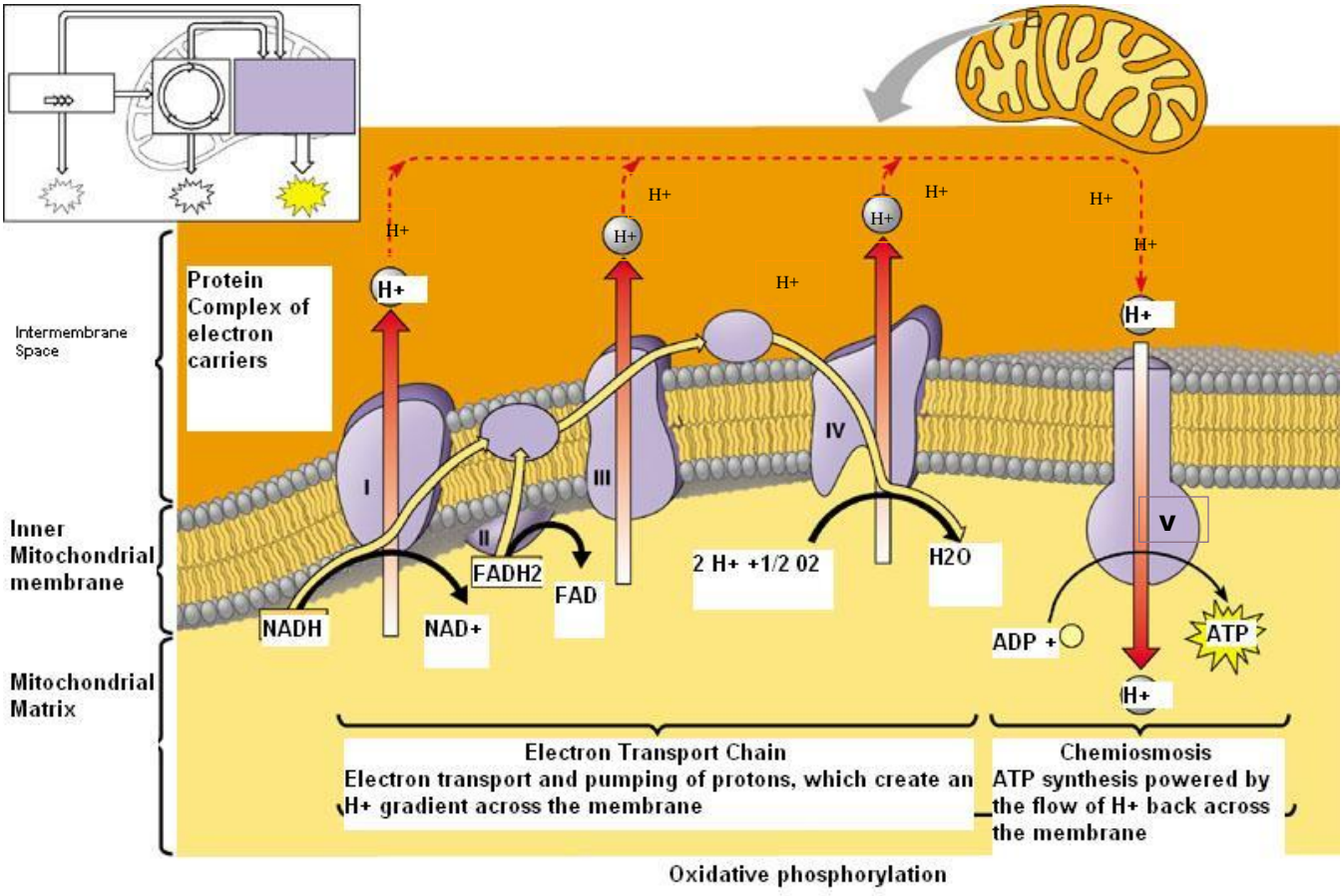
Oxidative Phosphorylation

How are the electrons in NADH and $FADH_2$ used to make ATP during cellular respiration?

Why?

The final phase of cellular respiration is **oxidative phosphorylation**. Both the electron transport chain and chemiosmosis make up oxidative phosphorylation. During this phase of cellular respiration, all of the NADH and $FADH_2$ that were produced in other phases of cellular respiration (glycolysis, the link reaction, and Krebs cycle) are used to make ATP. The process occurs in the protein complexes embedded in the inner mitochondrial membrane.

Diagram 1-The Electron Transport Chain and Chemiosmosis

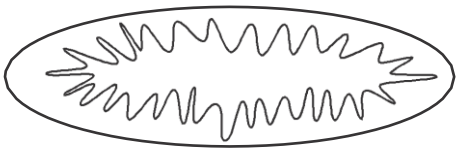


Refer to Diagram 1

1. a. Use some form of resources, name the protein complexes label I, III and IV.

b. Label the two electron carriers?

2. Consider the membranes illustrated in the diagram below. Circle a section of the mitochondria the ETC might be located.



