


## Chapter 8

### Photosynthesis: The Calvin Cycle

Life from Air CO<sub>2</sub>



- ### Remember what it means to be a plant...
- Need to **produce all organic molecules** necessary for growth
    - ◆ carbohydrates, lipids
    - ◆ proteins, nucleic acids
  - Need to **store chemical energy**
    - ◆ in stable form
    - ◆ can be moved around plant
    - ◆ saved for a rainy day

### Autotrophs

- Making energy & organic molecules from light energy
  - ◆ photosynthesis

carbon + water + energy → glucose + oxygen dioxide

$6\text{CO}_2 + 6\text{H}_2\text{O} + \text{light energy} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2$

- Convert solar energy to chemical energy
  - ◆ ATP → energy
  - ◆ NADPH → reducing power

→ → build stuff !!

### How is that helpful?

- Want to make  $\text{C}_6\text{H}_{12}\text{O}_6$ 
  - ◆ synthesis

How? From what? What raw materials are available?

called:  
"carbon fixation"

$\text{CO}_2$

↓

$\text{C}_6\text{H}_{12}\text{O}_6$

NADPH →

← NADP

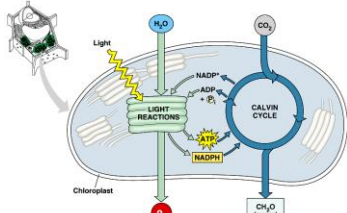
reduces CO<sub>2</sub>

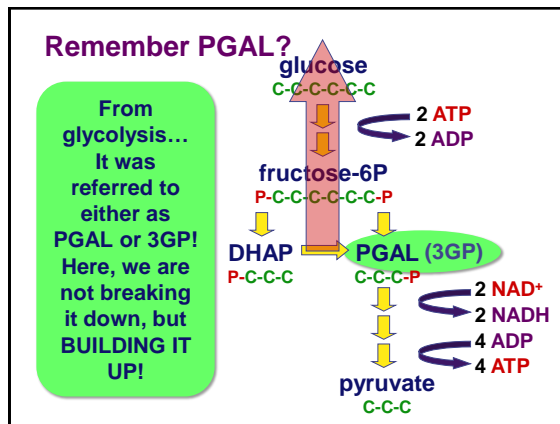
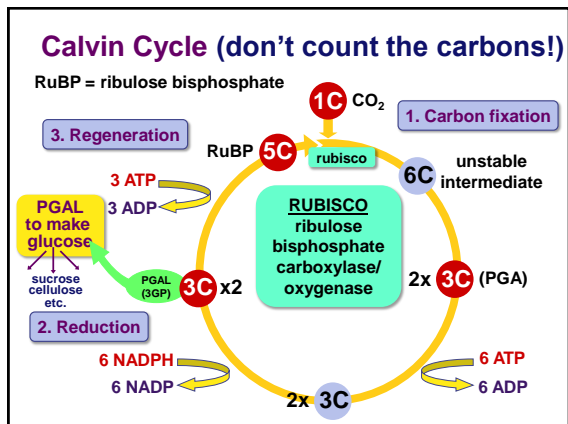
### From $\text{CO}_2 \rightarrow \text{C}_6\text{H}_{12}\text{O}_6$

- $\text{CO}_2$  has very little chemical energy
  - ◆ fully oxidized
- $\text{C}_6\text{H}_{12}\text{O}_6$  contains a lot of chemical energy
  - ◆ reduced
  - ◆ endergonic
- Reduction of  $\text{CO}_2 \rightarrow \text{C}_6\text{H}_{12}\text{O}_6$  proceeds in many small uphill steps
  - ◆ each catalyzed by specific enzyme
  - ◆ using energy stored in **ATP & NADPH**

