

OJEE MTech Biotechnology Sample Paper

02

A) Mode and Time: The exam is a Computer Based Test (CBT) lasting 120 minutes.

B) Total Questions: The exam contains 90 questions.

C) Marking Scheme & Rules:

- +4 marks for each correct answer; -1 mark for each incorrect answer.

Q1. Which of the following describes the thermodynamic advantage of the concerted (MWC) model of allostery over the sequential (KNF) model?

- A. It allows for mixed states of T and R subunits
- B. It explains negative cooperativity accurately
- C. It maintains structural symmetry by assuming all subunits transition simultaneously
- D. It requires a higher activation energy for substrate binding

Q2. In the context of the Ramachandran plot, what causes the major steric restrictions that prevent most amino acids from occupying the bottom right quadrant (positive ϕ , negative ψ)?

- A. Clash between carbonyl oxygen atoms
- B. Clash between the side chain and the peptide backbone
- C. Hydrogen bonding constraints within the helix
- D. The planar nature of the peptide bond

Q3. In a mixed inhibition scenario where the inhibitor binds with higher affinity to the enzyme-substrate complex than to the free enzyme, how will the Lineweaver-Burk plot appear?

- A. Lines intersect on the x-axis
- B. Lines intersect on the y-axis
- C. Lines intersect in the second quadrant
- D. Lines intersect in the third quadrant

Q4. The topological state of circular closed DNA is defined by the equation $L_k = T_w + W_r$. If DNA gyrase introduces negative supercoils, which parameter is primarily altered?

- A. Twist (T_w) increases

- B. Writhe (W_r) becomes more positive
- C. Linking number (L_k) decreases
- D. The equation becomes invalid

Q5. The GroEL/GroES chaperonin system in *E. coli* facilitates protein folding by:

- A. Providing a hydrophobic chamber to unfold misfolded proteins
- B. Covalently modifying the polypeptide chain
- C. Using ATP hydrolysis to drive conformational changes in a hydrophilic folding chamber
- D. Acting as a primary ribosome-associated chaperone

Q6. Which specific lipid component strongly restricts the transition from the liquid-ordered to the liquid-disordered state in eukaryotic cell membranes, acting as a bidirectional fluidity buffer?

- A. Phosphatidylserine
- B. Sphingomyelin
- C. Cholesterol
- D. Cardiolipin

Q7. The Haldane relationship in enzyme kinetics relates the kinetic parameters (V_{max} and K_m) of the forward and reverse reactions to the:

- A. Activation energy
- B. Equilibrium constant (K_{eq})
- C. Catalytic efficiency
- D. Turnover number

Q8. Ribonuclease P (RNase P) is a true ribozyme responsible for which cellular process?

- A. Splicing of Group I introns
- B. Maturation of the 5' end of tRNAs
- C. Peptide bond formation in the ribosome
- D. Degradation of mRNA

Q9. A competitive inhibitor is added to an enzymatic reaction. To maintain the original reaction velocity (v_0) observed without the inhibitor, one must:

- A. Increase the enzyme concentration
- B. Decrease the substrate concentration
- C. Increase the substrate concentration to infinitely high levels
- D. Add an allosteric activator

Q10. Which of the following weak interactions is independent of the distance separating the interacting molecules?

- A. Van der Waals forces
- B. Hydrogen bonds
- C. Dipole-dipole interactions
- D. None of the above; all depend on distance

Q11. In gluconeogenesis, the highly exergonic pyruvate kinase step of glycolysis is bypassed by the coordinated action of which two enzymes?

- A. Pyruvate carboxylase and PEP carboxykinase
- B. Pyruvate dehydrogenase and malate dehydrogenase
- C. Fructose-1,6-bisphosphatase and glucose-6-phosphatase
- D. Hexokinase and phosphofructokinase-1

Q12. Which anaplerotic reaction is the most crucial for replenishing oxaloacetate directly from pyruvate in the mammalian liver?

- A. Malic enzyme
- B. Pyruvate carboxylase
- C. PEP carboxykinase
- D. Isocitrate lyase

Q13. During the Q cycle in Complex III of the electron transport chain, how many protons are pumped into the intermembrane space for every molecule of ubiquinol (QH_2) fully oxidized?

- A. 2
- B. 4
- C. 6
- D. 8

Q14. In the regulation of the cell cycle, the Anaphase-Promoting Complex/Cyclosome (APC/C) triggers chromatid separation by ubiquitinating:

- A. Separase
- B. Cohesin
- C. Securin
- D. Cyclin D

Q15. An antiporter transports Solute A down its concentration gradient to drive Solute B against its gradient. This is an example of:

- A. Primary active transport
- B. Facilitated diffusion
- C. Secondary active transport
- D. Receptor-mediated endocytosis

Q16. Activation of Adenylate Cyclase by a $G\alpha_s$ protein directly leads to the synthesis of cAMP, which subsequently activates:

- A. Phospholipase C
- B. Protein Kinase B (Akt)
- C. Protein Kinase A (PKA)
- D. Calmodulin

Q17. In the intrinsic pathway of apoptosis, the release of cytochrome c from mitochondria leads to the formation of the apoptosome, which directly activates:

- A. Caspase-3
- B. Caspase-8
- C. Caspase-9
- D. Caspase-12

Q18. Glycogen phosphorylase, the key enzyme in glycogen breakdown, is fully activated by:

- A. Dephosphorylation via protein phosphatase 1 (PP1)
- B. Phosphorylation via phosphorylase kinase
- C. Allosteric binding of ATP

D. High concentrations of glucose-6-phosphate

Q19. If the intracellular concentration of K^+ is 150 mM and the extracellular concentration is 5 mM, what is the approximate equilibrium potential for K^+ at 37°C? (Assume $RT/F \approx 26.7$ mV)

- A. -90 mV
- B. -60 mV
- C. +60 mV
- D. +90 mV

Q20. The stoichiometric number of protons required to synthesize one ATP molecule by ATP synthase is largely determined by:

- A. The number of α and β subunits in the F_1 head
- B. The number of c-subunits in the F_o rotor
- C. The length of the γ stalk
- D. The proton motive force generated by Complex I

Q21. The unphosphorylated form of the Retinoblastoma (Rb) protein halts the cell cycle by binding and inhibiting which transcription factor?

