GAT B Biology

Sample Paper – 5

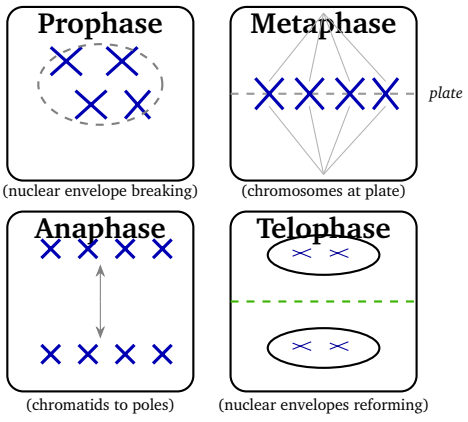
Duration: 23 Minutes **Maximum Marks: 15**

Instructions

- This paper contains **15** Multiple Choice Questions (Single Correct Answer), modelled on the Biology portion of **GAT B** entrance (Section A).
- Each correct answer carries **+1 mark**. There is **a deduction of 0.5 marks for each incorrect answer**.
- Only **one** option is correct. Choose carefully.
- Syllabus level: **NCERT Class 11 & 12 Biology — Cell Biology, Genetics, Plant & Human Physiology, Ecology, Evolution, and Biotechnology.**
- Use of mobile phones, calculators, or electronic gadgets is strictly prohibited.

Section A — Biology (15 Questions)

Q1. The diagram below shows the four stages of mitosis in a eukaryotic cell. During which stage do chromosomes align along the equatorial plate (metaphase plate) of the cell?



(A) Prophase

(B) Metaphase

(C) Anaphase

(D) Telophase

Q2. Two plants, both heterozygous for seed colour (Yy) and seed shape (Rr), are crossed with each other (YyRr $\times$ YyRr). Assuming the two genes assort independently and yellow (Y) and round (R) are dominant, what is the expected phenotypic ratio in the offspring?

(A) 9 : 3 : 3 : 1

(B) 1 : 2 : 1

(C) 3 : 1

(D) 1 : 1 : 1 : 1

Q3. Which enzyme, secreted by the exocrine pancreas and released into the duodenum, digests dietary proteins by cleaving internal peptide bonds in the small intestine?

(A) Salivary amylase

(B) Pancreatic lipase

(C) Pepsin

(D) Trypsin

Q4. In the Calvin cycle (dark reactions) of photosynthesis, carbon dioxide (CO_2) from the atmosphere is fixed into an organic compound. Which enzyme catalyses this crucial carbon-fixation step?

(A) Phosphofructokinase (PFK)

(B) Pyruvate carboxylase

(C) RuBisCO (Ribulose-1,5-bisphosphate carboxylase/oxygenase)

(D) Phosphoenolpyruvate (PEP) carboxylase

Q5. Pteridophytes (ferns and their allies) represent a more advanced level of plant evolution than bryophytes (mosses and liverworts). Which feature is present in pteridophytes but *absent* in bryophytes?

(A) Chlorophyll for photosynthesis

(B) A well-developed vascular system (xylem and phloem)

(C) Alternation of generations in the life cycle

(D) Reproduction by spores

Q6. Glycolysis converts one molecule of glucose (6C) into two molecules of pyruvate (3C each). Considering the ATP investment phase and the ATP payoff phase, what is the *net* gain of ATP molecules per glucose molecule in glycolysis alone?

(A) 2 ATP

(B) 4 ATP

(C) 8 ATP

(D) 36–38 ATP

Q7. The *lac* operon in *Escherichia coli* encodes enzymes for lactose metabolism and is under negative control by the lac repressor protein. Which molecule acts as the *inducer* that causes the repressor to dissociate from the operator, allowing transcription to proceed?

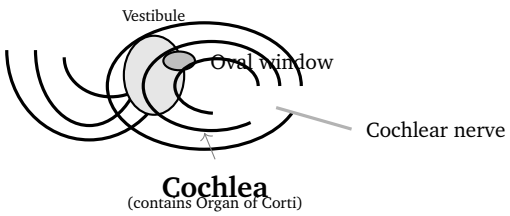
(A) Glucose

(B) Cyclic AMP (cAMP)

(C) Allolactose (a metabolite of lactose)

(D) RNA polymerase sigma factor

Q8. The diagram below shows a simplified schematic of the human inner ear. Which structure is responsible for converting sound vibrations (mechanical energy) into electrical nerve impulses that are transmitted to the brain via the cochlear nerve?



