

Chapter 10.

Photosynthesis:

The Calvin Cycle

Life from Air



Whoops! Wrong Calvin...



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



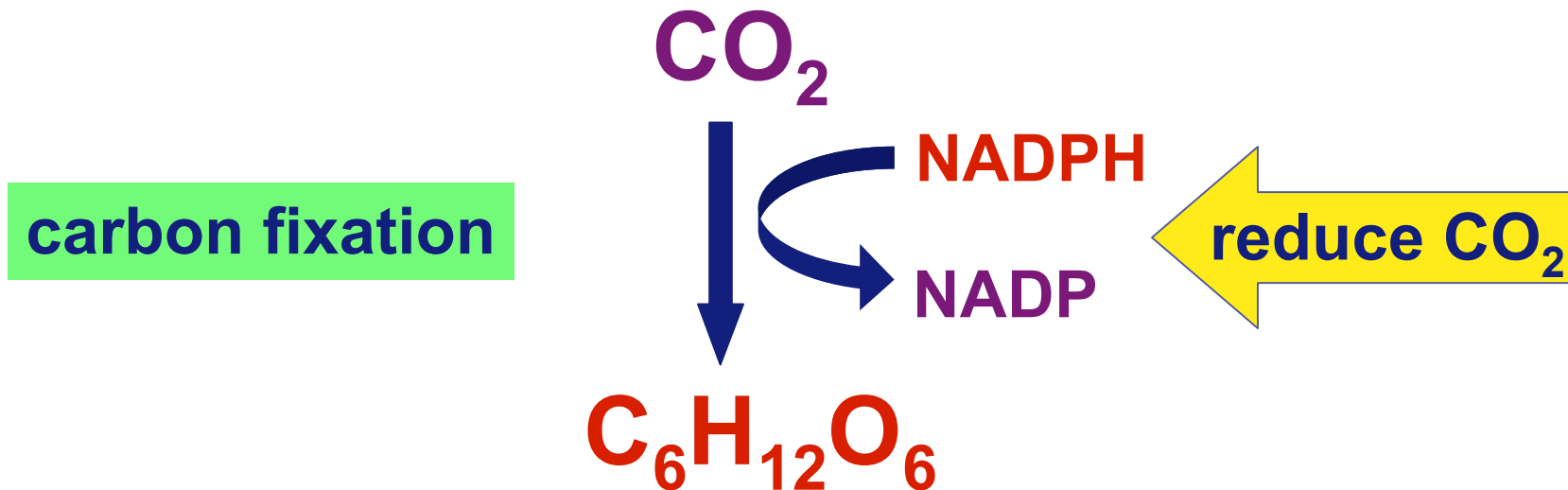
Light reactions

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

→ → **build stuff !!**

How is that helpful?

- Want to make $C_6H_{12}O_6$
 - ◆ synthesis
 - ◆ How? From what?
What raw materials are available?