- A. p53
- B. E2F
- C. c-Myc
- D. NF- κ B

Q22. Receptor tyrosine kinases (RTKs) initiate intracellular signaling cascades when their phosphorylated tyrosine residues are recognized by proteins containing:

- A. PH domains
- B. SH2 domains
- C. Zinc fingers
- D. Leucine zippers

Q23. The mechanistic target of rapamycin (mTOR) is a central regulator of cell metabolism. Under conditions of nutrient starvation, mTOR is:

- A. Activated, promoting translation
- B. Inhibited, inducing autophagy

- C. Activated, inducing apoptosis
- D. Inhibited, promoting glycogen synthesis

Q24. Which configuration of the patch-clamp technique is best suited for recording the macroscopic currents of all channels present on the entire cell membrane?

- A. Cell-attached patch
- B. Inside-out patch
- C. Outside-out patch
- D. Whole-cell recording

Q25. Heterolactic fermentation differs from homolactic fermentation in that it produces:

- A. Only lactic acid
- B. Lactic acid, ethanol, and CO₂
- C. Lactic acid and acetic acid
- D. Only ethanol and CO₂

Q26. The cross-linking of peptidoglycan during bacterial cell wall synthesis is catalyzed by transpeptidases, which are the primary targets of:

- A. Tetracyclines
- B. Aminoglycosides
- C. β -lactam antibiotics
- D. Macrolides

Q27. SNARE proteins are critical for vesicular transport. The specific pairing of v-SNAREs and t-SNAREs provides the energy for:

- A. Vesicle budding from the ER
- B. Membrane fusion
- C. Cargo loading into the vesicle
- D. Receptor recycling

Q28. Many bacteria secrete siderophores under specific environmental conditions. The primary function of siderophores is to:

- A. Chelate and transport iron
- B. Neutralize extracellular toxins

- C. Communicate via quorum sensing
- D. Break down complex carbohydrates

Q29. During diauxic growth of *E. coli* on glucose and lactose, the catabolite activator protein (CAP) is strictly required for the transcription of the lac operon. CAP binds to DNA only when complexed with:

- A. Lactose
- B. Allolactose
- C. cAMP
- D. ATP

Q30. In the non-cyclic photophosphorylation pathway of chloroplasts, the ultimate source of electrons is:

- A. Water
- B. Plastocyanin
- C. NADH
- D. Photosystem I

Q31. The MoFe protein of nitrogenase contains the active site for nitrogen reduction. This complex reaction requires how many ATP molecules to fix one molecule of N_2 into two molecules of NH_3 ?

- A. 8
- B. 12
- C. 16
- D. 24

Q32. Methanogenic archaea utilize unique coenzymes. Which coenzyme serves as the terminal methyl carrier in the reduction of CO_2 to methane?

- A. Tetrahydrofolate
- B. Coenzyme M
- C. Methanofuran
- D. Factor 420 (F_{420})

Q33. Eukaryotic flagella and cilia display a characteristic 9+2 microtubule arrangement. In contrast, centrioles and basal bodies possess a structure of:

- A. Nine singlet microtubules
- B. Nine doublet microtubules
- C. Nine triplet microtubules
- D. A solid proteinaceous core

Q34. Plant peroxisomes (glyoxysomes) play a unique metabolic role during seed germination by converting:

- A. Glucose to starch
- B. Fatty acids to carbohydrates
- C. Amino acids to ammonia
- D. Lignin to cellulose

Q35. In a continuous bioreactor, if the dilution rate (D) exceeds the maximum specific growth rate (μ_{max}) of the microorganism, what phenomenon occurs?

- A. Stationary phase
- B. Catabolite repression
- C. Washout
- D. Biofilm formation

Q36. The Ames test is widely used to evaluate the mutagenic potential of chemical compounds. It typically employs a mutant strain of *Salmonella typhimurium* that is defective in the synthesis of:

- A. Tryptophan
- B. Histidine
- C. Leucine
- D. Methionine

Q37. Which type of transposable element utilizes an RNA intermediate and a reverse transcriptase for its mobility within the genome?

- A. Class I transposons (Retrotransposons)
- B. Class II transposons (DNA transposons)
- C. Insertion Sequences (IS elements)
- D. Composite transposons

Q38. Two different plasmids are considered "incompatible" if they:

- A. Carry different antibiotic resistance genes
- B. Cannot be transformed into the same host species
- C. Share the same replication control mechanism
- D. Both integrate into the host chromosome

Q39. Natural competence for transformation in bacteria like *Streptococcus pneumoniae* is triggered by the accumulation of a secreted signaling peptide known as a:

- A. Sigma factor
- B. Competence stimulating peptide (CSP)
- C. Bacteriocin
- D. Quorum-quenching lactonase

Q40. Histone acetylation is generally associated with transcriptional activation because it:

- A. Increases the positive charge on histones, tightening DNA binding
- B. Neutralizes the positive charge of lysine residues, loosening chromatin
- C. Recruits DNA methyltransferases
- D. Promotes the assembly of the 30 nm fiber

Q41. Intrinsic (Rho-independent) termination of transcription in prokaryotes relies on the formation of:

- A. A GC-rich stem-loop followed by a poly-U tract in the RNA
- B. A protein complex binding to the Rut site
- C. A TATA-box binding protein
- D. A premature stop codon

Q42. The extraordinary fidelity of protein synthesis is maintained largely by aminoacyl-tRNA synthetases, which possess:

- A. 5' to 3' exonuclease activity
- B. Double-strand break repair mechanisms
- C. Editing (hydrolytic) sites to remove mischarged amino acids
- D. Ribozyme activity

Q43. According to the wobble hypothesis, if the first anticodon base (5' end) is Inosine (I), it can pair with which bases in the third position of the codon?

