IIT JAM Biotechnology

Sample Paper – 2

Collegedunia Practice Series | Exam Date: 14 February 2027

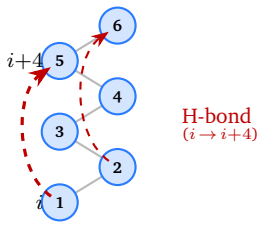
Instructions

- This paper contains **60 questions** carrying a maximum of **100 marks**. Duration: **3 hours (180 minutes)**.
- **Section A** (**Q1–Q30**, MCQ): Q1–Q10 carry **+1 mark** each; wrong response: $-\frac{1}{3}$ mark. Q11–Q30 carry **+2 marks** each; wrong response: $-\frac{2}{3}$ mark. Choose the **single best** option.
- **Section B** (**Q31–Q40**, MSQ): Each carries **+2 marks**. **No negative marking.** One or more options may be correct; full marks only if *all* correct options are selected; no partial credit.
- **Section C** (**Q41–Q60**, NAT): Q41–Q50 carry **+1 mark**; Q51–Q60 carry **+2 marks**. **No negative marking.** Enter the numerical answer using the virtual keypad.
- **No calculators, log tables, or electronic devices.** A virtual scientific calculator is provided in the CBT interface.

Section A — Multiple Choice Questions (MCQ)

***Q1–Q10**: 1 mark each ($-\frac{1}{3}$ for wrong). Choose the **single** correct option.*

Q1. Which type of protein secondary structure is primarily stabilised by hydrogen bonds formed between the C=O group of residue i and the N–H group of residue $i+4$ along the polypeptide backbone?



(A) β-pleated sheet
(B) β-turn
(C) Random coil
(D) α-helix

Q2. What is the primary function of Photosystem II (PSII) during the light-dependent reactions of photosynthesis?

(A) Oxidises water to release O_2 and supplies electrons to the photosynthetic electron transport chain
(B) Fixes atmospheric CO_2 onto an organic acceptor molecule
(C) Reduces $NADP^+$ to NADPH using electrons received from ferredoxin
(D) Transfers electrons directly to ferredoxin via plastocyanin

Q3. The rough endoplasmic reticulum (RER) is the primary site of synthesis of which class of cellular products?

(A) Glycogen and starch
(B) ATP via oxidative phosphorylation
(C) Proteins destined for secretion or insertion into membranes
(D) Fatty acids and cholesterol

Q4. In catabolic oxidation reactions (e.g., glycolysis and the TCA cycle), NAD^+ serves primarily as:

(A) A phosphate group donor in substrate-level phosphorylation
(B) An electron (hydride ion, H^-) acceptor, forming NADH
(C) A carbon carrier in transamination reactions
(D) A methyl group donor in one-carbon metabolism

Q5. Mendel's Law of Independent Assortment states that:

(A) Alleles of different genes located on non-homologous chromosomes are distributed to gametes independently of one another
(B) The dominant allele always masks the phenotypic expression of the recessive allele
(C) Each offspring inherits exactly one allele per locus from each parent
(D) Allele frequencies remain constant from generation to generation in a large, randomly mating population

Q6. In *Escherichia coli* DNA replication, which enzyme possesses $5' \to 3'$ polymerase activity, $5' \to 3'$ exonuclease activity for primer removal, and $3' \to 5'$ proofreading activity, enabling it to remove RNA primers and fill gaps?

(A) DNA Polymerase III

(B) Primase
(C) DNA ligase
(D) DNA Polymerase I

Q7. Bacterial conjugation is distinguished from transformation and transduction because it requires:

(A) Uptake of free DNA released into the extracellular environment
(B) Direct cell-to-cell contact mediated by a sex pilus (mating bridge)
(C) A bacteriophage to package and deliver donor DNA to the recipient
(D) Passive diffusion of plasmid DNA across the recipient cell membrane

Q8. The primary structural polysaccharide component of the cell walls of most fungi is:

(A) Cellulose
(B) Murein (peptidoglycan)
(C) Chitin
(D) Lignin

Q9. In a sandwich ELISA, the detectable signal (e.g., colour change) is generated by:

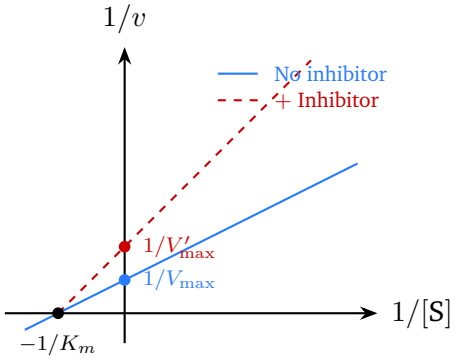
(A) An enzyme-linked secondary (detection) antibody that converts a colourless substrate into a coloured product
(B) Radioactive labelling of the primary capture antibody
(C) Antigen-induced agglutination of antibody-coated beads
(D) Direct fluorescence emitted by the target antigen upon binding to the capture antibody

Q10. Membrane fluidity is most effectively increased by increasing the proportion of which lipid component?

(A) Saturated long-chain fatty acids in the phospholipid bilayer
(B) Sphingomyelin relative to glycerophospholipids
(C) Cholesterol at high concentrations (above the critical threshold)
(D) Unsaturated fatty acids with *cis* double bonds in the acyl chains

*Q11–Q30: 2 marks each ($-\frac{2}{3}$ for wrong). Choose the **single** correct option.*

Q11. A Lineweaver–Burk (double-reciprocal) plot is constructed for an enzyme in the absence and presence of an inhibitor. As shown below, the inhibitor leaves the x-intercept ($-1/K_m$) unchanged but raises the y-intercept (increases $1/V_{\max}$). Which type of inhibition does this represent?



