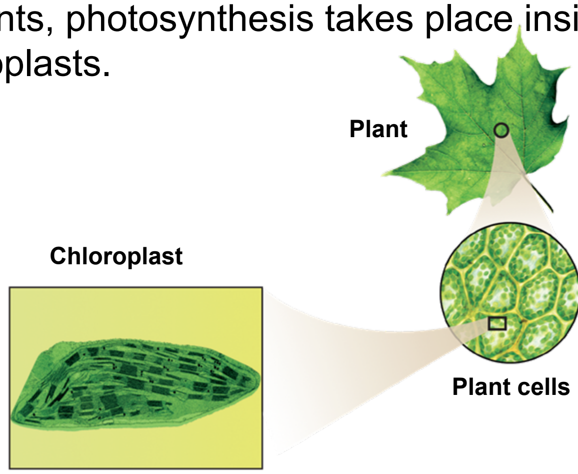
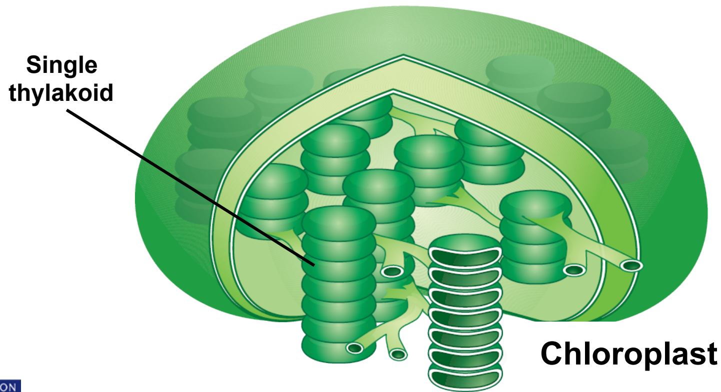
8-3 The Reactions of Photosynthesis

Inside a Chloroplast

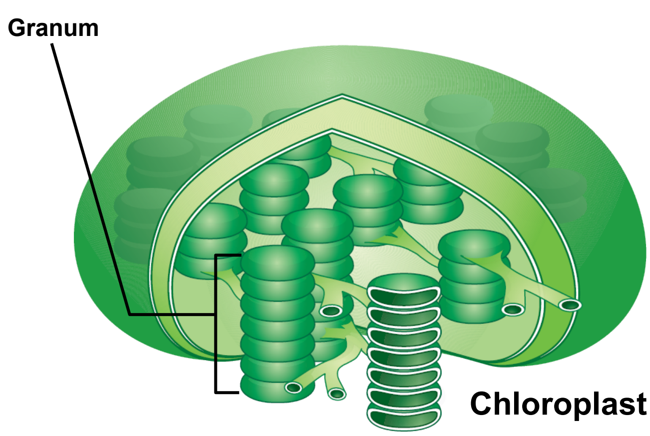
In plants, photosynthesis takes place inside chloroplasts.



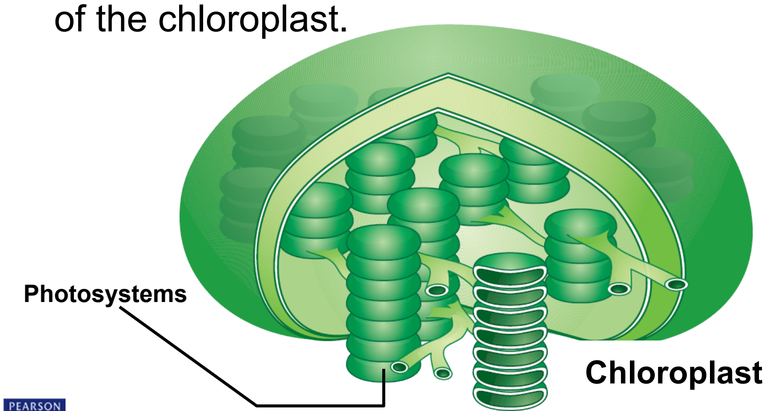
Chloroplasts contain **thylakoids**—saclike photosynthetic membranes.



Thylakoids are arranged in stacks known as grana. A singular stack is called a granum.



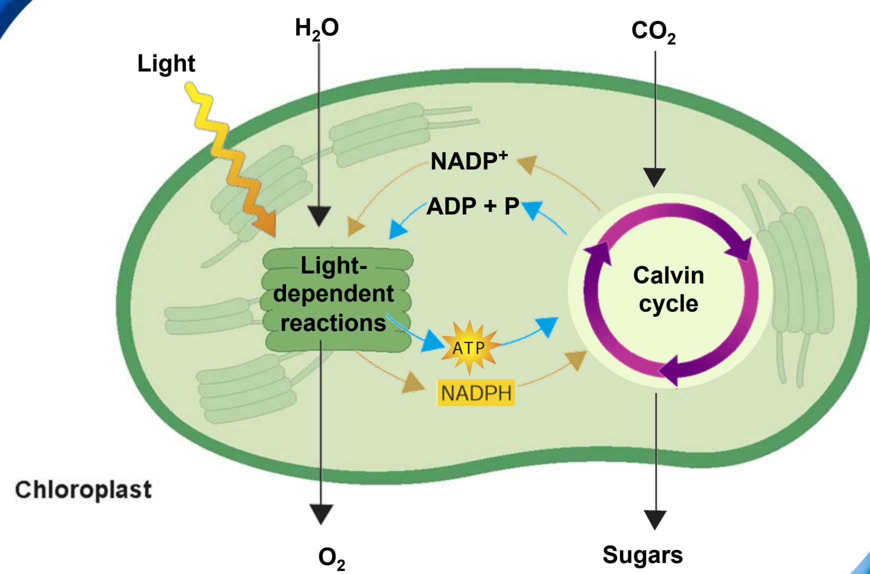
Proteins in the thylakoid membrane organize chlorophyll and other pigments into clusters called **photosystems**, which are the light-collecting units of the chloroplast.



