

ADDITIONAL MCAT HIGH-YIELD PRACTICE TESTS - BIOLOGICAL AND BIOCHEMICAL FOUNDATIONS OF LIVING SYSTEMS

MOLECULAR BIOLOGY & GENETICS (Questions 1-25)

1. During DNA replication, which enzyme removes RNA primers and replaces them with DNA?

- A. DNA ligase
 - B. DNA polymerase I
 - C. Primase
 - D. Helicase
-

2. A mutation that changes codon UAU (tyrosine) to UAA (stop) is classified as:

- A. Silent mutation
 - B. Missense mutation
 - C. Frameshift mutation
 - D. Nonsense mutation
-

3. In prokaryotic gene regulation, the lac operon is repressed when:

- A. Lactose is present and glucose is absent
- B. Glucose is present
- C. Both lactose and glucose are present
- D. Neither lactose nor glucose is present

4. Which RNA polymerase transcribes mRNA in eukaryotes?

- A. RNA polymerase I
 - B. RNA polymerase II
 - C. RNA polymerase III
 - D. RNA polymerase IV
-

5. Okazaki fragments are synthesized on:

- A. The template strand
 - B. The lagging strand
 - C. The leading strand
 - D. Both strands equally
-

6. Alternative splicing allows:

- A. DNA repair
 - B. RNA editing
 - C. Replication
 - D. Multiple proteins from one gene
-

7. The promoter region where RNA polymerase binds in prokaryotes is called the:

- A. -10 and -35 boxes (Pribnow box and -35 element)
- B. TATA box
- C. Shine-Dalgarno sequence

D. Kozak sequence

8. During translation, the A site of the ribosome:

- A. Holds the growing polypeptide chain
 - B. Is where peptide bonds form
 - C. Receives incoming aminoacyl-tRNA
 - D. Releases the tRNA after peptide bond formation
-

9. X-linked recessive traits:

- A. Affect males and females equally
 - B. Affect males more frequently than females
 - C. Skip generations randomly
 - D. Cannot be passed from fathers to sons
-

10. The Hardy-Weinberg equilibrium assumes:

- A. Natural selection is occurring
 - B. Mutations are frequent
 - C. Random mating occurs
 - D. Gene flow is significant
-

11. Which process increases genetic variation during meiosis?

- A. Crossing over and independent assortment
- B. DNA replication

- C. Cytokinesis
 - D. Chromatin condensation
-

12. A diploid organism with genotype AaBb can produce how many different gamete types?

- A. 2
 - B. 3
 - C. 4
 - D. 8
-

13. Semiconservative replication means:

- A. Only one strand is replicated
 - B. Each new DNA molecule contains one original and one new strand
 - C. DNA is replicated in sections
 - D. Only part of the chromosome replicates
-

14. The function of telomerase is to:

- A. Unwind DNA
 - B. Remove primers
 - C. Join Okazaki fragments
 - D. Extend telomeres at chromosome ends
-

15. In RNA processing, a 5' cap and poly-A tail:

- A. Are added to prokaryotic mRNA

- B. Increase mRNA stability and aid translation
 - C. Remove introns
 - D. Create the start codon
-

16. Wobble base pairing occurs between:

- A. mRNA and DNA
 - B. Two DNA strands
 - C. tRNA anticodon and mRNA codon (3rd position)
 - D. Amino acids
-

17. A test cross involves breeding an individual with unknown genotype to:

- A. A heterozygote
 - B. A homozygous dominant individual
 - C. A homozygous recessive individual
 - D. Any random individual
-

18. The operon model of gene regulation was first described for:

- A. Eukaryotes
 - B. Viruses
 - C. Archaea
 - D. Prokaryotes
-

19. Point mutations that do NOT change the amino acid sequence are called:

- A. Nonsense mutations
 - B. Missense mutations
 - C. Frameshift mutations
 - D. Silent mutations
-

20. DNA polymerase adds nucleotides in which direction?

- A. 3' to 5'
 - B. 5' to 3'
 - C. Both directions simultaneously
 - D. Direction varies by organism
-

21. Enhancers in eukaryotic gene regulation:

- A. Must be adjacent to the promoter
 - B. Can function at a distance and in either orientation
 - C. Only work in prokaryotes
 - D. Directly bind RNA polymerase
-

22. The central dogma of molecular biology describes:

- A. DNA → RNA → Protein
 - B. Protein → RNA → DNA
 - C. RNA → DNA → Protein
 - D. DNA → Protein → RNA
-

23. Restriction enzymes:

- A. Join DNA fragments
 - B. Replicate DNA
 - C. Transcribe RNA
 - D. Cut DNA at specific recognition sequences
-

24. In incomplete dominance:

- A. The dominant allele completely masks the recessive
 - B. Both alleles are fully expressed
 - C. The heterozygote shows an intermediate phenotype
 - D. Multiple alleles exist
-

25. The CRISPR-Cas9 system functions primarily as:

- A. A DNA replication mechanism
 - B. A gene editing tool
 - C. A translation enhancer
 - D. A chromosome segregation system
-

CELL BIOLOGY (Questions 26-50)

26. The plasma membrane is described as a fluid mosaic model because:

- A. It contains only lipids
- B. It's rigid and unchanging
- C. Proteins are static

D. Lipids and proteins move laterally

27. Gap junctions:

- A. Allow direct cytoplasmic communication between cells
 - B. Anchor cells to the extracellular matrix
 - C. Prevent all molecular passage
 - D. Only exist in plant cells
-

28. Lysosomes contain:

- A. DNA
 - B. Ribosomes
 - C. Hydrolytic enzymes for digestion
 - D. Photosynthetic pigments
-

29. Receptor-mediated endocytosis involves:

- A. Random uptake of extracellular fluid
 - B. Specific binding to membrane receptors
 - C. Exporting materials from the cell
 - D. Passive diffusion
-

30. The nuclear envelope is continuous with:

- A. The plasma membrane
- B. Lysosomes

- C. Mitochondria
 - D. The endoplasmic reticulum
-

31. Which structure is responsible for detoxifying drugs and synthesizing lipids?

- A. Rough ER
 - B. Golgi apparatus
 - C. Smooth ER
 - D. Lysosomes
-

32. Peroxisomes function in:

- A. Protein synthesis
 - B. Breaking down fatty acids and detoxifying hydrogen peroxide
 - C. Photosynthesis
 - D. ATP synthesis via oxidative phosphorylation
-

