Chapter 7
Capturing Solar Energy: Photosynthesis
What is Photosynthesis?

**Answer:** The capture of sunlight energy and the subsequent storage of that energy in chemical bonds

- **Chemical Bonds** = Glucose and Oxygen

**Chemical Reaction:**

\[
6 \text{ CO}_2 + 6 \text{ H}_2\text{O} + \text{ Light Energy} = \text{ C}_6\text{H}_{12}\text{O}_6 + 6 \text{ O}_2
\]

- **Carbon Dioxide**
- **Water**
- **Glucose**
- **Oxygen**

**Autotrophs** (“self-feeders”):

- Plants (Eukaryotes)
- Algae (Eukaryotes)
- Bacteria (Prokaryotes)
Leaves and Chloroplasts are Adaptations for Photosynthesis:

Leaf Design:

- Flattened shape (large surface area)
- Thin (light can penetrate entire leaf)
- Surrounded by a Cuticle:
  - Waxy covering that prevents water loss
- Contain Stomata:
  - Adjustable openings that regulate CO₂ uptake and O₂ release
- Filled with Mesophyll Cells:
  - Contain majority of chloroplast organelles
- Contain Vascular Bundles (Veins):
  - Supply water/minerals; Carry away sugars
Leaf Structure: (Figure 7.2)
Leaves and chloroplasts are adaptations for photosynthesis:

**Chloroplast Design:**

- Contain two membranes (inner and outer)
- Filled with **Stroma**:
  - Semi-fluid medium (light-independent reactions)
- Contain stacks of **Thylakoids (Grana)**:
  - Location of chlorophyll (light dependent reactions)
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Chloroplast Structure:
Overview of Photosynthesis:

(Figure in Text)
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**Light Dependant Reactions:**
The Conversion of Light Energy to Chemical Energy

1) Light is first captured by pigments in chloroplast
   - **Photon**: Packet of light energy
   - When photon hits leaf, the light is either:
     1) Absorbed
     2) Reflected (bounced back)
     3) Transmitted (passes through)
   - Chlorophyll and accessory pigments (e.g. carotenoids) absorb specific wavelengths of light
Pigment Absorption:

**Chlorophyll:**
- Blue & red light

**Carotenoids:**
- Blue & green light

**Phycocyanins:**
- Green & yellow light

(Figure 7.3)
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**Light Dependant Reactions:**
The Conversion of Light Energy to Chemical Energy

2) Light energy transferred to energy-carrier molecules
   - Reactions clustered in **Photosystems** (located in Thylakoids)
     1) Light-harvesting Complex (Gathers light)
     2) Electron Transport System (Energy-carrier molecules)
   - Photosystems utilize light energy to produce an energy transport molecule
     - **Photosystem II** generates ATP
     - **Photosystem I** generates NADPH
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Sequence of Events in Light Dependent Reactions:

Photosystem II:

1) Light energy excites electron in light-harvesting complex
2) Electron transport system accepts excited electron
3) ETS uses electron energy to synthesis ATP (chemiosmosis)
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Sequence of Events in Light Dependent Reactions:

**Photosystem I** (same time as photosystem II):

1) Light energy excites electron in light-harvesting complex
2) Electron transport system accepts excited electron
3) ETS captures electron to form NADPH

![Diagram of Photosynthesis](image)
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Sequence of Events in Light Dependent Reactions:

- Electrons lost in Photosystem I are replaced by electrons from Photosystem II:

![Diagram of photosynthesis sequence](image-url)
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Sequence of Events in Light Dependent Reactions:

- Electrons lost from Photosystem II are replaced by splitting water to form oxygen
Light-dependent Reactions:

(Figure 7.4)
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Light Independent Reactions:
Energy is Stored in Glucose Molecules

CO₂ + H₂O → C₆H₁₂O₆

- Energy from ATP & NADPH are necessary to drive process
- Occurs in stroma of the chloroplast
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**Calvin-Benson Cycle:** Set of reactions which capture carbon dioxide (C3 Cycle) 

Requires:

1) Carbon Dioxide (from air)
2) **Ribulose Bisphosphate** (RuBP): CO$_2$ capturing sugar
3) Multiple enzymes (catalyze reactions)
4) Energy (ATP & NADPH)
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Sequence of Events in Calvin-Benson (C₃) Cycle:

1) **Carbon Fixation**
   - CO₂ combines with ribulose bisphosphate (RuBP) to form phosphoglyceric acid (PGA)

2) **PGA is converted to glyceraldehyde-3-phosphate (G3P)**
   - Requires energy
   - G3P converted into glucose (1 glucose from 6 CO₂)

3) **G3P converted back to RuBP (requires energy)**

![Diagram of Calvin-Benson Cycle]

- CO₂ + H₂O → RuBP → PGA → ATP, NADPH → G3P → Glucose
Fate of Glucose:

1) Broken down for energy
2) Stored as starch (energy storage)
3) Converted to cellulose (structure)
4) Other chemical modifications (e.g. glycoprotein)
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Plants must balance between obtaining CO$_2$ and H$_2$O loss

- Cool, wet conditions $\rightarrow$ stomata open (plenty CO$_2$)
- Hot, dry conditions $\rightarrow$ stomata close (low CO$_2$)
  - Photosynthesis inefficient (photorespiration)

Plants living in arid conditions (e.g. corn) use C$_4$ pathway:

- CO$_2$ initially captured as oxaloacetate (mesophyll cells)
- Oxaloacetate releases CO$_2$ to bundle-sheath cells where photosynthesis continues as normal (↑ [CO$_2$])
C₄ Pathway:

In a C₄ plant, both mesophyll and bundle-sheath cells contain chloroplasts.
Photosynthesis Review:

Light-dependent reactions occur in thylakoids.

Light-independent reactions (C₃ cycle) occur in stroma.