# The Calvin Cycle

Section 6.2

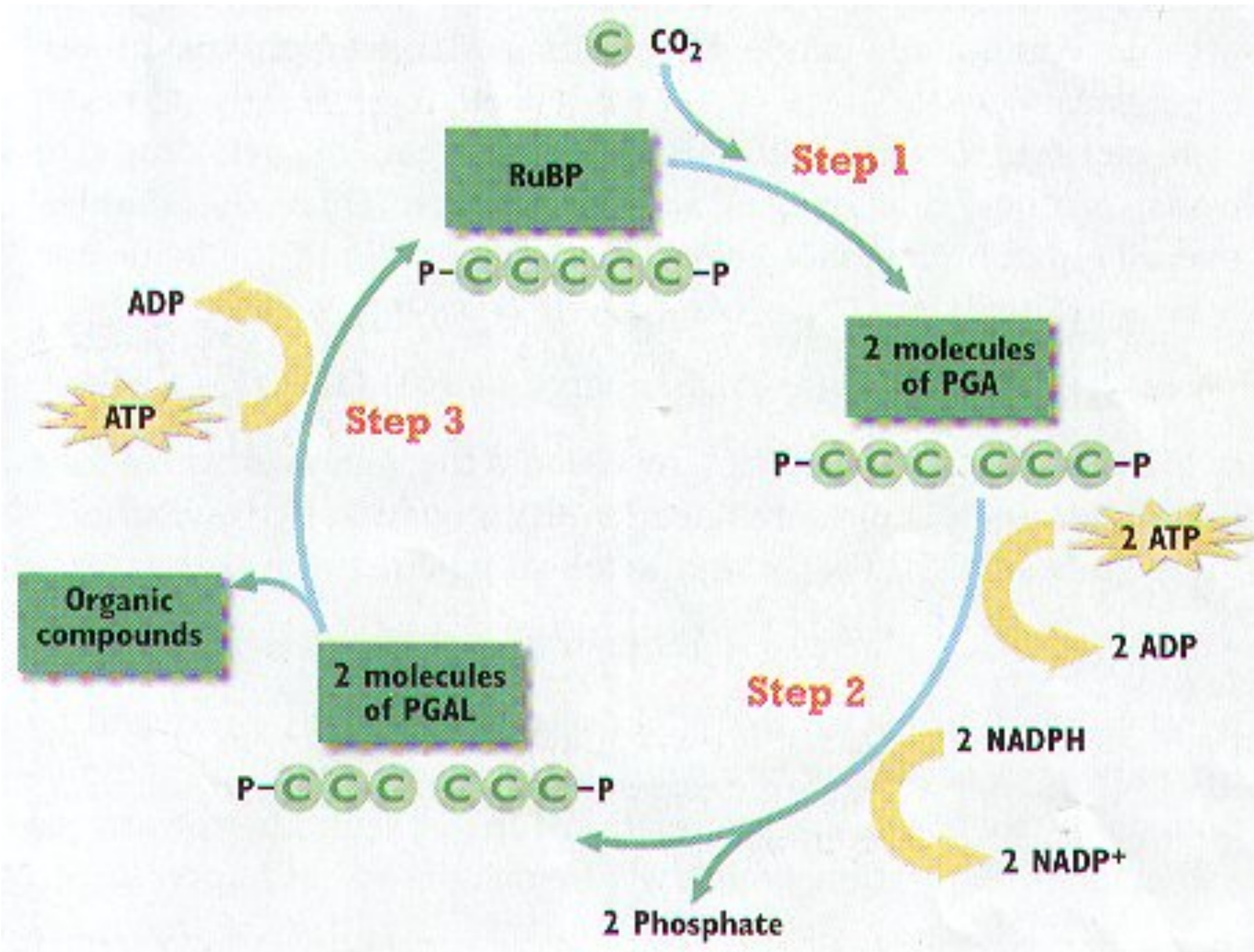
# Carbon Fixation by the Calvin Cycle

- Second set of reaction in photosynthesis involves a biochemical pathway known as the *Calvin Cycle*
  - Pathway produces organic compounds, using energy stored in ATP and NADPH from the light reactions
  - Named after Melvin Calvin