(A) Competitive inhibition
(B) Non-competitive inhibition
(C) Uncompetitive inhibition
(D) Substrate inhibition

Q12. Southern blotting is a molecular biology technique used to detect and characterise:

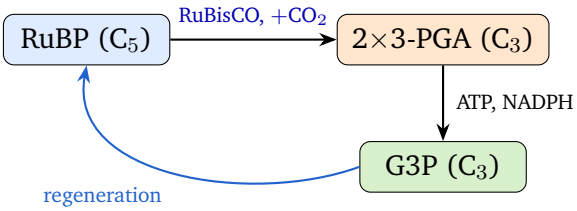
(A) Specific proteins after separation by SDS-PAGE
(B) Specific mRNA sequences (for gene expression analysis)
(C) Specific DNA sequences after restriction digestion and gel electrophoresis, using a labelled probe
(D) Antigen–antibody interactions in tissue sections (immunohistochemistry)

Q13. Intramolecular and intermolecular disulfide bonds ($-$S$-$S$-$) that stabilise protein structure are formed by the oxidative coupling of the thiol ($-$SH) side chains of which amino acid?

(A) Cysteine
(B) Methionine
(C) Serine

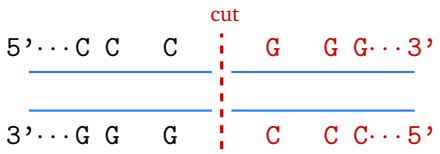
(D) Lysine

Q14. In the Calvin cycle (light-independent reactions of photosynthesis), the enzyme RuBisCO catalyses the fixation of CO_2 onto which 5-carbon phosphorylated acceptor molecule?



(A) Oxaloacetate (OAA)
(B) Phosphoenolpyruvate (PEP)
(C) 3-Phosphoglycerate (3-PGA)
(D) Ribulose-1,5-bisphosphate (RuBP)

Q15. The restriction endonuclease SmaI recognises the palindromic sequence 5′-CCCGGG-3′ and cuts between the 3rd and 4th bases (between CCC↓GGG on both strands). What type of DNA ends are generated?



(A) 5′ overhanging (sticky) ends
(B) Blunt ends
(C) 3′ overhanging (sticky) ends
(D) Nicks in only one strand

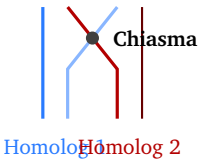
Q16. $CD4^+$ helper T lymphocytes become activated when their T-cell receptor (TCR) recognises a peptide antigen displayed on:

(A) MHC class II molecules on the surface of antigen-presenting cells (APCs)
(B) MHC class I molecules expressed on all nucleated cells
(C) Toll-like receptors (TLRs) on innate immune cells
(D) Membrane-bound immunoglobulins (B-cell receptors) on B cells

Q17. In prokaryotic translation initiation, the special initiator tRNA that is charged and placed directly into the ribosomal P-site carries which modified amino acid?

(A) Methionine (Met-$tRNA_{Met}$, the eukaryotic initiator form)
(B) N-Formyl-methionine (fMet-$tRNA_{fMet}$)
(C) N-Acetyl-methionine
(D) Selenocysteine (Sec-$tRNA_{Sec}$)

Q18. During which stage of meiosis does chromosomal crossing over (genetic recombination between non-sister chromatids of homologous chromosomes) primarily occur?



(A) Metaphase of mitosis
(B) Anaphase I of meiosis
(C) S phase of the cell cycle
(D) Pachytene substage of prophase I of meiosis

Q19. The β-oxidation of fatty acids (conversion to acetyl-CoA with production of NADH and $FADH_2$) occurs primarily in which cellular compartment?

(A) Cytosol
(B) Mitochondrial matrix
(C) Smooth endoplasmic reticulum
(D) Peroxisome (exclusively, for all chain lengths)

Q20. The trace (sum of the main diagonal elements) of the matrix $M = \begin{pmatrix} 5 & 3 \\ 2 & 4 \end{pmatrix}$ is:

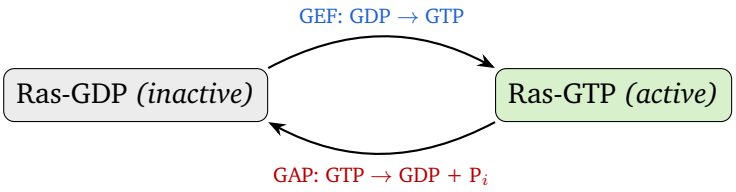
(A) 7
(B) 14
(C) 9

(D) 3

Q21. When glucose is abundant, transcription of the *E. coli* lac operon is repressed even in the presence of lactose. The molecular mechanism is that high glucose:

(A) Directly enhances lac repressor binding to the operator
(B) Activates adenylyl cyclase, raising cAMP levels and stimulating CRP-cAMP binding
(C) Causes allolactose to be degraded before it can inactivate the lac repressor
(D) Lowers intracellular cAMP, thereby reducing CRP (CAP) binding to the promoter and decreasing transcription

Q22. Ras, a monomeric GTPase, functions as a molecular switch in cell signalling. Ras is activated (switched ON) when:



(A) A guanine nucleotide exchange factor (GEF) promotes exchange of GDP for GTP
(B) A GTPase-activating protein (GAP) stimulates hydrolysis of bound GTP
(C) Ras binds directly to and activates adenylyl cyclase
(D) Ras is phosphorylated on tyrosine by an activated receptor tyrosine kinase (RTK)

Q23. An uncompetitive inhibitor binds exclusively to the enzyme-substrate (ES) complex. Compared to the uninhibited enzyme, the presence of an uncompetitive inhibitor causes:

(A) Increased apparent K_m with unchanged $V_{\max}$
(B) Decreased apparent K_m and decreased $V_{\max}$ (in the same proportion)
(C) Unchanged apparent K_m with decreased $V_{\max}$

(D) Increased apparent K_m and decreased $V_{\max}$

Q24. A hybridoma cell line used for monoclonal antibody production is created by fusing an antigen-primed B lymphocyte with a(n):

(A) Dendritic cell
(B) Natural killer (NK) cell
(C) Myeloma (immortalised B-cell tumour) cell
(D) T helper cell

Q25. Which combination of traits best characterises K-selected (K-strategist) species?

