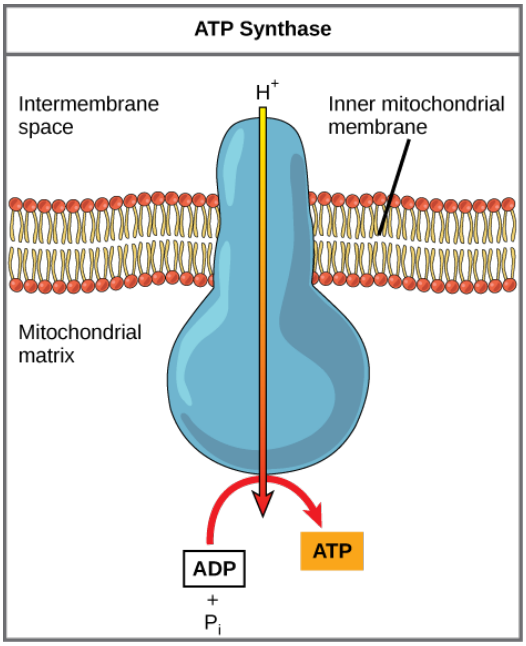
Biology 2e
Unit 2: The Cell
Chapter 7: Cellular Respiration

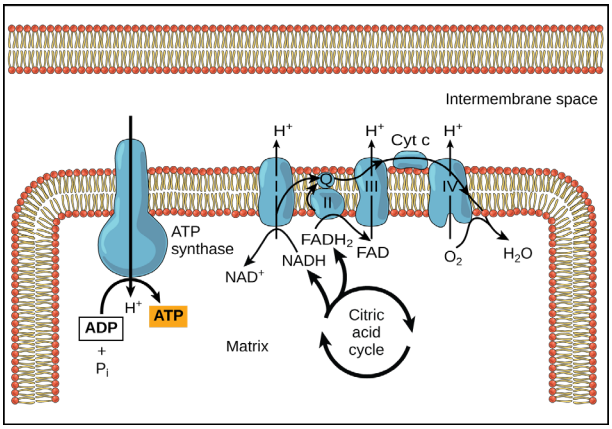
Visual Connection Questions

1. Dinitrophenol (DNP) is an "uncoupler" that makes the inner mitochondrial membrane "leaky" to protons. It was used until 1938 as a weight-loss drug. What effect would you expect DNP to have on the change in pH across the inner mitochondrial membrane? Why do you think this might be an effective weight-loss drug?



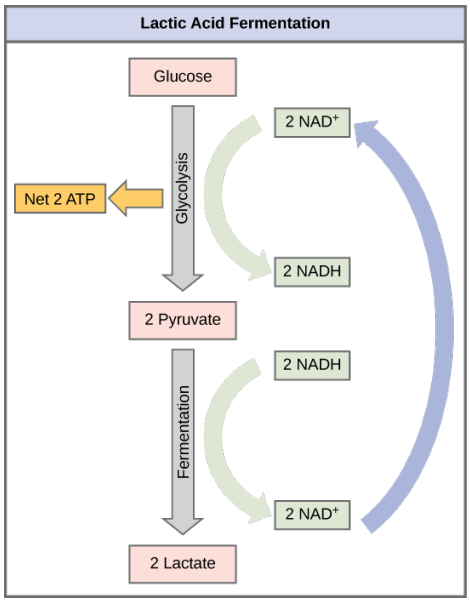
After DNP poisoning, the electron transport chain can no longer form a proton gradient, and ATP synthase can no longer make ATP. DNP is an effective diet drug because it uncouples ATP synthesis; in other words, after taking it, a person obtains less energy out of the food he or she eats. Interestingly, one of the worst side effects of this drug is hyperthermia, or overheating of the body. Since ATP cannot be formed, the energy from electron transport is lost as heat.

2. Cyanide inhibits cytochrome c oxidase, a component of the electron transport chain. If cyanide poisoning occurs, would you expect the pH of the intermembrane space to increase or decrease? What effect would cyanide have on ATP synthesis?



After cyanide poisoning, the electron transport chain can no longer pump electrons into the intermembrane space. The pH of the intermembrane space would increase, the pH gradient would decrease, and ATP synthesis would stop.

3. Tremetol, a metabolic poison found in the white snake root plant, prevents the metabolism of lactate. When cows eat this plant, it is concentrated in the milk they produce. Humans who consume the milk become ill. Symptoms of this disease, which include vomiting, abdominal pain, and tremors, become worse after exercise. Why do you think this is the case?



The illness is caused by lactate accumulation. Lactate levels rise after exercise, making the symptoms worse. Milk sickness is rare today, but was common in the Midwestern United States in the early 1800s.

