Chapter 7 PHOTOSYNTHESIS

The raw materials of photosynthesis, water and carbon dioxide, enter the cells of the leaf, and the products of photosynthesis, sugar and oxygen, leave the leaf.

The capture of solar energy by photosynthetic organisms and its conversion to the chemical energy of reduced organic compounds is the ultimate source of nearly all biological energy.

In plants encompasses two processes: the **light-dependent reactions,** or **light reactions,** which occur only when plants are illuminated, and the **carbon-assimilation reactions** (or **carbon fixation reactions**).

In the light reactions, chlorophyll and other pigments of photosynthetic cells absorb light energy and conserve it as ATP and NADPH; simultaneously, O2 is evolved.

In the carbon-assimilation reactions, ATP and NADPH are used to reduce CO2 to form triose phosphates, starch, and sucrose, and other products derived from them.

Photosynthesis in Plants Takes Place in Chloroplasts

Chloroplasts are surrounded by two membranes. This compartment contains many flattened, membrane-surrounded vesicles or sacs, the **thylakoids,** usually arranged in stacks called **grana**. Embedded in the thylakoid membranes (commonly called **lamellae**) are the photosynthetic pigments and the enzyme complexes that carry out the light reactions and ATP synthesis. The **stroma** contains most of the enzymes required for the carbon assimilation reactions.

Light Drives Electron Flow in Chloroplasts

Hill reaction:

The reaction was the first evidence that absorbed light energy causes electrons to flow from H2O to an electron acceptor.

Light Absorption

Chlorophylls Absorb Light Energy for Photosynthesis

The most important light-absorbing pigments in the thylakoid membranes are the **chlorophylls.**

Accessory Pigments Extend the Range of Light Absorption

In addition to chlorophylls, thylakoid membranes contain secondary light-absorbing pigments, or **accessory pigments,** called carotenoids. **Carotenoids** may be yellow, red, or purple. The most important are _**-carotene,** which is a red-orange isoprenoid, and the yellow carotenoid **lutein.**

Chlorophyll Funnels the Absorbed Energy to Reaction Centers by Exciton Transfer

All the pigment molecules in a photosystem can absorb photons, but only a few chlorophyll molecules associated with the photochemical reaction center are specialized to transduce light into chemical energy.

The Central Photochemical Event: Light-Driven Electron Flow

Light-driven electron transfer in plant chloroplasts during photosynthesis is accomplished by multienzyme systems in the thylakoid membrane.

Cyanobacteria and plants have two different photoreaction centers, arranged in tandem. This “Z scheme” shows the pathway of electron transfer from H_2O to $NADP^+$ in noncyclic photosynthesis.

■ Plant photosystem I passes electrons from its excited reaction center, P700, through a series of carriers to ferredoxin, which then reduces $NADP^+$ to NADPH.

■ The reaction center of plant photosystem II, P680, passes electrons to plastoquinone, and the electrons lost from P680 are replaced by electrons from H_2O.

ATP Synthesis by Photophosphorylation

In the Z scheme, while electrons moves from water to $NADP^+$, simultaneously, protons are pumped across the thylakoid membrane and energy is conserved as an electrochemical potential. This proton gradient drives the synthesis of ATP.

Photosynthetic Carbohydrate Synthesis

Green plants contain in their chloroplasts unique enzymatic machinery that catalyzes the conversion of CO_2 to simple organic compounds, a process called **CO_2 assimilation.** This process has been called **CO_2 fixation** or **carbon fixation, and is also often called the Calvin cycle.**

Carbon Dioxide Assimilation Occurs in Three Stages

The CO_2-assimilating reactions (the Calvin cycle) occur in three stages: the fixation reaction itself, catalyzed by **rubisco**. Rubisco condenses CO_2 with ribulose 1,5-bisphosphate and splits into two molecules of 3-phosphoglycerate.

Photorespiration and the C4 and CAM Pathways

In plants that, like mitochondrial respiration, consumes O_2 and produces CO_2 and, like photosynthesis, is driven by light. This process, photorespiration, is a costly side reaction of photosynthesis, a result of the lack of specificity of the enzyme rubisco.

Photorespiration Results from Rubisco’s Oxygenase Activity

In C4 Plants, CO_2 Fixation and Rubisco Activity Are Spatially Separated

In C4 plants, the carbon-assimilation pathway minimizes photorespiration: CO_2 is first fixed in mesophyll cells into a four-carbon compound, which passes into bundle-sheath cells and releases CO_2 in high concentrations.