33. The mitochondrial matrix contains:

- A. DNA and enzymes for the citric acid cycle
 - B. Only cristae
 - C. Chlorophyll
 - D. Ribosomes only
-

34. Tight junctions:

- A. Allow free passage of molecules between cells

- B. Anchor cells together with intermediate filaments
 - C. Seal adjacent epithelial cells to prevent leakage
 - D. Connect plant cells
-

35. Primary active transport:

- A. Doesn't require energy
 - B. Uses ATP directly to move substances against gradients
 - C. Always moves substances down gradients
 - D. Only transports water
-

36. The signal hypothesis describes:

- A. Nerve impulse transmission
 - B. How proteins are targeted to the ER
 - C. Cell cycle regulation
 - D. Apoptosis initiation
-

37. Centrioles are composed of:

- A. Actin filaments
 - B. Intermediate filaments
 - C. Microtubules in a 9+2 arrangement
 - D. Microtubules in a 9+0 arrangement
-

38. Which organelle modifies, sorts, and packages proteins?

- A. Ribosome
 - B. Lysosome
 - C. Mitochondrion
 - D. Golgi apparatus
-

39. Plasmodesmata in plant cells are analogous to which animal cell junction?

- A. Tight junctions
 - B. Desmosomes
 - C. Gap junctions
 - D. Adherens junctions
-

40. The sodium-potassium pump is an example of:

- A. Facilitated diffusion
 - B. Primary active transport using ATP
 - C. Osmosis
 - D. Simple diffusion
-

41. Cyclins and cyclin-dependent kinases (CDKs) regulate:

- A. Transcription only
 - B. Translation only
 - C. The cell cycle
 - D. Lipid metabolism
-

42. During which phase does DNA replication occur?

- A. G1 phase
 - B. S phase
 - C. G2 phase
 - D. M phase
-

43. The spindle checkpoint ensures:

- A. DNA has replicated
 - B. Chromosomes are properly attached to spindle fibers
 - C. Nutrients are available
 - D. The cell has grown sufficiently
-

44. Apoptosis differs from necrosis in that apoptosis:

- A. Is uncontrolled cell death
 - B. Causes inflammation
 - C. Is programmed cell death
 - D. Results from injury only
-

45. Autocrine signaling involves:

- A. Signals affecting distant cells
- B. Signals affecting neighboring cells
- C. Signals affecting the cell that secreted them
- D. Direct cell-to-cell contact

46. G protein-coupled receptors (GPCRs):

- A. Are intracellular receptors
 - B. Bind hydrophobic ligands
 - C. Activate G proteins upon ligand binding
 - D. Directly phosphorylate proteins
-

47. The extracellular matrix in animal tissues:

- A. Is composed primarily of DNA
 - B. Contains collagen, proteoglycans, and other proteins
 - C. Is found only in epithelial tissue
 - D. Prevents all cell movement
-

48. Cholesterol in the plasma membrane:

- A. Makes membranes more fluid at all temperatures
 - B. Has no effect on membrane properties
 - C. Reduces fluidity at high temperatures and prevents solidification at low temperatures
 - D. Is found only in plant cells
-

49. The difference between chromatin and chromosomes is:

- A. Chromatin is condensed, chromosomes are not
- B. Chromosomes are condensed chromatin visible during cell division
- C. They are identical structures

D. Chromosomes contain RNA, chromatin contains DNA

50. Sister chromatids separate during:

- A. Prophase
 - B. Metaphase
 - C. Telophase
 - D. Anaphase
-

BIOCHEMISTRY & METABOLISM (Questions 51-75)

51. Which metabolic pathway occurs in the cytoplasm?

- A. Glycolysis
 - B. Citric acid cycle
 - C. Oxidative phosphorylation
 - D. Beta-oxidation
-

52. The net ATP production from glycolysis (per glucose) is:

- A. 4 ATP
 - B. 0 ATP
 - C. 2 ATP
 - D. 38 ATP
-

53. Substrate-level phosphorylation differs from oxidative phosphorylation because it:

- A. Produces more ATP

- B. Directly transfers phosphate to ADP
 - C. Requires oxygen
 - D. Occurs only in mitochondria
-

54. In the citric acid cycle, acetyl-CoA combines with:

- A. Pyruvate
 - B. Citrate
 - C. Glucose
 - D. Oxaloacetate
-

55. The electron transport chain pumps protons into the:

- A. Mitochondrial intermembrane space
 - B. Cytoplasm
 - C. Matrix
 - D. Nucleus
-

56. ATP synthase produces ATP using:

- A. Direct phosphorylation
 - B. Substrate-level phosphorylation
 - C. The proton gradient (chemiosmosis)
 - D. Fermentation
-

57. Gluconeogenesis primarily occurs in the:

- A. Liver and kidneys
 - B. Muscle
 - C. Brain
 - D. Red blood cells
-

58. Glycogen is stored mainly in:

- A. Adipose tissue
 - B. Neurons
 - C. Red blood cells
 - D. Liver and muscle
-

59. The rate-limiting enzyme of glycolysis is:

- A. Phosphofructokinase-1
 - B. Hexokinase
 - C. Pyruvate kinase
 - D. Glucose-6-phosphatase
-

60. Beta-oxidation of fatty acids produces:

- A. Glucose
 - B. Glycerol
 - C. Acetyl-CoA
 - D. Pyruvate
-

61. Ketone bodies are produced in the liver during:

- A. Fed state with high insulin
 - B. Prolonged fasting or starvation
 - C. Immediately after eating
 - D. High carbohydrate intake
-

62. The pentose phosphate pathway produces:

- A. ATP only
 - B. Pyruvate
 - C. Acetyl-CoA
 - D. NADPH and ribose-5-phosphate
-

63. Glucagon's primary metabolic effect is to:

- A. Promote glucose uptake in muscle
 - B. Stimulate glycogen synthesis
 - C. Inhibit glycogen synthesis
 - D. Promote glycogen breakdown and gluconeogenesis
-

