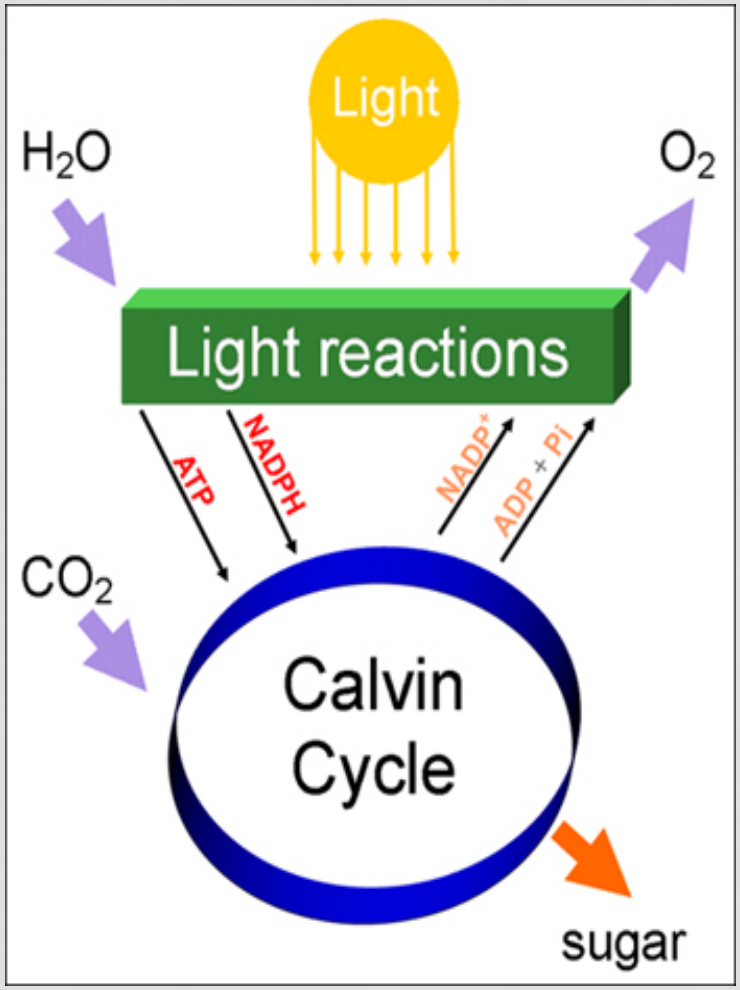
CHAPTER 6: PHOTOSYNTHESIS

CAPTURING & CONVERTING ENERGY

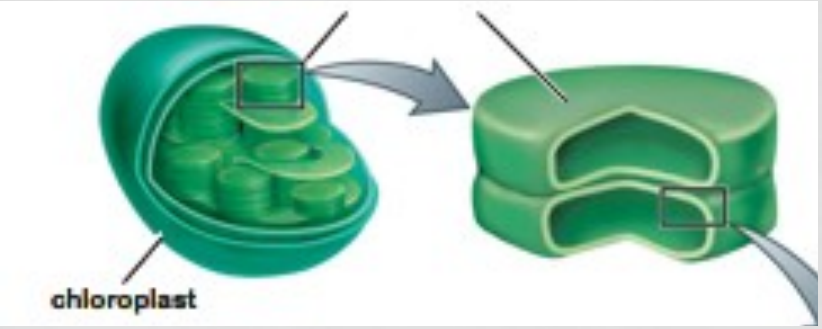
2 PROCESSES OF PHOTOSYNTHESIS

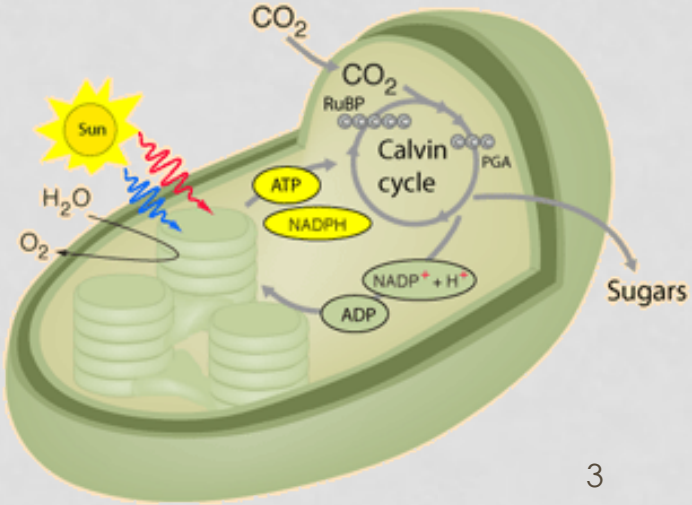
- Photosynthesis is actually 2 processes:
  - **light reactions** - convert solar energy (sunlight) to chemical energy (ATP & NADPH)
  - **dark reactions (Calvin cycle)** - light independent reactions; use energy produced & stored during light reactions (ATP & NADPH) & incorporates CO_2 from air into organic molecules (PGAL), which are converted to sugar (glucose)

