4.3A Light-Dependent Reactions

Photosynthesis in Detail

KEY CONCEPT Photosynthesis requires a series of chemical reactions.

MAIN IDEAS

- The first stage of photosynthesis captures and transfers energy.
- The second stage of photosynthesis uses energy from the first stage to make sugars.

VOCABULARY

photosystem, p. 108
electron transport chain, p. 109
ATP synthase, p. 110
Calvin cycle, p. 111

Review
chlorophyll, thylakoid, light-dependent reactions, light-independent reactions

CALIFORNIA STANDARDS

1.f ***Students know*** **usable energy is captured from sunlight by chloroplasts and is stored through the synthesis of sugar from carbon dioxide.**

1.i.* *Students know* how chemiosmotic gradients in the mitochondria and chloroplast store energy for ATP production.

Connect In a way, the sugar-producing cells in leaves are like tiny factories with assembly lines. In a factory, different workers with separate jobs have to work together to put together a finished product. Similarly, in photosynthesis many different chemical reactions, enzymes, and ions work together in a precise order to make the sugars that are the finished product.

MAIN IDEA

The first stage of photosynthesis captures and transfers energy.

In Section 4.2 you read a summary of photosynthesis. However, the process is much more involved than that general description might suggest. For example, during the light-dependent reactions, energy is captured and transferred in the thylakoid membranes by two groups of molecules called **photosystems**. The two photosystems are called photosystem I and photosystem II.

Overview of the Light-Dependent Reactions

The light-dependent reactions are the *photo-* part of photosynthesis. During the light-dependent reactions, chlorophyll and other light-absorbing molecules capture energy from sunlight. Water molecules are broken down into hydrogen ions, electrons, and oxygen gas. The oxygen is given off as a waste product. Sugars are not made during this part of photosynthesis.

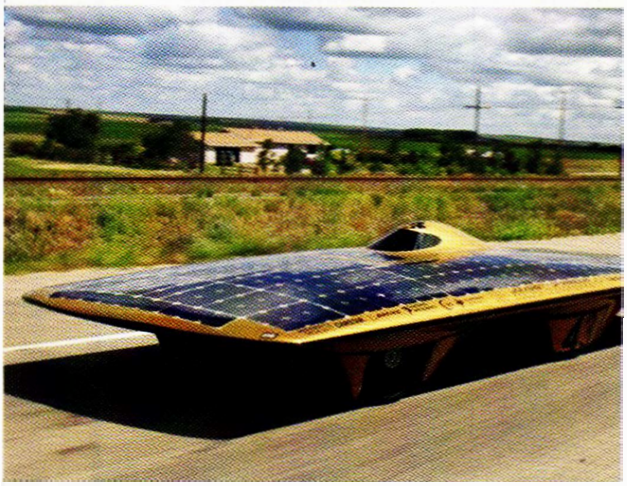


FIGURE 4.6 The light-dependent reactions capture energy from sunlight and transfer energy through electrons. The solar cells that power a solar car do the same thing.

The main functions of the light-dependent reactions are to capture and transfer energy. In these reactions, as in the solar car in **FIGURE 4.6,** energy is transferred to electrons. The electrons are only used for energy in a few specific processes. Recall a time you have gone to an amusement park. To go on rides, you needed special tickets that could only be used there. Similarly, the electrons are used for energy during photosynthesis but not for the cell's general energy needs.

Energy from the electrons is used to make molecules that act as energy carriers. These energy carriers are ATP and another molecule called NADPH. The ATP from the light-dependent reactions is usually not used for a cell's general energy needs. In this case, ATP molecules, along with NADPH molecules, go on to later stages of photosynthesis.

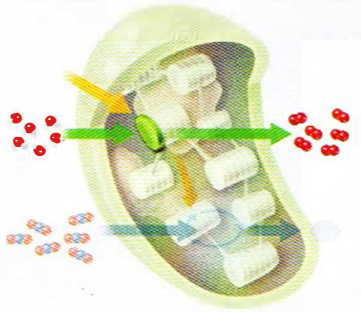
Photosystem II and Electron Transport

In photosystem II, chlorophyll and other light-absorbing molecules in the thylakoid membrane absorb energy from sunlight. The energy is transferred to electrons. Photosystem II, shown in **FIGURE 4.7**, needs water to function.