64. Insulin promotes:

- A. Glycogen breakdown
- B. Gluconeogenesis
- C. Lipolysis
- D. Glucose uptake and glycogen synthesis

65. The Cori cycle involves conversion of:

- A. Glucose to fat
- B. Protein to glucose
- C. Lactate (from muscle) to glucose (in liver)
- D. Ketones to glucose

66. Amino acids that cannot be synthesized by the body are called:

- A. Dispensable
- B. Essential
- C. Ketogenic
- D. Glucogenic

67. Transamination reactions require which vitamin cofactor?

- A. Vitamin B12
- B. Niacin
- C. Thiamine
- D. Pyridoxine (Vitamin B6)

68. The urea cycle occurs primarily in the:

- A. Kidney
- B. Muscle
- C. Liver

D. Brain

69. Which amino acid is both glucogenic and ketogenic?

- A. Leucine
 - B. Lysine
 - C. Alanine
 - D. Isoleucine
-

70. Cholesterol is the precursor for:

- A. Glycogen
 - B. Protein
 - C. Glucose
 - D. Steroid hormones and bile acids
-

71. HDL (high-density lipoprotein) is considered "good cholesterol" because it:

- A. Delivers cholesterol to peripheral tissues
 - B. Transports cholesterol from tissues to the liver
 - C. Increases atherosclerosis
 - D. Has no effect on health
-

72. The committed step in fatty acid synthesis involves:

- A. Acetyl-CoA carboxylase
- B. Fatty acid synthase

- C. Lipase
 - D. Acyl-CoA synthetase
-

73. Which vitamin deficiency causes beriberi?

- A. Vitamin C
 - B. Niacin
 - C. Riboflavin
 - D. Thiamine (Vitamin B1)
-

74. Scurvy results from deficiency of:

- A. Vitamin A
 - B. Vitamin C
 - C. Vitamin D
 - D. Vitamin K
-

75. NAD⁺ is derived from which vitamin?

- A. Niacin (Vitamin B3)
 - B. Thiamine
 - C. Riboflavin
 - D. Biotin
-

ORGAN SYSTEMS & PHYSIOLOGY (Questions 76-100)

76. The sinoatrial (SA) node is located in the:

- A. Left ventricle
 - B. Left atrium
 - C. Right atrium
 - D. Interventricular septum
-

77. Stroke volume is defined as:

- A. Total blood volume
 - B. Volume ejected per heartbeat
 - C. Heart rate per minute
 - D. Blood pressure reading
-

78. Systolic blood pressure represents:

- A. Pressure during ventricular relaxation
 - B. Pressure in the veins
 - C. Minimum arterial pressure
 - D. Pressure during ventricular contraction
-

79. Hemoglobin's affinity for oxygen decreases with:

- A. Increased pH and decreased temperature
 - B. Increased CO₂ and decreased pH (Bohr effect)
 - C. Decreased 2,3-BPG
 - D. Increased oxygen concentration only
-

80. The primary function of surfactant in the lungs is to:

- A. Transport oxygen
 - B. Reduce surface tension in alveoli
 - C. Increase airway resistance
 - D. Filter particles
-

81. Gas exchange in the lungs occurs in the:

- A. Bronchi
 - B. Trachea
 - C. Alveoli
 - D. Bronchioles
-

82. The medulla oblongata regulates breathing primarily by monitoring:

- A. Oxygen levels only
 - B. CO₂ levels and pH
 - C. Heart rate only
 - D. Blood pressure only
-

83. Filtration in the kidney occurs in the:

- A. Loop of Henle
- B. Collecting duct
- C. Renal pelvis
- D. Glomerulus (Bowman's capsule)

84. ADH (antidiuretic hormone) increases water reabsorption in the:

- A. Glomerulus
 - B. Proximal tubule
 - C. Collecting duct
 - D. Loop of Henle (descending limb only)
-

85. The juxtaglomerular apparatus secretes:

- A. ADH
 - B. Aldosterone
 - C. Renin
 - D. Insulin
-

86. Gastric chief cells secrete:

- A. Hydrochloric acid
 - B. Pepsinogen
 - C. Mucus
 - D. Gastrin
-

87. Parietal cells in the stomach produce:

- A. Pepsinogen
- B. Mucus
- C. Gastrin

D. Hydrochloric acid and intrinsic factor

88. Bile is produced by the liver and stored in the:

- A. Pancreas
 - B. Stomach
 - C. Gallbladder
 - D. Small intestine
-

89. Most nutrient absorption occurs in the:

- A. Stomach
 - B. Large intestine
 - C. Esophagus
 - D. Small intestine (duodenum, jejunum, ileum)
-

90. Insulin is secreted by which pancreatic cells?

- A. Beta cells (β -cells) in the islets of Langerhans
 - B. Alpha cells
 - C. Delta cells
 - D. Acinar cells
-

91. The primary male sex hormone is:

- A. Estrogen
- B. Progesterone

- C. FSH
 - D. Testosterone
-

92. Ovulation is triggered by a surge in:

- A. Estrogen only
 - B. LH (luteinizing hormone)
 - C. Progesterone
 - D. FSH only
-

93. The corpus luteum produces:

- A. FSH
 - B. LH
 - C. GnRH
 - D. Progesterone and estrogen
-

94. T cells mature in the:

- A. Bone marrow
 - B. Spleen
 - C. Lymph nodes
 - D. Thymus
-

95. B cells produce:

- A. Cytotoxic responses

- B. Cell-mediated immunity
 - C. Antibodies (immunoglobulins)
 - D. Only memory cells
-

96. The fight-or-flight response is mediated by the:

- A. Parasympathetic nervous system
 - B. Somatic nervous system
 - C. Sympathetic nervous system
 - D. Enteric nervous system
-

97. Action potentials are propagated along axons via:

- A. Continuous diffusion
 - B. Osmosis
 - C. Saltatory conduction (in myelinated neurons)
 - D. Active transport only
-

98. Neurotransmitters are released from:

- A. Dendrites
 - B. Cell body
 - C. Axon terminals (synaptic vesicles)
 - D. Nodes of Ranvier
-

99. The blood-brain barrier is formed primarily by:

- A. Neurons
 - B. Astrocytes and tight junctions of capillary endothelial cells
 - C. Microglia
 - D. Oligodendrocytes
-

100. Bone is continuously remodeled by:

- A. Chondrocytes only
- B. Osteocytes only
- C. Osteoblasts (build) and osteoclasts (break down)
- D. Fibroblasts

Answer Explanations

1. B - DNA polymerase I

DNA polymerase I has 5'→3' exonuclease activity that removes RNA primers laid down by primase, then fills the gaps with DNA nucleotides. DNA ligase subsequently seals the nicks between Okazaki fragments. DNA polymerase III is the main replicative enzyme but doesn't remove primers.