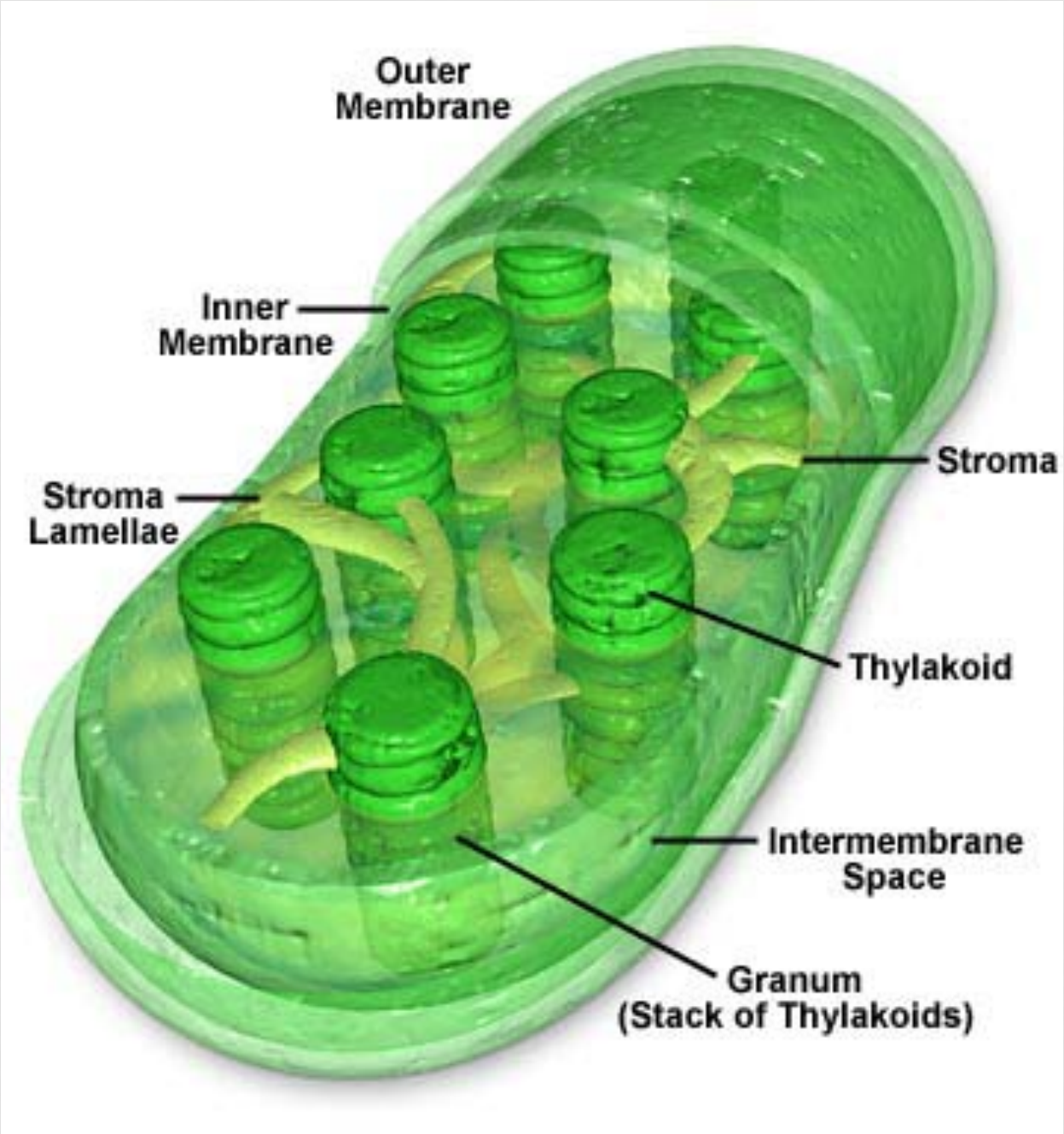


PHOTOSYNTHESIS

- Photosynthesis takes place in **chloroplast** organelle.
  - contains photosynthetic membranes that contain chlorophyll
    - light reactions take place in **photosynthetic membranes (thylakoids)**
