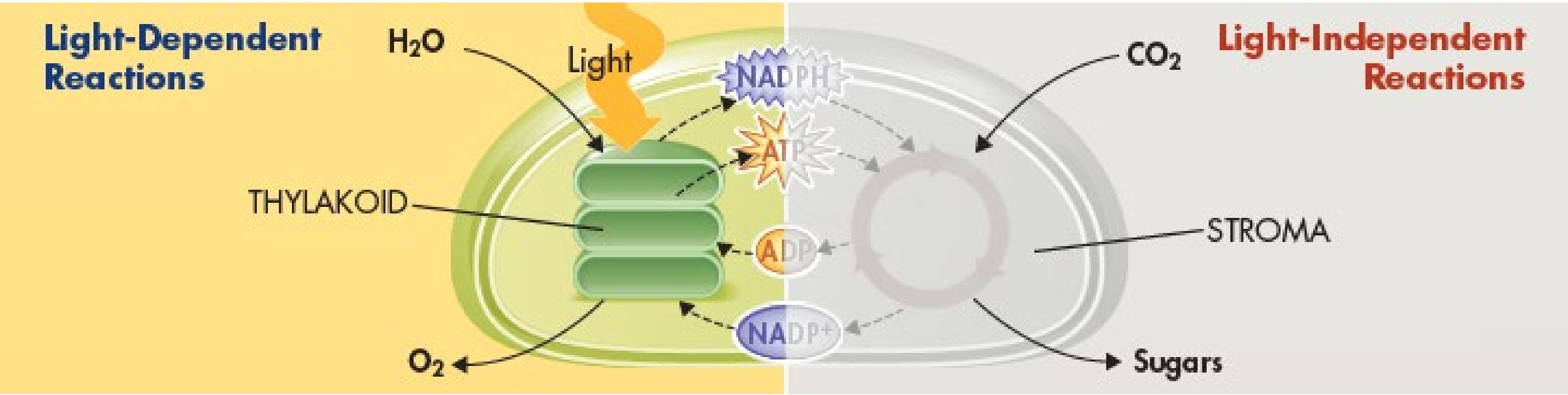
Lesson Overview

9.3 The Process of Photosynthesis

The Light-Dependent Reactions: Generating ATP and NADPH

The light-dependent reactions encompass the steps of photosynthesis that directly involve sunlight.

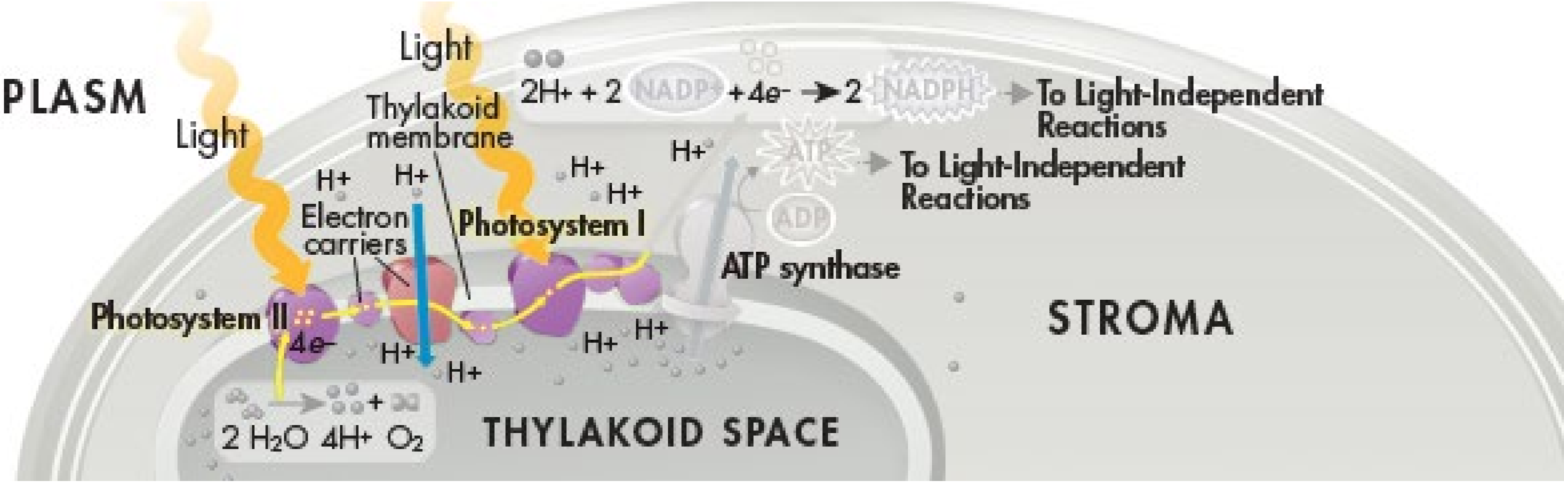
The light-dependent reactions occur in the thylakoids of chloroplasts.



The Light-Dependent Reactions: Generating ATP and NADPH

Thylakoids contain clusters of chlorophyll and proteins known as **photosystems.**

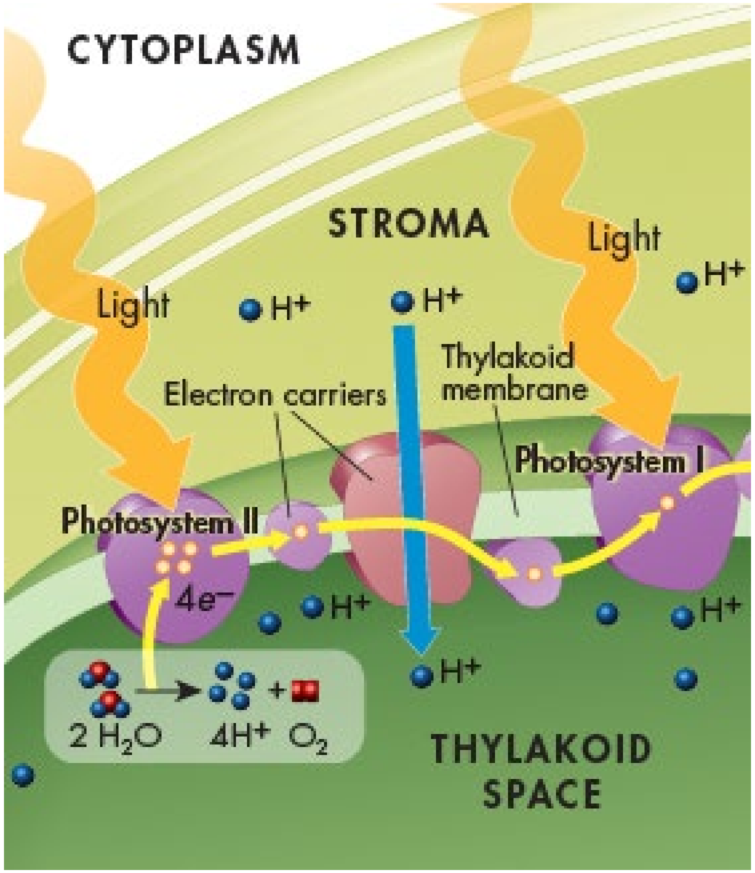
Photosystems absorb sunlight and generate high-energy electrons.



Photosystem II

Light energy is absorbed by electrons in the pigments within photosystem II, increasing the electrons' energy level.

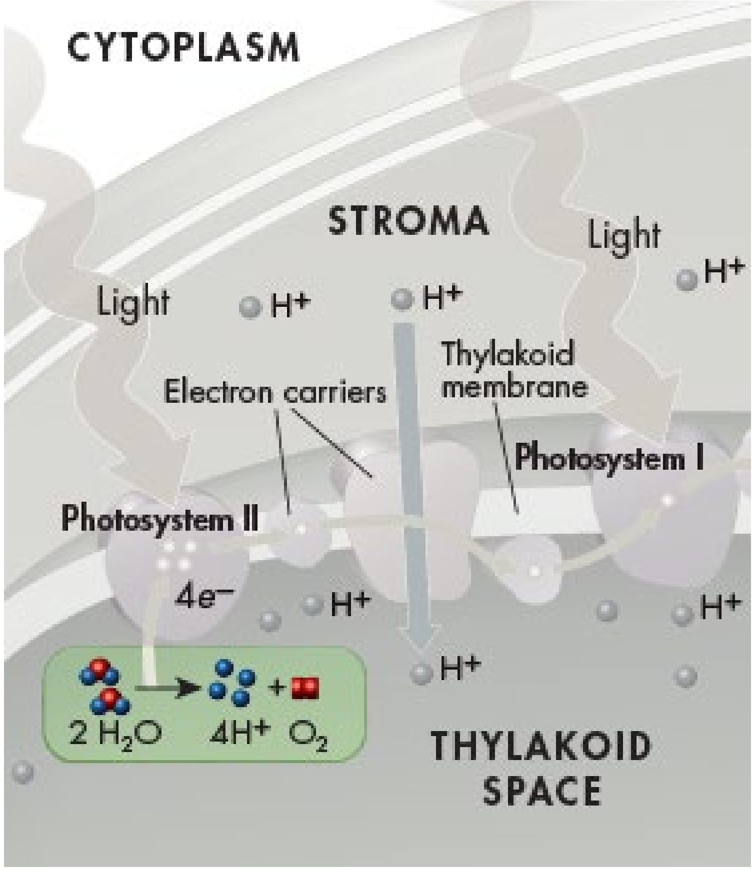
The high-energy electrons are passed to the **electron transport chain**, a series of electron carriers that shuttle high-energy electrons during ATP-generating reactions.



Photosystem II

The thylakoid membrane provides new electrons to chlorophyll from water molecules.

Enzymes of the inner surface of the thylakoid break up water molecules into 2 electrons, 2 H^+ ions, and 1 oxygen atom.

