

Biological and Biochemical Foundations of Living Systems Sample Paper 1

Passage I (Questions 1–5)

Investigators studying bacterial chemotaxis construct a mutant strain in which the methyl-accepting chemotaxis protein Tar is unable to be methylated. Wild-type Tar is methylated by the methyltransferase CheR and demethylated by the methylesterase CheB. Methylation increases the probability that the associated histidine kinase CheA will autophosphorylate and subsequently transfer the phosphoryl group to the response regulator CheY. Phospho-CheY interacts with the flagellar motor to promote clockwise rotation (tumbling).

In the mutant, swimming behavior is monitored in a spatial gradient of aspartate, a known attractant that binds Tar.

Question 1

Relative to wild-type cells, the methylation-deficient mutant is expected to:

- a) Exhibit persistently high tumbling frequency even in the presence of attractant
- b) Exhibit persistently low tumbling frequency regardless of attractant concentration
- c) Be unable to sense any change in attractant concentration
- d) Methylate CheA instead of Tar

Correct Answer: b) Exhibit persistently low tumbling frequency regardless of attractant concentration

Explanation:

Without methylation the kinase activity of CheA remains low, so little phospho-CheY is produced and tumbling is suppressed.

Question 2

Aspartate binding to Tar is most analogous to which eukaryotic signaling event?

- a) Ligand-induced dimerization of a receptor tyrosine kinase
- b) Hormone binding that activates a G-protein-coupled receptor
- c) Steroid binding to an intracellular nuclear receptor
- d) Substrate binding that allosterically activates a metabolic enzyme

Correct Answer: b) Hormone binding that activates a G-protein-coupled receptor

Explanation:

Tar is a transmembrane receptor that, upon ligand binding, alters the activity of an associated kinase cascade, closely paralleling GPCR signaling.

Question 3

CheY is an example of a response regulator. Its phosphorylation most likely occurs on which amino-acid side chain?

- a) Serine
- b) Threonine
- c) Tyrosine
- d) Aspartate

Correct Answer: d) Aspartate

Explanation:

Bacterial response regulators of the two-component system are phosphorylated on a conserved aspartate residue.

Question 4

If CheB were inactivated by mutation while CheR remained functional, the expected phenotype would be:

- a) Continuous tumbling even in uniform attractant
- b) Continuous smooth swimming even in uniform attractant
- c) Inability to tumble under any condition
- d) Rapid adaptation to any new attractant concentration

Correct Answer: a) Continuous tumbling even in uniform attractant

Explanation:

Loss of demethylation locks Tar in the highly methylated state, keeping CheA active and phospho-CheY levels high, which promotes tumbling.

Question 5

The overall chemotaxis pathway is an example of:

- a) A linear metabolic pathway with no feedback
- b) A two-component signal-transduction system
- c) A ligand-gated ion channel cascade
- d) An antibody–antigen recognition process

Correct Answer: b) A two-component signal-transduction system

Explanation:

The core module consists of a histidine kinase (CheA) and a response regulator (CheY), the defining architecture of bacterial two-component systems.

Independent Questions (Questions 6–9)

Question 6

Which of the following amino acids is most likely to be found in the interior of a soluble globular protein?

- a) Aspartate
- b) Lysine
- c) Phenylalanine
- d) Asparagine

Correct Answer: c) Phenylalanine

Explanation:

Phenylalanine is hydrophobic and is typically buried in the protein core; the other three residues are polar or charged and prefer solvent exposure.

Question 7

During DNA replication the lagging strand is synthesized discontinuously. The short segments are called:

- a) Primers
- b) Okazaki fragments
- c) Telomeres
- d) Promoters

Correct Answer: b) Okazaki fragments

Explanation:

Okazaki fragments are the discontinuous pieces of DNA synthesized on the lagging strand.

Question 8

A competitive inhibitor of an enzyme raises the apparent K_m but does not change V_{max} . This occurs because the inhibitor:

- a) Binds exclusively to the enzyme–substrate complex
- b) Competes with substrate for the active site
- c) Irreversibly covalently modifies a catalytic residue
- d) Alters the enzyme's quaternary structure

Correct Answer: b) Competes with substrate for the active site

Explanation:

Competitive inhibitors occupy the active site, so higher substrate concentrations are required to achieve the same fractional occupancy, raising apparent K_m while V_{max} remains reachable at saturating substrate.

Question 9

In the electron-transport chain, Complex IV (cytochrome c oxidase) transfers electrons to:

- a) Ubiquinone
- b) Cytochrome c
- c) Molecular oxygen
- d) NAD^+

Correct Answer: c) Molecular oxygen

Explanation:

Complex IV is the terminal oxidase that reduces O_2 to water.