1. **Foundational Comprehension:** Which hormone is correctly paired with its primary effect?  
   A. Insulin – increases blood glucose  
   B. Glucagon – promotes glycogen synthesis  
   C. Cortisol – mobilizes glucose during stress  
   D. Calcitonin – raises serum calcium  
   **Answer:** C. Cortisol – mobilizes glucose during stress.  
   **Explanation:** Cortisol increases blood glucose and is part of stress response; insulin decreases glucose, glucagon raises glucose by promoting gluconeogenesis/glycogenolysis; calcitonin lowers blood calcium.
2. **Application:** A patient with weight gain, high blood pressure, and excess cortisol likely has:  
   A. Addison’s disease  
   B. Cushing’s syndrome  
   C. Hyperthyroidism  
   D. Type 1 diabetes  
   **Answer:** B. Cushing’s syndrome.  
   **Explanation:** Excess cortisol leads to central obesity, hypertension characteristic of Cushing’s.
3. **Foundational Comprehension:** The mnemonic “GFR – Salt, Sugar, Sex” helps recall hormones from which organ?  
   A. Pituitary gland  
   B. Thyroid gland  
   C. Adrenal cortex  
   D. Pancreas  
   **Answer:** C. Adrenal cortex.  
   **Explanation:** Glomerulosa (salt=aldosterone), Fasciculata (sugar=cortisol), Reticularis (sex=androgens).
4. **Reasoning:** In primary hypothyroidism, what pattern of hormone levels is expected?  
   A. Low TSH, high T3/T4  
   B. High TSH, low T3/T4  
   C. Low TSH, low T3/T4  
   D. High TSH, high T3/T4  
   **Answer:** B. High TSH, low T3/T4.  
   **Explanation:** Thyroid failure leads to low thyroid hormones; pituitary increases TSH attempting compensation.
5. **Foundational Comprehension:** Which of the following best describes negative feedback in endocrine systems?  
   A. Hormone release triggers further amplification of the same signal  
   B. End-product accumulation suppresses upstream hormone secretion  
   C. Hormone levels remain constant regardless of change  
   D. Hormones degrade other hormones directly  
   **Answer:** B. End-product accumulation suppresses upstream hormone secretion.  
   **Explanation:** Negative feedback maintains homeostasis by reducing output when sufficient product exists.
6. **Application:** In Type 2 diabetes, the main defect is:  
   A. Autoimmune destruction of beta cells  
   B. Insulin resistance in target tissues  
   C. Lack of glucagon production  
   D. Excess cortisol production  
   **Answer:** B. Insulin resistance in target tissues.  
   **Explanation:** Type 2 diabetes involves peripheral insulin resistance, unlike Type 1 which is autoimmune insulin deficiency.
7. **Reasoning Beyond Text:** An acute stressor elevates blood glucose rapidly; this is mediated primarily through:  
   A. Aldosterone  
   B. Insulin  
   C. Epinephrine  
   D. Thyroxine  
   **Answer:** C. Epinephrine.  
   **Explanation:** Epinephrine mimics glucagon’s effect under stress to raise blood glucose for energy.
8. **Foundational Comprehension:** Which hormone is lipid-soluble and acts intracellularly?  
   A. Insulin  
   B. Growth hormone  
   C. Thyroid hormone  
   D. Epinephrine  
   **Answer:** C. Thyroid hormone.  
   **Explanation:** Thyroid hormones (T3/T4) are amino acid–derived but act intracellularly; steroid hormones also lipid-soluble. Peptide hormones like insulin act on surface receptors.
9. **Application:** A patient skipping breakfast on insulin therapy becomes sweaty, shaky, and confused because:  
   A. They have hyperglycemia from excess insulin  
   B. They are experiencing hypoglycemia due to insulin without substrate  
   C. Their cortisol is too high  
   D. They have increased glucagon secretion  
   **Answer:** B. They are experiencing hypoglycemia due to insulin without substrate.  
   **Explanation:** Insulin lowers blood glucose; without intake, hypoglycemia occurs.
10. **Test-Taking Strategy:** If a question asks which hormone both increases blood glucose and is released during stress, the best answer is:  
    A. Insulin  
    B. Aldosterone  
    C. Glucagon  
    D. Epinephrine  
    **Answer:** D. Epinephrine.  
    **Explanation:** Epinephrine is stress hormone that raises glucose; glucagon also does but not classically the acute “fight-or-flight” mediator.

 **Foundational Comprehension:** According to the central dogma, information flows:  
A. RNA → DNA → Protein  
B. DNA → Protein → RNA  
C. DNA → RNA → Protein  
D. Protein → RNA → DNA  
**Answer:** C. DNA → RNA → Protein.  
**Explanation:** Central dogma describes transcription followed by translation.

 **Foundational Comprehension:** During DNA replication, which enzyme is responsible for joining Okazaki fragments?  
A. Helicase  
B. DNA polymerase  
C. Ligase  
D. RNA polymerase  
**Answer:** C. Ligase.  
**Explanation:** Ligase seals nicks between Okazaki fragments on lagging strand.

 **Application:** A mutation that changes a codon to a stop codon is called:  
A. Silent mutation  
B. Missense mutation  
C. Nonsense mutation  
D. Frameshift mutation  
**Answer:** C. Nonsense mutation.  
**Explanation:** Introduces premature stop, truncating protein.

 **Foundational Comprehension:** In Mendelian inheritance, which law states that alleles for different genes assort independently?  
A. Law of Segregation  
B. Law of Independent Assortment  
C. Law of Dominance  
D. Hardy-Weinberg equilibrium  
**Answer:** B. Law of Independent Assortment.  
**Explanation:** Traits are inherited independently if genes are unlinked.

 **Application:** In a population in Hardy-Weinberg equilibrium, if p = 0.7, what is the expected frequency of heterozygotes?  
A. 0.09  
B. 0.42  
C. 0.49  
D. 0.21  
**Answer:** B. 0.42.  
**Explanation:** 2pq = 2\*(0.7)\*(0.3)=0.42.

 **Foundational Comprehension:** Which tool would you use to detect RNA expression levels?  
A. Southern blot  
B. Western blot  
C. Northern blot  
D. ELISA  
**Answer:** C. Northern blot.  
**Explanation:** Northern detects RNA; Southern for DNA, Western for protein.

 **Application:** CRISPR-Cas9 is best described as:  
A. A DNA replication enzyme  
B. A method to amplify DNA sequences  
C. A precise gene-editing tool  
D. A type of blotting technique  
**Answer:** C. A precise gene-editing tool.  
**Explanation:** CRISPR allows targeted genomic edits.

 **Reasoning Within the Text:** A researcher uses restriction enzymes to cut DNA and insert a corrected gene into a plasmid, then introduces it into bacteria. This is an example of:  
A. Hardy-Weinberg equilibrium  
B. Recombinant DNA technology  
C. Mendelian segregation  
D. Northern blotting  
**Answer:** B. Recombinant DNA technology.  
**Explanation:** Combining DNA from different sources via vectors uses recombinant DNA.

 **Foundational Comprehension:** A frameshift mutation caused by a single base insertion will likely:  
A. Have no effect on protein sequence  
B. Change a single amino acid only  
C. Alter the reading frame downstream, drastically changing the protein  
D. Create a premature stop codon without shifting frame  
**Answer:** C. Alter the reading frame downstream, drastically changing the protein.  
**Explanation:** Insertions/deletions not in multiples of three shift codons, changing many residues.

 **Test-Taking Strategy:** If a question describes a phenotype that appears in every generation and affects males and females equally, the most likely inheritance pattern is:  
A. Autosomal recessive  
B. X-linked recessive  
C. Autosomal dominant  
D. Mitochondrial  
**Answer:** C. Autosomal dominant.  
**Explanation:** Dominant traits appear every generation and affect sexes equally.