(A) High reproductive rate and short lifespan
(B) Small body size and production of many offspring per reproductive event
(C) Populations that are typically maintained far below their carrying capacity (K)
(D) Long lifespan, large body size, few offspring per reproductive event, and high parental investment

Q26. The value of $\lim_{x \to 0} \dfrac{\sin 3x}{x}$ is:

(A) 3
(B) 1
(C) 0
(D) ∞

Q27. Yeast artificial chromosomes (YACs) are used as cloning vectors for very large eukaryotic genomic inserts. The typical insert capacity of a YAC is:

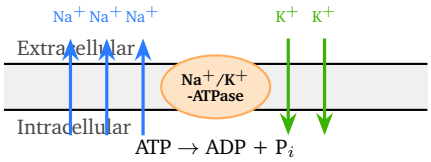
(A) Up to ∼45 kb (cosmid range)
(B) Up to 500 kb–2 Mb
(C) Up to ∼300 kb (BAC range)
(D) Up to ∼20 kb (lambda phage range)

Q28. Which DNA repair pathway is specifically responsible for correcting bulky, helix-distorting DNA lesions such as UV-induced cyclobutane pyrimidine

dimers (CPDs) and 6-4 photoproducts?

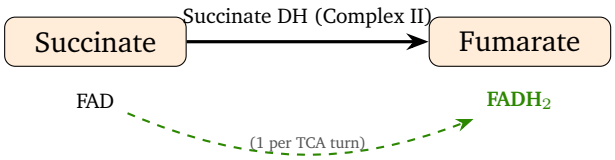
(A) Mismatch repair (MMR)
(B) Base excision repair (BER)
(C) Homologous recombination (HR) repair
(D) Nucleotide excision repair (NER)

Q29. The Na^+/K^+-ATPase (sodium-potassium pump) uses the energy of one ATP hydrolysis to transport ions against their concentration gradients. Per hydrolysis cycle, it moves:



(A) 2 Na^+ out and 3 K^+ in
(B) 3 K^+ out and 2 Na^+ in
(C) 3 Na^+ out and 2 K^+ in
(D) Na^+ and K^+ in the same direction (both inward)

Q30. How many $FADH_2$ molecules are produced per complete turn of the TCA (citric acid) cycle? The relevant step is shown below:



(A) 1
(B) 2
(C) 3
(D) 4

Section B — Multiple Select Questions (MSQ)

***Q31–Q40 [MSQ]**: 2 marks each. **No negative marking.** One or more options may be correct. Full marks only if* all *correct options are selected.*

Q31. Which of the following statements about the mitochondrial electron transport chain (ETC) are **correct**?

(A) Complex I (NADH dehydrogenase) accepts electrons from NADH and transfers them to ubiquinone (coenzyme Q)
(B) Complex II (succinate dehydrogenase) pumps protons across the inner mitochondrial membrane
(C) Complex IV (cytochrome c oxidase) accepts electrons from cytochrome c and reduces O_2 to H_2O
(D) Complex III (cytochrome bc_1 complex) accepts electrons from ubiquinol and reduces cytochrome c

Q32. Which of the following features are **characteristic of meiosis** (as opposed to mitosis)?

(A) Crossing over between non-homologous chromosomes
(B) Production of haploid daughter cells from a diploid parent cell
(C) Two sequential cell divisions (meiosis I and II) without an intervening S phase between them
(D) Pairing (synapsis) of homologous chromosomes during prophase I

Q33. Which of the following functions are performed by the **Golgi apparatus**?

(A) Transcription of ribosomal RNA (rRNA) by RNA Polymerase I
(B) O-linked and N-linked glycosylation and further modification of proteins
(C) Sorting and packaging of secretory and lysosomal proteins into vesicles for delivery
(D) Oxidative phosphorylation to generate ATP

Q34. Which of the following statements correctly describe the biology of **retroviruses**?

(A) Their genome consists of double-stranded DNA enclosed in the virion
(B) They encode the enzyme reverse transcriptase (an RNA-dependent DNA polymerase)

(C) Their single-stranded RNA genome is reverse-transcribed into double-stranded DNA, which integrates into the host chromosome as a provirus

(D) Retroviral replication occurs entirely in the cytoplasm without any involvement of the host nucleus

Q35. Which of the following statements about **bacterial transformation** are correct?

(A) Natural competence can be induced by nutrient limitation in some bacteria such as *Bacillus subtilis*

(B) Treatment of *E. coli* with $CaCl_2$ followed by heat shock is the standard method for artificially inducing competence

(C) Only single-stranded DNA can be taken up during transformation

(D) Transformation frequency is highest exclusively with supercoiled plasmid DNA

Q36. Which of the following properties correctly describe **DNA Polymerase III** of *E. coli*?

(A) It is the main replicative polymerase responsible for bulk chromosomal DNA synthesis

(B) It possesses $5' \to 3'$ exonuclease activity used for removing RNA primers

(C) It has $3' \to 5'$ exonuclease (proofreading) activity that excises misincorporated nucleotides

(D) It can initiate DNA synthesis *de novo* without a primer

Q37. Which of the following statements correctly describe the inheritance pattern of an **X-linked recessive** trait?

(A) Males (hemizygous X^aY) are affected more frequently than females

(B) An affected father (X^aY) passes the disease allele to all of his sons

(C) A carrier mother (X^AX^a) has approximately a 50% probability of transmitting the allele to each son

(D) The trait can appear to skip generations by being silently carried by heterozygous (carrier) females

Q38. Which of the following molecular events occur at the **G_1/S checkpoint** (restriction point) to allow entry into S phase?

(A) Phosphorylation of the retinoblastoma protein (Rb) by cyclin D–CDK4/6 complexes
(B) Activation of the anaphase-promoting complex/cyclosome (APC/C)
(C) Release of E2F transcription factors to activate genes required for DNA replication (S phase entry)
(D) Formation of the mitotic spindle and attachment to kinetochores

Q39. Which of the following are **products generated per single turn** of the TCA (citric acid) cycle?

(A) 3 NADH molecules (produced at the isocitrate DH, α-ketoglutarate DH, and malate DH steps)
(B) 1 $FADH_2$ molecule (produced at the succinate dehydrogenase step)
(C) 1 GTP (or ATP) via substrate-level phosphorylation at the succinyl-CoA synthetase step
(D) 1 NADPH molecule (in addition to NADH)

Q40. Which of the following post-translational modifications (PTMs) of proteins are **reversible**?

