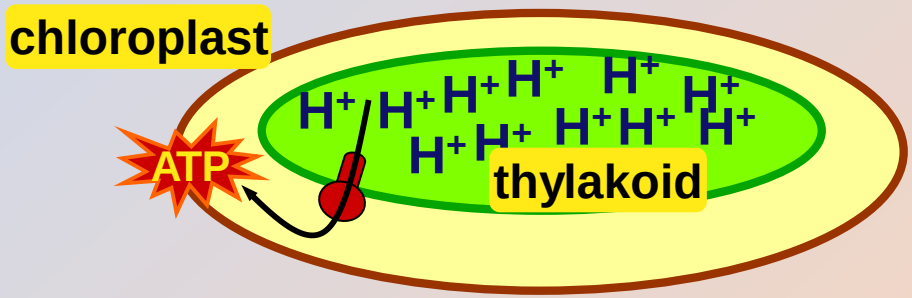
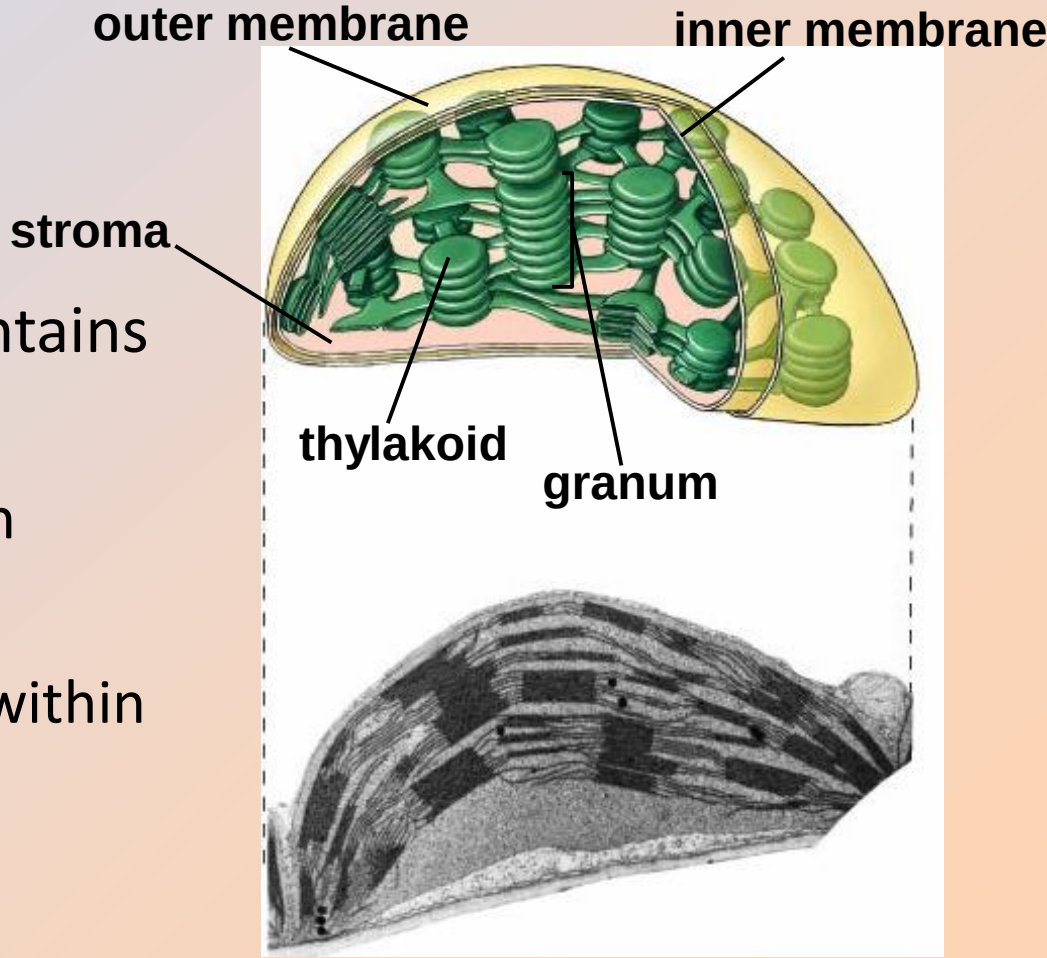
Photosynthesis 1: The Light Reactions (Ch. 8)

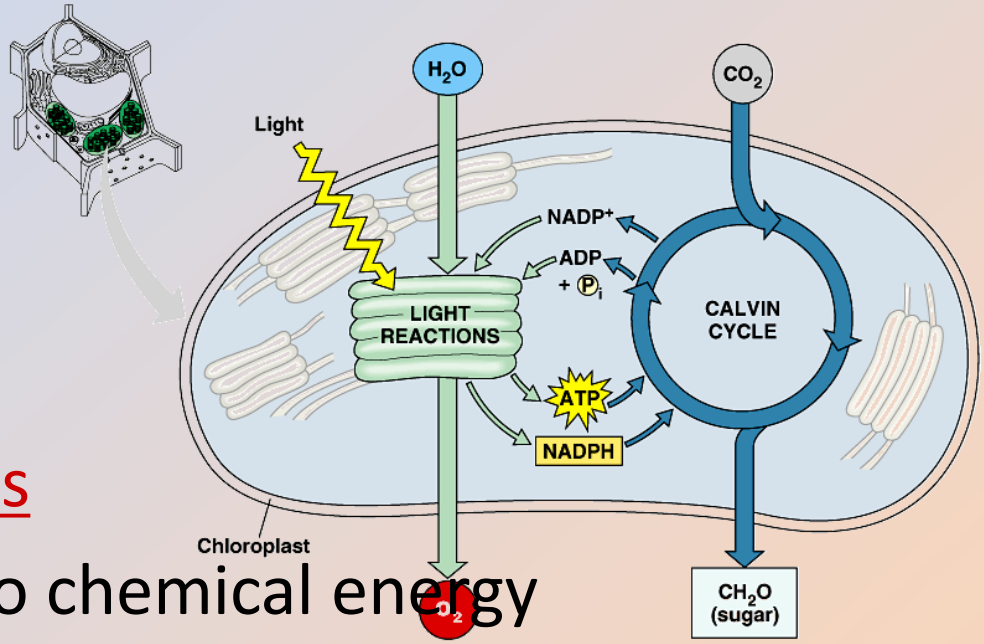
Plant structure

- Chloroplasts
  - double membrane
  - stroma
    - fluid-filled interior
  - thylakoid sacs
  - grana stacks
- Thylakoid membrane contains
  - chlorophyll molecules
  - electron transport chain
  - ATP synthase
    - H^+ gradient built up within thylakoid sac