The reactions of photosystems include: the light-dependent reactions and the light-independent reactions, or Calvin cycle.

The light-dependent reactions take place within the thylakoid membranes.

The Calvin cycle takes place in the **stroma**, which is the region outside the thylakoid membranes.



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Electron Carriers

When electrons in chlorophyll absorb sunlight, the electrons gain a great deal of energy.

Cells use electron carriers to transport these high-energy electrons from chlorophyll to other molecules.

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One carrier molecule is **NADP⁺**.

Electron carriers, such as NADP⁺, transport electrons.

NADP⁺ accepts and holds 2 high-energy electrons along with a hydrogen ion (H⁺). This converts the NADP⁺ into NADPH.

The conversion of NADP⁺ into NADPH is one way some of the energy of sunlight can be trapped in chemical form.

The NADPH carries high-energy electrons to chemical reactions elsewhere in the cell.

These high-energy electrons are used to help build a variety of molecules the cell needs, including carbohydrates like glucose.

What happens in the light-dependent reactions?

Light-Dependent Reactions

The light-dependent reactions require light.

The light-dependent reactions produce oxygen gas and convert ADP and $NADP^+$ into the energy carriers ATP and NADPH.

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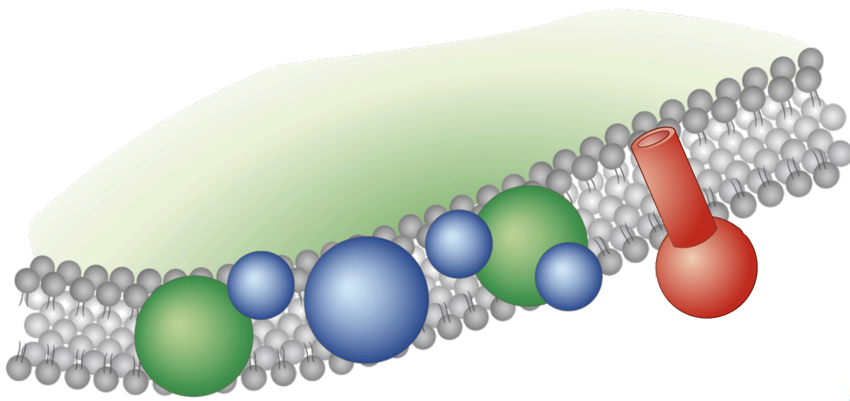

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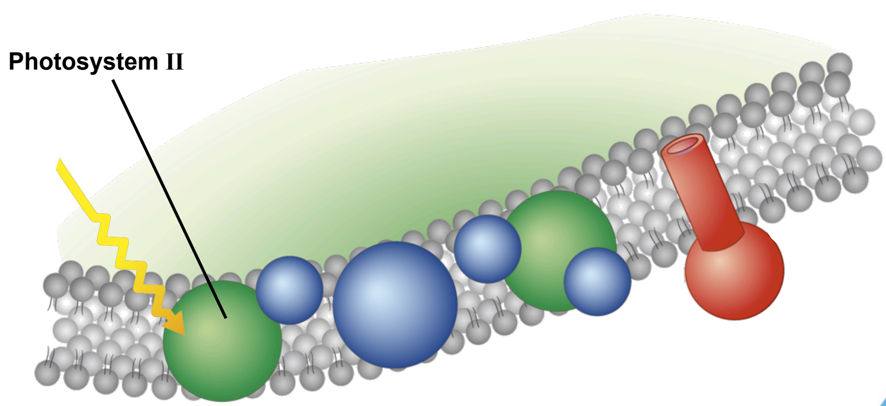
Photosynthesis begins when pigments in photosystem II absorb light, increasing their energy level.