(A) Tympanic membrane (eardrum)

(B) Malleus, incus, and stapes (ossicles)

(C) Semicircular canals

(D) Organ of Corti (within the cochlea)

Q9. The nitrogen cycle involves several key processes that transform nitrogen between its various forms. Which process directly converts atmospheric dinitrogen gas (N_2) into ammonia (NH_3), thereby making nitrogen available to living organisms?

(A) Nitrification

(B) Nitrogen fixation

(C) Denitrification

(D) Ammonification

Q10. During human oogenesis, the secondary oocyte is released from the ovary at ovulation. At which stage of meiosis is the secondary oocyte arrested at the time of ovulation, remaining in this stage until fertilization occurs?

(A) Metaphase II

(B) Prophase I

(C) Anaphase I

(D) Telophase II

Q11. Allopatric speciation is one of the most common modes by which new species arise. Which of the following correctly describes the mechanism of allopatric speciation?

(A) A single population inhabiting the same geographic area diverges into two species due to differences in food preferences

(B) A whole-genome duplication (polyploidy) within a single population produces reproductively isolated individuals

(C) A population is physically separated by a geographic barrier; the isolated sub-populations diverge independently and eventually become reproductively isolated

(D) Hybridisation between two species produces sterile offspring that later develop fertility through chromosome doubling

Q12. The Polymerase Chain Reaction (PCR) amplifies specific DNA sequences through repeated cycles of denaturation (up to 95°C), primer annealing, and extension. Which enzyme is routinely used in PCR because of its exceptional heat stability?

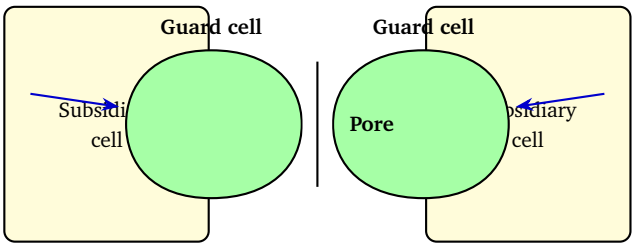
(A) DNA ligase

(B) Reverse transcriptase

(C) EcoRI restriction endonuclease

(D) Taq polymerase (isolated from *Thermus aquaticus*)

Q13. The diagram below shows a cross-sectional (en face) view of a stoma flanked by guard cells and subsidiary cells. What is the primary mechanism that causes the stomatal pore to open during the day?



(A) An influx of K^+ ions into guard cells lowers their water potential, causing osmotic water uptake and increased turgor pressure

(B) An efflux of K^+ ions from guard cells into subsidiary cells, which increases guard cell turgor

(C) Rising CO_2 concentration inside guard cells directly activates the proton-pump (H^+-ATPase) to drive stomatal opening

(D) Breakdown of starch into glucose in guard cell chloroplasts, which directly drives turgor increase by reducing osmotic potential

Q14. According to the sliding filament theory of muscle contraction, which protein functions as the molecular motor, using energy from ATP hydrolysis to generate the force that slides actin filaments toward the centre of the sarcomere?

(A) Actin

(B) Myosin

(C) Troponin

(D) Tropomyosin

Q15. Members of phylum Cnidaria (jellyfish, sea anemones, corals, *Hydra*) possess a unique, phylum-defining cell type not found in any other animal phylum. Which structure is exclusive to Cnidaria and is used for prey capture and defence through the injection of toxins?

(A) Parapodia

(B) Radula

(C) Nematocysts (cnidocytes)

(D) Setae (chaetae)

Solutions

Sol.1.

Solution

Concept — Stages of Mitosis: Mitosis is divided into four sequential stages: Prophase, Metaphase, Anaphase, and Telophase (PMAT). Each stage is defined by characteristic behaviour of the chromosomes and the mitotic spindle.

Step 1 — Identifying each stage:

- **Prophase**: Chromatin condenses into visible chromosomes; the nuclear envelope breaks down; spindle fibres begin to form from the centrosomes.
- **Metaphase**: The nuclear envelope is fully absent; the mitotic spindle is fully formed; spindle fibres (kinetochore microtubules) attach to the kinetochores of each sister chromatid and pull chromosomes to the cell's middle. Chromosomes align along the *metaphase plate* (equatorial plate) — the plane equidistant from both poles. This is the stage depicted in the top-right cell of the diagram.
- **Anaphase**: Sister chromatids are separated and pulled to opposite poles by shortening kinetochore microtubules.
- **Telophase**: Chromosomes arrive at the poles, decondense; the nuclear envelope reforms around each set; cytokinesis begins.

