Biological and Biochemical Foundations of Living Systems Mock Test

Passage I (Questions 1–6)

Investigators isolate a novel mitochondrial protein that appears to facilitate the transfer of electrons from Complex I to ubiquinone. Knock-out of the gene encoding this protein in cultured neurons results in elevated NADH/NAD^+ ratios, decreased oxygen consumption, and increased production of reactive oxygen species at Complex I. Addition of an exogenous membrane-permeable ubiquinone analogue partially restores oxygen consumption but does not normalize the NADH/NAD^+ ratio.

Western blots of mitochondrial fractions from the knock-out cells show normal levels of Complex I subunits, yet native gel electrophoresis reveals that the supercomplex assembly of Complex I with Complex III is disrupted.

Question 1

The elevated NADH/NAD^+ ratio in the knock-out cells most directly indicates that:

a) Glycolysis has stopped
b) Complex I is unable to oxidize NADH at a normal rate
c) The citric-acid cycle is accelerated
d) ATP synthase is blocked

Correct Answer: b) Complex I is unable to oxidize NADH at a normal rate

Explanation:
NADH accumulates when its oxidation by Complex I is impaired.

Question 2

Increased reactive oxygen species at Complex I is consistent with:

a) Faster electron flow through the entire chain
b) Backup of electrons within Complex I leading to partial reduction of oxygen
c) Complete absence of oxygen in the mitochondria
d) Over-activity of superoxide dismutase

Correct Answer: b) Backup of electrons within Complex I leading to partial reduction of oxygen

Explanation:
When forward electron transfer is blocked, electrons can leak to O_2 forming superoxide.

Question 3

The observation that an exogenous ubiquinone analogue restores oxygen consumption suggests that:

a) The analogue can accept electrons downstream of the blocked step
b) Complex IV is the primary defect
c) The proton gradient is irrelevant
d) Cytochrome c is missing

Correct Answer: a) The analogue can accept electrons downstream of the blocked step

Explanation:
A membrane-permeable quinone can bypass the defective transfer step and feed electrons into the downstream chain.

Question 4

Disruption of the Complex I–Complex III supercomplex most likely:

a) Increases the efficiency of electron channeling between the two complexes
b) Decreases the efficiency of electron channeling and may increase ROS production
c) Has no effect on electron transport
d) Causes immediate cell death by apoptosis

Correct Answer: b) Decreases the efficiency of electron channeling and may increase ROS production

Explanation:
Supercomplexes are thought to facilitate efficient electron transfer and minimize ROS generation; their loss impairs both functions.

Question 5

In wild-type mitochondria the oxidation of one molecule of NADH by the electron-transport chain yields approximately how many ATP?

a) 1
b) 1.5
c) 2.5
d) 4

Correct Answer: c) 2.5

Explanation:
Modern estimates assign ~2.5 ATP per NADH oxidized via the proton-motive force.

Question 6

The protein under study is most likely located in the:

a) Outer mitochondrial membrane
b) Intermembrane space only
c) Inner mitochondrial membrane
d) Mitochondrial matrix exclusively

Correct Answer: c) Inner mitochondrial membrane

Explanation:
Complexes I–IV and the mobile carriers that link them reside in or on the inner membrane.

Passage II (Questions 7–11)

A bacterial operon encoding enzymes for the catabolism of a rare sugar is under dual control. In the absence of the sugar a repressor protein binds the operator and prevents transcription. When the sugar is present it binds the repressor, causing the repressor to release the operator. In addition, low glucose levels raise cAMP, which binds CAP; the cAMP–CAP complex then binds upstream of the promoter and enhances RNA polymerase recruitment. Maximal transcription therefore occurs only when the sugar is available and glucose is scarce.

Question 7

This regulatory logic is an example of:

a) Positive regulation only
b) Negative regulation only
c) Both positive and negative regulation
d) Attenuation

Correct Answer: c) Both positive and negative regulation

Explanation:
Repressor-mediated control is negative; CAP-mediated enhancement is positive.

Question 8

When both the rare sugar and glucose are abundant, transcription of the operon is expected to be:

a) Maximal
b) Minimal
c) Intermediate
d) Completely abolished by attenuation

Correct Answer: b) Minimal

Explanation:
High glucose keeps cAMP low, so CAP does not activate; even though the repressor is off, transcription remains low.

Question 9

A mutation that prevents the repressor from binding the sugar but leaves operator binding intact would result in:

a) Constitutive high expression

b) Permanent repression regardless of sugar availability
c) Expression only when glucose is high
d) No change in regulation

Correct Answer: b) Permanent repression regardless of sugar availability

Explanation:
The repressor can no longer be inactivated by the inducer, so the operon stays off.

Question 10

CAP is an example of:

a) A sigma factor
b) An activator protein
c) A corepressor
d) A ribozyme

Correct Answer: b) An activator protein

Explanation:
cAMP–CAP binds DNA and increases the frequency of transcription initiation.

Question 11

The rare sugar functions in this system as:

a) A corepressor
b) An inducer
c) A repressor
d) An attenuator

Correct Answer: b) An inducer

Explanation:
Binding of the sugar inactivates the repressor and thereby induces expression.

Independent Questions (Questions 12–15)

Question 12

Which of the following is a characteristic of the genetic code?

a) It is overlapping
b) It is degenerate
c) It uses only two bases per codon
d) It is different in every species

Correct Answer: b) It is degenerate

Explanation:
Most amino acids are encoded by more than one codon (degeneracy).

Question 13

Histone acetylation is generally associated with:

a) Chromatin condensation and transcriptional repression
b) Chromatin relaxation and transcriptional activation
c) DNA methylation
d) Splicing of pre-mRNA

Correct Answer: b) Chromatin relaxation and transcriptional activation

Explanation:
Acetylation reduces the positive charge on histones, loosening DNA–histone interactions and facilitating transcription.

Question 14

A competitive inhibitor of an enzyme:

a) Decreases V_{max} and leaves K_m unchanged

b) Increases apparent K_m and leaves V_{max} unchanged
c) Decreases both K_m and V_{max}
d) Binds only to the enzyme–substrate complex

Correct Answer: b) Increases apparent K_m and leaves V_{max} unchanged

Explanation:
Competitive inhibitors raise the substrate concentration needed to reach half-maximal velocity.

Question 15

During translation the peptidyl transferase center is located in the:

a) Small ribosomal subunit
b) Large ribosomal subunit
c) Aminoacyl-tRNA synthetase
d) Initiation factor IF2

Correct Answer: b) Large ribosomal subunit

Explanation:
Peptidyl transferase activity is a ribozyme function of the 23S (or 28S) rRNA in the large subunit.