Photosynthesis: Using Light to Make Food (Slide 14)

§1 The Basic of Photosynthesis

1. Photosynthesis

1° is used by plants, algae (藻类) (protists 原生生物), and certain bacteria.

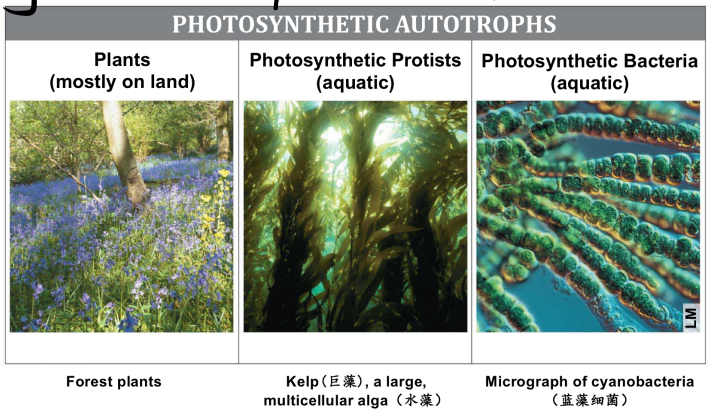
2° transforms light energy into chemical energy.

3° uses CO_2 and H_2O as starting materials, releases O_2 as a by-product.
the chemical energy produced via photosynthesis is stored in the bonds of sugar molecules.

2. Photo-autotrophs (光合自养生物)

1° Organisms that generate their own organic matter from inorganic ingredients are called autotrophs (自养生物)

2° Plants and other organisms that do this by photosynthesis are called photo-autotrophs (光合自养生物)
They are the producers for most ecosystems (生态系统)



§2 Chloroplasts: Sites of Photosynthesis

1. Chloroplasts (叶绿体)

1° light-absorbing organelles

2° the site of photosynthesis

3° found mostly in the interior cells of leaves.

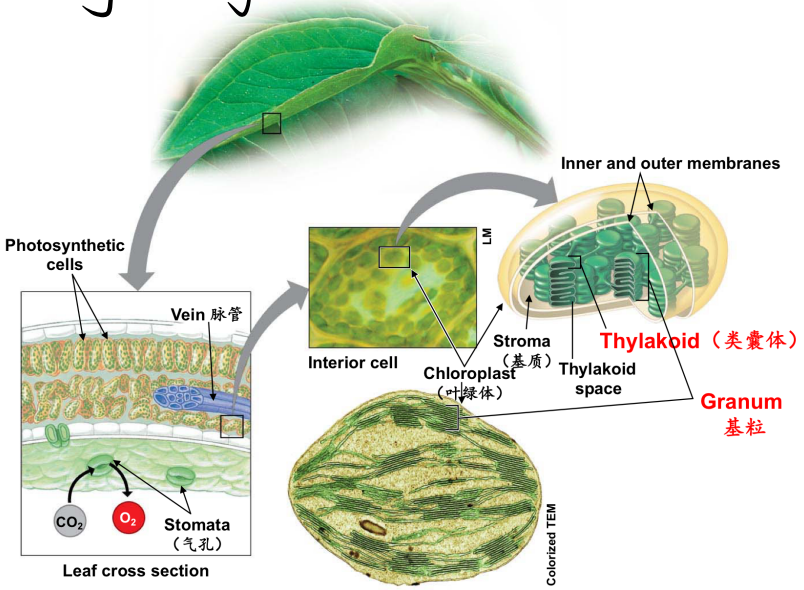
2. Membranes within the chloroplast

1° A chloroplast has a double-membrane envelope

2° The inner membrane encloses a compartment filled with stroma (基质), a thick fluid.

3° Suspended in the stroma are interconnected membrane sacs called thylakoid (类囊体)

4° The thylakoids are concentrated in stacks called grana (基粒) (singular, granum)



3. Stomata (气孔)

Stomata are tiny pores in leaves where

① carbon dioxide enters

② oxygen exits

4. Chlorophyll (叶绿素)

1° The green color of chloroplasts is from chlorophyll.