Why other options are wrong:

- Option A: In Prophase, chromosomes condense but align at the cell equator has not yet occurred.
- Option C: In Anaphase, chromosomes are actively moving *away* from the equatorial plate toward the poles; alignment has already ended.
- Option D: In Telophase, chromosomes have already reached the poles and are decondensing; the nuclear envelope is reforming, not aligning chromosomes.

Final Answer: Chromosomes align at the metaphase plate during Metaphase $\Rightarrow$ B

Answer: (B) Go Back to Q 1

Sol.2.

Solution

Concept — Dihybrid Cross and Mendel's Law of Independent Assortment: When two traits are governed by genes on different chromosomes (or far apart on the same chromosome), they assort independently during meiosis. A cross between two double-heterozygotes (AaBb $\times$ AaBb) produces a predictable phenotypic ratio.

Step 1 — Applying the product rule: Each gene pair behaves independently. For Yy $\times$ Yy: $\frac{3}{4}$ yellow (dominant) : $\frac{1}{4}$ green (recessive). For Rr $\times$ Rr: $\frac{3}{4}$ round (dominant) : $\frac{1}{4}$ wrinkled (recessive).

Step 2 — Combined phenotypic classes:

- Y_R_ (Yellow Round): $\frac{3}{4} \times \frac{3}{4} = \frac{9}{16}$
- Y_rr (Yellow Wrinkled): $\frac{3}{4} \times \frac{1}{4} = \frac{3}{16}$
- yyR_ (Green Round): $\frac{1}{4} \times \frac{3}{4} = \frac{3}{16}$
- yyrr (Green Wrinkled): $\frac{1}{4} \times \frac{1}{4} = \frac{1}{16}$

The ratio is $\mathbf{9 : 3 : 3 : 1}$.

Why other options are wrong:

- Option B (1:2:1): This is the *genotypic* ratio for a monohybrid cross (Aa $\times$ Aa), not the dihybrid phenotypic ratio.
- Option C (3:1): This is the *phenotypic* ratio for a monohybrid cross; for two independently assorting genes it does not apply.
- Option D (1:1:1:1): This is the ratio from a test cross (AaBb $\times$ aabb), where one parent is homozygous recessive for both traits.

Final Answer: The dihybrid F_2 phenotypic ratio is 9:3:3:1 $\Rightarrow$ $\boxed{\text{A}}$

Answer: (A) Go Back to Q 2

Sol.3.

Solution

Concept — Pancreatic Enzymes and Protein Digestion: Protein digestion occurs in two main sites: the stomach (by pepsin) and the small intestine (primarily by pancreatic proteases). The exocrine pancreas secretes proteolytic enzymes as inactive zymogens into the duodenum, where they are activated.

Step 1 — Trypsin as a pancreatic protease: The pancreas secretes **trypsinogen** (the inactive zymogen) into the duodenum via the pancreatic duct. Enteropeptidase (enterokinase) on the duodenal brush border cleaves trypsinogen to produce active **trypsin**. Trypsin is an endopeptidase (serine protease) that cleaves peptide bonds on the C-terminal side of the basic amino acids lysine and arginine. It functions optimally at the alkaline pH of the small intestine ($\sim$pH 7–8) and is the principal protease responsible for protein digestion in this compartment.

Why other options are wrong:

- Option A (Salivary amylase): Produced by the salivary glands; it digests *starch* (not proteins) in the mouth; its activity ceases in the acidic stomach.
- Option B (Pancreatic lipase): Also secreted by the pancreas, but it digests *dietary fats* (triglycerides) into fatty acids and monoglycerides, not proteins.
- Option C (Pepsin): A protease secreted as pepsinogen by chief cells of the *stomach*; it is active at acidic pH ($\sim$2) and is irreversibly denatured in the alkaline duodenum; it is NOT a pancreatic enzyme.

Final Answer: Trypsin (pancreatic protease) digests proteins in the small intestine $\Rightarrow$ $\boxed{\text{D}}$

Answer: (D) Go Back to Q 3

Sol.4.

Solution

Concept — Carbon Fixation in the Calvin Cycle: The Calvin cycle (also called the C_3 pathway or the Benson–Calvin cycle) takes place in the stroma of chloroplasts and uses ATP and NADPH from the light reactions to convert CO_2 into glyceraldehyde-3-phosphate (G3P), a precursor for glucose and other organic molecules.