- A. U, C, or A
- B. Only A or G
- C. Only U or C
- D. Any of the four bases (A, U, G, C)

Q44. Enhancers can activate transcription over vast distances. They typically achieve this by:

- A. Diffusing signaling molecules to the promoter
- B. Moving physically closer along the DNA backbone
- C. Forming chromatin loops facilitated by the Mediator complex
- D. Replicating the target gene multiple times

Q45. In a three-point testcross, if the observed number of double crossovers is significantly lower than the expected number calculated from single crossover frequencies, this indicates:

- A. Positive interference
- B. Negative interference
- C. Independent assortment
- D. Epistasis

Q46. A Robertsonian translocation involves the fusion of the long arms of two specific types of chromosomes, with the loss of their short arms. Which human chromosomes undergo this?

- A. Metacentric
- B. Submetacentric
- C. Acrocentric
- D. Telocentric

Q47. During DNA mismatch repair in *E. coli*, how does the MutS/MutL/MutH system distinguish the newly synthesized strand containing the error from the correct template strand?

- A. The template strand is heavily acetylated
- B. The template strand is methylated at GATC sequences

- C. The new strand contains Okazaki fragments
- D. The new strand lacks a 5' cap

Q48. For the CRISPR-Cas9 system to induce a double-strand break, the target DNA must be complementary to the guide RNA and immediately adjacent to a short sequence known as the:

- A. TATA box
- B. Protospacer Adjacent Motif (PAM)
- C. Shine-Dalgarno sequence
- D. Operator

Q49. A cross between two heterozygous mice for coat color yields a phenotypic ratio of 9 agouti : 3 black : 4 albino. This modified Mendelian ratio is a classic example of:

- A. Dominant epistasis
- B. Recessive epistasis
- C. Incomplete dominance
- D. Codominance

Q50. Genomic imprinting is an epigenetic phenomenon where the expression of an allele depends on its parent of origin. This parent-specific silencing is established via:

- A. DNA methylation during gametogenesis
- B. Histone acetylation in the zygote
- C. X-chromosome inactivation
- D. RNA interference

Q51. Full activation of a naive T cell requires two signals. Signal 1 is TCR-MHC peptide binding. Signal 2 is a costimulatory signal provided by the interaction between:

- A. CD4 and MHC Class II
- B. CD8 and MHC Class I
- C. CD28 on the T cell and B7 on the antigen-presenting cell
- D. Fas and FasL

Q52. Isotype (class) switching in B cells allows them to produce different antibody classes with the same antigen specificity. This process requires the enzyme:

- A. Recombinase Activating Gene (RAG) 1/2

- B. Activation-Induced Cytidine Deaminase (AID)
- C. Terminal Deoxynucleotidyl Transferase (TdT)
- D. DNA Polymerase η

Q53. The tuberculin skin test (Mantoux test) is a classic clinical example of which type of hypersensitivity reaction?

- A. Type I (IgE-mediated)
- B. Type II (Cytotoxic)
- C. Type III (Immune complex)
- D. Type IV (Delayed-type)

Q54. In the scale-up of an aerobic bioreactor, if the objective is to maintain a constant volumetric mass transfer coefficient (k_La), which operating parameter must usually be increased?

- A. Agitator speed
- B. Airflow rate (vvm)
- C. Both A and B
- D. Temperature

Q55. The Reynolds number (Re) characterizes the flow regime in a pipe or bioreactor. A Reynolds number greater than 4000 indicates:

- A. Laminar flow
- B. Transitional flow
- C. Turbulent flow
- D. Plug flow

Q56. The Del factor (∇) in industrial sterilization represents the natural logarithm of the ratio of initial to final spore concentration. A higher Del factor indicates:

- A. A less rigorous sterilization process
- B. A lower probability of contamination
- C. A lower required sterilization temperature
- D. A shorter holding time

Q57. Ammonium sulfate is frequently used in the primary recovery of proteins (salting out) because it:

- A. Denatures the target protein
- B. Decreases the solubility of proteins by competing for water of hydration
- C. Breaks disulfide bonds
- D. Acts as a strong reducing agent

Q58. In chromatography, the efficiency of a column is described by the number of theoretical plates (N). To achieve higher resolution, a column should have:

- A. A large N and a large Height Equivalent to a Theoretical Plate (HETP)
- B. A large N and a small HETP
- C. A small N and a large HETP
- D. A small N and a small HETP

Q59. When scaling up a stirred tank bioreactor based on the principle of constant power per unit volume (P/V), the impeller speed (N) in the larger vessel will typically be:

- A. Higher than in the smaller vessel
- B. Lower than in the smaller vessel
- C. Exactly the same
- D. Independent of the vessel geometry

Q60. Interferon- γ is a critical cytokine secreted primarily by Th1 cells and NK cells. Its primary immunological function is to:

- A. Activate macrophages and enhance cellular immunity
- B. Induce class switching to IgE
- C. Stimulate the production of eosinophils
- D. Downregulate MHC Class I expression

Q61. Consider a 4×4 matrix A . If all the rows of A are strictly identical to each other, what is the rank of matrix A ?

- A. 1
- B. 2
- C. 3
- D. 4

Q62. If a 3×3 matrix A has distinct real eigenvalues $\lambda_1, \lambda_2, \lambda_3$, the corresponding eigenvectors are guaranteed to be:

- A. Orthogonal
- B. Linearly dependent
- C. Linearly independent
- D. Unit vectors

Q63. For any square matrix, the sum of its eigenvalues is exactly equal to its:

- A. Determinant
- B. Trace
- C. Rank
- D. Nullity

Q64. Evaluate the limit: $\lim_{x \rightarrow 0} \frac{1 - \cos(x)}{x^2}$

- A. 0
- B. $1/2$
- C. 1
- D. ∞

Q65. A critical point of a two-variable function $f(x, y)$ is a local minimum if the determinant of its Hessian matrix is positive and:

- A. $\frac{\partial^2 f}{\partial x^2} < 0$
- B. $\frac{\partial^2 f}{\partial x^2} > 0$
- C. $\frac{\partial^2 f}{\partial x \partial y} = 0$
- D. The gradient is strictly non-zero

Q66. When changing the order of integration for the double integral $\int_0^1 \int_x^1 f(x, y) dy dx$, the new limits will be:

- A. $\int_0^1 \int_y^1 f(x, y) dx dy$
- B. $\int_0^1 \int_0^y f(x, y) dx dy$
- C. $\int_x^1 \int_0^1 f(x, y) dx dy$
- D. $\int_0^y \int_0^1 f(x, y) dx dy$

