MCB 102: Pantea's Sxn   Chapter 19 Problem Set Answer Key

1) Page: 690   Ans: E

Almost all of the oxygen (O_2) one consumes in breathing is converted to:

A) acetyl-CoA.
B) carbon dioxide (CO_2).
C) carbon monoxide and then to carbon dioxide.
D) none of the above.
E) **water.**

2) Page: 696   Ans: B

Antimycin A blocks electron transfer between cytochromes *b* and c_1. If intact mitochondria were incubated with antimycin A, excess NADH, and an adequate supply of O_2, which of the following would be found in the oxidized state?

A) Coenzyme Q
B) **Cytochrome a_3**
C) Cytochrome *b*
D) Cytochrome *e*
E) Cytochrome *f*

3) Page: 698   Ans: B

Cyanide, oligomycin, and 2,4-dinitrophenol (DNP) are inhibitors of mitochondrial aerobic phosphorylation. Which of the following statements correctly describes the mode of action of the three inhibitors?

A) Cyanide and 2,4-dinitrophenol inhibit the respiratory chain, and oligomycin inhibits the synthesis of ATP.
B) **Cyanide inhibits the respiratory chain, whereas oligomycin and 2,4-dinitrophenol inhibit the synthesis of ATP.**
C) Cyanide, oligomycin, and 2,4-dinitrophenol compete with O_2 for cytochrome oxidase (Complex IV).
D) Oligomycin and cyanide inhibit synthesis of ATP; 2,4-dinitrophenol inhibits the respiratory chain.
E) Oligomycin inhibits the respiratory chain, whereas cyanide and 2,4-dinitrophenol prevent the synthesis of ATP.

4) Page: 705   Ans: E

Which of the following statements about the chemiosmotic theory is *false*?

A) Electron transfer in mitochondria is accompanied by an asymmetric release of protons on *one* side of the inner mitochondrial membrane.
B) Energy is conserved as a transmembrane pH gradient.
C) Oxidative phosphorylation cannot occur in membrane-free preparations.
D) The effect of uncoupling reagents is a consequence of their ability to carry protons through membranes.
E) **The membrane ATPase, which plays an important role in other hypotheses for energy coupling, has no significant role in the chemiosmotic theory.**

5) Page: 709 Ans: D

When the $\Delta G'^{\circ}$ of the ATP synthesis reaction is measured on the surface of the ATP synthase enzyme, it is found to be close to zero. This is thought to be due to:

A) a very low energy of activation.
B) enzyme-induced oxygen exchange.
C) stabilization of ADP relative to ATP by enzyme binding.
D) **stabilization of ATP relative to ADP by enzyme binding.**
E) none of the above.

6) Page: 712 Ans: C

During oxidative phosphorylation, the proton motive force that is generated by electron transport is used to:

A) create a pore in the inner mitochondrial membrane.
B) generate the substrates (ADP and P_i) for the ATP synthase.
C) **induce a conformational change in the ATP synthase.**
D) oxidize NADH to NAD^+.
E) reduce O_2 to H_2O.

7) Page: 724 Ans: D

The light reactions in photosynthetic higher plants:

A) do not require chlorophyll.
B) produce ATP and consume NADH.
C) require the action of a single reaction center.
D) **result in the splitting of H_2O, yielding O_2.**
E) serve to produce light so that plants can see underground.

8) Page: 718 Ans: D

The rate of oxidative phosphorylation in mitochondria is controlled primarily by:

A) feedback inhibition by CO_2.
B) the availability of NADH from the TCA cycle.
C) the concentration of citrate (or) the glycerol-3-phosphate shuttle.
D) the mass-action ratio of the ATD-ADP system.
E) the presence of thermogenin.

9) Page: 723 Ans: A

In photophosphorylation, absorption of light energy in chloroplast “light reactions” leads to:

A) absorption of CO2 and release of O2.
B) absorption of O2 and release of CO2.
C) hydrolysis of ATP and reduction of NADP+.
D) synthesis of ATP and oxidation of NADPH.
E) use of iron-sulfur proteins.

10) Page: 725 Ans: A

Oxidative phosphorylation and photophosphorylation share all of the following *except:*

A) **chlorophyll.**
B) involvement of cytochromes.
C) participation of quinones.
D) proton pumping across a membrane to create electrochemical potential.
E) use of iron-sulfur proteins.