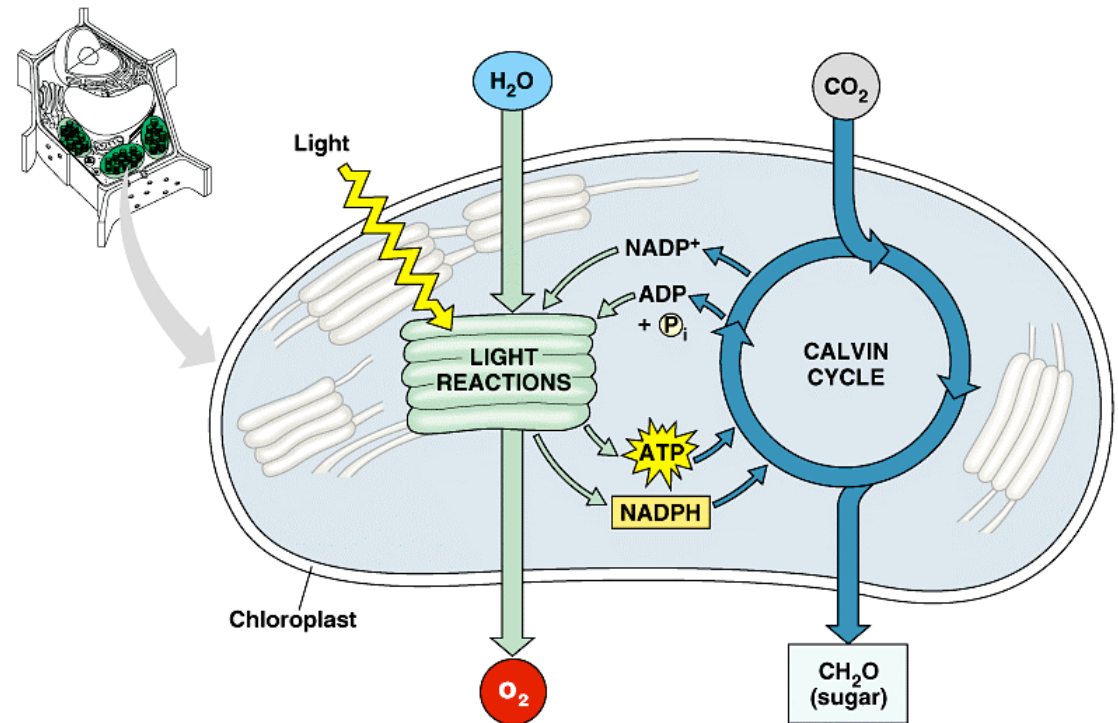


From $\text{CO}_2 \rightarrow \text{C}_6\text{H}_{12}\text{O}_6$

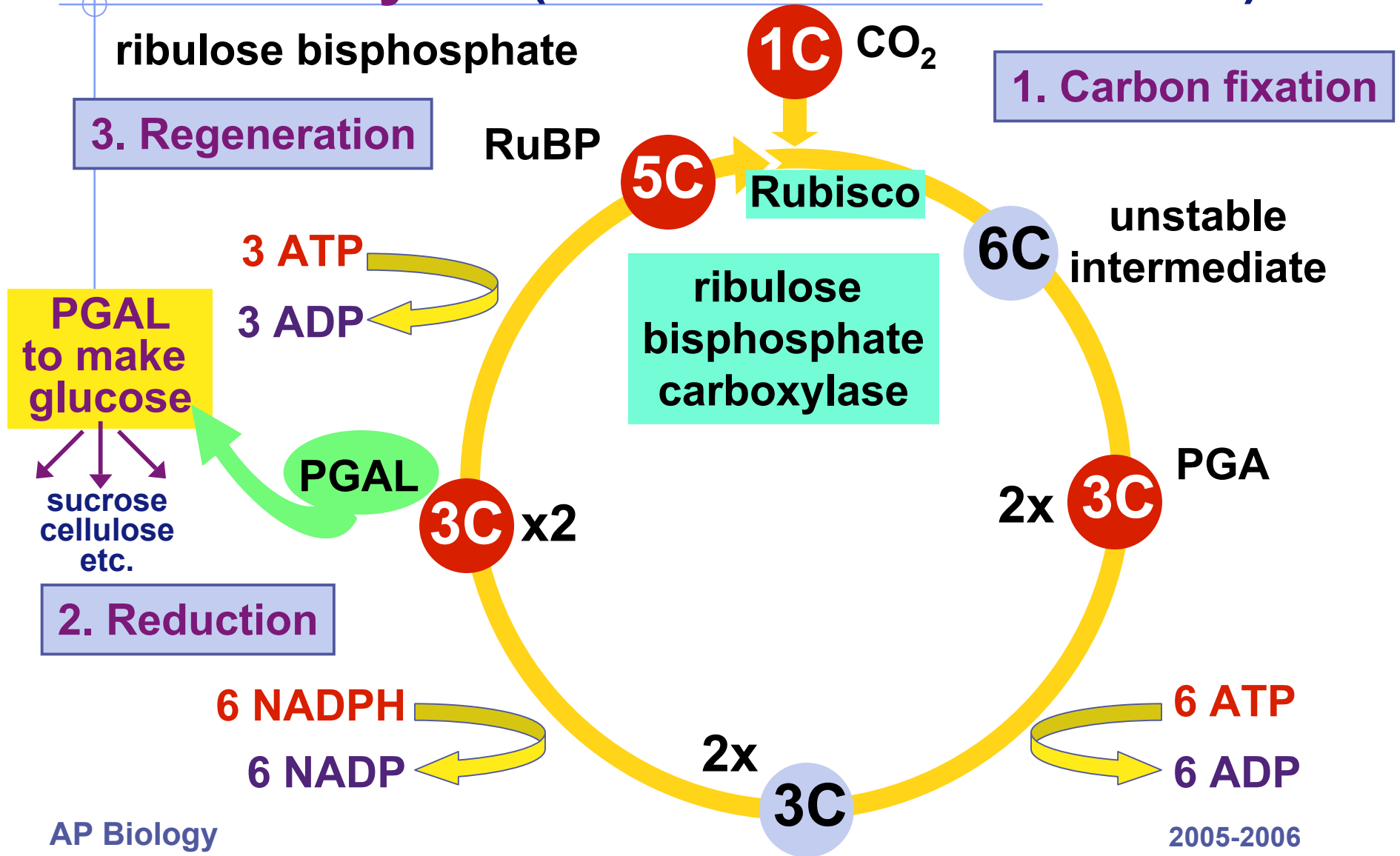
- CO_2 has very little chemical energy
 - ◆ fully oxidized
- $\text{C}_6\text{H}_{12}\text{O}_6$ contains a lot of chemical energy
 - ◆ reduced
 - ◆ endergonic
- Reduction of $\text{CO}_2 \rightarrow \text{C}_6\text{H}_{12}\text{O}_6$ proceeds in many small uphill steps
 - ◆ each catalyzed by specific enzyme
 - ◆ using energy stored in **ATP & NADPH**