1. **Reasoning Beyond the Text:** A patient with a mutation in a gene regulating cortisol production shows dysregulated stress responses. Understanding the central dogma is essential because:  
   A. Hormones are mutated directly in the bloodstream  
   B. Gene mutation affects protein (enzyme/receptor) synthesis altering cortisol regulation  
   C. DNA mutations only affect reproductive cells  
   D. Feedback loops are irrelevant  
   **Answer:** B. Gene mutation affects protein (enzyme/receptor) synthesis altering cortisol regulation.  
   **Explanation:** Mutation in gene (DNA) leads to altered mRNA/protein, affecting hormone pathways.
2. **Application:** A researcher wants to confirm that a CRISPR edit corrected a pathogenic allele at the DNA level and assess if the protein is properly expressed. Which pair of techniques would they use?  
   A. Northern blot and PCR  
   B. Southern blot and Western blot  
   C. Western blot and ELISA  
   D. Southern blot and Northern blot  
   **Answer:** B. Southern blot and Western blot.  
   **Explanation:** Southern confirms DNA modification; Western assesses protein expression.
3. **Foundational Comprehension:** Which endocrine feedback scenario exemplifies negative feedback?  
   A. Oxytocin release during labor increasing contractions  
   B. High blood glucose prompting insulin release to lower glucose  
   C. Epinephrine surge during fight-or-flight  
   D. Amplification cascade in hormone signaling  
   **Answer:** B. High blood glucose prompting insulin release to lower glucose.  
   **Explanation:** Elevated glucose triggers insulin, which reduces glucose—classic negative feedback.
4. **Application:** A heterozygous individual for a dominant disorder mates with a homozygous recessive partner. What proportion of offspring are expected to display the disease?  
   A. 0%  
   B. 25%  
   C. 50%  
   D. 100%  
   **Answer:** C. 50%.  
   **Explanation:** Heterozygote (Aa) × aa yields 50% Aa (affected), 50% aa.
5. **Test-Taking Strategy:** When a vignette mentions a hormone acting on surface receptors and triggering second-messenger cascades, the test-taker should recognize it as:  
   A. A steroid hormone  
   B. A lipid-soluble hormone  
   C. A peptide hormone  
   D. A gene-editing tool  
   **Answer:** C. A peptide hormone.  
   **Explanation:** Peptide hormones bind surface receptors (water-soluble) initiating signaling; steroid hormones cross membrane.
6. **Foundational Comprehension:** High ATP levels in a cell will most likely:  
   A. Activate PFK-1  
   B. Inhibit citrate synthase  
   C. Inhibit isocitrate dehydrogenase  
   D. Increase NADH oxidation  
   **Answer:** C. Inhibit isocitrate dehydrogenase.  
   **Explanation:** High ATP signals energy abundance, allosterically inhibiting enzymes like isocitrate dehydrogenase.
7. **Foundational Comprehension:** Which hormone promotes glycogenesis and suppresses gluconeogenesis?  
   A. Glucagon  
   B. Cortisol  
   C. Epinephrine  
   D. Insulin  
   **Answer:** D. Insulin.  
   **Explanation:** Insulin stimulates storage pathways (glycogenesis) and inhibits glucose production (gluconeogenesis).
8. **Application:** During fasting, which combination of hormonal signals is expected?  
   A. High insulin, low glucagon  
   B. High glucagon, increased PFK-1 activity  
   C. High glucagon, promotion of gluconeogenesis  
   D. High insulin, promotion of glycolysis  
   **Answer:** C. High glucagon, promotion of gluconeogenesis.  
   **Explanation:** Glucagon increases blood glucose via gluconeogenesis during fasting.
9. **Foundational Comprehension:** Epinephrine’s role in glucose regulation is best described as:  
   A. Mimicking insulin to lower blood sugar  
   B. Acting like glucagon to raise blood sugar during stress  
   C. Inhibiting gluconeogenesis  
   D. Promoting glycogen storage  
   **Answer:** B. Acting like glucagon to raise blood sugar during stress.  
   **Explanation:** Epinephrine mobilizes glucose for stress responses, similar to glucagon.
10. **Foundational Comprehension:** Which of the following is TRUE about enzyme inhibition?  
    A. Competitive inhibitors change Vmax but not Km  
    B. Noncompetitive inhibitors increase Km  
    C. Uncompetitive inhibitors bind only to enzyme-substrate complex  
    D. All inhibitors bind permanently  
    **Answer:** C. Uncompetitive inhibitors bind only to enzyme-substrate complex.  
    **Explanation:** Uncompetitive inhibitors require substrate binding before they can bind.
11. **Reasoning Within the Text:** A diabetic patient has high circulating glucose but low glycolytic flux in hepatocytes. This can best be explained by:  
    A. Elevated insulin sensitivity  
    B. Allosteric inhibition due to abundant ATP  
    C. Increased glucagon signaling only  
    D. Elevated enzyme concentration  
    **Answer:** B. Allosteric inhibition due to abundant ATP.  
    **Explanation:** High-energy state (high ATP) inhibits key glycolytic enzymes despite glucose availability.
12. **Application:** Which mnemonic helps recall that insulin drives glucose into cells?  
    A. GlucaGON = glucose GONE  
    B. INsuline = glucose go INto the cell  
    C. GFR – Salt, Sugar, Sex  
    D. “Lions Sit Under Many People For Fun”  
    **Answer:** B. INsuline = glucose go INto the cell.  
    **Explanation:** That mnemonic directly encodes insulin’s action.
13. **Test-Taking Strategy:** When distinguishing effects of insulin vs. glucagon in a vignette, the key difference is:  
    A. Insulin raises blood glucose; glucagon lowers it  
    B. Insulin promotes gluconeogenesis; glucagon promotes glycogenesis  
    C. Insulin promotes storage; glucagon promotes mobilization  
    D. Both have identical effects  
    **Answer:** C. Insulin promotes storage; glucagon promotes mobilization.  
    **Explanation:** Insulin stores glucose; glucagon mobilizes it.
14. **Reasoning Beyond the Text:** A stress-induced increase in blood glucose that aids rapid energy demands is adaptive because:  
    A. It suppresses PFK-1 to conserve energy  
    B. Epinephrine-mediated mobilization provides immediate substrate for ATP  
    C. It decreases gluconeogenesis  
    D. It increases citrate to inhibit glycolysis  
    **Answer:** B. Epinephrine-mediated mobilization provides immediate substrate for ATP.  
    **Explanation:** Stress response requires quick ATP; epinephrine raises glucose.
15. **Integrated Concept:** If a cell has high NADH and high citrate levels, which of the following is most likely?  
    A. Increased glycolytic flux  
    B. Activation of PFK-1  
    C. Overall downregulation of carbohydrate catabolism  
    D. Increased gluconeogenesis due to insulin  
    **Answer:** C. Overall downregulation of carbohydrate catabolism.  
    **Explanation:** High NADH and citrate signal energy sufficiency, inhibiting key catabolic enzymes.
16.  **Foundational Comprehension:** The central dogma summarizes information flow as:  
    A. RNA → DNA → Protein  
    B. DNA → RNA → Protein  
    C. Protein → RNA → DNA  
    D. DNA → Protein → RNA  
    **Answer:** B. DNA → RNA → Protein.  
    **Explanation:** Genetic information transcribed then translated.
17.  **Foundational Comprehension:** During DNA replication, the enzyme that joins Okazaki fragments is:  
    A. Helicase  
    B. DNA polymerase  
    C. Ligase  
    D. RNA polymerase  
    **Answer:** C. Ligase.  
    **Explanation:** Ligase seals nicks on lagging strand.
18.  **Application:** A nucleotide substitution that creates a premature stop codon is called:  
    A. Silent mutation  
    B. Missense mutation  
    C. Nonsense mutation  
    D. Frameshift mutation  
    **Answer:** C. Nonsense mutation.  
    **Explanation:** Introduces a stop codon truncating translation.
19.  **Foundational Comprehension:** Which Mendelian law explains that alleles for different genes are inherited independently?  
    A. Law of Segregation  
    B. Law of Independent Assortment  
    C. Law of Dominance  
    D. Hardy-Weinberg equilibrium  
    **Answer:** B. Law of Independent Assortment.  
    **Explanation:** Unlinked genes assort independently.
20.  **Application:** In a Hardy-Weinberg population with allele frequency p=0.6, what is the expected frequency of heterozygotes?  
    A. 0.36  
    B. 0.48  
    C. 0.24  
    D. 0.16  
    **Answer:** B. 0.48.  
    **Explanation:** 2pq = 2\*(0.6)\*(0.4)=0.48.
21.  **Foundational Comprehension:** Which process increases genetic diversity during meiosis?  
    A. Binary fission  
    B. Crossing over and independent assortment  
    C. Semi-conservative replication  
    D. Mitosis  
    **Answer:** B. Crossing over and independent assortment.  
    **Explanation:** Both generate variation in gametes.
22.  **Application:** A CRISPR-Cas9 edit intended to fix a missense mutation is best validated at the DNA level using:  
    A. Western blot  
    B. Northern blot  
    C. Southern blot  
    D. ELISA  
    **Answer:** C. Southern blot.  
    **Explanation:** Southern detects DNA modifications.
23.  **Reasoning Within the Text:** If a corrective allele is introduced and confers fitness, under Hardy-Weinberg conditions its frequency over generations will:  
    A. Remain unchanged  
    B. Decrease due to segregation  
    C. Increase if it provides a selective advantage  
    D. Immediately fix in the population  
    **Answer:** C. Increase if it provides a selective advantage.  
    **Explanation:** Advantageous alleles rise in frequency unless equilibrium assumptions are violated.
24.  **Foundational Comprehension:** Which codon signals the start of translation?  
    A. UAA  
    B. UAG  
    C. AUG  
    D. UGA  
    **Answer:** C. AUG.  
    **Explanation:** AUG codes for methionine and initiates translation.
25.  **Test-Taking Strategy:** A dominant trait appearing in every generation affecting both sexes equally likely follows which inheritance pattern?  
    A. Autosomal recessive  
    B. X-linked recessive  
    C. Autosomal dominant  
    D. Mitochondrial inheritance  
    **Answer:** C. Autosomal dominant.  
    **Explanation:** Dominant, equal sex distribution, vertical transmission.
26.  **Reasoning Beyond the Text:** A patient with a genetic mutation reducing insulin receptor expression has impaired glucose uptake. Understanding the central dogma explains this because:  
    A. Glucose directly mutates DNA  
    B. A DNA mutation leads to altered mRNA and dysfunctional receptor protein  
    C. Hormones modify DNA sequence  
    D. ATP levels become irrelevant  
    **Answer:** B. A DNA mutation leads to altered mRNA and dysfunctional receptor protein.  
    **Explanation:** Mutation in gene reduces proper protein (receptor) synthesis.
27.  **Application:** A researcher studies how a corrected metabolic gene spreads through a population and also its effect on enzyme activity in hepatocytes. Which two frameworks are they integrating?  
    A. Endocrine feedback and membrane transport  
    B. Population genetics and biochemical regulation  
    C. Cell division and immune signaling  
    D. Structural biology and cultural evolution  
    **Answer:** B. Population genetics and biochemical regulation.  
    **Explanation:** Combining allele frequency dynamics with metabolic enzyme function.
28.  **Foundational Comprehension:** What is the effect of a frameshift mutation on the protein product?  
    A. No change in amino acid sequence  
    B. Single amino acid substitution  
    C. Shifted reading frame altering downstream sequence  
    D. Enhanced protein stability  
    **Answer:** C. Shifted reading frame altering downstream sequence.  
    **Explanation:** Insertions/deletions not in multiples of three change the frame.
29.  **Test-Taking Strategy:** In a passage describing a metabolic phenotype caused by a genetic defect, the best approach is to first:  
    A. Guess hormone levels  
    B. Map the genetic mutation to its protein effect, then to pathway consequences  
    C. Ignore the mutation and focus on symptoms alone  
    D. Assume all regulation is transcriptional  
    **Answer:** B. Map the genetic mutation to its protein effect, then to pathway consequences.  
    **Explanation:** Understanding causal chain from gene to enzyme to phenotype clarifies mechanism.
30.  **Integrated Concept:** A novel allele correcting impaired gluconeogenesis emerges in a population. If the correction improves fitness and the population approximates Hardy-Weinberg assumptions except for selection, over time:  
    A. The allele frequency will stay constant  
    B. The allele frequency will decrease  
    C. The allele frequency will increase  
    D. The allele will be lost immediately  
    **Answer:** C. The allele frequency will increase.  
    **Explanation:** Positive selection drives beneficial alleles upward.
31.  **Foundational Comprehension:** High ATP in the cell leads to:  
    A. Activation of PFK-1  
    B. Allosteric inhibition of isocitrate dehydrogenase  
    C. Increased gluconeogenesis  
    D. Activation of fructose-1,6-bisphosphatase  
    **Answer:** B. Allosteric inhibition of isocitrate dehydrogenase.  
    **Explanation:** High ATP signals energy sufficiency and inhibits key metabolic enzymes.
32.  **Foundational Comprehension:** “INsuline = glucose go INto the cell” mnemonic emphasizes that insulin:  
    A. Raises blood glucose  
    B. Promotes gluconeogenesis  
    C. Stimulates glycogenesis and glycolysis  
    D. Antagonizes glucose uptake  
    **Answer:** C. Stimulates glycogenesis and glycolysis.  
    **Explanation:** Insulin promotes storage and utilization of glucose.
33.  **Application:** During fasting, which hormone profile is expected?  
    A. High insulin, low glucagon  
    B. High glucagon, increased gluconeogenesis  
    C. High insulin, increased glycolysis  
    D. High insulin and high epinephrine  
    **Answer:** B. High glucagon, increased gluconeogenesis.  
    **Explanation:** Glucagon mobilizes glucose in fasting.
34.  **Foundational Comprehension:** Epinephrine’s effect on blood glucose is most similar to:  
    A. Insulin  
    B. Glucagon  
    C. Growth hormone  
    D. Thyroxine  
    **Answer:** B. Glucagon.  
    **Explanation:** Epinephrine raises blood glucose during stress like glucagon.
35.  **Foundational Comprehension:** Which inhibitor type binds only to the enzyme-substrate complex?  
    A. Competitive  
    B. Noncompetitive  
    C. Uncompetitive  
    D. Allosteric  
    **Answer:** C. Uncompetitive.  
    **Explanation:** Uncompetitive inhibitors require substrate presence to bind.
36.  **Reasoning Within the Text:** A patient with insulin resistance has high blood glucose but impaired glycolysis because:  
    A. Elevated AMP is inhibiting PFK-1  
    B. High ATP and disrupted insulin signaling reduce flux  
    C. Glucagon is suppressed  
    D. Citrate is low  
    **Answer:** B. High ATP and disrupted insulin signaling reduce flux.  
    **Explanation:** Energy-sufficient signals and poor insulin effect explain impaired utilization.
37.  **Application:** Which hormone would you expect to be elevated during acute stress to rapidly increase available glucose?  
    A. Insulin  
    B. Glucagon  
    C. Epinephrine  
    D. Aldosterone  
    **Answer:** C. Epinephrine.  
    **Explanation:** Epinephrine mobilizes glucose in fight-or-flight.
38.  **Test-Taking Strategy:** To distinguish insulin from glucagon’s effects in a vignette, focus on whether the scenario describes:  
    A. Glucose storage vs. mobilization  
    B. Increased gluconeogenesis vs. increased glycolysis  
    C. Both A and B  
    D. Neither  
    **Answer:** C. Both A and B.  
    **Explanation:** Insulin stores glucose; glucagon mobilizes it.
39.  **Reasoning Beyond the Text:** Why might high NADH levels downregulate carbohydrate catabolism?  
    A. They signal energy deficit  
    B. They indicate sufficient reducing equivalents, inhibiting dehydrogenases  
    C. They directly activate PFK-1  
    D. They increase gluconeogenesis  
    **Answer:** B. They indicate sufficient reducing equivalents, inhibiting dehydrogenases.  
    **Explanation:** High NADH reflects energy sufficiency, leading to feedback inhibition.
40.  **Integrated Concept:** If a cell has high citrate and high ATP, what is the overall expected metabolic state?  
    A. Active glycolysis  
    B. Inhibited carbohydrate breakdown  
    C. Increased gluconeogenesis only  
    D. Unchanged metabolic flux  
    **Answer:** B. Inhibited carbohydrate breakdown.  
    **Explanation:** Both high citrate and ATP signal surplus, suppressing catabolic enzymes.
41. **Foundational Comprehension:** In the fluid mosaic model, cholesterol functions to:  
    A. Signal via ligand binding  
    B. Maintain membrane fluidity  
    C. Transport large proteins  
    D. Anchor cytoskeletal elements  
    **Answer:** B. Maintain membrane fluidity.  
    **Explanation:** Cholesterol modulates rigidity and fluidity of the lipid bilayer.
42. **Foundational Comprehension:** Kinesin and dynein transport cargo along:  
    A. Actin filaments  
    B. Intermediate filaments  
    C. Microtubules  
    D. Plasma membrane  
    **Answer:** C. Microtubules.  
    **Explanation:** Motor proteins move along tubulin-based microtubules.
43. **Application:** A neuron’s rapid signal transmission depends on:  
    A. Rigid cell membrane without proteins  
    B. Action potential propagation along the axon  
    C. Random diffusion of neurotransmitters only  
    D. Constant high intracellular ATP alone  
    **Answer:** B. Action potential propagation along the axon.  
    **Explanation:** Electrical impulses travel via depolarization/repolarization.
44. **Foundational Comprehension:** Which cytoskeletal element is primarily responsible for forming the mitotic spindle?  
    A. Microfilaments  
    B. Intermediate filaments  
    C. Microtubules  
    D. Extracellular matrix  
    **Answer:** C. Microtubules.  
    **Explanation:** Microtubules assemble the spindle for chromosome segregation.
45. **Foundational Comprehension:** Integral membrane proteins are embedded where?  
    A. In the cytosol only  
    B. Within the phospholipid bilayer  
    C. Outside the cell entirely  
    D. Only in the nucleus  
    **Answer:** B. Within the phospholipid bilayer.  
    **Explanation:** Integral proteins span or reside within the membrane.
46. **Application:** If a reflex bypasses the brain for speed, which structure is acting as the integration center?  
    A. Cerebrum  
    B. Spinal cord  
    C. Peripheral nerve ending  
    D. Autonomic ganglion  
    **Answer:** B. Spinal cord.  
    **Explanation:** Reflex arcs often integrate in the spinal cord for rapid response.
47. **Reasoning Within the Text:** A cell with disrupted dynein function would most likely have impaired:  
    A. Muscle contraction  
    B. Retrograde intracellular transport  
    C. Glycolytic regulation  
    D. DNA replication  
    **Answer:** B. Retrograde intracellular transport.  
    **Explanation:** Dynein moves cargo toward the cell center (retrograde).
48. **Foundational Comprehension:** Which of the following is a passive transport mechanism across the membrane?  
    A. Sodium-potassium pump  
    B. Endocytosis  
    C. Diffusion  
    D. Exocytosis  
    **Answer:** C. Diffusion.  
    **Explanation:** Diffusion moves molecules down concentration gradient without energy.
49. **Application:** An applicant designing a device to detect sympathetic activation should monitor:  
    A. Parasympathetic acetylcholine release  
    B. Action potential frequency in sympathetic neurons  
    C. DNA replication rates  
    D. Membrane cholesterol levels only  
    **Answer:** B. Action potential frequency in sympathetic neurons.  
    **Explanation:** Sympathetic activity manifests as increased neuronal firing.
50. **Test-Taking Strategy:** When evaluating a vignette about impaired cellular transport of vesicles, the student should consider dysfunction in:  
    A. Microfilaments exclusively  
    B. Intermediate filaments  
    C. Motor proteins like kinesin/dynein on microtubules  
    D. The nuclear envelope  
    **Answer:** C. Motor proteins like kinesin/dynein on microtubules.  
    **Explanation:** Vesicular trafficking depends on microtubule-associated motors.
51.  **Foundational Comprehension:** The coordination between change in membrane potential and cytoskeletal transport is essential for:  
    A. DNA replication  
    B. Neuronal signaling and synaptic vesicle trafficking  
    C. Gluconeogenesis only  
    D. Hormone synthesis in the adrenal cortex  
    **Answer:** B. Neuronal signaling and synaptic vesicle trafficking.  
    **Explanation:** Action potentials trigger vesicle release, relying on cytoskeletal transport.
52.  **Application:** A stress-sensing implant that responds to elevated circulating glucose and sympathetic tone must integrate knowledge of:  
    A. Enzyme Km only  
    B. Hormonal regulation of glucose and neuronal action potentials  
    C. DNA transcription rates  
    D. Cytokine signaling  
    **Answer:** B. Hormonal regulation of glucose and neuronal action potentials.  
    **Explanation:** Stress involves metabolic (glucose mobilization) and sympathetic neuronal signaling.
53.  **Reasoning Beyond the Text:** If a therapeutic targets improving insulin signal transduction and stabilizing microtubule transport in neurons, it is addressing:  
    A. Only endocrine feedback  
    B. Both metabolic regulation and intracellular trafficking  
    C. Genetic mutation correction  
    D. Membrane lipid composition  
    **Answer:** B. Both metabolic regulation and intracellular trafficking.  
    **Explanation:** Combining improved hormone signaling with cytoskeletal transport aids systemic response.
54.  **Foundational Comprehension:** Which combination best reflects integration of systemic and cellular processes in stress response?  
    A. Glucagon release + action potentials in parasympathetic neurons  
    B. Epinephrine-mediated glucose mobilization + sympathetic neuronal firing  
    C. Insulin secretion + microtubule degradation  
    D. High ATP inhibiting PFK-1 + decreased membrane fluidity  
    **Answer:** B. Epinephrine-mediated glucose mobilization + sympathetic neuronal firing.  
    **Explanation:** Stress triggers both metabolic and sympathetic activation.
55.  **Test-Taking Strategy:** When a question describes a cell with normal hormone levels but poor downstream metabolic response, the best initial inference is:  
    A. Dysfunctional allosteric regulation or receptor signaling  
    B. Genetic mutation in DNA replication machinery  
    C. Increased passive transport  
    D. Overactive microtubule motors  
    **Answer:** A. Dysfunctional allosteric regulation or receptor signaling.  
    **Explanation:** Normal hormone presence with impaired effect suggests signaling or feedback disruption.
56. **Foundational Comprehension:** In the male reproductive tract, where does sperm maturation occur?  
    A. Seminiferous tubules  
    B. Vas deferens  
    C. Epididymis  
    D. Ejaculatory duct  
    **Answer:** C. Epididymis.  
    **Explanation:** Sperm produced in seminiferous tubules mature in the epididymis.
57. **Foundational Comprehension:** Which phase of the female menstrual cycle involves progesterone production and endometrial preparation?  
    A. Follicular  
    B. Ovulatory  
    C. Luteal  
    D. Menstrual  
    **Answer:** C. Luteal.  
    **Explanation:** The luteal phase is characterized by progesterone secretion preparing for potential pregnancy.
58. **Application:** A patient with damage to the small intestine is most likely to present with:  
    A. Increased oxygen saturation  
    B. Impaired nutrient absorption  
    C. Elevated bile production  
    D. Enhanced gas exchange  
    **Answer:** B. Impaired nutrient absorption.  
    **Explanation:** Small intestine is primary site for nutrient absorption; damage reduces uptake.
59. **Foundational Comprehension:** Which organ produces bile to aid in fat digestion?  
    A. Pancreas  
    B. Liver  
    C. Stomach  
    D. Gall bladder  
    **Answer:** B. Liver.  
    **Explanation:** Liver produces bile; gallbladder stores it.
60. **Application:** A female patient with irregular menstrual cycles and iron-deficiency anemia is likely to have compounded fatigue due to:  
    A. Excess oxygen delivery and hormonal surplus  
    B. Poor nutrient absorption only  
    C. Combined hormonal imbalance and reduced oxygen-carrying capacity  
    D. Increased bile synthesis  
    **Answer:** C. Combined hormonal imbalance and reduced oxygen-carrying capacity.  
    **Explanation:** Irregular cycles may reflect endocrine disruption; anemia limits oxygen delivery, both cause fatigue.
61. **Foundational Comprehension:** What is the primary function of the diaphragm in respiration?  
    A. Filter air  
    B. Exchange gases in alveoli  
    C. Drive inhalation via contraction  
    D. Produce surfactant  
    **Answer:** C. Drive inhalation via contraction.  
    **Explanation:** Diaphragm contraction expands thoracic cavity for inhalation.
62. **Foundational Comprehension:** Which structure transports food from the mouth to the stomach?  
    A. Trachea  
    B. Esophagus  
    C. Bronchus  
    D. Small intestine  
    **Answer:** B. Esophagus.  
    **Explanation:** Esophagus delivers swallowed material to stomach.
63. **Reasoning Within the Text:** A patient with both malabsorption and menstrual irregularity is most likely to have fatigue because:  
    A. Only reproductive hormones consume energy  
    B. Nutrient deficits impair erythropoiesis and hormonal imbalance disrupts metabolic regulation  
    C. Increased alveolar gas exchange causes oxidative stress  
    D. Enhanced digestion creates toxic buildup  
    **Answer:** B. Nutrient deficits impair erythropoiesis and hormonal imbalance disrupts metabolic regulation.  
    **Explanation:** Malabsorption leads to deficiencies (e.g., iron) causing anemia; reproductive dysregulation adds endocrine stress.
64. **Test-Taking Strategy:** If an MCAT passage describes low oxygen delivery and irregular menses in a female, the evaluator should first consider:  
    A. Neurological causes  
    B. Integrated endocrine and hematologic dysfunction  
    C. Skin disorders  
    D. Purely pulmonary embolism  
    **Answer:** B. Integrated endocrine and hematologic dysfunction.  
    **Explanation:** Fatigue with irregular menses and low oxygen suggests combined endocrine and anemia causes.
65. **Application:** Which two systems are primarily implicated when a patient has shortness of breath and poor nutrient absorption?  
    A. Nervous and reproductive  
    B. Respiratory and digestive  
    C. Muscular and skeletal  
    D. Integumentary and lymphatic  
    **Answer:** B. Respiratory and digestive.  
    **Explanation:** Shortness of breath relates to respiratory; poor absorption to digestive.
66. **Foundational Comprehension:** The fluid mosaic model describes the cell membrane as:  
    A. A rigid crystalline structure  
    B. Static lipid layers with no protein movement  
    C. Dynamic with proteins floating in a lipid bilayer  
    D. Composed only of carbohydrates  
    **Answer:** C. Dynamic with proteins floating in a lipid bilayer.  
    **Explanation:** Fluid mosaic denotes flexibility and lateral movement of components.
67. **Foundational Comprehension:** Which molecule helps maintain membrane fluidity?  
    A. Glycoprotein  
    B. Cholesterol  
    C. DNA  
    D. ATP  
    **Answer:** B. Cholesterol.  
    **Explanation:** Cholesterol modulates membrane fluidity.
68. **Application:** Movement of water across a semipermeable membrane without energy input is:  
    A. Active transport  
    B. Osmosis  
    C. Endocytosis  
    D. Exocytosis  
    **Answer:** B. Osmosis.  
    **Explanation:** Osmosis is passive diffusion of water.
69. **Foundational Comprehension:** Which branch of the autonomic nervous system is responsible for “rest and digest”?  
    A. Sympathetic  
    B. Parasympathetic  
    C. Somatic  
    D. Central  
    **Answer:** B. Parasympathetic.  
    **Explanation:** Parasympathetic promotes restoration and digestion.
70. **Foundational Comprehension:** In neural signaling, what is the term for the rapid depolarization and repolarization event?  
    A. Synapse  
    B. Reflex arc  
    C. Action potential  
    D. Neurotransmitter  
    **Answer:** C. Action potential.  
    **Explanation:** Action potential transmits electrical signal along axon.
71. **Application:** A reflex that bypasses the brain and is processed in the spinal cord illustrates:  
    A. Voluntary movement  
    B. Reflex arc integration center being the spinal cord  
    C. Hormonal feedback  
    D. Central autonomic failure  