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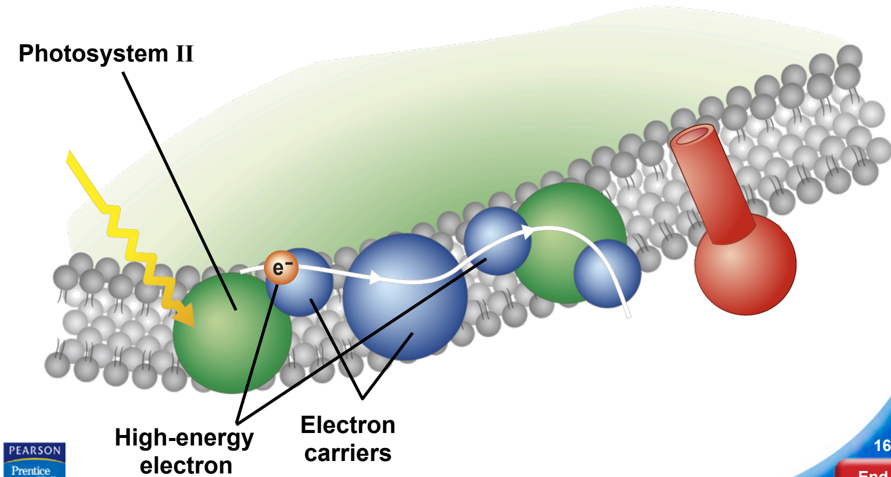
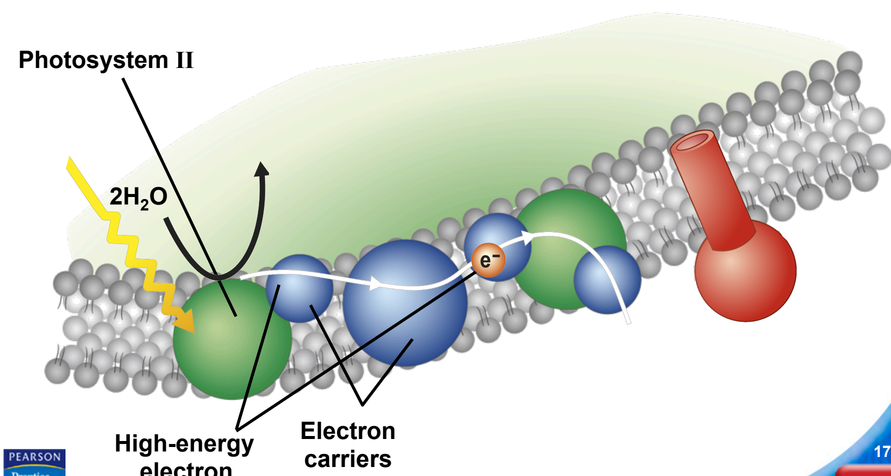
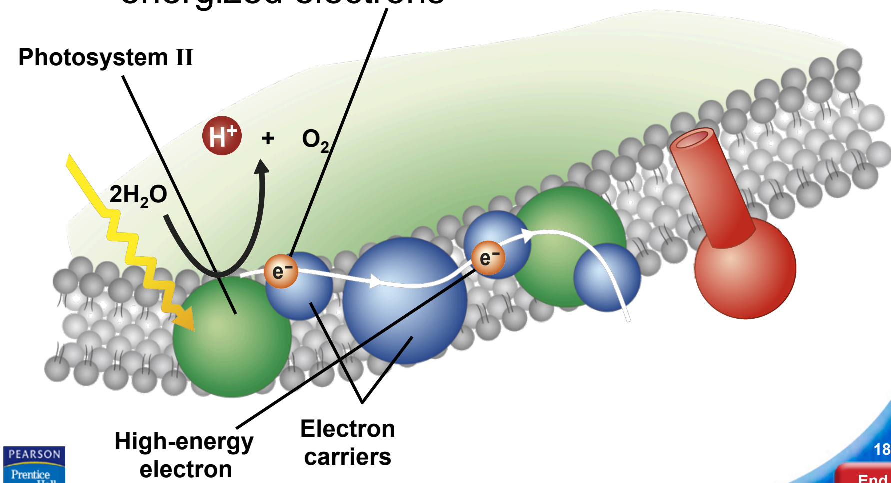
These high-energy electrons are passed on to the electron transport chain.



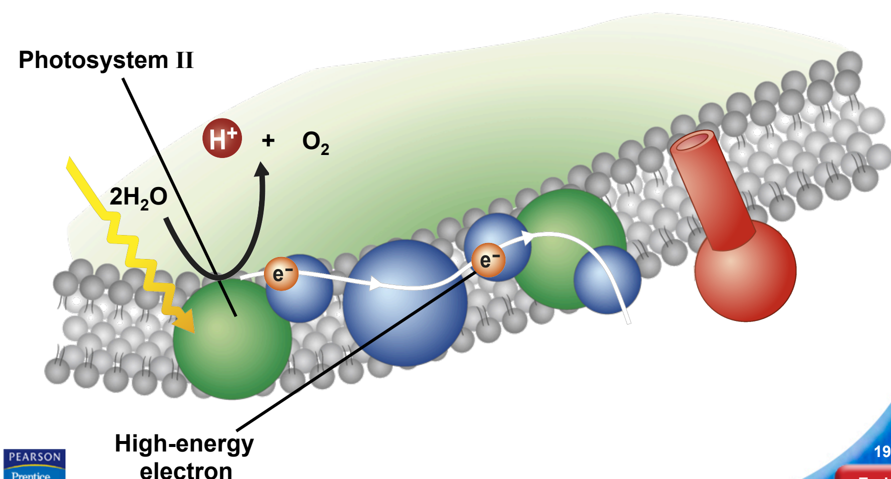
Enzymes on the thylakoid membrane break water molecules into:



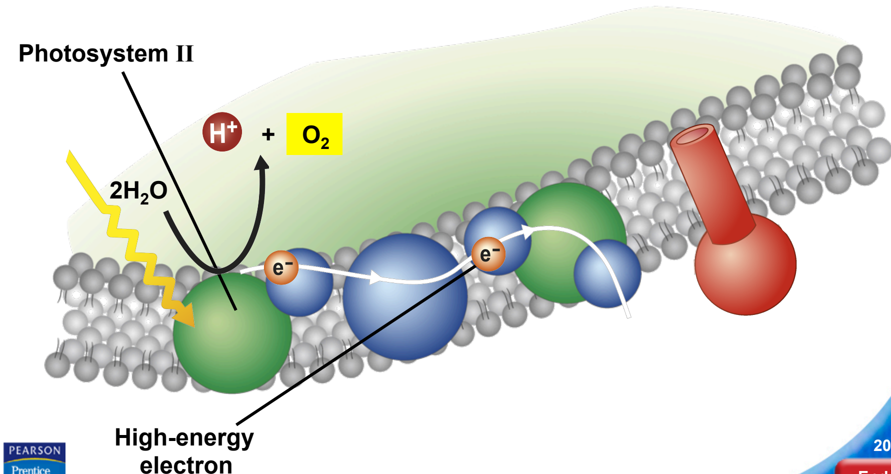
- hydrogen ions
- oxygen atoms
- energized electrons



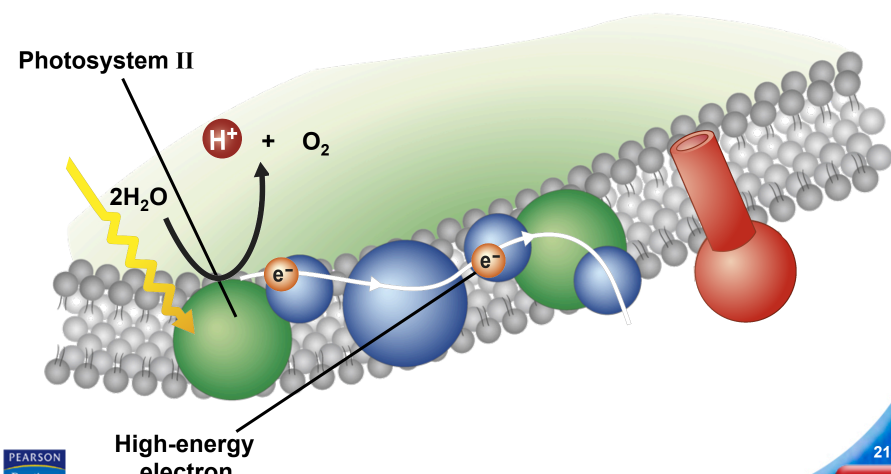
The energized electrons from water replace the high-energy electrons that chlorophyll lost to the electron transport chain.



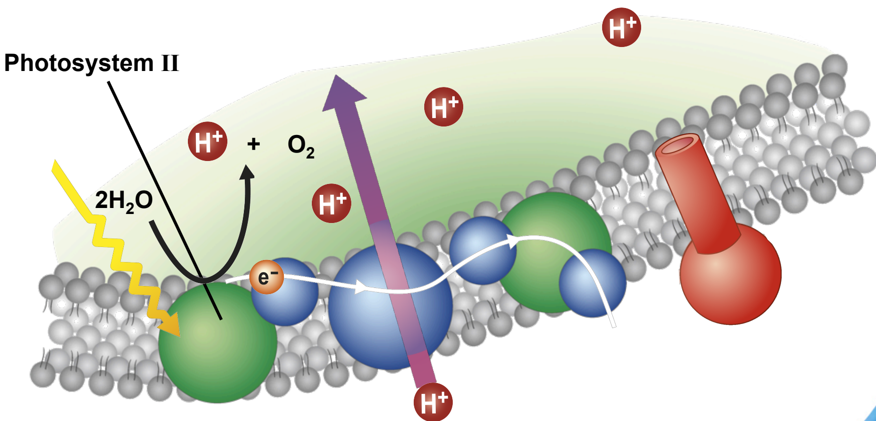
As plants remove electrons from water, oxygen is left behind and is released into the air.



The hydrogen ions left behind when water is broken apart are released inside the thylakoid membrane.

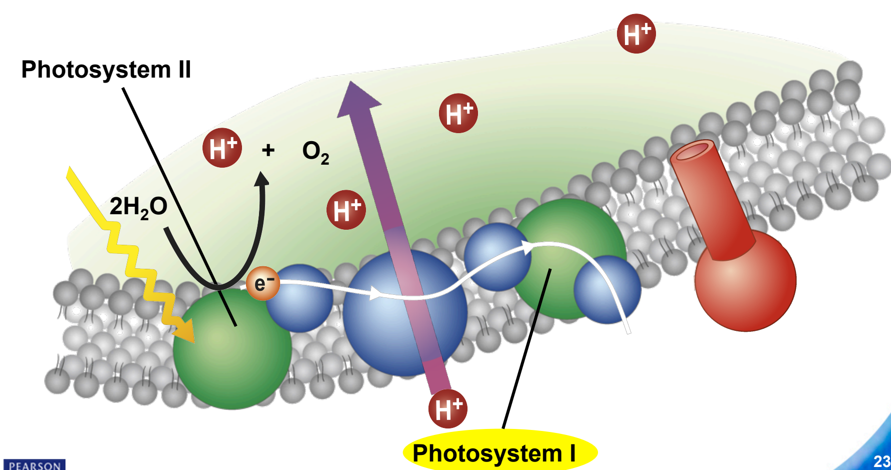


Energy from the electrons is used to transport H^+ ions from the stroma into the inner thylakoid space.