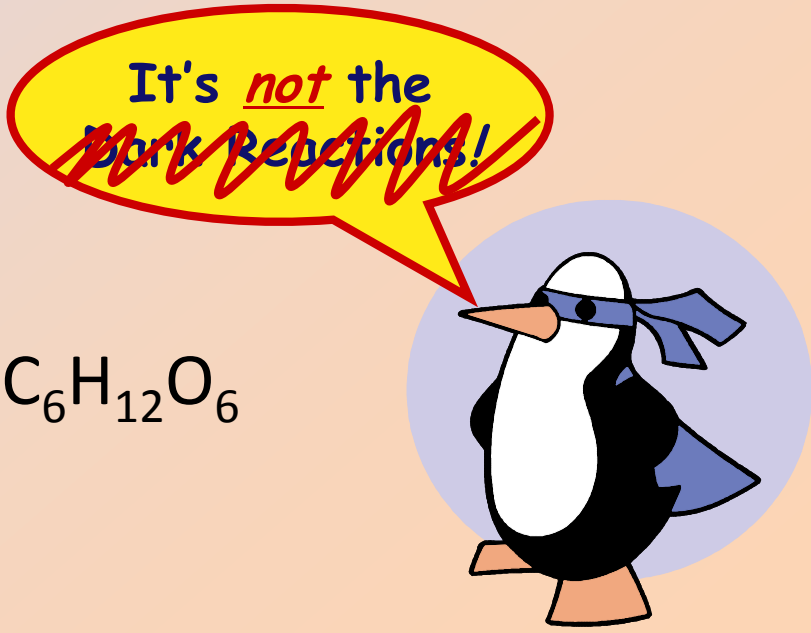




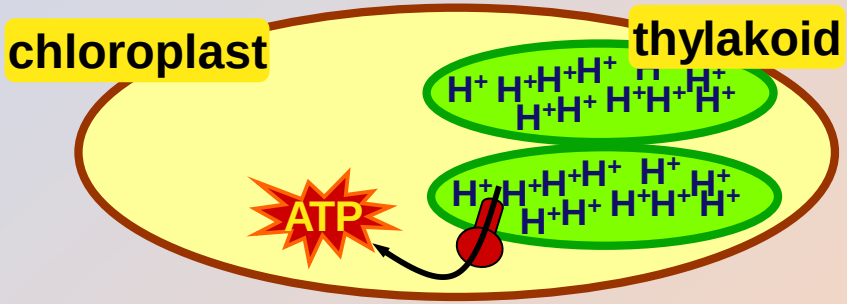
Photosynthesis



- Light reactions
  - light-dependent reactions
    - convert solar energy to chemical energy
    - ATP & NADPH
- Calvin cycle
  - light-independent reactions
  - sugar building reactions
    - uses ATP & NADPH to make $C_6H_{12}O_6$