    **Answer:** B. Reflex arc integration center being the spinal cord.  
    **Explanation:** Reflex arcs often use the spinal cord for rapid responses.
72. **Reasoning Within the Text:** Increased sympathetic activity will most likely cause:  
    A. Pupil constriction and digestion stimulation  
    B. Heartbeat slowing and increased saliva  
    C. Airways dilation and increased heartbeat  
    D. Restful metabolic conservation  
    **Answer:** C. Airways dilation and increased heartbeat.  
    **Explanation:** Sympathetic (“fight or flight”) increases heart rate and dilates airways.
73. **Foundational Comprehension:** Which membrane components are directly involved in cell recognition?  
    A. Integral proteins only  
    B. Carbohydrates (glycoproteins/glycolipids)  
    C. Cholesterol  
    D. Phospholipid tails  
    **Answer:** B. Carbohydrates (glycoproteins/glycolipids).  
    **Explanation:** Carbohydrate moieties mediate recognition and signaling.
74. **Application:** A device sensing enteric mechanoreceptor signals to modulate gut motility would rely on:  
    A. Passive diffusion only  
    B. Neural pathways integrating sensory input and autonomic output  
    C. Direct hormonal secretion into the gut lumen  
    D. Structural bone remodeling  
    **Answer:** B. Neural pathways integrating sensory input and autonomic output.  
    **Explanation:** Gut motility feedback involves neural circuits and autonomic regulation.
75. **Test-Taking Strategy:** If a vignette describes a sudden withdrawal of a signal due to uptake after synaptic release, which mechanism is being referenced?  
    A. Depolarization  
    B. Reflex arc  
    C. Reuptake  
    D. Active transport  
    **Answer:** C. Reuptake.  
    **Explanation:** Reuptake removes neurotransmitter from synaptic cleft, terminating signal.
76. **Foundational Comprehension:** Coordination between respiratory compromise (low O₂) and autonomic adjustments (increased sympathetic tone) exemplifies:  
    A. Isolated organ failure  
    B. Integrated systemic response to maintain perfusion  
    C. Reproductive system dominance  
    D. Passive diffusion failure  
    **Answer:** B. Integrated systemic response to maintain perfusion.  
    **Explanation:** Low oxygen triggers sympathetic activation to support vital functions.
77. **Application:** A patient with poor nutrient absorption develops hypotension and triggers a compensatory neural response; which systems are interacting?  
    A. Digestive and nervous  
    B. Muscular and skeletal  
    C. Endocrine only  
    D. Integumentary and lymphatic  
    **Answer:** A. Digestive and nervous.  
    **Explanation:** Malabsorption affects blood volume/pressure, eliciting neural compensation.
78. **Reasoning Beyond the Text:** An irregular menstrual cycle leading to iron-deficiency anemia may decrease oxygen delivery and thus stimulate:  
    A. Parasympathetic activity to slow heart rate  
    B. Sympathetic activity to increase cardiac output  
    C. Increased digestive enzyme secretion  
    D. Decreased respiratory drive  
    **Answer:** B. Sympathetic activity to increase cardiac output.  
    **Explanation:** Compensatory sympathetic activation increases perfusion when oxygen delivery is low.
79. **Foundational Comprehension:** Selective permeability of the cell membrane ensures:  
    A. All molecules freely cross  
    B. Only ions enter the cell  
    C. Regulation of internal environment by permitting some substances while restricting others  
    D. Proteins only are transported  
    **Answer:** C. Regulation of internal environment by permitting some substances while restricting others.  
    **Explanation:** Selective permeability maintains homeostasis.
80. **Test-Taking Strategy:** When interpreting a complex case involving gut dysfunction with autonomic symptoms, the best first step is to:  
    A. Consider isolated gastrointestinal pathology only  
    B. Map sensory input to neural output and evaluate compensatory systemic responses  
    C. Ignore neural involvement  
    D. Assume hormonal imbalance without evidence  
    **Answer:** B. Map sensory input to neural output and evaluate compensatory systemic responses.  
    **Explanation:** Integrated understanding of neural reflexes and systemic compensation yields better insight.
81.  **Foundational Comprehension:** Which blotting technique would you use to detect the presence of a specific RNA transcript?  
    A. Southern blot  
    B. Northern blot  
    C. Western blot  
    D. Ligand affinity blot  
    **Answer:** B. Northern blot.  
    **Explanation:** Northern blot uses an RNA probe to detect RNA.
82.  **Foundational Comprehension:** In SDS-PAGE under reducing conditions, what is the effect of the reducing agent?  
    A. Preserves disulfide-linked complexes  
    B. Breaks hydrogen bonds  
    C. Breaks disulfide bonds  
    D. Enhances ligand binding  
    **Answer:** C. Breaks disulfide bonds.  
    **Explanation:** Reducing SDS-PAGE uses agents like DTT to cleave disulfide bridges, denaturing quaternary structure.
83.  **Application:** A student observes that an inhibitor increases Km but leaves Vmax unchanged. This inhibitor is:  
    A. Noncompetitive  
    B. Competitive  
    C. Uncompetitive  
    D. Mixed  
    **Answer:** B. Competitive.  
    **Explanation:** Competitive inhibition raises Km (lower apparent affinity) without affecting Vmax.
84.  **Foundational Comprehension:** Which parameter reflects the substrate concentration at half-maximal velocity?  
    A. Vmax  
    B. kcat  
    C. Km  
    D. kcat/Km  
    **Answer:** C. Km.  
    **Explanation:** Km is the Michaelis constant indicating the [S] at half Vmax.
85.  **Application:** An inhibitor that binds only to the enzyme-substrate complex and decreases both Km and Vmax is:  
    A. Competitive  
    B. Noncompetitive  
    C. Uncompetitive  
    D. Irreversible  
    **Answer:** C. Uncompetitive.  
    **Explanation:** Uncompetitive inhibitors bind ES complex, lowering both Km and Vmax.
86.  **Reasoning Within the Text:** If a purified enzyme shows decreased Vmax with unchanged Km in the presence of a compound, the inhibitor type is:  
    A. Competitive  
    B. Noncompetitive  
    C. Mixed  
    D. Substrate analog  
    **Answer:** B. Noncompetitive.  
    **Explanation:** Noncompetitive inhibition reduces Vmax but does not alter Km.
87.  **Foundational Comprehension:** Which technique uses specific binding between a protein and its ligand to purify the protein?  
    A. Cation exchange chromatography  
    B. SDS-PAGE  
    C. Ligand affinity chromatography  
    D. Northern blot  
    **Answer:** C. Ligand affinity chromatography.  
    **Explanation:** Affinity chromatography retains proteins that specifically bind the immobilized ligand.
88.  **Application:** To verify that a purified protein is present and of expected size, which combination would be most direct?  
    A. PCR and Southern blot  
    B. Reducing SDS-PAGE followed by Western blot  
    C. Northern blot and ligand affinity  
    D. Noncompetitive inhibition assay  
    **Answer:** B. Reducing SDS-PAGE followed by Western blot.  
    **Explanation:** SDS-PAGE separates by size; Western blot detects the specific protein.
89.  **Test-Taking Strategy:** A candidate’s Lineweaver-Burk plot shows increased y-intercept and unchanged x-intercept upon inhibitor addition. This implies:  
    A. Competitive inhibition  
    B. Noncompetitive inhibition  
    C. Uncompetitive inhibition  
    D. No inhibition  
    **Answer:** B. Noncompetitive inhibition.  
    **Explanation:** Increased 1/Vmax (y-intercept) with same -1/Km (x-intercept) indicates noncompetitive inhibition.
90.  **Reasoning Beyond the Text:** If an inhibitor is found to bind irreversibly to an enzyme’s active site, what is a likely consequence?  
    A. Km increases only  
    B. Vmax decreases permanently  
    C. No change in kinetics  
    D. Reversible competitive behavior  
    **Answer:** B. Vmax decreases permanently.  
    **Explanation:** Irreversible inhibitors permanently inactivate enzyme, lowering effective Vmax
91. **Foundational Comprehension:** Which level of protein structure is determined by interactions between multiple polypeptide subunits?  
    A. Primary  
    B. Secondary  
    C. Tertiary  
    D. Quaternary  
    **Answer:** D. Quaternary.  
    **Explanation:** Quaternary structure refers to assembly of multiple polypeptide chains.
92. **Foundational Comprehension:** The fluid mosaic model describes the membrane as:  
    A. A rigid bilayer of lipids  
    B. A dynamic structure with lipids and proteins moving laterally  
    C. A protein-only barrier  
    D. An impermeable wall  
    **Answer:** B. A dynamic structure with lipids and proteins moving laterally.  
    **Explanation:** “Proteins Float Coolly” mnemonic emphasizes lateral mobility in the phospholipid bilayer.
93. **Application:** Which molecule helps buffer membrane fluidity across temperatures?  
    A. Phospholipid  
    B. Cholesterol  
    C. Glycoprotein  
    D. DNA  
    **Answer:** B. Cholesterol.  
    **Explanation:** Cholesterol prevents extremes of rigidity or fluidity.
94. **Foundational Comprehension:** A G-protein is activated when:  
    A. GDP binds to its alpha subunit  
    B. Ligand binds receptor causing GDP→GTP exchange on alpha subunit  
    C. GTP is hydrolyzed to GDP  
    D. Beta and gamma subunits dissociate  
    **Answer:** B. Ligand binds receptor causing GDP→GTP exchange on alpha subunit.  
    **Explanation:** Activation involves GDP release and GTP binding to alpha subunit upon receptor stimulation.
95. **Application:** Which transport process requires energy to move solutes against their concentration gradient directly using ATP?  
    A. Simple diffusion  
    B. Facilitated diffusion  
    C. Primary active transport  
    D. Osmosis  
    **Answer:** C. Primary active transport.  
    **Explanation:** Primary active transport uses ATP to move molecules against gradient (e.g., Na⁺/K⁺ pump).
96. **Foundational Comprehension:** Which endocytosis type is highly specific and uses receptor-ligand interactions?  
    A. Phagocytosis  
    B. Pinocytosis  
    C. Receptor-mediated endocytosis  
    D. Passive diffusion  
    **Answer:** C. Receptor-mediated endocytosis.  
    **Explanation:** Uses receptors for selective uptake of ligands.
97. **Foundational Comprehension:** Which membrane protein type spans the bilayer and often participates in signaling or transport?  
    A. Peripheral protein  
    B. Integral protein  
    C. Cytosolic enzyme  
    D. Carbohydrate  
    **Answer:** B. Integral protein.  
    **Explanation:** Integral proteins embed within the membrane, facilitating transport and signaling.
98. **Application:** A signaling cascade that uses cAMP as a secondary messenger is most likely initiated by:  
    A. Direct DNA binding  
    B. A GPCR activation  
    C. Passive diffusion of ions  
    D. Tight junction formation  
    **Answer:** B. A GPCR activation.  
    **Explanation:** GPCRs often activate adenylate cyclase to produce cAMP.
99. **Reasoning Within the Text:** Motor proteins transporting vesicles toward the cell periphery are using:  
    A. Dynein on microtubules  
    B. Myosin on actin  
    C. Kinesin on microtubules  
    D. Intermediate filaments  
    **Answer:** C. Kinesin on microtubules.  
    **Explanation:** Kinesin mediates anterograde (toward cell exterior) transport.
100. **Test-Taking Strategy:** If a passage describes a signal initiated by ligand binding that causes a conformational change opening an ion channel, this refers to:  
     A. Voltage-gated channel  
     B. Leak channel  
     C. Ligand-gated ion channel  
     D. Secondary active transport  
     **Answer:** C. Ligand-gated ion channel.  
     **Explanation:** Ligand binding directly gates the channel open.
101. **Foundational Comprehension:** The mnemonic “SNOW DROP” helps remember:  
     A. Types of enzyme inhibition  
     B. Order of glycolysis intermediates  
     C. Blotting techniques for DNA, RNA, and protein  
     D. Membrane transport mechanisms  
     **Answer:** C. Blotting techniques for DNA, RNA, and protein.  
     **Explanation:** SNOW DROP stands for Southern (DNA), Northern (RNA), Western (protein).
102. **Application:** A mutant receptor fails to activate G-proteins despite ligand binding. Which level of protein structure dysfunction is most likely implicated if the binding domain is intact but signal transduction is lost?  
     A. Primary structure  
     B. Secondary structure  
     C. Tertiary/quaternary conformational change  
     D. DNA mutation in promoter  
     **Answer:** C. Tertiary/quaternary conformational change.  
     **Explanation:** Signaling often depends on conformational change beyond ligand binding—reflecting higher-order structure.
103. **Reasoning Beyond the Text:** An engineered feedback system uses detection of high product concentration to inhibit its own synthesis via a membrane receptor cascade. This mirrors which biochemical principle?  
     A. Competitive inhibition  
     B. Positive feedback  
     C. Allosteric regulation with negative feedback-like control  
     D. Irreversible inhibition  
     **Answer:** C. Allosteric regulation with negative feedback-like control.  
     **Explanation:** High product leading to reduced synthesis aligns with negative feedback; membrane receptor cascade acts analogously to allosteric sensing.
104. **Foundational Comprehension:** Which combination correctly links molecule and its general role in signaling?  
     A. cAMP – primary active transport  
     B. GTP-bound Gα – inactive G-protein  
     C. Ligand binding – receptor activation  
     D. Tight junction – second messenger release  
     **Answer:** C. Ligand binding – receptor activation.  
     **Explanation:** Ligand binding initiates receptor-mediated signaling.
105. **Test-Taking Strategy:** When dissecting a passage describing decreased enzyme efficiency with unchanged substrate concentration, the best immediate inference is:  
     A. Decreased Km  
     B. A form of inhibition or alteration in kcat  
     C. Increased gene transcription  
     D. Enhanced ligand affinity  
     **Answer:** B. A form of inhibition or alteration in kcat.  
     **Explanation:** Reduced efficiency at same [S] suggests either inhibitor presence or lowered turnover (kcat).
106. **Foundational Comprehension:** Which macronutrient yields the most energy per gram?  
     A. Carbohydrates  
     B. Proteins  
     C. Fats  
     D. Nucleic acids  
     **Answer:** C. Fats.  
     **Explanation:** Fats are most energy-dense (9 kcal/g) compared to proteins and carbs.
107. **Foundational Comprehension:** The phrase “fats burn in the flame of carbohydrates” implies:  
     A. Fatty acids are converted directly to glucose  
     B. Carbohydrate intermediates are required for complete fat oxidation  
     C. Carbs are stored as fat before oxidation  
     D. Proteins are preferred over fats  
     **Answer:** B. Carbohydrate intermediates are required for complete fat oxidation.  
     **Explanation:** Oxaloacetate (a carbohydrate-derived intermediate) is necessary for acetyl-CoA to enter the TCA cycle.
108. **Application:** In prolonged fasting, which process is upregulated to provide alternative fuels?  
     A. Glycogenesis  
     B. Lipogenesis  
     C. Ketogenesis  
     D. Protein synthesis  
     **Answer:** C. Ketogenesis.  
     **Explanation:** Ketone bodies are produced from acetyl-CoA during prolonged fasting.
109. **Foundational Comprehension:** Which pathway synthesizes glucose from non-carbohydrate precursors?  
     A. Glycogenolysis  
     B. Glycolysis  
     C. Gluconeogenesis  
     D. Lipolysis  
     **Answer:** C. Gluconeogenesis.  
     **Explanation:** Gluconeogenesis uses amino acids and other substrates to generate glucose.
110. **Application:** Excess glucose beyond storage capacity is diverted into:  
     A. Glycogen  
     B. Fatty acid synthesis  
     C. Protein folding  
     D. Ketone body production  
     **Answer:** B. Fatty acid synthesis.  
     **Explanation:** Excess carbohydrate leads to lipogenesis.
111. **Reasoning Within the Text:** An obese patient has high intracellular acetyl-CoA but normal glycogen stores; which fate is most likely for the excess acetyl-CoA?  
     A. Entry into glycolysis  
     B. Conversion to ketone bodies  
     C. Storage as glycogen  
     D. Lipogenesis  
     **Answer:** D. Lipogenesis.  
     **Explanation:** When glycogen is replete, acetyl-CoA is shunted to fatty acid synthesis.
112. **Foundational Comprehension:** The “Please Get The Cell” mnemonic helps remember:  
     A. Steps in protein synthesis  
     B. Carb metabolism flow: Phosphorylation, Glycolysis, TCA, Cellular respiration  
     C. Amino acid essentiality  
     D. Membrane transport types  
     **Answer:** B. Carb metabolism flow: Phosphorylation, Glycolysis, TCA, Cellular respiration.  
     **Explanation:** It encodes the order of carbohydrate-derived energy generation.
113. **Application:** Which interconversion is NOT possible in human metabolism?  
     A. Amino acids to glucose  
     B. Excess glucose to fatty acids  
     C. Fatty acids to glucose  
     D. Proteins to ketone bodies  
     **Answer:** C. Fatty acids to glucose.  
     **Explanation:** Fatty acids cannot be converted into glucose in humans.
114. **Integrated Concept:** If a candidate argues that dietary protein can support blood glucose during starvation, which metabolic pathway supports that claim?  
     A. Lipogenesis  
     B. Glycogenolysis  
     C. Gluconeogenesis via deaminated amino acids  
     D. Ketogenesis  
     **Answer:** C. Gluconeogenesis via deaminated amino acids.  
     **Explanation:** Amino acids are converted to gluconeogenic substrates.
115. **Test-Taking Strategy:** A passage describes high energy status but continued fat synthesis from glucose. The best explanation involves:  
     A. Inhibited lipogenesis due to high ATP  
     B. Diversion of excess glucose into storage despite sufficient energy  
     C. Increased gluconeogenesis consuming glucose  
     D. Fatty acids being oxidized instead  
     **Answer:** B. Diversion of excess glucose into storage despite sufficient energy.  
     **Explanation:** Surplus carbohydrate is stored as fat even if energy is abundant.
116. **Foundational Comprehension:** Which base is present in RNA but not DNA?  
     A. Thymine  
     B. Guanine  
     C. Cytosine  
     D. Uracil  
     **Answer:** D. Uracil.  
     **Explanation:** RNA uses uracil instead of thymine.
117. **Foundational Comprehension:** DNA replication is semi-conservative because:  
     A. Both daughter strands are newly synthesized  
     B. One strand of each daughter is from the original molecule  
     C. It uses RNA primers only  
     D. It occurs in the cytoplasm  
     **Answer:** B. One strand of each daughter is from the original molecule.  
     **Explanation:** Semi-conservative replication retains one parental strand.
118. **Application:** A mutation causing a thymine dimer from UV exposure would most likely be corrected by:  
     A. Mismatch repair  
     B. Nucleotide excision repair  
     C. Homologous recombination  
     D. RNA interference  
     **Answer:** B. Nucleotide excision repair.  
     **Explanation:** Removes bulky lesions like thymine dimers.
119. **Foundational Comprehension:** The start codon for translation is:  
     A. UAA  
     B. AUG  
     C. UGA  
     D. UAG  
     **Answer:** B. AUG.  
     **Explanation:** AUG codes for methionine and initiates translation.
120. **Application:** A GPCR activates its Gα subunit by:  
     A. Hydrolyzing GTP to GDP  
     B. Exchanging GDP for GTP upon ligand binding  
     C. Phosphorylating the receptor  
     D. Internalizing via endocytosis  
     **Answer:** B. Exchanging GDP for GTP upon ligand binding.  
     **Explanation:** Ligand binding triggers GDP→GTP exchange to activate Gα.
121. **Foundational Comprehension:** Which membrane component buffers fluidity across temperature changes?  
     A. Phospholipid  
     B. Cholesterol  
     C. Glycoprotein  
     D. RNA  
     **Answer:** B. Cholesterol.  
     **Explanation:** Cholesterol stabilizes membrane fluidity.
122. **Application:** A signal transduction pathway using cAMP as a messenger is most likely initiated by:  
     A. Ligand-gated ion channel  
     B. GPCR activation  
     C. Tight junction formation  
     D. Passive diffusion  
     **Answer:** B. GPCR activation.  
     **Explanation:** GPCRs commonly activate adenylate cyclase to produce cAMP.
123. **Foundational Comprehension:** Which transport mechanism does NOT require energy?  
     A. Primary active transport  
     B. Secondary active transport  
     C. Facilitated diffusion  
     D. Endocytosis  
     **Answer:** C. Facilitated diffusion.  
     **Explanation:** Facilitated diffusion moves solutes down gradient without ATP.
124. **Integrated Concept:** A synthetic system detects high nucleotide levels and suppresses anabolic enzymes via membrane receptor signaling. This exemplifies:  
     A. Positive feedback  
     B. Signal integration analogous to negative feedback  
     C. Random mutation  
     D. Passive diffusion  
     **Answer:** B. Signal integration analogous to negative feedback.  
     **Explanation:** High product level leading to downregulation mirrors negative feedback via signaling cascade.
125. **Test-Taking Strategy:** If a passage describes a receptor that spans the membrane and initiates intracellular cascades when bound by ligand, the best identification is:  
     A. Peripheral protein  
     B. Integral receptor  
     C. Cytosolic enzyme  
     D. Extracellular matrix component  
     **Answer:** B. Integral receptor.  
     **Explanation:** Integral membrane receptors mediate ligand-induced signaling across bilayer.
126.  **Reasoning Within the Text:** A candidate claims that during starvation, amino acids maintain blood glucose while preserving fat stores. Which pair of processes supports that?  
     A. Glycolysis and lipogenesis  
     B. Gluconeogenesis and proteolysis  
     C. Ketogenesis and glycogen synthesis  
     D. Fatty acid oxidation and glycogenolysis  
     **Answer:** B. Gluconeogenesis and proteolysis.  
     **Explanation:** Proteins are broken down to amino acids, which feed gluconeogenesis.
127.  **Application:** A mutation in a membrane receptor prevents G-protein activation despite ligand binding. This likely reflects a defect in:  
     A. Ligand availability  
     B. Gα conformational exchange (GDP→GTP)  
     C. mRNA transcription  
     D. Passive diffusion  
     **Answer:** B. Gα conformational exchange (GDP→GTP).  
     **Explanation:** Ligand binding must trigger GDP→GTP swap to activate signaling.
128.  **Foundational Comprehension:** Which repair pathway would correct a single-base mismatch introduced during replication?  
     A. Base excision repair  
     B. Nucleotide excision repair  
     C. Mismatch repair  
     D. Homologous recombination  
     **Answer:** C. Mismatch repair.  
     **Explanation:** Mismatch repair fixes replication errors like base-base mismatches.
129.  **Reasoning Beyond the Text:** Designing a metabolic “sensor–effector” circuit that uses membrane receptors to tune gene expression based on nucleotide abundance requires understanding of:  
     A. Only carbohydrate metabolism  
     B. Nucleic acid status, receptor activation, second messenger signaling, and transcriptional regulation  
     C. DNA replication exclusively  
     D. Passive transport principles alone  
     **Answer:** B. Nucleic acid status, receptor activation, second messenger signaling, and transcriptional regulation.  
     **Explanation:** Integration spans sensing internal metabolites and propagating signals to control gene expression.
130.  **Test-Taking Strategy:** When evaluating a vignette that mixes high-energy substrates with downregulated anabolic enzymes via a membrane cascade, the best interpretive path is to:  
     A. Ignore signaling and focus on substrate levels  
     B. Infer that feedback through receptor-mediated sensing is modulating enzyme expression  
     C. Attribute everything to random mutation  
     D. Assume passive diffusion is blocked  
     **Answer:** B. Infer that feedback through receptor-mediated sensing is modulating enzyme expression.  
     **Explanation:** The described situation reflects integrated metabolic feedback through signaling.
131. **Foundational Comprehension:** In a redox reaction, which statement is true?  
     A. Oxidation and reduction occur independently.  
     B. The oxidizing agent loses electrons.  
     C. The reducing agent gains electrons.  
     D. One species is oxidized while another is reduced simultaneously.  
     **Answer:** D. One species is oxidized while another is reduced simultaneously.  
     **Explanation:** Redox reactions always pair oxidation with reduction; one loses electrons while the other gains.
132. **Application:** A student uses an ICE table and finds Q>KQ > KQ>K. What will happen to the system?  
     A. Shift toward products  
     B. No change  
     C. Shift toward reactants  
     D. K increases  
     **Answer:** C. Shift toward reactants.  
     **Explanation:** If Q>KQ > KQ>K, the reaction shifts left to reach equilibrium.
133. **Foundational Comprehension:** Which law describes how adding more reactant shifts equilibrium?  
     A. Boyle’s law  
     B. Le Chatelier’s principle  
     C. Nernst equation  
     D. Faraday’s law  
     **Answer:** B. Le Chatelier’s principle.  
     **Explanation:** Systems counteract disturbances; adding reactant shifts toward products.
134. **Application:** In a galvanic cell, which electrode is the site of oxidation and what is its charge?  
     A. Cathode, positive  
     B. Anode, negative  
     C. Anode, where reduction occurs  
     D. Cathode, negative  
     **Answer:** B. Anode, negative.  
     **Explanation:** In galvanic (spontaneous) cells, oxidation occurs at the anode, which is negative.
135. **Foundational Comprehension:** The Nernst equation is used to:  
     A. Calculate standard Gibbs free energy only  
     B. Adjust cell potential for non-standard conditions  
     C. Determine reaction order  
     D. Find the limiting reagent  
     **Answer:** B. Adjust cell potential for non-standard conditions.  
     **Explanation:** Nernst incorporates concentrations (Q) to find actual cell potential.
136. **Application:** Which quantity is directly proportional to the mass deposited at an electrode during electrolysis?  
     A. Voltage only  
     B. Charge passed  
     C. Temperature  
     D. Pressure  
     **Answer:** B. Charge passed.  
     **Explanation:** Faraday’s first law states mass deposited ∝ total charge.
137. **Reasoning Within the Text:** If a sensor interprets a drop in potential due to increased oxidized species, the underlying redox couple is:  
     A. More reduced overall  
     B. Shifted toward oxidation, changing equilibrium  
     C. Unchanged because cell potentials are standard  
     D. Showing increased spontaneity regardless of Q  
     **Answer:** B. Shifted toward oxidation, changing equilibrium.  
     **Explanation:** Altered concentrations shift redox equilibrium and observed potential.
138. **Test-Taking Strategy:** You’re given a reaction and asked to find the theoretical yield. The first step is to:  
     A. Convert grams to volume  
     B. Balance the chemical equation  
     C. Use the Nernst equation  
     D. Determine the pH  
     **Answer:** B. Balance the chemical equation.  
     **Explanation:** Stoichiometry requires a balanced equation before mole ratios.
139. **Application:** If the cell potential is positive under standard conditions, the associated reaction is:  
     A. Non-spontaneous  
     B. At equilibrium  
     C. Spontaneous  
     D. Endergonic  
     **Answer:** C. Spontaneous.  
     **Explanation:** Positive Ecell∘E^\circ\_{cell}Ecell∘​ corresponds to negative ΔG\Delta GΔG, spontaneous.
140. **Foundational Comprehension:** Which mnemonic helps remember that oxidation is loss and reduction is gain of electrons?  
     A. SNOW DROP  
     B. LEO the lion says GER  
     C. King Henry Died By Drinking Chocolate Milk  
     D. Pretty Vampires Never Run Together  
     **Answer:** B. LEO the lion says GER.  
     **Explanation:** LEO = Loss of Electrons is Oxidation; GER = Gain of Electrons is Reduction.
141. **Foundational Comprehension:** The Henderson-Hasselbalch equation is useful for:  
     A. Calculating cell potentials  
     B. Estimating pH of buffer solutions  
     C. Determining gas densities  
     D. Assigning oxidation numbers  
     **Answer:** B. Estimating pH of buffer solutions.  