From Light reactions to Calvin cycle

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



Calvin cycle (don't count the carbons!)



Remember

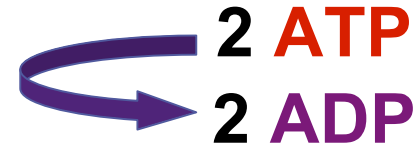
PGAL?

glycolysis



glucose

C-C-C-C-C-C



fructose-6P

P-C-C-C-C-C-P



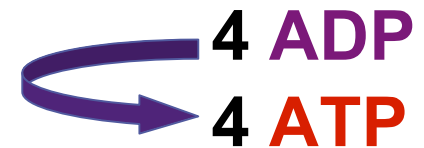
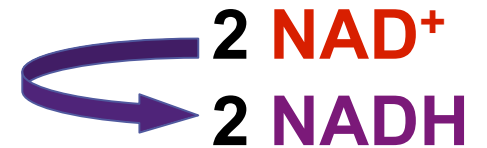
DHAP

P-C-C-C



PGAL

C-C-C-P



pyruvate

C-C-C

Calvin cycle

- **PGAL**

- ◆ end product of Calvin cycle
- ◆ energy rich sugar
- ◆ 3 carbon compound
- ◆ “C3 photosynthesis”

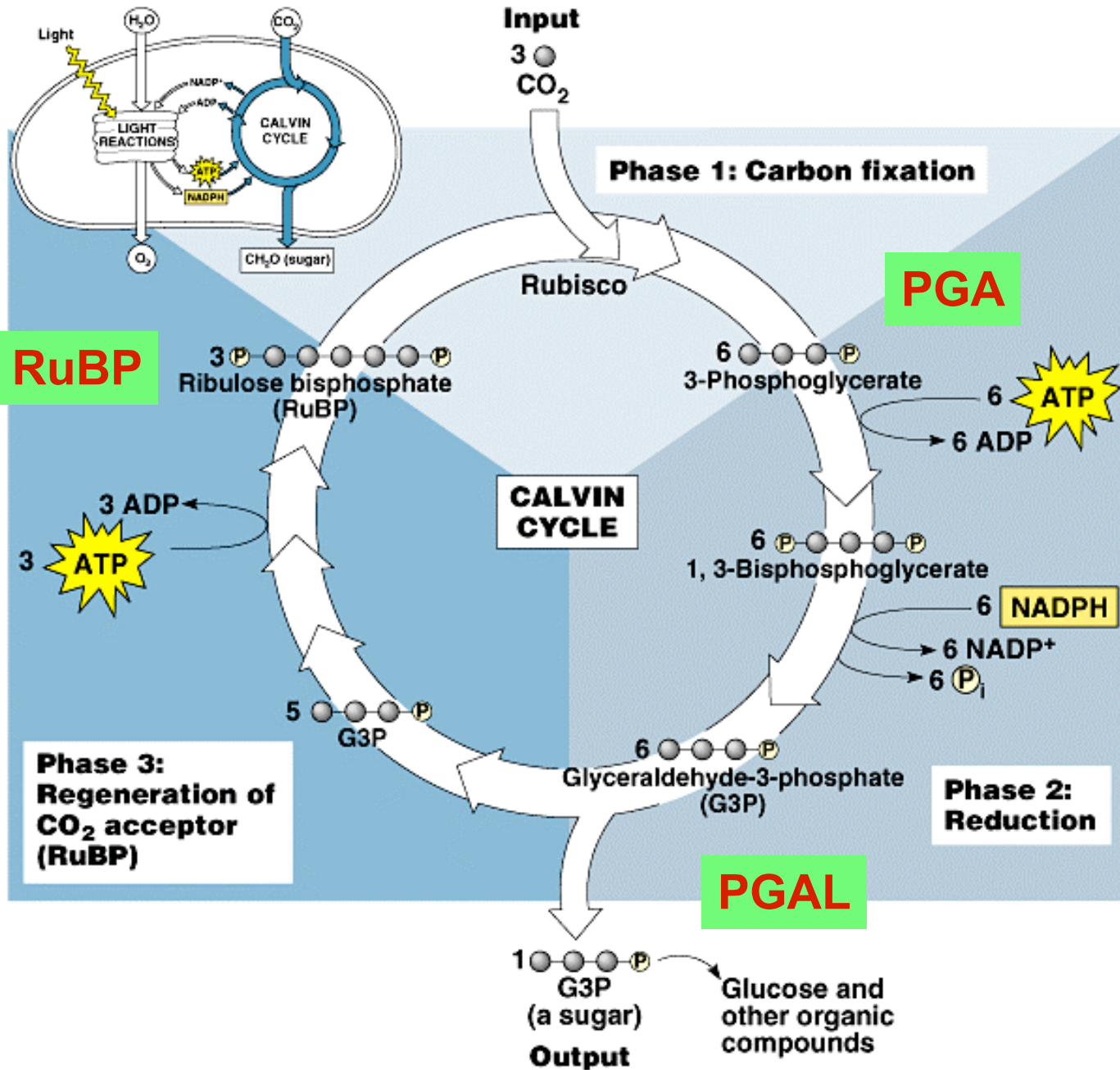
- **PGAL** → → important intermediate

PGAL → → glucose → → carbohydrates

→ → lipids

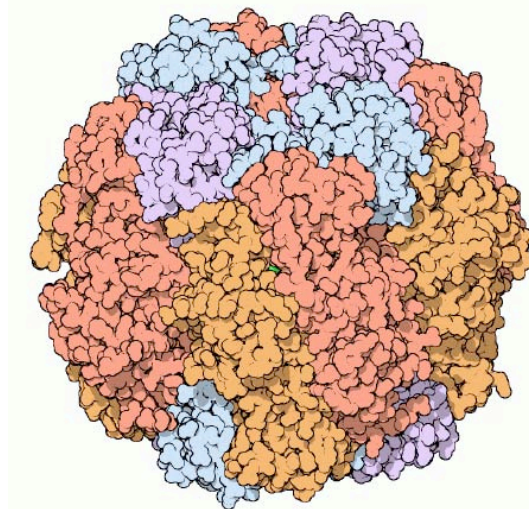
→ → amino acids

→ → nucleic acids



Rubisco

- Enzyme which fixes carbon from atmosphere
 - ◆ ribulose biphosphate carboxylase
 - ◆ the most important enzyme in the world!
 - it makes life out of air!
 - ◆ definitely the most abundant enzyme



Accounting

- The accounting is complicated
 - ◆ 3 turns of Calvin cycle = 1 **PGAL**
 - ◆ 3 **CO₂** → 1 **PGAL** (3C)
 - ◆ 6 turns of Calvin cycle = 1 **C₆H₁₂O₆** (6C)
 - ◆ 6 **CO₂** → 1 **C₆H₁₂O₆** (6C)
 - ◆ 18 **ATP** + 12 **NADPH** → 1 **C₆H₁₂O₆**
 - ◆ 6 **ATP** = left over from light reactions for cell to use elsewhere