2° Chlorophyll is a pigment (色素) (light absorbing molecule) in the chloroplasts that plays a central role in photosynthesis.

3° It is build into the thylakoid membrane.

§3 An Overview of Photosynthesis

1. The overall equation

$$6CO_2 + 6H_2O \xrightarrow[\text{Photosynthesis}]{\text{Light energy}} C_6H_{12}O_6 + 6O_2$$

2. About energy

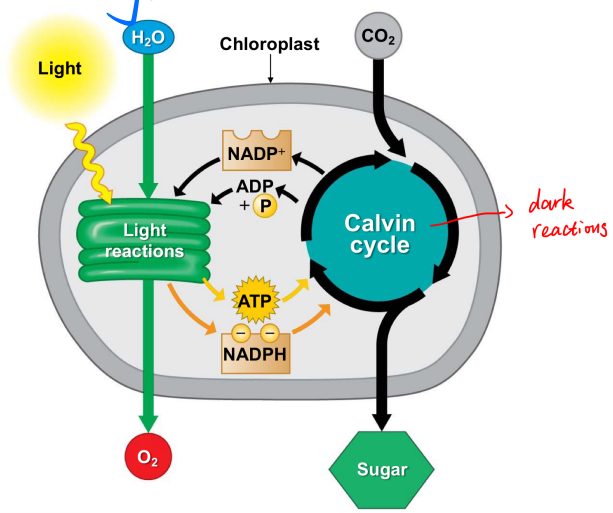
1° Photosynthesis is a metabolic pathway to obtain, process and store energy.

2° Photosynthesis is a chemical transformation that require a lot of energy.

The sunlight absorbed by chlorophyll provides that energy.

3° Electrons are added to CO_2 to produce sugar.

3. Two stages



§4 The Nature of Sunlight

1. Wave-particle duality of light

Light behaves as

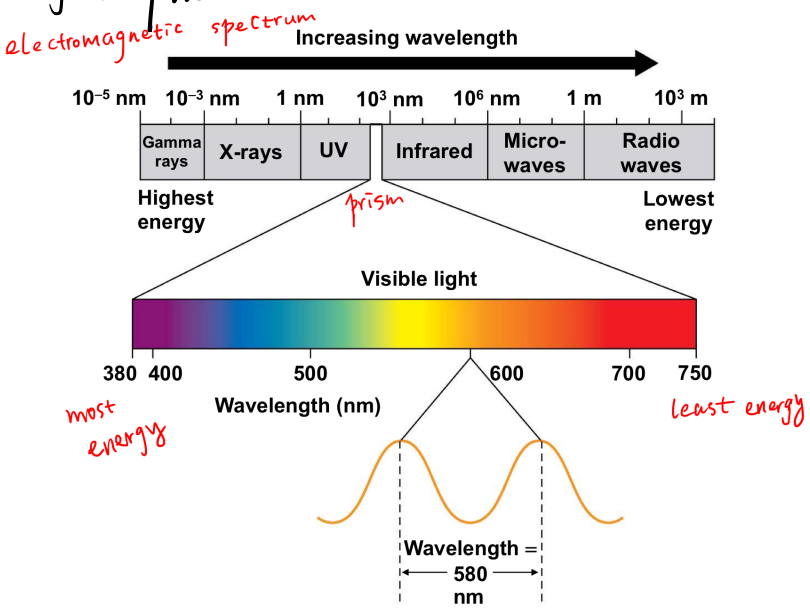
1° waves

2° discrete packets of energy called photons (光子), fixed quantities of light energy.