2. D - Nonsense mutation

A nonsense mutation changes a codon that specifies an amino acid into a stop codon (UAA, UAG, or UGA). This results in premature termination of translation and a truncated protein. Silent mutations don't change the amino acid, missense mutations change one amino acid to another, and frameshift mutations involve insertions or deletions.

3. C - Both lactose and glucose are present

When glucose is present, it prevents CAP-cAMP from activating the lac operon, even if lactose is available. This is catabolite repression - bacteria preferentially use glucose. The operon is maximally expressed when lactose is present and glucose is absent. When neither is present, the repressor blocks transcription.

4. C - RNA polymerase III

RNA polymerase II transcribes ALL mRNA (messenger RNA) genes in eukaryotes, as well as some non-coding RNAs including microRNAs (miRNAs), long non-coding RNAs (lncRNAs), and most small nuclear RNAs (snRNAs).

5. B - The lagging strand

During DNA replication, the lagging strand is synthesized discontinuously in short segments (Okazaki fragments) in the 5'→3' direction away from the replication fork. The leading strand is synthesized continuously. This occurs because DNA polymerase can only synthesize in the 5'→3' direction.

6. D - Multiple proteins from one gene

Alternative splicing allows different combinations of exons to be joined together, producing multiple mRNA variants and thus multiple protein isoforms from a single gene. This dramatically increases proteomic diversity without requiring more genes. It's a key mechanism for generating complexity in eukaryotes.

7. A - -10 and -35 boxes (Pribnow box and -35 element)

In prokaryotes, RNA polymerase recognizes and binds to the -10 box (Pribnow box, with consensus sequence TATAAT) and -35 region. The TATA box is eukaryotic. The Shine-Dalgarno sequence is the ribosome binding site on mRNA, not a promoter element.

8. C - Receives incoming aminoacyl-tRNA

The ribosome has three sites: A (aminoacyl) site receives incoming charged tRNA, P (peptidyl) site holds the tRNA carrying the growing polypeptide chain, and E (exit) site is where tRNA leaves after donating its amino acid. Peptide bond formation occurs between amino acids in the A and P sites.

9. B - Affect males more frequently than females

X-linked recessive traits affect males (XY) more frequently because males have only one X chromosome - if they inherit the recessive allele, they express the trait. Females (XX) need two copies of the recessive allele to express the trait. Males cannot pass X-linked traits to sons (sons get the Y chromosome from fathers).

10. C - Random mating occurs

Hardy-Weinberg equilibrium assumes: (1) No mutations, (2) Random mating, (3) No natural selection, (4) Large population size (no genetic drift), (5) No gene flow (migration).

The key shows D. Let me check what D says - "Gene flow is significant" would VIOLATE Hardy-Weinberg. The correct answer should state what the equilibrium ASSUMES, which is "No gene flow" or "Random mating."

11. A - Crossing over and independent assortment

Two mechanisms increase genetic variation during meiosis: (1) Crossing over (recombination) exchanges genetic material between homologous chromosomes during prophase I, and (2) Independent assortment randomly distributes maternal and paternal chromosomes to gametes during metaphase I. These create new allele combinations.

12. C - 4

An organism with genotype AaBb has two heterozygous loci. Each locus can contribute two possible alleles to gametes. Using the multiplication rule: $2 \times 2 = 4$ possible gamete types: AB, Ab, aB, ab. This follows from independent assortment during meiosis.

13. B - Each new DNA molecule contains one original and one new strand

Semiconservative replication means each daughter DNA molecule consists of one parental (original) strand and one newly synthesized strand. This was demonstrated by the Meselson-Stahl experiment using

nitrogen isotopes. Conservative replication would keep both original strands together; dispersive would mix old and new throughout.

14. D - Extend telomeres at chromosome ends

Telomerase is a reverse transcriptase that extends telomeres - repetitive sequences at chromosome ends that shorten with each cell division. Telomerase carries an RNA template and adds telomeric repeats, preventing loss of coding sequences. It's active in germ cells and stem cells but not most somatic cells.

15. B - Increase mRNA stability and aid translation

In eukaryotes, the 5' methylguanosine cap and 3' poly-A tail increase mRNA stability, facilitate export from nucleus, and enhance translation. Prokaryotic mRNA lacks these modifications.

16. C - tRNA anticodon and mRNA codon (3rd position)

Wobble base pairing occurs at the third position of the codon (5' end of anticodon), where non-Watson-Crick pairing is tolerated. This allows one tRNA to recognize multiple codons differing in the third position, explaining why fewer than 61 tRNAs are needed for 61 sense codons.

17. C - A homozygous recessive individual

A test cross breeds an individual with unknown genotype (but dominant phenotype) to a homozygous recessive individual. If any offspring show the recessive phenotype, the unknown parent must be heterozygous. If all offspring show dominant phenotype, the unknown parent is likely homozygous dominant.

18. D - Prokaryotes

The operon model was first described by Jacob and Monod for the lac operon in *E. coli* (prokaryote). Operons are clusters of genes transcribed together under one promoter, common in prokaryotes. Eukaryotic gene regulation is generally more complex with individual gene transcription.

19. D - Silent mutations

Silent mutations (synonymous mutations) are point mutations that don't change the amino acid due to genetic code degeneracy - multiple codons specify the same amino acid. Nonsense creates stop codons, missense changes amino acids.

20. B - 5' to 3'

DNA polymerase can only add nucleotides to the 3'-OH group, so synthesis proceeds 5'→3'. This is why the lagging strand requires Okazaki fragments.

21. B - Can function at a distance and in either orientation

Enhancers are regulatory DNA sequences that increase transcription. Unlike promoters, they can be located far from the gene (thousands of base pairs away), work in either orientation (forward or reverse), and function upstream or downstream of the gene. They bind transcription factors that interact with the promoter through DNA looping.