Q67. The Divergence Theorem relates a surface integral over a closed surface S to a volume integral over the enclosed region V . It states that $\iint_S \mathbf{F} \cdot d\mathbf{S}$ equals:

A. $\iiint_V (\nabla \times \mathbf{F}) dV$

B. $\iiint_V (\nabla \cdot \mathbf{F}) dV$

C. $\iiint_V \nabla f dV$

D. $\int_C \mathbf{F} \cdot d\mathbf{r}$

Q68. The differential equation $x^2 y'' - 3xy' + 4y = 0$ is an example of a:

A. Linear constant coefficient equation

B. Cauchy-Euler equation

C. Legendre polynomial equation

D. Bessel equation

Q69. In solving a non-homogeneous linear differential equation, the method of Variation of Parameters requires finding the Wronskian of:

A. The particular solutions

B. The fundamental solutions of the corresponding homogeneous equation

C. The forcing function and its derivative

D. The integrating factors

Q70. The logistic growth model is described by the ODE $\frac{dP}{dt} = rP(1 - \frac{P}{K})$. As time $t \rightarrow \infty$, the population $P(t)$ asymptotically approaches:

A. 0

B. r C. K D. ∞

Q71. In numerical integration, the global truncation error for the composite Trapezoidal rule is proportional to:

A. h B. h^2 C. h^3 D. h^4

Q72. The Secant method for finding the root of an equation $f(x) = 0$ requires how many initial guesses, and does it require the derivative $f'(x)$?

- A. One guess, derivative required
- B. One guess, derivative not required
- C. Two guesses, derivative required
- D. Two guesses, derivative not required

Q73. Newton's divided difference interpolation polynomial is particularly advantageous over Lagrange interpolation because:

- A. It prevents Runge's phenomenon completely
- B. It handles non-evenly spaced data points while Lagrange cannot
- C. It allows for the easy addition of new data points without recalculating previous terms
- D. It is exact for all transcendental functions

Q74. In a diagnostic test, the probability of a positive result given the disease is 0.95 (Sensitivity). If the disease prevalence is 0.01, finding the probability that a person has the disease given a positive result requires:

- A. Poisson distribution
- B. Bayes' theorem
- C. Central Limit Theorem
- D. Markov's inequality

Q75. In hypothesis testing, a Type II error occurs when the researcher:

- A. Rejects a true null hypothesis
- B. Fails to reject a false null hypothesis
- C. Accepts a false alternative hypothesis
- D. Chooses an incorrect significance level

Q76. Which continuous probability distribution possesses the "memoryless" property, making it ideal for modeling the time between independent random events?

- A. Normal distribution
- B. Uniform distribution
- C. Exponential distribution
- D. Weibull distribution

Q77. In simple linear regression ($y = \beta_0 + \beta_1 x + \epsilon$), the Ordinary Least Squares (OLS) estimator for the slope (β_1) minimizes:

- A. The sum of the absolute errors
- B. The sum of the squared residuals
- C. The perpendicular distance from points to the line
- D. The maximum absolute error

Q78. If P is an orthogonal projection matrix onto a subspace, which of the following properties must P satisfy?

- A. $P = P^{-1}$
- B. $P^2 = P$ and $P = P^T$
- C. $\text{Det}(P) = 1$
- D. $\text{Trace}(P) = 0$

Q79. The Taylor series expansion of $f(x) = e^x$ centered at $x = 0$ (Maclaurin series) is:

- A. $\sum_{n=0}^{\infty} (-1)^n \frac{x^{2n}}{(2n)!}$
- B. $\sum_{n=0}^{\infty} \frac{x^n}{n!}$
- C. $\sum_{n=0}^{\infty} (-1)^n \frac{x^{2n+1}}{(2n+1)!}$
- D. $\sum_{n=1}^{\infty} \frac{x^n}{n}$

Q80. The explicit Euler method for solving initial value problems numerically is considered conditionally stable. Its stability relies heavily on:

- A. Choosing a sufficiently large step size h
- B. Choosing a sufficiently small step size h
- C. The function being linear
- D. The function being independent of t

Q81. "Centrifuge" is to "Sedimentation" as "Thermocycler" is to:

- A. Electrophoresis
- B. Amplification
- C. Distillation
- D. Chromatography

Q82. Find the odd one out from the group of laboratory techniques:

- A. SDS-PAGE
- B. Agarose Gel Electrophoresis
- C. Isoelectric Focusing
- D. Mass Spectrometry

Q83. If "PROTEIN" is coded as "OQNUDHM", what will be the code for "MUTATION"? (Pattern: shift each letter by -1)

- A. LTSZSHNM
- B. LVUBSJPO
- C. LVSZSHNM
- D. NVSZSHPO

Q84. Complete the numerical series: 2, 5, 11, 23, 47, ?

- A. 95
- B. 94
- C. 97
- D. 89

Q85. Statements: All enzymes are catalysts. No catalyst is a lipid.
Conclusions: I. No enzyme is a lipid. II. Some lipids are enzymes.

- A. Only I follows
- B. Only II follows
- C. Both I and II follow
- D. Neither I nor II follows

Q86. Which Venn diagram correctly represents the relationship between "Antibodies", "Immunoglobulins", and "T-cell receptors"?

- A. Immunoglobulins strictly encompass Antibodies, while T-cell receptors form a separate intersecting circle.
- B. Antibodies and Immunoglobulins are the exact same circle, T-cell receptors are entirely separate.
- C. Three overlapping circles.

D. Antibodies inside T-cell receptors, Immunoglobulins outside.

Q87. Pointing to a boy in a photograph, Reena said, "He is the only son of the only child of my grandfather." How is Reena related to that boy?

- A. Mother
- B. Aunt
- C. Sister
- D. Cousin

Q88. Six people (P, Q, R, S, T, U) are sitting around a circular table facing the center. P is between T and S. U is between Q and R. T is to the immediate right of Q. Who is sitting to the immediate left of S?