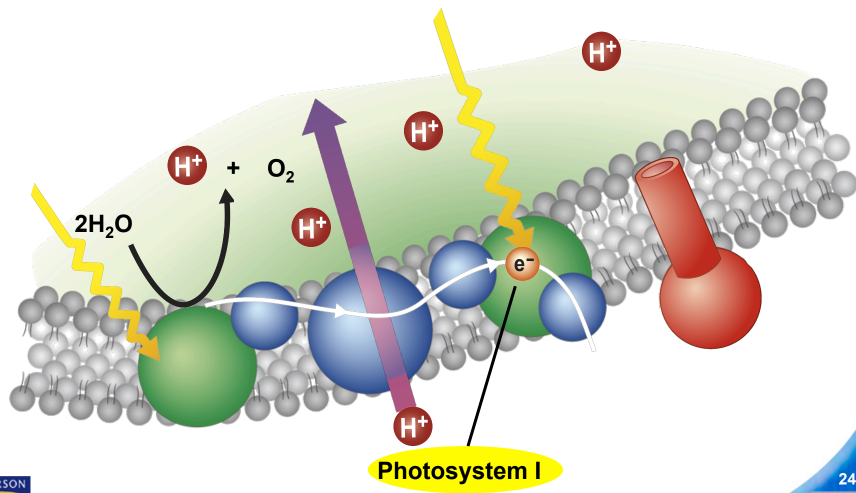


8-3 The Reactions of Photosynthesis → Light-Dependent Reactions

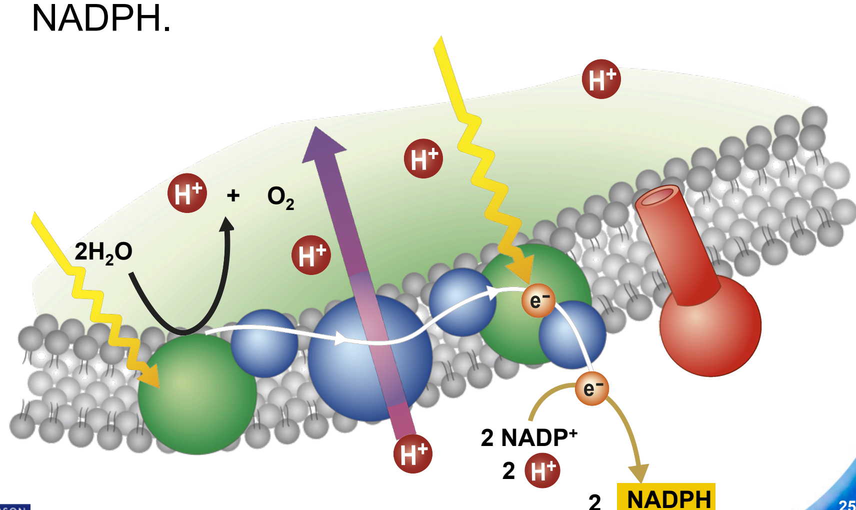
High-energy electrons move through the electron transport chain from photosystem II to photosystem I.



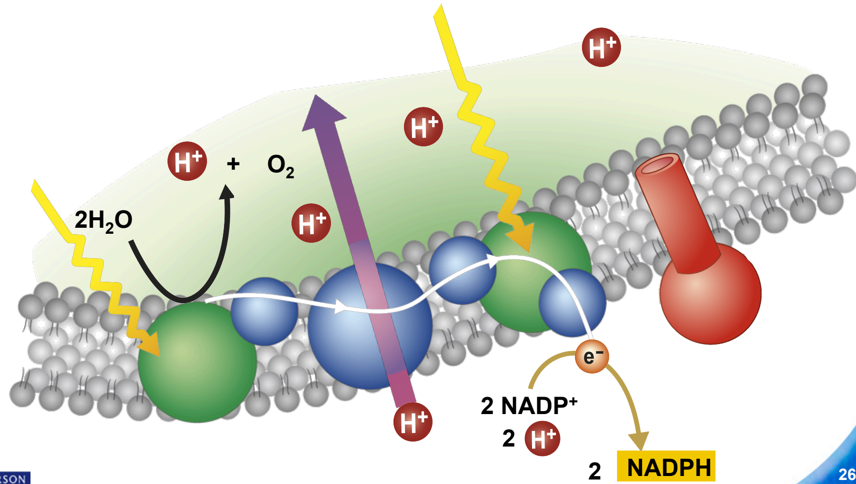
Pigments in photosystem I use energy from light to re-energize the electrons.



$NADP^+$ then picks up these high-energy electrons, along with H^+ ions, and becomes NADPH.

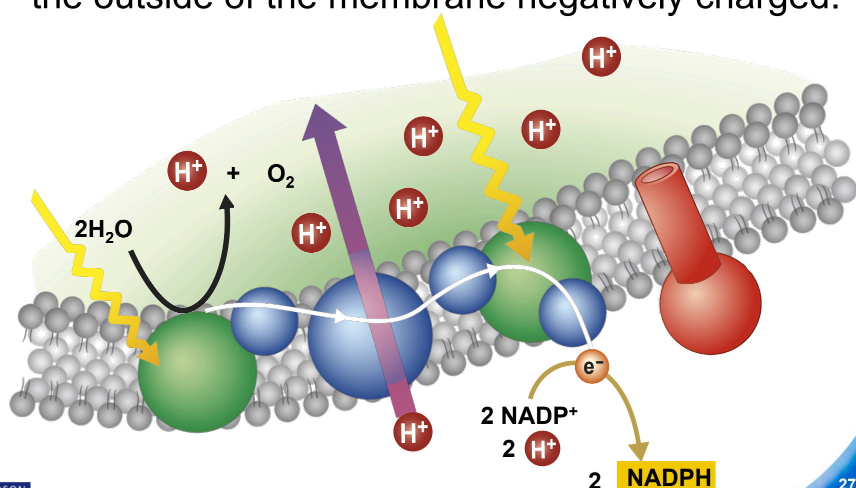


As electrons are passed from chlorophyll to $NADP^+$, more H^+ ions are pumped across the membrane.

