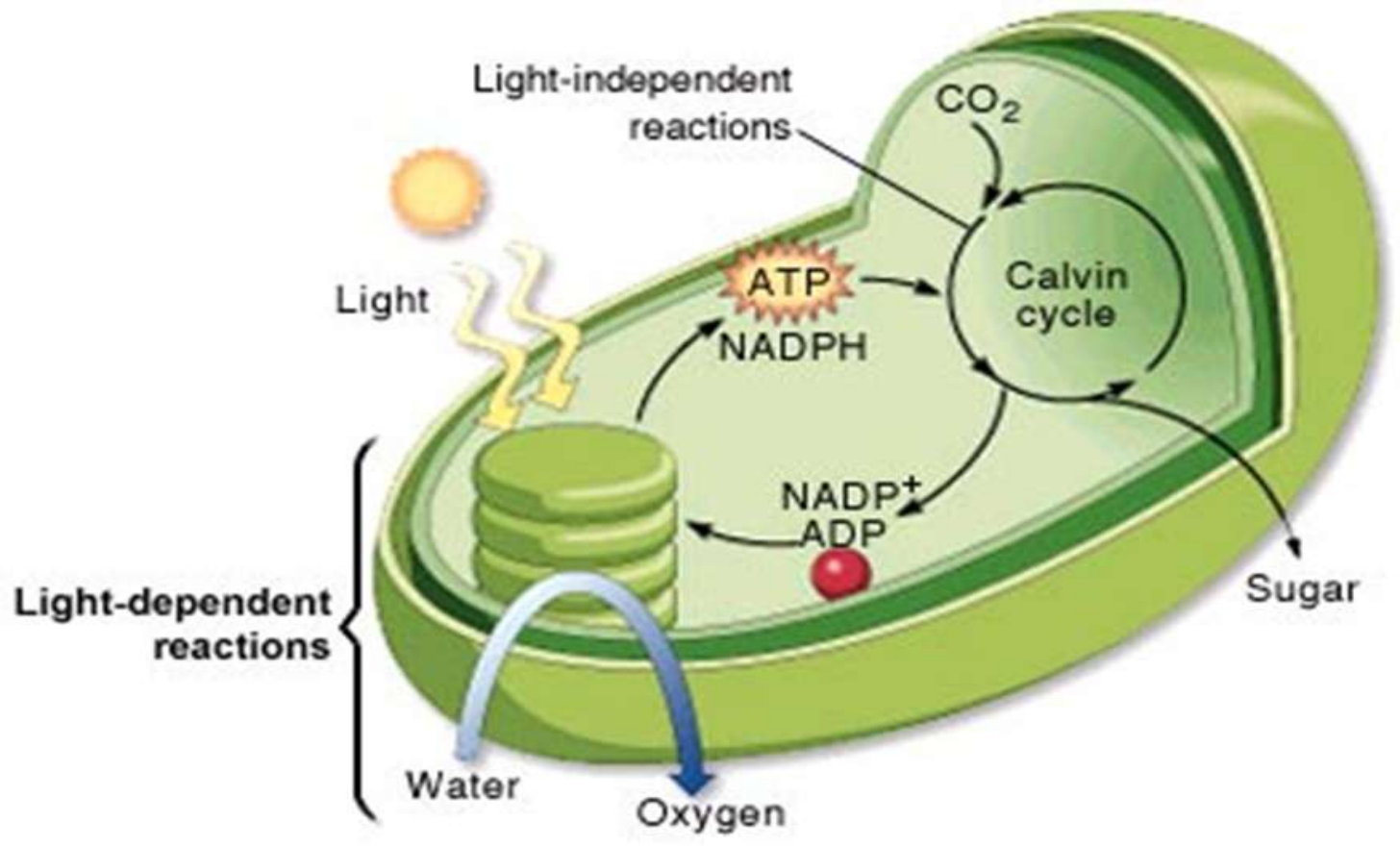
Photosynthesis

Chapter 4– Energy and Metabolism



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- Students will derive the relationship between single-celled and multi-celled organisms and the increasing complexity of systems.

a. Explain the cycling of energy through the process of photosynthesis and respiration.

Questions To Think About

- What molecule serves as the primary energy source for metabolism?
- What process forms the basis of almost all food chains on Earth?
- The energy of movement is referred to as _____ energy.