Step 1 — Role of RuBisCO: RuBisCO (Ribulose-1,5-bisphosphate carboxylase/oxygenase, EC 4.1.1.39) is the enzyme that catalyses the carboxylation step: CO_2 + Ribulose-1,5-bisphosphate (RuBP, a 5C compound) $\rightarrow$ two molecules of 3-phosphoglycerate (3-PGA, a 3C compound). RuBisCO is the most abundant enzyme on Earth and is the primary gateway through which inorganic carbon enters the biosphere. It is present in the stroma in very high concentrations because it is enzymatically slow ($\sim$3–10 CO_2 fixed per second).

Why other options are wrong:

- Option A (Phosphofructokinase): A key regulatory enzyme of *glycoly-*

sis (cytoplasm); it phosphorylates fructose-6-phosphate to fructose-1,6-bisphosphate; it has no role in the Calvin cycle.
- Option B (Pyruvate carboxylase): Found in the mitochondrial matrix; it carboxylates pyruvate to oxaloacetate as the first step of *gluconeogenesis* and to replenish TCA cycle intermediates; not part of the Calvin cycle.
- Option D (PEP carboxylase): This enzyme fixes CO_2 in *C_4 plants and CAM plants* (not in the Calvin cycle itself); it carboxylates phosphoenolpyruvate (PEP) to oxaloacetate in mesophyll cells as the initial CO_2 capture step, after which CO_2 is transferred to bundle sheath cells where RuBisCO completes fixation.

Final Answer: RuBisCO is the enzyme that fixes CO_2 in the Calvin cycle $\Rightarrow$ C

Answer: (C) Go Back to Q 4

Sol.5.

Solution

Concept — Evolutionary Advancement from Bryophytes to Pteridophytes: Bryophytes (Division Bryophyta: mosses, liverworts, hornworts) and pteridophytes (Division Pteridophyta: ferns, horsetails, club mosses) both belong to the kingdom Plantae and share several features (e.g., chlorophyll, spore reproduction, alternation of generations). However, pteridophytes represent a major evolutionary advancement over bryophytes.

Step 1 — Vascular tissue as the defining distinction: The key innovation in pteridophytes is the presence of a **well-developed vascular system**, comprising xylem (for water and mineral transport) and phloem (for organic nutrient transport). This vascular tissue is completely absent in bryophytes, which lack true roots, stems, and leaves (they have rhizoids, stems, and leaf-like structures without vascular bundles). The vascular system in pteridophytes enables efficient long-distance transport of water and nutrients, allowing these plants to attain greater size and colonise drier terrestrial habitats. The sporophyte is the dominant, independent generation in pteridophytes (unlike bryophytes where the gametophyte is dominant).

Why other options are wrong:

- Option A (Chlorophyll): Both bryophytes and pteridophytes are photosynthetic and possess chlorophyll; this is not a distinguishing feature.
- Option C (Alternation of generations): Both groups exhibit alternation of generations between a sporophyte (diploid) and gametophyte (haploid)

phase; this is a shared ancestral character of all land plants.
- Option D (Reproduction by spores): Both bryophytes and pteridophytes reproduce by spores produced by the sporophyte generation; this is not unique to pteridophytes.

Final Answer: Presence of a well-developed vascular system distinguishes pteridophytes from bryophytes $\Rightarrow$ $\boxed{\text{B}}$

Answer: (B) Go Back to Q 5

Sol.6.

Solution

Concept — ATP Yield from Glycolysis: Glycolysis is the ten-step metabolic pathway occurring in the cytoplasm that converts one glucose molecule (6C) into two pyruvate molecules (3C each). It consists of an energy investment phase (steps 1–5) and an energy payoff phase (steps 6–10).

Step 1 — Counting ATP:

- **Investment phase** (steps 1 and 3): 2 ATP are consumed to phosphorylate glucose to fructose-1,6-bisphosphate.
- **Payoff phase** (steps 7 and 10): 4 ATP are produced by substrate-level phosphorylation (2 ATP per pyruvate $\times$ 2 pyruvate).
- **Net ATP** $= 4 - 2 =$ **2** ATP per glucose.

Additionally, 2 NADH are produced in the payoff phase (step 6), but NADH is not ATP.