1. **Energy absorbed from sunlight** Chlorophyll and other light-absorbing molecules in the thylakoid membrane absorb energy from sunlight. The energy is transferred to electrons (e^-). High-energy electrons leave the chlorophyll and enter an **electron transport chain,** which is a series of proteins in the membrane of the thylakoid.
2. **Water molecules split** Enzymes break down water molecules. Oxygen, hydrogen ions (H^+), and electrons are separated from each other. The oxygen is released as waste. The electrons from water replace those electrons that left chlorophyll when energy from sunlight was absorbed.
3. **Hydrogen ions transported** Electrons move from protein to protein in the electron transport chain. Their energy is used to pump H^+ ions from outside to inside the thylakoid against a concentration gradient. The H^+ ions build up inside the thylakoid. Electrons move on to photosystem I.

Photosystem I and Energy-Carrying Molecules

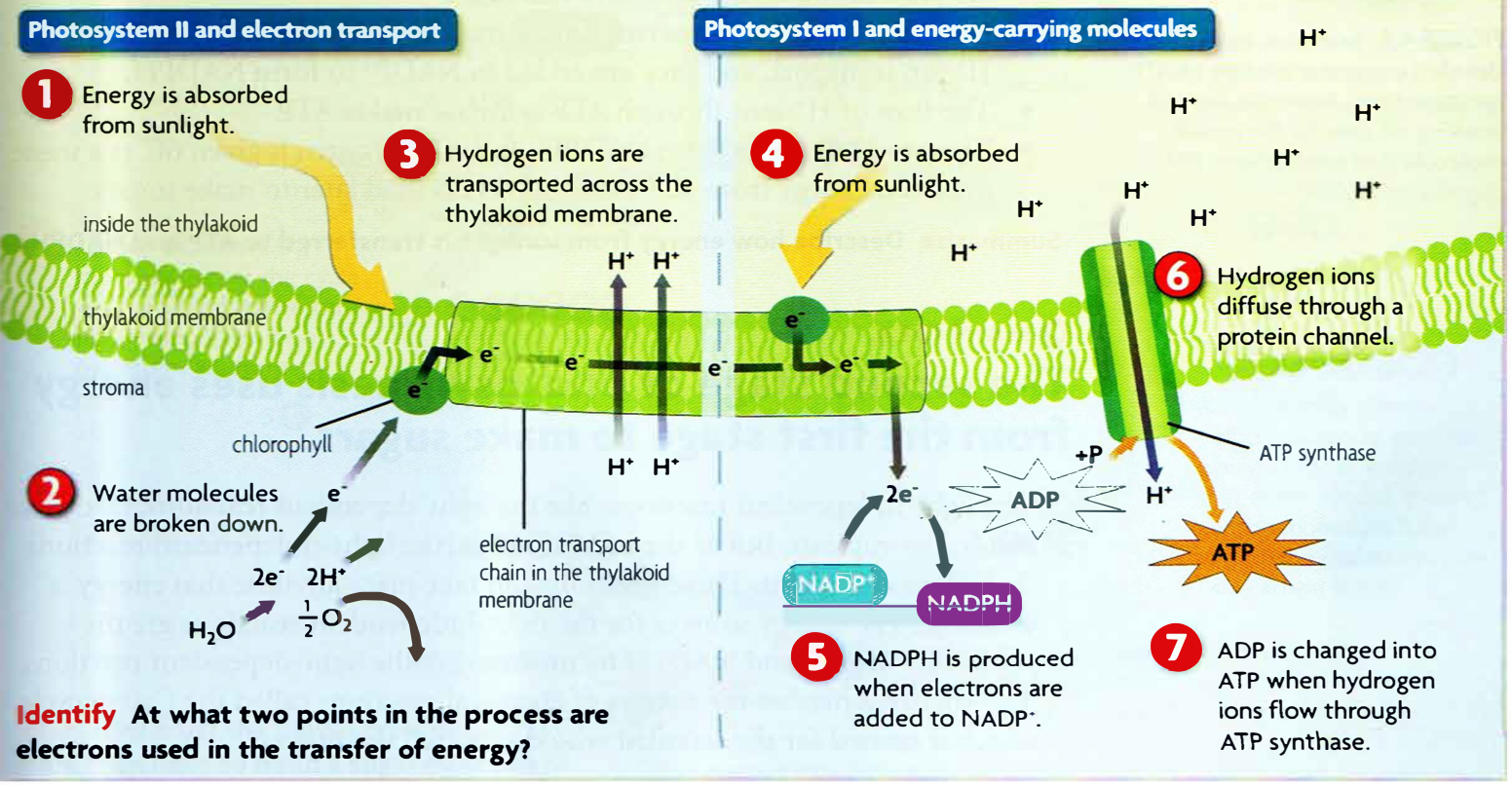
In photosystem I, chlorophyll and other light-absorbing molecules in the thylakoid membrane also absorb energy from sunlight. The energy is added to electrons, some of which enter photosystem I from photosystem II.