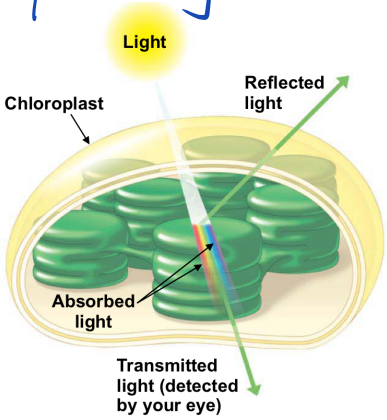
2. Wavelength and energy

1° $E = hc/\lambda$

2° The shorter the wavelength of light, the greater the energy of a photon.



§5 Chloroplast Pigments



1. Chlorophyll a (叶绿素a)

1° participates directly in the light reactions

2° absorbs mainly blue-violet and red light

3° is the core pigment (reaction center)

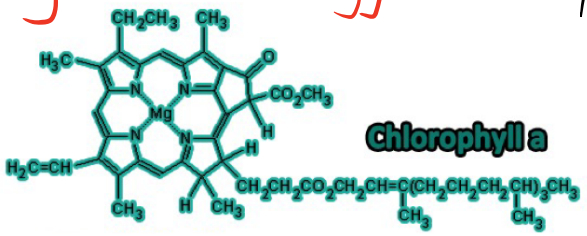
Other pigments are accessory pigments

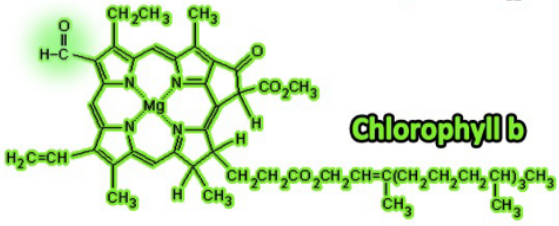
2. Chlorophyll b

1° is very similar to chlorophyll a,

2° absorbs mainly blue and orange light

3° conveys absorbed energy to chlorophyll a.





3. Carotenoids (类胡萝卜素)

1° absorb mainly blue-green light (only in bacteria)

2° absorb and dissipate excessive light energy that might damage chlorophyll.

3° Some carotenoids are human nutrients.

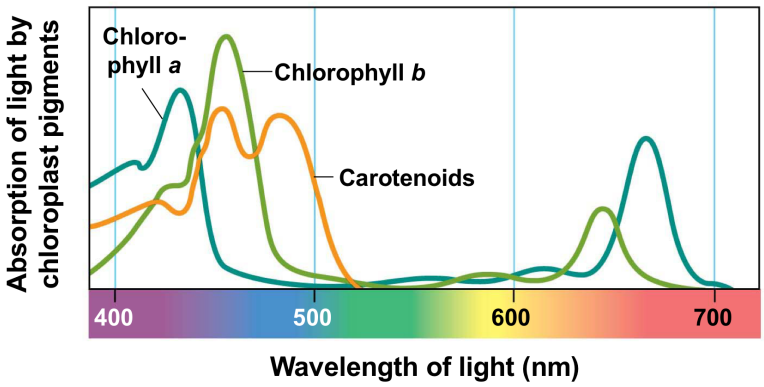
- **Beta-carotene**
  - is a bright orange/red pigment found in pumpkins, sweet potatoes, and car
  - is converted to vitamin A in the bo

- **Lycopene** (番茄红素)
  - is a bright red pigment found in tomatoes, watermelon, and red peppers and
  - is an antioxidant (抗氧化剂) that is being studied for potential anti-cancer properties.

4° The spectacular colors of fall foliage (树叶) are due partly to the yellow-orange light reflected from carotenoids.

- **The decreasing temperatures in autumn cause a decrease in the levels of chlorophyll.**
- **This allows the colors of the longer-lasting carotenoids (类胡萝卜素) to be seen in all their fall glory.**

4. Pigments can absorb specific portions of visible light



5. The absorption and transport of photon energy

When a pigment molecule absorbs a photon, one of the pigment's electrons gains energy and is pumped to a higher-energy orbital.