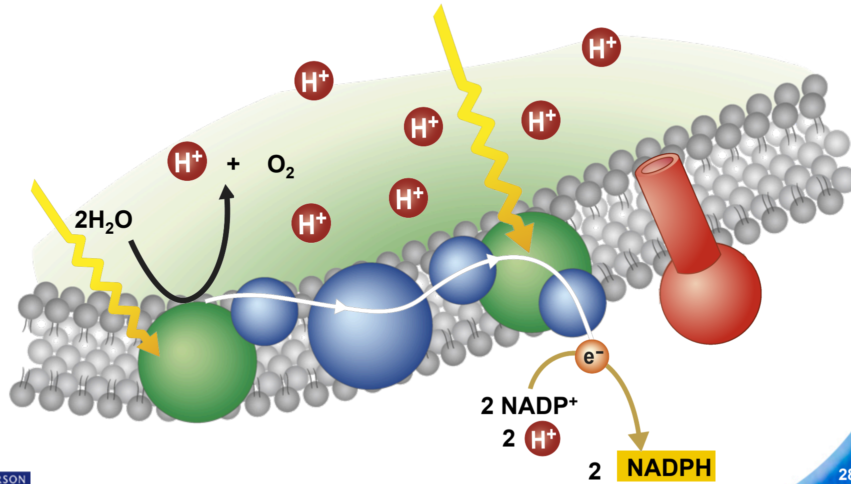


8-3 The Reactions of Photosynthesis ➡ Light-Dependent Reactions

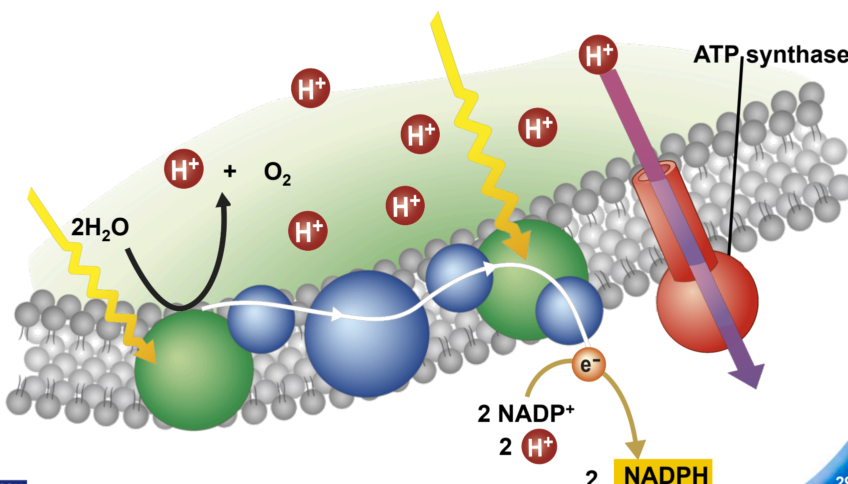
Soon, the inside of the membrane fills up with positively charged hydrogen ions, which makes the outside of the membrane negatively charged.



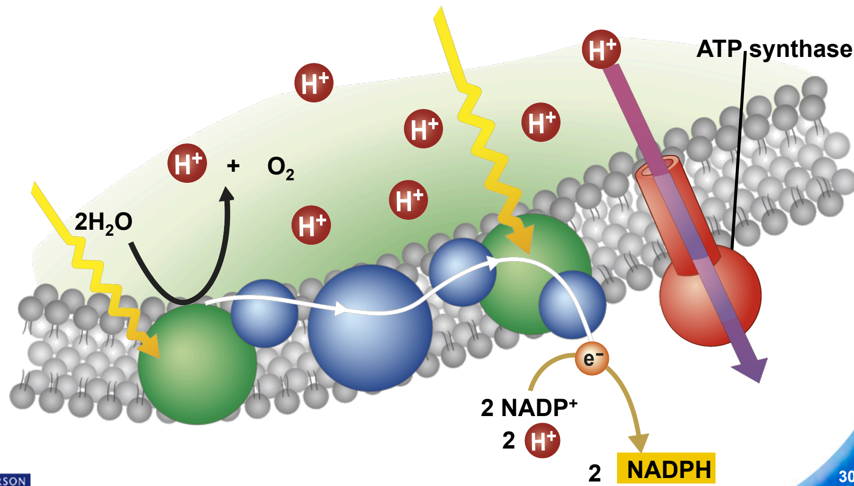
The difference in charges across the membrane provides the energy to make ATP