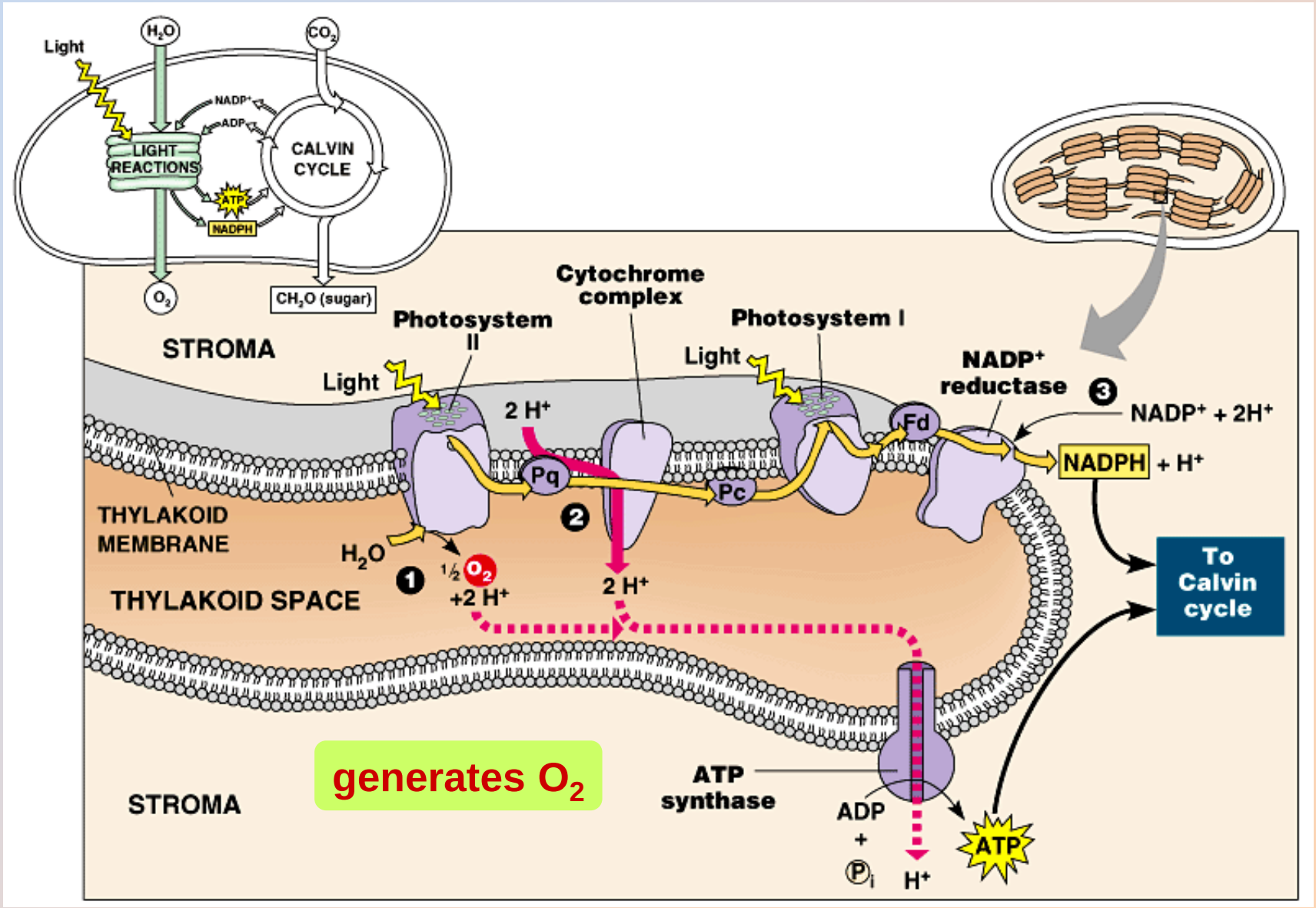
Light reactions



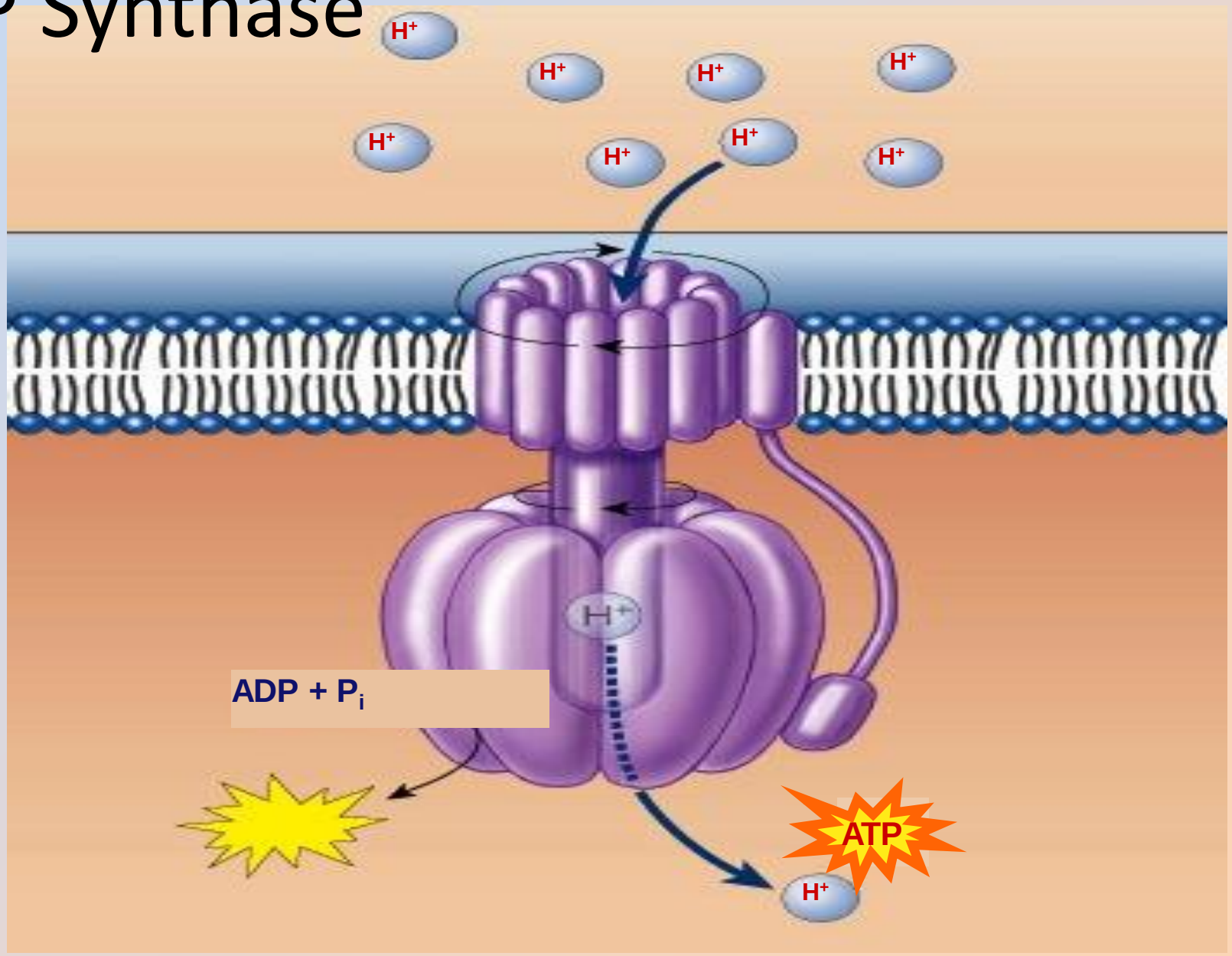
- Electron Transport Chain
  - like in cellular respiration
  - proteins in organelle membrane
  - electron acceptors
    - NADPH
  - proton (H^+) gradient across inner membrane
  - ATP synthase enzyme

