic and ecological importance:

- *Sphagnum* (peat moss): waterlogged habitats; forms peat over thousands of years (a major carbon sink and fossil fuel precursor).
- Pioneers in primary succession (bare rock $\rightarrow$ soil formation through hyphae and root acids).
- Indicators of air quality (sensitive to SO_2 pollution).

Final Answer: Lack vascular tissue; gametophyte dominant; water-dependent sperm $\Rightarrow$ C

Answer: (C) Go Back to Q32

Q33.

Solution

Concept — Gymnosperms — the naked-seed plants: First seed-bearing plants ($\sim$ 360 Mya, late Devonian). Dominated the Mesozoic "Age of Reptiles" before being largely displaced by angiosperms in the Cretaceous.

Step 1 — The defining feature: naked seeds. Ovules are borne directly on the surface of megasporophylls (scales of female cones, modified leaves). After fertilisation, the seeds develop in the open — not enclosed within a fruit. In angiosperms, by contrast, ovules are enclosed in the ovary, which ripens into the fruit.

Step 2 — Other characteristics:

- Mostly woody, often large trees.
- Vascular tissue with xylem composed of tracheids (no vessels, except in Gnetales).
- Phloem with sieve cells (no companion cells, no sieve tube elements).
- Pollination is wind-mediated (anemophilous); pollen reaches ovules via a pollination droplet at the micropyle.
- Sperm cells are non-motile (with one exception — Cycadales and Ginkgoales retain ciliated swimming sperm).
- Single fertilisation (NOT double fertilisation as in angiosperms); endosperm is haploid and is actually the female gametophyte tissue, formed BEFORE fertilisation.

Step 3 — Four living groups:

- Cycadales (*Cycas*, *Zamia*): palm-like; "living fossils".
- Ginkgoales: single living species *Ginkgo biloba*.
- Coniferales (largest order): *Pinus*, *Cedrus*, *Pseudotsuga*, *Sequoia*, *Picea*.
- Gnetales: *Ephedra*, *Welwitschia*, *Gnetum* (anatomically most "angiosperm-like").

Step 4 — Notable gymnosperms:

- Coast redwood (*Sequoia sempervirens*): tallest tree on Earth ($\sim 116\,\mathrm{m}$).
- Giant sequoia (*Sequoiadendron giganteum*): most massive single living thing.
- Bristlecone pine: longest-lived non-clonal organism ($> 4{,}800$ years).

Final Answer: Naked seeds (ovules borne on cone scales, not enclosed in fruit) $\Rightarrow$ C

Answer: (C) Go Back to Q33

Q34.

Solution

Concept — Typhoid fever: A serious systemic infection still causing ~ 11 million cases and $128{,}000$ deaths globally each year, mostly in South Asia and sub-Saharan Africa.

Step 1 — Pathogen: ***Salmonella enterica*** serovar *Typhi* (commonly *S. typhi*). A gram-negative, motile, flagellated, non-sporing, non-encapsulated bacillus in family Enterobacteriaceae. Strictly human host.

Step 2 — Transmission: Faecal-oral route via contaminated food or water. Asymptomatic chronic carriers (gallbladder colonisation — "Typhoid Mary" was the most famous case) shed bacteria for years.

Step 3 — Pathogenesis and clinical features:

- Ingested bacteria invade Peyer's patches in the ileum, then disseminate to mesenteric lymph nodes and blood (primary bacteraemia).
- Survive inside macrophages.
- Re-disseminate (secondary bacteraemia) $\rightarrow$ clinical disease.
- Symptoms (week 1): stepladder fever rising to $40\,^{\circ}\mathrm{C}$, relative bradycardia, headache, abdominal pain, hepatosplenomegaly.
- Classic "rose spots" (pink macules) on trunk.
- Complications (week 3): intestinal perforation (Peyer's patch ulcers), GI bleeding, encephalopathy.

Step 4 — Diagnosis and treatment:

- Blood culture (gold standard, week 1); stool culture (later); Widal test (O and H agglutinins, less reliable).
- Treatment: fluoroquinolones (ciprofloxacin) historically; due to resistance, now azithromycin or ceftriaxone are first-line in many regions.
- Prevention: typhoid conjugate vaccine (TCV) recommended by WHO; safe drinking water, sanitation, hand hygiene.

Final Answer: *Salmonella typhi* $\Rightarrow$ $\boxed{\text{B}}$

Answer: (B) Go Back to Q34

Q35.

Solution

Concept — Active vs passive, natural vs artificial immunity: A 2×2 classification of acquired (adaptive) immunity.

Step 1 — Four categories:

	Natural	Artificial
Active	Recovery from infection	Vaccination
Passive	Maternal antibodies	Antibody injection (ATS)

Step 2 — Active vs passive:

- **Active:** the recipient's own immune system mounts a response; produces antibodies and memory cells; slow onset (days to weeks) but long-lasting protection.
- **Passive:** pre-formed antibodies introduced from outside; immediate protection but short-lived ($\sim$ 2–3 weeks); no memory cells generated.

