GENERATION OF PROTON MOTIVE FORCE

Three complexes (Complex I, III, and IV) in the ETC are proton pumps (as previously shown in table 8.1). Electrons being passed on provide the energy for these complexes to pump protons or H^+ from the matrix to the intermembrane space. The electrons from NADH activate all three pumps while the electrons from $FADH_2$ activate only two (Complex III and IV).

Because the pumps transport H^+ in a single direction, a proton gradient is created. This refers to a difference in the amount of H^+ in the two sides of the inner mitochondrial membrane—there are more of these protons in the intermembrane space than in the matrix.

The intermembrane space that is gaining H^+ is obviously the positive side while the matrix losing H^+ is the negative one. Since opposite charges attract, the negative charge of the matrix attracts the H^+ in the intermembrane space. Also, the higher concentration of protons in the intermembrane space drives the diffusion of H^+ into the matrix that has lesser amount of these ions. Therefore, both the differences in charge and in concentration favor the movement of H^+ from the intermembrane space back into the matrix. This electrochemical gradient of H^+ is also known as the *proton motive force* because it stores energy that is used to form ATP.

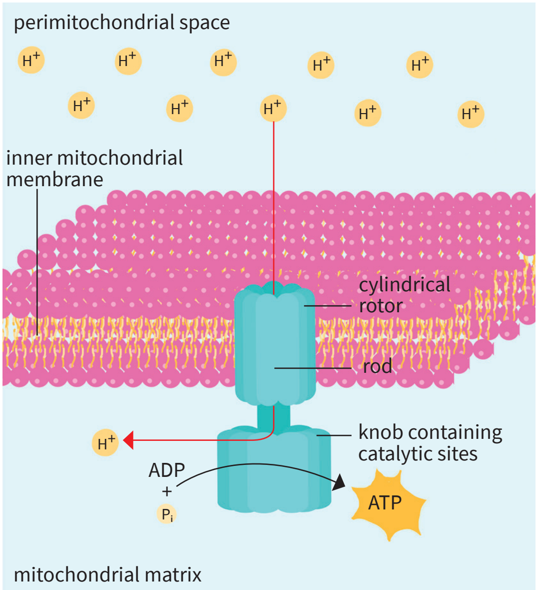

Fig. 8.8 Chemiosmosis at the mitochondrial ATP synthase complex combines proton diffusion and energy production.

Energy Production by the Mitochondrial ATP Synthase Complex

H^+ diffuses back into the matrix through a channel in the *ATP synthase complex* (fig. 8.8). In lesson 6.3, this is described as a generator found in the chloroplast. This complex is also embedded in the inner mitochondrial membrane along with the ETC and sometimes referred to as Complex V. As the protons flow into the matrix, catalytic subunits of the complex in the matrix are powered to produce ATP from ADP and inorganic phosphate. If you recall, this process of combining energy production and proton diffusion also takes place in the chloroplast and is called *chemiosmosis.*

The process of combining ADP and inorganic phosphate (P_i) in this complex is known as *oxidative phosphorylation.* Based on its name, this process is driven by oxygen. How is oxygen involved in the combination of ADP and P_i in the ATP synthase complex?

Recall that oxygen is such a strong oxidizing agent that it causes the electrons from NADH and $FADH_2$ to be released and passed along the ETC. These electrons activate the pumping of protons from the matrix into the intermembrane space, creating a gradient. This gradient causes the protons to move back into the matrix via the ATP synthase complex and, in so doing, provides the energy for ATP synthesis. Therefore, without oxygen, ATP synthase complex cannot produce ATP.

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