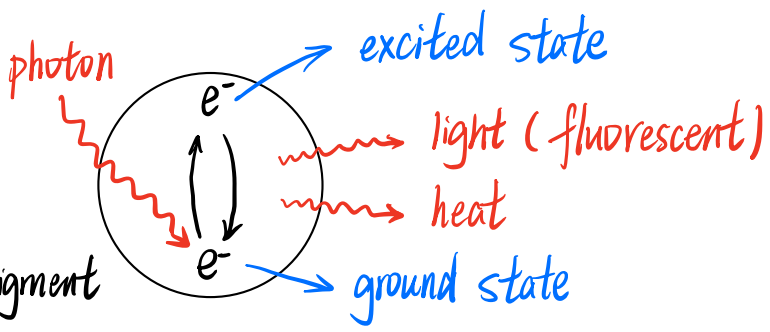
1° The electron is now said to be "excited".

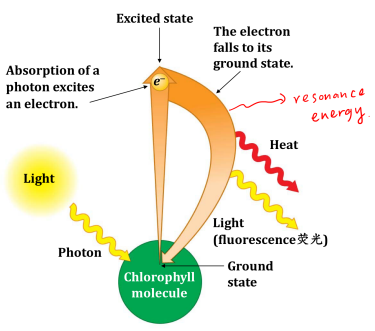
2° The excited state is highly unstable

3° An excited electron usually loses its excess energy and falls back to its ground state almost immediately.

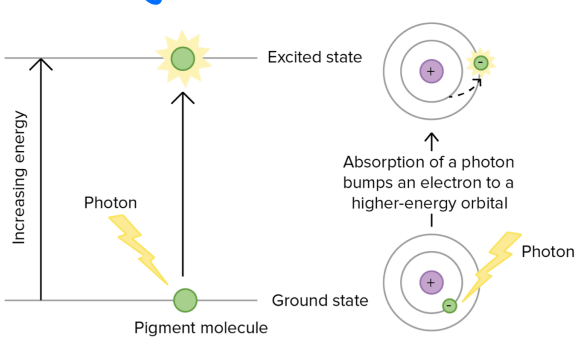
4° Most pigments release heat energy as their light-excited electrons fall back to ground state.

5° Some pigments emit light as well as heat after absorbing photons.





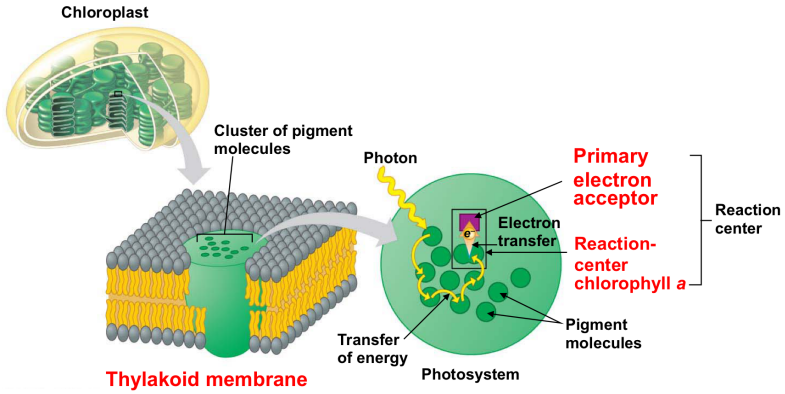
(a) Absorption of a photon



b. The functions of cluster of pigment molecules

1° In the thylakoid membrane, chlorophyll molecules are organized with other molecules in photosystems (光合体系).

2° Each photosystem has a cluster of a few hundred pigment molecules, including chlorophyll a and b, and some carotenoids.



3° This cluster of pigment molecules functions as light-gathering antenna.

① When a photo strikes one of the pigment molecules, the energy jumps from molecule to molecule until it arrives at the reaction center of the photosystem.

② The reaction center consists of chlorophyll a molecules that sit next to a primary electron acceptor (原初电子受体), which traps the light-excited electron from the chlorophyll a in the reaction center.

③ Another team of molecules built into the thylakoid membrane then use that trapped energy to make ATP and NADH.