Why other options are wrong:

- Option B (4 ATP): This is the *gross* ATP produced in the payoff phase, before subtracting the 2 ATP invested; the *net* yield is only 2 ATP.
- Option C (8 ATP): This figure does not correspond to any real count in glycolysis; it may arise from incorrectly doubling the net yield or confusing it with another pathway.
- Option D (36–38 ATP): This is the total ATP yield from complete *aerobic respiration* of one glucose (glycolysis + pyruvate oxidation + Krebs cycle + oxidative phosphorylation); it is not from glycolysis alone.

Final Answer: Net ATP gain from glycolysis per glucose is 2 ATP $\Rightarrow$ $\boxed{\text{A}}$

Answer: (A) Go Back to Q 6

Sol.7.

Solution

Concept — *lac* Operon Induction in *E. coli*: The *lac* operon (Jacob–Monod model, 1961) is a paradigm of gene regulation in prokaryotes. It encodes three structural genes (*lacZ*: β-galactosidase; *lacY*: permease; *lacA*: transacetylase) needed for lactose catabolism, and is regulated by negative (repressor) and positive (CAP-cAMP) controls.

Step 1 — Mechanism of induction: In the absence of lactose, the lac repressor protein (encoded by *lacI*) binds tightly to the *lac* operator, blocking RNA polymerase and preventing transcription. When lactose is present, a small amount is converted by residual β-galactosidase into **allolactose** (an isomeric product with a β-1,6-glycosidic linkage, unlike lactose's β-1,4 linkage). Allolactose is the true **inducer**: it binds to the allosteric site of the lac repressor, causing a conformational change that releases the repressor from the operator. RNA polymerase can then transcribe the structural genes.

Why other options are wrong:

- Option A (Glucose): Glucose has the *opposite* effect — when glucose is present, cAMP levels fall (because adenylate cyclase is inhibited), so the CAP protein cannot bind, and the operon is poorly transcribed despite lactose being present (glucose catabolite repression).
- Option B (cAMP): cAMP activates the CAP (catabolite activator protein) for *positive* control of the operon when glucose is absent, but cAMP is not the inducer that removes the repressor; allolactose is.
- Option D (RNA polymerase sigma factor): The sigma factor is part of RNA polymerase that recognises promoter sequences; it is not a regulatory molecule that induces the operon by acting on the repressor.

Final Answer: Allolactose (a metabolite of lactose) is the inducer of the *lac* operon $\Rightarrow$ C

Answer: (C) Go Back to Q 7

Sol.8.

Solution

Concept — Auditory Transduction in the Inner Ear: Hearing involves a series of energy conversions: sound waves (pressure waves in air) $\rightarrow$ mechanical vibrations of the tympanic membrane $\rightarrow$ amplified vibrations via ossicles $\rightarrow$ fluid pressure waves in the cochlea $\rightarrow$ mechanical displacement of the basilar membrane $\rightarrow$ electrical nerve signals.

Step 1 — The Organ of Corti as the transducer: The **Organ of Corti** is the sensory epithelium located on the basilar membrane within the cochlea. It contains approximately 15,000–20,000 **hair cells** (mechanoreceptors). When sound-induced fluid waves displace the basilar membrane, the stereocilia (hair bundles) of hair cells are deflected against the overlying tectorial membrane. This mechanical deflection opens mechanosensitive ion channels (tip links), causing an influx of K^+ and Ca^{2+} into the hair cells, depolarising them. The resulting receptor potential triggers neurotransmitter (glutamate) release onto spiral ganglion neurons, which form the cochlear branch of the vestibulocochlear nerve (CN VIII) and carry action potentials to the auditory cortex. This conversion of mechanical to electrical signals is **mechanoelectrical transduction**.

Why other options are wrong:

- Option A (Tympanic membrane): The eardrum converts airborne sound waves into mechanical vibrations; it does not produce nerve impulses.
- Option B (Ossicles — malleus, incus, stapes): The three bones of the middle ear form a mechanical lever system that amplifies and transmits vibrations from the tympanic membrane to the oval window; they do not produce electrical signals.
- Option C (Semicircular canals): The three semicircular canals detect rotational (angular) acceleration of the head for the sense of *balance* (vestibular system); they are not involved in hearing.

Final Answer: The Organ of Corti (within the cochlea) converts sound vibrations into nerve impulses $\Rightarrow$ $\boxed{\text{D}}$

Answer: (D) Go Back to Q 8

Sol.9.

Solution

Concept — Nitrogen Cycle Processes: Nitrogen (N) is an essential element of amino acids, nucleic acids, and chlorophyll. Atmospheric N_2 (≈78% of air) is chemically very stable and cannot be directly utilised by most organisms. The nitrogen cycle includes several interconversion processes.