Review Questions

4. The energy currency used by cells is _____.
a. ATP

5. A reducing chemical reaction _____.
b. adds an electron to the substrate

6. During the second half of glycolysis, what occurs?
c. ATP is made.

7. What is removed from pyruvate during its conversion into an acetyl group?
d. carbon dioxide

8. What do the electrons added to NAD^+ do?
b. They go to another pathway for ATP production.

9. GTP or ATP is produced during the conversion of _____.
b. succinyl CoA into succinate

10. How many NADH molecules are produced on each turn of the citric acid cycle?
c. three

11. What compound receives electrons from NADH?
a. FMN

12. Chemiosmosis involves _____.
c. the movement of hydrogen ions across a mitochondrial membrane

13. Which of the following fermentation methods can occur in animal skeletal muscles?
a. lactic acid fermentation

14. A major connection for sugars in glycolysis is _____.
a. glucose-6-phosphate

15. Beta-oxidation is _____.
c. the breakdown of fatty acids

16. The effect of high levels of ADP is to _____ in cellular respiration.
a. increase the activity of specific enzymes

17. The control of which enzyme exerts the most control on glycolysis?
b. phosphofructokinase

Critical Thinking Questions

18. Why is it beneficial for cells to use ATP rather than energy directly from the bonds of carbohydrates? What are the greatest drawbacks to harnessing energy directly from the bonds of several different compounds?

ATP provides the cell with a way to handle energy in an efficient manner. The molecule can be charged, stored, and used as needed. Moreover, the energy from hydrolyzing ATP is delivered as a consistent amount. Harvesting energy from the bonds of several different compounds would result in energy deliveries of different quantities.

19. Nearly all organisms on earth carry out some form of glycolysis. How does that fact support or not support the assertion that glycolysis is one of the oldest metabolic pathways?

If glycolysis evolved relatively late, it likely would not be as universal in organisms as it is. It probably evolved in very primitive organisms and persisted, with the addition of other pathways of carbohydrate metabolism that evolved later.

20. Because they lose their mitochondria during development, red blood cells cannot perform aerobic respiration; however, they do perform glycolysis in the cytoplasm. Why do all cells need an energy source, and what would happen if glycolysis were blocked in a red blood cell?

All cells must consume energy to carry out basic functions, such as pumping ions across membranes. A red blood cell would lose its membrane potential if glycolysis were blocked, and it would eventually die.

21. What is the primary difference between a circular pathway and a linear pathway?

In a circular pathway, the final product of the reaction is also the initial reactant. The pathway is self-perpetuating, as long as any of the intermediates of the pathway are supplied. Circular pathways are able to accommodate multiple entry and exit points, thus being particularly well suited for amphibolic pathways. In a linear pathway, one trip through the pathway completes the pathway, and a second trip would be an independent event.

22. How do the roles of ubiquinone and cytochrome c differ from the other components of the electron transport chain?

Q and cytochrome c are transport molecules. Their function does not result directly in ATP synthesis in that they are not pumps. Moreover, Q is the only component of the electron transport chain that is not a protein. Ubiquinone and cytochrome c are small, mobile, electron carriers, whereas the other components of the electron transport chain are large complexes anchored in the inner mitochondrial membrane.

23. What accounts for the different number of ATP molecules that are formed through cellular respiration?

Few tissues except muscle produce the maximum possible amount of ATP from nutrients. The intermediates are used to produce needed amino acids, fatty acids, cholesterol, and sugars for nucleic acids. When NADH is transported from the cytoplasm to the mitochondria, an active transport mechanism is used, which decreases the amount of ATP that can be made. The

electron transport chain differs in composition between species, so different organisms will make different amounts of ATP using their electron transport chains.

24. What is the primary difference between fermentation and anaerobic respiration?

Fermentation uses glycolysis only. Anaerobic respiration uses all three parts of cellular respiration, including the parts in the mitochondria like the citric acid cycle and electron transport; it also uses a different final electron acceptor instead of oxygen gas.

25. Would you describe metabolic pathways as inherently wasteful or inherently economical, and why?

They are very economical. The substrates, intermediates, and products move between pathways and do so in response to finely tuned feedback inhibition loops that keep metabolism balanced overall. Intermediates in one pathway may occur in another, and they can move from one pathway to another fluidly in response to the needs of the cell.

26. How does citrate from the citric acid cycle affect glycolysis?

Citrate can inhibit phosphofructokinase by feedback regulation.

27. Why might negative feedback mechanisms be more common than positive feedback mechanisms in living cells?

Negative feedback mechanisms actually control a process; it can turn it off, whereas positive feedback accelerates the process, allowing the cell no control over it. Negative feedback naturally maintains homeostasis, whereas positive feedback drives the system away from equilibrium.