Today's Objectives

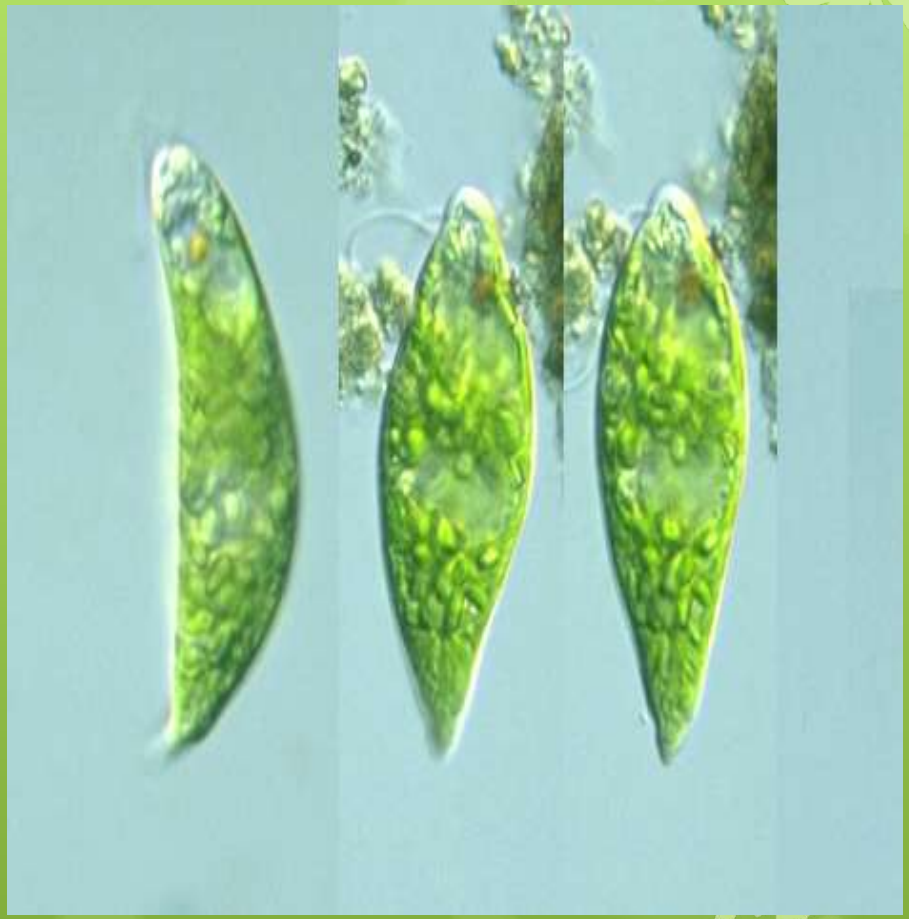
- Given information and/or diagrams on the process of photosynthesis, write and/or identify the equation, raw materials, sites, products, factors affecting the process, and the role of chlorophyll in the light and dark reactions.

Autotrophs

- Plants and some other types of organisms that contain **chlorophyll** are able to use **light energy from the sun to produce food.**

Autotrophs

- **Autotrophs include organisms that make their own food**
- Autotrophs can use the sun's energy **directly**



Euglena

Heterotrophs

- **Heterotrophs are organisms that CANNOT make their own food**
- Heterotrophs **CANNOT directly** use the sun's energy

Energy

- Energy can take many forms such as **light, heat, electrical, chemical, mechanical**
- Energy can be changed from **one form to another**
- Energy is stored in **chemical bonds**

Candles release energy as heat & light

ATP: The Cell's Currency

- Adenosine Triphosphate
- Energy from **food** is converted into high energy bonds in **ATP**
- **ADP + P + energy → ATP**
- Contains **3 high-energy phosphate bonds, adenine, and ribose**

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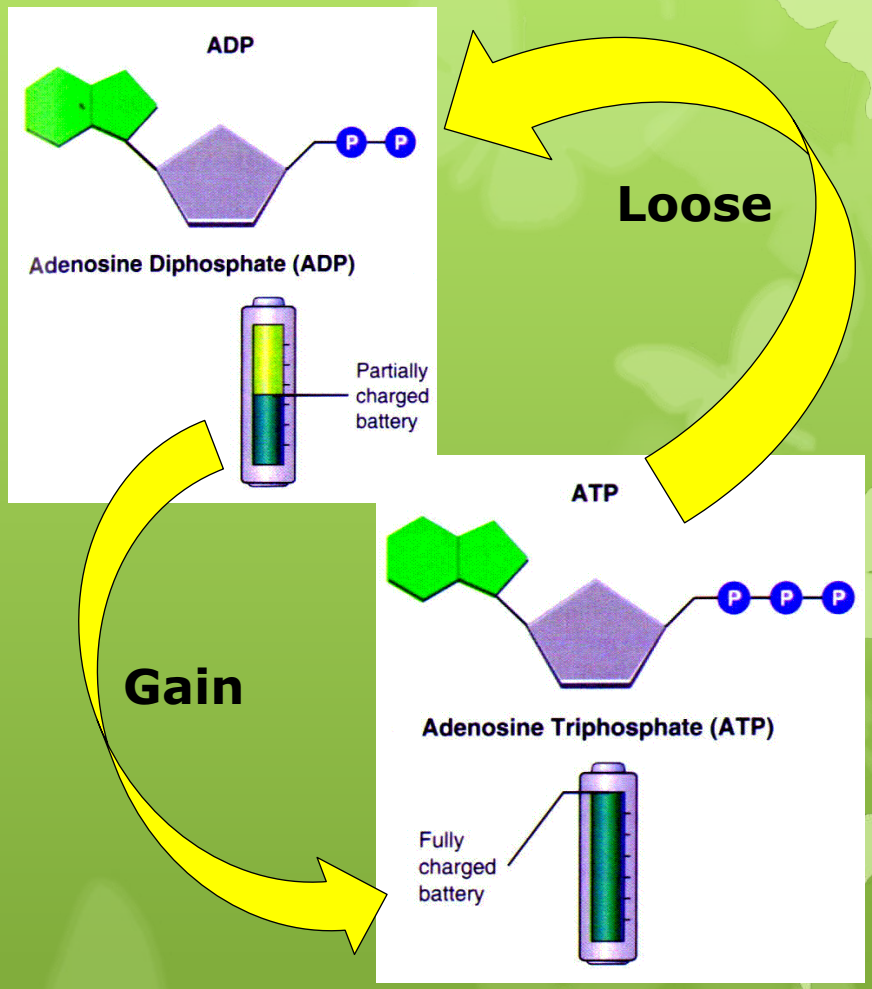
Importance of ATP

- Principal compound used to **store energy** in living organisms
- Provides all the energy for the **cells activities**
- The process of releasing ATP's energy & reforming the molecule is called **phosphorylation**

Releasing Energy from ATP

- **Adding** a phosphate group to ADP **stores energy in ATP**
- **Removing** a phosphate group from ATP, **releases energy & forms ADP**



Uses of ATP

Cells use ATP for:

- Active transport
- Movement
- Photosynthesis
- Cellular Respiration
- All other cellular reactions

Summary

Use each of the terms below just once to complete the passage.

energy phosphateadenosine charged
ATP chemical bonds work ribose

To do biological **(1)** _____ , cells require energy. A quick source of energy that cells use is the molecule **(2)** _____ . The **(3)** _____ in this molecule is stored in its **(4)** _____. ATP is composed of a(n) **(5)** _____ molecule bonded to a(n) **(6)** _____ sugar. Three **(7)** _____ molecules called **(8)** _____ groups are attached to the sugar.