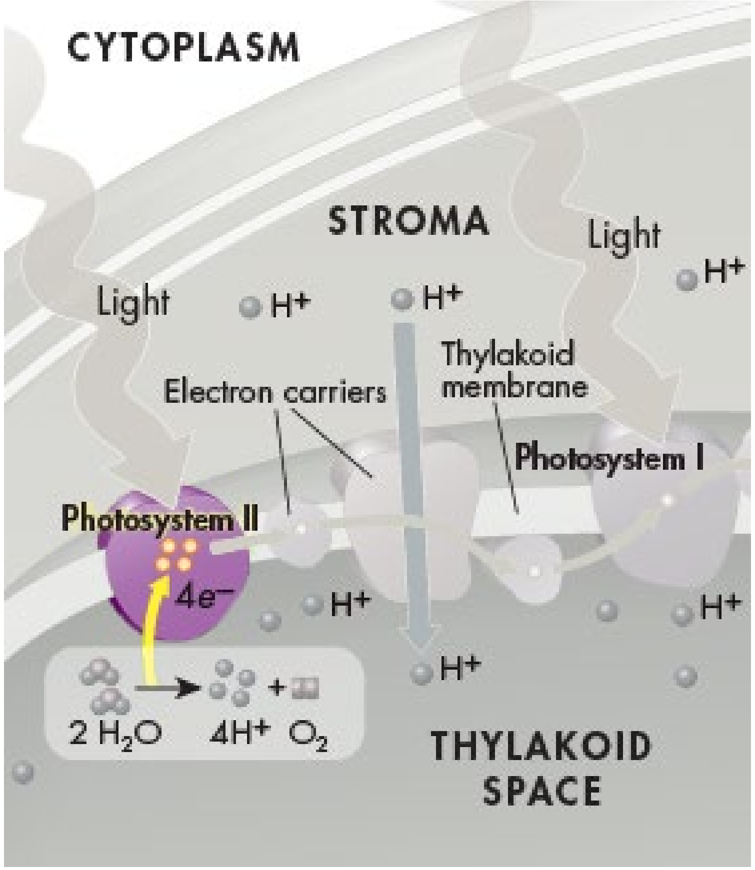


Photosystem II

The 2 electrons replace the high-energy electrons that have been lost to the electron transport chain.

Oxygen is released into the air. This reaction is the source of nearly all of the oxygen in Earth's atmosphere.

The H^+ ions are released inside the thylakoid.



The light reactions of photosynthesis occur in

1. Chloroplast inner membrane
2. Chloroplast outer membrane
3. stroma
4. thylakoids

The oxygen released into the air by photosynthesis comes from

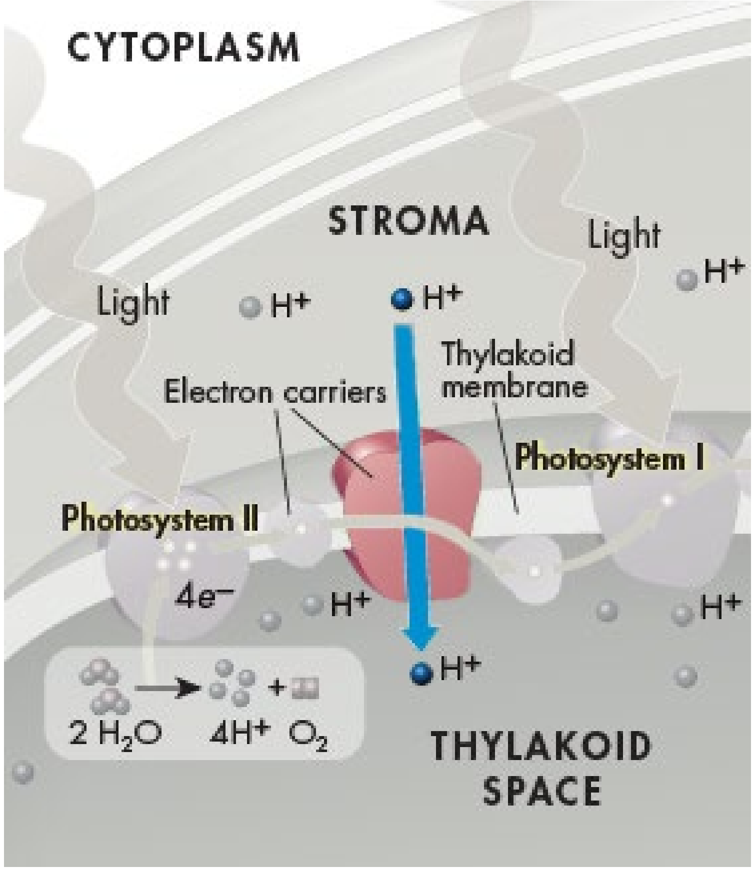
1. Carbon dioxide
2. water
3. glucose
4. sunlight

The light reactions require light.

1. True
2. False

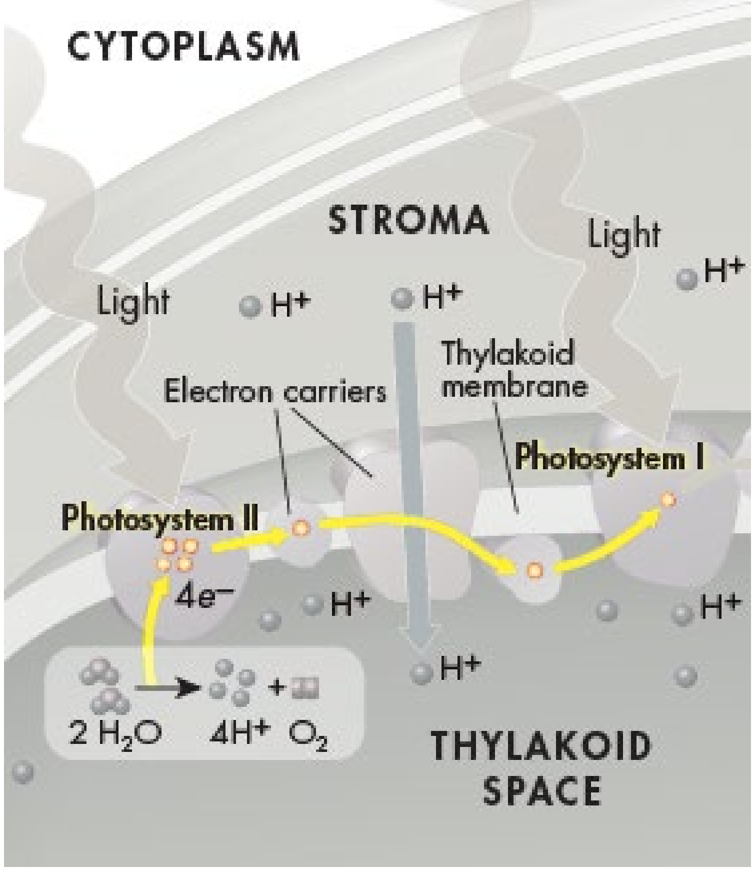
Electron Transport Chain

Energy from the electrons is used by proteins in the electron transport chain to pump H^+ ions from the stroma into the thylakoid space.



Electron Transport Chain

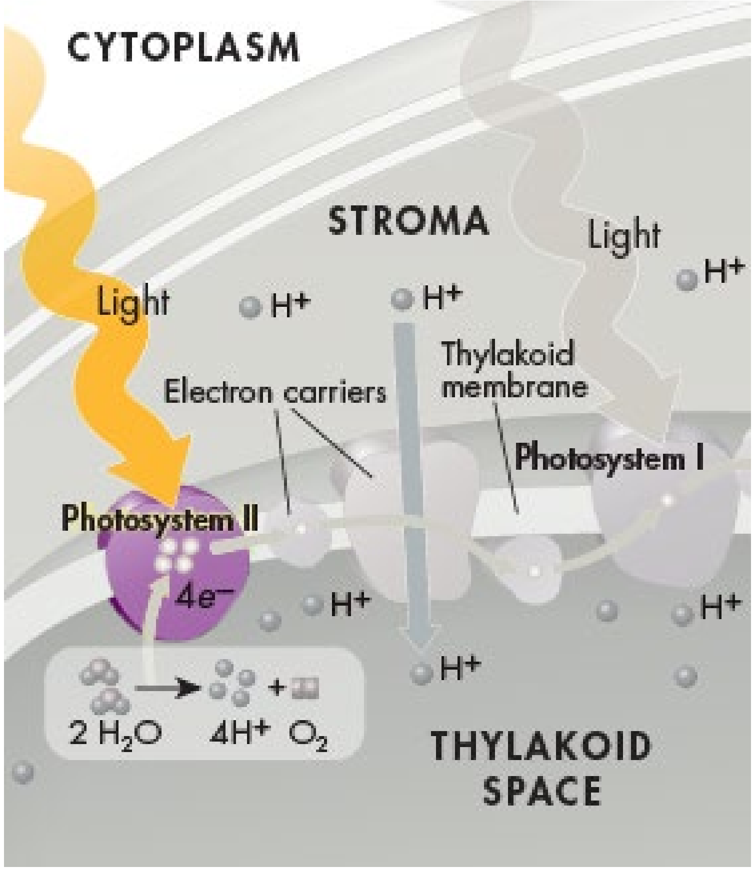
At the end of the electron transport chain, the electrons pass to photosystem I.



Photosystem I

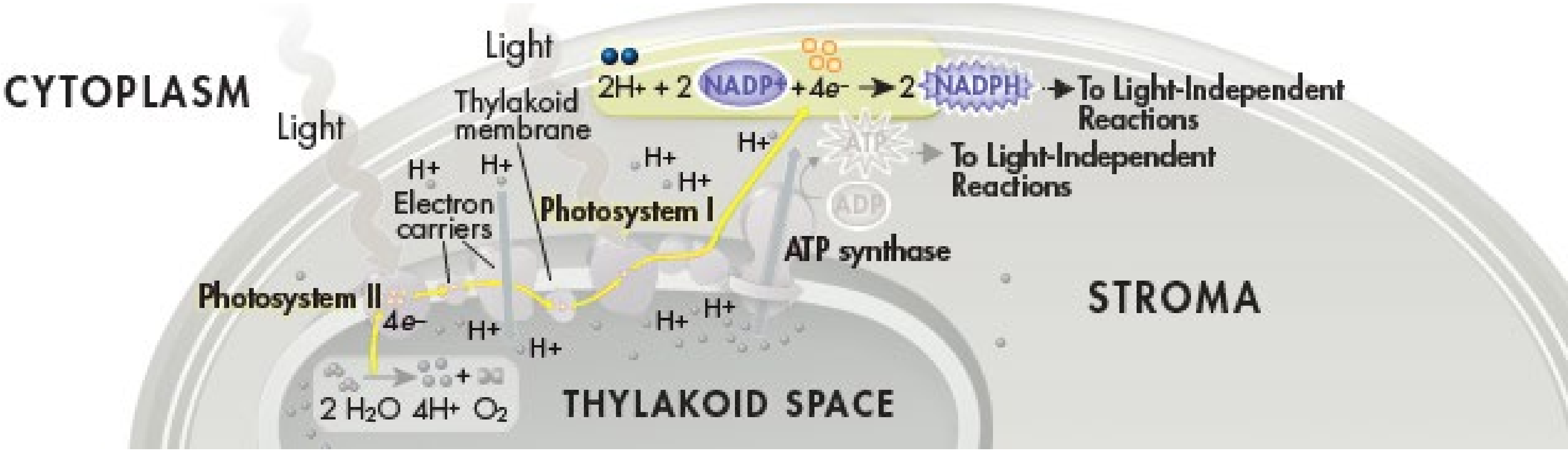
Because some energy has been used to pump H^+ ions across the thylakoid membrane, electrons do not contain as much energy when they reach photosystem I.