3. Refer to Diagram 1.

a. Name the region in Diagram 1 where the highest concentration of hydrogen ion (H^+) is located.

b. According to Diagram 1, how do the hydrogen ions reach this area?

4. Explain what is happening at complex I

5. Explain why energy is required to move the hydrogen ions across the membrane in the direction indicated in Diagram 1.

6. In the Glycolysis and Krebs Cycle it produces electron acceptors, what are they and how many are produced in each step?

7. High potential energy electrons provide the energy necessary to pump hydrogen ions across the inner mitochondrial membrane.

a. What molecules carry these high potential energy electrons?

b. How many hydrogen ions are moved across each protein complex for one electron acceptor?

c. In total how many hydrogen ions are moved across the membrane for each of the two types of electron acceptor in the ETC?

d. When the electrons are released from the electron acceptor molecules, what else is produced?

e. Is the release of an electron from one of these electron acceptor molecules oxidation or reduction?

8. Refer to Diagram 1.

a. What molecule is the final electron acceptor after the electron has moved through the electron transport chain?

b. What compound is formed as a final product of the electron transport chain?

c. Where does this process takes place(couple of things to mention here)

9. Is any ATP produced in the electron transport chain?

10. Is any ATP used in the electron transport chain?

11. Video 1 - click on the video link or copy and paste the url to watch the video and answer the question that follows:
https://www.youtube.com/watch?v=6W-7FG9KlpA

a. What is the name of the force called that is generated across the membrane?

b. Name the co-enzymes mentioned?

c. What are the products of the reduced form of the co-enzymes?

d. Where does the electrons released from the second co-enzyme?

e. What are the membrane impermeable to?

f. What is the special protein channel does the protons passes through to re-enter the matrix?

Video 2- Chemiosmosis

Watch the video and answer the questions-
https://www.youtube.com/watch?v=3y1dO4nNaKY

12. Desribe the movement of hydrogen ions through the membrane illustrated in video 2.

13. Would free energy be required for the hydrogen ions to move in the direction shown? Explain your reasoning.

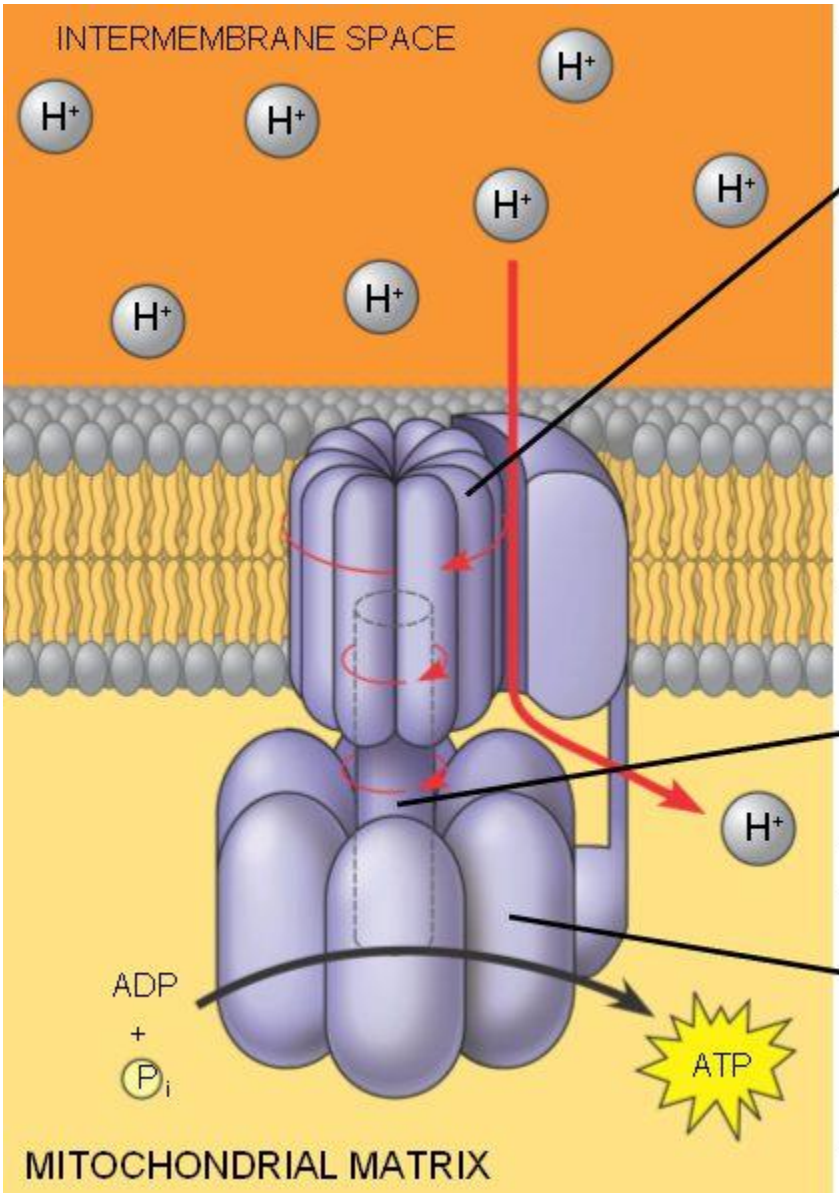
14. What is the name of the embedded protein that provides a channel for the hydrogen ions to pass through the membrane?