    - dark reactions take place **outside photosynthetic membranes (stroma)**







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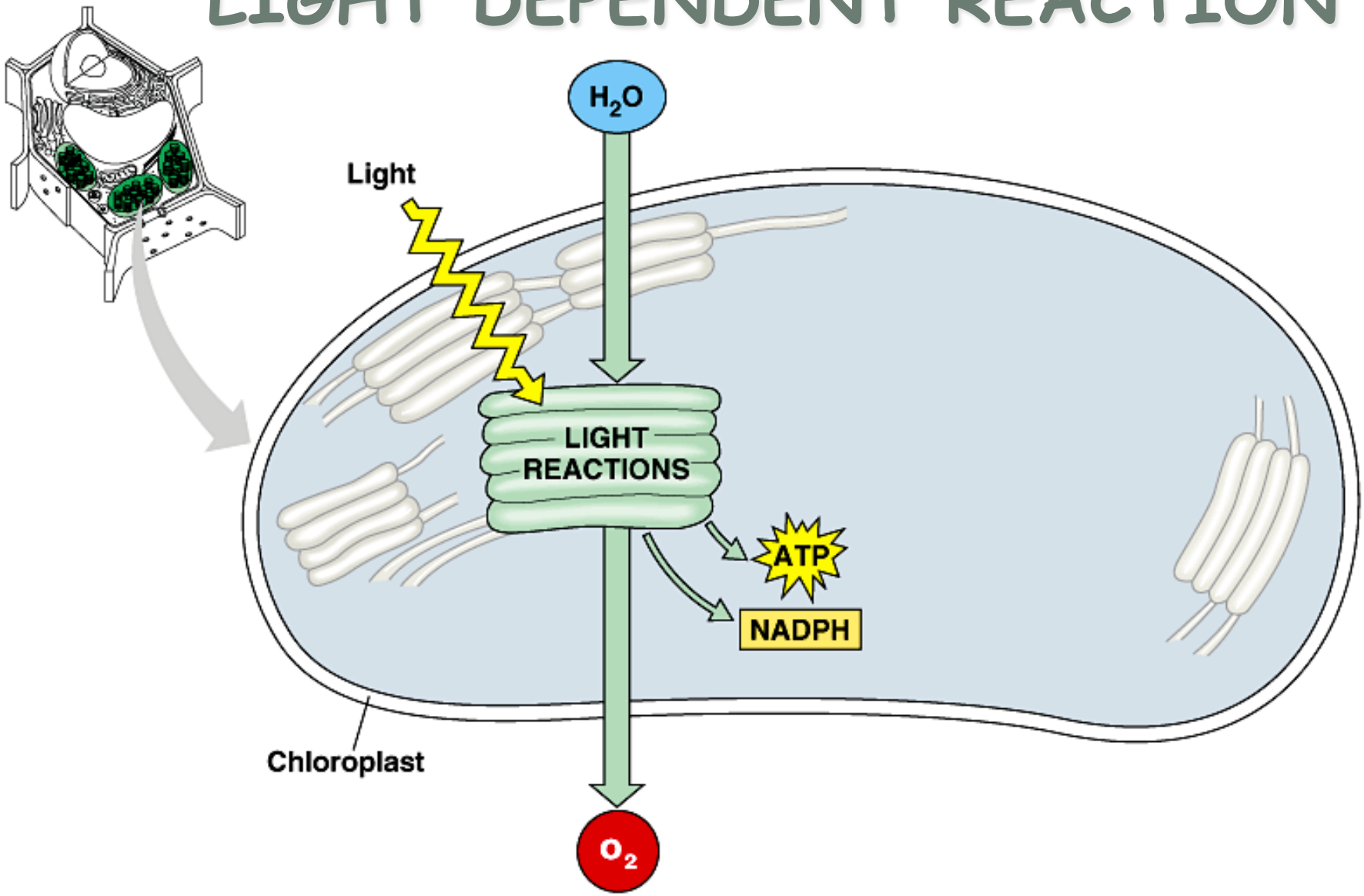
LIGHT REACTIONS