Pigments in photosystem I use energy from light to reenergize the electrons.



Photosystem I

At the end of a short second electron transport chain, NADP$^+$ molecules in the stroma pick up the high-energy electrons and H$^+$ ions at the outer surface of the thylakoid membrane to become NADPH.



As electrons are passed through the electron transport chain, they lose energy.

1. True
2. False

Electrons are re-energized at photosystem III.

1. True
2. False

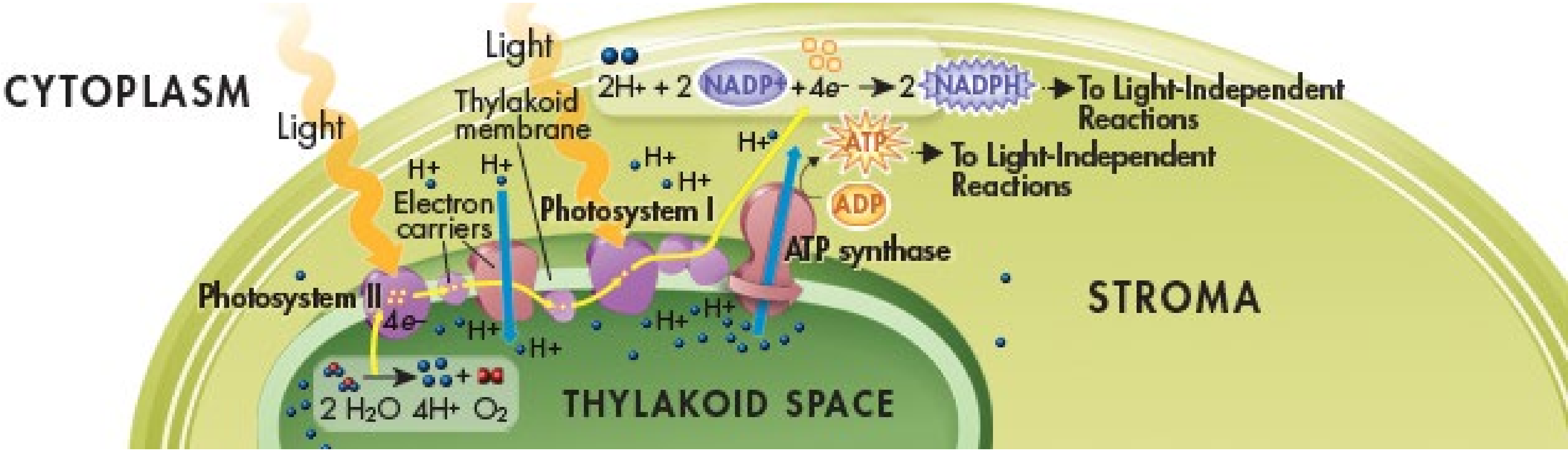
Energized electrons at the end of the light reactions are collected by

1. Carbon dioxide
2. water
3. glucose
4. NADP+

Hydrogen Ion Movement and ATP Formation

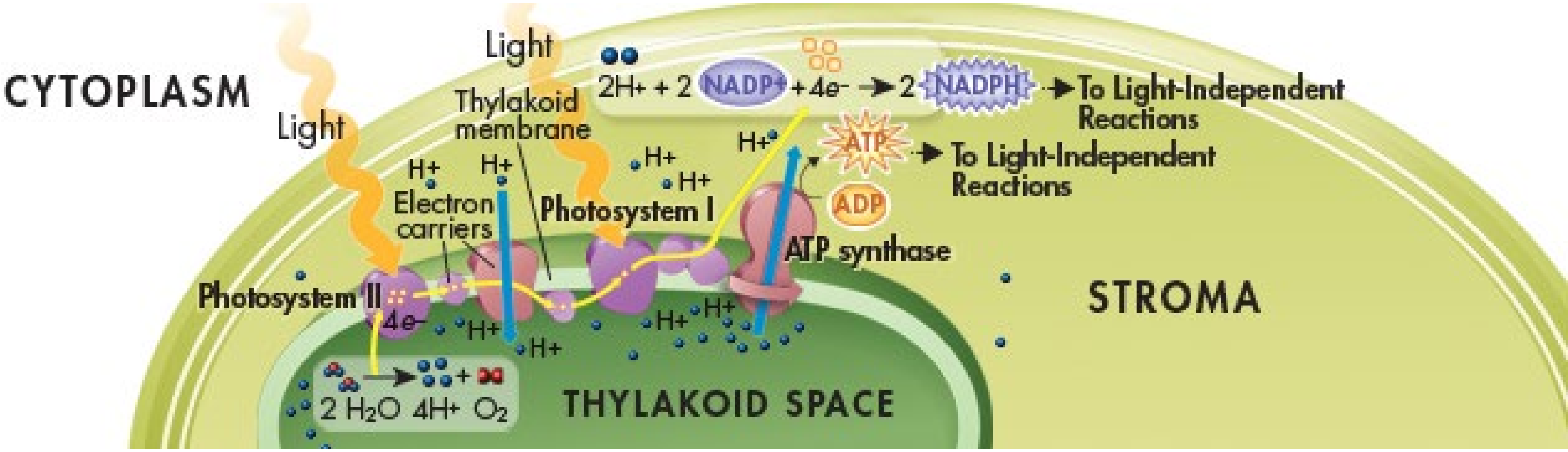
H^+ ions accumulate within the thylakoid space from the splitting of water and from being pumped in from the stroma.

The buildup of H^+ ions makes the stroma negatively charged relative to the space within the thylakoids.



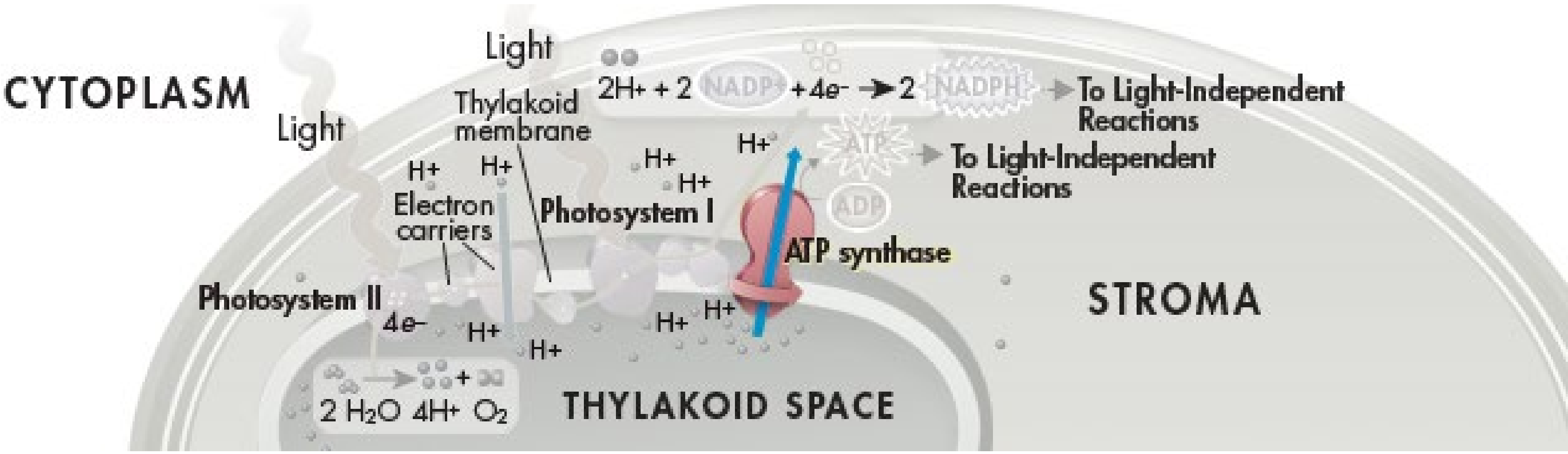
Hydrogen Ion Movement and ATP Formation

This gradient, the difference in both charge and H^+ ion concentration across the membrane, provides the energy to make ATP.



Hydrogen Ion Movement and ATP Formation

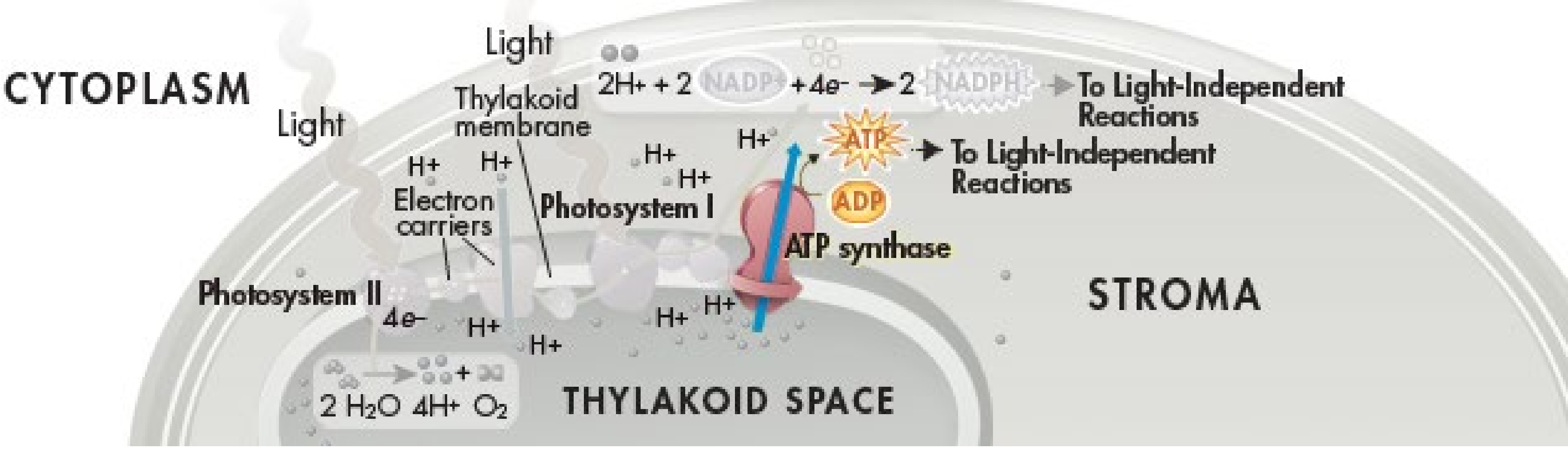
H^+ ions cannot directly cross the thylakoid membane. However, the thylakoid membrane contains a protein called **ATP synthase t**hat spans the membrane and allows H^+ ions to pass through it.