22. A - DNA → RNA → Protein

The correct central dogma flow is: **DNA → RNA → Protein** (transcription then translation). This describes the normal flow of genetic information, with exceptions like reverse transcription in retroviruses.

23. D - Cut DNA at specific recognition sequences

Restriction endonucleases (restriction enzymes) recognize specific palindromic DNA sequences (usually 4-8 bp) and cut the DNA at or near these sites. Different enzymes recognize different sequences. They're essential tools for molecular cloning and genetic engineering. DNA ligase joins fragments; polymerases replicate.

24. C - The heterozygote shows an intermediate phenotype

In incomplete dominance, neither allele is completely dominant. Heterozygotes display an intermediate phenotype between the two homozygotes. Classic example: red (RR) and white (WW) flowers producing pink (RW) heterozygotes. This differs from codominance where both traits are fully expressed.

25. B - A gene editing tool

CRISPR-Cas9 is a revolutionary gene editing system derived from bacterial adaptive immunity. The Cas9 enzyme cuts DNA at sites specified by a guide RNA, allowing precise gene knockouts, insertions, or modifications. It's widely used in research and has therapeutic potential.

26. D - Lipids and proteins move laterally

The fluid mosaic model describes the plasma membrane as a fluid lipid bilayer with embedded proteins that can move laterally (within their layer). Lipids and proteins are not fixed but can diffuse within the membrane, giving it fluid properties. The "mosaic" refers to the diverse protein distribution.

27. A - Allow direct cytoplasmic communication between cells

Gap junctions are channels formed by connexin proteins that directly connect the cytoplasm of adjacent animal cells, allowing passage of ions, small molecules, and electrical signals. This enables coordinated activity in tissues like cardiac muscle. Tight junctions seal cells; desmosomes anchor them.

28. C - Hydrolytic enzymes for digestion

Lysosomes contain acid hydrolases (digestive enzymes) that break down macromolecules, damaged organelles, and engulfed materials. The acidic pH (~4.5) inside lysosomes activates these enzymes. Lysosomes function in autophagy, phagocytosis, and cellular digestion.

29. B - Specific binding to membrane receptors

Receptor-mediated endocytosis involves specific ligands binding to cell surface receptors, which then cluster in clathrin-coated pits. This selective process allows cells to concentrate and internalize specific molecules (like LDL cholesterol, transferrin, hormones) rather than random uptake.

30. D - The endoplasmic reticulum

The nuclear envelope consists of two lipid bilayers continuous with the endoplasmic reticulum. Nuclear pores span both membranes, allowing selective transport between nucleus and cytoplasm. The outer nuclear membrane is contiguous with the rough ER and may have ribosomes attached.

31. C - Smooth ER

Smooth endoplasmic reticulum lacks ribosomes and functions in lipid synthesis (including phospholipids, steroids), drug/toxin detoxification (via cytochrome P450 enzymes), and calcium storage. Rough ER synthesizes proteins destined for secretion or membrane insertion.

32. B - Breaking down fatty acids and detoxifying hydrogen peroxide

Peroxisomes contain enzymes for beta-oxidation of very long chain fatty acids and detoxification reactions that produce and then break down hydrogen peroxide (H_2O_2). Catalase converts H_2O_2 to water and oxygen. Peroxisomes also participate in biosynthetic pathways like plasmalogen synthesis.

33. A - DNA and enzymes for the citric acid cycle

The mitochondrial matrix contains: (1) Mitochondrial DNA, (2) Ribosomes (for mitochondrial protein synthesis), (3) Enzymes for citric acid cycle, (4) Enzymes for fatty acid beta-oxidation, (5) Enzymes for some amino acid metabolism.

34. C - Seal adjacent epithelial cells to prevent leakage

Tight junctions seal adjacent epithelial cells, preventing molecules from passing between cells (paracellular pathway). They create barriers in tissues like intestinal epithelium and blood-brain barrier. Plant cells don't have tight junctions; they have plasmodesmata.

35. B - Uses ATP directly to move substances against gradients

Primary active transport uses ATP hydrolysis directly to move substances against their concentration gradients. Examples: Na^+/K^+ -ATPase, Ca^{2+} -ATPase, H^+ -ATPase. This differs from secondary active transport, which uses an existing gradient created by primary active transport.

36. B - How proteins are targeted to the ER

The signal hypothesis explains how proteins are directed to the endoplasmic reticulum. An N-terminal signal sequence on the growing polypeptide is recognized by the signal recognition particle (SRP), which directs the ribosome-mRNA complex to the ER membrane for cotranslational translocation.

37. D - Microtubules in a 9+0 arrangement

Centrioles consist of nine triplets of microtubules arranged in a cylinder (9+0 pattern) - no central microtubules. They organize the mitotic spindle and form the base of cilia and flagella. The 9+2 arrangement (9 doublets + 2 central singlets) is found in cilia and flagella, not centrioles.

38. D - Golgi apparatus

The Golgi apparatus receives proteins from the ER, modifies them (glycosylation, phosphorylation, proteolytic cleavage), sorts them, and packages them into vesicles for transport to their final destinations (lysosomes, plasma membrane, secretion).

39. C - Gap junctions

Plasmodesmata are cytoplasmic channels through plant cell walls that directly connect adjacent plant cells, allowing transport of materials and communication. They're functionally analogous to gap junctions in animal cells, though structurally different.

40. B - Primary active transport using ATP

The Na^+/K^+ -ATPase pump uses ATP hydrolysis to transport 3 Na^+ ions out and 2 K^+ ions in against their concentration gradients. This is the classic example of primary active transport, maintaining ion gradients essential for nerve impulses, muscle contraction, and secondary active transport.

41. C - The cell cycle

Cyclins are proteins whose concentrations fluctuate during the cell cycle. They activate cyclin-dependent kinases (CDKs), which phosphorylate target proteins to drive cell cycle transitions ($\text{G1} \rightarrow \text{S}$, $\text{G2} \rightarrow \text{M}$). Different cyclin-CDK complexes control different checkpoints.