§6 Light Reaction (光反应)

1. The first photosystem

1° Photons excite electrons in the chlorophyll of the first photosystem

2° These photons are then trapped by the primary electron acceptor.

3° This photosystem then replaces the lost electrons by extracting new ones from water.

4° This step releases O_2

2. Electron transport chain

1° Energized electrons from the first photosystem pass down an electron transport chain to the second photosystem.

2° The chloroplast uses the energy released by this electron "fall" to make ATP.

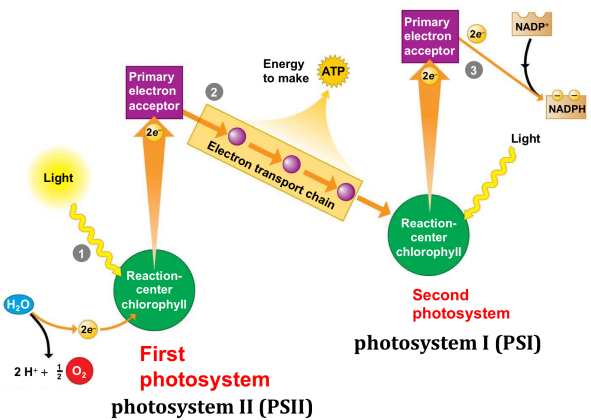
3. The second photosystem

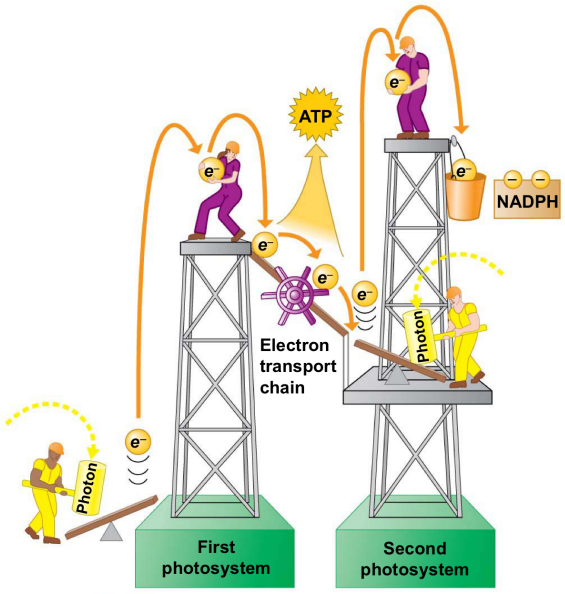
1° Photons excite electrons in the chlorophyll of the second photosystem

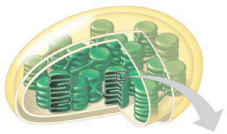
2° These photons are then trapped by the primary electron acceptor.

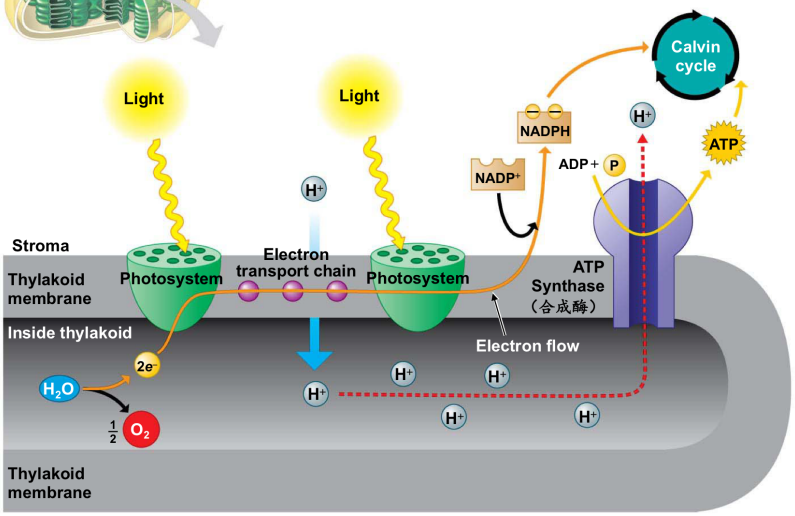
3° The primary electron acceptor transfers its light-excited electron to $NADP^+$, reducing it to NADPH.