Hydrogen Ion Movement and ATP Formation

Powered by the gradient, H^+ ions pass through ATP synthase and force it to rotate.

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



Hydrogen Ion Movement and ATP Formation

This process, called **chemiosmosis**, enables light-dependent electron transport to produce not only NADPH (at the end of the electron transport chain), but ATP as well.

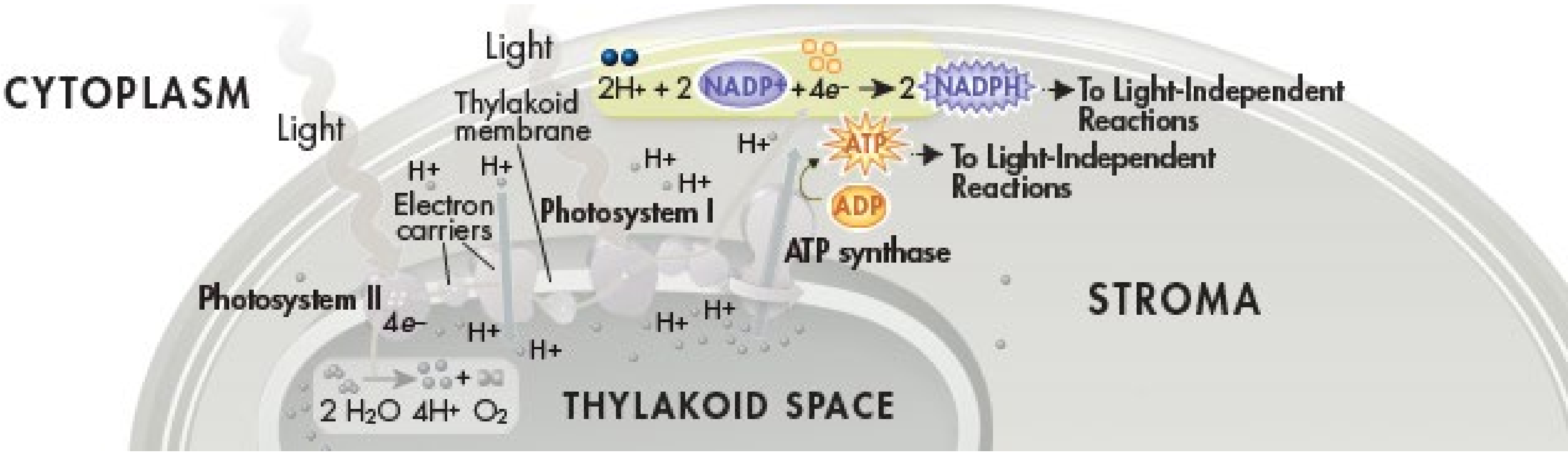


Fig. 10-5-1

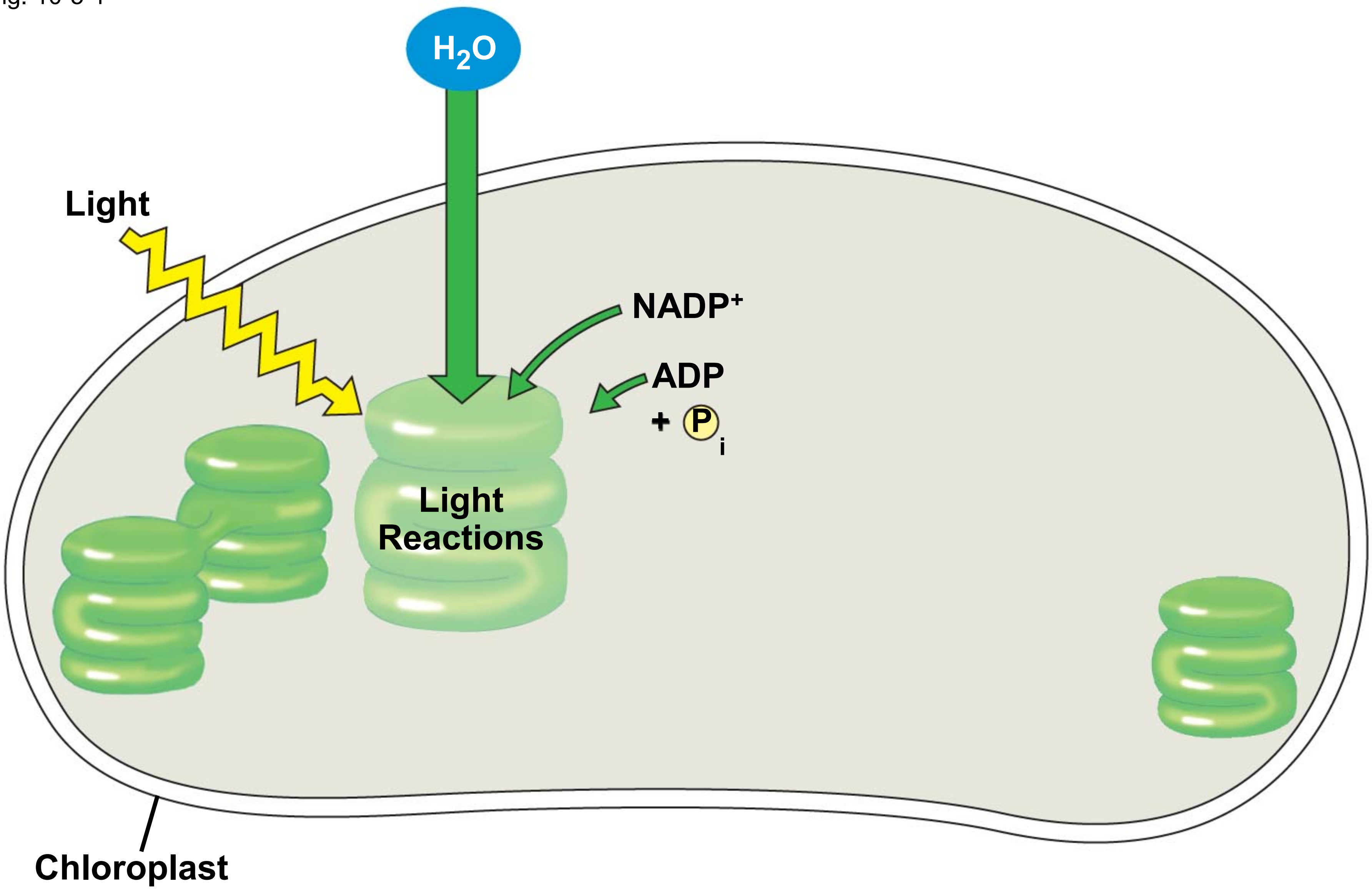


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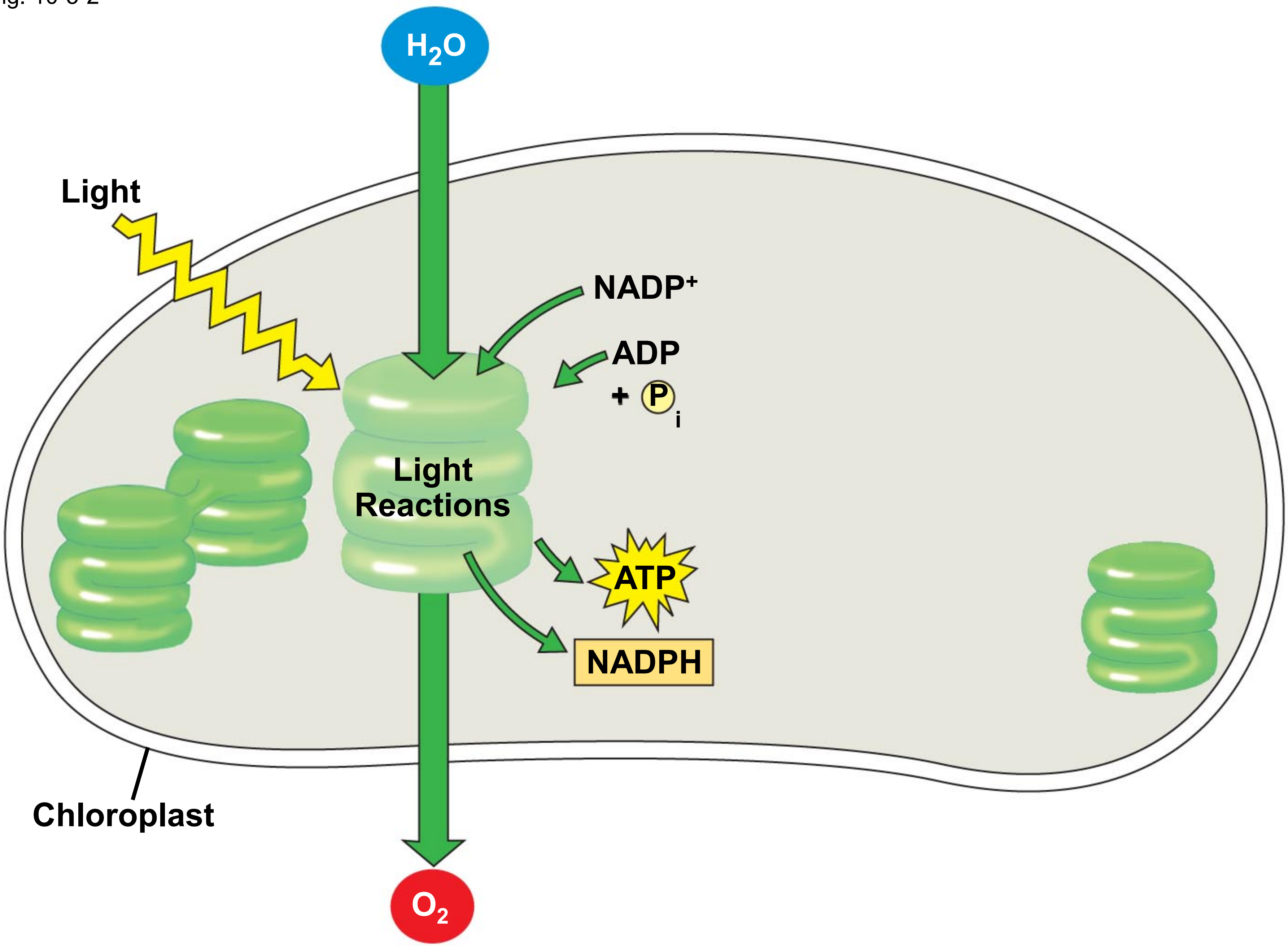
Fig. 10-5-2