Chloroplasts transform light energy into chemical energy of ATP

- use electron carrier NADPH

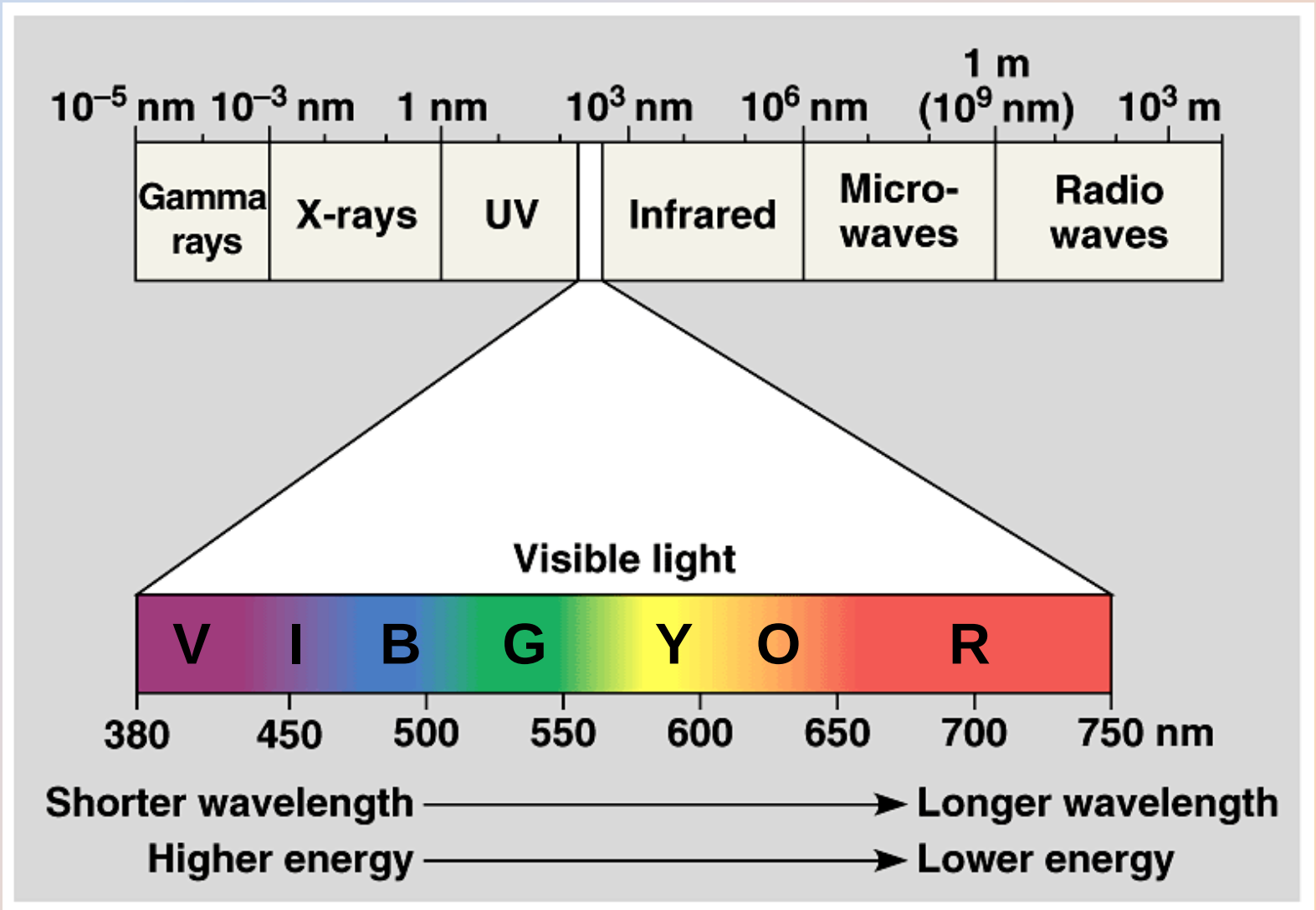


ATP Synthase



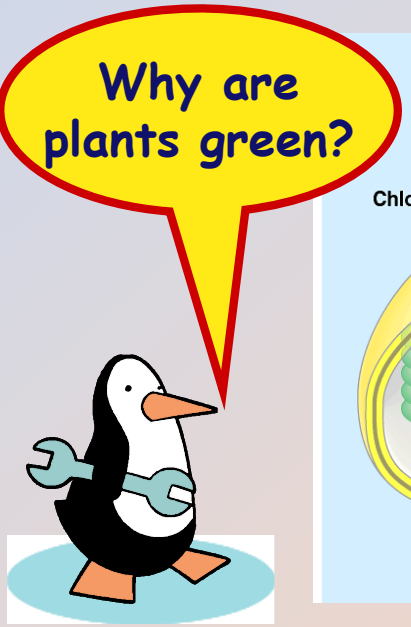
A Look at Light

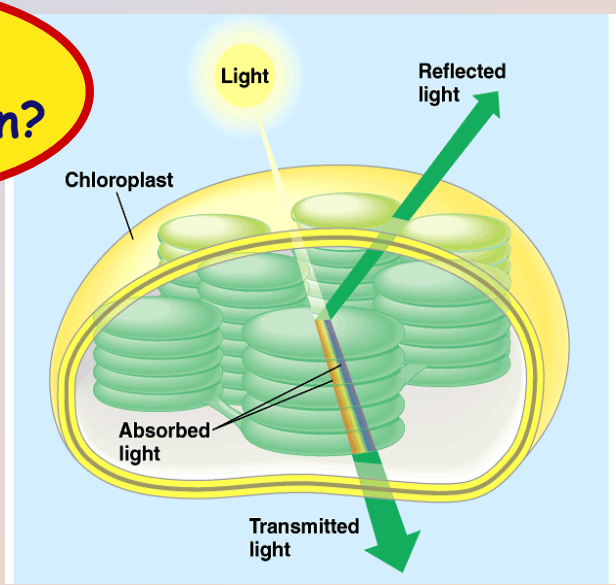
- The spectrum of color

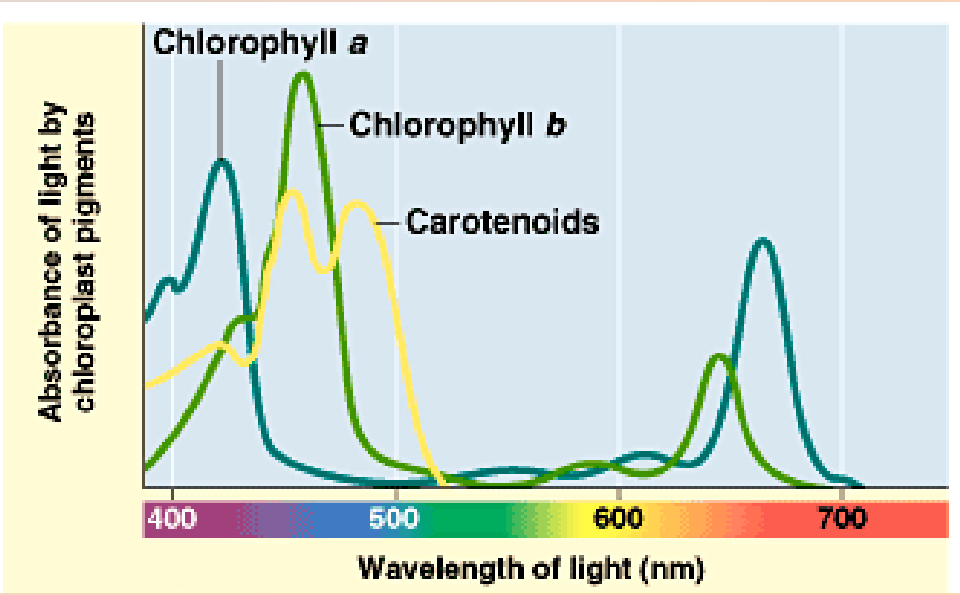


Light: absorption spectra

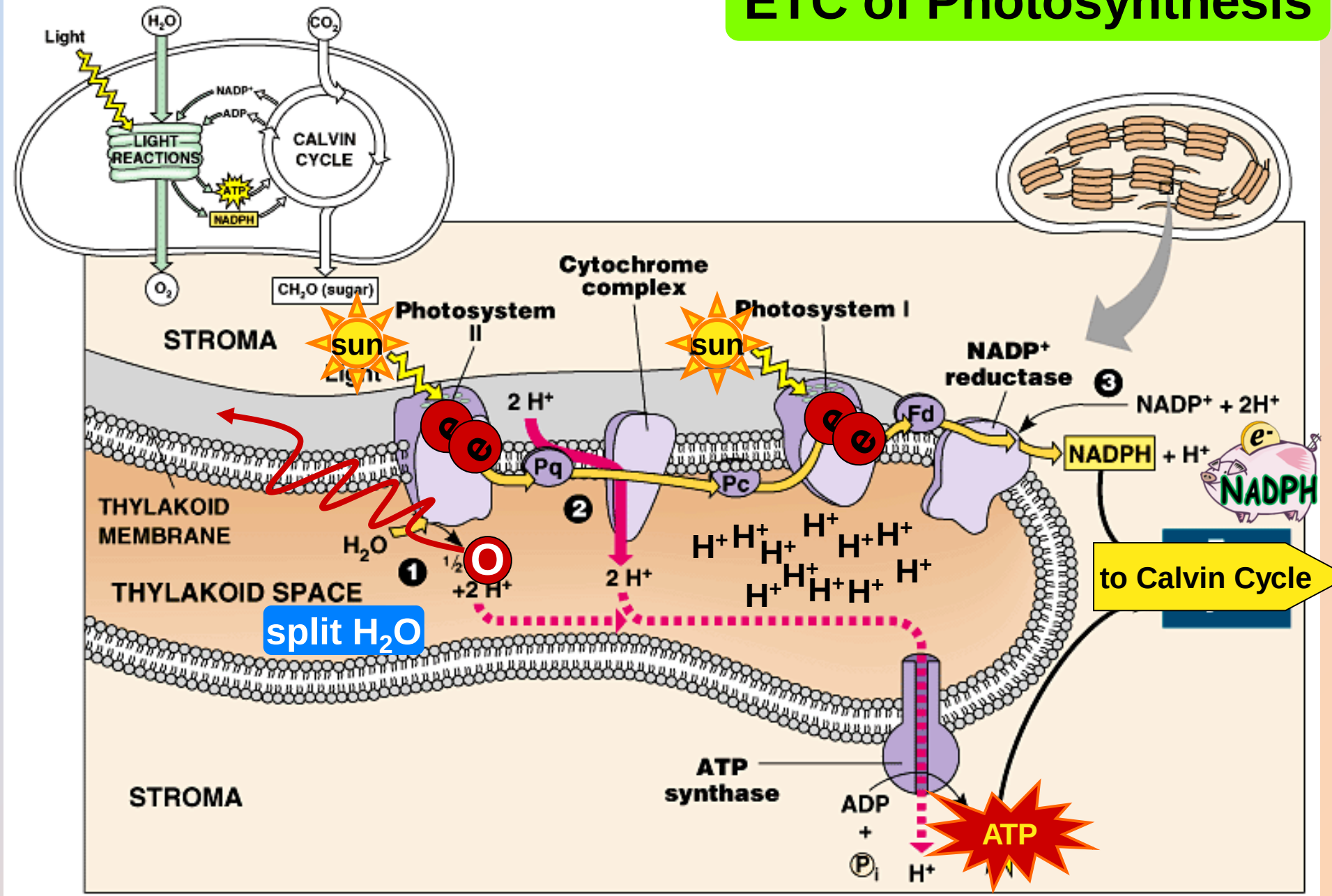
- Photosynthesis gets energy by absorbing wavelengths of light
  - chlorophyll *a*
    - absorbs best in red & blue wavelengths & least in green







ETC of Photosynthesis



Light reactions of Photosynthesis

- uses light energy to produce
  - ATP & NADPH
    - go to Calvin cycle
- Chlorophyll absorbs light
    - splits H_2O
    - O combines with another O to form O_2
    - O_2 released to atmosphere
    - and we breathe easier!

Photosynthesis summary

Where did the energy come from?

Where did the electrons come from?

Where did the H_2O come from?

Where did the O_2 come from?

Where did the O_2 go?

Where did the H^+ come from?

Where did the ATP come from?

What will the ATP be used for?

Where did the NADPH come from?

What will the NADPH be used for?

…stay tuned for the Calvin cycle

Light reactions

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

- What can we do now?