     **Explanation:** It relates pH to pKa and ratio of conjugate base to acid.
142. **Foundational Comprehension:** A buffer is composed of:  
     A. Strong acid and strong base  
     B. Weak acid and its conjugate base  
     C. Only water  
     D. Pure salt  
     **Answer:** B. Weak acid and its conjugate base.  
     **Explanation:** Buffers resist pH change using weak acid/base pairs.
143. **Application:** If blood pH drops, the body’s compensatory response to maintain homeostasis likely involves:  
     A. Ignoring bicarbonate buffering  
     B. Utilizing the buffer system to absorb excess H⁺  
     C. Increasing oxidation numbers  
     D. Shifting equilibrium to produce more acid  
     **Answer:** B. Utilizing the buffer system to absorb excess H⁺.  
     **Explanation:** Bicarbonate buffer mitigates acidosis by neutralizing H⁺.
144. **Foundational Comprehension:** Which free energy change corresponds to a spontaneous reaction?  
     A. ΔG>0\Delta G > 0ΔG>0  
     B. ΔG=0\Delta G = 0ΔG=0  
     C. ΔG<0\Delta G < 0ΔG<0  
     D. Undefined  
     **Answer:** C. ΔG<0\Delta G < 0ΔG<0.  
     **Explanation:** Negative Gibbs free energy means exergonic/spontaneous.
145. **Application:** Coupling an endergonic biosynthetic reaction to ATP hydrolysis allows it to proceed because:  
     A. ATP hydrolysis is endergonic too  
     B. The combined ΔG\Delta GΔG becomes negative  
     C. Entropy decreases  
     D. Temperature drops  
     **Answer:** B. The combined ΔG\Delta GΔG becomes negative.  
     **Explanation:** Favorable ATP hydrolysis drives unfavorable processes via coupling.
146. **Foundational Comprehension:** According to the ideal gas law, if temperature increases at constant pressure and moles, volume will:  
     A. Decrease  
     B. Remain same  
     C. Increase  
     D. Become zero  
     **Answer:** C. Increase.  
     **Explanation:** Charles’s law: V∝TV \propto TV∝T at constant P and n.
147. **Application:** In a mixture of gases, the total pressure equals:  
     A. The product of partial pressures  
     B. The average of partial pressures  
     C. The sum of partial pressures  
     D. The difference between highest and lowest partial pressure  
     **Answer:** C. The sum of partial pressures.  
     **Explanation:** Dalton’s law: total pressure is sum of each gas’s partial pressure.
148. **Reasoning Within the Text:** During intense exercise, accumulation of lactic acid lowers pH; what happens to buffer capacity as more acid is added?  
     A. It increases indefinitely  
     B. It remains unchanged  
     C. It is exhausted and pH drops more steeply  
     D. pH becomes neutral  
     **Answer:** C. It is exhausted and pH drops more steeply.  
     **Explanation:** Buffers have limits; added acid beyond capacity causes larger pH change.
149. **Test-Taking Strategy:** If a question describes a spontaneous process coupled to a non-spontaneous one, the student should identify:  
     A. That the net ΔG\Delta GΔG is positive  
     B. That coupling renders the overall ΔG\Delta GΔG negative  
     C. That entropy is irrelevant  
     D. That equilibrium shifts to reactants  
     **Answer:** B. That coupling renders the overall ΔG\Delta GΔG negative.  
     **Explanation:** Coupling uses favorable reactions to drive unfavorable ones.
150. **Application:** If oxygen partial pressure decreases in tissues, what immediate gas law implication helps explain reduced diffusion?  
     A. Increase in total pressure  
     B. Lower driving force for diffusion due to decreased partial pressure gradient  
     C. Ideal gas law becomes invalid  
     D. Temperature must drop  
     **Answer:** B. Lower driving force for diffusion due to decreased partial pressure gradient.  
     **Explanation:** Diffusion depends on partial pressure differences; reduced PO2P\_{O\_2}PO2​​ lowers flux.
151.  **Foundational Comprehension:** A biosensor measuring redox potential in blood must consider pH because:  
     A. pH doesn’t affect redox couples  
     B. Proton concentration shifts equilibria of many half-reactions, altering observed potential  
     C. Dalton’s law overrides redox behavior  
     D. Gibbs free energy is independent of pH  
     **Answer:** B. Proton concentration shifts equilibria of many half-reactions, altering observed potential.  
     **Explanation:** Redox potentials often depend on [H⁺]; pH changes affect Nernst equation outcomes.
152.  **Application:** In lactic acidosis, the buffer system is overwhelmed and oxygen delivery drops. Which combined factors exacerbate tissue hypoxia?  
     A. Increased PO2P\_{O\_2}PO2​​ and higher pH  
     B. Lower oxygen diffusion gradient and impaired enzyme-driven ATP production due to unfavorable energetics  
     C. Elevated buffer capacity  
     D. Spontaneous generation of ATP  
     **Answer:** B. Lower oxygen diffusion gradient and impaired enzyme-driven ATP production due to unfavorable energetics.  
     **Explanation:** Acidosis reduces oxygen unloading efficiency and disturbs metabolic coupling.
153.  **Reasoning Beyond the Text:** A system that senses falling oxygen partial pressure and triggers increased cardiac output is using:  
     A. Passive diffusion only  
     B. Integrated physiological feedback analogous to chemical equilibrium adjustments  
     C. Redox potential changes directly  
     D. Buffer exhaustion  
     **Answer:** B. Integrated physiological feedback analogous to chemical equilibrium adjustments.  
     **Explanation:** Body responds to perturbations to restore homeostasis, comparable to Le Chatelier’s principle.
154.  **Foundational Comprehension:** If a novel drug shifts a redox equilibrium such that the reduced form dominates, what happens to the measured potential (assuming a standard half-reaction)?  
     A. It increases without bound  
     B. It shifts according to the Nernst equation reflecting increased reduced species  
     C. It remains at standard potential  
     D. It becomes meaningless  
     **Answer:** B. It shifts according to the Nernst equation reflecting increased reduced species.  
     **Explanation:** Changes in ratio of oxidized/reduced species alter potential per Nernst.
155.  **Test-Taking Strategy:** When a passage layers acid-base imbalance, redox shift, and gas exchange failure, the best way to approach the question is to:  
     A. Tackle each system sequentially, then synthesize how they interrelate  
     B. Ignore one of the systems  
     C. Assume equilibrium holds for all  
     D. Focus only on gas laws  
     **Answer:** A. Tackle each system sequentially, then synthesize how they interrelate.  
     **Explanation:** Complex vignettes require decomposing interacting components before integrating.
156. **Foundational Comprehension:** If a system at equilibrium experiences an increase in product concentration, the reaction will:  
     A. Shift right  
     B. Shift left  
     C. Remain unchanged  
     D. Increase temperature  
     **Answer:** B. Shift left.  
     **Explanation:** Per Le Chatelier’s principle, adding product pushes the system toward reactants.
157. **Foundational Comprehension:** The Henderson-Hasselbalch equation is primarily used to:  
     A. Compute cell potentials  
     B. Estimate the pH of a buffer  
     C. Determine oxidation states  
     D. Calculate gas pressure  
     **Answer:** B. Estimate the pH of a buffer.  
     **Explanation:** It relates pH to pKa and base/acid ratio in buffer systems.
158. **Application:** During lactic acidosis, the buffering system begins to fail; what happens to blood pH and why?  
     A. pH rises due to increased base  
     B. pH falls more steeply because buffer capacity is exhausted  
     C. pH remains constant indefinitely  
     D. pH oscillates randomly  
     **Answer:** B. pH falls more steeply because buffer capacity is exhausted.  
     **Explanation:** Buffers have finite capacity; excess H⁺ leads to larger pH changes.
159. **Foundational Comprehension:** A reaction with ΔG<0\Delta G < 0ΔG<0 is:  
     A. Non-spontaneous  
     B. At equilibrium  
     C. Spontaneous  
     D. Driven by external energy  
     **Answer:** C. Spontaneous.  
     **Explanation:** Negative Gibbs free energy indicates an exergonic, spontaneous process.
160. **Application:** Coupling an endergonic reaction to ATP hydrolysis allows the overall process to proceed because:  
     A. ATP hydrolysis is also endergonic  
     B. The combined ΔG\Delta GΔG becomes more positive  
     C. The combined ΔG\Delta GΔG becomes negative  
     D. Entropy decreases  
     **Answer:** C. The combined ΔG\Delta GΔG becomes negative.  
     **Explanation:** Favorable ATP hydrolysis drives unfavorable reactions via coupling.
161. **Foundational Comprehension:** Which definition of acids/bases involves proton donors and acceptors?  
     A. Arrhenius  
     B. Lewis  
     C. Brønsted-Lowry  
     D. IUPAC  
     **Answer:** C. Brønsted-Lowry.  
     **Explanation:** Brønsted-Lowry defines acids as proton donors and bases as acceptors.
162. **Application:** If tissue partial pressure of oxygen decreases, oxygen diffusion into cells is impaired because:  
     A. The equilibrium constant changes  
     B. The partial pressure gradient (driving force) is reduced  
     C. pH increases  
     D. Redox potentials become standardized  
     **Answer:** B. The partial pressure gradient (driving force) is reduced.  
     **Explanation:** Gas diffusion depends on partial pressure differences; lower PO2P\_{O\_2}PO2​​ reduces flux.
163. **Test-Taking Strategy:** In a vignette describing metabolic stress with declining pH and lowered oxygen availability, the best approach is to:  
     A. Focus only on oxygen  
     B. Treat each system separately then integrate their effects  
     C. Ignore acid-base effects  
     D. Assume all processes are at equilibrium  
     **Answer:** B. Treat each system separately then integrate their effects.  
     **Explanation:** Complex interactions require decomposing and synthesizing.
164. **Foundational Comprehension:** Which change would alter the equilibrium constant KKK?  
     A. Adding reactant  
     B. Adding product  
     C. Changing temperature  
     D. Adding a catalyst  
     **Answer:** C. Changing temperature.  
     **Explanation:** Only temperature affects the value of KKK; catalysts don't change position.
165. **Integrated Concept:** In exercise-induced acidosis, which combination most directly worsens muscle performance?  
     A. Enhanced buffering + high PO2P\_{O\_2}PO2​​  
     B. Buffer exhaustion + reduced oxygen diffusion gradient  
     C. Increased pH + spontaneous ΔG\Delta GΔG  
     D. Elevated partial pressure + increased entropy  
     **Answer:** B. Buffer exhaustion + reduced oxygen diffusion gradient.  
     **Explanation:** Falling pH with limited oxygen impairs energy production.
166.  **Foundational Comprehension:** In a galvanic cell, oxidation occurs at the:  
     A. Cathode  
     B. Salt bridge  
     C. Anode  
     D. External circuit  
     **Answer:** C. Anode.  
     **Explanation:** Oxidation (loss of electrons) occurs at the anode; remembered via “AN OX.”
167.  **Foundational Comprehension:** Which mnemonic helps recall that reduction is gain of electrons?  
     A. SNOW DROP  
     B. LEO the lion says GER  
     C. King Henry Died By Drinking Chocolate Milk  
     D. TePNa  
     **Answer:** B. LEO the lion says GER.  
     **Explanation:** Loss of Electrons is Oxidation; Gain of Electrons is Reduction.
168.  **Application:** A sensor reports a potential shift because proton concentration changed; which equation relates this effect to the actual cell potential?  
     A. Henderson-Hasselbalch  
     B. Ideal gas law  
     C. Nernst equation  
     D. Faraday’s law  
     **Answer:** C. Nernst equation.  
     **Explanation:** The Nernst equation adjusts potentials for non-standard conditions, including [H⁺].
169.  **Foundational Comprehension:** Faraday’s first law states that the mass deposited at an electrode is proportional to:  
     A. Voltage applied  
     B. Charge passed  
     C. Temperature  
     D. pH  
     **Answer:** B. Charge passed.  
     **Explanation:** Mass ∝ total charge (Q = It).
170.  **Application:** If a redox couple becomes more reduced in concentration relative to oxidized form, the cell potential will:  
     A. Remain at standard potential  
     B. Shift per the Nernst equation  
     C. Always increase  
     D. Be unaffected by concentration  
     **Answer:** B. Shift per the Nernst equation.  
     **Explanation:** Relative species concentrations alter potential.
171.  **Foundational Comprehension:** Which periodic trend explains why fluorine is a strong oxidizing agent?  
     A. Large atomic radius  
     B. Low electronegativity  
     C. High electronegativity and low atomic size  
     D. High shielding  
     **Answer:** C. High electronegativity and low atomic size.  
     **Explanation:** Strong tendency to gain electrons makes it oxidizing.
172.  **Application:** In designing an electrode, selecting a metal with low ionization energy relates to its:  
     A. Tendency to gain electrons  
     B. Reactivity as a reducing agent (loses electrons easily)  
     C. Solubility in water  
     D. Buffer capacity  
     **Answer:** B. Reactivity as a reducing agent (loses electrons easily).  
     **Explanation:** Metals with low ionization energy lose electrons and act as reducing agents.
173.  **Foundational Comprehension:** The common ion effect will:  
     A. Increase solubility of a salt  
     B. Suppress dissociation of a salt  
     C. Change the oxidation state  
     D. Alter temperature directly  
     **Answer:** B. Suppress dissociation of a salt.  
     **Explanation:** Adding a shared ion shifts equilibrium to reduce solubility.
174.  **Integrated Concept:** A sensor’s redox mediator becomes less soluble due to increased concentration of a common ion; this impacts:  
     A. Equilibrium position for mediator dissolution and thus availability for electron transfer  
     B. Gibbs free energy only  
     C. Nernst equation structure  
     D. Oxygen partial pressure  
     **Answer:** A. Equilibrium position for mediator dissolution and thus availability for electron transfer.  
     **Explanation:** Reduced solubility decreases active species in solution, shifting equilibrium.
175.  **Test-Taking Strategy:** When faced with a vignette about a wearable redox sensor influenced by pH, periodic trend–based electrode selection, and signal calibration, the first step is to:  
     A. Ignore concentration effects  
     B. Identify how changes in proton concentration and species availability affect half-cell potentials  
     C. Assume standard conditions  
     D. Only consider the salt bridge function  
     **Answer:** B. Identify how changes in proton concentration and species availability affect half-cell potentials.  
     **Explanation:** Understanding how real conditions (pH, concentrations) shift potentials is foundational.
176.  **Reasoning Within the Text:** A candidate integrates redox potential shifts due to local acidosis (lower pH) into sensor output. Which two concepts are they combining?  
     A. Gas laws and periodic trends  
     B. Henderson-Hasselbalch and ideal gas law  
     C. Nernst equation and acid-base influence on redox equilibria  
     D. Buffer capacity and atomic radius  
     **Answer:** C. Nernst equation and acid-base influence on redox equilibria.  
     **Explanation:** Proton concentration affects redox potentials via the Nernst relationship.
177.  **Application:** If a lowering of pH shifts a half-reaction equilibrium, causing decreased sensor voltage, you would infer:  
     A. Increased spontaneous oxidations irrespective of concentration  
     B. Proton involvement in the redox half-reaction modifying potential  
     C. Buffering improving signal  
     D. Dalton’s law interfering  
     **Answer:** B. Proton involvement in the redox half-reaction modifying potential.  
     **Explanation:** H⁺ participates in many biological redox reactions affecting E.
178.  **Foundational Comprehension:** Which statement best describes dynamic equilibrium?  
     A. Only reactants exist  
     B. Forward and reverse reactions stop  
     C. Forward and reverse reactions proceed at equal rates  
     D. The system is open to matter exchange  
     **Answer:** C. Forward and reverse reactions proceed at equal rates.  
     **Explanation:** Concentrations remain steady despite ongoing reactions.
179.  **Reasoning Beyond the Text:** To improve sensor sensitivity to oxidative shifts, choosing an electrode material whose redox partner has a steep Nernst dependence on pH would:  
     A. Blur signal changes  
     B. Amplify detectable potential differences with small pH shifts  
     C. Make the sensor independent of local chemistry  
     D. Eliminate need for calibration  
     **Answer:** B. Amplify detectable potential differences with small pH shifts.  
     **Explanation:** Strong pH sensitivity in the half-reaction yields larger voltage changes for small proton fluctuations.
180.  **Test-Taking Strategy:** When a passage weaves equilibrium shifts, acid-base disturbance, and electrochemical readouts, the most effective method is to:  
     A. Treat the scenario as purely electrochemical  
     B. Sequentially parse each chemical domain (equilibrium, pH, redox) then integrate their interactions  
     C. Assume cell potential is standard  
     D. Disregard buffer effects  
     **Answer:** B. Sequentially parse each chemical domain (equilibrium, pH, redox) then integrate their interactions.  
     **Explanation:** Decomposing complex, multi-system passages avoids oversight and supports correct synthesis.
181.  **Foundational Comprehension:** In stoichiometric calculations, why is balancing the chemical equation the first step?  
     A. To determine the buffer capacity  
     B. To establish mole ratios for reactants and products  
     C. To calculate partial pressures  
     D. To set the temperature  
     **Answer:** B. To establish mole ratios for reactants and products.  
     **Explanation:** Balanced equations provide the mole ratios needed for stoichiometry.
182.  **Foundational Comprehension:** According to Dalton’s law, the total pressure of a gas mixture is:  
     A. The product of partial pressures  
     B. The difference between the highest and lowest partial pressure  
     C. The sum of partial pressures  
     D. Independent of individual gas contributions  
     **Answer:** C. The sum of partial pressures.  
     **Explanation:** Dalton’s law states total pressure equals sum of each gas’s partial pressure.
183.  **Application:** If a mountaineer ascends and temperature drops while volume of lung air remains roughly constant, what happens to pressure of contained oxygen (assuming moles constant)?  
     A. Increases  
     B. Decreases  
     C. Remains same  
     D. Becomes negative  
     **Answer:** B. Decreases.  
     **Explanation:** Gay-Lussac’s law: pressure is directly proportional to temperature; lower T reduces pressure.
184.  **Foundational Comprehension:** Le Chatelier’s principle predicts that adding more acid to a buffered system will:  
     A. Shift equilibrium to consume H⁺  
     B. Produce more H⁺  
     C. Change the value of K  
     D. Have no effect  
     **Answer:** A. Shift equilibrium to consume H⁺.  
     **Explanation:** The system opposes added H⁺, adjusting to restore balance.
185.  **Application:** During lactic acidosis, why does pH begin to drop more sharply after some time?  
     A. Buffer system gains capacity  
     B. Partial pressure of oxygen increases  
     C. Buffer capacity is exhausted  
     D. Gibbs free energy becomes positive  
     **Answer:** C. Buffer capacity is exhausted.  
     **Explanation:** Buffers have limits; beyond that, added acid causes larger pH changes.
186.  **Foundational Comprehension:** A reaction with ΔG<0\Delta G < 0ΔG<0 under physiological conditions is:  
     A. Non-spontaneous  
     B. At equilibrium  
     C. Spontaneous  
     D. Impossible  
     **Answer:** C. Spontaneous.  
     **Explanation:** Negative Gibbs free energy denotes spontaneity.
187.  **Application:** In hypoxia, lowered oxygen partial pressure reduces diffusion into tissues because:  
     A. The equilibrium constant changes  
     B. The partial pressure gradient driving diffusion shrinks  
     C. Temperature increases  
     D. Stoichiometry fails  
     **Answer:** B. The partial pressure gradient driving diffusion shrinks.  
     **Explanation:** Diffusion depends on pressure differences; lower PO2P\_{O\_2}PO2​​ reduces flux.
188.  **Test-Taking Strategy:** Faced with a vignette combining gas law changes, acid-base imbalance, and energetics, the best analytical sequence is to:  
     A. Ignore gas laws  
     B. Integrate all at once without decomposition  
     C. Separate each domain (gas behavior, pH shifts, free energy) then synthesize  
     D. Assume equilibrium everywhere  
     **Answer:** C. Separate each domain (gas behavior, pH shifts, free energy) then synthesize.  
     **Explanation:** Decomposing complex interactions aids accurate understanding.
189.  **Foundational Comprehension:** Which variable change will alter the equilibrium constant KKK?  
     A. Adding reactant  
     B. Adding product  
     C. Changing temperature  
     D. Adding catalyst  
     **Answer:** C. Changing temperature.  
     **Explanation:** Only temperature affects KKK; catalysts do not.
190.  **Integrated Concept:** A runner at altitude has low PO2P\_{O\_2}PO2​​, rising lactic acid, and reduced ATP yield. Which combination best explains their fatigue?  
     A. High oxygen gradient + ample buffering  
     B. Low diffusion driving force + buffer exhaustion + unfavorable energetics  
     C. Increased Gibbs free energy coupled to spontaneous reactions  
     D. Elevated pH improving enzyme function  
     **Answer:** B. Low diffusion driving force + buffer exhaustion + unfavorable energetics.  
     **Explanation:** All interact to impair ATP production and lead to fatigue.
191. **Foundational Comprehension:** In a galvanic cell, where does oxidation occur?  
     A. Cathode  
     B. Salt bridge  
     C. Anode  
     D. External resistor  
     **Answer:** C. Anode.  
     **Explanation:** Oxidation happens at the anode; mnemonic “AN OX.”
192. **Foundational Comprehension:** What does the mnemonic “LEO the lion says GER” remind you?  
     A. Equilibrium shifts  
     B. Oxidation is loss, reduction is gain of electrons  
     C. Gas law relationships  
     D. Buffer equations  
     **Answer:** B. Oxidation is loss, reduction is gain of electrons.  
     **Explanation:** LEO = Loss of Electrons is Oxidation; GER = Gain of Electrons is Reduction.
193. **Application:** A sensor’s measured cell potential changes because local proton concentration increases. Which equation accounts for this adjustment?  
     A. Henderson-Hasselbalch  
     B. Ideal gas law  
     C. Nernst equation  
     D. Faraday’s law  
     **Answer:** C. Nernst equation.  
     **Explanation:** Nernst adjusts cell potential for concentration changes including H⁺.
194. **Foundational Comprehension:** According to Faraday’s first law, the mass deposited during electrolysis is proportional to:  
     A. Voltage  
     B. Charge passed  
     C. Temperature  
     D. pH  
     **Answer:** B. Charge passed.  
     **Explanation:** Mass ∝ total charge (Q = I × t).
195. **Application:** If the ratio of reduced to oxidized species increases in a half-cell, the observed potential will:  
     A. Stay at standard  
     B. Shift according to the Nernst equation  
     C. Always become more positive regardless of reaction  
     D. Be independent of concentration  
     **Answer:** B. Shift according to the Nernst equation.  
     **Explanation:** Changing species ratios affect potential.
196. **Foundational Comprehension:** Which periodic trend explains why elements like fluorine are strong oxidizing agents?  
     A. Large atomic radius  
     B. High electronegativity  
     C. Low ionization energy  
     D. Strong shielding  
     **Answer:** B. High electronegativity.  
     **Explanation:** Electronegativity increases across a period, making F eager to gain electrons.
197. **Application:** Selecting a metal with low ionization energy for the anode enhances its behavior as:  
     A. Oxidizing agent  
     B. Reducing agent  
     C. Buffer  
     D. Ligand  
     **Answer:** B. Reducing agent.  
     **Explanation:** Low ionization energy metals lose electrons easily (reduce others).
198. **Foundational Comprehension:** The **common ion effect** in a solution will:  
     A. Increase solubility of a salt  
     B. Suppress dissociation of a salt  
     C. Change oxidation numbers  
     D. Raise temperature  
     **Answer:** B. Suppress dissociation of a salt.  
     **Explanation:** Adding a shared ion shifts equilibrium to reduce solubility.
199. **Integrated Concept:** A redox mediator becomes less available due to suppressed solubility from a common ion; this will:  
     A. Increase cell potential automatically  
     B. Shift equilibrium of mediator dissolution, limiting electron transfer  
     C. Make Nernst equation invalid  
     D. Increase oxygen partial pressure  
     **Answer:** B. Shift equilibrium of mediator dissolution, limiting electron transfer.  
     **Explanation:** Reduced soluble mediator decreases active species, altering equilibrium and signal.
200. **Test-Taking Strategy:** When interpreting a diagnostic sensor’s output influenced by pH, redox state, and electrode material, the most logical first step is to:  
     A. Assume standard potentials  
     B. Evaluate how proton concentration and species availability modify half-cell potentials  
     C. Ignore electrode selection  
     D. Treat bioenergetics separately  
     **Answer:** B. Evaluate how proton concentration and species availability modify half-cell potentials.  
     **Explanation:** Real-condition adjustments via Nernst and equilibrium are foundational.
201. **Reasoning Within the Text:** A wearable sensor detects decreasing voltage in tandem with a drop in pH during metabolic acidosis. Which combination best explains the signal change?  
     A. Dalton’s law and Boyle’s law  
     B. Common ion effect and gas law  
     C. Proton involvement in the redox half-reaction altering potential via the Nernst equation  
     D. Stoichiometric imbalance only  
     **Answer:** C. Proton involvement in the redox half-reaction altering potential via the Nernst equation.  
     **Explanation:** pH (H⁺ concentration) affects redox potentials per Nernst.
202. **Application:** A candidate wants to correlate low oxygen availability with shifted redox readings in muscle. They must integrate:  
     A. Gas diffusion gradients and pH-dependent redox potential changes  
     B. Only periodic trends  
     C. Only equilibrium constants  
     D. Stoichiometry of unrelated reactions  
     **Answer:** A. Gas diffusion gradients and pH-dependent redox potential changes.  
     **Explanation:** Hypoxia lowers oxygen partial pressure; acidosis changes redox via H⁺—both affect cellular redox readouts.
203. **Foundational Comprehension:** Dynamic equilibrium means:  
     A. No reactions occur  
     B. Only products are present  
     C. Forward and reverse reaction rates are equal  
     D. System is open to matter exchange  
     **Answer:** C. Forward and reverse reaction rates are equal.  
     **Explanation:** Concentrations stay constant while reactions continue.
204. **Reasoning Beyond the Text:** Designing a sensor that flags when bioenergetic coupling fails would most likely monitor:  
     A. Only Gibbs free energy directly  
     B. Changes in redox potential alongside pH and oxygen gradients to infer disrupted favorable/unfavorable reaction coupling  
     C. Periodic trends in salts  
     D. Stoichiometry of inert gases  
     **Answer:** B. Changes in redox potential alongside pH and oxygen gradients to infer disrupted favorable/unfavorable reaction coupling.  
     **Explanation:** Bioenergetic failure manifests in altered redox state, acid-base balance, and oxygen availability.
205. **Test-Taking Strategy:** When a passage layers hypoxia, acidosis, and redox sensor drift, the optimal approach is to:  
     A. Focus exclusively on redox data  
     B. Sequentially identify the chemical perturbations (gas, pH, redox), then evaluate their combined effect on the signal  
     C. Discard pH as noise  
     D. Assume constant buffer capacity  
     **Answer:** B. Sequentially identify the chemical perturbations (gas, pH, redox), then evaluate their combined effect on the signal.  
     **Explanation:** Layered physiological disturbances require decomposition before integration.