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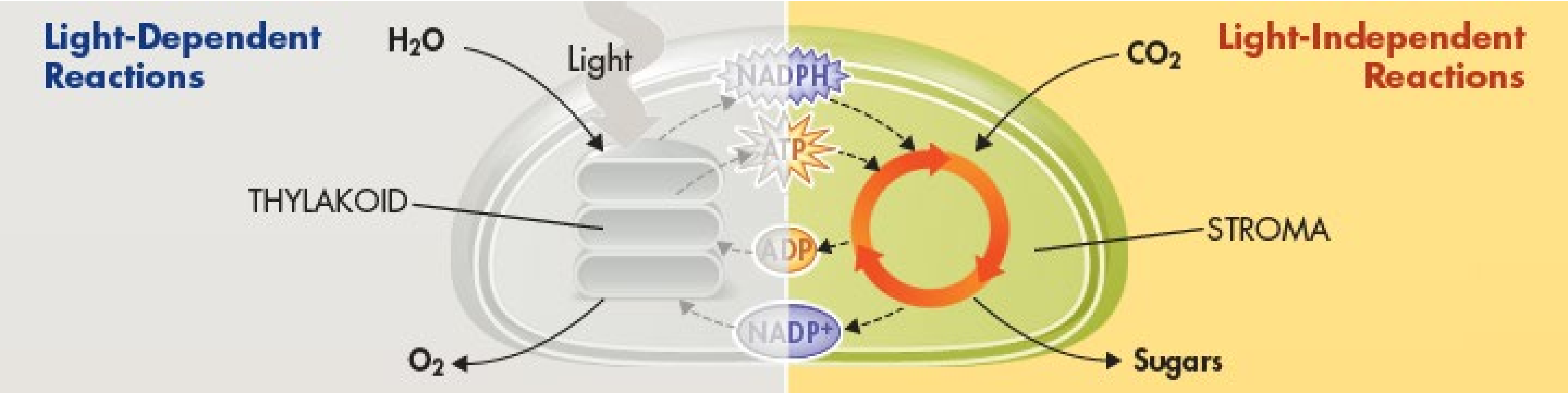
The Light-Independent Reactions: Producing Sugars

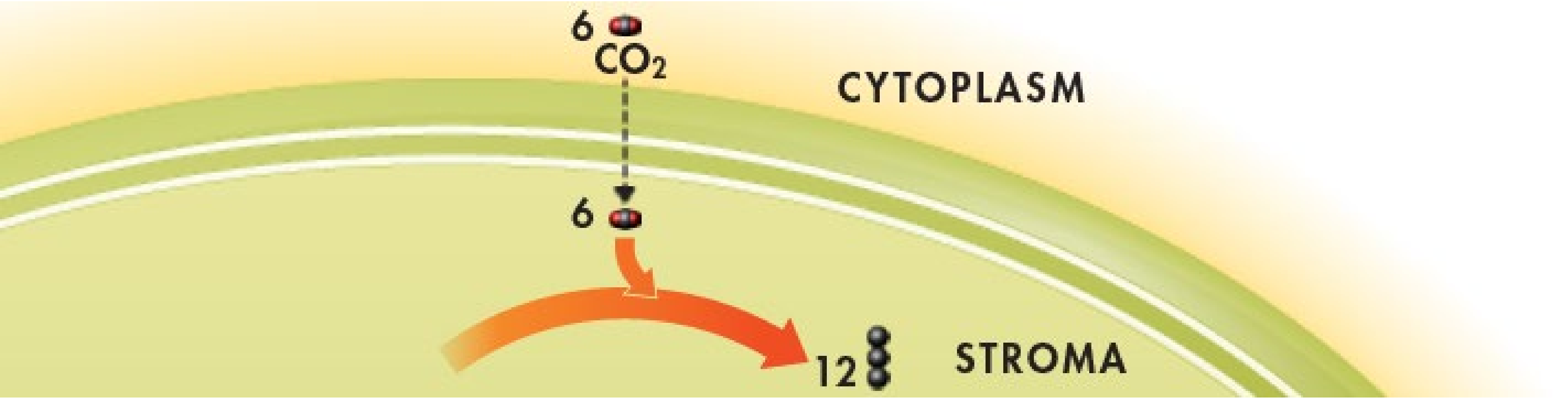
During the light-independent reactions, also known as the **Calvin cycle**, plants use the energy that ATP and NADPH contains to build carbohydrates.



Carbon Dioxide Enters the Cycle

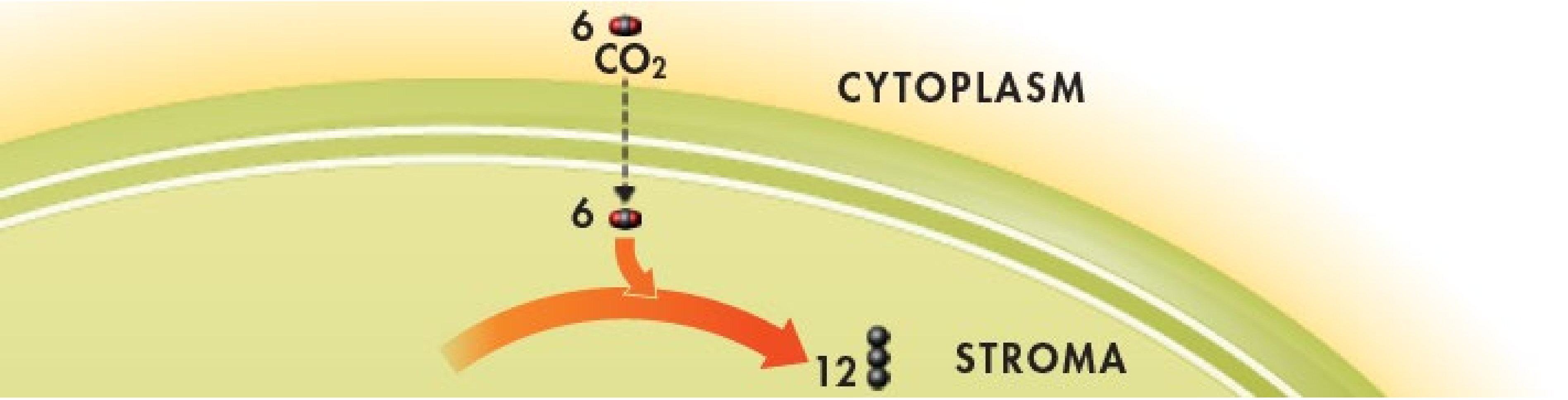
Carbon dioxide molecules enter the Calvin cycle from the atmosphere.

An enzyme in the stroma of the chloroplast combines carbon dioxide molecules with 5-carbon compounds that are already present in the organelle, producing 3-carbon compounds that continue into the cycle.



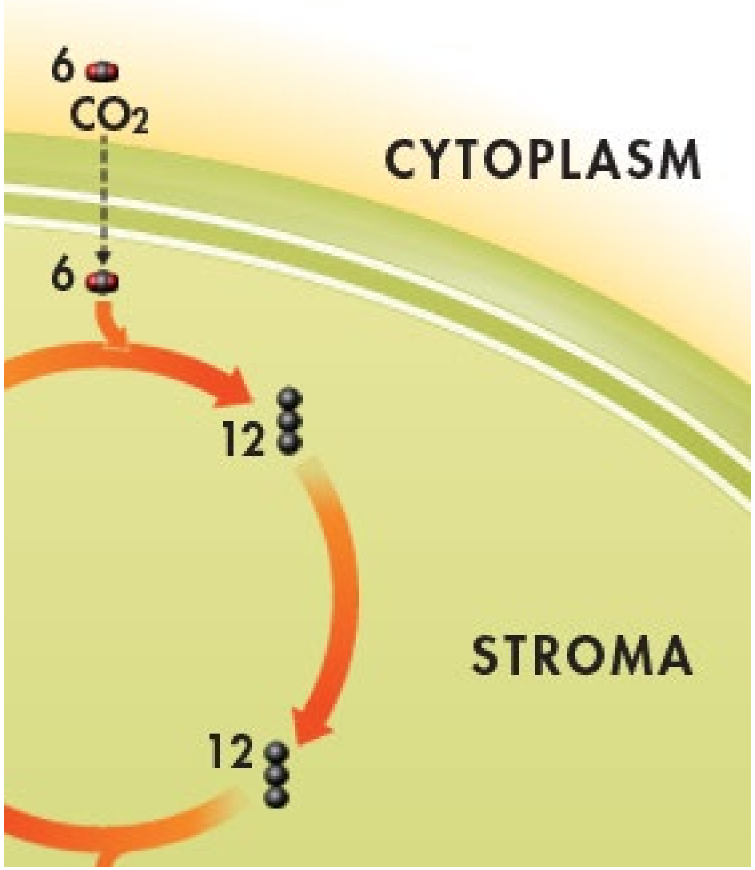
Carbon Dioxide Enters the Cycle

For every 6 carbon dioxide molecules that enter the cycle, a total of twelve 3-carbon compounds are produced.