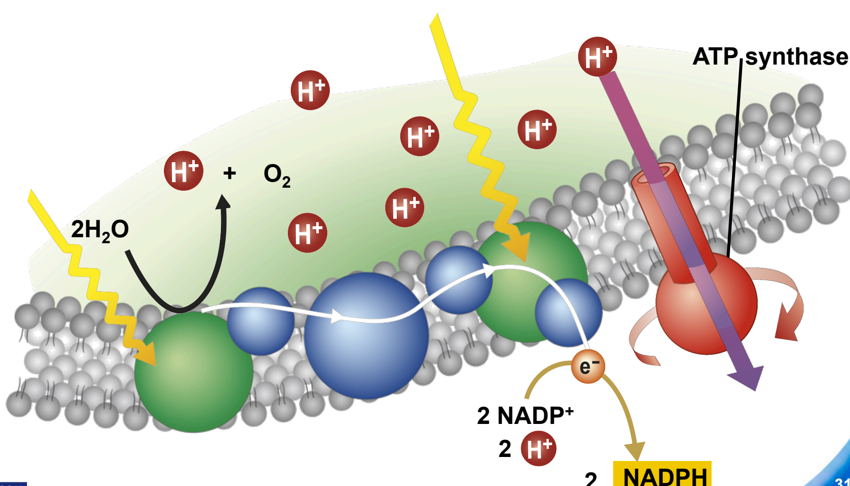
H^+ ions cannot cross the membrane directly.



The cell membrane contains a protein called **ATP synthase** that allows H^+ ions to pass through it

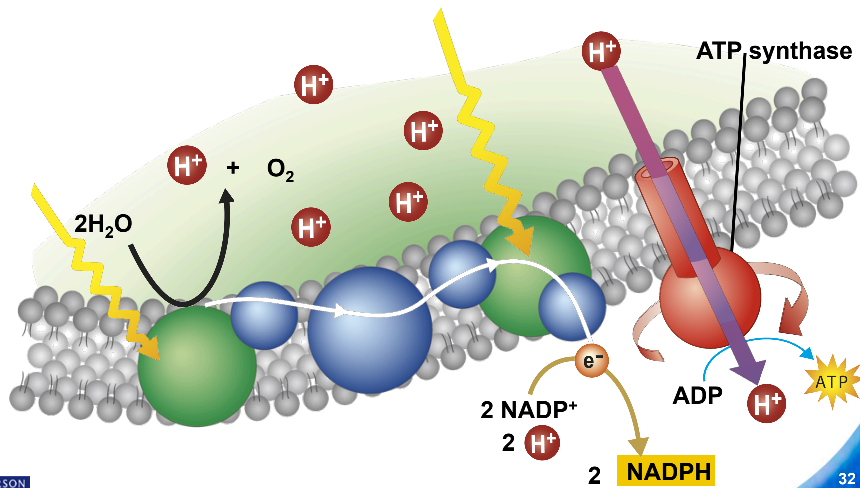


As H^+ ions pass through ATP synthase, the protein rotates.



8-3 The Reactions of Photosynthesis ➡ Light-Dependent Reactions

As it rotates, ATP synthase binds ADP and a phosphate group together to produce ATP.



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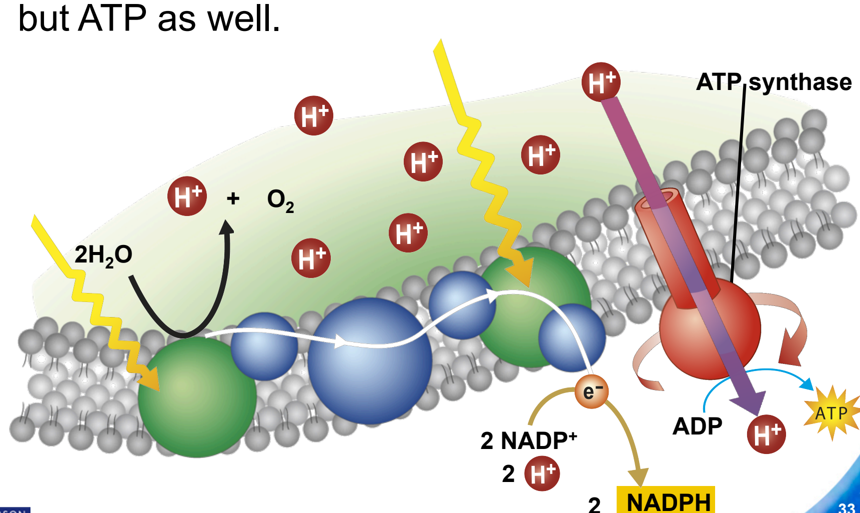
8-3 The Reactions of Photosynthesis ➡ Light-Dependent Reactions

Because of this system, light-dependent electron transport produces not only high-energy electrons but ATP as well.



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The light-dependent reactions use water, ADP, and $NADP^+$.

The light-dependent reactions produce oxygen, ATP, and NADPH.

These compounds provide the energy to build energy-containing sugars from low-energy compounds.

What is the Calvin cycle?

The Calvin Cycle

ATP and NADPH formed by the light-dependent reactions contain an abundance of chemical energy, but they are not stable enough to store that energy for more than a few minutes.

During the **Calvin cycle** plants use the energy that ATP and NADPH contain to build high-energy compounds that can be stored for a long time.