Step 1 — Nitrogen fixation defined: Nitrogen fixation is the biological or abiotic process that cleaves the triple bond of N_2 and converts it to ammonia (NH_3):

$$N_2 + 8H^+ + 8e^- + 16\,\text{ATP} \xrightarrow{\text{nitrogenase}} 2\,\text{NH}_3 + H_2 + 16\,\text{ADP} + 16\,P_i$$

The enzyme **nitrogenase** (nitrogenase reductase + dinitrogenase) catalyses this reaction and is present in: (a) free-living bacteria (*Azotobacter*, *Clostridium*, *Anabaena*); (b) symbiotic bacteria (*Rhizobium* in legume root nodules). This is the only biological pathway that introduces new "fixed" nitrogen into the biosphere.

Why other options are wrong:

- Option A (Nitrification): The oxidation of NH_3 to NO_2^- (by *Nitrosomonas*) and then to NO_3^- (by *Nitrobacter*); it does not convert N_2 — it oxidises already-fixed ammonia.
- Option C (Denitrification): The anaerobic reduction of NO_3^- or NO_2^- back to N_2 or N_2O by bacteria (*Pseudomonas*, *Thiobacillus*); this is the *reverse* of fixation, releasing nitrogen to the atmosphere.
- Option D (Ammonification): The decomposition of organic nitrogen compounds (proteins, nucleic acids) in dead organisms and waste into NH_3/NH_4^+ by saprophytic microorganisms; it recycles fixed nitrogen but does not fix N_2.

Final Answer: Nitrogen fixation converts atmospheric N_2 to NH_3 ⇒ B

Answer: (B) Go Back to Q 9

Sol.10.

Solution

Concept — Meiotic Arrest During Oogenesis: Human oogenesis involves two meiotic divisions but is not completed in one continuous event. Instead, it is interrupted (arrested) at specific stages, and completion depends on hormonal signals (LH surge) and fertilization.

Step 1 — Timeline of meiotic arrest:

- **Fetal life**: Oogonia enter meiosis and the resulting *primary oocytes* are arrested at **Prophase I** (specifically, the diplotene sub-stage). They remain arrested here for years to decades.
- **Puberty and each menstrual cycle**: Under the LH surge, the primary oocyte completes Meiosis I and divides asymmetrically into the *secondary oocyte* (large, retains most cytoplasm) and the first polar body. The secondary oocyte immediately enters Meiosis II but arrests at **Metaphase II**.
- **Ovulation**: The secondary oocyte (arrested at Metaphase II) is released from the ovary.
- **Fertilization**: Entry of a sperm triggers completion of Meiosis II; the secondary oocyte becomes the mature ovum (egg) plus a second polar body.

Why other options are wrong:

- Option B (Prophase I): This is where the *primary oocyte* is arrested (in the ovarian follicle from fetal life); the *secondary oocyte* released at ovulation has already passed this stage.
- Option C (Anaphase I): This is a transient, brief phase during which homologous chromosomes separate in Meiosis I; no sustained arrest occurs here.
- Option D (Telophase II): This stage is reached only *after* fertilization triggers the completion of Meiosis II; it is not the stage of arrest at ovulation.

Final Answer: The secondary oocyte is arrested at Metaphase II at the time of ovulation $\Rightarrow$ $\boxed{\text{A}}$

Answer: (A) Go Back to Q 10

Sol.11.

Solution

Concept — Modes of Speciation: Speciation is the evolutionary process by which new biological species arise. The two primary modes are allopatric speciation (geographic separation) and sympatric speciation (within the same geographic area). The word "allopatric" derives from the Greek *allos* (other) and *patra* (homeland).

Step 1 — Mechanism of allopatric speciation: Allopatric speciation occurs when a population is physically divided into two or more groups by a geographic barrier — such as a mountain range, river, ocean, desert, or glaciation. The isolated sub-populations are then subject to different selective pressures, genetic drift (especially in small populations, by the founder effect or bottleneck effect), and accumulation of distinct mutations. Over many generations, the sub-populations diverge genetically. Eventually, even if the geographic barrier is removed, the populations are no longer able to interbreed successfully (reproductive isolation has been achieved), and they are recognised as separate species. This is the most common mode of speciation in sexually reproducing animals.

