Cellular Respiration in Detail

4.5B Electron Transport Chain

MAIN IDEA

The electron transport chain is the second main part of cellular respiration.

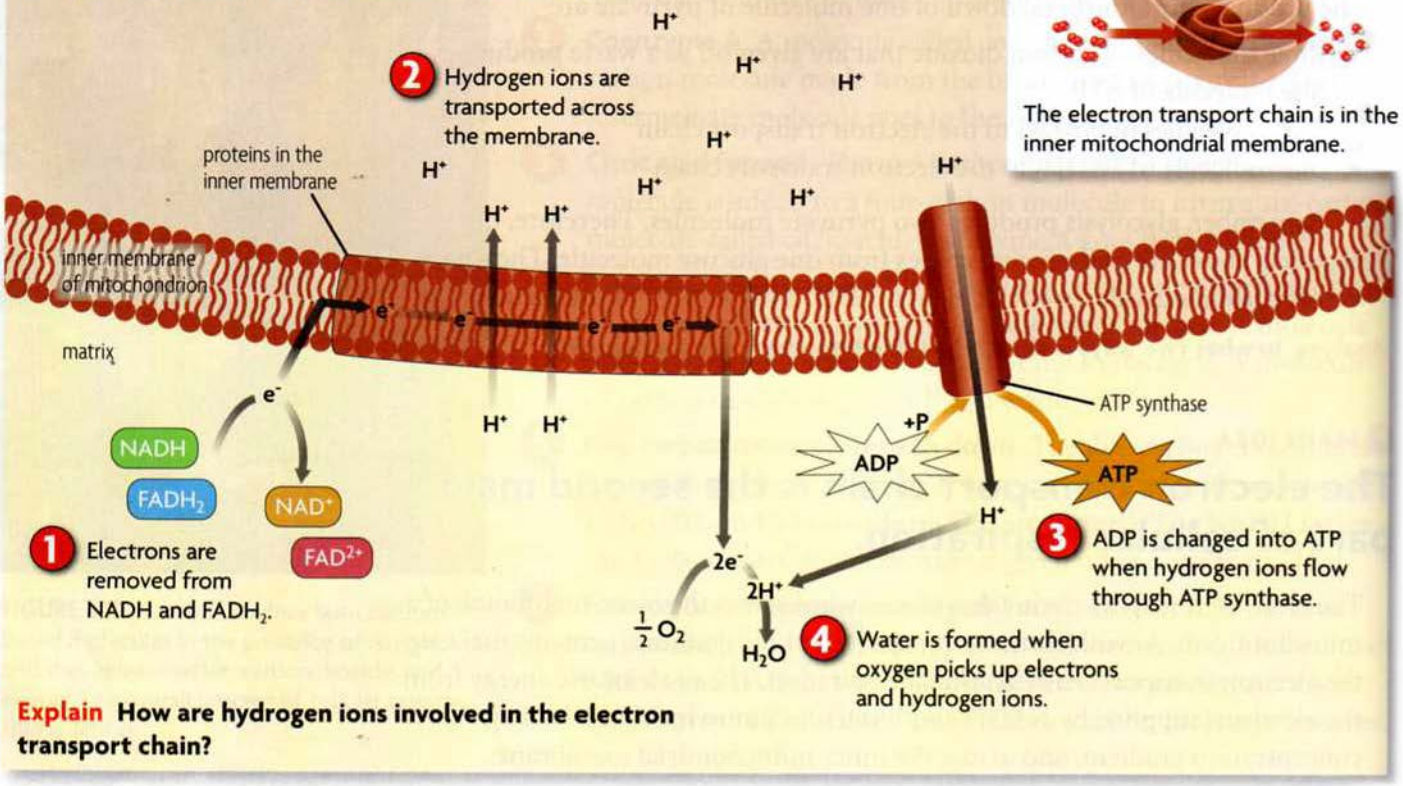
The electron transport chain takes place in and across the inner membrane of a mitochondrion. As with electron transport in photosynthesis, proteins make up the electron transport chain in cellular respiration. The proteins use energy from the electrons supplied by NADH and $FADH_2$ to pump hydrogen ions against a concentration gradient, and across the inner mitochondrial membrane.