- A. P
- B. R
- C. U
- D. Q

Q89. A bioreactor's dissolved oxygen drops from 100% to 20% linearly over 40 minutes, then remains stable. If the critical oxygen limit is 30%, at what time did the reactor cross into the critical zone?

- A. 25 minutes
- B. 30 minutes
- C. 35 minutes
- D. 40 minutes

Q90. There are three boxes labeled "DNA", "RNA", and "DNA & RNA". Every single box is incorrectly labeled. You are allowed to sequence one molecule from one box. Which box should you pick from to accurately deduce the contents of all three boxes?

- A. The "DNA" box
- B. The "RNA" box
- C. The "DNA & RNA" box
- D. It is impossible to tell

Solutions

1. Answer: C

Explanation: The MWC (symmetry) model posits that all subunits of an allosteric enzyme must exist in the same conformation (either all T or all R). This maintains the structural symmetry of the oligomeric protein during transitions, unlike the KNF model which allows mixed intermediate states.

2. Answer: B

Explanation: The Ramachandran plot's bottom right quadrant corresponds to positive ϕ and negative ψ angles. For all L-amino acids (except glycine), this combination causes a severe steric clash between the side chain and the peptide backbone's carbonyl oxygen.

3. Answer: C

Explanation: In mixed inhibition where the inhibitor favors the enzyme-substrate complex ($\alpha' > \alpha$), both the apparent V_{max} and K_m decrease. This causes the lines on a Lineweaver-Burk plot to intersect in the second quadrant (top left).

4. Answer: C

Explanation: DNA gyrase (a type II topoisomerase) uses ATP to actively introduce negative supercoils into closed circular DNA. This mathematically results in a decrease in the overall Linking number (L_k) of the DNA molecule.

5. Answer: C

Explanation: The GroEL/GroES complex forms a cylindrical chamber. ATP hydrolysis drives a conformational change that expands and encapsulates the misfolded protein in a largely hydrophilic environment, encouraging it to refold properly by burying its hydrophobic residues.

6. Answer: C

Explanation: Cholesterol acts as a bidirectional fluidity buffer in eukaryotic membranes. Its rigid steroid ring prevents hydrocarbon chains from packing too closely at low temperatures, while simultaneously restricting their excessive movement at high temperatures.

7. Answer: B

Explanation: The Haldane relationship proves that kinetic parameters are strictly constrained by thermodynamics. It mathematically links the V_{max} and K_m values of an enzyme's forward and reverse reactions directly to the reaction's equilibrium constant (K_{eq}).

8. Answer: B

Explanation: Ribonuclease P (RNase P) is an endonuclease essential for tRNA maturation. It is a classic ribozyme, meaning its catalytic activity resides entirely within its RNA component, which specifically cleaves the 5' leader sequence from precursor tRNAs.

9. Answer: C

Explanation: A competitive inhibitor binds reversibly to the active site, competing directly with the substrate. By increasing the substrate concentration to infinitely high levels, the substrate can completely outcompete the inhibitor, restoring the original V_{max} .

10. Answer: D

Explanation: All standard non-covalent weak interactions depend heavily on the distance between the interacting molecules. Van der Waals forces decay at $1/r^6$, dipole-dipole at $1/r^3$, and even long-range ionic interactions follow an inverse square law ($1/r^2$).

11. Answer: A

Explanation: The conversion of PEP to pyruvate by pyruvate kinase in glycolysis is highly exergonic and irreversible. Gluconeogenesis bypasses this by first converting pyruvate to oxaloacetate (via pyruvate carboxylase) and then to PEP (via PEP carboxykinase).

12. Answer: B

Explanation: Anaplerotic reactions replenish TCA cycle intermediates. The most significant anaplerotic reaction in the mammalian liver is catalyzed by pyruvate carboxylase, which directly converts pyruvate and bicarbonate into oxaloacetate.

13. Answer: B

Explanation: During the Q cycle in Complex III, the oxidation of one molecule of ubiquinol (QH_2) releases 2 protons directly. The cycle's complex electron routing ultimately results in a total of 4 protons being pumped into the intermembrane space per QH_2 oxidized.

14. Answer: C

Explanation: The APC/C is an E3 ubiquitin ligase that triggers the metaphase-to-anaphase transition. It ubiquitinates securin, marking it for degradation. The destruction of securin releases the enzyme separase, which then cleaves the cohesin rings holding sister chromatids together.

15. Answer: C

Explanation: Secondary active transport relies on the electrochemical gradient of one solute (often established previously by primary active transport) to drive the transport of another solute against its gradient. Antiporters move these solutes in opposite directions.

16. Answer: C

Explanation: When a G-protein coupled receptor activates a G_{α_s} subunit, it stimulates Adenylate Cyclase to convert ATP into cyclic AMP (cAMP). The accumulated cAMP acts as a secondary messenger to allosterically activate Protein Kinase A (PKA).

17. Answer: C

Explanation: In the intrinsic apoptotic pathway, cytochrome c released from mitochondria binds to Apaf-1. This triggers the assembly of the heptameric apoptosome complex, which recruits and directly activates the initiator caspase, Caspase-9.

18. Answer: B

Explanation: Glycogen phosphorylase is regulated by covalent modification. It is converted from its less active 'b' form to its fully active 'a' form via phosphorylation by the enzyme phosphorylase kinase, a process stimulated by glucagon or epinephrine signaling.

19. Answer: A

Explanation: Using the Nernst equation for K^+ at body temperature (37°C):
 $E_K \approx 61.5 \times \log_{10}([K^+]_{out}/[K^+]_{in})$. Substituting the values gives $61.5 \times \log_{10}(5/150) \approx 61.5 \times (-1.477) \approx -90.8 \text{ mV}$.

20. Answer: B

Explanation: The F_o rotor of ATP synthase consists of a ring of c-subunits. The number of c-subunits determines how many protons must flow through the complex to complete one full 360° rotation, which inherently synthesizes exactly 3 ATP molecules.

21. Answer: B

Explanation: The Retinoblastoma (Rb) protein acts as a critical G1 checkpoint guardian. In its hypophosphorylated (active) state, it strongly binds and inhibits the E2F transcription factor family, preventing the transcription of genes necessary for S-phase entry.