→ → build stuff *!!*

photosynthesis

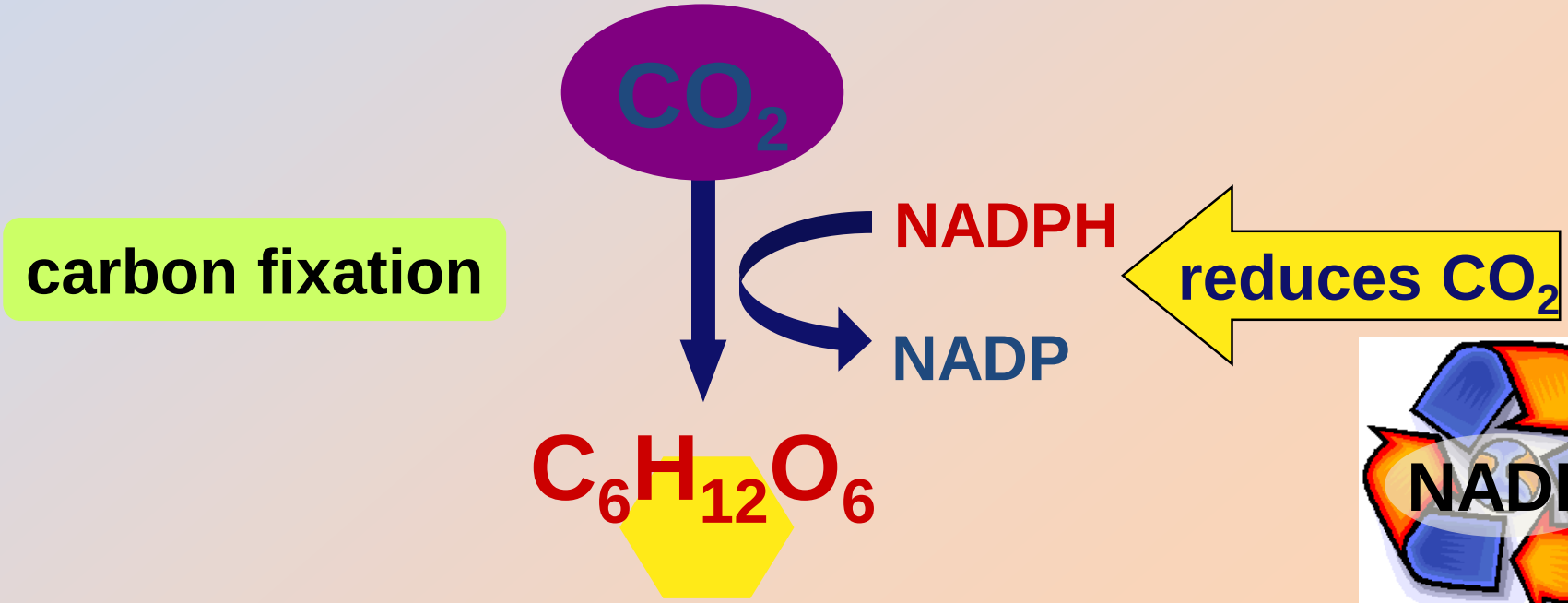
The Calvin Cycle

1950s | 1961

Whoops! Wrong Calvin…

How is that helpful?

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



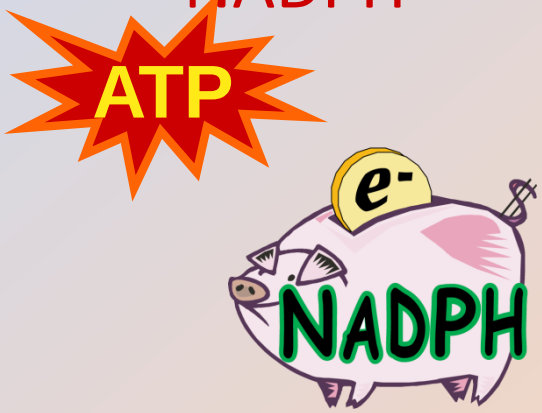
From $CO_2 \rightarrow C_6H_{12}O_6$

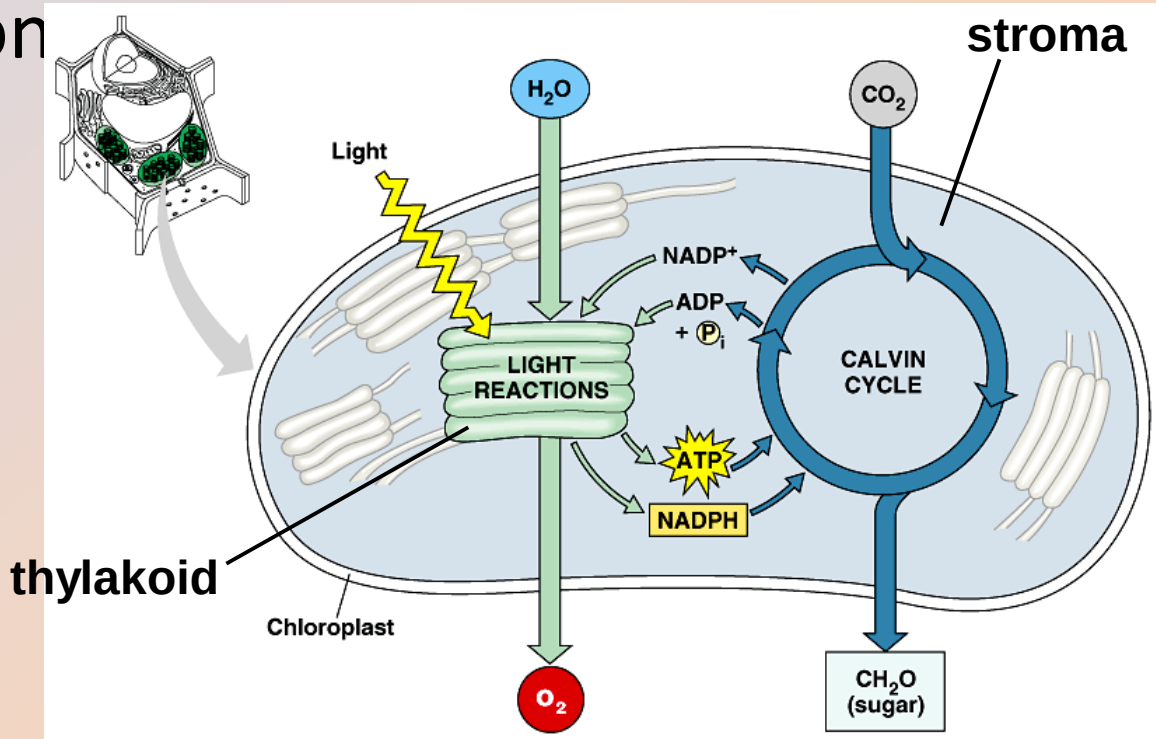
- CO_2 has very little chemical energy
- $C_6H_{12}O_6$ contains a lot of chemical energy