**Passage 1: Equilibrium / Acid-Base / Bioenergetics / Gas**

1. **Foundational Comprehension:** Which change will alter the value of an equilibrium constant KKK?  
   A. Adding more reactant  
   B. Adding a catalyst  
   C. Changing temperature  
   D. Removing product  
   **Answer:** C. Changing temperature.  
   **Explanation:** Only temperature changes KKK; catalysts and adding/removing species shift position but not the constant.
2. **Foundational Comprehension:** The Henderson-Hasselbalch equation is most useful for:  
   A. Calculating cell potential  
   B. Predicting pH of a buffer system  
   C. Determining gas density  
   D. Assigning oxidation states  
   **Answer:** B. Predicting pH of a buffer system.  
   **Explanation:** It relates pH to pKa and ratio of conjugate base to acid.
3. **Application:** During sustained high-intensity exercise, lactic acid accumulates and the buffer system is overwhelmed. What happens to pH and why?  
   A. pH rises because acid is neutralized completely  
   B. pH drops more sharply because buffer capacity is exhausted  
   C. pH stays constant because equilibrium is restored instantly  
   D. pH becomes basic due to overcompensation  
   **Answer:** B. pH drops more sharply because buffer capacity is exhausted.  
   **Explanation:** Buffers resist change only up to their capacity; excess H⁺ causes steeper decline.
4. **Foundational Comprehension:** A spontaneous biochemical reaction will have:  
   A. Positive ΔG\Delta GΔG  
   B. ΔG=0\Delta G = 0ΔG=0  
   C. Negative ΔG\Delta GΔG  
   D. Undefined ΔG\Delta GΔG  
   **Answer:** C. Negative ΔG\Delta GΔG.  
   **Explanation:** Negative Gibbs free energy indicates exergonic, spontaneous process.
5. **Application:** Coupling an endergonic process to ATP hydrolysis allows it to proceed because:  
   A. ATP hydrolysis increases entropy independently  
   B. The overall ΔG\Delta GΔG becomes negative  
   C. The equilibrium constant is unchanged  
   D. Enthalpy becomes positive  
   **Answer:** B. The overall ΔG\Delta GΔG becomes negative.  
   **Explanation:** Favorable ATP hydrolysis drives unfavorable reactions.
6. **Foundational Comprehension:** Le Chatelier’s principle predicts that adding more acid to a buffer will:  
   A. Shift equilibrium to produce more H⁺  
   B. Shift equilibrium to consume added H⁺  
   C. Change the value of KaK\_aKa​  
   D. Have no effect  
   **Answer:** B. Shift equilibrium to consume added H⁺.  
   **Explanation:** System counteracts added acid to restore balance.
7. **Application:** In altitude-induced hypoxia, oxygen diffusion into tissues decreases primarily because:  
   A. Partial pressure gradient decreases  
   B. Temperature rises  
   C. Buffer capacity increases  
   D. KKK changes  
   **Answer:** A. Partial pressure gradient decreases.  
   **Explanation:** Lower PO2P\_{O\_2}PO2​​ reduces the driving force for diffusion.
8. **Test-Taking Strategy:** When confronted with a vignette combining gas law changes, acidosis, and altered metabolic spontaneity, the best approach is to:  
   A. Address each domain (gas behavior, acid-base, energetics) separately then integrate  
   B. Focus solely on gas behavior  
   C. Assume equilibrium everywhere  
   D. Ignore Gibbs free energy  
   **Answer:** A. Address each domain (gas behavior, acid-base, energetics) separately then integrate.  
   **Explanation:** Decomposing complex systems avoids misinterpretation.
9. **Foundational Comprehension:** Which definition describes a Brønsted-Lowry base?  
   A. Electron pair acceptor  
   B. Proton donor  
   C. Electron pair donor  
   D. Proton acceptor  
   **Answer:** D. Proton acceptor.  
   **Explanation:** Brønsted-Lowry bases accept protons.
10. **Integrated Concept:** A fatigued high-altitude climber has low oxygen delivery and falling pH. Which combination best explains impaired ATP production?  
    A. Efficient diffusion + high buffer capacity  
    B. Reduced diffusion gradient + buffer exhaustion + less favorable reaction energetics  
    C. Elevated ΔG<0 making everything spontaneous  
    D. Increased oxygen partial pressure  
    **Answer:** B. Reduced diffusion gradient + buffer exhaustion + less favorable reaction energetics.  
    **Explanation:** All three combine to lower metabolic efficiency.
11.  **Foundational Comprehension:** In a galvanic cell, where does oxidation occur?  
    A. Cathode  
    B. Salt bridge  
    C. Anode  
    D. External circuit  
    **Answer:** C. Anode.  
    **Explanation:** Oxidation occurs at the anode (AN OX mnemonic).
12.  **Foundational Comprehension:** What does “LEO the lion says GER” help you remember?  
    A. Direction of equilibrium shift  
    B. Oxidation is loss, reduction is gain of electrons  
    C. Gas law relationships  
    D. Acid-base definitions  
    **Answer:** B. Oxidation is loss, reduction is gain of electrons.  
    **Explanation:** Mnemonic for electron transfer in redox.
13.  **Application:** A sensor’s potential changes because proton concentration rises locally. Which equation accounts for this?  
    A. Henderson-Hasselbalch  
    B. Ideal gas law  
    C. Nernst equation  
    D. Faraday’s law  
    **Answer:** C. Nernst equation.  
    **Explanation:** Adjusts electrode potential based on concentrations including [H+][H^+][H+].
14.  **Foundational Comprehension:** According to Faraday’s first law, the amount of substance deposited during electrolysis is proportional to:  
    A. Voltage  
    B. Charge passed  
    C. Temperature  
    D. pH  
    **Answer:** B. Charge passed.  
    **Explanation:** Mass deposited ∝ total charge (Q = I × t).
15.  **Application:** If the ratio of reduced to oxidized form increases, the cell potential will:  
    A. Remain at standard value  
    B. Shift according to the Nernst equation  
    C. Always become more negative  
    D. Be independent of concentrations  
    **Answer:** B. Shift according to the Nernst equation.  
    **Explanation:** Concentration ratios affect actual potential.
16.  **Foundational Comprehension:** Which periodic trend makes fluorine a strong oxidizing agent?  
    A. Large atomic radius  
    B. High electronegativity  
    C. Low shielding  
    D. High metallic character  
    **Answer:** B. High electronegativity.  
    **Explanation:** Strong pull on electrons makes it readily reduced.
17.  **Application:** Choosing a metal with low ionization energy for the anode optimizes it as a:  
    A. Reducing agent  
    B. Oxidizing agent  
    C. Buffer component  
    D. Ligand  
    **Answer:** A. Reducing agent.  
    **Explanation:** Easily loses electrons, donating them in oxidation.
18.  **Foundational Comprehension:** The common ion effect will:  
    A. Increase solubility of a salt  
    B. Suppress dissociation of a salt  
    C. Change oxidation numbers  
    D. Alter temperature  
    **Answer:** B. Suppress dissociation of a salt.  
    **Explanation:** Shared ions shift equilibrium, reducing solubility.
19.  **Integrated Concept:** If a redox mediator becomes less available due to common ion suppression, the sensor’s signal is affected because:  
    A. Cell potential becomes standard  
    B. Equilibrium for mediator dissolution shifts, lowering active species for electron transfer  
    C. Faraday’s constant changes  
    D. Proton concentration rises automatically  
    **Answer:** B. Equilibrium for mediator dissolution shifts, lowering active species for electron transfer.  
    **Explanation:** Reduced solubility reduces mediator concentration, weakening signal.
20.  **Test-Taking Strategy:** Given a complex device combining local pH changes, redox sensing, and electrode material choice, the best initial analytic step is to:  
    A. Assume standard potentials  
    B. Evaluate how proton concentration and species availability modify half-cell potentials  
    C. Ignore periodic trends  
    D. Focus only on the salt bridge  
    **Answer:** B. Evaluate how proton concentration and species availability modify half-cell potentials.  
    **Explanation:** Real-condition adjustments are foundational to interpreting signal.
21. **Reasoning Within the Text:** A wearable sensor shows decreasing voltage during tissue acidosis. Which mechanism explains this?  
    A. Dalton’s law affecting partial pressures  
    B. Proton involvement in the redox half-reaction altering electrode potential via Nernst  
    C. Change in periodic trends  
    D. Buffer creation of more oxidized species  
    **Answer:** B. Proton involvement in the redox half-reaction altering electrode potential via Nernst.  
    **Explanation:** H⁺ concentration modifies redox potentials.
22. **Application:** To correlate hypoxia with altered redox readings, a researcher should integrate:  
    A. Gas diffusion limitations and pH-dependent potential shifts  
    B. Only periodic trends  
    C. Only equilibrium constants  
    D. Stoichiometry of unrelated reactions  
    **Answer:** A. Gas diffusion limitations and pH-dependent potential shifts.  
    **Explanation:** Low oxygen reduces electron acceptor availability; acidosis shifts redox potentials.
23. **Foundational Comprehension:** Dynamic equilibrium means:  
    A. Reactions have stopped  
    B. Only products exist  
    C. Forward and reverse rates are equal  
    D. System is open  
    **Answer:** C. Forward and reverse rates are equal.  
    **Explanation:** Concentrations stay constant while reactions proceed.
24. **Reasoning Beyond the Text:** A design to detect failing metabolic coupling would best monitor:  
    A. Only Gibbs free energy directly  
    B. Redox potential shifts, pH changes, and oxygen gradients together  
    C. Periodic trends alone  
    D. Static equilibrium constants  
    **Answer:** B. Redox potential shifts, pH changes, and oxygen gradients together.  
    **Explanation:** Bioenergetic failure manifests across these interconnected parameters.
25. **Test-Taking Strategy:** When tackling a passage layering hypoxia, acidosis, and electrochemical sensor drift, you should:  
    A. Isolate each perturbation and then synthesize their combined effect  
    B. Focus only on sensor output  
    C. Disregard pH as secondary  
    D. Assume constant buffer capacity  
    **Answer:** A. Isolate each perturbation and then synthesize their combined effect.  
    **Explanation:** Systematic decomposition prevents missing interactions.
26. **Foundational Comprehension:** In an aldol condensation, what is the role of the α-hydrogen?  
    A. Acts as an electrophile  
    B. Is abstracted to form the enolate nucleophile  
    C. Stabilizes the carbonyl via resonance  
    D. Serves as a leaving group  
    **Answer:** B. Is abstracted to form the enolate nucleophile.  
    **Explanation:** Deprotonation at the α-carbon creates the enolate that attacks another carbonyl.
27. **Application:** A student wants to favor an SN2 reaction over SN1. Which condition would help?  
    A. Use a tertiary substrate in a polar protic solvent  
    B. Use a primary substrate with a strong nucleophile in a polar aprotic solvent  
    C. Use a weak nucleophile and tertiary carbon  
    D. Use a polar protic solvent and high temperature  
    **Answer:** B. Use a primary substrate with a strong nucleophile in a polar aprotic solvent.  
    **Explanation:** SN2 favors less hindered substrates, strong nucleophiles, and polar aprotic solvents.
28. **Foundational Comprehension:** Which of the following is true about SN1 reactions?  
    A. They proceed with inversion of configuration exclusively  
    B. They involve a carbocation intermediate and can lead to racemization  
    C. They require strong nucleophiles and minimal steric hindrance  
    D. They are second-order in mechanism  
    **Answer:** B. They involve a carbocation intermediate and can lead to racemization.  
    **Explanation:** SN1 is unimolecular, forms planar carbocation, allowing attack from either side.
29. **Application:** In a crossed aldol condensation between two different aldehydes, product mixtures arise primarily because:  
    A. The reaction cannot proceed without a catalyst  
    B. Each aldehyde can act as both nucleophile and electrophile, giving multiple combinations  
    C. Dehydration is impossible  
    D. α-Hydrogens are absent  
    **Answer:** B. Each aldehyde can act as both nucleophile and electrophile, giving multiple combinations.  
    **Explanation:** Crossed aldols without selectivity produce mixtures unless one partner lacks α-hydrogens or is controlled.
30. **Foundational Comprehension:** Electrophilic aromatic substitution differs from electrophilic addition in that:  
    A. The aromaticity is temporarily lost and then restored  
    B. π bonds are broken permanently  
    C. It only happens on alkenes  
    D. It proceeds via nucleophilic attack first  
    **Answer:** A. The aromaticity is temporarily lost and then restored.  
    **Explanation:** The sigma complex forms, disrupting aromaticity, which is regained after substitution.
31. **Foundational Comprehension:** Which spectroscopic feature is characteristic of a carbonyl group in IR?  
    A. Broad peak around 3200–3600 cm⁻¹  
    B. Sharp peak near 1700 cm⁻¹  
    C. Signals at 0.8–1.5 ppm in ¹H NMR  
    D. Aromatic stretch at 6–8 ppm  
    **Answer:** B. Sharp peak near 1700 cm⁻¹.  
    **Explanation:** Carbonyl C=O stretching appears around 1700 cm⁻¹ in IR.
32. **Application:** A molecule shows a proton signal at ~7 ppm in ¹H NMR and a sharp C=O at ~170 ppm in ¹³C NMR. Which functional group is likely present?  
    A. Alkane  
    B. Aromatic ketone  
    C. Alcohol  
    D. Alkene  
    **Answer:** B. Aromatic ketone.  
    **Explanation:** Aromatic protons appear 6–8 ppm; carbonyl carbons show in 160–220 ppm region.
33. **Foundational Comprehension:** What distinguishes enantiomers from diastereomers?  
    A. Enantiomers are not mirror images  
    B. Diastereomers have identical physical properties  
    C. Enantiomers are non-superimposable mirror images with opposite optical activity  
    D. Diastereomers must differ at all stereocenters  
    **Answer:** C. Enantiomers are non-superimposable mirror images with opposite optical activity.  
    **Explanation:** Enantiomers rotate plane-polarized light oppositely; diastereomers have different properties.
34. **Application:** For naming a compound with multiple functional groups, which guideline helps determine the suffix?  
    A. Use alphabetical order only  
    B. Highest priority functional group becomes suffix per IUPAC hierarchy  
    C. Always use alcohol as suffix  
    D. Use the most abundant group  
    **Answer:** B. Highest priority functional group becomes suffix per IUPAC hierarchy.  
    **Explanation:** Functional group priority determines naming conventions.
35. **Reasoning:** A student misnumbers a cyclic compound’s substituents, violating the lowest locant rule. This error would primarily affect:  
    A. Spectroscopic properties  
    B. IUPAC name correctness  
    C. Chirality  
    D. Reaction mechanism  
    **Answer:** B. IUPAC name correctness.  
    **Explanation:** Lowest locant rule affects systematic naming.
36. **Foundational Comprehension:** In TLC with a polar stationary phase, which compound would have the lowest Rf?  
    A. Nonpolar alkane  
    B. Polar alcohol  
    C. Noble gas  
    D. Hydrocarbon gas  
    **Answer:** B. Polar alcohol.  
    **Explanation:** Polar compounds interact more strongly and travel less.
37. **Application:** Which technique would best distinguish between two enantiomers of a chiral drug?  
    A. Standard TLC  
    B. Optical activity measurement (e.g., polarimetry)  
    C. IR spectroscopy alone  
    D. Gel electrophoresis  
    **Answer:** B. Optical activity measurement (e.g., polarimetry).  
    **Explanation:** Enantiomers differ only in optical rotation.
38. **Foundational Comprehension:** What is the effect of strong hydrogen bonding on boiling point?  
    A. Lowers boiling point  
    B. Raises boiling point  
    C. Has no effect  
    D. Makes compound non-volatile  
    **Answer:** B. Raises boiling point.  
    **Explanation:** Hydrogen bonding increases intermolecular attractions, elevating BP.
39. **Application:** A compound has both an alcohol and a carboxylic acid. According to IUPAC priority, which functional group is the suffix?  
    A. Alcohol  
    B. Carboxylic acid  
    C. Neither  
    D. Both equally  
    **Answer:** B. Carboxylic acid.  
    **Explanation:** Carboxylic acids have higher naming priority than alcohols.
40. **Foundational Comprehension:** Which mnemonic helps recall that enantiomers are non-superimposable mirror images?  
    A. SN2: IN a FLIP  
    B. MIRROR  
    C. LEO the lion says GER  
    D. C.A.N. H.A.R.D.  
    **Answer:** B. MIRROR.  
    **Explanation:** “MIRROR” cues that enantiomers are mirror images.
41. **Application:** A student wants to separate volatile compounds; which technique is most appropriate?  
    A. HPLC  
    B. GC  
    C. NMR  
    D. Western blot  
    **Answer:** B. GC.  
    **Explanation:** Gas chromatography separates volatile components.
42. **Foundational Comprehension:** Which of the following reactions involves nucleophilic attack on a polarized carbonyl carbon?  
    A. Electrophilic aromatic substitution  
    B. SN1 substitution  
    C. Nucleophilic addition  
    D. Electrophilic addition to alkenes  
    **Answer:** C. Nucleophilic addition.  
    **Explanation:** Nucleophiles attack the electrophilic carbon in C=O.
43. **Application:** A student observes inversion of stereochemistry at a chiral carbon after reaction. Which mechanism likely occurred?  
    A. SN1  
    B. Electrophilic aromatic substitution  
    C. SN2  
    D. Aldol condensation  
    **Answer:** C. SN2.  
    **Explanation:** SN2 proceeds via backside attack causing inversion.
44. **Integrated Concept:** Designing a synthetic route that ensures a single stereoisomer while forming a new C–C bond would best avoid:  
    A. SN2 reactions  
    B. Crossed aldol condensation without control  
    C. Using a strong nucleophile  
    D. Employing polar aprotic solvents  
    **Answer:** B. Crossed aldol condensation without control.  
    **Explanation:** Uncontrolled crossed aldols yield mixtures of stereoisomers; strategic choices mitigate that.
45. **Test-Taking Strategy:** If a passage describes a planar intermediate leading to loss of chirality, the student should think:  
    A. SN2 mechanism  
    B. Carbocation intermediate (SN1) with racemization potential  
    C. Aldol condensation only forms chiral centers  
    D. Electrophilic addition preserves stereochemistry  
    **Answer:** B. Carbocation intermediate (SN1) with racemization potential.  
    **Explanation:** Planar carbocation allows attack from either face, causing racemization.
46. **Foundational Comprehension:** Which functional group would show a broad O–H stretch in IR and increase boiling point due to hydrogen bonding?  
    A. Alkene  
    B. Alcohol  
    C. Ether  
    D. Alkane  
    **Answer:** B. Alcohol.  
    **Explanation:** Alcohols hydrogen bond strongly, showing broad IR peaks and elevated BPs.
47. **Application:** An organic molecule shows distinct peaks at 160 ppm (¹³C NMR) and 7 ppm (¹H NMR) along with a sharp 1700 cm⁻¹ stretch in IR. What likely class does it belong to?  
    A. Aliphatic alkane  
    B. Aromatic carbonyl-containing compound (e.g., benzaldehyde)  
    C. Simple alcohol  
    D. Alkyl halide  
    **Answer:** B. Aromatic carbonyl-containing compound (e.g., benzaldehyde).  
    **Explanation:** Aromatic signals and carbonyl stretch indicate such structure.
48. **Reasoning Beyond the Text:** A drug candidate exists as a racemic mixture; why might separating enantiomers be pharmacologically important?  
    A. Diastereomers have identical activity  
    B. Enantiomers can have different receptor interactions and side effects  
    C. Optical activity doesn’t affect biology  
    D. Both enantiomers are always inert  
    **Answer:** B. Enantiomers can have different receptor interactions and side effects.  
    **Explanation:** Biological systems are chiral; enantiomers can differ in efficacy/toxicity.
49. **Integrated Concept:** To confirm that a synthesized molecule has the intended functional groups and purity, the most comprehensive approach is:  
    A. TLC only  
    B. IR for functional groups, NMR for structure, and chromatography for purity  
    C. Rely solely on nomenclature  
    D. Use only mass  
    **Answer:** B. IR for functional groups, NMR for structure, and chromatography for purity.  
    **Explanation:** Combining techniques gives structural and purity confirmation.
50. **Test-Taking Strategy:** When a passage discusses competing pathways (e.g., SN1 vs SN2, crossed aldol mixtures), the best first step is to:  
    A. Identify substrate structure, solvent, and nucleophile to predict mechanism selectivity  
    B. Assume both pathways occur equally  
    C. Ignore stereochemistry  
    D. Choose randomly  
    **Answer:** A. Identify substrate structure, solvent, and nucleophile to predict mechanism selectivity.  
    **Explanation:** Mechanistic prediction depends on these contextual factors.
51.  **Foundational Comprehension:** In IUPAC nomenclature, which rule ensures substituents receive the lowest possible numbers?  
    A. Alphabetical order  
    B. Lowest locant rule  
    C. Functional group priority  
    D. Prefix stacking  
    **Answer:** B. Lowest locant rule.  
    **Explanation:** Assigns numbering to give substituents the smallest possible locants.
52.  **Foundational Comprehension:** Which functional group takes priority as a suffix over the other in naming: alcohol or carboxylic acid?  
    A. Alcohol  
    B. Carboxylic acid  
    C. They are equal  
    D. Depends on chain length  
    **Answer:** B. Carboxylic acid.  
    **Explanation:** Carboxylic acids outrank alcohols; the alcohol becomes a prefix.
53.  **Application:** A molecule has a double bond with higher-priority substituents on the same side. Its stereochemical descriptor is:  
    A. E  
    B. Z  
    C. Cis only  
    D. Trans only  
    **Answer:** B. Z.  
    **Explanation:** “Z” (zusammen) indicates highest-priority groups on the same side.
54.  **Foundational Comprehension:** Enantiomers differ in that they:  
    A. Are superimposable  
    B. Rotate plane-polarized light in opposite directions  
    C. Have different connectivity  
    D. Always have different boiling points  
    **Answer:** B. Rotate plane-polarized light in opposite directions.  
    **Explanation:** Enantiomers are mirror images with opposite optical activity.
55.  **Foundational Comprehension:** Diastereomers:  
    A. Are mirror images  
    B. Have identical physical properties always  
    C. Differ in spatial arrangement and are not mirror images  
    D. Are the same as constitutional isomers  
    **Answer:** C. Differ in spatial arrangement and are not mirror images.  
    **Explanation:** Diastereomers have different properties and are not mirror images.
56.  **Application:** A drug is sold as a racemic mixture. Why might separating its enantiomers improve therapeutic index?  
    A. Enantiomers have identical effects  
    B. One enantiomer may have desired activity while the other causes side effects  
    C. Racemates are always inactive  
    D. Optical activity is irrelevant biologically  
    **Answer:** B. One enantiomer may have desired activity while the other causes side effects.  
    **Explanation:** Biological targets are chiral; enantiomers can differ in efficacy and toxicity.
57.  **Foundational Comprehension:** Which carbohydrate-specific stereoisomer differs at the anomeric carbon?  
    A. Epimer  
    B. Enantiomer  
    C. Anomer  
    D. Constitutional isomer  
    **Answer:** C. Anomer.  
    **Explanation:** Anomers differ at the anomeric carbon (α vs β).
58.  **Foundational Comprehension:** What does the mnemonic “MIRROR” cue in stereochemistry?  
    A. Diastereomers  
    B. Constitutional isomers  
    C. Enantiomers as non-superimposable mirror images  
    D. Tautomers  
    **Answer:** C. Enantiomers as non-superimposable mirror images.  
    **Explanation:** Helps recall enantiomeric relationship.
59.  **Application:** In a compound with both ketone and alcohol groups, the suffix used in the name will reflect:  
    A. Alcohol only  
    B. Ketone only  
    C. Higher priority group (ketone) as suffix, alcohol as prefix if lower  
    D. Neither  
    **Answer:** C. Higher priority group (ketone) as suffix, alcohol as prefix if lower.  
    **Explanation:** Functional group hierarchy determines suffix.
60.  **Reasoning:** Misapplying the lowest locant rule when naming a cyclic compound would most directly compromise:  
    A. Spectral interpretation  
    B. Name accuracy  
    C. Reaction mechanism  
    D. Stereochemistry  
    **Answer:** B. Name accuracy.  
    **Explanation:** Lowest locant affects systematic naming correctness.
61.  **Foundational Comprehension:** What makes the carbonyl carbon electrophilic?  
    A. Resonance donation from carbon  
    B. Inductive effect of oxygen pulling electron density away  
    C. Lack of hybridization  
    D. Presence of a hydrogen only  
    **Answer:** B. Inductive effect of oxygen pulling electron density away.  
    **Explanation:** Electronegative oxygen creates a partial positive on carbon.
62.  **Foundational Comprehension:** In nucleophilic addition to a carbonyl, the nucleophile attacks:  
    A. Oxygen  
    B. Carbon  
    C. Both simultaneously  
    D. Neither  
    **Answer:** B. Carbon.  
    **Explanation:** Electrophilic carbon is attacked, forming an alkoxide intermediate.
63.  **Application:** Which spectroscopic signal would confirm the presence of a carbonyl in a molecule?  
    A. Broad IR peak at 3300 cm⁻¹  
    B. Sharp IR peak near 1700 cm⁻¹  
    C. ¹H NMR signal at 0.9 ppm only  
    D. Absence of signals in NMR  
    **Answer:** B. Sharp IR peak near 1700 cm⁻¹.  
    **Explanation:** Characteristic C=O stretch appears there.
64.  **Foundational Comprehension:** Where would a carbonyl carbon appear in ¹³C NMR?  
    A. 0–50 ppm  
    B. 100–120 ppm  
    C. 160–220 ppm  
    D. 300–350 ppm  
    **Answer:** C. 160–220 ppm.  
    **Explanation:** Carbonyl carbons resonate in that downfield region.
65.  **Application:** A compound shows aromatic proton signals at ~7 ppm in ¹H NMR and a carbonyl stretch in IR. Which class is probable?  
    A. Alkane  
    B. Aromatic ketone  
    C. Ether  
    D. Alkyl halide  
    **Answer:** B. Aromatic ketone.  
    **Explanation:** Combines aromatic and carbonyl signatures.
66.  **Foundational Comprehension:** Strong hydrogen bonding in a molecule will:  
    A. Lower its boiling point  
    B. Raise its boiling point  
    C. Eliminate IR signals  
    D. Make it nonpolar  
    **Answer:** B. Raise its boiling point.  
    **Explanation:** Increased intermolecular attraction elevates boiling point.
67.  **Application:** In TLC with a polar stationary phase, which functional group leads to the lowest Rf?  
    A. Nonpolar alkyl chain  
    B. Polar hydroxyl group  
    C. Noble gas  
    D. Saturated hydrocarbon  
    **Answer:** B. Polar hydroxyl group.  
    **Explanation:** Strong interaction with polar phase slows travel.
68.  **Application:** To separate volatile organic compounds, the technique of choice is:  
    A. TLC  
    B. GC  
    C. IR spectroscopy  
    D. NMR  
    **Answer:** B. GC.  
    **Explanation:** Gas chromatography separates based on volatility.
69.  **Integrated Concept:** A synthesized intermediate may epimerize at one stereocenter. To detect this, the applicant should use:  
    A. Simple mass measurement  
    B. Optical activity or chiral chromatography to detect diastereomeric/enantiomeric mixtures  
    C. Infrared alone  
    D. Boiling point only  
    **Answer:** B. Optical activity or chiral chromatography to detect diastereomeric/enantiomeric mixtures.  
    **Explanation:** Epimers are stereoisomers; optical rotation or separation reveals mixtures.
70.  **Test-Taking Strategy:** When a vignette describes conflicting spectroscopic signals for isomeric products, the first step is to:  
    A. Ignore functional group context  
    B. Map expected IR/NMR signatures to possible isomers and compare  
    C. Assume purity  
    D. Skip to biological activity  
    **Answer:** B. Map expected IR/NMR signatures to possible isomers and compare.  
    **Explanation:** Systematically matching spectral data helps discriminate isomers.
71.  **Foundational Comprehension:** Which pair are constitutional isomers?  
    A. Enantiomers  
    B. Molecules with same formula but different connectivity  
    C. Epimers  
    D. Anomers  
    **Answer:** B. Molecules with same formula but different connectivity.  
    **Explanation:** Structural (constitutional) isomers differ in atom connectivity.
72.  **Foundational Comprehension:** An epimer differs from another sugar at:  
    A. The anomeric carbon only  
    B. One stereocenter other than the anomeric carbon  
    C. All stereocenters  
    D. Connectivity  
    **Answer:** B. One stereocenter other than the anomeric carbon.  
    **Explanation:** Epimers differ at a single stereocenter.
73.  **Application:** A compound with multiple substituents on a ring must be numbered to give substituents:  
    A. Highest possible locants  
    B. Lowest set of locants according to IUPAC  
    C. Alphabetical order only  
    D. Based on size  
    **Answer:** B. Lowest set of locants according to IUPAC.  
    **Explanation:** Ensures systematic and minimal numbering.
74.  **Integrated Concept:** To confirm both configuration (e.g., enantiomeric purity) and functional group presence in a chiral carbonyl compound, the best combination of techniques is:  
    A. Mass spectrometry alone  
    B. Polarimetry plus IR/NMR  
    C. TLC only  
    D. Boiling point determination  
    **Answer:** B. Polarimetry plus IR/NMR.  
    **Explanation:** Polarimetry assesses chirality; IR/NMR identifies functional groups and structural context.
75.  **Test-Taking Strategy:** When synthesizing a molecule with multiple stereochemical concerns and functional groups, the most reliable way to ensure correct structure is to:  
    A. Rely on one spectroscopic method  
    B. Cross-validate with complementary techniques (NMR, IR, chiral analysis) and naming conventions  
    C. Guess based on reagents  
    D. Ignore stereochemistry  
    **Answer:** B. Cross-validate with complementary techniques (NMR, IR, chiral analysis) and naming conventions.  
    **Explanation:** Combining orthogonal data minimizes misassignment.
76. **Foundational Comprehension:** In IUPAC nomenclature, what does the lowest locant rule ensure?  
    A. Substituents are alphabetized  
    B. Functional groups are ranked  
    C. Substituents receive the smallest possible numbers  
    D. The longest chain is ignored  
    **Answer:** C. Substituents receive the smallest possible numbers.  
    **Explanation:** The lowest locant rule assigns numbering to give substituents minimal locants for consistency.
77. **Foundational Comprehension:** Which functional group has higher priority when determining the suffix: alcohol or carboxylic acid?  
    A. Alcohol  
    B. Carboxylic acid  
    C. They are equal  
    D. Depends on saturation  
    **Answer:** B. Carboxylic acid.  
    **Explanation:** Carboxylic acids outrank alcohols; the alcohol becomes a prefix (hydroxy-).
78. **Application:** A molecule contains a double bond with its highest-priority substituents on the same side. Which descriptor is correct?  
    A. E  
    B. Z  
    C. Cis only  
    D. Trans only  
    **Answer:** B. Z.  
    **Explanation:** “Z” indicates highest-priority groups are together (zusammen).
79. **Foundational Comprehension:** Enantiomers are best described as:  
    A. Different connectivity isomers  
    B. Non-superimposable mirror images with opposite optical activity  
    C. Stereoisomers that are not mirror images  
    D. Constitutional isomers  
    **Answer:** B. Non-superimposable mirror images with opposite optical activity.  
    **Explanation:** Enantiomers rotate plane-polarized light in opposite directions and are mirror images.
80. **Foundational Comprehension:** Diastereomers:  
    A. Always have identical physical properties  
    B. Are mirror images  
    C. Differ in spatial arrangement and are not mirror images  
    D. Are the same as enantiomers  
    **Answer:** C. Differ in spatial arrangement and are not mirror images.  
    **Explanation:** Diastereomers have different properties and aren’t mirror images.
81. **Application:** Which pair represents epimers?  
    A. Stereoisomers differing at only one stereocenter (non-anomeric)  
    B. Non-superimposable mirror images  
    C. Constitutional isomers  
    D. Geometric isomers  
    **Answer:** A. Stereoisomers differing at only one stereocenter (non-anomeric).  
    **Explanation:** Epimers differ at a single stereocenter other than the anomeric.
82. **Foundational Comprehension:** Anomers differ at:  
    A. Any stereocenter  
    B. The anomeric carbon in cyclic sugars  
    C. The connectivity of atoms  
    D. Their molecular formula  
    **Answer:** B. The anomeric carbon in cyclic sugars.  
    **Explanation:** Anomers are a subtype of epimers at the anomeric carbon (α vs β).
83. **Application:** A drug is administered as a racemic mixture. Why might isolating one enantiomer be pharmacologically advantageous?  
    A. Enantiomers always have identical effects  
    B. One enantiomer may be active while the other is inactive or harmful  
    C. Racemates are easier to metabolize  
    D. Optical activity doesn’t matter biologically  
    **Answer:** B. One enantiomer may be active while the other is inactive or harmful.  
    **Explanation:** Biological targets are chiral; enantiomers can differ in efficacy or toxicity.
84. **Foundational Comprehension:** What mnemonic helps recall that enantiomers are mirror images?  
    A. A Before B  
    B. MIRROR  
    C. Zame side  
    D. Lowest locant  
    **Answer:** B. MIRROR.  
    **Explanation:** “MIRROR” cues that enantiomers are non-superimposable mirror images.
85. **Application:** A molecule has both a carboxylic acid and an alcohol. Which naming strategy is correct?  
    A. Name alcohol as suffix, acid as prefix  
    B. Name both equally  
    C. Carboxylic acid as suffix, alcohol as hydroxy- prefix  
    D. Ignore functional group priority  
    **Answer:** C. Carboxylic acid as suffix, alcohol as hydroxy- prefix.  
    **Explanation:** Higher-priority carboxylic acid dictates suffix; lower-priority alcohol is prefixed.
86. **Foundational Comprehension:** Constitutional (structural) isomers differ in:  
    A. Spatial arrangement only  