Why other options are wrong:

- Option A: Describes *sympatric* speciation (same geographic area) driven by ecological/behavioural divergence, not allopatric.
- Option B: Polyploidy (genome duplication) can produce instant sympatric speciation in plants (e.g., allopolyploidy in wheat); it is *sympatric*, not allopatric, and does not involve geographic separation.
- Option D: This describes a form of hybridisation followed by polyploidy (allopolyploidy), another mechanism of sympatric speciation; it does not involve geographic barriers.

Final Answer: Allopatric speciation occurs via geographic isolation and independent divergence $\Rightarrow$ C

Answer: (C) Go Back to Q 11

Sol.12.

Solution

Concept — PCR and Thermostable DNA Polymerase: PCR (Polymerase Chain Reaction), developed by Kary Mullis in 1983 (Nobel Prize 1993), exponentially amplifies a specific DNA target sequence using repeated thermocycling. Each cycle involves: (1) denaturation at ∼94–96°C to separate the double-stranded DNA; (2) annealing at ∼50–65°C for primers to bind; (3) extension at ∼72°C for DNA synthesis.

Step 1 — Why Taq polymerase is essential: A standard (mesophilic) DNA polymerase (e.g., the Klenow fragment of DNA Pol I from *E. coli*) would be irreversibly denatured during the high-temperature denaturation step (∼95°C). **Taq polymerase**, isolated from the thermophilic bacterium *Thermus aquaticus* (found in hot springs at ∼70°C), is naturally thermostable: it retains activity after repeated exposure to 95°C and has an optimal extension temperature of ∼72°C. This eliminates the need to add fresh enzyme after each cycle, making PCR fully automatable in a thermocycler. Taq polymerase was first isolated from *T. aquaticus* by Thomas Brock and further characterised by David Gelfand.

Why other options are wrong:

- Option A (DNA ligase): Joins DNA fragments with compatible ends (sticky or blunt); it is used in cloning and DNA repair, not in PCR amplification.
- Option B (Reverse transcriptase): An RNA-dependent DNA polymerase that converts mRNA to cDNA; it is used in RT-PCR (first step) but not in subsequent PCR thermocycling.
- Option C (EcoRI restriction endonuclease): A sequence-specific endonuclease that cuts double-stranded DNA at the recognition site 5'-GAATTC-3'; it is used to cut DNA for cloning, not for amplification.

Final Answer: Taq polymerase (from *Thermus aquaticus*) is the thermostable enzyme used in PCR ⇒ D

Answer: (D) Go Back to Q 12

Sol.13.

Solution

Concept — Stomatal Opening Mechanism (Guard Cell Physiology): Stomata are pores flanked by two guard cells in the leaf epidermis. They regulate gas exchange (CO_2 in, O_2 and water vapour out) and transpiration. Stomatal opening and closing are driven by changes in guard cell turgor pressure, which depends on ion and water movements.

Step 1 — K^+ ion hypothesis: The primary mechanism of stomatal opening (demonstrated by Fischer in 1968) is driven by light. Blue light activates the plasma membrane **H^+-ATPase proton pump** in guard cells, which pumps H^+ out of the cell. This hyperpolarises the guard cell membrane (inside becomes more negative), creating an electrochemical gradient that drives K^+ ions to flow *into* guard cells through voltage-gated inward-rectifying K^+ channels. Cl^- and malate^{2-} (synthesised from starch-derived PEP) accumulate as counter-ions to maintain electrical neutrality. The dramatic increase in K^+ (from $\sim$100 mM to $\sim$500 mM) lowers the water potential (Ψ_s) of guard cells; water enters by osmosis; turgor pressure increases. The unevenly thickened guard cell walls (thicker on the inner side facing the pore) cause the cells to bow outward, widening the pore.

Why other options are wrong:

- Option B: An *efflux* of K^+ from guard cells is what happens during stomatal *closure* — loss of K^+ reduces turgor pressure, causing the pore to close.
- Option C: *Rising* CO_2 concentration (above $\sim$400 ppm) actually causes stomata to *close* via a pathway involving carbonic anhydrase and downstream signalling; it is falling CO_2 (due to active photosynthesis) that contributes to opening.
- Option D: The outdated starch-sugar hypothesis proposed that starch breakdown to sugars increased osmotic solutes, but modern evidence shows that K^+ flux, not sugar accumulation, is the primary driver; also, breaking starch down into glucose would *raise* solute concentration (reducing water potential) but this is a secondary, slower mechanism at best.

Final Answer: K^+ influx into guard cells drives osmotic water uptake and stomatal opening $\Rightarrow$ A

Answer: (A) Go Back to Q 13

Sol.14.