4° This photosystem then replaces the lost electrons using the electrons which passes through the electron transport chain.

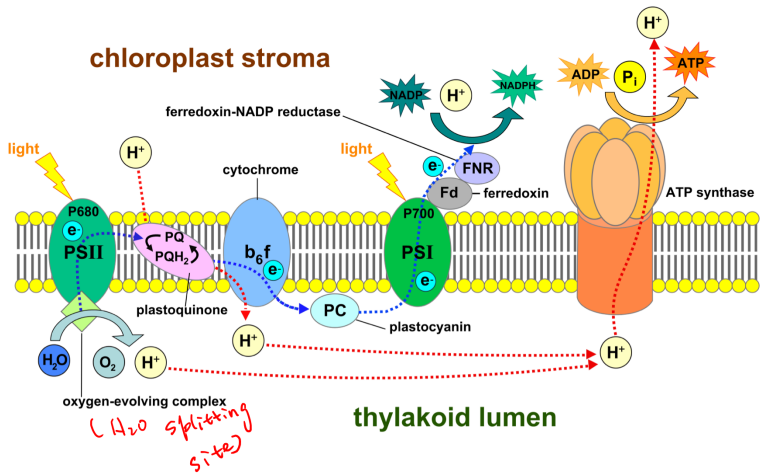








Additional reference slide



§7 The Calvin Cycle

1. The Calvin cycle (卡尔文循环)

1° The Calvin cycle constructs an energy-rich sugar molecule called glyceraldehyde 3-phosphate (G3P) (三磷酸甘油醛) using

① carbon from CO_2

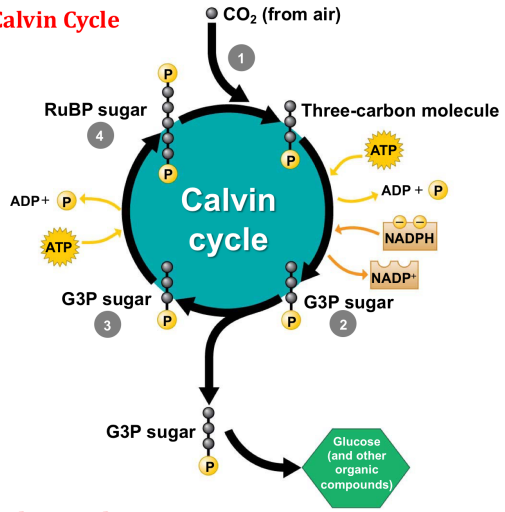
② energy from ATP

③ high-energy electrons from NADPH

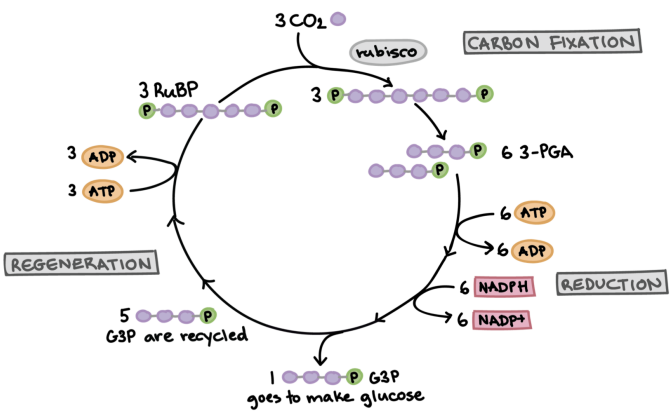
2° The plant cell can then use G3P as the raw material to make glucose and other organic compounds.

2. The process of the Calvin cycle

The Calvin Cycle



The Calvin Cycle



The Calvin Cycle