    B. Mirror image relationship  
    C. Atom connectivity  
    D. Optical activity  
    **Answer:** C. Atom connectivity.  
    **Explanation:** They have the same formula but different connectivity.
87. **Application:** A synthetic intermediate has epimerized at one center unexpectedly. Which analytical approach best distinguishes the epimeric mixture?  
    A. Mass spec only  
    B. Chiral analysis or optical activity measurement  
    C. Simple boiling point  
    D. Infrared ignoring stereochemistry  
    **Answer:** B. Chiral analysis or optical activity measurement.  
    **Explanation:** Epimers are stereoisomers; chiral techniques detect configuration changes.
88. **Foundational Comprehension:** Misnumbering a cyclic compound’s substituents violates which naming principle?  
    A. Alphabetization  
    B. E/Z assignment  
    C. Lowest locant rule  
    D. Stereochemistry  
    **Answer:** C. Lowest locant rule.  
    **Explanation:** Lowest locant ensures substituents get minimal numbers; misnumbering breaks this.
89. **Application:** A medicinal chemist must distinguish a diastereomeric impurity from the desired product. Which statement is true?  
    A. Diastereomers have identical physical properties  
    B. Diastereomers can be separated based on differing properties  
    C. Diastereomers are mirror images  
    D. Diastereomers cannot be distinguished without crystallography  
    **Answer:** B. Diastereomers can be separated based on differing properties.  
    **Explanation:** Unlike enantiomers, diastereomers have different physical/chemical properties.
90. **Test-Taking Strategy:** When confronted with a molecule containing multiple functional groups, the first step to name it is to:  
    A. Alphabetize everything  
    B. Identify the highest-priority functional group for the suffix  
    C. Randomly choose a suffix  
    D. Assign stereochemistry first  
    **Answer:** B. Identify the highest-priority functional group for the suffix.  
    **Explanation:** Functional group hierarchy guides naming structure.
91. **Foundational Comprehension:** Which descriptor distinguishes when highest-priority alkene substituents are on opposite sides?  
    A. Z  
    B. E  
    C. α  
    D. Racemic  
    **Answer:** B. E.  
    **Explanation:** “E” (entgegen) indicates opposite sides.
92. **Application:** A drug candidate exhibiting no net optical rotation likely indicates:  
    A. Single enantiomer  
    B. Racemic mixture  
    C. Diastereomer  
    D. Constitutional isomer  
    **Answer:** B. Racemic mixture.  
    **Explanation:** Equal enantiomers cancel optical activity.
93. **Integrated Concept:** Why is correct stereochemical assignment important for pharmacodynamics?  
    A. Stereochemistry never affects binding  
    B. Enantiomers can interact differently with chiral biological targets  
    C. Only molecular weight matters  
    D. Connectivity is irrelevant  
    **Answer:** B. Enantiomers can interact differently with chiral biological targets.  
    **Explanation:** Biological macromolecules are chiral; stereochemistry affects efficacy and safety.
94. **Foundational Comprehension:** The priority mnemonic “Crazy Elephants And Ants Keep All Apples And Avocados Aligned” helps recall the order for:  
    A. Alkene geometry  
    B. Functional group naming priority  
    C. Types of isomers  
    D. Stereochemical inversion  
    **Answer:** B. Functional group naming priority.  
    **Explanation:** It lists hierarchy (carboxylic acid > ester > amide > etc.) for suffix selection.
95. **Application:** A molecule is incorrectly named because a lower-priority group was used as the suffix. What error was made?  
    A. Wrong stereochemistry  
    B. Functional group priority misapplied  
    C. Incorrect E/Z assignment  
    D. Mirror image confusion  
    **Answer:** B. Functional group priority misapplied.  
    **Explanation:** Suffix must reflect highest-priority group.
96. **Foundational Comprehension:** Which is true about constitutional isomers versus stereoisomers?  
    A. Constitutional isomers differ only in spatial arrangement  
    B. Stereoisomers have different connectivity  
    C. Constitutional isomers differ in atom connectivity  
    D. They are the same  
    **Answer:** C. Constitutional isomers differ in atom connectivity.  
    **Explanation:** Structural isomers have same formula but different bonding orders.
97. **Application:** In reporting multiple stereoisomeric impurities, the applicant must:  
    A. Use vague names  
    B. Properly classify enantiomers, diastereomers, epimers, and anomers and name each according to IUPAC  
    C. Only report the desired product  
    D. Ignore stereochemical differences  
    **Answer:** B. Properly classify enantiomers, diastereomers, epimers, and anomers and name each according to IUPAC.  
    **Explanation:** Precise classification/naming avoids regulatory and interpretive errors.
98. **Test-Taking Strategy:** When given a complex polyfunctional molecule, what sequence minimizes mistakes in naming?  
    A. Assign stereochemistry, then choose suffix, then number  
    B. Identify highest-priority functional group, determine parent chain and numbering (lowest locant), then apply stereochemical descriptors  
    C. Alphabetize before identifying parent chain  
    D. Guess based on familiarity  
    **Answer:** B. Identify highest-priority functional group, determine parent chain and numbering (lowest locant), then apply stereochemical descriptors.  
    **Explanation:** Systematic ordering reduces misnaming.
99. **Integrated Concept:** A diastereomeric impurity in a drug batch shows different melting point and solubility than the desired product. This arises because:  
    A. Diastereomers have identical properties  
    B. They are not mirror images and thus have different physical properties  
    C. They are constitutional isomers  
    D. Optical rotation cancels out  
    **Answer:** B. They are not mirror images and thus have different physical properties.  
    **Explanation:** Diastereomers differ in spatial configuration yielding different behavior.
100. **Test-Taking Strategy:** If a passage mentions “non-superimposable mirror images” and “racemic mixture,” the student should immediately think:  
     A. Diastereomers and constitutional isomers  
     B. Enantiomers and a 1:1 mixture canceling optical activity  
     C. E/Z isomerism  
     D. Functional group priority  
     **Answer:** B. Enantiomers and a 1:1 mixture canceling optical activity.  
     **Explanation:** Racemic mixture consists of enantiomers with opposite rotations, net zero optical activity.
101.  **Foundational Comprehension:** According to Poiseuille’s law, if vessel radius is halved, how does flow change, assuming other factors constant?  
     A. Decreases by 2  
     B. Decreases by 4  
     C. Decreases by 8  
     D. Decreases by 16  
     **Answer:** D. Decreases by 16.  
     **Explanation:** Flow ∝ r⁴, so halving radius reduces flow by (1/2)4=1/16(1/2)^4 = 1/16(1/2)4=1/16.
102.  **Application:** Vasoconstriction in arterioles raises systemic vascular resistance primarily because:  
     A. Blood viscosity decreases  
     B. Radius reduction exponentiates resistance  
     C. Vessel length increases  
     D. Pressure drops proportionally  
     **Answer:** B. Radius reduction exponentiates resistance.  
     **Explanation:** Small decreases in radius greatly increase resistance due to fourth-power dependency.
103.  **Foundational Comprehension:** In a series circuit, which quantity is the same across all components?  
     A. Voltage  
     B. Resistance  
     C. Current  
     D. Power  
     **Answer:** C. Current.  
     **Explanation:** Series circuits have the same current through each element.
104.  **Foundational Comprehension:** Ohm’s law states:  
     A. V = I × R  
     B. V = R / I  
     C. I = V / P  
     D. R = V + I  
     **Answer:** A. V = I × R.  
     **Explanation:** Voltage equals current times resistance.
105.  **Application:** A sensor output is noisy; adding an RC low-pass filter with a large τ will:  
     A. Increase high-frequency noise  
     B. Smooth rapid fluctuations  
     C. Block DC signal  
     D. Invert the signal  
     **Answer:** B. Smooth rapid fluctuations.  
     **Explanation:** Large time constant averages out fast variations, reducing noise.
106.  **Integrated Reasoning:** A device measuring blood flow uses pressure transducers. To convert pressure change into a voltage signal, the designer must rely on:  
     A. Poiseuille’s law and Ohm’s law  
     B. Snell’s law and reflection  
     C. Photon energy equation  
     D. Radioactive half-life  
     **Answer:** A. Poiseuille’s law and Ohm’s law.  
     **Explanation:** Flow changes per Poiseuille affect pressure; electrical conversion obeys Ohm’s law.
107.  **Foundational Comprehension:** The work-energy theorem states that work done on an object equals:  
     A. Its potential energy  
     B. Change in kinetic energy  
     C. Force times velocity  
     D. Mass times acceleration  
     **Answer:** B. Change in kinetic energy.  
     **Explanation:** W = ΔKE.
108.  **Application:** An implanted device must minimize power usage. Which energy principle helps determine if a sensor’s signal processing is spontaneous or requires input?  
     A. Gibbs free energy  
     B. Snell’s law  
     C. Poiseuille’s law  
     D. Ohm’s law  
     **Answer:** A. Gibbs free energy.  
     **Explanation:** ΔG indicates whether processes proceed without additional input (spontaneous) or need energy.
109.  **Foundational Comprehension:** Sound waves differ from light waves in that:  
     A. Sound needs no medium  
     B. Light is longitudinal  
     C. Sound requires a medium and is longitudinal  
     D. Light travels slower in vacuum  
     **Answer:** C. Sound requires a medium and is longitudinal.  
     **Explanation:** Sound is mechanical and longitudinal; light is electromagnetic and transverse.
110.  **Foundational Comprehension:** Photon energy depends on:  
     A. Wavelength only  
     B. Frequency only  
     C. Both frequency and Planck’s constant  
     D. Amplitude  
     **Answer:** C. Both frequency and Planck’s constant.  
     **Explanation:** E=hfE = h fE=hf; higher frequency yields greater energy.
111.  **Application:** Which radiation type requires the most shielding due to highest penetration?  
     A. Alpha  
     B. Beta  
     C. Gamma  
     D. Positron  
     **Answer:** C. Gamma.  
     **Explanation:** Gamma rays are highly penetrating, requiring thick lead or concrete.
112.  **Foundational Comprehension:** In radioactive decay, after one half-life, what fraction of the original nuclei remains?  
     A. 0  
     B. 1/4  
     C. 1/2  
     D. 2/3  
     **Answer:** C. 1/2.  
     **Explanation:** Half of the sample decays each half-life.
113.  **Application:** A radiotracer’s activity decreases with time. Which relationship best models this decline?  
     A. Linear  
     B. Exponential  
     C. Stepwise  
     D. Constant  
     **Answer:** B. Exponential.  
     **Explanation:** Radioactive decay follows exponential decay governed by half-life.
114.  **Foundational Comprehension:** Snell’s law describes:  
     A. Reflection angles  
     B. Refraction between media  
     C. Photon energy  
     D. Wave interference  
     **Answer:** B. Refraction between media.  
     **Explanation:** n1sin⁡θ1=n2sin⁡θ2n\_1\sin\theta\_1 = n\_2\sin\theta\_2n1​sinθ1​=n2​sinθ2​ governs bending of light.
115.  **Application:** A patient with myopia is best corrected with:  
     A. Convex lens  
     B. Concave lens  
     C. Mirror  
     D. Polarizer  
     **Answer:** B. Concave lens.  
     **Explanation:** Myopia focuses images in front of retina; diverging (concave) lens spreads light.
116.  **Foundational Comprehension:** The speed of light in vacuum is approximately:  
     A. 3×106 m/s3 \times 10^6\ \text{m/s}3×106 m/s  
     B. 3×108 m/s3 \times 10^8\ \text{m/s}3×108 m/s  
     C. 3×1010 m/s3 \times 10^{10}\ \text{m/s}3×1010 m/s  
     D. 3×105 m/s3 \times 10^5\ \text{m/s}3×105 m/s  
     **Answer:** B. 3×108 m/s3 \times 10^8\ \text{m/s}3×108 m/s.  
     **Explanation:** Fundamental constant of light speed.
117.  **Integrated Reasoning:** In designing the dual-modality tool, why must the applicant consider both photon frequency and tissue penetration?  
     A. Higher frequency always reduces resolution  
     B. Higher frequency increases photon energy, improving resolution but potentially increasing tissue damage  
     C. Penetration is independent of frequency  
     D. Lower energy photons are always better  
     **Answer:** B. Higher frequency increases photon energy, improving resolution but potentially increasing tissue damage.  
     **Explanation:** E=hf; trade-off between diagnostic clarity and safety.
118.  **Foundational Comprehension:** In a parallel circuit:  
     A. Current is the same through all branches  
     B. Voltage divides among elements  
     C. Voltage is the same across each branch  
     D. Total resistance is the sum of individual resistances  
     **Answer:** C. Voltage is the same across each branch.  
     **Explanation:** Parallel configuration maintains equal voltage.
119.  **Application:** To reduce exposure in radiation-based diagnostics, one should:  
     A. Increase source proximity  
     B. Maximize time near source  
     C. Use appropriate shielding and increase distance  
     D. Remove shielding for clarity  
     **Answer:** C. Use appropriate shielding and increase distance.  
     **Explanation:** Radiation safety: minimize exposure, maximize distance, use shielding.
120.  **Foundational Comprehension:** The work done by a force acting over displacement at an angle is:  
     A. W=Fd   
     B. W=Fdsinθ  
     C. W=Fdcosθ  
     D. W=mgh  
     **Answer:** C. W=Fdcosθ.  
     **Explanation:** Component of force along displacement does work.
121.  **Application:** A detector circuit has multiple loops; ensuring voltage sums to zero around each loop relies on:  
     A. Ohm’s law only  
     B. Kirchhoff’s Voltage Law  
     C. Poiseuille’s law  
     D. Gibbs free energy  
     **Answer:** B. Kirchhoff’s Voltage Law.  
     **Explanation:** KVL states sum of voltage changes around a closed loop is zero.
122.  **Foundational Comprehension:** What does the root mean square (rms) velocity of gas molecules depend on?  
     A. Pressure and volume  
     B. Temperature and molar mass  
     C. pH  
     D. Photon energy  
     **Answer:** B. Temperature and molar mass.  
     **Explanation:** vrms​∝T/M​; higher T increases speed; heavier molecules move slower.
123.  **Integrated Concept:** A hemodynamic monitor detects sudden drop in flow and interprets it as increased resistance; which physiological change could cause that?  
     A. Vasodilation  
     B. Decreased blood viscosity  
     C. Vasoconstriction  
     D. Shorter vessel length  
     **Answer:** C. Vasoconstriction.  
     **Explanation:** Narrowing vessel reduces radius, increasing resistance and decreasing flow.
124.  **Application:** In optical imaging, bending of light when passing between media of different refractive indices is described by:  
     A. Reflection law  
     B. Snell’s law  
     C. Doppler effect  
     D. Photoelectric effect  
     **Answer:** B. Snell’s law.  
     **Explanation:** Governs refraction ​sinθ1​=n2​sinθ2​.
125.  **Test-Taking Strategy:** When presented with a device combining flow sensing, electrical signal processing, and radiotracer decay, the best analytical approach is to:  
     A. Treat each physical domain separately (fluid, circuit, decay), then integrate their outputs  
     B. Assume ideal behavior across all systems  
     C. Focus only on the electrical component  
     D. Ignore decay kinetics  
     **Answer:** A. Treat each physical domain separately (fluid, circuit, decay), then integrate their outputs.  
     **Explanation:** Decomposing complex, multi-physics systems prevents oversight and supports correct synthesis.
126.  **Foundational Comprehension:** According to Poiseuille’s law, if vessel radius decreases by half, flow decreases by what factor?  
     A. 2  
     B. 4  
     C. 8  
     D. 16  
     **Answer:** D. 16.  
     **Explanation:** Flow ∝ r⁴, so halving the radius reduces flow to (1/2)4=1/16(1/2)^4 = 1/16(1/2)4=1/16.
127.  **Application:** Vasoconstriction primarily increases resistance because:  
     A. Viscosity drops  
     B. Length of vessel shortens  
     C. Radius reduction has a fourth-power effect  
     D. Pressure decreases  
     **Answer:** C. Radius reduction has a fourth-power effect.  
     **Explanation:** Small decreases in radius dramatically increase resistance per Poiseuille’s law.
128.  **Foundational Comprehension:** The kinetic molecular theory states that average kinetic energy of gas particles is proportional to:  
     A. Pressure  
     B. Volume  
     C. Temperature (Kelvin)  
     D. Molar mass  
     **Answer:** C. Temperature (Kelvin).  
     **Explanation:** KE∝TKE \propto TKE∝T; higher temperature increases molecular motion.
129.  **Application:** In a sensor interpreting respiratory gas levels, a sudden temperature increase at constant volume would:  
     A. Decrease pressure (Boyle’s law)  
     B. Increase pressure (Gay-Lussac’s law)  
     C. Leave pressure unchanged  
     D. Decrease moles  
     **Answer:** B. Increase pressure (Gay-Lussac’s law).  
     **Explanation:** Pressure is directly proportional to temperature at constant volume.
130.  **Foundational Comprehension:** Ohm’s law is best expressed as:  
     A. V = I / R  
     B. V = I × R  
     C. I = R / V  
     D. R = V + I  
     **Answer:** B. V = I × R.  
     **Explanation:** Voltage equals current times resistance.
131.  **Application:** A data acquisition circuit uses an RC low-pass filter with a large time constant τ. The effect on a pulsatile blood pressure signal is to:  
     A. Sharpen rapid spikes  
     B. Smooth out high-frequency noise  
     C. Block the DC baseline  
     D. Invert the waveform  
     **Answer:** B. Smooth out high-frequency noise.  
     **Explanation:** Large τ averages rapid fluctuations, reducing noise.
132.  **Integrated Reasoning:** A sepsis monitor detects elevated arteriolar resistance and translates it to a voltage. Which combination of principles is directly involved?  
     A. Snell’s law and photon energy  
     B. Poiseuille’s law and Ohm’s law  
     C. Half-life decay and diffusion  
     D. Reflection and refraction  
     **Answer:** B. Poiseuille’s law and Ohm’s law.  
     **Explanation:** Resistance changes in vessels influence pressure (fluid dynamics), then converted electrically per Ohm’s law.
133.  **Foundational Comprehension:** Gibbs free energy (ΔG) determines:  
     A. Pressure of a gas  
     B. Spontaneity of a process  
     C. Electrical resistance  
     D. Light refraction  
     **Answer:** B. Spontaneity of a process.  
     **Explanation:** Negative ΔG indicates spontaneous reactions.
134.  **Foundational Comprehension:** Work done by a force acting over a displacement at an angle θ is:  
     A. W = Fd  
     B. W = Fd sinθ  
     C. W = Fd cosθ  
     D. W = mgh  
     **Answer:** C. W = Fd cosθ.  
     **Explanation:** Only the component of force along displacement does work.
135.  **Foundational Comprehension:** In a parallel circuit:  
     A. Current is the same through each branch  
     B. Voltage is the same across each branch  
     C. Total resistance is the sum of individual resistances  
     D. Voltage divides among components  
     **Answer:** B. Voltage is the same across each branch.  
     **Explanation:** Parallel configuration maintains equal voltage; current splits.
136.  **Foundational Comprehension:** Which radiation type has the highest penetration power and thus requires the most substantial shielding?  
     A. Alpha  
     B. Beta  
     C. Gamma  
     D. Positron  
     **Answer:** C. Gamma.  
     **Explanation:** Gamma rays are highly penetrating; require thick lead or concrete.
137.  **Application:** A radiotracer with a half-life of 4 hours is used in imaging. After 8 hours, what fraction of the original sample remains?  
     A. 1/4  
     B. 1/2  
     C. 1/8  
     D. 3/4  
     **Answer:** A. 1/4.  
     **Explanation:** Two half-lives passed: (1/2)2=1/4(1/2)^2 = 1/4(1/2)2=1/4.
138.  **Foundational Comprehension:** Photon energy is given by which equation?  
     A. E=mc2E = mc^2E=mc2  
     B. E=hfE = h fE=hf  
     C. E=12mv2E = \frac{1}{2}mv^2E=21​mv2  
     D. E=qVE = qVE=qV  
     **Answer:** B. E=hfE = h fE=hf.  
     **Explanation:** Photon energy is Planck’s constant times frequency.
139.  **Application:** To minimize patient radiation exposure during diagnostics, one should:  
     A. Increase time near source  
     B. Remove shielding  
     C. Maximize distance and use proper shielding  
     D. Use highest-energy gamma rays available  
     **Answer:** C. Maximize distance and use proper shielding.  
     **Explanation:** Radiation safety principles: minimize exposure with distance and shielding.
140.  **Foundational Comprehension:** Snell’s law governs which optical phenomenon?  
     A. Reflection  
     B. Refraction  
     C. Interference  
     D. Diffraction  
     **Answer:** B. Refraction.  
     **Explanation:** n1sin⁡θ1=n2sin⁡θ2n\_1 \sin\theta\_1 = n\_2 \sin\theta\_2n1​sinθ1​=n2​sinθ2​ describes bending of light between media.
141.  **Application:** A patient with myopia needs correction with:  
     A. Convex lens  
     B. Concave lens  
     C. Prism  
     D. Polarizer  
     **Answer:** B. Concave lens.  
     **Explanation:** Myopic eye focuses images in front of retina; diverging lens spreads light.
142.  **Foundational Comprehension:** Which of the following statements correctly distinguishes sound from light?  
     A. Sound is transverse and needs no medium; light is longitudinal and needs a medium  
     B. Sound is mechanical and longitudinal, requiring a medium; light is electromagnetic and transverse  
     C. Both require a medium  
     D. Both are longitudinal waves  
     **Answer:** B. Sound is mechanical and longitudinal, requiring a medium; light is electromagnetic and transverse.  
     **Explanation:** Fundamental difference in propagation and wave type.
143.  **Integrated Concept:** In hybrid optical–nuclear imaging, why is choosing photon frequency a trade-off?  
     A. Higher frequency reduces energy  
     B. Higher frequency improves resolution but increases potential tissue damage  
     C. Frequency has no effect on imaging  
     D. Lower frequency always gives better penetration with no downside  
     **Answer:** B. Higher frequency improves resolution but increases potential tissue damage.  
     **Explanation:** E=hfE = h fE=hf; higher-frequency photons are more energetic.
144.  **Application:** A surgeon uses a lens system to visualize tissue. The bending of light at interfaces inside tissue must be accounted for using:  
     A. Ohm’s law  
     B. Snell’s law  
     C. Poiseuille’s law  
     D. Half-life equations  
     **Answer:** B. Snell’s law.  
     **Explanation:** Refraction in heterogeneous media follows Snell’s relationship.
145.  **Foundational Comprehension:** The equation v=fλv = f \lambdav=fλ describes:  
     A. Energy of a photon  
     B. Wave speed as product of frequency and wavelength  
     C. Work done  
     D. Voltage in a circuit  
     **Answer:** B. Wave speed as product of frequency and wavelength.  
     **Explanation:** Fundamental wave relationship.
146.  **Test-Taking Strategy:** When a passage describes signal degradation and mentions τ = RC, the student should recognize that:  
     A. It's referring to a radioactive decay constant  
     B. It’s the time constant determining how fast a capacitor charges/discharges  
     C. It’s the equation for photon energy  
     D. It’s fluid resistance scaling  
     **Answer:** B. It’s the time constant determining how fast a capacitor charges/discharges.  
     **Explanation:** τ = RC is the RC circuit time constant controlling response speed.
147.  **Foundational Comprehension:** The root mean square velocity of gas molecules increases when:  
     A. Temperature decreases  
     B. Molar mass increases  
     C. Temperature increases  
     D. Volume decreases only  
     **Answer:** C. Temperature increases.  
     **Explanation:** vrms∝T/Mv\_{rms} \propto \sqrt{T/M}vrms​∝T/M​; higher T increases molecular speed.
148.  **Application:** In interpreting a drop in blood flow with the same driving pressure, a clinician should infer:  
     A. Vasodilation  
     B. Decreased resistance  
     C. Vasoconstriction increasing resistance  
     D. Increased vessel length  
     **Answer:** C. Vasoconstriction increasing resistance.  
     **Explanation:** Narrowed radius increases resistance, reducing flow.
149.  **Integrated Reasoning:** A multimodal imaging device must account for both refraction and radiation safety. Which pair of considerations is essential?  
     A. Snell’s law for light path and shielding for gamma rays  
     B. Ohm’s law and Boyle’s law  
     C. Poiseuille’s law and wave speed  
     D. Gibbs free energy and half-life only  
     **Answer:** A. Snell’s law for light path and shielding for gamma rays.  
     **Explanation:** Optics dictates image formation; radiation protection reduces exposure.
150.  **Test-Taking Strategy:** Faced with a passage combining fluid resistance, electrical filtering, and radioactive decay, the best approach is to:  
     A. Integrate all concepts at once without separation  
     B. Decompose into domains (fluid dynamics, circuit behavior, decay kinetics) then synthesize  
     C. Ignore the electrical component  
     D. Focus solely on decay kinetics  
     **Answer:** B. Decompose into domains (fluid dynamics, circuit behavior, decay kinetics) then synthesize.  
     **Explanation:** Systematic breakdown prevents misinterpretation of complex multi-physics scenarios.
151.  **Foundational Comprehension:** According to Poiseuille’s law, halving the radius of a vessel changes flow by what factor (all else equal)?  
     A. 1/2  
     B. 1/4  
     C. 1/8  
     D. 1/16  
     **Answer:** D. 1/16.  
     **Explanation:** Flow is proportional to r4r^4r4; (1/2)4=1/16(1/2)^4 = 1/16(1/2)4=1/16.
152.  **Application:** A sudden increase in arteriolar tone (vasoconstriction) primarily raises resistance because:  
     A. Blood viscosity decreases  
     B. Vessel length shortens  
     C. Radius reduction has a fourth-power effect  
     D. Pressure falls  
     **Answer:** C. Radius reduction has a fourth-power effect.  
     **Explanation:** Small decreases in radius lead to large resistance increases per Poiseuille’s law.
153.  **Foundational Comprehension:** The average kinetic energy of gas particles is directly proportional to:  
     A. Pressure  
     B. Volume  
     C. Temperature in Kelvin  
     D. Molar mass  
     **Answer:** C. Temperature in Kelvin.  
     **Explanation:** Kinetic molecular theory states KE∝TKE \propto TKE∝T.
154.  **Application:** If the temperature of a fixed-volume respiratory gas sample increases, the pressure will:  
     A. Decrease  
     B. Remain constant  
     C. Increase  
     D. Become negative  
     **Answer:** C. Increase.  
     **Explanation:** Gay-Lussac’s law: pressure ∝ temperature at constant volume.
155.  **Foundational Comprehension:** Ohm’s law is best expressed as:  
     A. V = I / R  
     B. V = I × R  
     C. I = R / V  
     D. R = V + I  
     **Answer:** B. V = I × R.  
     **Explanation:** Voltage equals current times resistance.
156.  **Application:** In an RC low-pass filter with a large time constant, a pulsatile blood pressure signal will be:  
     A. Sharpened  
     B. Smoothed  
     C. Inverted  
     D. Eliminated entirely  
     **Answer:** B. Smoothed.  
     **Explanation:** Large τ averages out rapid fluctuations, reducing high-frequency noise.
157.  **Integrated Reasoning:** Converting increased microvascular resistance into a stable voltage signal requires knowledge of:  
     A. Snell’s law and photon energy  
     B. Poiseuille’s law and Ohm’s law  
     C. Radioactive decay kinetics  
     D. Diffraction patterns  
     **Answer:** B. Poiseuille’s law and Ohm’s law.  
     **Explanation:** Fluid resistance alters pressure (Poiseuille), which is transduced electrically per Ohm.
158.  **Foundational Comprehension:** A negative Gibbs free energy (ΔG) indicates:  
     A. Non-spontaneous process  
     B. Spontaneous process  
     C. No net energy change  
     D. System at equilibrium  
     **Answer:** B. Spontaneous process.  
     **Explanation:** ΔG < 0 denotes spontaneity.
159.  **Foundational Comprehension:** Work done by a force at angle θ over displacement d is:  
     A. W = Fd  
     B. W = Fd sinθ  
     C. W = Fd cosθ  
     D. W = mgh  
     **Answer:** C. W = Fd cosθ.  
     **Explanation:** Only the component of force along displacement does work.
160.  **Foundational Comprehension:** In a parallel electrical circuit:  
     A. Current is the same through each branch  
     B. Voltage is the same across each branch  
     C. Total resistance is the sum of individual resistances  
     D. Voltage divides among branches  
     **Answer:** B. Voltage is the same across each branch.  
     **Explanation:** Parallel topology maintains equal voltage.
161.  **Foundational Comprehension:** Which radiation type has the greatest penetration and thus demands the heaviest shielding?  
     A. Alpha  
     B. Beta  
     C. Gamma  
     D. Neutron  
     **Answer:** C. Gamma.  
     **Explanation:** Gamma rays are highly penetrating; require dense shielding.
162.  **Application:** A radiotracer with a half-life of 3 hours is used. After 9 hours, what fraction remains?  
     A. 1/8  
     B. 1/3  
     C. 1/4  
     D. 1/2  
     **Answer:** A. 1/8.  
     **Explanation:** Three half-lives: (1/2)3=1/8(1/2)^3 = 1/8(1/2)3=1/8.
163.  **Foundational Comprehension:** Photon energy is given by:  
     A. E=mc2E = mc^2E=mc2  
     B. E=12mv2E = \frac{1}{2}mv^2E=21​mv2  
     C. E=hfE = h fE=hf  
     D. E=qVE = qVE=qV  
     **Answer:** C. E=hfE = h fE=hf.  
     **Explanation:** Planck’s relation for photon energy.
164.  **Application:** To reduce a patient’s radiation exposure during imaging, the clinician should:  
     A. Increase time near source  
     B. Remove shielding  
     C. Increase distance and apply shielding  
     D. Use highest-energy photons available  
     **Answer:** C. Increase distance and apply shielding.  
     **Explanation:** Radiation safety: minimize exposure by distance/time/shielding.
165.  **Foundational Comprehension:** Snell’s law governs:  
     A. Reflection  
     B. Refraction  
     C. Interference  
     D. Polarization  
     **Answer:** B. Refraction.  
     **Explanation:** Describes bending of light between media via indices.
166.  **Application:** Which lens corrects myopia?  
     A. Convex  
     B. Concave  
     C. Plano  
     D. Polarizing  
     **Answer:** B. Concave.  
     **Explanation:** Diverges light to move focal point back onto retina.
167.  **Foundational Comprehension:** Which is true about sound vs. light?  
     A. Sound is transverse and needs no medium; light is longitudinal  
     B. Sound is mechanical and requires a medium; light is electromagnetic and does not  
     C. Both require a medium  
     D. Light is slower than sound in vacuum  
     **Answer:** B. Sound is mechanical and requires a medium; light is electromagnetic and does not.  
     **Explanation:** Fundamental difference in propagation.
168.  **Integrated Concept:** Why must photon frequency be balanced in hybrid optical–nuclear imaging?  
     A. Higher frequency lowers resolution  
     B. Higher frequency increases energy, enhancing resolution but raising tissue damage risk  
     C. Frequency has no impact on safety  
     D. Lower frequency always better  
     **Answer:** B. Higher frequency increases energy, enhancing resolution but raising tissue damage risk.  
     **Explanation:** E=hfE = h fE=hf; more energetic photons can harm tissue.
169.  **Application:** A clinician correcting hyperopia uses:  
     A. Concave lens  
     B. Convex lens  
     C. Mirror  
     D. Diffraction grating  
     **Answer:** B. Convex lens.  
     **Explanation:** Converges light to move focal point forward onto retina.
170.  **Foundational Comprehension:** The wave relation v=fλv = f \lambdav=fλ describes:  
     A. Photon energy  
     B. Wave speed  
     C. Electrical power  
     D. Pressure  
     **Answer:** B. Wave speed.  
     **Explanation:** Product of frequency and wavelength.
171.  **Test-Taking Strategy:** Seeing τ = RC in a passage about signal filtering should prompt the reader to recognize:  
     A. Radioactive decay constant  
     B. Capacitor charging/discharging time constant  
     C. Gibbs free energy  
     D. Fluid resistance  
     **Answer:** B. Capacitor charging/discharging time constant.  
     **Explanation:** RC defines filter responsiveness.
172.  **Foundational Comprehension:** Root mean square velocity of gas molecules increases when:  
     A. Temperature decreases  
     B. Molar mass increases  
     C. Temperature increases  
     D. Pressure decreases only  
     **Answer:** C. Temperature increases.  
     **Explanation:** vrms∝T/Mv\_{rms} \propto \sqrt{T/M}vrms​∝T/M​; higher T → faster molecules.
173.  **Application:** A sudden drop in measured flow with constant driving pressure suggests:  
     A. Vasodilation  
     B. Decreased viscosity  
     C. Vasoconstriction  
     D. Shorter vessel length  
     **Answer:** C. Vasoconstriction.  
     **Explanation:** Narrowed radius increases resistance, reducing flow.
174.  **Integrated Reasoning:** A multimodal diagnostic device must account for both optical path distortion and radiation safety. Which pair is essential?  
     A. Ohm’s law and Boyle’s law  
     B. Snell’s law and appropriate shielding for gamma rays  
     C. Poiseuille’s law and Gibbs free energy exclusively  
     D. Wave speed formula and half-life only  
     **Answer:** B. Snell’s law and appropriate shielding for gamma rays.  
     **Explanation:** Optics for imaging; shielding for safety.
175.  **Test-Taking Strategy:** When a passage layers vascular resistance, signal filtering, and radiotracer kinetics, the most effective approach is to:  
     A. Integrate immediately without breakdown  
     B. Decompose into individual physical domains then synthesize  
     C. Focus only on the most familiar topic  
     D. Ignore decay behavior  
     **Answer:** B. Decompose into individual physical domains then synthesize.  
     **Explanation:** Systematic analysis prevents oversight in complex multi-physics scenarios.