(A) Phosphorylation of serine, threonine, or tyrosine residues (reversed by specific phosphatases)
(B) Proteolytic cleavage of signal peptides from newly synthesised proteins
(C) Acetylation of lysine residues on histone tails by histone acetyltransferases (HATs), reversed by HDACs
(D) N-Myristoylation (covalent attachment of myristic acid to the N-terminal glycine)

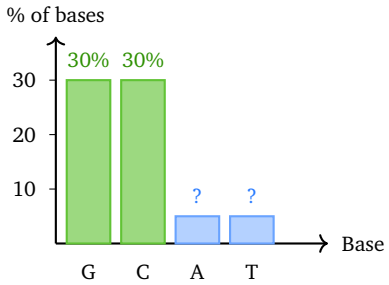
Section C — Numerical Answer Type (NAT)

***Q41–Q50**: 1 mark each. **No negative marking.** Enter the exact numerical answer.*

Q41. A bacterial culture is inoculated with 10^4 cells (CFU). The doubling time is 45 minutes. The number of cells (in units of $\times 10^4$ CFU) after exactly 3 hours is:

Q42. A single polypeptide chain consisting of 50 amino acid residues is synthesised by translation. The number of water molecules released during the formation of all peptide bonds in this chain is:

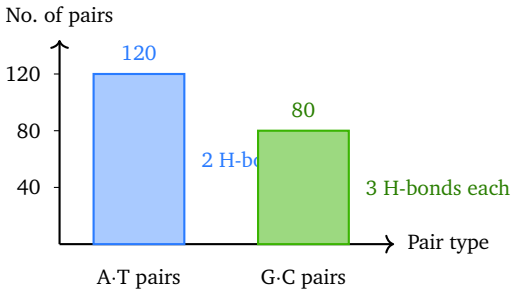
Q43. A double-stranded DNA molecule has a base composition of 30% Guanine (G). Using Chargaff's rules, the percentage of Thymine (T) bases in this molecule is:



Q44. The number of codons in the standard genetic code that specify the amino acid **Valine** is:

Q45. In a population, the genotype frequencies are: AA $= 0.49$, Aa $= 0.42$, aa $= 0.09$. The frequency of allele A (to 2 decimal places) is:

Q46. A linear double-stranded DNA molecule of 200 base pairs has a G+C content of 40%. The total number of hydrogen bonds in this molecule is:



Q47. The **net** number of ATP molecules produced per glucose molecule by *substrate-level phosphorylation only* during glycolysis (excluding any contribution from subsequent oxidative phosphorylation of NADH/$FADH_2$) is:

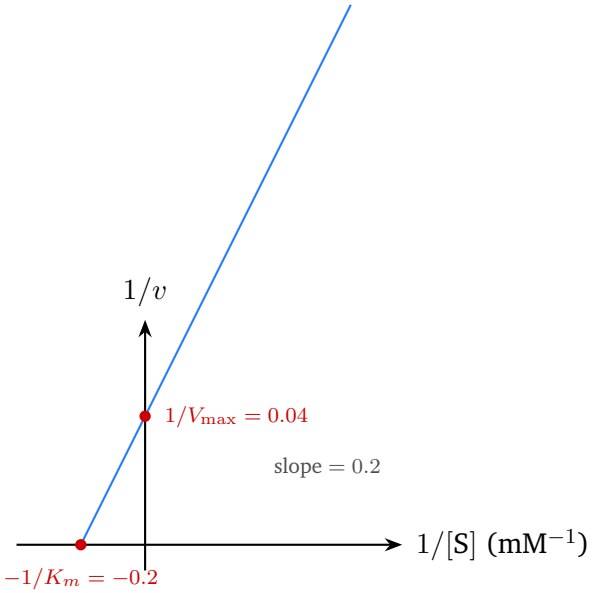
Q48. The half-life of ^{125}I is approximately 60 days. The fraction of an initial ^{125}I sample remaining after 120 days is (express as a decimal):

Q49. A buffer is prepared by mixing equal volumes of 0.20 M acetic acid and 0.20 M sodium acetate solutions. Given that the pK_a of acetic acid is 4.74, the pH of this buffer (to 2 decimal places) is:

Q50. A linear double-stranded DNA fragment of 20,000 bp is treated with a restriction enzyme that cuts the DNA on average once every 5,000 bp. The expected number of DNA fragments generated is:

Q51–Q60**: 2 marks each. **No negative marking.

Q51. A Lineweaver–Burk plot for an enzyme-catalysed reaction has a **slope** of $0.2\,\text{mM}\cdot\text{min}/\mu\text{mol}$ and a y-intercept of $0.04\,\text{min}/\mu\text{mol}$. The Michaelis constant K_m (in mM) is:

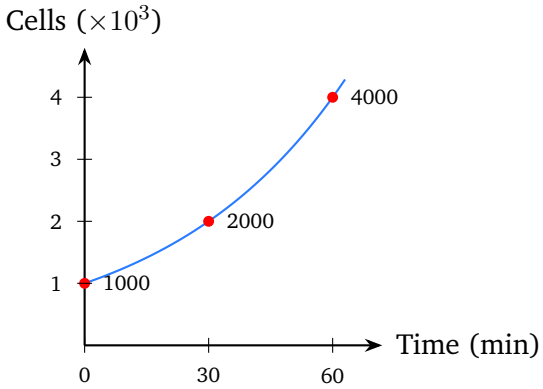


Q52. In a trihybrid cross AaBbCc $\times$ AaBbCc (all three gene loci independently assort), the expected number of offspring with the genotype **AaBbCc** out of 1024 total offspring is:

Q53. The value of the derivative of $f(x) = x^3 + 3x^2 - 2x + 5$ evaluated at $x = 2$ is:

Q54. A dataset consists of eight values: 3, 5, 5, 7, 8, 8, 9, 11. The arithmetic mean (average) of this dataset is:

Q55. A bacterial culture starts with 1,000 cells. The specific growth rate is $\mu = (\ln 2)/30\,\text{min}^{-1}$ (i.e., doubling time = 30 min). The number of cells after 60 minutes is:



Q56. The value of the definite integral $\displaystyle\int_1^3 (2x+1)\,dx$ is:

Q57. The pH of a 0.05 M HCl solution (fully dissociated, at 25°C) is (to 2 decimal places):

Q58. An enzyme preparation has a total protein content of 0.5 mg and a total activity of 120 nmol min^{-1}. The specific activity of this preparation (in nmol min^{-1} mg^{-1}) is:

Q59. A protein consists of 220 amino acid residues. Using an average residue mass of 110 Da, the approximate molecular weight of this protein (in Da) is:

Q60. In a population of 625 individuals, exactly 25 individuals display blood type O (genotype ii). Assuming Hardy–Weinberg equilibrium and that only alleles I^A and i exist at this locus, the frequency of the i allele (to 2 decimal places) is:

Answer Key — IIT JAM Biotechnology Sample Paper 2

Section A — MCQ (Q1–Q30)

Q	Ans	Q	Ans	Q	Ans	Q	Ans	Q	Ans
1	D	2	A	3	C	4	B	5	A
6	D	7	B	8	C	9	A	10	D
11	B	12	C	13	A	14	D	15	B
16	A	17	B	18	D	19	B	20	C
21	D	22	A	23	B	24	C	25	D
26	A	27	B	28	D	29	C	30	A

Section B — MSQ (Q31–Q40)

Q	Correct options	Q	Correct options
31	(A), (C) and (D)	36	(A) and (C)
32	(B), (C) and (D)	37	(A), (C) and (D)
33	(B) and (C)	38	(A) and (C)
34	(B) and (C)	39	(A), (B) and (C)
35	(A) and (B)	40	(A) and (C)

Section C — NAT (Q41–Q60)

Q	Answer	Q	Answer	Q	Answer	Q	Answer
41	16	46	480	51	5	56	10
42	49	47	2	52	128	57	1.30
43	20	48	0.25	53	22	58	240
44	4	49	4.74	54	7	59	24200
45	0.70	50	5	55	4000	60	0.20

Detailed Solutions

SECTION A — MCQ

Q1. **Answer: (D)**

Solution

In an α-helix, each backbone C=O of residue i forms a hydrogen bond with the N–H of residue $i+4$, giving 3.6 residues per turn. A β-sheet uses inter-strand H-bonds; a β-turn spans only 4 residues in a loop; a random coil has no regular H-bond pattern. **(D)**

Q2. **Answer: (A)**

Solution

Photosystem II (PSII) performs the water-splitting reaction ($2H_2O \rightarrow 4H^+ + 4e^- + O_2$) and feeds electrons into the photosynthetic ETC via plastoquinone. CO_2 fixation is the Calvin cycle (option B); NADPH production and ferredoxin reduction occur at PSI (options C, D). **(A)**

Q3. **Answer: (C)**

Solution

The rough ER is studded with ribosomes that translate mRNAs encoding secretory proteins, membrane proteins, and lysosomal proteins; these are co-translationally inserted into the ER lumen or membrane. Glycogen/starch synthesis occurs in the cytosol; ATP synthesis occurs in mitochondria; fatty acid synthesis occurs in the cytosol and SER. **(C)**

Q4. **Answer: (B)**

Solution

NAD^+ is reduced to NADH by accepting two electrons (as a hydride ion, H^-) from the substrate. This regeneration of NAD^+ is essential for continued catabolic flux. It is not a phosphate donor (that role belongs to ADP/ATP or PEP), not a carbon carrier, and not a methyl donor (that is S-adenosylmethionine). **(B)**

Q5. **Answer: (A)**

Solution

The Law of Independent Assortment states that alleles at different loci on non-homologous chromosomes segregate independently during gamete formation, producing a $9:3:3:1$ phenotypic ratio in dihybrid crosses. Option B is the Law of Dominance; option C is the Law of Segregation; option D is the Hardy–Weinberg principle. **(A)**

Q6. **Answer: (D)**

Solution

E. coli DNA Polymerase I uniquely combines $5' \to 3'$ polymerase, $5' \to 3'$ exonuclease (for primer removal and nick-translation), and $3' \to 5'$ exonuclease (proofreading) activities. Pol III is the main replicative polymerase but lacks $5' \to 3'$ exonuclease activity; primase synthesises RNA primers; ligase seals nicks. **(D)**

Q7. **Answer: (B)**

Solution

Conjugation requires physical contact between donor and recipient cells via a sex pilus (F-pilus), which forms a mating bridge for DNA transfer. Transformation involves uptake of free extracellular DNA (option A); transduction uses a bacteriophage vector (option C); passive diffusion does not drive plasmid transfer (option D). **(B)**

Q8. **Answer: (C)**

Solution

Fungal cell walls are composed primarily of chitin (a polymer of N-acetylglucosamine). Cellulose is the structural polysaccharide of plant cell walls; peptidoglycan (murein) is the bacterial cell wall polymer; lignin is a phenolic polymer found in plant secondary cell walls. **(C)**

Q9. **Answer: (A)**

Solution

In a sandwich ELISA, a capture antibody immobilises the antigen; a second enzyme-conjugated detection antibody then binds the antigen. Addition of a chromogenic substrate produces a coloured product whose absorbance is proportional to antigen concentration. Radioactive labels, bead agglutination, and direct antigen fluorescence are features of other assay formats. **(A)**

Q10. **Answer: (D)**

Solution

Cis unsaturated fatty acids introduce kinks in acyl chains, preventing tight packing and increasing bilayer fluidity. Long saturated chains and sphingomyelin increase order/rigidity; high concentrations of cholesterol also rigidify the bilayer by filling void space between acyl chains. **(D)**

Q11. **Answer: (B)**

Solution

When the x-intercept ($-1/K_m$) is unchanged but the y-intercept ($1/V_{\max}$) is raised, apparent K_m is unaltered while apparent $V_{\max}$ decreases. This is the hallmark of **non-competitive inhibition**: the inhibitor binds a site distinct from the active site, does not affect substrate binding affinity (K_m constant), but reduces the maximum catalytic rate. Competitive inhibition shifts the x-intercept; uncompetitive inhibition shifts both intercepts in parallel (same slope). **(B)**

Q12. **Answer: (C)**

Solution

Southern blotting: genomic DNA is digested with restriction enzymes, separated by agarose gel electrophoresis, transferred (blotted) to a membrane, and hybridised with a labelled probe to identify specific DNA sequences. Western blotting detects proteins (option A); Northern blotting detects mRNA (option B); immunohistochemistry uses antibodies on tissue sections (option D). **(C)**

Q13. **Answer: (A)**

Solution

Cysteine's thiol ($-$SH) side chain undergoes oxidation to form disulfide bonds ($-$S$-$S$-$). Methionine also contains sulfur but as a thioether (not reactive for S–S bond formation); serine bears a hydroxyl group; lysine has an amino group. **(A)**