42. B - S phase

The cell cycle consists of interphase (G1, S, G2) and M phase (mitosis). DNA replication occurs during S (synthesis) phase. G1 is growth before replication, G2 is growth and preparation after replication, and M phase is when cell division occurs.

43. B - Chromosomes are properly attached to spindle fibers

The spindle assembly checkpoint (metaphase checkpoint) ensures all chromosomes are properly attached to spindle microtubules from both poles before anaphase begins. This prevents chromosome missegregation and aneuploidy. Unattached kinetochores inhibit the anaphase-promoting complex.

44. C - Is programmed cell death

Apoptosis is programmed, controlled cell death involving characteristic morphological changes (cell shrinkage, chromatin condensation, membrane blebbing, formation of apoptotic bodies). It doesn't cause inflammation. Necrosis is uncontrolled cell death from injury, causing inflammation and damage to neighboring cells.

45. C - Signals affecting the cell that secreted them

Autocrine signaling occurs when a cell secretes signals that bind to receptors on its own surface, affecting itself. Examples: cancer cells secreting growth factors, immune cells regulating themselves. Paracrine signals affect nearby cells, endocrine signals affect distant cells.

46. C - Activate G proteins upon ligand binding

GPCRs are seven-transmembrane domain receptors that, upon ligand binding, undergo conformational changes activating associated G proteins. G proteins then activate or inhibit downstream effectors like adenylyl cyclase or phospholipase C. This is a major signal transduction mechanism.

47. B - Contains collagen, proteoglycans, and other proteins

The extracellular matrix (ECM) is a complex network of proteins (collagen, elastin, fibronectin, laminin) and polysaccharides (proteoglycans, hyaluronic acid) secreted by cells. It provides structural support, regulates cell behavior, and facilitates cell communication. Composition varies by tissue type.

48. C - Reduces fluidity at high temperatures and prevents solidification at low temperatures

Cholesterol modulates membrane fluidity: At high temperatures, it restrains phospholipid movement, reducing fluidity. At low temperatures, it prevents tight packing of phospholipids, maintaining fluidity and preventing solidification. This "fluidity buffer" helps maintain optimal membrane function across temperature ranges.

49. B - Chromosomes are condensed chromatin visible during cell division

Chromatin is the complex of DNA and histone proteins existing in a relatively dispersed state during interphase. During cell division, chromatin condenses into visible chromosomes. Chromosomes are the highly compact form of chromatin. Same material, different levels of compaction.

50. D - Anaphase

Sister chromatids (joined at the centromere) separate during anaphase when cohesin proteins are cleaved. The separated chromatids (now individual chromosomes) move to opposite poles of the cell. This ensures each daughter cell receives identical genetic information.

51. A - Glycolysis

Glycolysis occurs in the cytoplasm and breaks down glucose (6-carbon) into two pyruvate molecules (3-carbon each). It produces 2 net ATP and 2 NADH. The citric acid cycle occurs in the mitochondrial matrix, oxidative phosphorylation in the inner mitochondrial membrane, and beta-oxidation in the mitochondrial matrix.

52. C - 2 ATP

Glycolysis produces 4 ATP via substrate-level phosphorylation but consumes 2 ATP in early steps (hexokinase and phosphofructokinase reactions). Net production: $4 - 2 = 2$ ATP per glucose. Also produces 2 NADH (which can generate more ATP via oxidative phosphorylation).

53. B - Directly transfers phosphate to ADP

Substrate-level phosphorylation directly transfers a phosphate group from a high-energy substrate to ADP, forming ATP. Examples: phosphoglycerate kinase and pyruvate kinase in glycolysis. Oxidative phosphorylation uses the electron transport chain and proton gradient to synthesize ATP via ATP synthase.

54. D - Oxaloacetate

The citric acid cycle begins when acetyl-CoA (2 carbons) combines with oxaloacetate (4 carbons) to form citrate (6 carbons), catalyzed by citrate synthase. Through the cycle, two carbons are released as CO₂, regenerating oxaloacetate. This allows the cycle to continue.

55. A - Mitochondrial intermembrane space

The electron transport chain in the inner mitochondrial membrane pumps protons (H⁺) from the matrix into the intermembrane space, creating a proton gradient. This chemiosmotic gradient stores energy that ATP synthase uses to synthesize ATP as protons flow back into the matrix.

56. C - The proton gradient (chemiosmosis)

ATP synthase uses the proton-motive force - the electrochemical gradient of H^+ across the inner mitochondrial membrane. As protons flow through ATP synthase down their gradient (from intermembrane space to matrix), the enzyme's rotation drives ATP synthesis from $ADP + P_i$. This is chemiosmotic coupling.

57. A - Liver and kidneys

Gluconeogenesis synthesizes glucose from non-carbohydrate precursors (lactate, amino acids, glycerol). It occurs primarily in liver (90%) and kidney cortex (10%). Muscle lacks glucose-6-phosphatase, the final enzyme, so it cannot release glucose. The brain and RBCs don't perform gluconeogenesis.

58. D - Liver and muscle

Glycogen, the storage form of glucose, is stored mainly in liver (can be released to blood to maintain glucose levels) and skeletal muscle (used locally for muscle activity, not released). Liver glycogen maintains blood glucose; muscle glycogen fuels muscle contraction.

59. A - Phosphofructokinase-1

Phosphofructokinase-1 (PFK-1) catalyzes the committed, rate-limiting step of glycolysis: fructose-6-phosphate \rightarrow fructose-1,6-bisphosphate. It's allosterically regulated: inhibited by ATP and citrate (high energy signals), activated by AMP and ADP (low energy signals). This is the main regulatory point.

60. C - Acetyl-CoA

Beta-oxidation breaks down fatty acids in the mitochondrial matrix, cleaving two carbons at a time as acetyl-CoA. Each cycle also produces $FADH_2$ and NADH. Acetyl-CoA enters the citric acid cycle for further oxidation. Beta-oxidation doesn't produce glucose (fatty acids can't be converted to glucose in animals).

61. B - Prolonged fasting or starvation

Ketone bodies (acetoacetate, β -hydroxybutyrate, acetone) are produced by the liver from acetyl-CoA during prolonged fasting, starvation, or untreated diabetes when glucose is unavailable and fatty acid oxidation exceeds the citric acid cycle's capacity. The brain can use ketone bodies as alternative fuel.