Glycolysis

This pathway breaks down glucose into pyruvate.

|  |  |  |
| --- | --- | --- |
| Enzyme | Unique Characteristics | Inhibitors |
| Hexokinase | Phosphorylates glucose to lock it inside the cell. It operates with a high affinity for glucose and is found in most tissues. Glucokinase (Hexokinase IV) in the liver is a unique isoform with a lower glucose affinity, allowing it to become active only at high blood glucose levels for glycogen synthesis. | Glucose-6-phosphate (product inhibition) |
| Phosphofructokinase-1 (PFK-1) | Catalyzes the committed and rate-limiting step of glycolysis. It is allosterically regulated by a variety of molecules. | High levels of ATP and citrate signal high energy reserves. |
| Pyruvate Kinase | Catalyzes the final, irreversible step. Its activity is tightly modulated by allosteric effectors and isozymes vary between tissues. | ATP and alanine signal high energy and metabolic sufficiency. |

Gluconeogenesis

This pathway synthesizes glucose from non-carbohydrate precursors.

|  |  |  |
| --- | --- | --- |
| Enzyme | Unique Characteristics | Inhibitors |
| Fructose-1,6-bisphosphatase | Serves as a key control point for gluconeogenesis, preventing a "futile cycle" by reversing the PFK-1 reaction. | Fructose-2,6-bisphosphate and AMP inhibit it, ensuring that glycolysis is active when energy is needed. |
| Phosphoenolpyruvate Carboxykinase (PEPCK) | Catalyzes the conversion of oxaloacetate to PEP. Its expression is strongly regulated by hormones like glucagon and insulin. | High insulin levels repress its gene expression. |

Citric acid cycle

This cycle oxidizes acetyl-CoA for energy production.

|  |  |  |
| --- | --- | --- |
| Enzyme | Unique Characteristics | Inhibitors |
| Citrate Synthase | A classic example of "induced fit" allosteric regulation, where binding of oxaloacetate triggers a conformational change that allows acetyl-CoA binding. | High levels of ATP, NADH, and succinyl-CoA indicate a surplus of energy. |
| Isocitrate Dehydrogenase | Distinguishes between the stereoisomers of isocitrate. Mutations in this enzyme are linked to some cancers. | ATP and NADH allosterically inhibit it. |
| α-Ketoglutarate Dehydrogenase | This multi-enzyme complex is highly sensitive to oxidative stress and has a narrow optimal pH range, making it a vulnerable point in the cycle. | NADH and succinyl-CoA provide feedback inhibition. |

Oxidative phosphorylation

This process generates ATP using the proton gradient from the electron transport chain (ETC).

|  |  |  |
| --- | --- | --- |
| Enzyme | Unique Characteristics | Blockers |
| Complex I (NADH Dehydrogenase) | Pumps four protons per NADH, starting the ETC. It is one of the main sites of reactive oxygen species (ROS) production. | Rotenone and Amytal block the electron transfer to ubiquinone. |
| Complex II (Succinate Dehydrogenase) | The only enzyme part of both the citric acid cycle and the ETC, but it does not pump protons. | Malonate (competitive inhibitor) and Atpenin A5. |
| Complex III (Cytochrome c Reductase) | Functions as a dimer and uses the unique Q cycle mechanism to transfer electrons, pumping protons across the membrane. | Antimycin A and Stigmatellin inhibit electron transfer. |
| Complex IV (Cytochrome c Oxidase) | Transfers electrons to oxygen, the final electron acceptor, reducing it to water. Electrons flow against the charge gradient here. | Cyanide and carbon monoxide bind to the active site and block oxygen from accepting electrons. |
| ATP Synthase (Complex V) | A miniature rotary motor composed of F₀ and F₁ subunits. Its rotation is coupled to proton flow, which drives ATP synthesis. | Oligomycin blocks the F₀ proton channel, inhibiting ATP synthesis. |

Fatty acid metabolism

This includes synthesis and breakdown of fatty acids.

|  |  |  |
| --- | --- | --- |
| Enzyme | Unique Characteristics | Inhibitors |
| Acetyl-CoA Carboxylase (ACC) | Catalyzes the committed and rate-limiting step of fatty acid synthesis. It can form polymers for activity. | Palmitoyl-CoA (feedback inhibition) and AMPK-mediated phosphorylation. |
| Carnitine Palmitoyltransferase 1 (CPT1) | The rate-limiting enzyme for transporting long-chain fatty acids into the mitochondria for beta-oxidation. It has tissue-specific isoforms. | Malonyl-CoA (the product of ACC) inhibits CPT1, ensuring fatty acid synthesis and breakdown do not occur simultaneously. |

Pentose phosphate pathway

This pathway produces NADPH and nucleotide precursors.

|  |  |  |
| --- | --- | --- |
| Enzyme | Unique Characteristics | Inhibitors |
| Glucose-6-phosphate Dehydrogenase (G6PD) | Catalyzes the first and rate-limiting step of the oxidative phase. It is crucial for producing NADPH to protect red blood cells from oxidative damage. | NADPH (product feedback inhibition). |

Precursors for biochemical pathways concisely

Glycolysis:

 Starts with glucose. Other monosaccharides like fructose and galactose also feed into this pathway.

Gluconeogenesis: Synthesizes new glucose primarily from lactate, glycerol, and glucogenic amino acids. Fatty acids with an odd number of carbons can also be used, but even-chain fatty acids cannot contribute to net glucose synthesis in humans.

Citric Acid Cycle (Krebs Cycle): The main entry precursor is acetyl-CoA, which is derived from the breakdown of carbohydrates, fats, and proteins. The cycle is sustained by intermediates like oxaloacetate, which is replenished by various anaplerotic precursors, such as amino acids.

Fatty Acid Synthesis: The key precursor is acetyl-CoA, which is transported from the mitochondria to the cytosol for synthesis. NADPH is also required for reduction steps.

Fatty Acid Oxidation (Beta-Oxidation): The precursor is fatty acyl-CoA, which is transported into the mitochondria via the carnitine transport system.

Pentose Phosphate Pathway (PPP): The central precursor for the oxidative phase is glucose-6-phosphate. This pathway produces the nucleotide precursor ribose-5-phosphate and the reducing agent NADPH.

Urea Cycle: The main nitrogen precursors are ammonia (as carbamoyl phosphate) and aspartate, which donate the nitrogen atoms for urea synthesis.

Purine Synthesis: The *de novo* pathway starts with ribose-5-phosphate and uses amino acids (glycine, aspartate, glutamine), CO₂, and tetrahydrofolate derivatives to build the purine ring.

Glucose catabolism

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Pathway | Location | Direct energy produced | Reducing agents produced | Total per glucose |
| Glycolysis | Cytosol | 2 ATP (net) | 2 NADH | 2 ATP, 2 NADH |
| Pyruvate oxidation | Mitochondrial matrix | — | 2 NADH | 2 NADH |
| Citric Acid Cycle | Mitochondrial matrix | 2 ATP (or GTP) | 6 NADH, 2 FADH₂ | 2 ATP (or GTP), 6 NADH, 2 FADH₂ |
| Total (before ETC) | — | 4 ATP | 10 NADH, 2 FADH₂ | 4 ATP, 10 NADH, 2 FADH₂ |

*Note: The actual ATP yield can vary depending on the efficiency of the Electron Transport Chain (ETC) shuttles that transport glycolytic NADH into the mitochondria.*

Other pathways

Pentose Phosphate Pathway (PPP)

* Location: Cytosol.
* Reducing agents produced: 2 NADPH molecules per glucose-6-phosphate that enters the oxidative phase of the pathway.
* Function: NADPH is primarily used for anabolic (building) reactions, such as fatty acid synthesis and cholesterol synthesis, and to protect against oxidative stress by reducing glutathione.

Beta-oxidation (Fatty Acid Oxidation)

* Location: Mitochondrial matrix.
* Energy and reducing agents: The yield of energy carriers depends on the length of the fatty acid chain. For a 16-carbon fatty acid (e.g., palmitate), beta-oxidation produces:
  + 8 acetyl-CoA
  + 7 NADH
  + 7 FADH₂
* Acetyl-CoA entry into Krebs Cycle: The acetyl-CoA molecules produced can then enter the citric acid cycle for further oxidation to generate additional NADH and FADH₂.
* Total ATP for Palmitate: Complete oxidation of palmitate generates approximately 106 ATP.

**Glycolysis**

The catabolic breakdown of one glucose molecule into two pyruvate molecules in the cell's cytosol. It is a 10-step process divided into two phases:

* **Energy Investment Phase** (steps 1–5): Glucose is phosphorylated and cleaved into two molecules of glyceraldehyde-3-phosphate, consuming 2 ATP.
* **Energy Payoff Phase** (steps 6–10): The two glyceraldehyde-3-phosphate molecules are converted to two pyruvate molecules, generating 4 ATP and 2 NADH.

**Steps:**

1. **Phosphorylation of Glucose:** Glucose is phosphorylated by **hexokinase** to form glucose-6-phosphate, using 1 ATP.
2. **Isomerization:** Glucose-6-phosphate is converted into fructose-6-phosphate by **phosphoglucose isomerase**.
3. **Phosphorylation of Fructose-6-Phosphate:** Fructose-6-phosphate is phosphorylated by **phosphofructokinase-1 (PFK-1)** to form fructose-1,6-bisphosphate, using 1 ATP.
4. **Cleavage:** Fructose-1,6-bisphosphate is cleaved by **aldolase** into dihydroxyacetone phosphate (DHAP) and glyceraldehyde-3-phosphate (G3P).
5. **Isomerization:** DHAP is converted to G3P by **triosephosphate isomerase**, so two G3P molecules continue the pathway.
6. **Oxidation and Phosphorylation:** G3P is oxidized and phosphorylated by **glyceraldehyde-3-phosphate dehydrogenase** to form 1,3-bisphosphoglycerate and 1 NADH. (This step happens twice per glucose).
7. **Substrate-Level Phosphorylation:** A phosphate is transferred from 1,3-bisphosphoglycerate to ADP by **phosphoglycerate kinase**, producing 3-phosphoglycerate and 1 ATP. (Happens twice).
8. **Phosphate Relocation:** 3-phosphoglycerate is converted to 2-phosphoglycerate by **phosphoglycerate mutase**.
9. **Dehydration:** A water molecule is removed from 2-phosphoglycerate by **enolase** to form phosphoenolpyruvate (PEP).
10. **Substrate-Level Phosphorylation:** A phosphate is transferred from PEP to ADP by **pyruvate kinase**, producing pyruvate and 1 ATP. (Happens twice).

Gluconeogenesis

The anabolic pathway that synthesizes glucose from non-carbohydrate precursors, primarily in the liver. It largely reverses glycolysis but uses bypass reactions for the three irreversible steps.

**Bypass reactions:**

1. **Pyruvate to Phosphoenolpyruvate (PEP):**
   * **Carboxylation:** Pyruvate is carboxylated by **pyruvate carboxylase** in the mitochondria to form oxaloacetate.
   * **Conversion:** Oxaloacetate is converted to PEP by **phosphoenolpyruvate carboxykinase (PEPCK)**.
2. **Fructose-1,6-bisphosphate to Fructose-6-phosphate:** Fructose-1,6-bisphosphate is dephosphorylated by **fructose-1,6-bisphosphatase**.
3. **Glucose-6-phosphate to Glucose:** Glucose-6-phosphate is dephosphorylated by **glucose-6-phosphatase** in the endoplasmic reticulum.

Citric acid cycle (Krebs cycle or TCA cycle)

A central metabolic hub that completes the oxidation of acetyl-CoA. It takes place in the mitochondrial matrix.

**Steps:**

1. **Citrate formation:** Acetyl-CoA combines with oxaloacetate to form citrate, catalyzed by **citrate synthase**.
2. **Isomerization:** Citrate is isomerized to isocitrate by **aconitase**.
3. **Oxidative Decarboxylation:** Isocitrate is oxidized to α-ketoglutarate, releasing CO₂ and producing NADH, catalyzed by **isocitrate dehydrogenase**.
4. **Oxidative Decarboxylation:** α-Ketoglutarate is oxidized to succinyl-CoA, releasing CO₂ and producing NADH, catalyzed by **α-ketoglutarate dehydrogenase complex**.
5. **Substrate-Level Phosphorylation:** Succinyl-CoA is converted to succinate, producing GTP (which can be used to make ATP), catalyzed by **succinyl-CoA synthetase**.
6. **Oxidation:** Succinate is oxidized to fumarate, producing FADH₂, catalyzed by **succinate dehydrogenase**.
7. **Hydration:** Fumarate is hydrated to malate by **fumarase**.
8. **Oxidation:** Malate is oxidized to regenerate oxaloacetate, producing NADH, catalyzed by **malate dehydrogenase**.

Beta-oxidation

The catabolic breakdown of fatty acids into acetyl-CoA in the mitochondrial matrix. It's a cyclical process of four steps that repeats until the fatty acid is completely oxidized.

**Steps:**

1. **Dehydrogenation:** Acyl-CoA is oxidized, forming a double bond and producing FADH₂, catalyzed by **acyl-CoA dehydrogenase**.
2. **Hydration:** A water molecule is added across the double bond, catalyzed by **enoyl-CoA hydratase**.
3. **Oxidation:** The hydroxyl group is oxidized, producing NADH, catalyzed by **3-hydroxyacyl-CoA dehydrogenase**.
4. **Thiolysis:** The bond is cleaved by **thiolase**, releasing one acetyl-CoA and a new acyl-CoA two carbons shorter.

Electron Transport Chain (ETC) and Oxidative Phosphorylation

This process uses the reduced electron carriers NADH and FADH₂ to create an electrochemical gradient that powers ATP synthesis. It occurs in the inner mitochondrial membrane.

**Steps:**

1. **Electron Delivery:** NADH and FADH₂ donate electrons to Complexes I and II, respectively.
2. **Proton Pumping:** As electrons move through Complexes I, III, and IV, the energy released pumps protons from the mitochondrial matrix into the intermembrane space, creating an electrochemical gradient.
3. **Final Electron Acceptor:** At Complex IV, electrons transfer to oxygen which is reduced to water
4. **ATP Synthesis:** Protons flow back into the matrix through **ATP synthase (Complex V)**, and the energy from this flow drives ATP synthesis.

Pentose Phosphate Pathway (PPP)

This pathway runs parallel to glycolysis and produces NADPH and ribose-5-phosphate. It is divided into an oxidative phase and a non-oxidative phase.

* **Oxidative Phase (irreversible):**
  1. **Dehydrogenation:** Glucose-6-phosphate is oxidized, producing NADPH, catalyzed by **glucose-6-phosphate dehydrogenase**.
  2. **Hydrolysis:** An intermediate is hydrolyzed to 6-phosphogluconate.
  3. **Decarboxylation:** 6-phosphogluconate is oxidized and decarboxylated, producing another NADPH and a 5-carbon ribulose-5-phosphate.
* **Non-Oxidative Phase (reversible):**
  1. **Rearrangement:** Ribulose-5-phosphate is converted into other sugars, including ribose-5-phosphate for nucleotide synthesis and intermediates that can re-enter glycolysis, using enzymes like **transketolase** and **transaldolase**.

# Missed Quizzes

**What is the main role of the ubiquitin-proteasome system in cellular processes?**

The ubiquitin-proteasome system primarily targets proteins for degradation, maintaining cellular protein levels. Activation of zymogens involves different mechanisms, such as proteolytic cleavage, not directly related to the ubiquitin-proteasome system's main function.

**Describe how histone acetylation affects gene expression.**

Histone acetylation adds acetyl groups to histones, reducing their positive charge and loosening DNA wrapping. This open chromatin structure allows transcription factors easier access to DNA, promoting gene expression. The incorrect options misunderstand the role of acetylation in chromatin dynamics and gene regulation.

**Describe the role of thiamine (B1) in metabolic processes.**

Thiamine (B1) is crucial for carbohydrate metabolism, specifically aiding in the decarboxylation of alpha-keto acids, which is essential for energy production.

**Describe the role of niacin (B3) in metabolic pathways and the types of coenzymes it produces.**

The correct option highlights niacin's vital role in producing NAD and NADP, essential for energy metabolism.

**What is the primary benefit of proteolytic cleavage in enzyme activation?**

The correct answer highlights that proteolytic cleavage protects enzymes from premature activation, which could lead to tissue damage.

**What coenzyme is formed from pantothenic acid (B5) that is crucial for metabolism?**

Coenzyme A, formed from B5, is essential for fatty acid metabolism and the synthesis of acetyl-CoA.

**Describe the role of folate (B9) in the synthesis of nucleotides and its importance in cellular metabolism.**

The correct option highlights folate's critical role in nucleotide synthesis through its conversion to tetrahydrofolate (THF), essential for one-carbon transfers in DNA synthesis.

**What is the inducible nature of the lac operon?**

The lac operon is a classic example of gene regulation, where the presence of lactose activates the operon by removing the repressor.

**For the following scenario, indicate what the outcome would be: Acetylation of histones by HAT.**

Acetylation of histones by histone acetyltransferases (HATs) relaxes chromatin structure, promoting access for transcription machinery. This contrasts with repression, where tighter chromatin would inhibit transcription. Understanding the role of histone modifications is crucial in gene regulation.

**If a deficiency in pantothenic acid occurs, which metabolic process would likely be disrupted?**

Fatty acid metabolism relies on pantothenic acid for coenzyme A synthesis, crucial for fatty acid synthesis and oxidation.

**The lac operon in E. coli is regulated by lactose, which**

Lactose binds to the repressor in the lac operon, causing it to change shape and detach from the operator, thus inactivating the repressor.

The figure above shows a model of the lac operon. Repressor binds to the operator to block transcription if there is no lactose available but comes off if lactose is available and it binds a lactose metabolite, allolactose. If the Repressor protein is mutated so it cannot bind to DNA, what will happen to transcription of the lac operon?

Which cytoskeletal component is primarily responsible for the contraction during cytokinesis?

**Which cytoskeletal component is primarily responsible for the formation of the mitotic spindle during cell division?**

Microtubules are crucial for forming the mitotic spindle, which separates chromosomes during cell division. In contrast, intermediate filaments provide structural support, microfilaments are involved in cell movement, and actin filaments play roles in muscle contraction and cell shape, leading to common misconceptions about their functions.

**Which cytoskeletal component do motor proteins use for transport within cells?**

Motor proteins primarily use microtubules for intracellular transport, as they provide the necessary tracks for movement. Intermediate filaments offer structural support but do not facilitate transport like microtubules do.

**Which cytoskeletal component is primarily responsible for the contraction during cytokinesis?**

Microfilaments, primarily composed of actin, play a crucial role in **cytokinesis** by forming the contractile ring that pinches the cell membrane. In contrast, microtubules are involved in cell division but primarily assist in chromosome separation, while intermediate filaments and neurofilaments provide structural support, not contraction

**Which cytoskeletal filament is primarily responsible for providing mechanical support to cells?**

Intermediate filaments offer structural stability and resist mechanical stress, unlike microfilaments and actin filaments, which are more involved in cell movement and shape. Microtubules primarily facilitate transport within cells.

**What role does the zinc ion (Zn2+) play in the function of carbonic anhydrase?**

Zinc ions (Zn²⁺) are essential for the catalytic activity of carbonic anhydrase, directly participating in the enzyme's reaction mechanism. They do not function as allosteric modulators, which influence enzyme activity indirectly.

**If a patient is hyperventilating, what physiological changes would you expect to observe in their blood pH and carbon dioxide levels?**

Hyperventilation leads to excessive exhalation of carbon dioxide, causing a decrease in its levels and an increase in blood pH (respiratory alkalosis).

**Which of the following interactions is most prominently involved in proper protein folding**

Ionic bonds contribute to protein stability but are not the primary force in folding. Hydrogen bonds are crucial for maintaining secondary structures like alpha helices and beta sheets, making them the most significant in proper protein folding.

**How does the absence of glucose-6-phosphate dehydrogenase (G6PD) affect red blood cell function?**

The correct option highlights that G6PD is crucial for producing NADPH, which protects red blood cells from oxidative damage.

**If a drug were to disrupt microfilament function, what cellular processes might be affected?**

Microfilaments are crucial for cell motility and maintaining shape, not directly involved in DNA replication or transcription.

**Describe the roles of the three types of protein filaments in the eukaryotic cytoskeleton.**

* Microfilament = structural support and facilitate cell movement
* Intermediate filament = Mechanical strength
* Microtubule = intracellular transport and cell division

**If a drug were to inhibit tubulin polymerization, what effect would this have on microtubule dynamics and cellular processes?**

Inhibiting tubulin polymerization directly affects microtubule dynamics, leading to impaired cellular processes such as cell division and transport.

**Describe the role of microfilaments in the process of cytokinesis.**

The correct answer highlights that microfilaments specifically create a contractile ring, essential for physically dividing the cell.

**If a mutation occurs that impairs the function of kinesins, what cellular process would likely be disrupted?**

Kinesins are motor proteins essential for transporting organelles along microtubules.

**Describe how the zinc ion (Zn2+) contributes to the enzymatic activity of carbonic anhydrase.**

Your answer is incorrect because the zinc ion's primary role in carbonic anhydrase is to polarize water, aiding in carbon dioxide hydration. Modifying the active site is not its main function; instead, it enhances the enzyme's catalytic efficiency through water molecule polarization.

**Describe how metal ion cofactors contribute to enzyme function in biochemical reactions.**

The correct option highlights that metal ion cofactors not only stabilize the enzyme's active site but also actively participate in the chemical reactions.

**Disulfide bonds are found in which level of protein structure?**

Disulfide bonds are covalent links between cysteine residues, stabilizing the three-dimensional shape of proteins. They do not form in primary or secondary structures, which involve peptide bonds and hydrogen bonds, respectively. Quaternary structure refers to multiple polypeptide chains, where disulfide bonds can also occur but are primarily associated with tertiary structure.

**If an experiment shows that the concentration of the enzyme-substrate complex is increasing over time, what implication does this have regarding the assumptions of the Michaelis-Menten model?**

Your answer is incorrect because an increasing enzyme-substrate complex indicates that the system is not at steady-state, where concentrations remain constant. The correct answer reflects that the steady-state assumption may not hold, suggesting dynamic changes in the complex concentration.

**Which of the following is true regarding Glucose 6-Phosphate Dehydrogenase?**

Your answer only addresses one aspect of G6PD's role. While GSH deficiency does lead to hemolytic anemia, G6PD is also crucial for NADPH regeneration, which is necessary for glutathione regeneration. Thus, all statements are correct, making "All of the above" the right choice.

**Dynamic instability in microtubules stems from the intrinsic capacity of tubulin molecules to hydrolyze:**

Dynamic instability is due to tubulin's ability to hydrolyze GTP, not tubulin dimers. GTP hydrolysis leads to conformational changes that promote microtubule growth and shrinkage, while tubulin dimers are the building blocks of microtubules, not the source of instability.

**Agents such as urea and quandine hydrochloride denature proteins by disrupting the hydrogen bonds.**

Hydrophobic interactions are not primarily disrupted by urea and quandine hydrochloride; these agents mainly target hydrogen bonds, which are crucial for maintaining protein structure.

**Which molecule is primarily derived from the breakdown of fats and can be used in gluconeogenesis during fasting?**

Lactate is produced from anaerobic glycolysis, not fat breakdown. Glycerol, derived from triglycerides, can enter gluconeogenesis during fasting, making it the correct answer.

**Which lipoprotein is known for transporting cholesterol back to the liver?**

HDL, or high-density lipoprotein, is often referred to as "good cholesterol" because it helps remove excess cholesterol from tissues and transports it back to the liver for excretion. In contrast, LDL (low-density lipoprotein) carries cholesterol to cells, which can lead to plaque buildup in arteries.

**Describe how increased secretion of VLDL can contribute to atherosclerosis.**

The correct option highlights that elevated VLDL increases triglycerides, contributing to plaque buildup in arteries, a key factor in atherosclerosis.

Describe the significance of the 5' cap and poly-A tail in eukaryotic pre-mRNA processing.

* 5' cap: Protects mRNA from degradation and assist in ribosome binding
* Poly-A tail:
  + Enhances stability and export from the nucleus.
  + Attachment of Poly A tail: Adds a sequence of adenine nucleotides to the 3' end of a eukaryotic mRNA transcript.

**If Malonyl-CoA levels are elevated in a cell, what effect would this have on fatty acid degradation?**

Malonyl-CoA inhibits fatty acid degradation by blocking carnitine acyltransferase, preventing fatty acids from entering the mitochondria for oxidation.

**Describe how malonyl-CoA affects the transport of fatty acyl-CoA into the mitochondria.**

Malonyl-CoA actually inhibits CPT1, which prevents fatty acyl-CoA from entering the mitochondria for beta-oxidation.

**Assume that a transition mutation results in an amino acid substitution in the resulting polypeptide. What level of protein structure might be affected as a result?**

The primary structure refers only to the sequence of amino acids. A substitution can impact not just this sequence but also the secondary, tertiary, and quaternary structures due to changes in interactions and folding, hence affecting all levels of protein structure.

**Which type of lipoprotein is primarily responsible for transporting cholesterol from the liver to tissues and is associated with an increased risk of atherosclerosis?**

VLDL primarily transports triglycerides, not cholesterol, and is less associated with atherosclerosis risk. LDL is the main lipoprotein for cholesterol transport from the liver to tissues, making it the correct answer in this context.

**Which of the following characteristics would be evident in an untreated Type 1 diabetic patient?**

In untreated Type 1 diabetes, the lack of insulin leads to increased hepatic gluconeogenesis, not decreased. Insulin normally inhibits gluconeogenesis; without it, the liver produces more glucose, contributing to hyperglycemia. Your choice reflects a misunderstanding of insulin's role.

**The enzyme that catalyzes the rate-limiting step of fatty acid synthesis is \_\_\_\_\_\_\_. It is positively regulated by \_\_\_\_\_\_\_\_\_.**

Acetyl CoA carboxylase is indeed the enzyme for fatty acid synthesis, but it is positively regulated by citrate, not malonyl CoA. Malonyl CoA is a product of the reaction and serves as an inhibitor rather than a regulator.

**Which lipoprotein is known for transporting cholesterol back to the liver?**

LDL (low-density lipoprotein) transports cholesterol to tissues, potentially leading to plaque buildup. HDL (high-density lipoprotein) is responsible for transporting cholesterol back to the liver for excretion or recycling, making it the correct answer.

**What specific type of DNA damage is primarily addressed by base excision repair (BER)?**

Base excision repair (BER) specifically targets single-strand breaks and small base lesions, not mismatches. Mismatches are typically corrected by mismatch repair mechanisms, which are distinct from BER processes. Your answer is incorrect because nucleotide excision repair (NER) removes a segment of DNA that includes several nucleotides surrounding the damage, not just the damaged ones. This broader removal is essential for effective repair.

**Which stage of the cell cycle is most conducive to homologous recombination?**

Homologous recombination primarily occurs during the G2 phase when the DNA has been replicated and is ready for repair and recombination. In contrast, the S phase focuses on DNA synthesis, making it less conducive for this process.

**If a drug inhibits the binding of cyclins to CDKs, which of the following outcomes would most likely occur in a cell?**

Inhibiting cyclin-CDK binding disrupts cell cycle regulation, preventing progression through interphase.