9. How is energy stored and released by ATP?

10. How do cells use the energy released from ATP?

Glucose

- Glucose is a monosaccharide
- **$C_6H_{12}O_6$**
- One molecule of glucose stores **90 times** more chemical energy than one molecule of ATP

History of Photosynthesis

Early Questions on Plants

Several centuries ago, the question was:

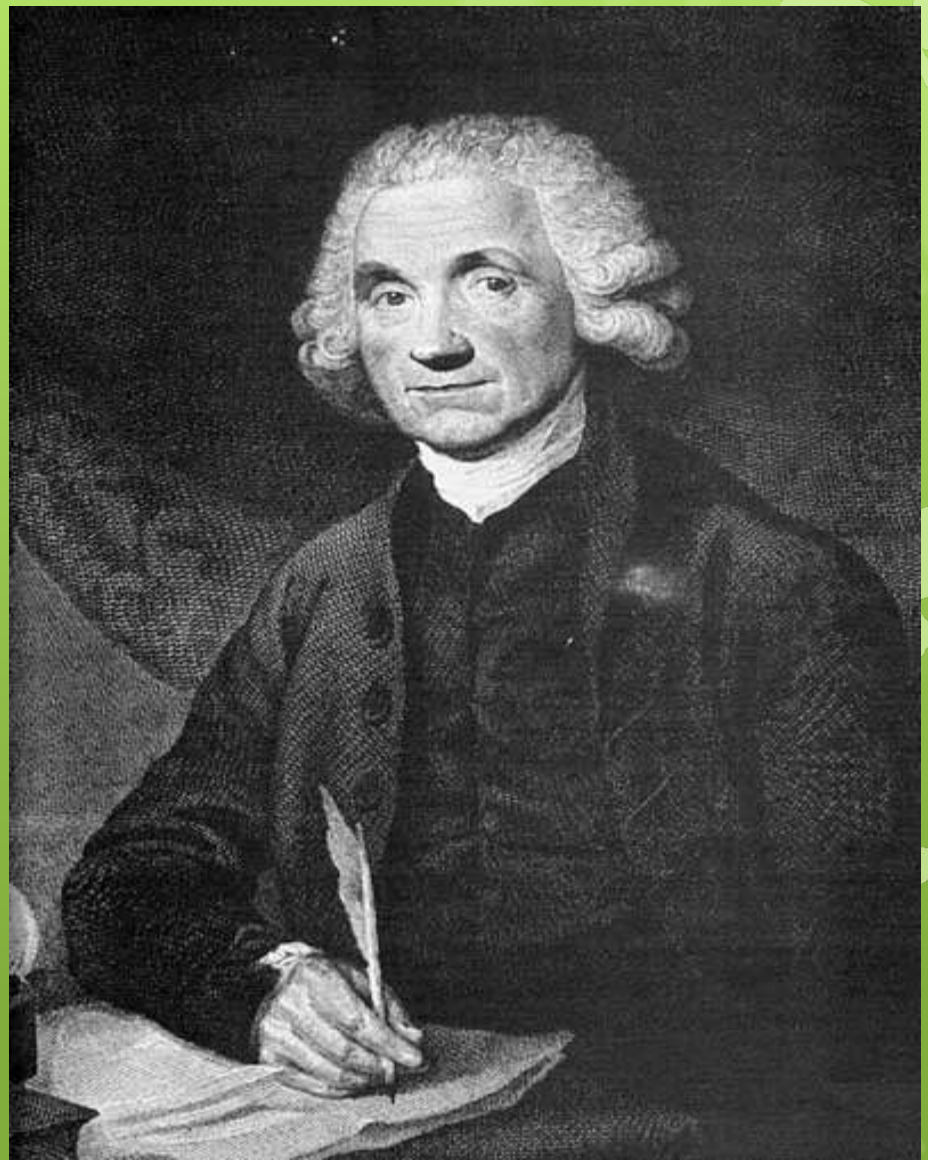
Does the increase in mass of a plant come from the air? The soil? The water?