Light-dependent reactions take place in and across the thylakoid membrane.

FIGURE 4.7 Light-Dependent Reactions

Photosystems II and I absorb energy from sunlight and transfer energy to the Calvin cycle.



Identify **At what two points in the process are electrons used in the transfer of energy?**

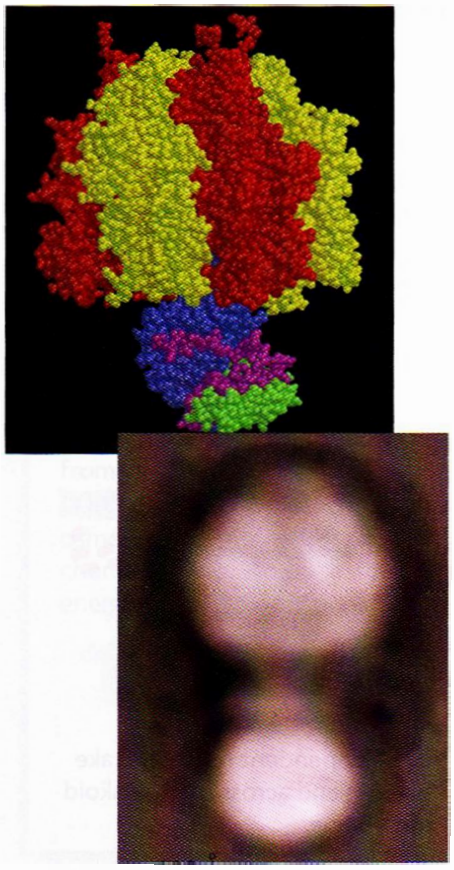


FIGURE 4.8 Scientists have made detailed computer models of ATP synthase (top). Scientists are still working on viewing the actual molecule (bottom). (colored TEM: magnification 1,800,000×)

4 **Energy absorbed from sunlight** As in photosystem II, chlorophyll and other light-absorbing molecules inside the thylakoid membrane absorb energy from sunlight. Electrons are energized and leave the molecules.

5 **NADPH produced** The energized electrons are added to a molecule called $NADP^+$, which functions like ADP. A molecule called NADPH is made. In photosynthesis, NADPH functions like ATP. The molecules of NADPH go to the light-independent reactions.

ATP Production

The final part of the light-dependent reactions makes ATP. The production of ATP depends on the H^+ ions that build up inside the thylakoid from photosystem II, and on a complex enzyme in the thylakoid membrane.

6 **Hydrogen ion diffusion** Hydrogen ions flow through a protein channel in the thylakoid membrane. Recall that the concentration of H^+ ions is higher inside the thylakoid than it is outside. This difference in H^+ ion concentration is called a chemiosmotic gradient, which stores potential energy. Therefore, the ions flow through the channel by diffusion.

7 **ATP produced** The protein channel in step 6 is part of a complex enzyme called **ATP synthase,** shown in **FIGURE 4.8**. As the ions flow through the channel, ATP synthase makes ATP by adding phosphate groups to ADP.

Summary of the Light-Dependent Reactions

- Energy is captured from sunlight by light-absorbing molecules. The energy is transferred to electrons that enter an electron transport chain.
- Water molecules are broken down into H^+ ions, electrons, and oxygen molecules. The water molecules provide the H^+ ions and electrons that are used in the light-dependent reactions.
- Energized electrons have two functions. They provide energy for H^- ion transport, and they are added to $NADP^+$ to form NADPH.
- The flow of H^+ ions through ATP synthase makes ATP.
- The products are oxygen, NADPH, and ATP. Oxygen is given off as a waste product. Energy from ATP and NADPH is used later to make sugars.