11) Pages: 728-729 Ans: C

In what order do the following five steps occur in the photochemical reaction centers?

1) Excitation of the chlorophyll *a* molecule at the reaction center
2) Replacement of the electron in the reaction center chlorophyll
3) Light excitation of antenna chlorophyll molecule
4) Passage of excited electron to electron-transfer chain
5) Exiton transfer to neighboring chlorophyll

A) 1-2-3-4-5
B) 3-2-5-4-1
C) **3-5-1-4-2**
D) 4-2-3-5-1
E) 5-4-3-2-1

12) Page: 696

As you read and answer this question, you are (presumably) consuming oxygen. What single reaction accounts for most of your oxygen consumption?

Ans: O_2 is converted to H_2O by electrons from the respiratory chain. The final step is the one catalyzed by cytochrome oxidase (Complex IV).

13) Page: 696

Show the path of electrons from ubiquinone (Q or coenzyme Q) to oxygen in the mitochondrial respiratory chain. One of the two compounds (Q and O_2) has a standard reduction potential ($E'°$) of 0.82 V, and the other, 0.045 V. Which value belongs to each compound? How did you deduce this?

Ans: $QH_2 \rightarrow$ cyt $b \rightarrow$ cyt $c_1 \rightarrow$ cyt $c \rightarrow$ cyt $(a + a_3) \rightarrow O_2$
$E'°$ for O_2 must be the larger positive value (+0.82) because electron flow occurs spontaneously to the electron acceptor with the more positive $E'°$.

14) Pages: 696-701

Diagram the path of electron flow from NADH to the final electron acceptor during electron transport in mitochondria. For each electron carrier, indicate whether only electrons, or both electrons and protons, are accepted/donated by that carrier. Indicate with an arrow where electrons from succinate oxidation enter the chain of carriers.

Ans: NADH (both) $\rightarrow$ FP (both) $\rightarrow$ Q (both) $\rightarrow$ cyt b (e^- only) $\rightarrow$ cyt c_1 (e^- only) $\rightarrow$ cyt c (e^- only) $\rightarrow$ cyt $(a + a_3)$ (e^- only) $\rightarrow O_2$ (both)

Electrons from succinate enter at Q.

15) Page: 701

During electron transfer through the mitochondrial respiratory chain, the overall reaction is: NADH + 1/2 O_2 + H^+ → NAD^+ + H_2O. The difference in reduction potentials for the two half-reactions ($\Delta E'°$) is +1.14 V. Show how you would calculate the standard free-energy change, $\Delta G'°$, for the reaction as written above. (The Faraday constant, ℑ, is 96.48 kJ/V·mol.)

Ans: $\Delta G'° = -n\Im\Delta E'°$ = (–2)(96.48 kJ/V·mol)(1.14V) = –220 kJ/mol

16) Pages: 705, 707

Give an example of (a) an uncoupler of oxidative phosphorylation, and (b) an inhibitor of respiration. (c) Describe the difference in the effects of such uncouplers and inhibitors on mitochondrial function.

Ans: (a) Uncouplers include DNP, valinomycin, and CCCP. (b) Respiration inhibitors include antimycin A, piericidin A, CN^-, rotenone, and amytal. (c) Uncouplers stop formation of ATP while allowing electron transfer to continue. Inhibitors of respiration block both electron transfer and phosphorylation.

17) Page: 706

The skunk cabbage (*Symphocarpus foetidus*) can maintain a temperature of 10–25 °C higher than the temperature of the surrounding air. Suggest a mechanism for this.

Ans: One possible heat-generating mechanism is partially uncoupled mitochondria in which some of the energy of electron flow is dissipated as heat.

18) Pages: 705-717

Using a simple diagram of the chemiosmotic theory, explain why anything that makes the mitochondrial membrane leaky stops ATP synthesis in the mitochondria.