# Carbon Fixation by the Calvin Cycle

- Atoms from $CO_2$ are bonded or "fixed" into organic compounds
- Incorporation of $CO_2$ into organic compounds is known as *carbon fixation*

# Calvin Cycle's 3 steps



# 3 major steps to Calvin Cycle

- Occurs within the stroma of the chloroplast

**STEP 1:**

- – $CO_2$ diffuses into the stroma from the surrounding cytosol
- – Enzyme combines a $CO_2$ molecule with a five-carbon carbohydrate called RuBP
- – Product is a six-carbon molecule that splits immediately into a pair of three-carbon molecules known as PGA

**STEP 2:**

- PGA is converted into another three-carbon molecule called PGAL in a 2-part process:
  - 1.) each PGA molecule receives a phosphate group from a molecule of ATP.
  - 2.) The resulting compound then receives a proton from NADPH and releases a phosphate group producing PGAL
- In addition to PGAL, these reactions produce ADP, $NADP^+$ and phosphate

## STEP 3:

- Most of the PGAL is converted back into RuBP in a complicated series of reactions.
- Require a phosphate group from another molecule of ATP, which is changed into ADP.
- By regenerating the RuBP that was consumed in Step 1, the reactions of Step 3 allow the Calvin Cycle to continue
- Some PGAL molecules are not converted into RuBP – they leave the Calvin Cycle and can be used by the plant to make other organic compounds

# Balance Sheet for Photosynthesis

- Each turn of the Calvin Cycle fixes one $CO_2$ molecule…since PGAL is a three-carbon compound, it takes three turns of the cycle to produce each molecule of PGAL.
- For each turn of the cycle 2 ATP, and 2 NADPH molecules are used in Step 2, and 1 ATP molecule used in Step 3
  - Therefore 3 turns of the Calvin cycle uses 9 molecules of ATP and 6 molecules of NADPH

- Simplest overall equation for photosynthesis, including both the light reactions and the Calvin Cycle can be written as:

$CO_2 + H_2O$ + light energy → $(CH_2O)_n + O_2$

The $(CH_2O)$ represents the general formula for a carbohydrate.

# Alternative Pathways

- Plant species that fix carbon exclusively through the Calvin Cycle are known as *C3 plants* because of the three-carbon compound PGA that is initially formed
- Other plant species fix carbon through alternative pathways and then release it to enter the Calvin Cycle

- Most of the water loss from a plant occurs through small pores called *stomata* which are usually located on the undersurface of leaves
- Stomata are the major passageways through which $CO_2$ enters and $O_2$ leaves a plant
- When stomata are partly closed, the level of $CO_2$ in the plant falls as $CO_2$ is consumed in the Calvin cycle
- At the same time, the level of $O_2$ in the plant rises as the light reactions split water and generate $O_2$

# $C_4$ Pathway

- Allows certain plants to fix $CO_2$ into FOUR-Carbon Compounds.
  - Such plants lose only about half as much water as $C_3$ plants when producing the same amount of carbohydrates
- During the hottest part of the day, C4 plants have their stomata partially closed.
- $C_4$ plants include corn, sugar cane and crabgrass.

# The CAM Pathway

- They fix carbon through a pathway called CAM.
  - Plants that use the CAM Pathway by opening their Stomata at night and Closing it during the day, the opposite of what other plants do.
  - At night, CAM plants take in $CO_2$ and fix it into organic compounds.
  - During the day, $CO_2$ is released from these compounds and enters the Calvin Cycle.
  - Because CAM Plants have their Stomata open at night, they grow very slowly, But they lose less water than $C_3$ or $C_4$ plants.