Q14. **Answer: (D)**

Solution

In the Calvin cycle, RuBisCO catalyses carboxylation of ribulose-1,5-bisphosphate (RuBP, a 5-carbon molecule) with one CO_2 to generate two molecules of 3-phosphoglycerate (3-PGA). OAA is the CO_2 acceptor in C4 plants; PEP is the ac-

ceptor in CAM/C4 mesophyll; 3-PGA is the *product*, not the acceptor. **(D)**

Q15. **Answer: (B)**

Solution

SmaI cuts directly between CCC↓GGG on both strands at the same central position. Since cleavage occurs at the same position on both strands, the resulting ends have no single-stranded overhangs — these are **blunt ends**. Sticky (staggered) ends arise when cuts on the two strands are offset (e.g., EcoRI, HindIII). **(B)**

Q16. **Answer: (A)**

Solution

$CD4^+$ helper T cells express a TCR that recognises peptide–MHC class II complexes on professional antigen-presenting cells (dendritic cells, macrophages, B cells). MHC class I presents to $CD8^+$ cytotoxic T cells (option B); TLRs are pattern-recognition receptors on innate cells (option C); BCRs bind antigen on B cells (option D). **(A)**

Q17. **Answer: (B)**

Solution

In prokaryotes, the initiator tRNA carries N-formyl-methionine (fMet). The formyl group on the α-amino group distinguishes it from elongator Met-tRNA and ensures it occupies the P-site directly during 30S initiation complex assembly. Eukaryotes use unmodified Met-$tRNA_i^{Met}$ (option A); N-acetyl-methionine and selenocysteine are not initiators. **(B)**

Q18. **Answer: (D)**

Solution

Homologous recombination (crossing over) between non-sister chromatids of paired homologs occurs during the **pachytene** substage of prophase I, after synaptonemal complex assembly (zygotene) stabilises the bivalents. Metaphase of mitosis (option A) and anaphase I (option B) are post-recombination stages; DNA replication (S phase, option C) precedes meiosis. **(D)**

Q19. **Answer: (B)**

Solution

For most fatty acids, β-oxidation occurs in the **mitochondrial matrix**. Long-chain acyl-CoAs are transported across the inner mitochondrial membrane as acylcarnitine. Peroxisomes perform β-oxidation of very-long-chain and branched-chain fatty acids (not exclusively all chain lengths, so option D is incorrect). The cytosol is the site of *synthesis*, not oxidation. **(B)**

Q20. **Answer: (C)**

Solution

The trace of a square matrix is the sum of its main diagonal elements:

$$\text{tr}(M) = 5 + 4 = 9.$$

(C)

Q21. **Answer: (D)**

Solution

High glucose activates phosphodiesterase (via the PTS system), which degrades cAMP. Low cAMP means the catabolite activator protein (CAP/CRP) cannot bind DNA, so transcription of the *lac* operon is low even when lactose is present. Option B is the opposite of what happens; option A is incorrect (glucose does not directly enhance repressor binding); option C is incorrect. **(D)**

Q22. **Answer: (A)**

Solution

Ras is activated when a guanine nucleotide exchange factor (GEF), such as SOS, catalyses the release of GDP and binding of GTP (which is abundant in the cytosol). GAP accelerates GTP hydrolysis, turning Ras *off* (option B). Ras does not directly activate adenylyl cyclase in mammalian cells (option C), and Ras activation does not require tyrosine phosphorylation of Ras itself (option D). **(A)**

Q23. **Answer: (B)**

Solution

An uncompetitive inhibitor binds only the ES complex, stabilising it. This lowers the apparent K_m (more substrate appears to bind) and lowers $V_{\max}$ by the same factor α'. On a Lineweaver–Burk plot, the lines for inhibited and uninhibited enzyme are

parallel (same slope, shifted intercepts). **(B)**

Q24. **Answer: (C)**

Solution

A hybridoma is formed by fusing an antigen-stimulated B lymphocyte (which secretes a specific antibody) with a **myeloma** cell (an immortalised plasma cell tumour). The B cell provides antigen specificity; the myeloma cell confers immortality. The hybrid cells are selected in HAT medium. **(C)**

Q25. **Answer: (D)**

Solution

K-selected (K-strategist) species live near their carrying capacity (K), are characterised by long lifespans, large body size, slow maturation, few offspring per reproductive event, and high parental investment (e.g., elephants, great apes). Options A and B describe r-strategists; option C contradicts the definition (K-strategists are maintained *near* K, not far below it). **(D)**

Q26. **Answer: (A)**

Solution

Using the standard limit $\lim_{x\to 0} \dfrac{\sin ax}{x} = a$:

$$\lim_{x\to 0} \frac{\sin 3x}{x} = 3 \lim_{x\to 0} \frac{\sin 3x}{3x} = 3 \times 1 = 3.$$

(A)

Q27. **Answer: (B)**

Solution

Yeast artificial chromosomes (YACs) carry all functional chromosomal elements (ARS, CEN, TEL) and can accommodate inserts of **500 kb to ∼2 Mb**, making them ideal for mapping large eukaryotic genomes. Lambda phage holds up to ∼20 kb; cosmids ∼45 kb; BACs ∼300 kb. **(B)**

Q28. **Answer: (D)**

Solution

Nucleotide excision repair (NER) recognises and removes bulky, helix-distorting lesions such as UV-induced cyclobutane pyrimidine dimers (CPDs) and 6-4 photoproducts. It excises a $\sim$25–30 nucleotide oligonucleotide containing the lesion. MMR corrects replication errors/mismatches; BER handles small base modifications; HR repairs double-strand breaks. **(D)**

Q29. **Answer: (C)**

Solution

The Na^+/K^+-ATPase pumps **3 Na^+ out** and **2 K^+ in** per ATP hydrolysed, generating an electrogenic potential (net outward positive charge). This ratio (3:2) is fixed by the pump's stoichiometry and is essential for maintaining resting membrane potential. **(C)**

Q30. **Answer: (A)**

Solution

Per complete TCA cycle turn, succinate dehydrogenase (Complex II) oxidises succinate to fumarate, reducing **1 FAD** to **1 $FADH_2$**. The three dehydrogenase steps (isocitrate DH, α-ketoglutarate DH, malate DH) each produce 1 NADH. Thus **1 $FADH_2$** per turn. **(A)**