Carbon Dioxide Enters the Cycle

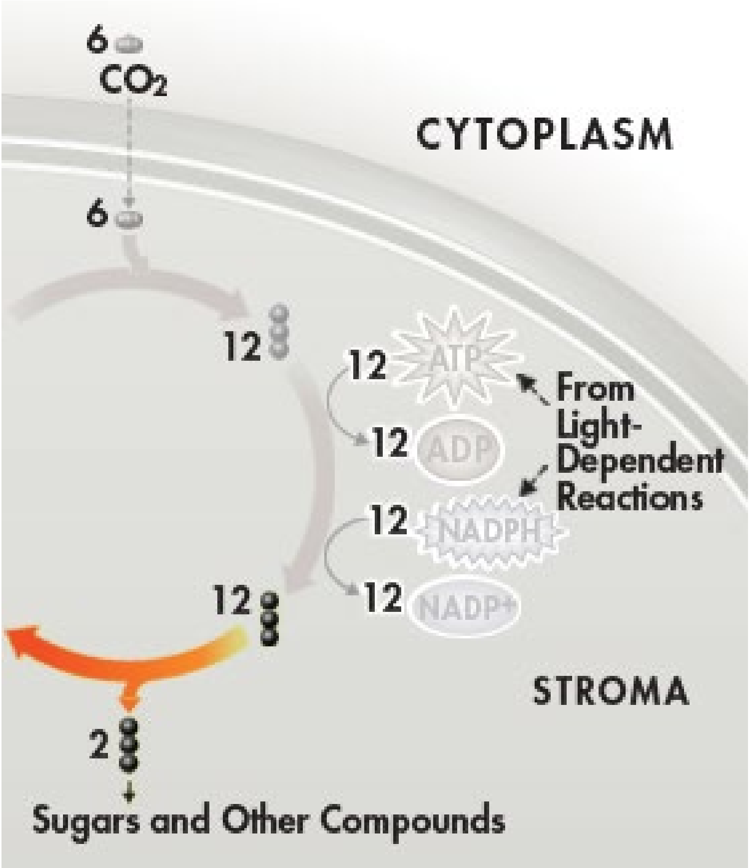
Other enzymes in the chloroplast then convert the 3-carbon compounds into higher-energy forms in the rest of the cycle, using energy from ATP and high-energy electrons from NADPH.



Sugar Production

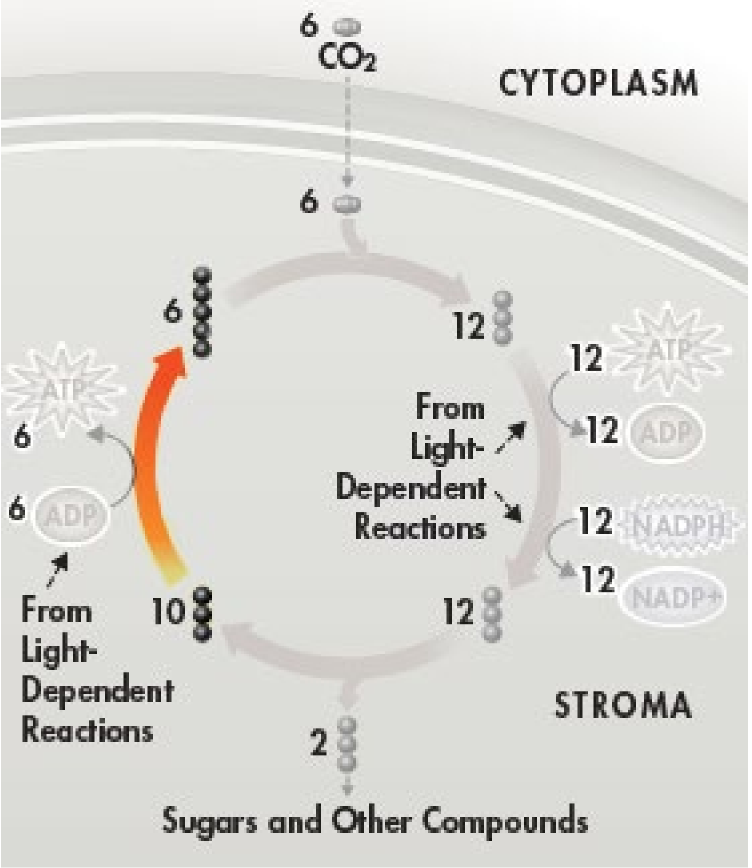
At midcycle, two of the twelve 3-carbon molecules are removed from the cycle.

These molecules become the building blocks that the plant cell uses to produce sugars, lipids, amino acids, and other compounds.



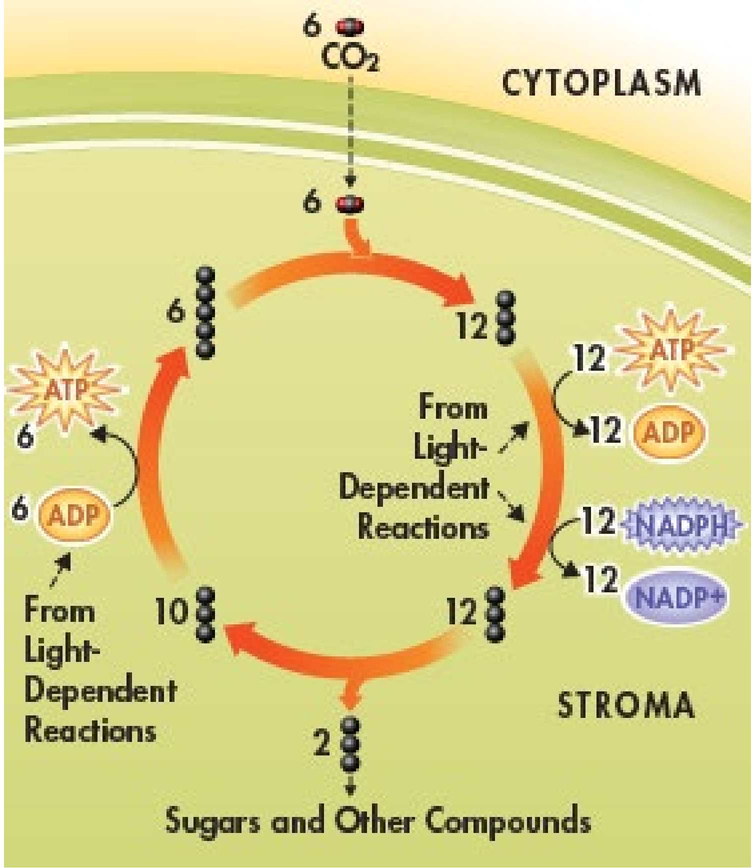
Sugar Production

The remaining ten 3-carbon molecules are converted back into six 5-carbon molecules that combine with six new carbon dioxide molecules to begin the next cycle.



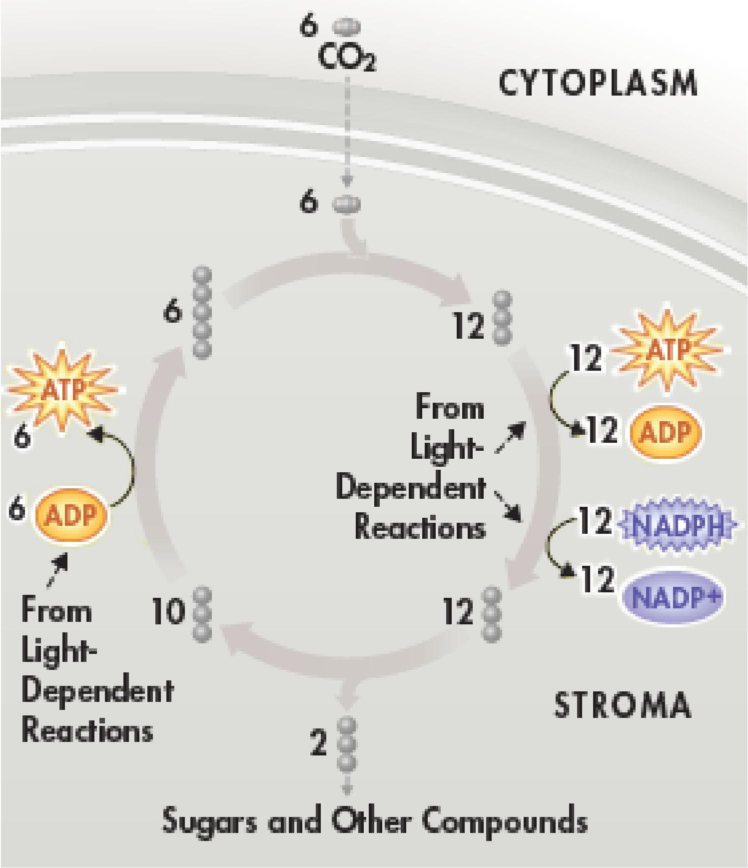
Summary of the Calvin Cycle

The **Calvin cycle** uses 6 molecules of carbon dioxide to produce a single 6-carbon sugar molecule.



Summary of the Calvin Cycle

The energy for the reactions is supplied by compounds produced in the light-dependent reactions.



Summary of the Calvin Cycle

The plant uses the sugars produced by the Calvin cycle to meet its energy needs and to build macromolecules needed for growth and development.