Van Helmont's Experiment 1643

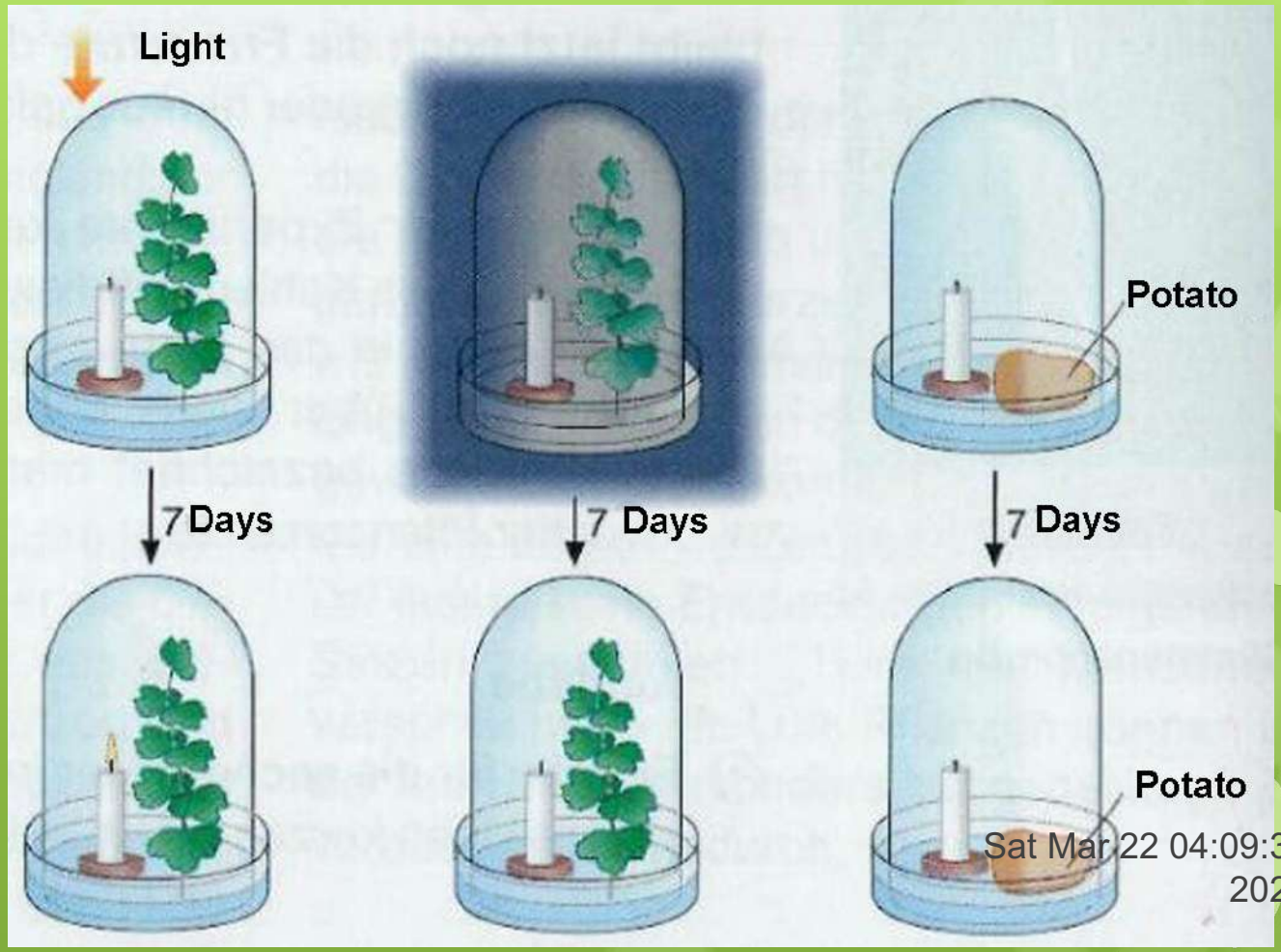
- Planted a **seed** into a pre-measured amount of soil and watered for 5 years
- **Weighed plant & soil.** Plant was 75 kg, soil was the same
- Concluded **mass** was from the **water**

Priestley's Experiment 1771

- Burned a candle in a bell jar until it went out
- Placed a sprig of mint in the bell jar for a few days
- Candle could be relit and burn
- Concluded plants **released** a substance **(O_2)** necessary for burning



Jan Ingenhousz's Experiment 1779



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Repeated Priestley's experiment with & without

Results of Ingenhousz's Experiment

- Showed that Priestley's results only occurred in the **presence of sunlight**
- **Light** was necessary for plants to produce the **"Burning Gas" or oxygen**

Melvin Calvin 1948

- First to trace the path that carbon (CO_2) takes in forming Glucose
- Does **NOT require sunlight**
- Called the **Calvin Cycle** or **Light Independent Reaction**
- Also known as the **Dark Reaction**

Rudolf Marcus 1992

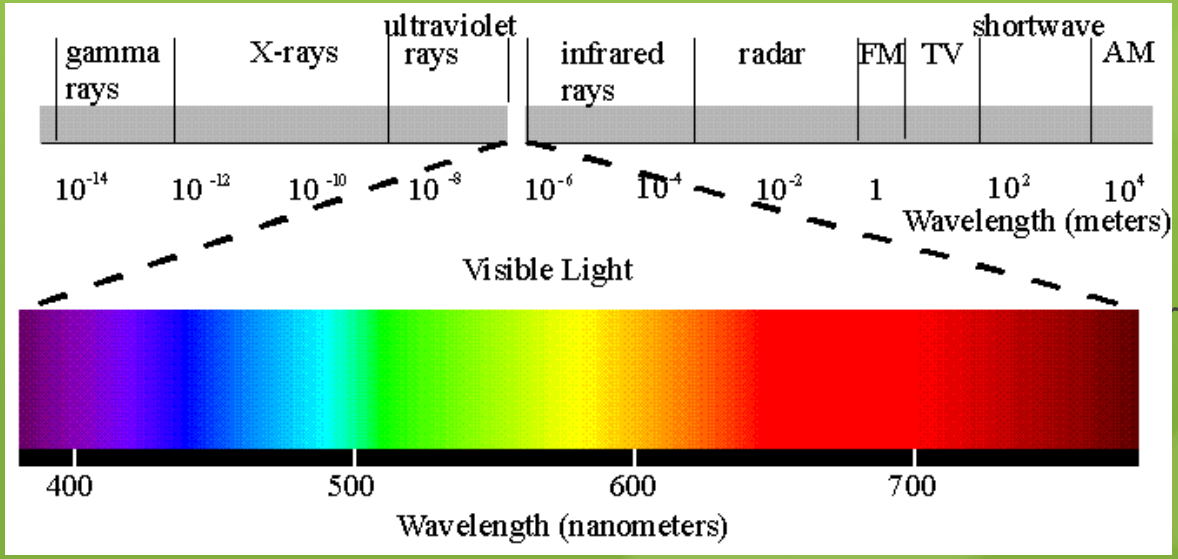
- Studied the Light Independent Reaction
- Described the Electron Transport Chain (ETC)