Photosynthesis summary

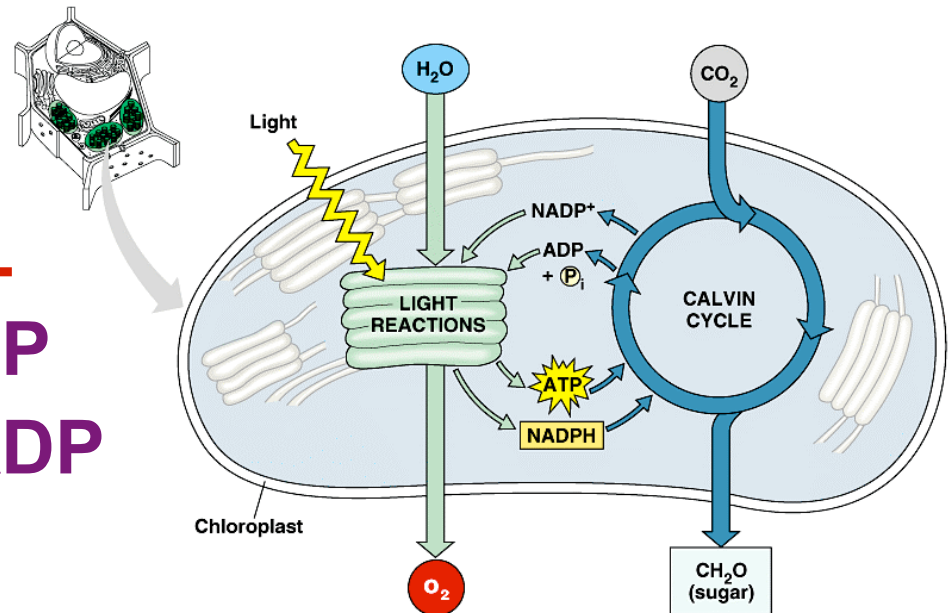
- Making energy & organic molecules from light energy

carbon + water + energy → glucose + oxygen
dioxide



Photosynthesis summary

- **Light reactions**
 - ◆ produced **ATP**
 - ◆ produced **NADPH**
 - ◆ consumed **H₂O**
 - ◆ produced **O₂** as byproduct
- **Calvin cycle**
 - ◆ consumed **CO₂**
 - ◆ produced **PGAL**
 - ◆ regenerated **ADP**
 - ◆ regenerated **NADP**



Summary of photosynthesis



- Where did the CO_2 come from?
- Where did the CO_2 go?
- Where did the H_2O come from?
- Where did the H_2O go?
- Where did the energy come from?
- What's the energy used for?
- What will the $\text{C}_6\text{H}_{12}\text{O}_6$ be used for?
- Where did the O_2 come from?
- Where will the O_2 go?
- What else is involved that is not listed in this equation?

Supporting a biosphere



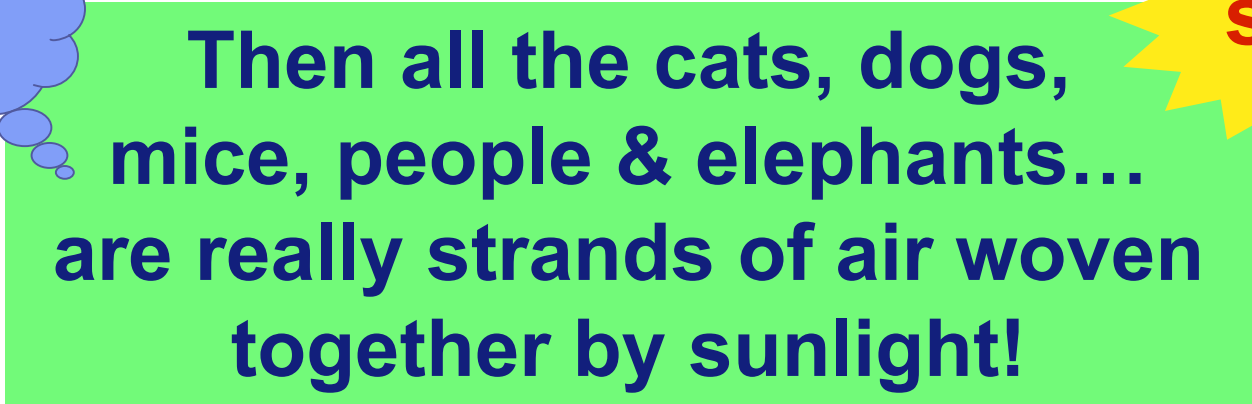
- **On global scale, photosynthesis is the most important process for the continuation of life on Earth**
 - ◆ each year photosynthesis synthesizes 160 billion tons of carbohydrate
 - ◆ heterotrophs are dependent on plants as food source for fuel & raw materials

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!



sun



Any Questions??