Solution

Concept — Sliding Filament Theory of Muscle Contraction: Proposed by Hugh Huxley, Andrew Huxley, Jean Hanson, and Ralph Niedergerke in 1954, the sliding filament theory states that muscle contraction occurs not because myofilaments shorten, but because thin (actin) filaments slide past thick (myosin) filaments, shortening the sarcomere.

Step 1 — Myosin as the molecular motor: Myosin II (the isoform in skeletal muscle) consists of two heavy chains and four light chains, forming a structure with a globular head (S1 fragment) connected via a flexible neck to a coiled-coil tail. The **myosin head** is the molecular motor: it has two functional domains — an **actin-binding site** and an **ATPase active site**. The myosin ATPase cycle drives contraction: (1) ATP binds myosin head $\rightarrow$ head detaches from actin; (2) ATP hydrolysis ($\rightarrow$ ADP + P_i) $\rightarrow$ head "cocks" to a high-energy conformation; (3) head reattaches to actin at a new position; (4) power stroke: P_i release $\rightarrow$ head pivots 5–10 nm, pulling actin filament toward M-line, generating force; (5) ADP released, rigor state until new ATP binds. This cycle repeats $\sim$5 times per second per head.

Why other options are wrong:

- Option A (Actin): Actin forms the thin filaments that serve as the "track" or "rail" along which myosin heads walk; actin itself is not the motor — it is the substrate upon which myosin acts.
- Option C (Troponin): Troponin is a regulatory protein complex (TnI, TnT, TnC) on the thin filament that, when Ca^{2+} binds TnC, causes tropomyosin to shift and expose myosin-binding sites on actin; it regulates *when* contraction can occur, but does not generate force.
- Option D (Tropomyosin): Tropomyosin is a fibrous regulatory protein that, in the resting state, blocks myosin-binding sites on actin; Ca^{2+}-induced troponin conformational change moves tropomyosin aside to permit cross-bridge formation; it does not generate force.

Final Answer: Myosin is the molecular motor protein that drives muscle contraction $\Rightarrow$ $\boxed{\text{B}}$

Answer: (B) Go Back to Q 14

Sol.15.

Solution

Concept — Cnidarian Unique Structures (Cnidocytes and Nematocysts): Phylum Cnidaria (Greek: *knide* = nettle) encompasses ∼10,000 species of aquatic, mostly marine animals including jellyfish (Scyphozoa), sea anemones and corals (Anthozoa), and *Hydra* (Hydrozoa). They are diploblastic (two germ layers: ectoderm and endoderm), have a tissue level of organisation, and exhibit radial symmetry.

Step 1 — Cnidocytes (nematocysts) as the synapomorphy of Cnidaria: Cnidocytes (also called stinging cells or nematocytes) are highly specialised cells found *exclusively* in the ectoderm of all cnidarians — no other animal phylum possesses them. Each cnidocyte contains a **nematocyst** (also called a cnida or stinging organelle): a membrane-bound capsule with a coiled, hollow, barbed tube. When triggered by mechanical or chemical stimuli (via a cilium-like receptor called the *cnidocil*), the nematocyst fires by explosive eversion in $<$700 nanoseconds (one of the fastest biological processes known), penetrating prey or predator and injecting paralysing toxins (hypnotoxin, actinoporin). This structure is used in prey capture and defence, and is the defining (synapomorphic) character of phylum Cnidaria.

Why other options are wrong:

- Option A (Parapodia): Paddle-like, fleshy lateral appendages used for locomotion and gas exchange in polychaete annelid worms (e.g., *Nereis*); found in phylum Annelida, not Cnidaria.
- Option B (Radula): A ribbon-like, chitinous rasping organ covered with tiny teeth, used for scraping food from surfaces; found in most molluscs (e.g., snails, chitons) in phylum Mollusca, not Cnidaria.
- Option D (Setae/chaetae): Stiff, chitinous bristles projecting from the body wall of annelids (earthworms, leeches, polychaetes) and some arthropods; they aid in locomotion and anchoring; not found in Cnidaria.

Final Answer: Nematocysts (cnidocytes) are the structure unique to phylum Cnidaria $\Rightarrow$ C

Answer: (C) Go Back to Q 15

Answer Key

Q	Ans	Q	Ans	Q	Ans	Q	Ans	Q	Ans
1	B	2	A	3	D	4	C	5	B
6	A	7	C	8	D	9	B	10	A
11	C	12	D	13	A	14	B	15	C