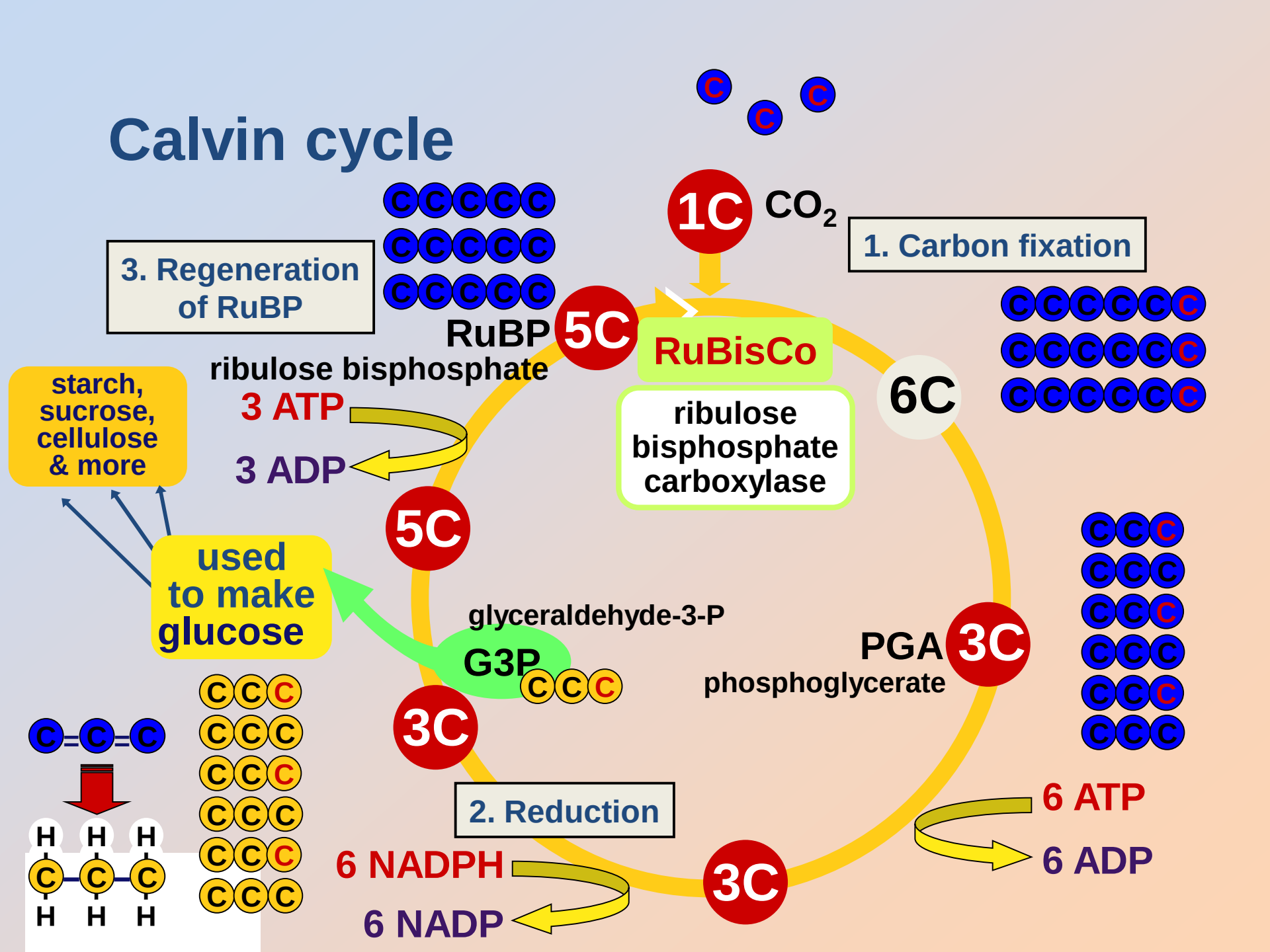
- Synthesis = endergonic process
  - put in a lot of energy
- $CO_2 \rightarrow C_6H_{12}O_6$ proceeds in many small uphill steps
  - each catalyzed by a specific enzyme
  - using energy stored in ATP & NADPH

From Light reactions to Calvin cycle

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

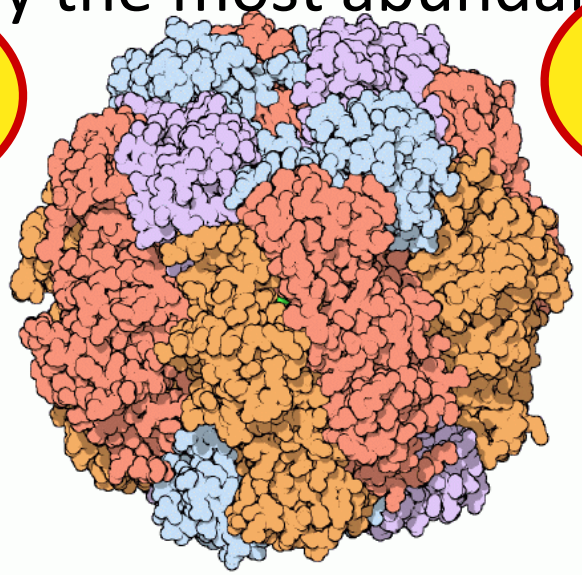





Calvin cycle
1C
CO_2
1. Carbon fixation
RuBP
ribulose bisphosphate
5C
RuBisCo
ribulose bisphosphate carboxylase
6C
3. Regeneration of RuBP
3 ATP
3 ADP
starch, sucrose, cellulose & more
used to make glucose
5C
glyceraldehyde-3-P
G3P
3C
PGA
phosphoglycerate
3C
2. Reduction
6 NADPH
6 NADP
3C
6 ATP
6 ADP

RuBisCo

- Enzyme which fixes carbon from air
  - ribulose bisphosphate carboxylase
  - the most important enzyme in the world!
    - it makes life out of air!
    - [illegible]itely the most abundant