62. D - NADPH and ribose-5-phosphate

The pentose phosphate pathway (hexose monophosphate shunt) branches from glycolysis, oxidizing glucose-6-phosphate. It produces NADPH (for biosynthesis and antioxidant defense) and ribose-5-phosphate (for nucleotide synthesis). The oxidative phase generates NADPH; the non-oxidative phase interconverts sugars.

63. D - Promote glycogen breakdown and gluconeogenesis

Glucagon, secreted by pancreatic alpha cells during fasting, raises blood glucose by: (1) activating glycogen phosphorylase (glycogen breakdown), (2) inhibiting glycogen synthase, (3) activating gluconeogenesis enzymes, (4) promoting lipolysis. It opposes insulin's effects.

64. D - Glucose uptake and glycogen synthesis

Insulin, secreted by pancreatic beta cells in response to high blood glucose, lowers blood glucose by: (1) promoting glucose uptake (GLUT4 translocation in muscle/adipose), (2) activating glycogen synthesis, (3) promoting lipogenesis, (4) inhibiting gluconeogenesis and glycogenolysis.

65. C - Lactate (from muscle) to glucose (in liver)

The Cori cycle: During anaerobic exercise, muscle produces lactate from glucose. Lactate travels to the liver, where it's converted back to glucose via gluconeogenesis. Glucose returns to muscle. This cycle shifts metabolic burden from muscle to liver but costs 4 ATP net.

66. B - Essential

Essential amino acids cannot be synthesized by the body and must be obtained from diet. In humans: phenylalanine, valine, threonine, tryptophan, methionine, leucine, isoleucine, lysine, histidine (PVT TIM HALL). Non-essential (dispensable) amino acids can be synthesized.

67. D - Pyridoxine (Vitamin B6)

Transamination reactions transfer amino groups between amino acids and α -keto acids, interconverting amino acids. These reactions require pyridoxal phosphate (PLP), the active form of vitamin B6, as cofactor. ALT and AST are transaminases used clinically to assess liver function.

68. C - Liver

The urea cycle converts toxic ammonia from amino acid catabolism into urea for excretion by kidneys. It occurs primarily in liver, involving both mitochondrial (first two steps) and cytoplasmic (remaining steps) reactions. Defects in urea cycle enzymes cause hyperammonemia.

69. D - Isoleucine

Most amino acids are either purely glucogenic (can be converted to glucose via gluconeogenesis intermediates) or purely ketogenic (produce only acetyl-CoA or acetoacetate). Five amino acids are both: isoleucine, phenylalanine, tryptophan, threonine, and tyrosine. Leucine and lysine are purely ketogenic.

70. D - Steroid hormones and bile acids

Cholesterol is the precursor for: (1) steroid hormones (cortisol, aldosterone, testosterone, estrogen, progesterone), (2) bile acids/salts (aid fat digestion), (3) vitamin D. It's also a crucial membrane component. Despite its bad reputation, cholesterol is essential for life.

71. B - Transports cholesterol from tissues to the liver

HDL ("good cholesterol") performs reverse cholesterol transport - removing excess cholesterol from peripheral tissues and returning it to the liver for excretion as bile. High HDL levels are protective against atherosclerosis. LDL delivers cholesterol to tissues and promotes plaque formation.

72. A - Acetyl-CoA carboxylase

Acetyl-CoA carboxylase catalyzes the committed, rate-limiting step of fatty acid synthesis: acetyl-CoA → malonyl-CoA. It requires biotin as cofactor. It's regulated by: activated by insulin and citrate; inhibited by glucagon, epinephrine, and palmitoyl-CoA (end-product inhibition).

73. D - Thiamine (Vitamin B1)

Thiamine deficiency causes beriberi, affecting the cardiovascular and nervous systems. Thiamine pyrophosphate (TPP) is a cofactor for enzymes including pyruvate dehydrogenase, α -ketoglutarate dehydrogenase, and transketolase. Deficiency impairs energy metabolism, especially affecting high-energy-demand tissues.

74. B - Vitamin C

Scurvy results from vitamin C (ascorbic acid) deficiency. Vitamin C is required for collagen synthesis (hydroxylation of proline and lysine residues). Symptoms include poor wound healing, bleeding gums, loose teeth, and weakened connective tissue. Historically affected sailors on long voyages.

75. A - Niacin (Vitamin B3)

NAD⁺ and NADP⁺ are derived from niacin (nicotinic acid/nicotinamide). NAD⁺/NADH is the major electron carrier in catabolic reactions (glycolysis, citric acid cycle). NADP⁺/NADPH is used in anabolic reactions (fatty acid synthesis) and antioxidant defense. Niacin deficiency causes pellagra.

76. C - Right atrium

The sinoatrial (SA) node is located in the wall of the right atrium near the entrance of the superior vena cava. It's the heart's natural pacemaker, spontaneously depolarizing and setting the heart rate (~60-100 bpm). The electrical signal spreads through atria, then to the AV node.

77. B - Volume ejected per heartbeat

Stroke volume is the volume of blood ejected by each ventricle per heartbeat (typically ~70 mL at rest). Cardiac output = Stroke Volume \times Heart Rate. Stroke volume is determined by preload (venous return), contractility, and afterload (arterial pressure).

78. D - Pressure during ventricular contraction

Systolic blood pressure (the higher number, e.g., 120 mmHg) represents the maximum arterial pressure during ventricular contraction (systole). Diastolic pressure (lower number, e.g., 80 mmHg) is the minimum pressure during ventricular relaxation (diastole) when the aortic valve is closed.

79. b - Increased CO₂ and decreased pH (Bohr effect)

The Bohr effect: Increased CO₂ and decreased pH (more H⁺) reduce hemoglobin's oxygen affinity, promoting oxygen release in metabolically active tissues. Also, increased temperature and 2,3-BPG decrease affinity. This is physiologically important for oxygen delivery.

80. B - Reduce surface tension in alveoli

Surfactant is a phospholipid mixture (mainly dipalmitoylphosphatidylcholine) secreted by type II alveolar cells. It reduces surface tension in alveoli, preventing collapse during exhalation and reducing work of breathing. Deficiency causes respiratory distress syndrome in premature infants.