Ans: There are three central elements in the chemiosmotic model:
(1) Electron flow through asymmetrically arranged membrane-bound carriers causes transmembrane flow of H^+, creating a proton gradient (a proton motive force).
(2) The proton motive force drives protons back across the membrane via specific proton channels (composed of F_o).
(3) The energy released by downhill movement of protons is captured when ADP and P_i are condensed by ATP synthase (F_oF_1). Anything that makes the membrane leaky to protons (an uncoupler such as 2,4-dinitrophenol, or mechanical breakage of the membrane) prevents formation of a proton gradient. With no proton gradient, there is no energy source for ATP synthesis by F_oF_1 (ATP synthase). (See Fig. 19-17, p. 705, and Fig. 19-30, p. 717.)

19) Pages: 709-712

Explain briefly the current model for how the proton motive force that is generated by electron transport is used to drive the ATP synthesis reaction.

Ans: The tight binding of ATP by the enzyme stabilizes it and makes the $\Delta G'°$ of the synthetic reaction more favorable. Once the reaction has occurred, the ATP product must be released from the enzyme. The proton motive force causes protons to move across the inner mitochondrial membrane through the pore in the F_o complex. This movement leads to conformational changes that decrease the affinity of the F_1 portion of the synthase for ATP, resulting in its release from the enzyme.

20) Page: 718

Although molecular oxygen (O_2) does not participate directly in any of the reactions of the citric acid cycle, the cycle operates only when O_2 is present. Explain this observation.

Ans: The citric acid cycle produces NADH, which is normally reoxidized to NAD^+ by the passage of electrons through the respiratory chain to O_2. With no O_2 to accept electrons, NADH accumulates, NAD^+ is depleted, and the citric acid cycle slows for lack of NAD^+.

21) Pages: 721, 699

Cytochrome c plays two distinct and very important roles in mammalian cells: (1) in the mitochondrial electron transport chain, and (2) in apoptotic cell death. Describe the roles of cytochrome c in these two processes.

Ans: In the electron transport chain, cytochrome c accepts electrons from complex III and transfers them to complex IV. In the electron transport chain, cytochrome c is the only water soluble carrier. It operates in the space between the outer and inner mitochondrial membranes. In apoptotic cell death, the permeability of the outer mitochondrial membrane increases dramatically allowing the escape of cytochrome c into the cytoplasm where it activates caspase 9, one of the main proteolytic enzymes active in apoptosis.

22) Page: 722

Oxidative stress results when the superoxide anion (O_2^-) is formed as a side reaction of mitochondrial electron transport. This oxygen anion radical is made nontoxic by the action of four enzymes of the mitochondrial matrix. Name these four enzymes and briefly describe the role of each in detoxifying the superoxide anion (O_2^-).

Ans: The enzymes are (1) superoxide dismutase, (2) glutathione peroxidase, (3) glutathione reductase, and (4) nicotinamide nucleotide transhydrogenase. Superoxide dismutase acts on two O_2^-, converting them to one molecule of water and one of H_2O_2. Next, glutathione peroxidase reduces the H_2O_2 to two molecules of water with the concomitant oxidation of 2 glutathiones (GSH) to a molecule of oxidized glutathione (GSSG). Glutathione reductase re-reduces the oxidized glutathione with the conversion of NADPH to $NADP^+$. In the final step, nicotinamide nucleotide transhydrogenase replenishes the NADPH consumed in the glutathione reductase reaction using reduced NADH as the electron donor.

23) Pages: 729, 733

Describe what happens at photosystem I from the point where an antenna chlorophyll molecule absorbs a photon of light to the passage of an electron to $NADP^+$.

Ans: The antenna chlorophyll molecule passes the energy of the photon, via exciton transfer, to neighboring chlorophyll molecules and ultimately to reaction center chlorophyll molecules. This excites P700 to P700*, which donates an electron to A_0. From A_0, electrons pass to phylloquinone (A_1), through an Fe-S protein, to ferredoxin, then through a flavoprotein to $NADP^+$.

$P700^* \rightarrow A_0 \rightarrow A_1 \rightarrow$ Fe-S $\rightarrow NADP^+$ (See Figs. 19-43, p. 698, and 19-46, p. 703.)

24) Page: 734

During photophosphorylation in plants, electrons flow through a series of carriers in the chloroplast. What is the ultimate donor of electrons, and what is the ultimate acceptor? What provides the energy to move those electrons?

Ans: The ultimate donor is H_2O, and the acceptor, $NADP^+$. The energy that drives this electron flow is from light.