SECTION B — MSQ

Q31. **Answer: (A,C,D)**

Solution

(A) Correct: Complex I (NADH dehydrogenase) oxidises NADH and reduces ubiquinone (CoQ). **(B) Wrong**: Complex II (succinate dehydrogenase) does *not* pump protons; it feeds electrons into the CoQ pool without contributing to the proton gradient. **(C) Correct**: Complex IV (cytochrome c oxidase) reduces O_2 to H_2O using electrons from cytochrome c. **(D) Correct**: Complex III (cytochrome bc_1) oxidises ubiquinol and reduces cytochrome c via the Q-cycle. **Correct: (A), (C) and (D)**

Q32. **Answer: (B,C,D)**

Solution

(A) Wrong: Crossing over in meiosis occurs between *homologous* chromosomes (non-sister chromatids of the same homolog pair), not between non-homologous chromosomes. **(B) Correct**: Meiosis produces haploid (n) cells from a diploid (2n) parent. **(C) Correct**: Meiosis I and meiosis II occur sequentially without an intervening S phase. **(D) Correct**: Synapsis (pairing) of homologous chromosomes occurs during zygotene–pachytene of prophase I, forming bivalents. **Correct: (B), (C) and (D)**

Q33. **Answer: (B,C)**

Solution

(A) Wrong: rRNA transcription by RNA Pol I occurs in the *nucleolus*. **(B) Correct**: The Golgi modifies N-linked oligosaccharides (added in the ER) and adds O-linked sugars. **(C) Correct**: The Golgi sorts and packages proteins into vesicles destined for secretion, lysosomes, or the plasma membrane. **(D) Wrong**: Oxidative phosphorylation takes place in the *inner mitochondrial membrane*. **Correct: (B) and (C)**

Q34. **Answer: (B,C)**

Solution

(A) Wrong: The retroviral *virion* genome is two copies of **single-stranded RNA**, not dsDNA. **(B) Correct**: Retroviruses encode reverse transcriptase (RT), an RNA-dependent DNA polymerase. **(C) Correct**: RT converts the ssRNA genome into dsDNA; this proviral dsDNA integrates into the host chromosome. **(D) Wrong**: Integration of proviral DNA requires nuclear import of the pre-integration complex; the host nucleus is *essential*. **Correct: (B) and (C)**

Q35. **Answer: (A,B)**

Solution

(A) Correct: *Bacillus subtilis* naturally enters competence under nutrient-limiting/high-density conditions via the ComK pathway. **(B) Correct**: $CaCl_2$ treatment makes *E. coli* membranes permeable; a brief 42°C heat shock drives DNA uptake. **(C) Wrong**: Double-stranded DNA *can* be taken up (it is commonly used in transformation protocols). **(D) Wrong**: While supercoiled plasmids transform more efficiently, transformation is not restricted exclusively to supercoiled DNA. **Correct: (A) and (B)**

Q36. **Answer: (A,C)**

Solution

(A) Correct: DNA Pol III holoenzyme is the main replicative polymerase in *E. coli*, synthesising the bulk of chromosomal DNA. **(B) Wrong**: The $5' \to 3'$ exonuclease activity for primer removal belongs to **DNA Pol I**, not Pol III. **(C) Correct**: Pol III possesses $3' \to 5'$ exonuclease (proofreading) activity in its ε (epsilon) subunit, achieving an error rate of $\sim 10^{-7}$. **(D) Wrong**: Like all DNA polymerases, Pol III cannot initiate synthesis *de novo*; it requires a 3′-OH primer (provided by primase). **Correct: (A) and (C)**

Q37. **Answer: (A,C,D)**

Solution

(A) Correct: Males (X^aY) are hemizygous and express the trait with a single copy; females need two copies, so males are affected more often. **(B) Wrong**: An affected father (X^aY) passes his X chromosome to all *daughters*, not to sons (sons receive the Y chromosome). **(C) Correct**: Each son of a carrier mother (X^AX^a) has a 1/2 chance of inheriting X^a. **(D) Correct**: Heterozygous carrier females (X^AX^a) are phenotypically normal; the trait can appear to skip generations. **Correct: (A), (C) and (D)**

Q38. **Answer: (A,C)**

Solution

(A) Correct: Cyclin D–CDK4/6 phosphorylates Rb, disrupting its binding to E2F transcription factors. **(B) Wrong**: APC/C (anaphase-promoting complex) is activated at the *metaphase–anaphase transition* (M phase), not at G_1/S. **(C) Correct**: Release of E2F activates transcription of S-phase genes (e.g., cyclin E, DNA polymerase components). **(D) Wrong**: Spindle formation and kinetochore attachment are M-phase events. **Correct: (A) and (C)**

Q39. **Answer: (A,B,C)**

Solution

Per TCA cycle turn: **(A) Correct**: 3 NADH are generated at the isocitrate dehydrogenase, α-ketoglutarate dehydrogenase, and malate dehydrogenase steps. **(B) Correct**: 1 $FADH_2$ is produced at the succinate dehydrogenase step. **(C) Correct**: 1 GTP (or ATP in animals) is produced by substrate-level phosphorylation at succinyl-CoA synthetase. **(D) Wrong**: The TCA cycle produces *NADH*, not NADPH; NADPH is produced in the pentose phosphate pathway and by isocitrate dehydrogenase in some contexts, but *not* in the standard mitochondrial TCA cycle. **Correct: (A), (B)**

and (C)

Q40. **Answer: (A,C)**

Solution

(A) Correct: Phosphorylation of Ser/Thr/Tyr is reversed by specific serine, threonine, or tyrosine phosphatases. **(B) Wrong**: Proteolytic cleavage of signal peptides is *irreversible*; peptide bonds cannot be re-formed under physiological conditions. **(C) Correct**: Histone acetylation (by HATs) is reversed by histone deacetylases (HDACs), making it a dynamic, reversible modification. **(D) Wrong**: N-myristoylation (co-translational addition of myristic acid to the N-terminal Gly via an amide bond) is *irreversible* under normal physiological conditions. **Correct: (A) and (C)**

SECTION C — NAT

Q41. **Answer: (16)**

Solution

Total time = 3 h = 180 min. Number of doublings $= \dfrac{180}{45} = 4$. Final count:

$$N = 10^4 \times 2^4 = 10^4 \times 16 = 16 \times 10^4 \text{ CFU}.$$

Answer: **16** (in units of $\times 10^4$ CFU).