22. Answer: B

Explanation: Upon ligand binding, RTKs dimerize and autophosphorylate their intracellular tyrosine residues. These newly formed phosphotyrosines serve as high-affinity docking sites for downstream signaling proteins containing Src Homology 2 (SH2) domains.

23. Answer: B

Explanation: mTOR is a master regulator that promotes cell growth when nutrients are abundant. Under conditions of nutrient starvation or cellular stress, mTOR is actively inhibited, which shuts down anabolic processes and induces catabolic autophagy for survival.

24. Answer: D

Explanation: In whole-cell patch-clamp recording, the membrane patch inside the pipette is ruptured via suction. This establishes electrical and fluid continuity with the cell's interior, allowing the measurement of macroscopic currents from the entire cell membrane.

25. Answer: B

Explanation: Homolactic fermenters convert glucose almost entirely into lactic acid using the aldolase enzyme. Heterolactic fermenters lack aldolase and instead use the phosphoketolase pathway, producing a mixture of lactic acid, ethanol, and CO_2 .

26. Answer: C

Explanation: Transpeptidases (often called Penicillin-Binding Proteins or PBPs) cross-link the peptidoglycan chains to strengthen the bacterial cell wall. β -lactam antibiotics physically mimic the D-Ala-D-Ala substrate, irreversibly binding and inactivating these enzymes.

27. Answer: B

Explanation: Vesicle fusion is a highly unfavorable process thermodynamically. The spontaneous, highly stable pairing of v-SNAREs (on the vesicle) and t-SNAREs (on the target membrane) into a four-helix bundle provides the necessary mechanical force to drive membrane fusion.

28. Answer: A

Explanation: Iron is biologically essential but highly insoluble in aerobic environments at neutral pH. Bacteria secrete siderophores—small, high-affinity iron-chelating compounds—to scavenge ferric iron (Fe^{3+}) from the environment and transport it back into the cell.

29. Answer: C

Explanation: The Catabolite Activator Protein (CAP) requires cyclic AMP (cAMP) as an allosteric effector. When glucose levels drop, cAMP levels rise, complexing with CAP. This complex binds near the lac promoter to recruit RNA polymerase, enabling diauxic shift.

30. Answer: A

Explanation: In non-cyclic photophosphorylation (the Z-scheme), electrons are continually extracted from the environment to reduce $NADP^+$. The ultimate source of these electrons is water, which is photolyzed at the oxygen-evolving complex of Photosystem II.

31. Answer: C

Explanation: Biological nitrogen fixation is highly energy-intensive due to the stable triple bond of N_2 . The reduction of one molecule of N_2 to two molecules of ammonia (NH_3) strictly requires 8 electrons and the hydrolysis of 16 ATP molecules.

32. Answer: B

Explanation: Methanogenesis involves unique C1 carrier coenzymes. Coenzyme M (CoM) carries the methyl group in the final, energy-conserving step, where methyl-CoM is reduced by the methyl-coenzyme M reductase to release methane gas.

33. Answer: C

Explanation: While motile cilia and flagella have a $9 + 2$ arrangement of microtubule doublets, the basal bodies that anchor them (and the closely related centrioles) consist of a distinct cylindrical array of nine microtubule triplets with no central pair ($9 + 0$).

34. Answer: B

Explanation: During early germination before photosynthesis is possible, plant seeds rely on glyoxysomes. These specialized peroxisomes execute the glyoxylate cycle, allowing the net conversion of stored lipid fatty acids into carbohydrates (sucrose) to fuel growth.

35. Answer: C

Explanation: In a chemostat, the specific growth rate (μ) adjusts to equal the dilution rate (D). If D is increased beyond the organism's biological maximum growth rate (μ_{max}), the cells are removed faster than they can divide, resulting in system "washout."

36. Answer: B

Explanation: The Ames test utilizes specific histidine auxotrophs (His^-) of *Salmonella typhimurium*. These mutants cannot grow on media lacking histidine unless a mutagenic chemical causes a reverse mutation, restoring their ability to synthesize the amino acid.

37. Answer: A

Explanation: Class I transposons, or retrotransposons, mobilize via a "copy-and-paste" mechanism. They are transcribed into an RNA intermediate, which is then reverse-transcribed back into DNA by a reverse transcriptase before integrating elsewhere in the genome.

38. Answer: C

Explanation: Plasmid incompatibility arises when two distinct plasmids utilize the exact same origin of replication or replication control machinery (Rep proteins/RNAs). They compete for the same host resources, preventing both from being stably maintained in the same lineage.

39. Answer: B

Explanation: Natural competence in many Gram-positive bacteria like *S. pneumoniae* is density-dependent (quorum sensing). It is triggered by the extracellular accumulation of a specific signaling autoinducer known as the Competence Stimulating Peptide (CSP).

40. Answer: B

Explanation: Histone acetyltransferases (HATs) add acetyl groups to the positively charged lysine residues on histone tails. This neutralizes their positive charge, weakening their electrostatic affinity for the negatively charged DNA backbone, thereby loosening chromatin for transcription.

41. Answer: A

Explanation: Rho-independent termination relies on the transcribed RNA itself. The RNA forms a stable, GC-rich hairpin (stem-loop) structure immediately followed by a run of weak Uridine-Adenine (U-A) base pairs, causing the RNA polymerase to pause and physically dissociate.

42. Answer: C

Explanation: Aminoacyl-tRNA synthetases are remarkably accurate because many possess a secondary "editing" or hydrolytic active site. If an incorrect (but structurally similar) amino acid is attached to the tRNA, this site recognizes and hydrolyzes the errant bond.

43. Answer: A

Explanation: According to Crick's Wobble Hypothesis, the 5' base of the anticodon has relaxed pairing rules. An Inosine (I) at this wobble position can successfully form hydrogen bonds with Uracil (U), Cytosine (C), or Adenine (A) in the 3' position of the mRNA codon.

44. Answer: C

Explanation: Enhancers act independently of distance or orientation because the flexible DNA backbone loops back on itself. This brings the enhancer-bound transcription factors into direct physical contact with the promoter, stabilized by the large Mediator protein complex.