Step 3 — ATS (anti-tetanus serum): Hyperimmune antisera — antibodies raised in another organism (historically horses, increasingly humanised) against the tetanus toxin (tetanospasmin). Given as emergency post-exposure prophylaxis in unimmunised individuals with tetanus-prone wounds. Used along with the tetanus toxoid vaccine: passive immunity buys time while active immunity develops.

Step 4 — Other examples of passive artificial immunity:

- Anti-snake venom (polyvalent against multiple species).
- Anti-rabies immunoglobulin (HRIG).
- Anti-hepatitis B immunoglobulin (HBIG).
- Botulinum antitoxin.
- Convalescent plasma (was used early in COVID-19).

Final Answer: Passive artificial immunity $\Rightarrow$ $\boxed{\text{D}}$

Answer: (D) Go Back to Q35

Q36.

Solution

Concept — Sulfonamides — the first effective antibacterial chemotherapy: Discovered by Gerhard Domagk (1932, Nobel 1939) when he found that prontosil (a red dye) cured bacterial infections in mice. The active metabolite of prontosil is sulfanilamide.

Step 1 — Mechanism — competitive inhibition of folate synthesis: Sulfonamides are structural analogues of p**-aminobenzoic acid (PABA)**, a precursor required by bacteria to synthesise folic acid (folate).

- Bacterial dihydropteroate synthase normally combines PABA with pteridine to form dihydropteroate (early step of folate synthesis).
- Sulfonamides compete with PABA for binding to this enzyme, blocking folate synthesis.
- Without folate, bacteria cannot make thymidylate (and hence DNA), purines, methionine, glycine, serine $\rightarrow$ bacteriostatic effect.

Step 2 — Selective toxicity:

- Bacteria **must** synthesise their own folate (no folate transporters; they cannot take it up from the environment).
- Mammals obtain folate from the diet $\rightarrow$ unaffected by sulfonamide action.

This is a textbook example of how exploiting biochemical differences between host and pathogen gives selective antimicrobial action.

Step 3 — Clinical applications:

- Urinary tract infections (sulfamethoxazole, often combined with trimethoprim — co-trimoxazole, which blocks the next step, dihydrofolate reductase).
- Pneumocystis jirovecii pneumonia in immunocompromised patients.
- Toxoplasmosis (with pyrimethamine).
- Topical: sulfacetamide for eye infections; silver sulfadiazine for burn wounds.

Step 4 — Resistance and side effects: Widespread resistance (altered enzyme target; folate uptake; overproduction of PABA). Side effects: rash (including rare but severe Stevens-Johnson syndrome), haemolysis in G6PD-deficient patients.

Final Answer: Competitive inhibition of folate synthesis (PABA analog) $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q36

Q37.

Solution

Concept — Global carbon cycle and major reservoirs: The flow of carbon among atmosphere, biosphere, hydrosphere, lithosphere.

Step 1 — Major carbon reservoirs (in gigatonnes C):

- Sedimentary rocks (carbonate rocks, fossil fuels): $> 100{,}000{,}000$ GtC — the largest reservoir, but exchanges with the active cycle on geological timescales.
- **Oceans (dissolved inorganic carbon: CO_2, HCO_3^-, CO_3^{2-}):** $\sim 38{,}000$ **GtC** — by far the largest *actively exchanging* reservoir.
- Soils (organic matter): $\sim 2{,}500$ GtC.
- Atmosphere: ~ 870 GtC (rising rapidly).
- Terrestrial biomass (forests, grasslands): ~ 550 GtC.
- Surface ocean biota: small.

Step 2 — Why oceans hold so much carbon:

- CO_2 is highly soluble in cold seawater.
- Most dissolved CO_2 converts to bicarbonate and carbonate ions, allowing much more to be stored than gaseous solubility would suggest.
- Marine organisms incorporate carbon into calcium carbonate shells, which eventually settle as sediments.

Step 3 — Ocean acidification: As atmospheric CO_2 rises (from ~ 280 ppm pre-industrial to ~ 420 ppm in 2024), oceans absorb $\sim 30\%$ of anthropogenic CO_2. This shifts equilibrium $\Rightarrow$ more H^+, lower pH (already dropped ~ 0.1 unit $= 30\%$ more acidic). This dissolves carbonate shells and threatens marine calcifying organisms.

Step 4 — Carbon cycle disruption: Fossil fuel combustion releases ~ 10 GtC/year. Deforestation contributes $\sim$ 1–2 GtC. Roughly 50% stays in atmosphere, 25% taken up by oceans, 25% by land sinks.

Final Answer: The oceans $\Rightarrow$ $\boxed{\text{B}}$

Answer: (B) Go Back to Q37

Q38.

Solution

Concept — Population age pyramids (age-structure diagrams): A graphical tool plotting the proportion (or number) of individuals in each age class (typically 5-year cohorts), with males on one side, females on the other.

Step 1 — Three classic shapes:

- **Pyramid (triangular, broad base):** expanding population. High birth rate, high mortality, many young; typical of developing nations (India, Nigeria, Pakistan).
- **Bell or dome (vertical sides, slightly tapering top):** stable, stationary population. Birth rate $\approx$ death rate; zero net growth. Typical of slow-growing developed countries.
- **Urn or inverted pyramid (narrow base):** declining population. Low birth rate, ageing population; typical of countries like Japan, Italy, Germany.