15. The flow of hydrogen ions through the protein channel provides free energy to do work. What process in this phase requires energy?

Read This!

The embedded protein complex, ATP synthase, is more of a machine than a chemical enzyme. Research has shown that a protein "rotor" down the middle of the ATP synthase complex turns as hydrogen ions flow through. This rotates other proteins, which then "squeeze" the ADP and inorganic phosphate groups together to form ATP.

Diagram 2- Chemiosmosis



16. During oxidative phosphorylation, what molecule is being phosphorylated?

17. Under ideal conditions each NADH molecule will result in three ATP molecules, and each $FADH_2$ molecule will result in two ATP molecules during oxidative phosphorylation. Calculate the total number of ATP molecules that might be produced in this phase of cellular respiration from one glucose molecule.

18. Considering all the stages of cellular respiration (glycolysis, link, Krebs cycle, and oxidative phosphorylation) how many ATP molecules are produced from one glucose molecule, assuming ideal circumstances?

19. Consider the overall chemical reaction for cellular respiration.

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O$$

Complete the table below to identify the phase of cellular respiration where each of the reactants are used, the products are produced, and the location in the cell where that phase occurs. You may need to refer back to previous activities on cellular respiration.

	Reactants		**Products**		
	$C_6H_{12}O_6$	$6O_2$	$6CO_2$	$6H_2O$	38ATP
Phase(s) at which it is used or produced					
Location					

Extension Questions

20. **Substrate level phosphorylation** is the term used for phosphorylation that removes a phosphate from one molecule and joins it to another molecule. Oxidative phosphorylation is the term used for the attachment of free inorganic phosphate to a molecule. Identify the phases of cellular respiration that use substrate level phosphorylation and that use oxidative phosphorylation.

21. Which side of the inner mitochondrial membrane would have a higher pH?

22. During glycolysis the enzyme hexokinase uses ATP to transfer a phosphate to glucose to form fructose-diphosphate. Suppose that a cell has only glucose available for energy and that the activ- ity of hexokinase is suddenly stopped. Explain in detail what is most likely to occur in the cell.

23. *a*. Click on the link below, view the video and then answer the questions that follows. You are to write your answer on the table below.

http://highered.mheducation.com/sites/0072507470/student_view0/chapter25/animation__electron_transport_system_and_atp_synthesis__quiz_1_.html

b. . Click on the link below, view the video and then answer the questions that follows. You are to write your answer on the table below.

http://highered.mheducation.com/sites/0072507470/student_view0/chapter25/animation__electron_transport_system_and_atp_synthesis__quiz_2_.html

c. . Click on the link below, view the video and then answer the questions that follows. You are to write your answer on the table below.

http://highered.mheducation.com/sites/0072507470/student_view0/chapter25/animation__electron_transport_system_and_formation_of_atp__quiz_1_.html

d. Click on the link below, view the video and then answer the questions that follows. You are to write your answer on the table below.

http://highered.mheducation.com/sites/0072507470/student_view0/chapter25/animation__electron_transport_system_and_formation_of_atp__quiz_2_.html

e. . Click on the link below, view the video and then answer the questions that follows. You are to write your answer on the table below.

http://highered.mheducation.com/sites/0072507470/student_view0/chapter25/animation__how_glycolysis_works.html

f. . Click on the link below, view the video and then answer the questions that follows. You are to write your answer on the table below.

http://highered.mheducation.com/sites/0072507470/student_view0/chapter25/animation__how_the_krebs_cycle_works__quiz_1_.html

g. . Click on the link below, view the video and then answer the questions that follows. You are to write your answer on the table below.

http://highered.mheducation.com/sites/0072507470/student_view0/chapter25/animation__how_the_krebs_cycle_works__quiz_2_.html

h. . Click on the link below, view the video and then answer the questions that follows. You are to write your answer on the table below.

http://highered.mheducation.com/sites/0072507470/student_view0/chapter25/animation__how_the_nad__works.html

Quiz/Question	1	2	3	4	5
1					
2					
3					
4					
5					
6					
7					
8					

23. Prokaryote cells must have energy for cellular processes just like eukaryote cells do. Yet, they have no mitochondria.

a. Which phase(s) of cellular respiration would be unaffected by the lack of mitochondria in a cell?

b. The link reaction and Krebs cycle occur in the cytoplasm of prokaryotes in the same way that they occur in the mitochondria of eukaryotes. However, a concentration gradient across a membrane is a requirement of the electron transport chain. Propose an alternate site for this phase of cellular respiration in prokaryotic cells.