45. Answer: A

Explanation: Interference measures how one crossover event affects the probability of a second nearby. Positive interference occurs when the presence of one crossover physically or mechanistically inhibits the formation of a second, resulting in fewer double crossovers than expected.

46. Answer: C

Explanation: A Robertsonian translocation is a specific chromosomal rearrangement where the long (q) arms of two acrocentric chromosomes (such as chromosomes 13, 14, 15, 21, or 22) fuse at the centromere, with the tiny, non-essential short (p) arms usually being lost.

47. Answer: B

Explanation: In *E. coli*, the enzyme Dam methylase adds methyl groups to adenines in GATC sequences. Immediately following replication, the parental template strand is methylated, but the newly synthesized daughter strand is temporarily unmethylated, allowing the repair machinery to distinguish them.

48. Answer: B

Explanation: The Cas9 endonuclease relies on the guide RNA for sequence targeting, but it cannot bind or cleave the DNA unless the target sequence is immediately flanked by a brief, specific sequence called the Protospacer Adjacent Motif (PAM, typically NGG).

49. Answer: B

Explanation: A 9:3:4 phenotypic ratio is characteristic of recessive epistasis. This occurs when the homozygous recessive genotype at one locus (e.g., preventing any pigment deposition, causing albinism) completely masks the phenotypic expression of alleles at a second locus.

50. Answer: A

Explanation: Genomic imprinting is an epigenetic mechanism where specific genes are monoallelically silenced based on the parent of origin. This parent-specific silencing is established primarily through heavy DNA methylation at imprint control regions during gametogenesis.

51. Answer: C

Explanation: For a naive T cell to become fully activated, it requires both antigen recognition (Signal 1 via TCR) and a robust costimulatory signal (Signal 2). Signal 2 is mediated by the binding of CD28 on the T cell surface to B7 (CD80/86) molecules on the APC.

52. Answer: B

Explanation: Class switch recombination changes the antibody heavy chain constant region (e.g., from IgM to IgG). This process is initiated by Activation-Induced Cytidine Deaminase (AID), which deaminates cytosines to uracils in switch regions, triggering DNA double-strand breaks.

53. Answer: D

Explanation: The Mantoux (tuberculin) test is a classic Type IV, or delayed-type, hypersensitivity reaction. It is not antibody-mediated; rather, it takes 48-72 hours because it relies on the recruitment and activation of memory Th1 cells and macrophages at the injection site.

54. Answer: C

Explanation: The volumetric mass transfer coefficient (k_La) dictates oxygen transfer efficiency. During bioreactor scale-up, to keep k_La constant and prevent oxygen starvation, engineers typically manipulate both the agitator speed (power input) and the sparged airflow rate (vvm).

55. Answer: C

Explanation: The Reynolds number (Re) is a dimensionless parameter ratio of inertial to viscous forces. In pipes or standard geometries, an $Re < 2100$ indicates smooth, laminar flow, while an $Re > 4000$ indicates chaotic, fully turbulent flow.

56. Answer: B

Explanation: The Del factor ($\nabla = \ln(N_0/N_t)$) quantifies the stringency of a sterilization protocol. A higher Del factor indicates a massive reduction in the target microbial population, translating directly to a much lower statistical probability of survival and contamination.

57. Answer: B

Explanation: Ammonium sulfate is highly soluble and strongly kosmotropic. At high concentrations, it heavily outcompetes the protein molecules for binding to water. Stripped of their hydration shells, hydrophobic patches on proteins interact, causing them to aggregate and "salt out".

58. Answer: B

Explanation: Column efficiency in chromatography is maximized when the peak broadening is minimal. This corresponds to having a very high number of theoretical plates (N) crammed into the column, which inherently requires each plate to have a very small height (HETP).

59. Answer: B

Explanation: When scaling up maintaining constant P/V , the power depends on $N^3 D^5$ and volume on D^3 . As the impeller diameter (D) increases in the larger vessel, the required impeller rotational speed (N) must be significantly reduced to keep the P/V ratio constant.

60. Answer: A

Explanation: Interferon- γ (Type II interferon) is the defining cytokine of the Th1 subset. Its primary role is to heavily activate macrophages (increasing their microbicidal activity) and to upregulate MHC molecule expression, driving a strong cell-mediated immune response.

61. Answer: A

Explanation: The rank of a matrix is the maximum number of linearly independent row or column vectors. Since all four rows are exactly identical, three of them can be reduced to zero via row operations, leaving only one linearly independent row. Thus, the rank is 1.

62. Answer: C

Explanation: A fundamental theorem of linear algebra states that eigenvectors corresponding to distinct eigenvalues of any square matrix are strictly linearly independent. They only guarantee orthogonality if the matrix is symmetric.

63. Answer: B

Explanation: For any $n \times n$ square matrix, the sum of all its eigenvalues (counting multiplicities) is mathematically identical to the trace of the matrix, which is defined as the sum of the elements along the main diagonal.

64. Answer: B

Explanation: Applying L'Hôpital's rule twice (due to the $0/0$ form) or using the

Maclaurin series for $\cos(x) \approx 1 - x^2/2$, the expression becomes $(1 - (1 - x^2/2))/x^2 = (x^2/2)/x^2 = 1/2$.

65. Answer: B

Explanation: By the Second Derivative Test for functions of two variables, a critical point is a local minimum if the determinant of the Hessian ($D = f_{xx}f_{yy} - (f_{xy})^2$) is strictly positive, AND the second partial derivative with respect to x (f_{xx}) is also strictly positive.

66. Answer: B

Explanation: The original limits specify a triangular region: y goes from x to 1, and x goes from 0 to 1. Graphing this shows the region is bounded by $y = x$, $y = 1$, and $x = 0$. Changing the order to $dx dy$, x goes from 0 to y , and y goes from 0 to 1.

67. Answer: B

Explanation: The Divergence Theorem (Gauss's Theorem) states that the outward flux of a vector field $\mathbf{F}$ across a closed surface S is equal to the volume integral of the divergence of $\mathbf{F}$ ($\nabla \cdot \mathbf{F}$) over the region V enclosed by the surface.