Step 2 — The diagram in the question: A pyramid with broad base and rapid taper $\Rightarrow$ **expanding population**. Each younger cohort is larger than the one above, implying high birth rate exceeds mortality.

Step 3 — Demographic transition: Populations typically progress through:

- Stage 1: high birth, high death rate; small total population.
- Stage 2: high birth, falling death rate (better health care, sanitation); explosive growth.
- Stage 3: falling birth rate, low death rate; growth slows.
- Stage 4: low birth, low death rate; stable.
- Stage 5 (debated): birth rate falls below death rate; decline.

Step 4 — Implications:

- Expanding populations face high demand for education, jobs, food.
- Declining populations face old-age dependency burden, shrinking workforce.

Final Answer: Expanding (growing) population $\Rightarrow$ $\boxed{\text{C}}$

Answer: (C) Go Back to Q38

Q39.

Solution

Concept — pBR322 — a workhorse cloning vector: Constructed by Francisco Bolivar and Raymond Rodriguez (1977). One of the first general-purpose plasmid cloning vectors; widely used pedagogically.

Step 1 — Essential features of a cloning vector:

(a) **Origin of replication (*ori*):** allows autonomous replication independent of host chromosome. pBR322 uses the pMB1/ColE1-derived origin → 15–20 copies per cell.

(b) **Selectable markers:** pBR322 has **TWO** antibiotic-resistance genes:

- amp^R (bla): encodes β-lactamase, conferring ampicillin resistance.
- tet^R: confers tetracycline resistance.

(c) **Unique restriction sites for cloning:**

- Some sites are within the amp^R gene (e.g. *PstI*, *ScaI*).
- Some are within the tet^R gene (e.g. *BamHI*, *HindIII*, *SalI*).
- Some are outside both (e.g. *EcoRI*).

(d) **Small size (4,361 bp):** easy to manipulate and transform.

Step 2 — Insertional inactivation: The brilliance of the two-marker design: insert foreign DNA at a restriction site *inside* the tet^R gene → that gene is disrupted → recombinant plasmids confer ampicillin resistance but NOT tetracycline resistance. Selection scheme:

- Plate transformants on ampicillin → only cells with the plasmid grow.
- Replica-plate to tetracycline → cells that fail to grow contain the recombinant (insert) plasmid; cells that DO grow contain the empty, religated plasmid.

Step 3 — Modern vectors: pUC19 and derivatives replaced pBR322 for routine cloning (blue-white screening via *lacZ*α disruption is more convenient than replica plating). Specialised vectors include cosmids, BACs, YACs for large inserts; expression vectors with strong promoters.

Final Answer: *ori* + selectable markers + unique restriction sites ⇒ $\boxed{\text{A}}$

Answer: (A) Go Back to Q39

Q40.

Solution

Concept — Agarose gel electrophoresis of DNA: The standard laboratory technique to separate and visualise DNA fragments by size. Underlies cloning, restriction mapping, PCR analysis, DNA fingerprinting.

Step 1 — Principle:

- DNA carries a **uniform negative charge** per unit length (one negative charge per phosphate group of the backbone).
- In an electric field, DNA migrates from cathode ($-$) to anode ($+$).
- Agarose forms a porous gel matrix; the pore size depends on agarose concentration (typically 0.5–2%).
- Smaller fragments thread through the pores more easily, so they move faster and farther.
- Larger fragments encounter more resistance and migrate more slowly.
- Result: a size-ordered ladder of bands.

Step 2 — Procedure:

(a) Pour molten agarose into a casting tray with a comb $\rightarrow$ gel sets with wells.
(b) Submerge gel in running buffer (TAE or TBE).
(c) Load DNA samples mixed with loading dye (glycerol for density, dye for tracking).
(d) Apply voltage (~ 100 V).
(e) DNA bands separate over 30 min to a few hours.
(f) Stain with ethidium bromide (intercalates between bases, fluoresces orange under UV) or safer alternatives (SYBR Safe).
(g) Visualise on a UV transilluminator; photograph.

Step 3 — Size estimation: A DNA ladder (mixture of fragments of known sizes) is run alongside samples. Migration distance is inversely proportional to the log of fragment size (within the resolving range of the gel).

Step 4 — Variations:

- Polyacrylamide gel electrophoresis (PAGE): higher resolution; for small DNA (< 1 kb) or proteins (SDS-PAGE for size; native PAGE for size + charge + conformation).
- Pulsed-field gel electrophoresis (PFGE): for very large DNA (> 50 kb to chromosomal size); periodic reorientation of the field.

- Capillary electrophoresis: high-throughput, used in DNA sequencing and STR profiling.

Step 5 — Applications: Checking PCR amplification, restriction digestion patterns, plasmid integrity, DNA extraction quality, Southern blot preparation, recovering specific DNA fragments by gel purification.

Final Answer: Size of DNA fragments $\Rightarrow$ $\boxed{\text{D}}$

Answer: (D) Go Back to Q40

Answer Key

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