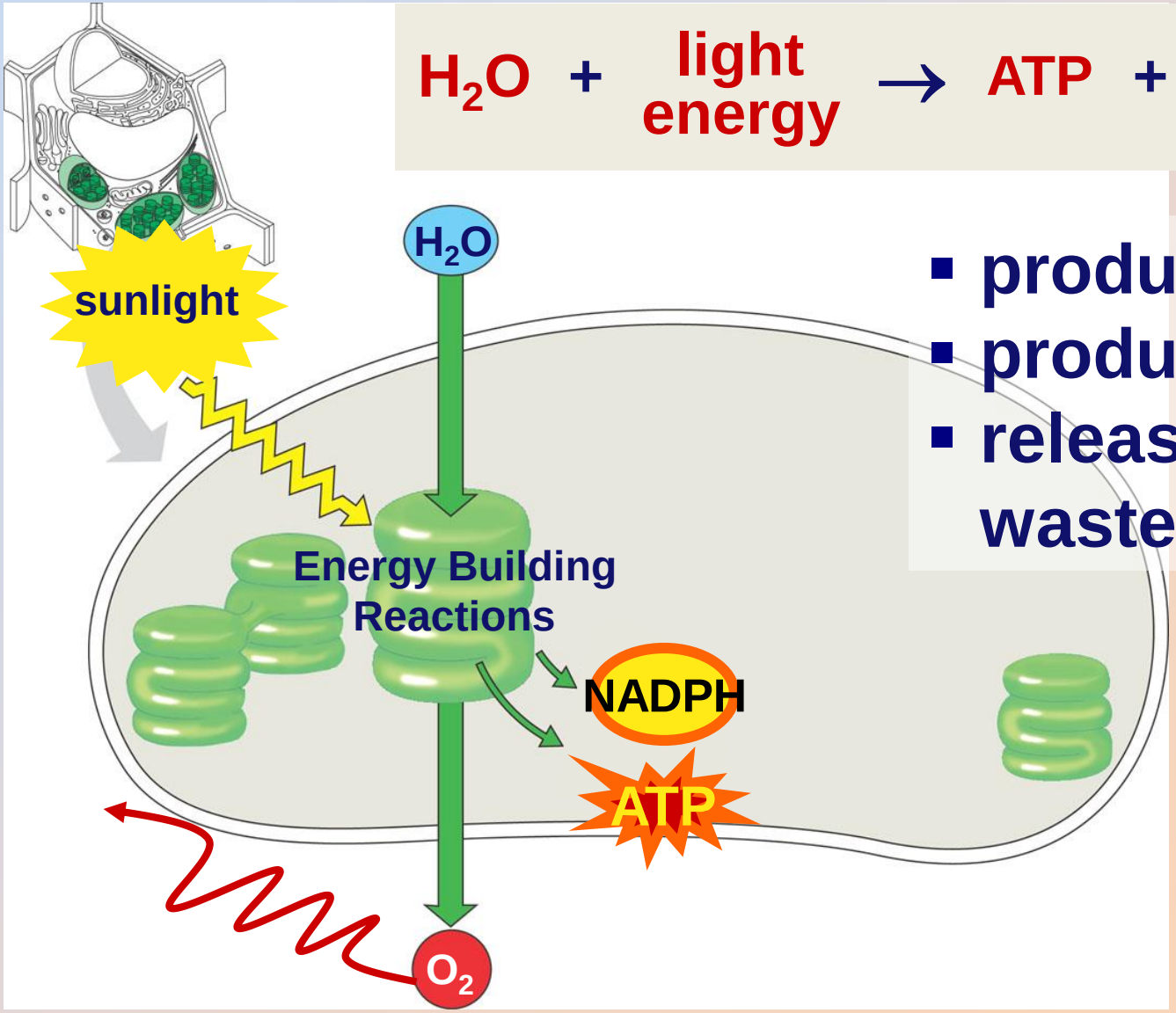


Accounting

- The accounting is complicated
  - 3 turns of Calvin cycle = 1 G3P
  - 3 CO_2 → 1 G3P (3C)
  - 6 turns of Calvin cycle = 1 $C_6H_{12}O_6$ (6C)
  - 6 CO_2 → 1 $C_6H_{12}O_6$ (6C)
  - 18 ATP + 12 NADPH → 1 $C_6H_{12}O_6$
  - any ATP left over from light reactions will be used elsewhere by the cell