68. Answer: B

Explanation: A Cauchy-Euler equation is a linear differential equation where the power of the independent variable coefficient precisely matches the order of the derivative ($ax^n y^{(n)} + bx^{n-1} y^{(n-1)} \dots = 0$). The given equation perfectly fits this definition.

69. Answer: B

Explanation: The method of Variation of Parameters for a non-homogeneous ODE ($y'' + p(x)y' + q(x)y = g(x)$) requires constructing the Wronskian determinant solely from the linearly independent fundamental solutions (y_1, y_2) of the associated homogeneous ODE.

70. Answer: C

Explanation: In the logistic growth equation, r represents the intrinsic growth rate and K represents the carrying capacity. As the population P approaches K , the term $(1 - P/K)$ approaches 0, reducing the growth rate to zero and causing $P(t)$ to asymptote at K .

71. Answer: B

Explanation: While the local truncation error (error on a single sub-interval) for the Trapezoidal rule is proportional to $O(h^3)$, the global truncation error accumulated over the entire integration domain drops by one order of h , scaling proportionally to $O(h^2)$.

72. Answer: D

Explanation: The Secant method is a root-finding algorithm that uses a succession of roots of secant lines. It requires two initial guesses to draw the first secant line, but crucially, it does not require the evaluation of the function's derivative.

73. Answer: C

Explanation: Newton's divided difference polynomial is constructed iteratively. Unlike the Lagrange method (which requires complete recalculation of the entire polynomial if a data point is added), the Newton method allows new points to be

incorporated simply by adding higher-order terms.

74. Answer: B

Explanation: Calculating the probability of having a disease given a positive test result ($P(\text{Disease}|\text{Positive})$) requires reversing the conditional probabilities ($P(\text{Positive}|\text{Disease})$). This inversion of conditional probabilities is specifically solved using Bayes' Theorem.

75. Answer: B

Explanation: In statistical hypothesis testing, a Type I error is rejecting a true null hypothesis (false positive). A Type II error occurs when the researcher fails to reject a null hypothesis that is actually false in reality (a false negative).

76. Answer: C

Explanation: The exponential distribution is the only continuous probability distribution that possesses the "memoryless" property. This means that the probability of an event occurring in the next interval is completely independent of how much time has already elapsed.

77. Answer: B

Explanation: The Ordinary Least Squares (OLS) algorithm determines the best-fitting line through a set of data points by explicitly minimizing the sum of the squares of the vertical residuals (the differences between the observed and predicted y values).

78. Answer: B

Explanation: A matrix P represents an orthogonal projection onto a subspace if and only if it is idempotent (applying it twice yields the same result, $P^2 = P$) and it is symmetric ($P = P^T$).

79. Answer: B

Explanation: The Maclaurin series represents a function as an infinite sum of terms calculated from its derivatives at zero. Because the derivative of e^x is always e^x , and $e^0 = 1$, the expansion elegantly simplifies to $\sum_{n=0}^{\infty} \frac{x^n}{n!}$.

80. Answer: B

Explanation: Explicit Euler is a conditionally stable numerical method. For the numerical solution to remain bounded and not diverge wildly from the true solution, the step size h must be chosen to be strictly smaller than a specific stability threshold determined by the system's eigenvalues.

81. Answer: B

Explanation: A "Centrifuge" is the specific laboratory instrument used to perform the process of "Sedimentation". Analogously, a "Thermocycler" is the specific instrument used to perform the process of DNA "Amplification" (via PCR).

82. Answer: D

Explanation: SDS-PAGE, Agarose Gel Electrophoresis, and Isoelectric Focusing are all techniques that separate biomolecules primarily using an applied electric field. Mass Spectrometry is the odd one out, separating ionized fragments based purely on their mass-to-charge (m/z) ratio.

83. Answer: A

Explanation: The coding pattern involves shifting each letter backward by one

position in the alphabet (-1 shift). Applying this to "MUTATION": M becomes L, U becomes T, T becomes S, A becomes Z, T becomes S, I becomes H, O becomes N, N becomes M. This yields LTSZSHNM.

84. Answer: A

Explanation: The logic of this numerical series involves multiplying the previous term by 2 and then adding 1. ($2 \times 2 + 1 = 5$; $5 \times 2 + 1 = 11$; $11 \times 2 + 1 = 23$; $23 \times 2 + 1 = 47$). Therefore, the next term is $47 \times 2 + 1 = 95$.

85. Answer: A

Explanation: If "All enzymes are catalysts" ($\text{Enzymes} \subset \text{Catalysts}$) and "No catalyst is a lipid" ($\text{Catalysts} \cap \text{Lipids} = \emptyset$), it logically follows that the set of Enzymes cannot intersect with Lipids. Thus, Conclusion I (No enzyme is a lipid) strictly follows. Conclusion II is false.

86. Answer: A

Explanation: Biologically, all secreted antibodies belong to the broader superfamily of immunoglobulins (which also includes membrane-bound forms). Therefore, Antibodies are a subset inside Immunoglobulins. T-cell receptors belong to the Ig superfamily but are distinct from immunoglobulins/antibodies.

87. Answer: C

Explanation: "The only child of my grandfather" refers to Reena's parent (mother or father). "The only son of [my parent]" refers to Reena's brother. Since the boy in the photograph is her brother, Reena is the sister to that boy.

88. Answer: B

Explanation: Arranging the statements clockwise: T is right of Q ($Q \rightarrow T$). P is between T S ($T \rightarrow P \rightarrow S$). U is between Q R ($R \rightarrow U \rightarrow Q$). The full circle clockwise is $R \rightarrow U \rightarrow Q \rightarrow T \rightarrow P \rightarrow S$. Facing the center, the person immediately to the left (clockwise) of S is R.

89. Answer: C

Explanation: The dissolved oxygen drops 80% (from 100% to 20%) over 40 minutes, which is a steady rate of 2% per minute. To reach the critical 30% threshold, it must drop 70% from the starting point. This drop takes $70\%/2\% \text{ per min} = 35$ minutes.

90. Answer: C

Explanation: Because every label is completely wrong, the box labeled "DNA & RNA" must contain only one component. By pulling one molecule from the "DNA & RNA" box (e.g., DNA), you immediately know its true identity (DNA). The rest can be logically deduced.