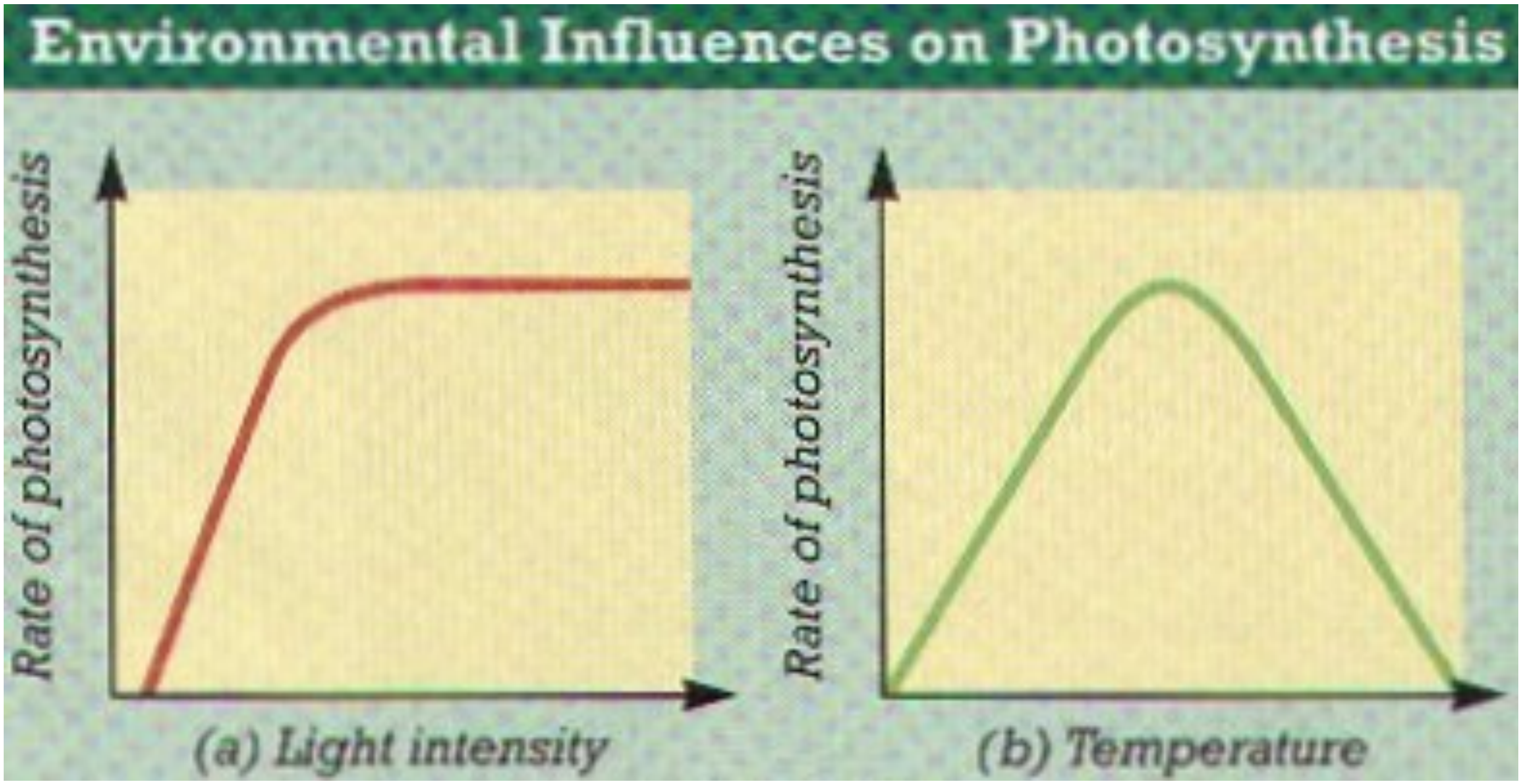
# 3 things affecting Photosynthesis

1. **LIGHT INTENSITY** - One of the most important. As light intensity INCREASES, the rate of photosynthesis initially INCREASES and then levels off to a plateau
2. . **CO2 LEVELS AROUND THE PLANT** - Increasing the level of $CO_2$ stimulates photosynthesis until the rate reaches a plateau

# 3 things affecting Photosynthesis

3. **TEMPERATURE** - Raising the temperature ACCELERATES the Chemical Reactions involved in Photosynthesis.

   The rate of Photosynthesis generally PEAKS at a certain temperatures, and photosynthesis begins to decrease when the temperature is further increased


Environmental Influences on Photosynthesis
Rate of photosynthesis
(a) Light intensity
Rate of photosynthesis
(b) Temperature