- can be divided into 4 basic processes:
  - light absorption
  - electron transport
  - oxygen production
  - ATP formation
- Use H_2O, ADP, & $NADP^+$ to produce O_2, ATP, & NADPH

LIGHT DEPENDENT REACTION



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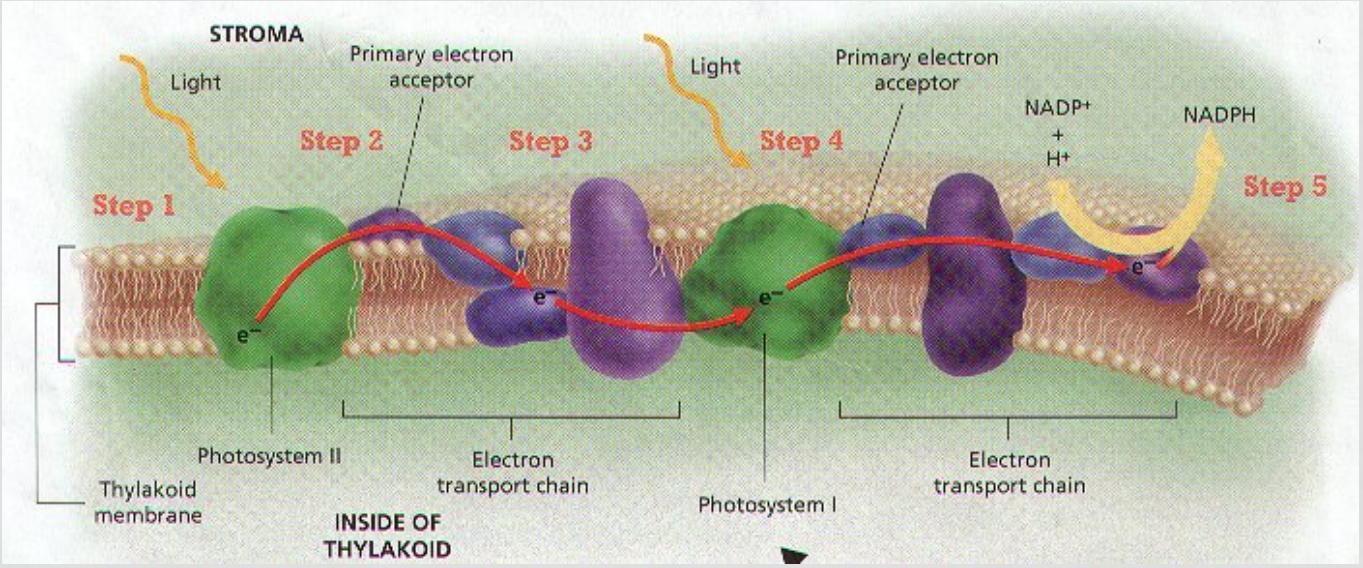
LIGHT REACTIONS: LIGHT ABSORPTION

- **Thylakoid contains <u>photosystems</u> (clusters of pigment molecules) that are able to capture sunlight energy.**

- 2 photosystems in green plants:
  photosystem I (PSI) & photosystem II (PSII)
  - contain chlorophyll molecules + other pigments
  - absorbs light energy & passes it from 1 pigment molecule to another until it reaches special pair of chlorophyll molecules in reaction center
  - here high energy electrons are released & passed to 1st of many electron carriers

LIGHT REACTIONS: ELECTRON TRANSPORT

- upon release from reaction center, high-energy electrons transferred along series of electron carriers (electron transport chain) in photosynthetic membrane
- **move electrons to NADP+ to form NADPH**