Q42. **Answer: (49)**

Solution

Each peptide bond formation releases one water molecule. A chain of 50 amino acids requires **49** peptide bonds (joining residues 1–2, 2–3, . . . , 49–50). Hence 49 water molecules are released. Answer: **49**.

Q43. **Answer: (20)**

Solution

By Chargaff's rules: $\%\text{G} = \%\text{C} = 30\%$. Therefore $\%\text{A} + \%\text{T} = 100 - 60 = 40\%$, and since $\%\text{A} = \%\text{T}$:

$$\%\text{T} = \frac{40}{2} = 20\%.$$

Answer: **20**.

Q44. **Answer: (4)**

Solution

Valine (Val, V) is encoded by the codons GUU, GUC, GUA, and GUG — all four GU-codons (the third position is synonymous). Answer: **4**.

Q45. **Answer: (0.70)**

Solution

The frequency of allele A is calculated as:

$$f(A) = f(AA) + \tfrac{1}{2}\, f(Aa) = 0.49 + \tfrac{1}{2}(0.42) = 0.49 + 0.21 = 0.70.$$

Answer: **0.70**.

Q46. **Answer: (480)**

Solution

G+C content = 40% of 200 bp $=$ 80 G–C pairs; A+T content $=$ 60% of 200 bp $=$ 120 A–T pairs.

$$\text{Total H-bonds} = 80 \times 3 + 120 \times 2 = 240 + 240 = 480.$$

Answer: **480**.

Q47. **Answer: (2)**

Solution

Glycolysis consumes 2 ATP (hexokinase and phosphofructokinase steps) and produces 4 ATP (two phosphoglycerate kinase and two pyruvate kinase steps) by substrate-level phosphorylation. Net yield:

$$4 - 2 = 2 \text{ ATP per glucose.}$$

Answer: **2**.

Q48. **Answer: (0.25)**

Solution

120 days $= 2 \times 60$ days $=$ 2 half-lives. Fraction remaining:

$$\left(\tfrac{1}{2}\right)^2 = \frac{1}{4} = 0.25.$$

Answer: **0.25**.

Q49. **Answer: (4.74)**

Solution

Equal volumes of equimolar acetic acid and sodium acetate gives a 1:1 ratio of acid to conjugate base. By the Henderson–Hasselbalch equation:

$$\text{pH} = \text{p}K_a + \log\left(\frac{[\text{A}^-]}{[\text{HA}]}\right) = 4.74 + \log(1) = 4.74 + 0 = 4.74.$$

Answer: **4.74**.

Q50. **Answer: (5)**

Solution

A restriction enzyme cutting every 5,000 bp in a 20,000 bp linear fragment produces 4 cuts, generating $4 + 1 = 5$ fragments (for a linear molecule, number of fragments = number of cuts $+1$). Answer: **5**.

Q51. **Answer: (5)**

Solution

From the Lineweaver–Burk plot: y-intercept $= 1/V_{\max} = 0.04 \Rightarrow V_{\max} = 25\,\mu$mol/min. The slope $= K_m/V_{\max}$:

$$K_m = \text{slope} \times V_{\max} = 0.2 \times 25 = 5\,\text{mM}.$$

Answer: **5** mM.

Q52. **Answer: (128)**

Solution

For each locus, $P(\text{Aa} \mid \text{Aa} \times \text{Aa}) = 1/2$. The three loci assort independently, so:

$$P(\text{AaBbCc}) = \tfrac{1}{2} \times \tfrac{1}{2} \times \tfrac{1}{2} = \tfrac{1}{8}.$$

Expected number $= 1024 \times \frac{1}{8} = 128$. Answer: **128**.

Q53. **Answer: (22)**

Solution

Differentiate $f(x) = x^3 + 3x^2 - 2x + 5$:

$$f'(x) = 3x^2 + 6x - 2.$$

Evaluate at $x = 2$:

$$f'(2) = 3(4) + 6(2) - 2 = 12 + 12 - 2 = 22.$$

Answer: **22**.

Q54. **Answer: (7)**

Solution

Sum of values: $3 + 5 + 5 + 7 + 8 + 8 + 9 + 11 = 56$. Number of values $= 8$.

$$\bar{x} = \frac{56}{8} = 7.$$

Answer: **7**.

Q55. **Answer: (4000)**

Solution

Doubling time $= 30$ min. In 60 min there are $60/30 = 2$ doublings.

$$N = 1000 \times 2^2 = 1000 \times 4 = 4000 \text{ cells}.$$

Answer: **4000**.

Q56. **Answer: (10)**

Solution

$$\int_1^3 (2x + 1)\, dx = \Big[x^2 + x\Big]_1^3 = (9 + 3) - (1 + 1) = 12 - 2 = 10.$$

Answer: **10**.

Q57. **Answer: (1.30)**

Solution

HCl is a strong acid that fully dissociates: $[\mathrm{H}^+] = 0.05\,\mathrm{M} = 5 \times 10^{-2}\,\mathrm{M}$.

$$\mathrm{pH} = -\log(5 \times 10^{-2}) = 2 - \log 5 = 2 - 0.699 \approx 1.30.$$

Answer: **1.30**.

Q58. **Answer: (240)**

Solution

Specific activity = total activity / total protein:

$$\text{Specific activity} = \frac{120\,\text{nmol}\,\text{min}^{-1}}{0.5\,\text{mg}} = 240\,\text{nmol}\,\text{min}^{-1}\,\text{mg}^{-1}.$$

Answer: **240** nmol min^{-1} mg^{-1}.

Q59. **Answer: (24200)**

Solution

MW = number of residues $\times$ average residue mass $= 220 \times 110\,\text{Da} = 24{,}200\,\text{Da}$.
Answer: **24200** Da.

Q60. **Answer: (0.20)**

Solution

Under Hardy–Weinberg equilibrium, $q^2 = f(ii) = \frac{25}{625} = 0.04$. Therefore:

$$q = \sqrt{0.04} = 0.20.$$

Answer: **0.20**.