81. C - Alveoli

Gas exchange occurs in alveoli - tiny air sacs with thin walls surrounded by capillaries. Oxygen diffuses from alveolar air into blood; CO₂ diffuses from blood into alveolar air. The large surface area (~70 m²) and thin barrier (~0.5 μ m) optimize diffusion.

82. B - CO₂ levels and pH

The medulla oblongata's respiratory centers (dorsal and ventral respiratory groups) primarily respond to CO₂ levels and pH (via chemoreceptors). Increased CO₂ (or decreased pH) stimulates ventilation. Peripheral chemoreceptors in carotid and aortic bodies also detect O₂ levels.

83. D - Glomerulus (Bowman's capsule)

Filtration occurs in the renal corpuscle, where blood pressure forces fluid from glomerular capillaries into Bowman's capsule, forming filtrate. The filtration barrier (endothelium, basement membrane, podocytes) allows water and small solutes through but retains blood cells and large proteins.

84. C - Collecting duct

ADH (vasopressin), released by the posterior pituitary in response to high blood osmolarity or low blood volume, increases water reabsorption in collecting ducts by inserting aquaporin-2 water channels. This concentrates urine and conserves water. Diabetes insipidus results from ADH deficiency or resistance.

85. C - Renin

The juxtaglomerular apparatus (JG cells in afferent arteriole and macula densa in distal tubule) secretes renin in response to low blood pressure, low sodium, or sympathetic stimulation. Renin initiates the renin-angiotensin-aldosterone system (RAAS), raising blood pressure and increasing sodium retention.

86. B - Pepsinogen

Gastric chief cells secrete pepsinogen, the inactive precursor of pepsin. In the acidic stomach environment (pH ~2), pepsinogen is cleaved to active pepsin, which digests proteins. Parietal cells secrete HCl and intrinsic factor; mucous cells secrete protective mucus.

87. D - Hydrochloric acid and intrinsic factor

Parietal cells (oxyntic cells) in gastric glands secrete: (1) HCl, which creates acidic environment for pepsin activity and kills bacteria, and (2) intrinsic factor, which is essential for vitamin B12 absorption in the ileum. Parietal cell antibodies cause pernicious anemia.

88. C - Gallbladder

Bile is produced by hepatocytes in the liver, stored and concentrated in the gallbladder, and released into the duodenum via the common bile duct when stimulated by CCK (cholecystokinin). Bile contains bile salts that emulsify fats, aiding lipid digestion and absorption.

89. D - Small intestine (duodenum, jejunum, ileum)

Most nutrient absorption occurs in the small intestine, which has large surface area (villi and microvilli) and specialized transport mechanisms. Duodenum: iron, some minerals. Jejunum: most nutrients. Ileum: vitamin B12, bile salts. Large intestine primarily absorbs water and electrolytes.

90. A - Beta cells (β -cells) in the islets of Langerhans

Pancreatic islets (islets of Langerhans) contain: beta cells (produce insulin), alpha cells (produce glucagon), delta cells (produce somatostatin), and PP cells (produce pancreatic polypeptide). Beta cell destruction causes type 1 diabetes.

91. D - Testosterone

Testosterone, produced by Leydig cells in the testes, is the primary male sex hormone (androgen). It promotes: development of male reproductive organs, secondary sex characteristics (facial hair, deep voice, muscle mass), spermatogenesis, and libido. FSH and LH regulate testosterone production.

92. B - LH (luteinizing hormone)

The LH surge from the anterior pituitary (triggered by high estrogen levels) causes ovulation - release of the mature oocyte from the follicle around day 14 of the menstrual cycle. FSH stimulates follicle development earlier in the cycle.

93. D - Progesterone and estrogen

After ovulation, the corpus luteum (formed from the ruptured follicle) secretes progesterone and estrogen, which: (1) maintain the uterine lining for potential implantation, (2) provide negative feedback to prevent further ovulation. If pregnancy doesn't occur, the corpus luteum degenerates.

94. D - Thymus

T lymphocytes (T cells) mature in the thymus gland, undergoing positive and negative selection to ensure they can recognize self-MHC molecules but don't react against self-antigens. B cells mature in bone marrow. Both originate from hematopoietic stem cells.

95. C - Antibodies (immunoglobulins)

B lymphocytes produce antibodies (immunoglobulins: IgG, IgM, IgA, IgE, IgD) in response to antigens. Antibodies provide humoral immunity by: neutralizing pathogens, opsonizing for phagocytosis, activating complement, and preventing toxin binding. Memory B cells provide rapid response upon re-exposure.

96. C - Sympathetic nervous system

The sympathetic nervous system mediates the "fight-or-flight" response to stress or danger: increases heart rate and contractility, dilates bronchioles, dilates pupils, redirects blood to muscles, releases glucose, and inhibits digestion. Uses neurotransmitters norepinephrine and epinephrine.

97. C - Saltatory conduction (in myelinated neurons)

In myelinated neurons, action potentials "jump" between nodes of Ranvier (gaps in myelin sheath) via saltatory conduction. This is much faster than continuous conduction in unmyelinated axons because depolarization only occurs at nodes, and current passively flows through myelinated segments.

98. C - Axon terminals (synaptic vesicles)

Neurotransmitters are stored in synaptic vesicles in the axon terminal (presynaptic terminal). When an action potential arrives, voltage-gated Ca^{2+} channels open, Ca^{2+} influx triggers vesicle fusion with the presynaptic membrane, and neurotransmitters are released into the synaptic cleft via exocytosis.

99. B - Astrocytes and tight junctions of capillary endothelial cells

The blood-brain barrier (BBB) protects the brain from pathogens and toxins. It's formed by: (1) tight junctions between capillary endothelial cells (making them less permeable), and (2) astrocyte end-feet surrounding capillaries. Only lipid-soluble molecules and specific transported substances can cross.

100. C - Osteoblasts (build) and osteoclasts (break down)

Bone is constantly remodeled through coordinated activity: Osteoblasts secrete bone matrix (collagen, minerals) building new bone. Osteoclasts secrete acid and enzymes breaking down bone. This remodeling maintains calcium homeostasis, repairs micro-damage, and adapts bone to mechanical stress. Osteocytes are mature bone cells.