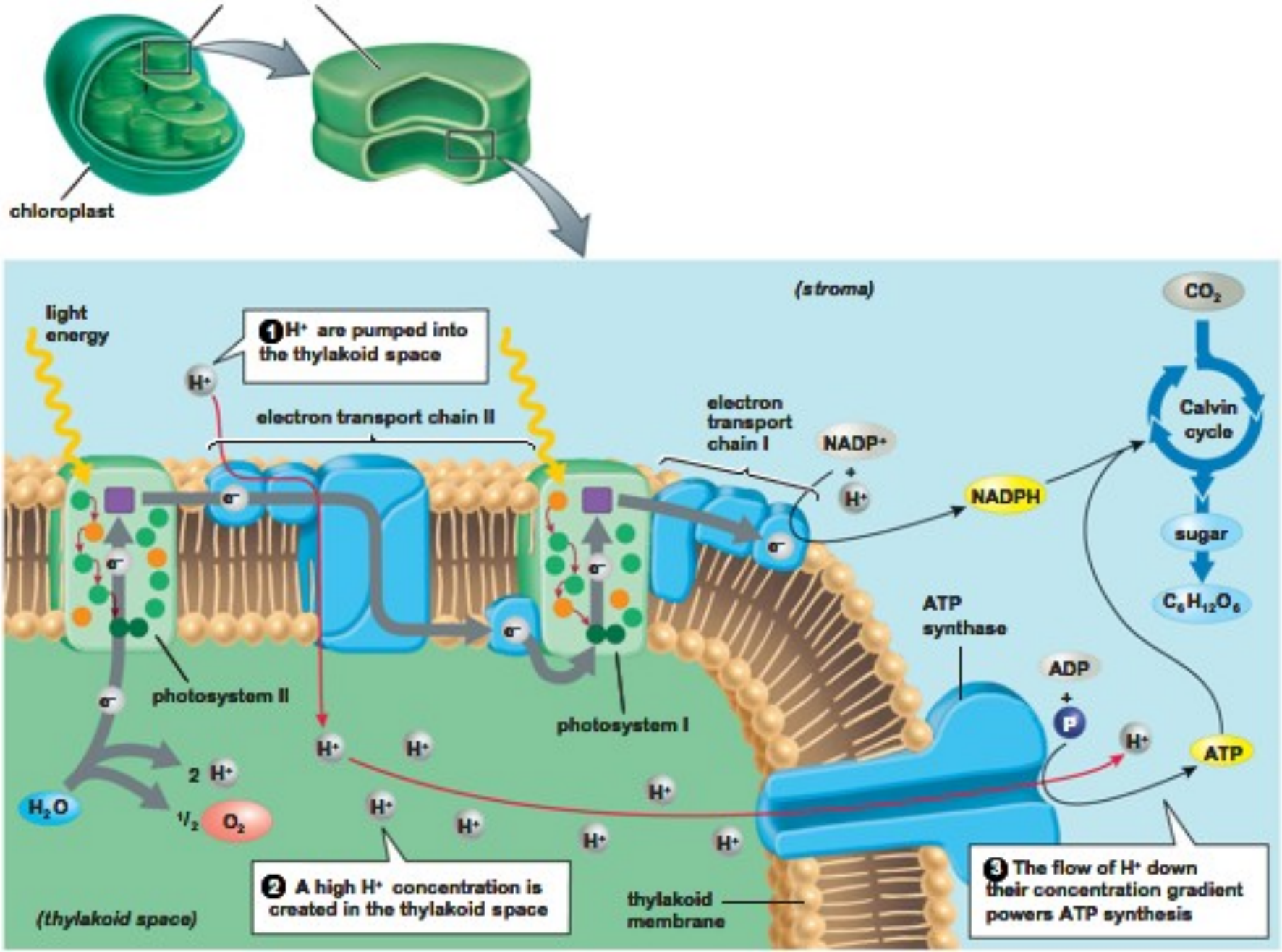


LIGHT REACTIONS: OXYGEN PRODUCTION

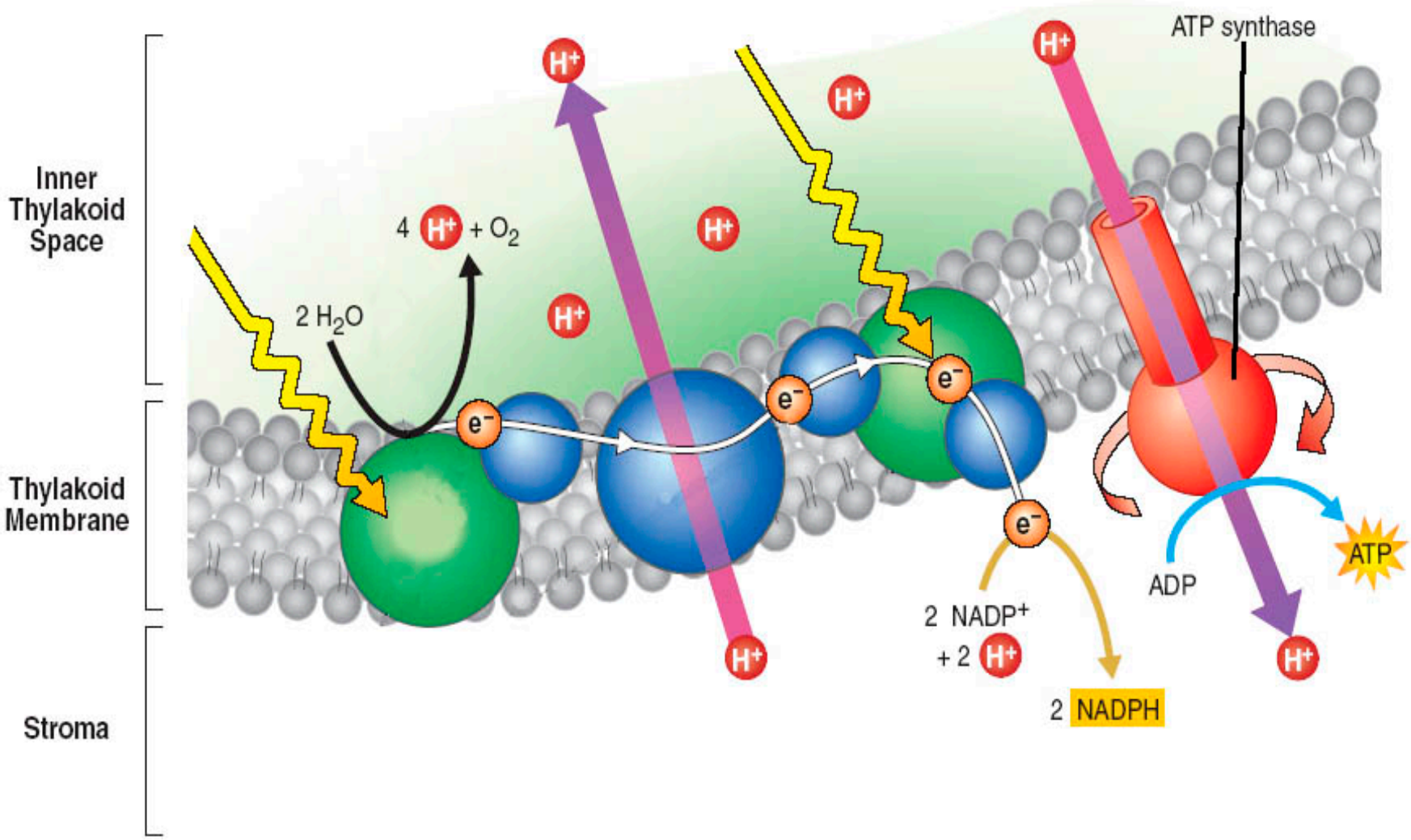
- so chlorophyll doesn't run out of **electrons** when forming **NADPH**, thylakoid has a system that takes electrons from **H_2O**.
  - bi-product of reaction is **oxygen** molecules (**O_2**) which eventually get released into the air