Photosynthesis

- **$6\ CO_2 + 6\ H_2O + E \rightarrow C_6H_{12}O_6 + 6\ O_2$**
- **Basis** of most of the earth's **food chains**
- Produces and maintains **all** of the **earth's atmospheric oxygen**
- Most oxygen **produced in the oceans**

Photosynthetic Pigments

- Mostly **chlorophyll a and chlorophyll b**
- Accessory pigments: (cannot transfer the sun's light directly)
  - Carotenoids
  - Anthocyanins
- Each pigment absorbs a particular wavelength of light in the **visible spectrum**



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Chlorophyll a

- Found in all **plants, algae, & cyanobacteria.**
- Makes photosynthesis possible
- Participates **directl**y in the Light Reactions
- Can **accept energy** from chlorophyll b

Chlorophyll b

- Chlorophyll b is an **accessory pigment**
- Acts **indirectly** in photosynthesis by **transferring** the **light it absorbs to chlorophyll a**
- Like chlorophyll a, it absorbs red & blue light and ***REFLECTS GREEN***

Think Critically

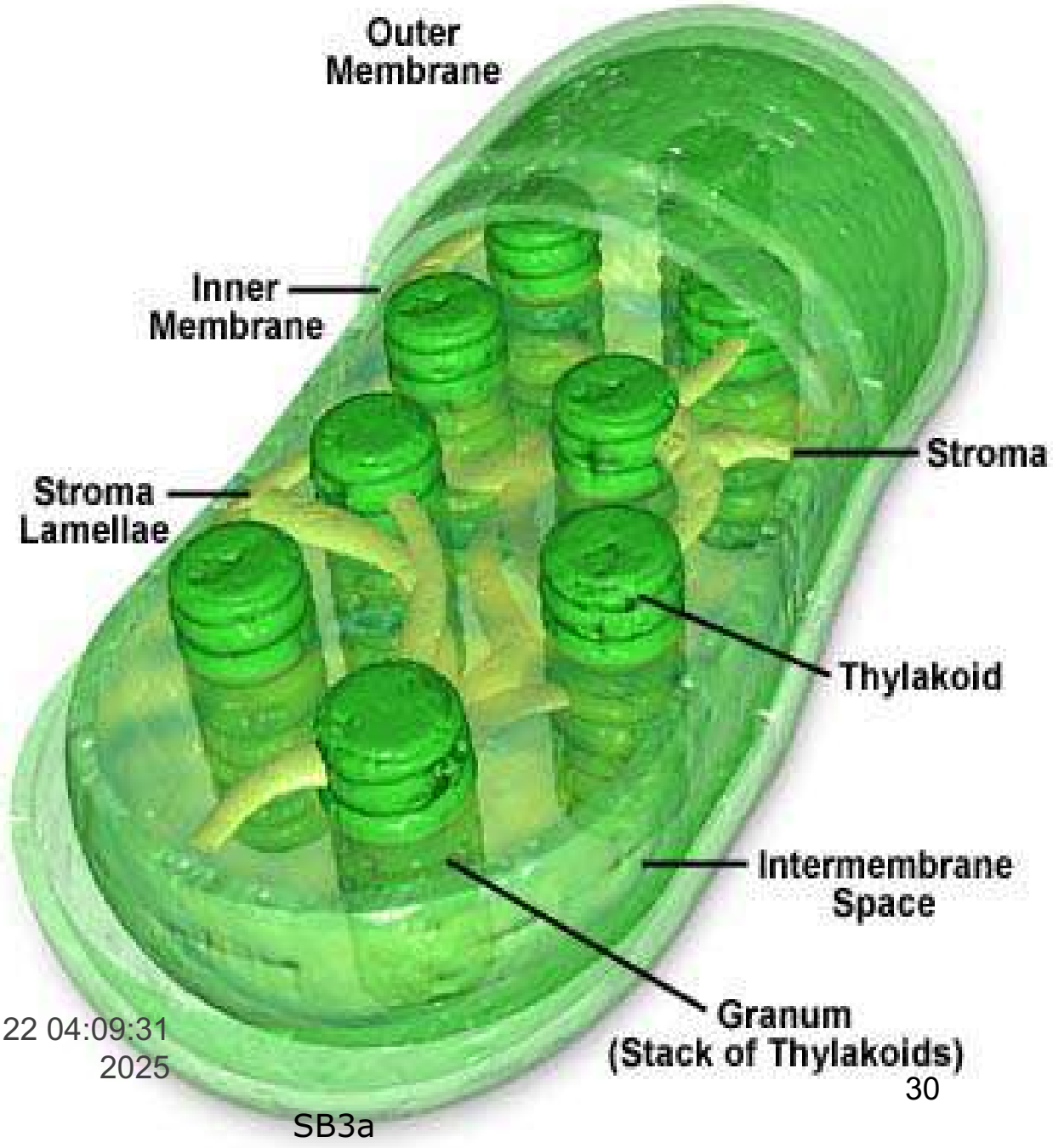
Some plant leaves contain yellow and red pigments as well as chlorophyll. In the fall, those leaves may become red or yellow. Suggest an explanation for those color changes.