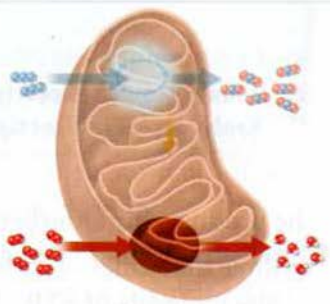
The ions later flow back through the membrane to produce ATP. Oxygen is needed at the end of the process to pick up electrons that have gone through the chain. The electron transport chain is shown in **FIGURE 4.15.**

1. **Electrons removed** Proteins inside the inner membrane of the mitochondrion take high-energy electrons from NADH and $FADH_2$. Two molecules of NADH and one molecule of $FADH_2$ are used.
2. **Hydrogen ions transported** High-energy electrons travel through the proteins in the electron transport chain. The proteins use energy from the electrons to pump hydrogen ions across the inner membrane to produce a chemiosmotic gradient, just as in photosynthesis. The hydrogen ions build up on the inside of the inner mitochondrial membrane.
3. **ATP produced** Just as in photosynthesis, the flow of hydrogen ions is used to make ATP. Hydrogen ions diffuse through a protein channel in the inner membrane of the mitochondrion. The channel is part of the ATP synthase enzyme. ATP synthase adds phosphate groups to ADP to make ATP molecules. For each pair of electrons that passes through the electron transport chain, an average of three ATP molecules are made.
4. **Water formed** Oxygen finally enters the cellular respiration process. The oxygen picks up electrons and hydrogen ions to form water. The water molecules are given off as a waste product.

FIGURE 4.15 The Electron Transport Chain

Energy from the Krebs cycle is used to produce ATP.





The electron transport chain is in the inner mitochondrial membrane.

Explain **How are hydrogen ions involved in the electron transport chain?**

The products of cellular respiration—including glycolysis—are

- Carbon dioxide from the Krebs cycle and from the breakdown of pyruvate before the Krebs cycle
- Water from the electron transport chain
- A net gain of up to 38 ATP molecules for every glucose molecule—2 from glycolysis, 2 from the Krebs cycle, and up to 34 from the electron transport chain

FIGURE 4.16 Like sandbags passed down a line of people, high-energy electrons are passed along a chain of proteins in the inner mitochondrial membrane.

Comparing Cellular Respiration and Photosynthesis

Again, think about how photosynthesis and cellular respiration are approximately the reverse of each other. Photosynthesis stores energy from sunlight as chemical energy. In contrast, cellular respiration releases stored energy as ATP and heat. Look at **FIGURE 4.17**, and think about other similarities and differences between the processes.

FIGURE 4.17 PHOTOSYNTHESIS AND CELLULAR RESPIRATION

	PHOTOSYNTHESIS	CELLULAR RESPIRATION
Organelle for process	chloroplast	mitochondrion
Reactants	CO_2 and H_2O	sugars ($C_6H_{12}O_6$) and O_2
Electron transport chain	proteins within thylakoid membrane	proteins within inner mitochondrial membrane
Cycle of chemical reactions	Calvin cycle in stroma of chloroplasts builds sugar molecules	Krebs cycle in matrix of mitochondria breaks down carbon-based molecules
Products	sugars ($C_6H_{12}O_6$) and O_2	CO_2 and H_2O

Recall the roles of electrons, hydrogen ions, and ATP synthase. In both processes, high-energy electrons are transported through proteins. Their energy is used to pump hydrogen ions across a membrane. And the flow of hydrogen ions through ATP synthase produces ATP. As you can see, the parts of the processes are very similar, but their end points are very different.

Analyze **How does the electron transport chain depend on the Krebs cycle?**

4.5 ASSESSMENT

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REVIEWING MAIN IDEAS

1. What is the role of pyruvate in cellular respiration? 1.g
2. Describe in your own words the function of the Krebs cycle. 1.g
3. Explain the functions of electrons, hydrogen ions, and oxygen in the electron transport chain. 1.i*

CRITICAL THINKING

4. **Compare and Contrast** Describe the similarities and differences between the Krebs cycle and the Calvin cycle. 6.d
5. **Evaluate** Is oxygen necessary for the production of all ATP in your cells? Why or why not?

Connecting CONCEPTS

6. **Common Ancestry** Protein molecules called cytochromes are part of the electron transport chain. They are nearly identical in every known aerobic organism. How do these molecules show the unity of life on Earth? 1.g