LIGHT REACTIONS: ATP FORMATION

- **uses energy generated by hydrogen ion (H^+) gradient to produce ATP**
- hydrogen ions (H^+)
  - H^+ left behind when H_2O are released inside thykaloid
  - in addition, as electrons are passed from chlorophyll to $NADP^+$, more H^+ are pumped across membrane
- membrane fills up with H^+ ions, making outside of photosynthetic membrane - charge & inside + charge ← source of energy
- enzyme in thylakoid makes use of this energy. Attaches phosphate molecule to ADP → ATP


chloroplast
light energy
1 H+ are pumped into the thylakoid space
(stroma)
electron transport chain II
electron transport chain I
NADP+
NADPH
CO2
Calvin cycle
sugar
C6H12O6
ATP synthase
ADP
ATP
photosystem II
photosystem I
2 H+
H2O
1/2 O2
2 A high H+ concentration is created in the thylakoid space
thylakoid membrane
(thylakoid space)
3 The flow of H+ down their concentration gradient powers ATP synthesis

LIGHT DEPENDENT REACTION



LIGHT REACTION SUMMARY

Reactants:

- H_2O
- Light Energy

Energy Products:

- ATP
- NADPH

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LIGHT-INDEPENDENT REACTIONS
THE CALVIN CYCLE

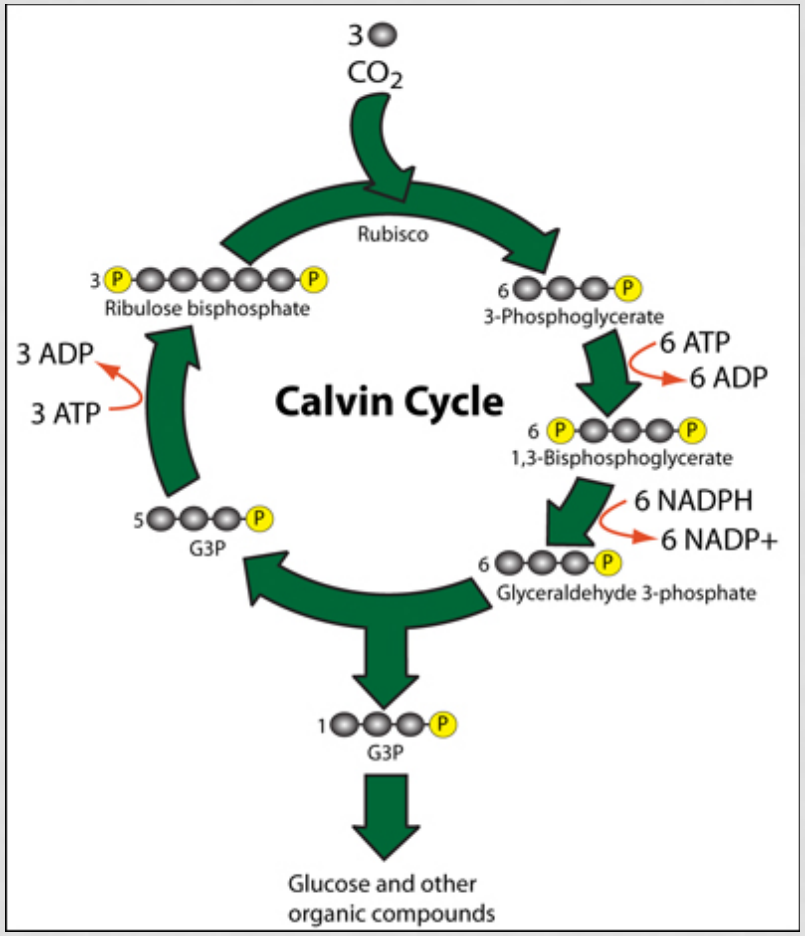
- ATP & NADPH can only store the chemical energy for a few minutes
- The Calvin cycle uses the energy from ATP & NADPH to make high-energy compounds that can store the energy longer (sugars)
- Light independent reaction = **does NOT require light**

DARK REACTIONS

- **Calvin cycle** – name given to the cycle of dark reactions in photosynthesis
- **Inorganic molecule CO_2 is used to make a complex organic molecules (i.e. glucose).**
- **enzyme** (rubisco) speeds up this reaction.
- this complex organic molecule can be considered a building block that can be used to make other biologically important molecules, including glucose

DARK REACTIONS

- Use **ATP & NADPH produced in light reaction**
- main purpose of dark reactions (Calvin cycle) is to produce chemical "building block" **PGAL → Glucose** (**p**hospho**g**lycer**al**dehyde)
- makes other compounds too like amino acids, lipids, other carbs etc.