Structure of a Chloroplast

- **Double membrane** organelle
- Outer membrane **smooth**
- **Inner membrane** forms stacks of connected sacs called **thylakoids**
- Thylakoid stack is called the **granum** (grana-plural)
- Gel-like material around grana called **stroma**

Function of Stroma

- **Light Independent** reactions occur here
- **ATP used** to make carbohydrates like **glucose**
- Location of the **Calvin Cycle**


Outer Membrane
Inner Membrane
Stroma
Stroma Lamellae
Thylakoid
Intermembrane Space
Granum (Stack of Thylakoids)

Thylakoid Membrane

- **Light Dependent** reactions occur here
- Photosystems are made up of **clusters of chlorophyll molecules**
- Photosystems are **embedded in the thylakoid membranes**
- The two photosystems are:

Photosystem I

Photosystem II

Light vs. Dark Reaction

Light Reaction

- AKA **Light Dependent Reaction**
- **Needs light** to occur
- Splitting of water (photolysis) by light **produces O_2**
  - **Due to Photosystem II electrons being excited**
- Converts light energy into **ATP**
- Occurs in the

Dark Reaction

- AKA **Light Independent Reaction and Calvin Cycle**
- **Does not need light**
- Uses ATP to **convert CO_2 to glucose**
- Occurs in **stroma**

Overview of Photosynthesis

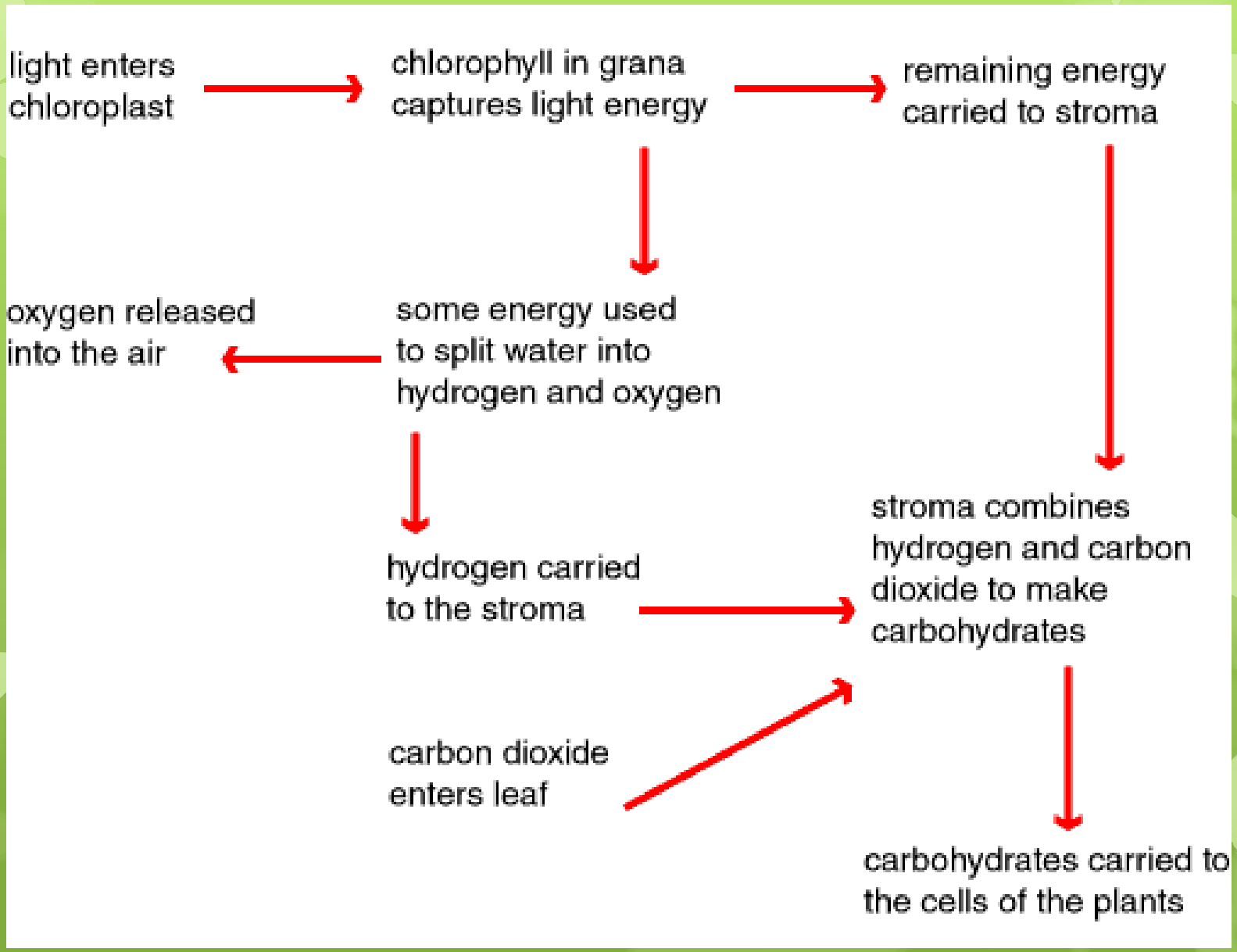
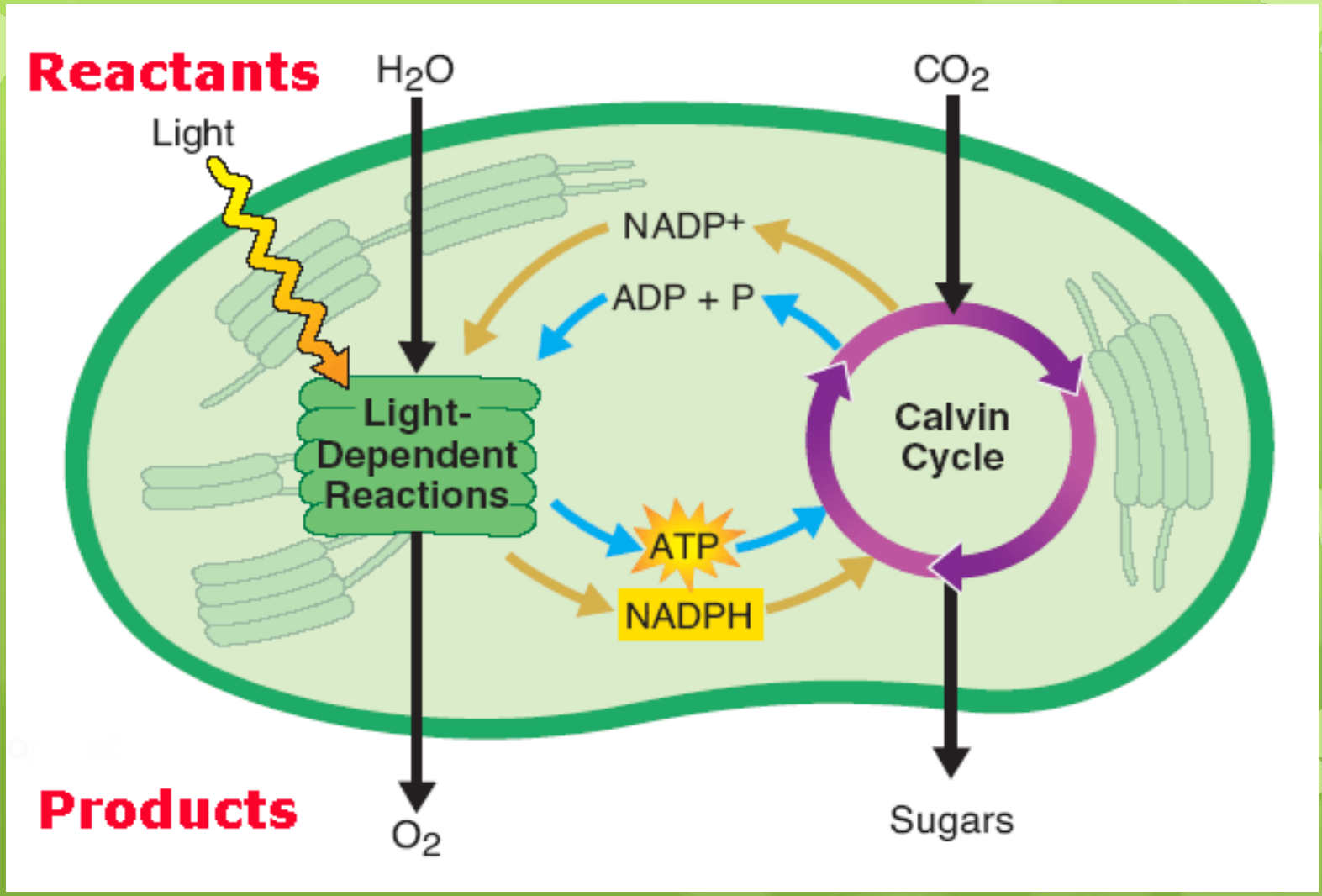