**Describe the impact of BRCA-1 dysfunction on genomic integrity and cell survival.**

BRCA-1 is crucial for homologous recombination, a DNA repair process. Its dysfunction leads to an accumulation of mutations, compromising genomic integrity and increasing cell death. The correct option highlights BRCA-1's specific role in repairing double-strand breaks, a critical function in maintaining genomic stability. The BRCA1 protein primarily functions in the repair of double-strand breaks by assembling with other proteins. Mismatch repair involves different proteins, such as MLH1 and MSH2, making your answer incorrect. BRCA1 primarily functions in signaling for DNA repair rather than preventing double strand breaks directly. It relays signals from ATM to activate repair processes, while preventing breaks during G1 is not its main role. The BRCA1 protein is primarily involved in repairing DNA damage, particularly double-strand breaks

**Which checkpoint is responsible for ensuring that DNA replication is complete before cell division?**

The G2/M checkpoint verifies that DNA replication is complete and checks for DNA damage before mitosis. The S phase checkpoint focuses on the replication process itself, while the G1/S checkpoint assesses cell readiness for DNA synthesis, and the metaphase checkpoint ensures proper chromosome alignment during division.

**In a scenario where a cell experiences multiple double-strand breaks and has limited access to homologous sequences, which repair mechanism is likely to be utilized more frequently, and why?**

Homologous recombination requires a homologous template, which is limited in your scenario. Non-homologous end joining is preferred for its ability to repair double-strand breaks without needing such templates, making it more suitable under those conditions.

**What is the role of the MutS protein in DNA repair mechanisms?**

MutS specifically recognizes and binds to mismatched DNA bases, initiating mismatch repair. It does not play a role in homologous recombination, which is a different repair process involving other proteins. Your answer misidentified the function of MutS. Mismatch repair in E. coli begins with MutS recognizing the mismatched pair, not DNA polymerase III. The polymerase is involved later in the repair process, but it does not initiate the mismatch repair.

**Homologous recombination repair (HRR) relies on the use of an available template for repair. Based on what you know about the cell cycle, when do you think HRR would most likely occur?**

HRR primarily occurs during the S and G2 phases when sister chromatids are available as templates for repair. G1 lacks these templates, making your answer incorrect.

**If a cell experiences a significant DNA mutation during interphase, which phase of the cell cycle would be most critical for activating repair mechanisms?**

Interphase encompasses the entire period before mitosis, including G1 and S phases. While G1 is important for monitoring DNA integrity, the most critical phase for activating repair mechanisms after a mutation is interphase, as it allows for comprehensive repair processes before cell division.

**A researcher treats cells with a chemical that prevents DNA synthesis from starting. This treatment would trap the cells in which part of the cell cycle?**

Cells in the G2 phase have already completed DNA synthesis. The treatment prevents DNA synthesis, trapping cells in the G0/G1 phase, where they prepare for DNA replication. Your answer indicates a misunderstanding of the cell cycle stages.

**Which stage of the cell cycle is most conducive to homologous recombination?**

Homologous recombination primarily occurs during the G2 phase when the DNA is replicated and the cell prepares for mitosis. In the S phase, DNA replication is happening, but the necessary structures for recombination are not fully established.

**Which of the following membrane activities requires energy from ATP?**

The GLUT-1 carrier protein facilitates glucose transport without energy, relying on concentration gradients. In contrast, the Na+/K+ pump actively moves Na+ ions against their gradient, requiring ATP. Your answer misidentified a passive transport process as requiring energy.

**Which of the following best describes the normal role of tumor suppressor genes?**

Tumor suppressor genes primarily function to inhibit cell cycle progression, preventing uncontrolled cell division. While they can indirectly suppress cancer cell growth, their main role is regulating the cell cycle, not directly targeting tumor cells. Your answer reflects a secondary effect rather than the primary function.

**Which of the following is true about histone acetyltransferase?**

Your answer is incorrect because HATs actually promote gene expression by adding acetyl groups to histones, which relaxes chromatin structure, making it more accessible for transcription. Compaction is associated with histone deacetylases (HDACs), not HATs.

**What is the role of B7 (biotin) in the pyruvate carboxylase reaction?**

Your answer is incorrect because biotin acts as a cofactor that directly delivers carbon dioxide to pyruvate in the carboxylation reaction. It does not bind carbon dioxide for phosphorylation activation; that process is unrelated to biotin's role in this specific reaction.

**What is the function of Pyridoxal, Vitamin B6?**

Your answer is incorrect because while Vitamin B6 is involved in amino acid metabolism, its primary role is as a coenzyme in amino acid and glycogen metabolism, not nucleic acid metabolism.

**If a deficiency in pantothenic acid occurs, which metabolic process would likely be disrupted?**

Fatty acid metabolism relies on pantothenic acid for coenzyme A synthesis, crucial for fatty acid synthesis and breakdown.

**If a patient presents with symptoms of neurological impairment and is diagnosed with thiamine deficiency, which metabolic pathway would you expect to be most affected?**

Nucleotide synthesis is not primarily affected by thiamine deficiency. Thiamine is crucial for the citric acid cycle, which is vital for energy production. Its deficiency disrupts this pathway, leading to neurological symptoms due to impaired energy metabolism.

**A DNA sequence containing regulatory elements (binding sites for transcription factors) that can influence transcription activation from a distant location that may even be downstream from the regulated gene is called \_\_\_\_\_\_ .**

Promoters are located near the transcription start site and initiate transcription, while enhancers can be located far from the gene they regulate and enhance transcription from a distance. Your answer does not account for this key difference in function and location.

**If a patient has a condition that leads to consistently high blood glucose levels, which enzyme would you expect to be more active in their liver, glucokinase or hexokinase, and why?**

Hexokinase is indeed active at low glucose levels, but it becomes saturated and less effective when glucose is high. Glucokinase, however, is specifically designed to function at elevated glucose levels, making it the correct choice in this scenario.

**What type of inhibition does malonate exert on Complex II?**

Malonate competes with succinate for the active site of Complex II, characteristic of competitive inhibition. Allosteric inhibition involves binding at a different site, altering enzyme activity without competing for the active site, which does not apply in this case.

**What is the primary role of NADPH in cellular metabolism?**

NADPH primarily serves as a reducing agent in anabolic reactions, providing the necessary electrons for biosynthesis. Energy production is mainly associated with ATP, not NADPH, which is crucial for building molecules rather than breaking them down.

**Describe the effect on the lac operon when the repressor protein is unable to bind to the operator region.**

The correct option highlights that without the repressor binding, RNA polymerase can continuously transcribe the operon.

**What are the primary functions of actin filaments in cells?**

Actin filaments primarily facilitate cell movement and provide structural support for maintaining cell shape. Cell division and energy production are functions associated with other cellular components, not specifically actin filaments.

**What is the primary role of the cornea in the visual system?**

The cornea primarily focuses light onto the retina, while the iris regulates light entry. Your answer describes the iris's function, not the cornea's.

**What is the primary role of the lens in the eye?**

The lens primarily bends light rays to focus them onto the retina, unlike the other options.

A screenshot of a graph

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## BIO — Lac Operon Expression

**Q1**

In the **Glucose+, Lactose+** condition, lac operon transcription is low primarily because:  
A) The repressor is bound to the operator  
B) **cAMP is low, so CAP does not activate transcription**  
C) RNA polymerase is inhibited by lactose  
D) Allolactose prevents RNA polymerase binding

**Answer: B**  
**Explanation:** With glucose present, **adenylate cyclase is less active → low cAMP**, so **CAP–cAMP** does not bind the promoter to recruit RNA polymerase. Although lactose (via allolactose) removes the repressor, **catabolite repression** keeps transcription low.

**Q2**

Which condition maximizes **lacZ (β-galactosidase)** expression?  
A) Glucose+, Lactose−  
B) Glucose+, Lactose+  
C) **Glucose−, Lactose+**  
D) Glucose−, Lactose−

**Answer: C**  
**Explanation:** **Lactose present** → repressor off; **no glucose** → high cAMP, **CAP–cAMP** binds and promotes **maximal** transcription.

**Q3**

An E. coli strain has a **lacI⁻** mutation (nonfunctional repressor). Which bar would increase the most relative to wild-type?  
A) Glucose+, Lactose−  
B) Glucose−, Lactose−  
C) **Both A and B would rise**  
D) Neither; lacI⁻ has no effect

**Answer: C**  
**Explanation:** Without a functional repressor (**lacI⁻**), the operon can be transcribed even without lactose; **catabolite repression** still limits expression when glucose is present, but the **“off” bars rise** compared with wild-type.

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## BCH — DNA Melting Curves (A260 vs Temperature)

**Q4**

Compared with **35% GC** DNA in **normal salt**, **65% GC** DNA in the same buffer will show a melting curve with:  
A) Lower Tm and steeper slope  
B) **Higher Tm (shifted right)**  
C) Lower A260 at all temperatures  
D) No change in Tm but lower A260 at high T

**Answer: B**  
**Explanation:** **Higher GC% → more H-bonds and stronger base stacking** → **higher Tm** (curve right-shift).

**Q5**

Which change would **decrease** the Tm **most** for a given DNA duplex?  
A) Increasing NaCl from 50 mM to 150 mM  
B) Increasing GC content from 40% to 60%  
C) **Reducing monovalent salt concentration to near zero**  
D) Extending the duplex by 50 bp

**Answer: C**  
**Explanation:** **Lower ionic strength** increases electrostatic repulsion among phosphates, **destabilizing** the duplex and **lowering Tm**.

**Q6**

Why does A260 increase as DNA melts?  
A) Phosphodiester bonds absorb more UV when cleaved  
B) **Base stacking decreases, exposing bases (hyperchromic effect)**  
C) Hydrogen bonding increases absorbance  
D) Protein contaminants increase absorbance at 260 nm

**Answer: B**  
**Explanation:** **Unstacking** of bases during denaturation increases **UV absorbance at 260 nm**—the **hyperchromic effect**.

**Speed Notes (what to memorize)**

* **Lac operon:** **Lactose removes repressor; no glucose → high cAMP–CAP** → maximal transcription.
* **DNA Tm:** **↑GC% & ↑salt → ↑Tm**; hyperchromicity = ↑A260 upon strand separation.

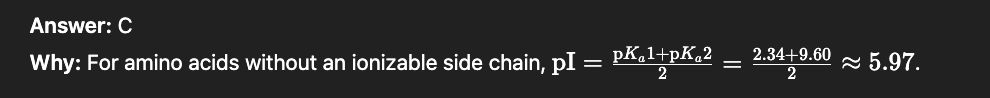
A graph of a curve

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**Q1. What is the isoelectric point (pI) of glycine (no ionizable side chain)?**

A. 3.0  
B. 5.0  
C. **5.97**  
D. 8.0

**Answer:** C



**Q2. At pH = pKa₂, how many equivalents of OH⁻ have been added (per mole of glycine)?**

A. 0.25 eq  
B. 0.50 eq  
C. 1.00 eq  
D. **1.50 eq**

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**Q3. Which structure predominates at pH 7?**

A. H₂N–CH₂–COO⁻ (net −1)  
B. **H₃N⁺–CH₂–COO⁻ (zwitterion, net ≈ 0)**  
C. H₃N⁺–CH₂–COOH (net +1)  
D. H₂N–CH₂–COOH (net 0)

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A screen shot of a graph

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## Figure — Michaelis–Menten with inhibitors

**What to notice (concise):**

* **Competitive inhibition:** curves show a **rightward shift**; **Vmax unchanged**, **Km ↑** (needs more substrate to reach ½Vmax).
* **Noncompetitive (pure):** curves show a **lower ceiling**; **Vmax ↓**, **Km unchanged** (binding affinity same, capacity reduced).
* **MCAT takeaway:** *Right shift = competitive; Lower maximum = noncompetitive.*

**3 MCQs**

**1) An inhibitor increases the apparent Km but does not change Vmax. Which mechanism best fits?**  
A. Uncompetitive  
B. Noncompetitive (pure)  
C. Competitive  
D. Irreversible  
**Answer: C.**  
**Why:** Competitive inhibitors raise **Km** (right shift) but keep **Vmax** the same. Uncompetitive lowers both; pure noncompetitive lowers Vmax only; irreversible typically lowers Vmax.

**2) At very high substrate concentrations, which inhibitor’s effect is minimized the most?**  
A. Competitive  
B. Noncompetitive (pure)  
C. Uncompetitive  
D. Mixed (Km ↑, Vmax ↓)  
**Answer: A.**  
**Why:** Excess substrate outcompetes **competitive** inhibitors, restoring Vmax. Noncompetitive and mixed decrease Vmax regardless of [S]; uncompetitive cannot be overcome by adding substrate.

**3) An enzyme assay shows the same Km but a decreased Vmax after adding an inhibitor. Which is most consistent?**  
A. Competitive  
B. Pure noncompetitive  
C. Uncompetitive  
D. Allosteric activator  
**Answer: B.**  
**Why:** **Pure noncompetitive** reduces **Vmax** without altering **Km**. Competitive raises Km; uncompetitive lowers both; an activator would increase activity, not decrease it.

# Figures

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## Figure — O₂–Hb Dissociation (Left vs Right Shift)

**What to notice (concise):**

* **Right shift (↓affinity, ↑P50):** ↑CO₂, ↑Temp, ↑2,3-BPG, ↓pH → **better unloading in tissues** (curve right/down at a given pO₂).
* **Left shift (↑affinity, ↓P50):** ↓CO₂, ↓Temp, ↓2,3-BPG, ↑pH, **HbF** → **tighter binding, less unloading**.
* **At pO₂≈40 mmHg (tissue):** right shift yields **lower saturation** → more O₂ delivered; left shift yields **higher saturation** → less delivery.
* **At pO₂≈100 mmHg (lungs):** curves are all near 100% → loading is relatively preserved.

**3 MCQs**

**1) During intense exercise, muscle temperature and CO₂ rise. What happens to hemoglobin’s P50 and O₂ affinity?**  
A. P50 ↓; affinity ↑  
B. P50 ↑; affinity ↓  
C. P50 unchanged; affinity ↓  
D. P50 ↑; affinity ↑  
**Answer: B.**  
**Why:** Heat and CO₂ (plus acidosis) cause a **right shift** → **P50 increases** and **affinity decreases**, enhancing tissue unloading.

**2) Which statement best explains why fetal hemoglobin (HbF) is left-shifted vs adult HbA?**  
A. HbF binds 2,3-BPG more strongly, stabilizing the T state  
B. HbF binds 2,3-BPG more weakly due to γ-chain composition  
C. HbF has a higher Hill coefficient than HbA  
D. HbF is more readily carbamylated by CO₂  
**Answer: B.**  
**Why:** **HbF (αγ₂)** interacts **less** with 2,3-BPG than HbA (α₂β₂), favoring the R state → **higher affinity** (left shift).

**3) A patient with acute hyperventilation develops respiratory alkalosis. Predicted effect at tissues?**  
A. Left shift → ↓O₂ delivery  
B. Left shift → ↑O₂ delivery  
C. Right shift → ↑O₂ delivery  
D. Right shift → ↓O₂ delivery  
**Answer: A.**  
**Why:** Alkalosis causes a **left shift** (affinity ↑), so Hb holds O₂ more tightly → **reduced unloading** to tissues.

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## Figure — Allosteric Cooperativity & Modulators

**What to notice (concise):**

* **Noncooperative (n=1):** hyperbolic (Michaelis-like).
* **Positive cooperativity (n>1):** **sigmoidal** curve; **K₀.₅** is the [S] giving ½Vmax (analogous to Km).
* **Allosteric activator:** **left shift** (K₀.₅ ↓) → higher activity at the same [S].
* **Allosteric inhibitor:** **right shift** (K₀.₅ ↑) → lower activity at the same [S].
* **MCAT takeaway:** Sigmoid = cooperativity (T⇄R states); left shift = activator; right shift = inhibitor.

**3 MCQs**

**1) An enzyme shows a sigmoidal v–[S] curve that becomes more hyperbolic after adding compound X. Which is most consistent?**  
A. X increases Hill coefficient  
B. X converts the enzyme to a Michaelis–Menten monomer  
C. X decreases Hill coefficient (n → 1) by stabilizing the R state  
D. X competitively inhibits the enzyme active site  
**Answer: C.**  
**Rationale:** Loss of sigmoidity (toward hyperbolic) implies **cooperativity decreases** (effective **n ↓**). Stabilizing the **R state** or breaking subunit communication can produce this. Competitive inhibition shifts Km but doesn’t remove sigmoidity.

**2) Adding an allosteric activator most directly produces which kinetic change at sub-saturating [S]?**  
A. Vmax ↑ with no change in K₀.₅  
B. K₀.₅ ↓ (left shift), v increases at the same [S]  
C. K₀.₅ ↑ (right shift), v decreases at the same [S]  
D. Km ↓ with Vmax ↓  
**Answer: B.**  
**Rationale:** Classic activators **lower K₀.₅** (better apparent affinity) so activity rises at a given substrate level. Effects on Vmax vary by system; the hallmark tested is the **left shift**.

**3) Which statement best distinguishes cooperative from noncooperative enzymes?**  
A. Cooperative enzymes follow zero-order kinetics at all [S]  
B. Cooperative enzymes have a constant Hill coefficient across all [S]  
C. Cooperative enzymes exhibit **sigmoidal** kinetics due to subunit interaction (Hill n>1)  
D. Noncooperative enzymes cannot be regulated allosterically  
**Answer: C.**  
**Rationale:** **Sigmoidal curves** arise from subunit interactions (n>1). Kinetics are not zero-order at all [S]; the Hill slope is local/approximate; noncooperative enzymes can still have allosteric sites in some systems, but they don’t show cooperativity in substrate binding.

A screen shot of a graph

AI-generated content may be incorrect.

## Figure — Glycine speciation vs pH (diprotic)

**What to notice (concise):**

* **pKa₁≈2.34:** –COOH deprotonates → **zwitterion** dominates just above this pH.
* **pKa₂≈9.60:** –NH₃⁺ deprotonates → **anion** dominates just above this pH.
* **Isoelectric point (pI)** for neutral side-chain AAs: **pI ≈ (pKa₁ + pKa₂)/2 ≈ 5.97** → net charge ≈ 0 (zwitterion maximal).
* **Buffering is strongest near each pKa**; curves are flattest there.

**3 MCQs**

**1) At pH 6.0, which glycine species predominates and what is the net charge?**  
A. H₃N⁺–CH₂–COOH; **+1**  
B. H₃N⁺–CH₂–COO⁻; **0**  
C. H₂N–CH₂–COO⁻; **–1**  
D. Equal mix of +1 and –1; **0**  
**Answer: B.**  
**Rationale:** pH 6≈pI; **zwitterion** predominates (net **0**).

**2) A solution contains glycine at pH 2.34. What is true about conjugate species and buffering?**  
A. [zwitterion] ≫ [cation]; no buffering  
B. [cation] = [zwitterion]; **maximal buffering for the first step**  
C. [anion] = [zwitterion]; maximal buffering for the second step  
D. [anion] ≫ [zwitterion]; no buffering  
**Answer: B.**  
**Rationale:** At **pH = pKa₁**, the **acid and conjugate base are equal**, and the system buffers best for that equilibrium.

**3) For a neutral side-chain amino acid, which formula gives the pI?**  
A. (pKa(side chain) + pKa₂)/2  
B. (pKa₁ + pKa(side chain))/2  
C. **(pKa₁ + pKa₂)/2**  
D. (pKa₁ + pKa₂ + pKa(side chain))/3  
**Answer: C.**  
**Rationale:** With no ionizable side chain, **pI is the average of the two backbone pKa’s** that flank the neutral (zwitterionic) species.

A diagram of a cell block

AI-generated content may be incorrect.

## Figure — GPCR Core Paths (Gs, Gi, Gq)

**What to notice (concise):**

* **Activation sequence:** Ligand → GPCR → **Gα swaps GDP→GTP**, separates from **Gβγ**.
* **Gs:** **Adenylyl cyclase ↑ → cAMP ↑ → PKA ↑** → phosphorylation cascades; in heart, ↑inotropy; in smooth muscle, **↓MLCK**.
* **Gi:** **Adenylyl cyclase ↓ → cAMP ↓ → PKA ↓**; Gβγ can open **GIRK** K⁺ channels.
* **Gq:** **PLC ↑ → PIP₂ → IP₃ + DAG; IP₃ → Ca²⁺ release; DAG → PKC ↑** → contraction, secretion, gene programs.
* **Desensitization:** **GRK → β-arrestin** binding → internalization/signaling bias.
* **Toxins:** **Cholera** locks **Gs ON** (cAMP↑); **Pertussis** locks **Gi OFF** (cAMP↑).

**3 MCQs**

**1) A hormone binds a receptor that increases PLC activity and intracellular Ca²⁺. Which G-protein is most likely engaged and what are the key second messengers?**  
A. Gs; cAMP & PKA  
B. **Gq; IP₃ & DAG**  
C. Gi; cAMP & PKA  
D. Gt; cGMP & PKG  
**Answer: B.**  
**Rationale:** **Gq→PLC→IP₃/DAG**; IP₃ raises Ca²⁺ from ER; DAG activates PKC.

**2) A bacterial toxin causes persistent watery diarrhea by ADP-ribosylating a G protein so that adenylyl cyclase is constitutively active. Which pairing is correct?**  
A. Pertussis toxin; Gs locked ON  
B. **Cholera toxin; Gs locked ON**  
C. Pertussis toxin; Gi locked ON  
D. Cholera toxin; Gi locked OFF  
**Answer: B.**  
**Rationale:** **Cholera** keeps **Gs** active → **cAMP↑** → CFTR-mediated Cl⁻ and water secretion.

**3) A drug reduces heart rate by activating muscarinic M₂ receptors in the SA node. Which pathway best explains the immediate ionic effect?**  
A. Gs activation → cAMP↑ → PKA-mediated Ca²⁺ influx  
B. **Gi βγ subunits open GIRK K⁺ channels → hyperpolarization**  
C. Gq activation → IP₃-mediated Ca²⁺ release → depolarization  
D. Gi α subunit inhibits phospholipase C  
**Answer: B.**  
**Rationale:** Cardiac **M₂** receptors couple to **Gi**; **Gβγ** opens **GIRK** channels → K⁺ efflux, membrane **hyperpolarization**, slowing pacemaker rate.

A screen shot of a graph

AI-generated content may be incorrect.

## Figure — Dose–response (log scale)

**What to notice (concise):**

* **Competitive antagonist:** curve shifts **right** (EC₅₀ ↑), **Emax unchanged** → antagonism can be overcome with more agonist.
* **Noncompetitive antagonist:** **Emax ↓** (lower ceiling), EC₅₀ similar → cannot be fully overcome by adding agonist.
* **MCAT takeaway:** *Parallel right shift = competitive; lower maximum = noncompetitive.*

**3 MCQs**

**1) A new drug shifts the norepinephrine dose–response rightward without changing the maximal effect on blood pressure. What mechanism best fits?**  
A. Irreversible antagonist  
B. **Competitive antagonist**  
C. Partial agonist  
D. Noncompetitive antagonist  
**Answer:** **B.**  
**Rationale:** A pure **competitive antagonist** increases **EC₅₀** but leaves **Emax** unchanged, producing a parallel right shift.

**2) In isolated bronchi, even high concentrations of β₂-agonist cannot restore maximal relaxation after drug X is added. Which is most consistent with X?**  
A. Competitive antagonist at the β₂ receptor  
B. **Noncompetitive (or irreversible) antagonist**  
C. Inverse agonist with higher EC₅₀  
D. Allosteric activator  
**Answer:** **B.**  
**Rationale:** If **Emax remains depressed** despite excess agonist, the blocker is **noncompetitive/irreversible** (reduces receptor number or signaling capacity), not purely competitive.

**3) Which change would decrease agonist potency but not efficacy?**  
A. Decreasing receptor density by 50%  
B. **Adding a reversible competitive antagonist**  
C. Adding a noncompetitive antagonist  
D. Using a partial agonist instead of a full agonist  
**Answer:** **B.**  
**Rationale:** A **reversible competitive** blocker reduces **potency** (EC₅₀ ↑) but preserves **efficacy** (Emax same). Lower receptor density or noncompetitive antagonism lower **Emax**; a partial agonist inherently has lower **Emax**.

A graph with lines and numbers

AI-generated content may be incorrect.

**Figure — Neuron Action Potential & Refractory Periods**

**What to notice (concise):**

* **Depolarization:** voltage-gated **Na⁺ channels open** → rapid upstroke to ~+30–40 mV.
* **Repolarization:** **Na⁺ channels inactivate**; **K⁺ channels open** → membrane potential falls past rest.
* **Afterhyperpolarization:** K⁺ channels close slowly → undershoot (~–80 mV) before returning to **rest (~–70 mV)**.
* **Absolute refractory:** during Na⁺ **inactivation**, another spike **cannot** occur.
* **Relative refractory:** during undershoot, a spike **can** occur but needs a **stronger** stimulus (threshold effectively higher).

## 3 MCQs

**1) Tetrodotoxin (TTX) blocks voltage-gated Na⁺ channels. Which immediate effect best predicts the change in the waveform?**  
A. Higher peak because K⁺ channels compensate  
B. **No rapid upstroke; action potential fails to initiate**  
C. Longer relative refractory period but normal depolarization  
D. Larger afterhyperpolarization due to Na⁺ accumulation  
**Answer:** **B.**  
**Rationale:** Without Na⁺ channel opening, **threshold cannot trigger** the **depolarization phase**, so the spike is abolished.

**2) A neuron is stimulated repeatedly during the shaded “relative refractory” phase. Compared with baseline, which response is expected and why?**  
A. Same amplitude because Na⁺ channels are fully reset  
B. **Smaller amplitude because persistent K⁺ conductance opposes depolarization**  
C. Larger amplitude because the membrane is closer to threshold  
D. No action potentials because Na⁺ channels are inactivated  
**Answer:** **B.**  
**Rationale:** During the **relative refractory** period, many **K⁺ channels remain open**, increasing outward current; a larger stimulus can still elicit a spike, but **amplitude is reduced**.

**3) Which intervention most shortens the absolute refractory period?**  
A. **Faster recovery from Na⁺ channel inactivation**  
B. Increased extracellular K⁺  
C. Application of a K⁺ channel blocker (e.g., TEA)  
D. Lowering extracellular Na⁺ concentration  
**Answer:** **A.**  
**Rationale:** The **absolute refractory** period persists until **Na⁺ channels recover** from inactivation; speeding that recovery shortens it. Elevated [K⁺] or TEA primarily affect repolarization/relative refractory; reducing [Na⁺] impairs depolarization.