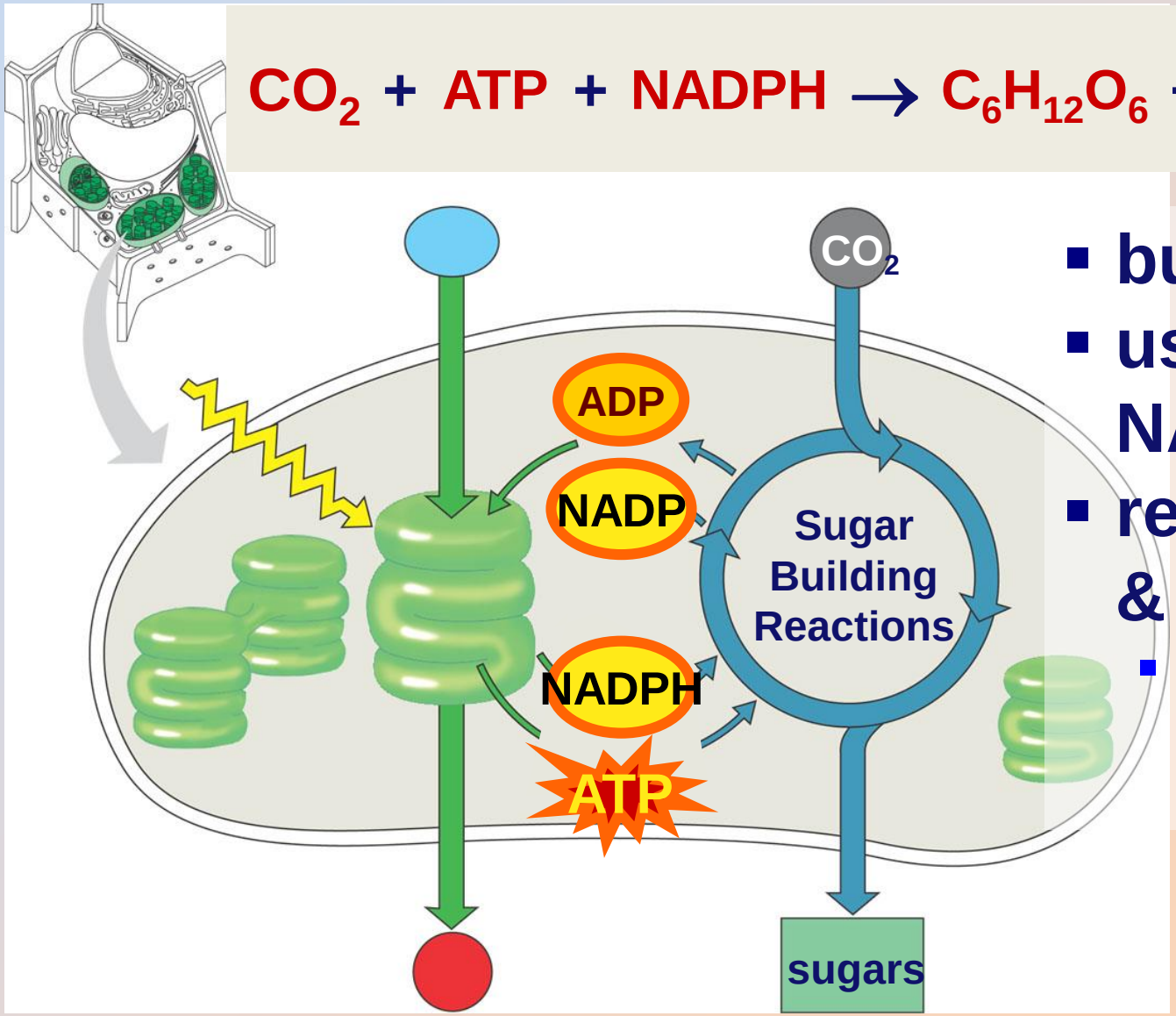
Light Reactions

H_2O + light energy → ATP + NADPH + O_2



- produces ATP
- produces NADPH
- releases O_2 as a waste product

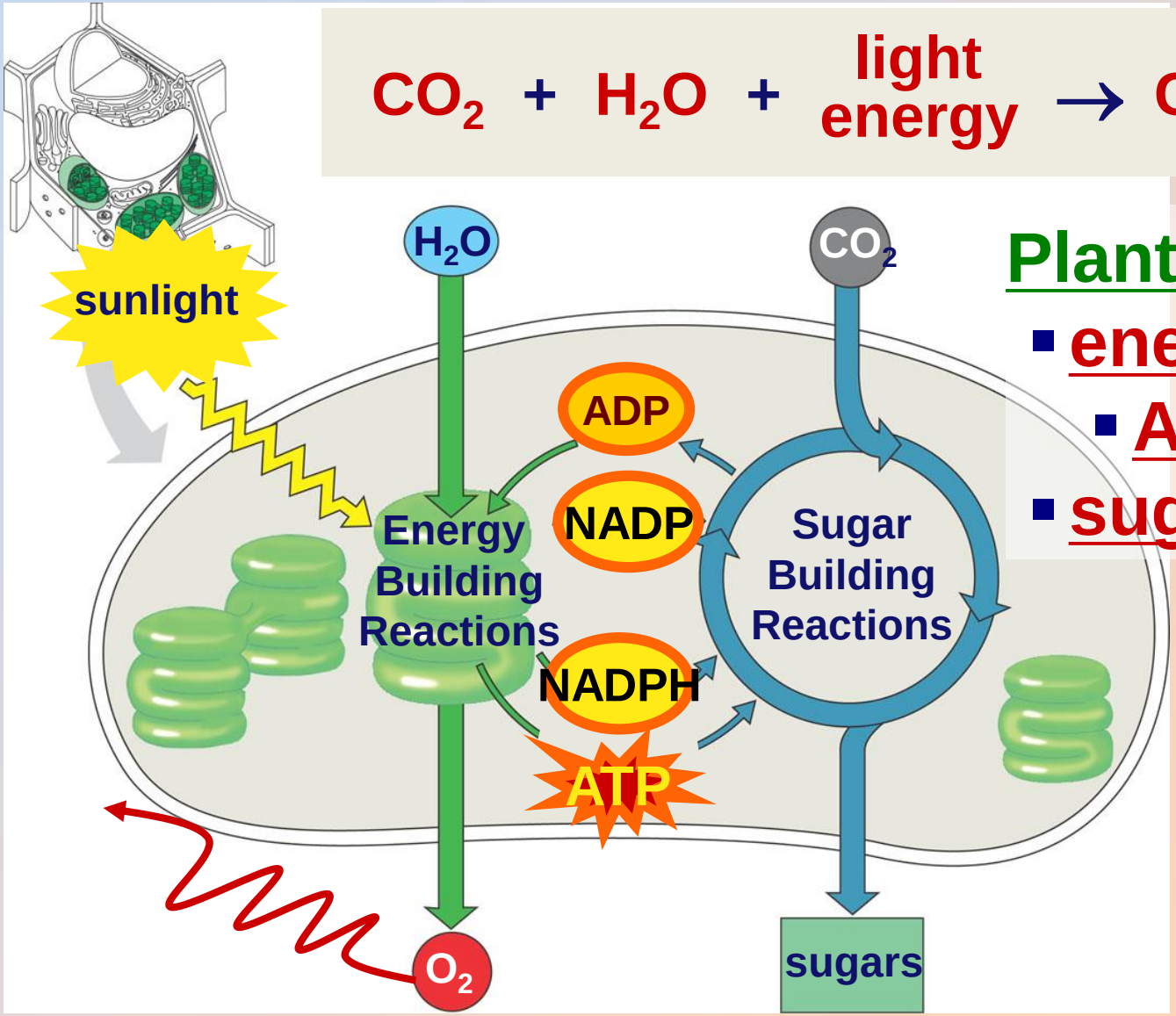
Calvin Cycle



- builds sugars
- uses ATP & NADPH
- recycles ADP & NADP
  - back to make more ATP & NADPH

Putting it all together

$$CO_2 + H_2O + \text{light energy} \rightarrow C_6H_{12}O_6 + O_2$$



Plants make both:

- **energy**
  - **ATP & NADPH**
- **sugars**

Summary of photosynthesis

$$6CO_2 + 6H_2O + \text{light energy} \rightarrow C_6H_{12}O_6 + 6O_2$$

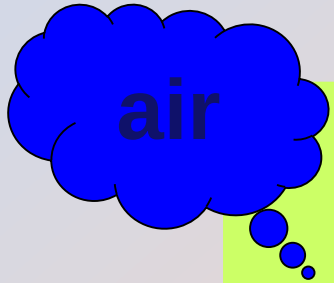
- Where did the CO_2 come from?
- Where did the CO_2 go?
- Where did the H_2O come from?
- Where did the H_2O go?
- Where did the energy come from?
- What's the energy used for?
- What will the $C_6H_{12}O_6$ be used for?
- Where did the O_2 come from?
- Where will the O_2 go?
- What else is involved…not 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…
    - captures 121 billion tons of CO_2
    - 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 by sunlight out of thin air
- All the solid material of every animal was built from plant material



Then all the plants, cats, dogs, elephants & people … are really particles of air woven together by strands of sunlight!

If plants can do it…
You can learn it*!*

Ask Questions*!!*

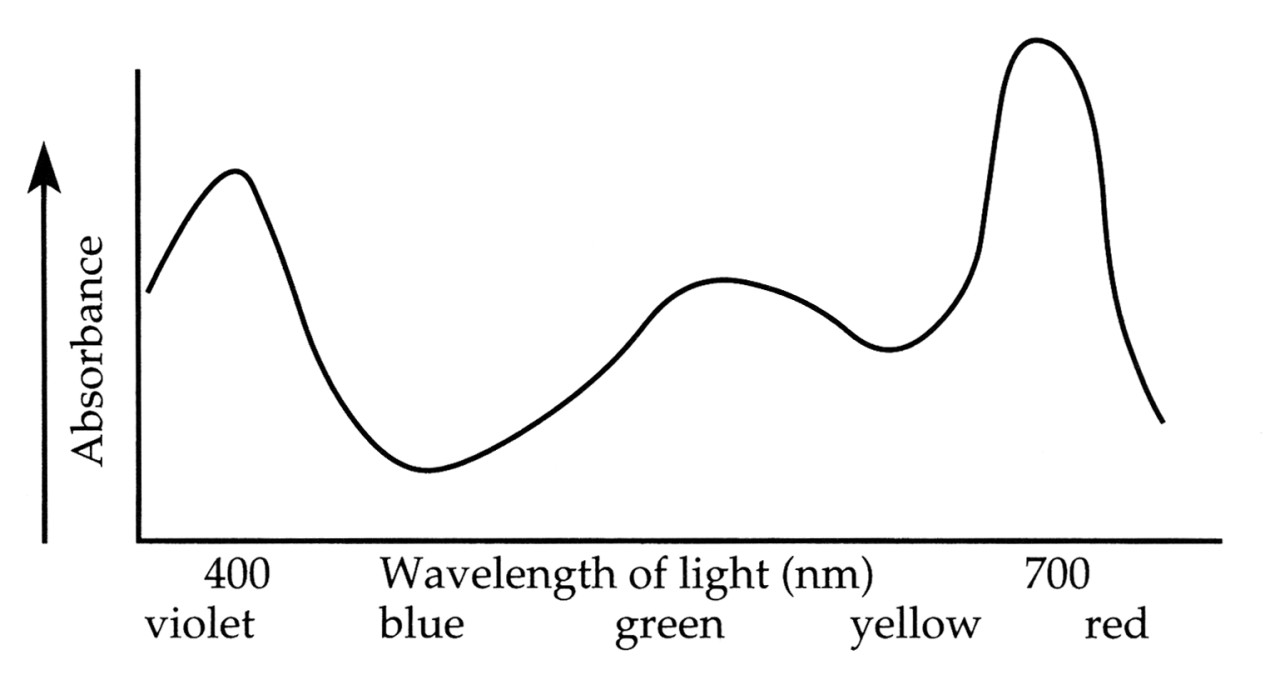
A lovely, animated song

You can grow if you Ask Questions!

Review Questions

1. Below is an absorption spectrum for an unknown pigment molecule. What color would this pigment appear to you?

A. violet
B. blue
C. green
D. yellow
E. red



2. In green plants, most of the ATP for synthesis of proteins, cytoplasmic streaming, and other cellular activities comes directly from
   A. photosystem I.
   B. the Calvin cycle.
   C. oxidative phosphorylation.
   D. noncyclic photophosphorylation.
   E. cyclic photophosphorylation.

3. What portion of an illuminated plant cell would you expect to have the lowest pH?
   A. nucleus
   B. vacuole
   C. chloroplast
   D. stroma of chloroplast
   E. thylakoid space

4. A new flower species has a unique photosynthetic pigment. The leaves of this plant appear to be reddish yellow. What wavelengths of visible light are *not* being absorbed by this pigment?

   A. red and yellow
   B. blue and violet
   C. green and yellow
   D. blue, green, and red
   E. green, blue, and violet

5. Assume a thylakoid is somehow punctured so that the interior of the thylakoid is no longer separated from the stroma. This damage will have the most direct effect on which of the following processes?
   A. the splitting of water
   B. the absorption of light energy by chlorophyll
   C. the flow of electrons from photosystem II to photosystem I
   D. the synthesis of ATP
   E. the reduction of $NADP^+$

6. Which of the following conclusions does *not* follow from studying the absorption spectrum for chlorophyll *a* and the action spectrum for photosynthesis?

   A. Not all wavelengths are equally effective for photosynthesis.
   B. There must be accessory pigments that broaden the spectrum of light that contributes energy for photosynthesis.
   C. The red and blue areas of the spectrum are most effective in driving photosynthesis.
   D. Chlorophyll owes its color to the absorption of green light.
   E. Chlorophyll *a* has two absorption peaks.