Diagram of Photosynthesis



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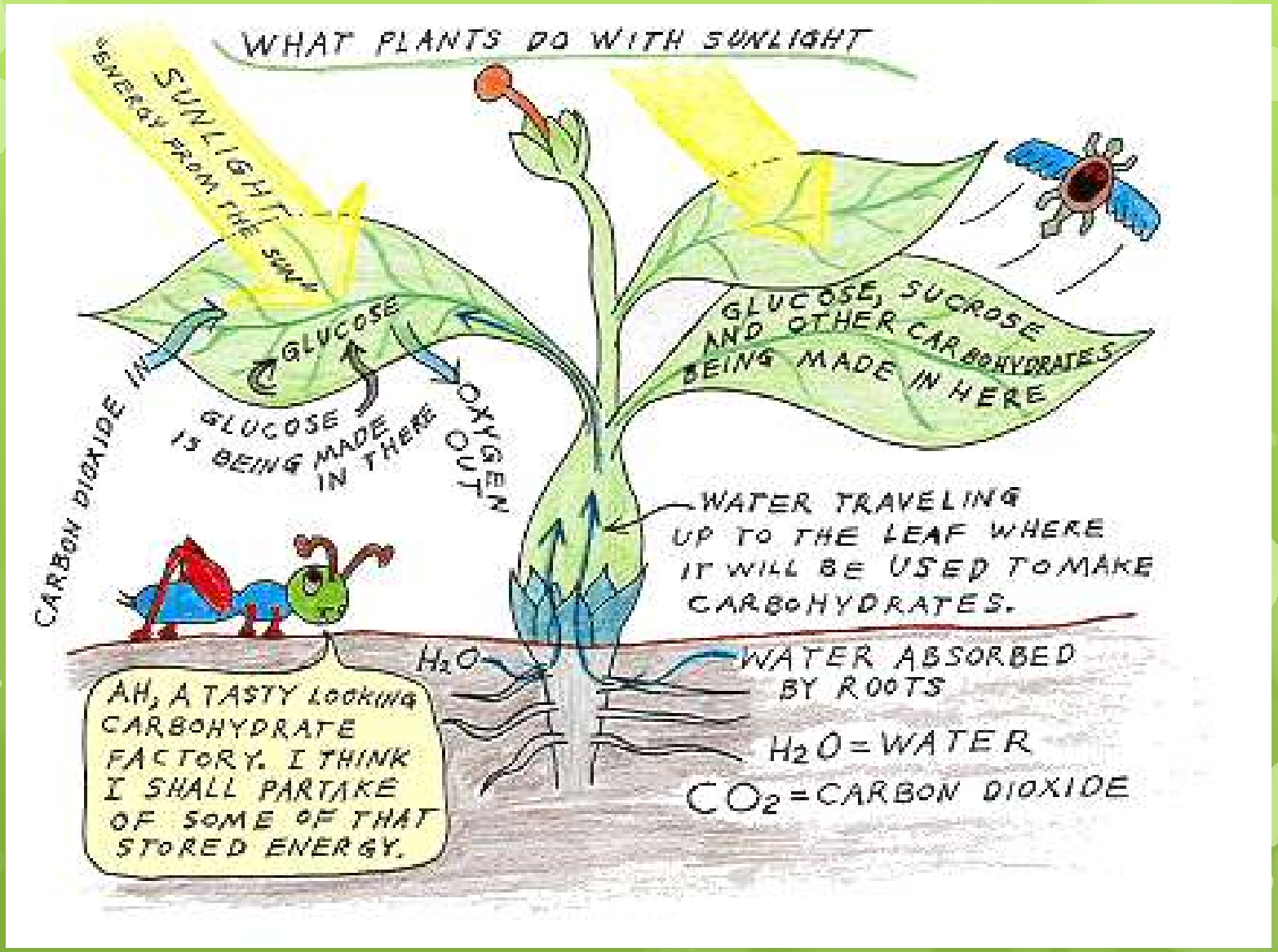


