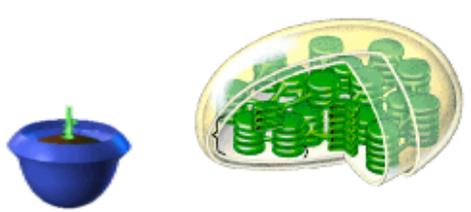


Chapter 10.3

Photosynthesis: The Calvin Cycle

Life from Air CO₂



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 dioxide + water + energy → glucose + oxygen

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

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

→ → build stuff !!

How is that helpful?

- Want to make C₆H₁₂O₆
 - ◆ synthesis

How? From what? What raw materials are available?

called:
“carbon fixation”

CO₂

↓

C₆H₁₂O₆

NADPH →

← NADP

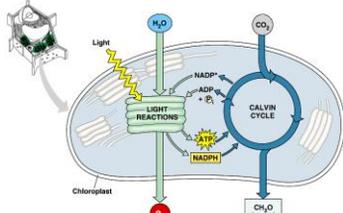
← reduces CO₂

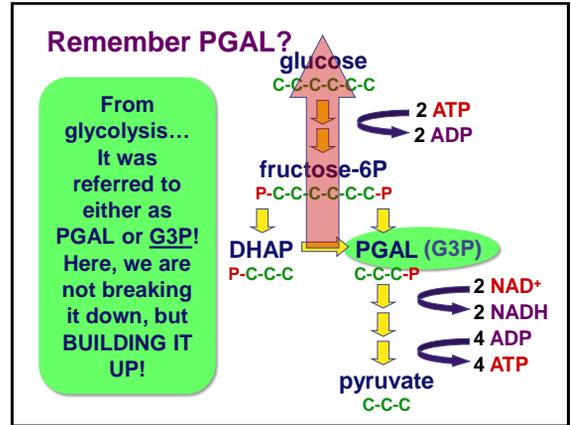
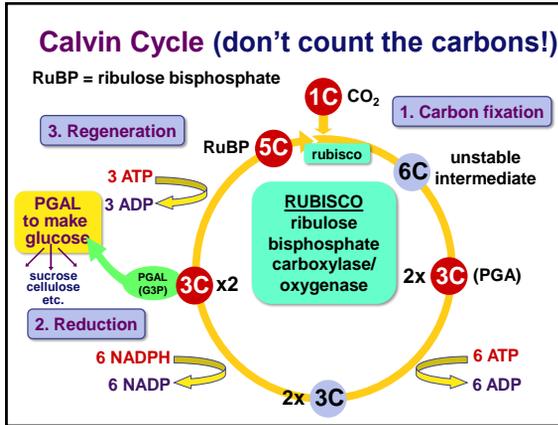
From CO₂ → C₆H₁₂O₆

- CO₂ has very little chemical energy
 - ◆ fully oxidized
- C₆H₁₂O₆ contains a lot of chemical energy
 - ◆ reduced
 - ◆ endergonic
- Reduction of CO₂ → C₆H₁₂O₆ proceeds in many small uphill steps
 - ◆ each catalyzed by specific enzyme
 - ◆ using energy stored in **ATP & NADPH**

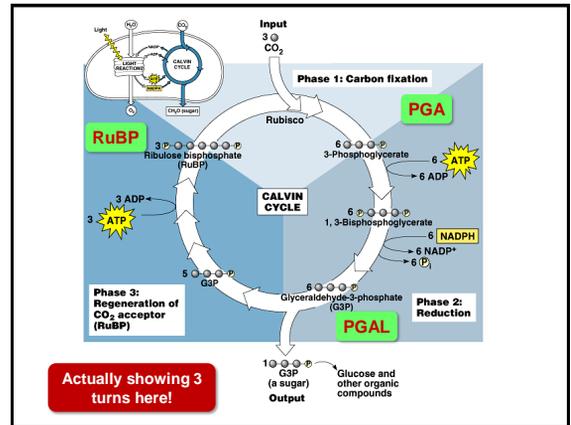
From Light Reactions to Calvin Cycle

- 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 → → important intermediate
 - PGAL → → glucose → → carbohydrates
 - → lipids
 - → amino acids
 - → nucleic acids

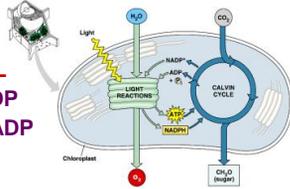


- ### Rubisco
- Enzyme which fixes carbon from atmosphere
 - ribulose biphosphate carboxylase /oxygenase
 - the most important enzyme in the world!
 - it makes life out of air!
 - definitely the most abundant enzyme
 - 50% of all protein in each plant leaf
-

- ### Energy Accounting
- The accounting is complicated
 - 3 turns of Calvin cycle = 1 PGAL
 - 3 $\text{CO}_2 \rightarrow 1\text{ PGAL (3C)}$
 - 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 → 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 **H₂O**
 - ◆ produced **O₂** as byproduct
- **Calvin cycle**
 - ◆ consumed **CO₂**
 - ◆ produced **PGAL**
 - ◆ regenerated **ADP**
 - ◆ regenerated **NADP**



Photosynthesis Summary

carbon dioxide + water + energy → glucose + oxygen



- Where did the CO₂ come from (biologically speaking)?
- Where did the CO₂ go?
- Where did the H₂O come from (biologically speaking)?
- Where did the H₂O go?
- Where did the energy come from?
- What's the energy used for?
- What will the C₆H₁₂O₆ be used for?
- Where did the O₂ come from?
- Where will the O₂ go (biologically speaking)?
- 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 organic 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!

sun

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