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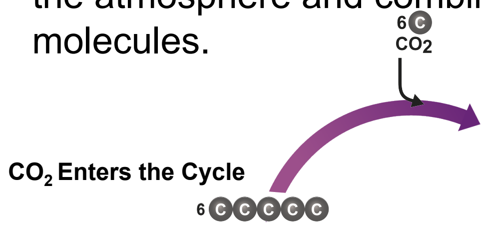
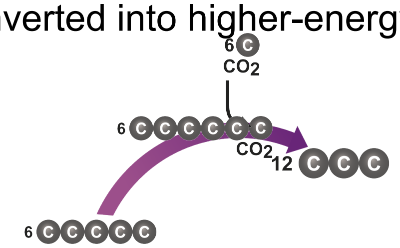
The Calvin cycle uses ATP and NADPH from the light-dependent reactions to produce high-energy sugars.

Because the Calvin cycle does not require light, these reactions are also called the light-independent reactions.

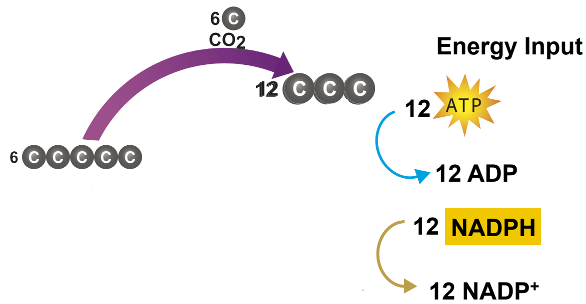
Six carbon dioxide molecules enter the cycle from the atmosphere and combine with six 5-carbon molecules.



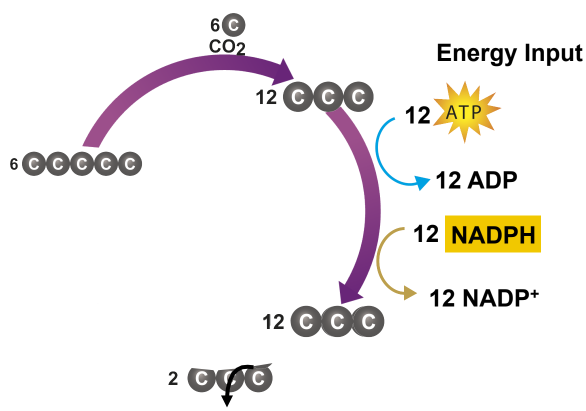
The result is twelve 3-carbon molecules, which are then converted into higher-energy forms.



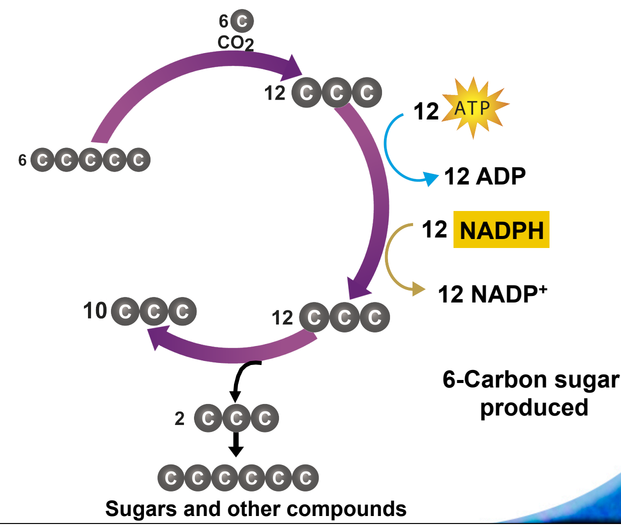
The energy for this conversion comes from ATP and high-energy electrons from NADPH.



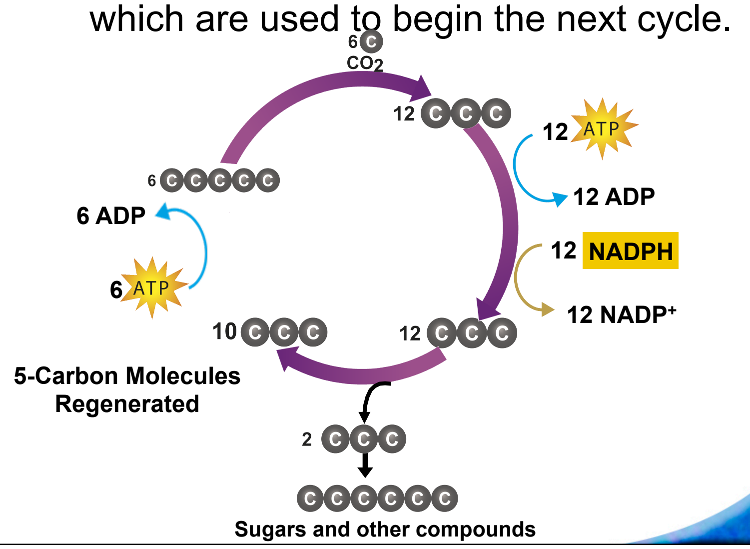
Two of twelve 3-carbon molecules are removed from the cycle.



The molecules are used to produce sugars, lipids, amino acids and other compounds.



The 10 remaining 3-carbon molecules are converted back into six 5-carbon molecules, which are used to begin the next cycle.



The two sets of photosynthetic reactions work together.

- The light-dependent reactions trap sunlight energy in chemical form.
- The light-independent reactions use that chemical energy to produce stable, high-energy sugars from carbon dioxide and water.

Factors Affecting Photosynthesis

Many factors affect the rate of photosynthesis, including:

- Water
- Temperature
- Intensity of light