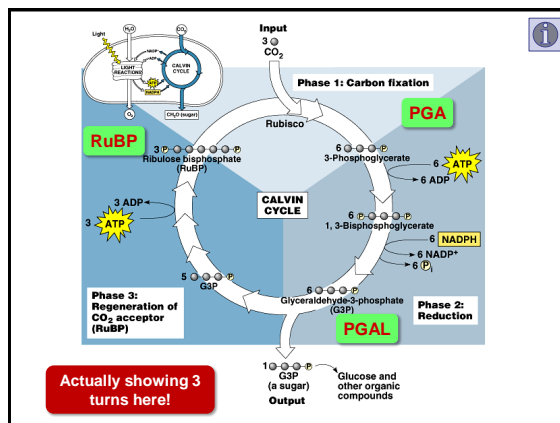
### From Light Reactions to Calvin Cycle

- Calvin cycle
  - ◆ occurs in chloroplast stroma
- Need products of light reactions to drive synthesis reactions
  - ◆ ATP
  - ◆ NADPH





- ### Calvin Cycle
- PGAL
    - end product of Calvin cycle
    - energy rich sugar
    - 3 carbon compound
    - "C3 photosynthesis"
  - PGAL  $\rightarrow \rightarrow$  important intermediate
    - PGAL  $\rightarrow \rightarrow$  glucose  $\rightarrow \rightarrow$  carbohydrates
    - $\rightarrow \rightarrow$  lipids
    - $\rightarrow \rightarrow$  amino acids
    - $\rightarrow \rightarrow$  nucleic acids

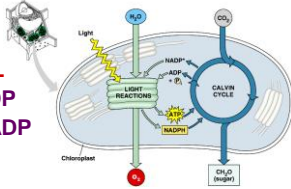


- ### Rubisco
- Enzyme which fixes carbon from atmosphere
    - ribulose biphosphate carboxylase /oxygenase
    - the most important enzyme in the world!
      - it makes life out of air!
    - definitely the most abundant enzyme
    - 50% of all protein in each plant leaf
- 

- ### Energy Accounting
- The accounting is complicated
    - 3 turns of Calvin cycle = 1 PGAL
    - 3  $\text{CO}_2 \rightarrow 1$  PGAL (3C)
    - 6 turns of Calvin cycle = 1  $\text{C}_6\text{H}_{12}\text{O}_6$  (6C)
    - 6  $\text{CO}_2 \rightarrow 1$   $\text{C}_6\text{H}_{12}\text{O}_6$  (6C)
    - 18 ATP + 12 NADPH  $\rightarrow 1$   $\text{C}_6\text{H}_{12}\text{O}_6$
    - 6 ATP = left over from light reactions for cell to use elsewhere

### Photosynthesis Summary

- **Light reactions**
  - ◆ produced **ATP**
  - ◆ produced **NADPH**
  - ◆ consumed **H<sub>2</sub>O**
  - ◆ produced **O<sub>2</sub>** as byproduct
- **Calvin cycle**
  - ◆ consumed **CO<sub>2</sub>**
  - ◆ produced **PGAL**
  - ◆ regenerated **ADP**
  - ◆ regenerated **NADP**



### Photosynthesis Summary

carbon dioxide + water + energy → glucose + oxygen



- Where did the CO<sub>2</sub> come from?
- Where did the CO<sub>2</sub> go?
- Where did the H<sub>2</sub>O come from?
- Where did the H<sub>2</sub>O go?
- Where did the energy come from?
- What's the energy used for?
- What will the C<sub>6</sub>H<sub>12</sub>O<sub>6</sub> be used for?
- Where did the O<sub>2</sub> come from?
- Where will the O<sub>2</sub> go?
- What else is involved that is not listed in this equation?

### Supporting a Biosphere

- On global scale, photosynthesis is the most important process for the continuation of life on Earth
  - ◆ each year photosynthesis synthesizes 160 billion tons of carbohydrate
  - ◆ heterotrophs are dependent on plants as food source for fuel & raw materials



### The Poetic Perspective

- All the solid material of every **plant** was built out of thin air...
- All the solid material of every **animal** was built from **plant** material...

air ...then all the cats, dogs, mice, people & elephants... are really strands of air woven together by sunlight!

As Carl Sagan put it: "We are STARSTUFF."

Any Questions??