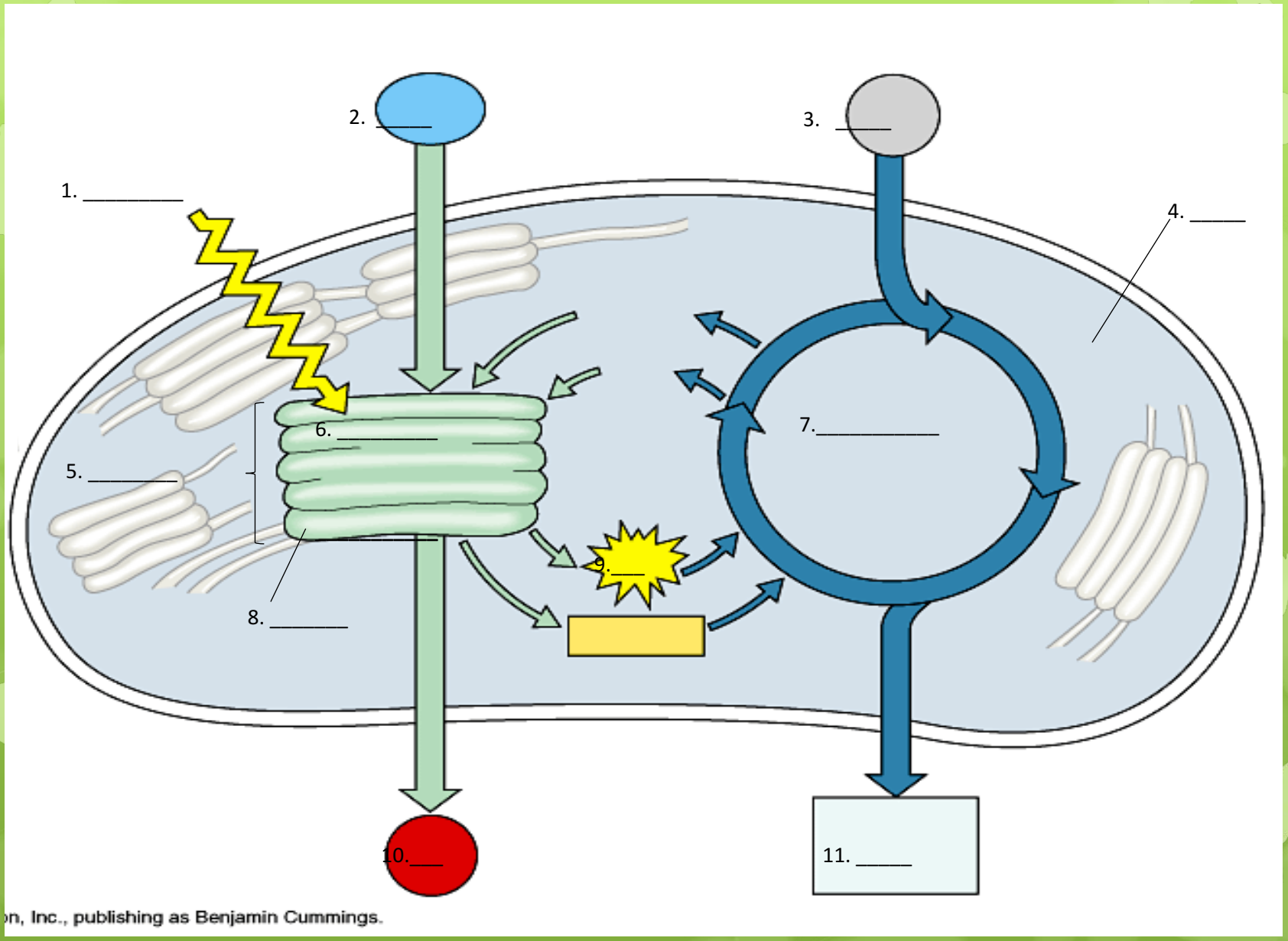
Factors Affecting the Rate of Photosynthesis

- Amount of available water
  - Shortage of water can slow or stop photosynthesis
- Temperature
  - Enzymes needed work best at 0°C and 30°C
- Amount of available light energy
  - Increasing light, increases photosynthesis

Think Critically

1. During which step is oxygen produced?
2. During which step is sugar produced?
3. Would sugar still be produced at night?
4. Would sugar be produced if the Light Dependent reactions had not occurred?
5. Would the rate of photosynthesis change under drought conditions or in arid climates?

Review Structure



Think Critically

Many of the sun's rays may be blocked by dust or clouds formed by volcanic eruptions or pollution. What are some possible short-term and long-term effects of this on photosynthesis?