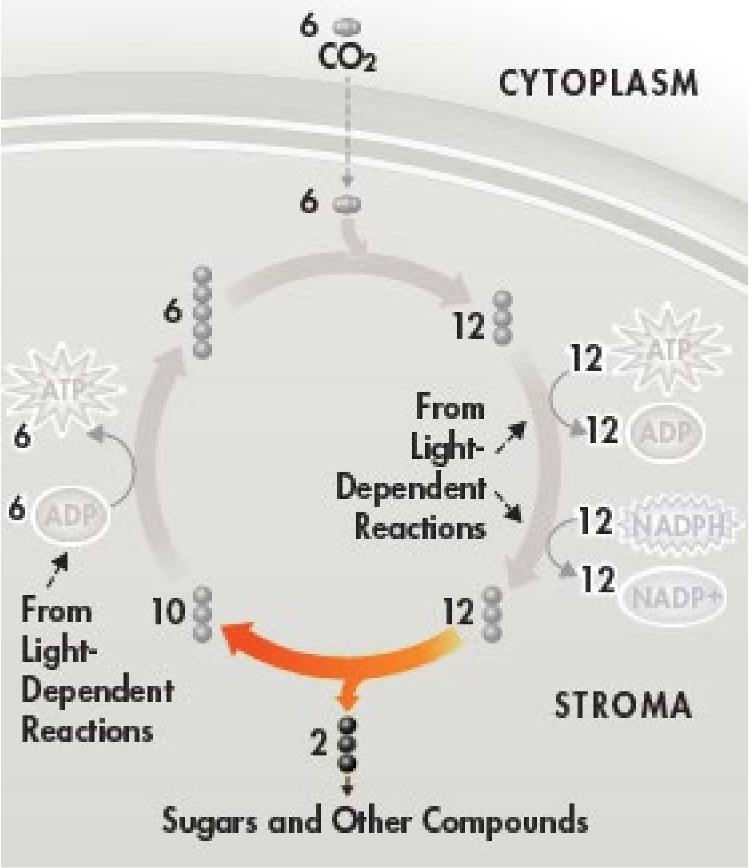


Fig. 10-5-1

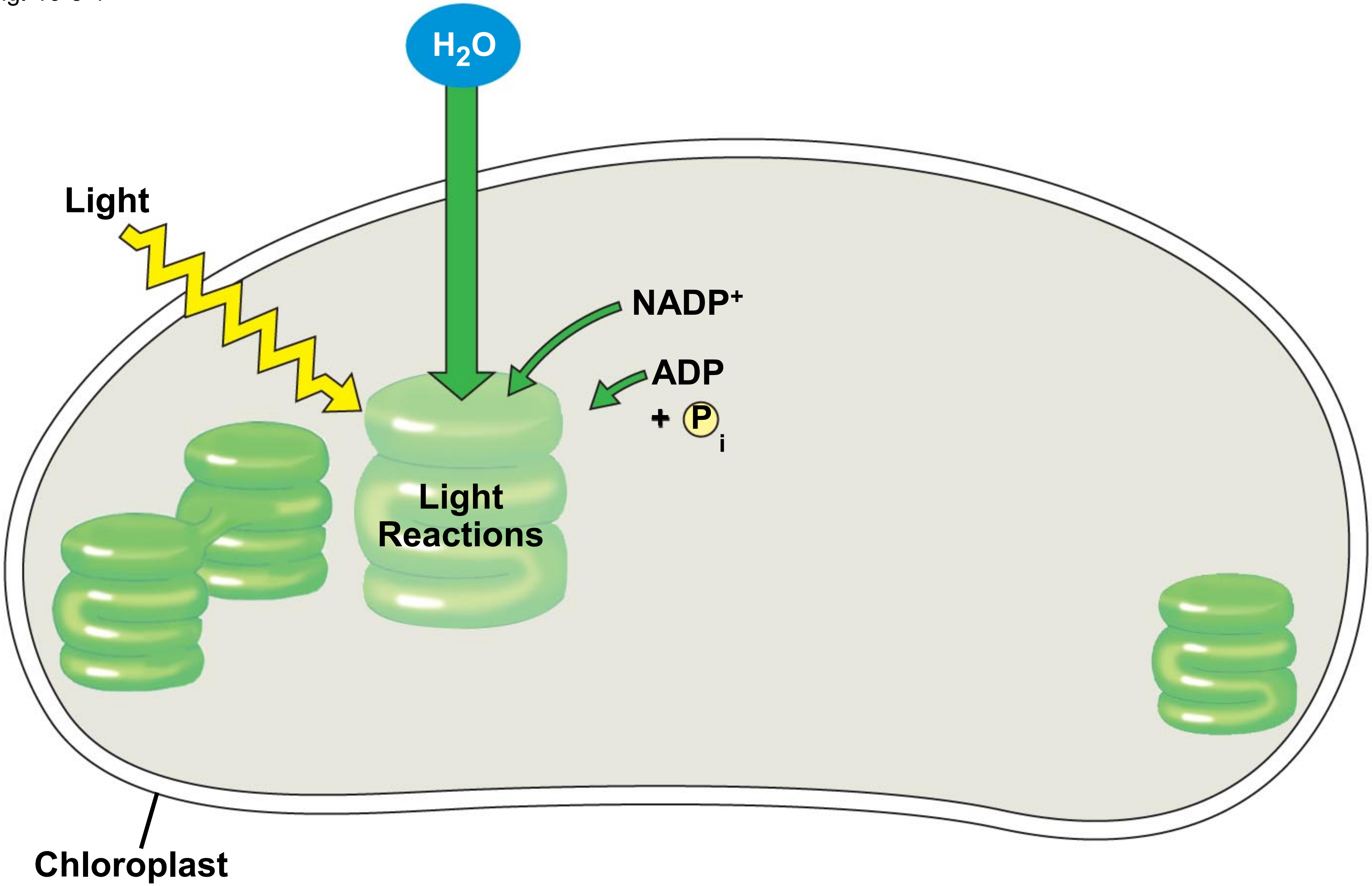


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Fig. 10-5-2

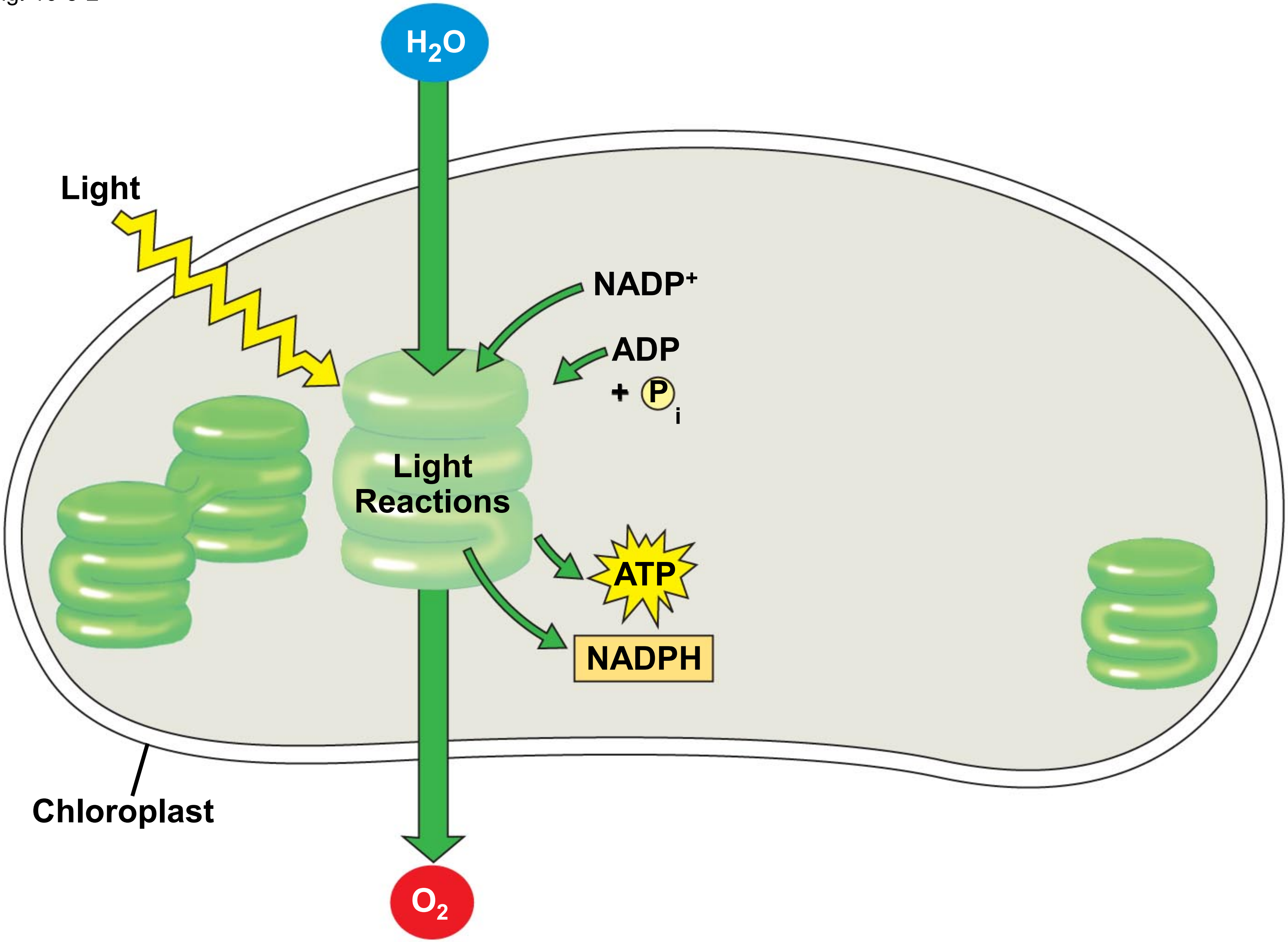

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Fig. 10-5-3

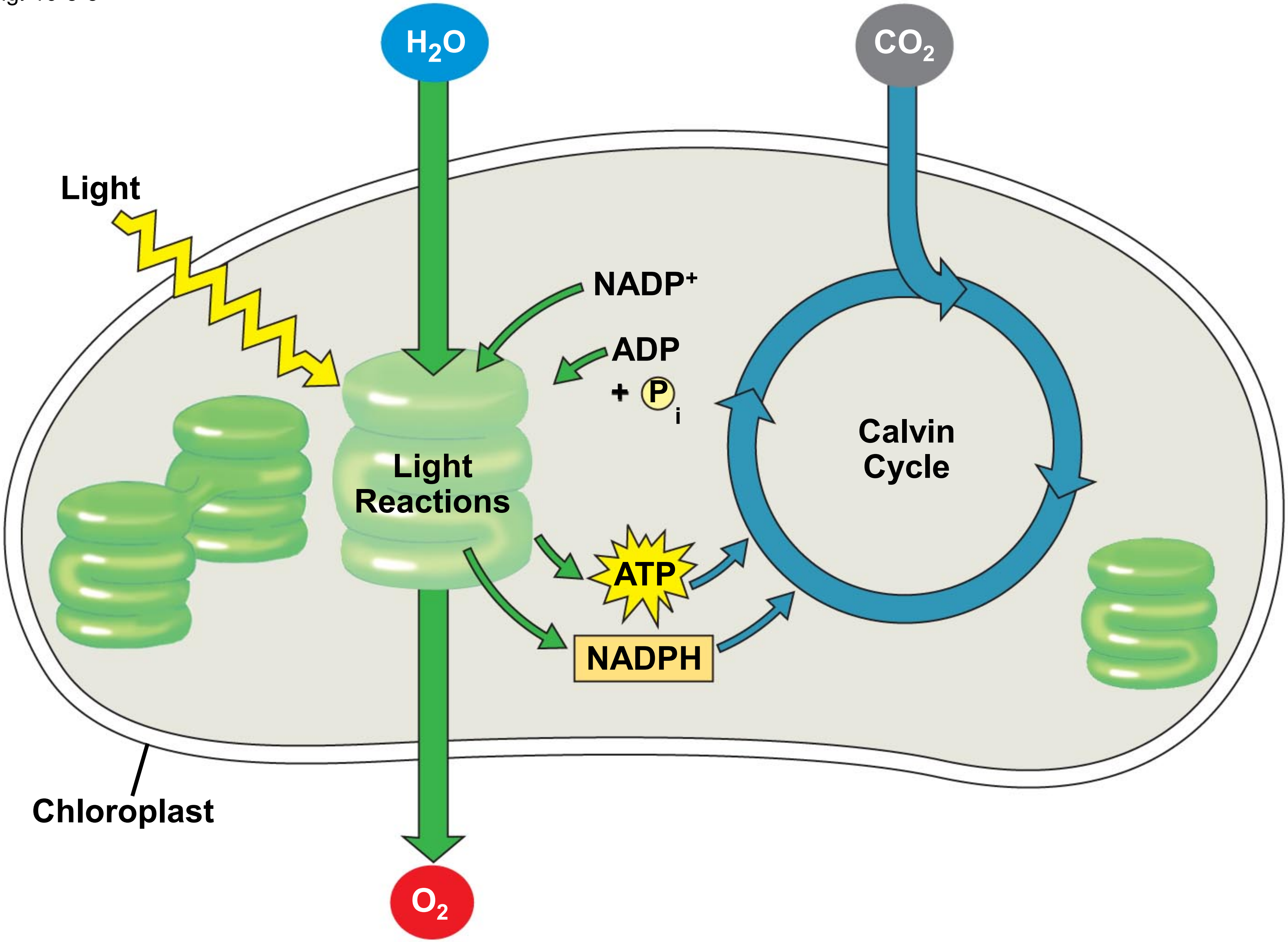

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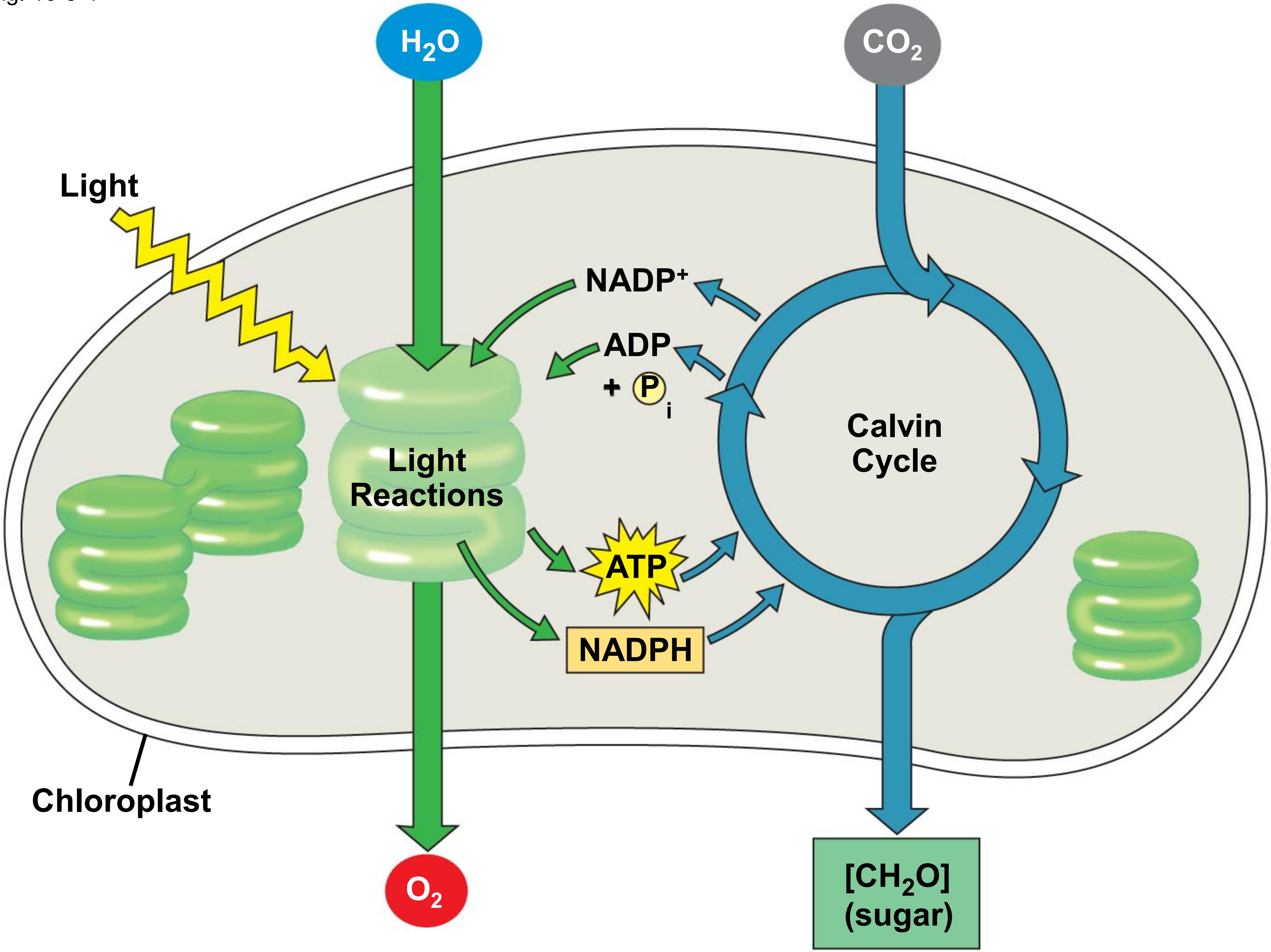
Fig. 10-5-4



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In order to function properly, the Calvin cycle needs

1. ATP
2. NADPH
3. Carbon dioxide
4. all of the above

The Calvin cycle occurs in

1. Chloroplast inner membrane
2. Chloroplast outer membrane
3. stroma
4. thylakoids

Temperature, Light, and Water

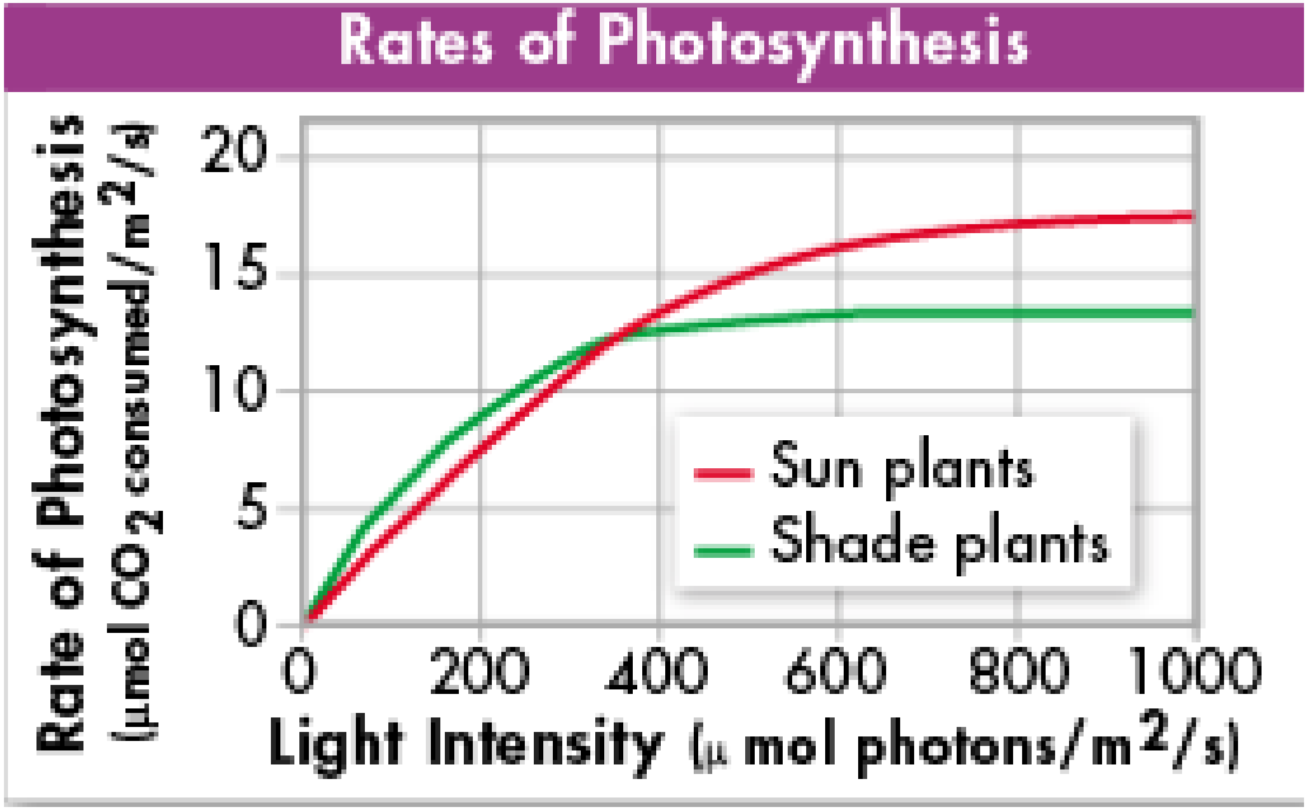
The reactions of photosynthesis are made possible by enzymes that function best between 0° C and 35° C.

Temperatures above or below this range may affect those enzymes, slowing down the rate of photosynthesis or stopping it entirely.

Temperature, Light, and Water

High light intensity increases the rate of photosynthesis.

After the light intensity reaches a certain level, the plant reaches its maximum rate of photosynthesis.



Temperature, Light, and Water

a shortage of water can slow or even stop photosynthesis.

Water loss can also damage plant tissues.

Photosynthesis Under Extreme Conditions

C4 and CAM plants have biochemical adaptations that minimize water loss while still allowing photosynthesis to take place in intense sunlight.

C4 Photosynthesis

C4 plants have a specialized chemical pathway that allows them to capture even very low levels of carbon dioxide and pass it to the Calvin cycle.

The name “C4 plant” comes from the fact that the first compound formed in this pathway contains 4 carbon atoms.

The C4 pathway requires extra energy in the form of ATP to function.

C4 organisms include crop plants like corn, sugar cane, and sorghum.

CAM Plants

CAM (**Crassulacean Acid Metabolism**) plants admit air into their leaves only at night, where carbon dioxide is combined with existing molecules to produce organic acids, “trapping” the carbon within the leaves.

During the daytime, when leaves are tightly sealed to prevent water loss, these compounds release carbon dioxide, enabling carbohydrate production.

CAM plants include pineapple trees, many desert cacti, and “ice plants”.