LIGHT INDEPENDENT REACTION

- ATP & NADPH from light reactions used as energy
- Atmospheric CO_2 is used to make sugars like glucose and fructose
- Six-carbon Sugars made during the Calvin Cycle
- Occurs in the stroma

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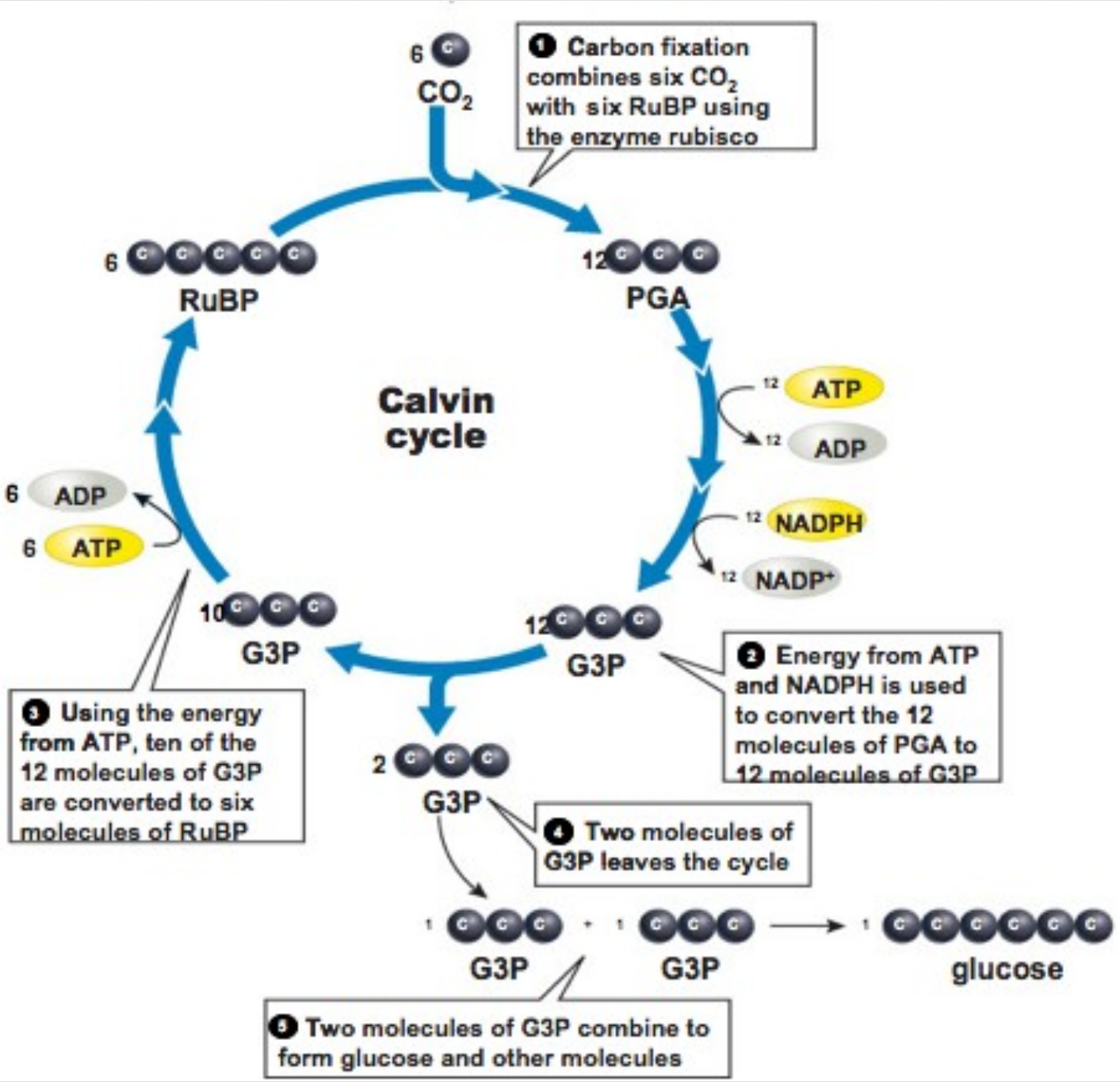
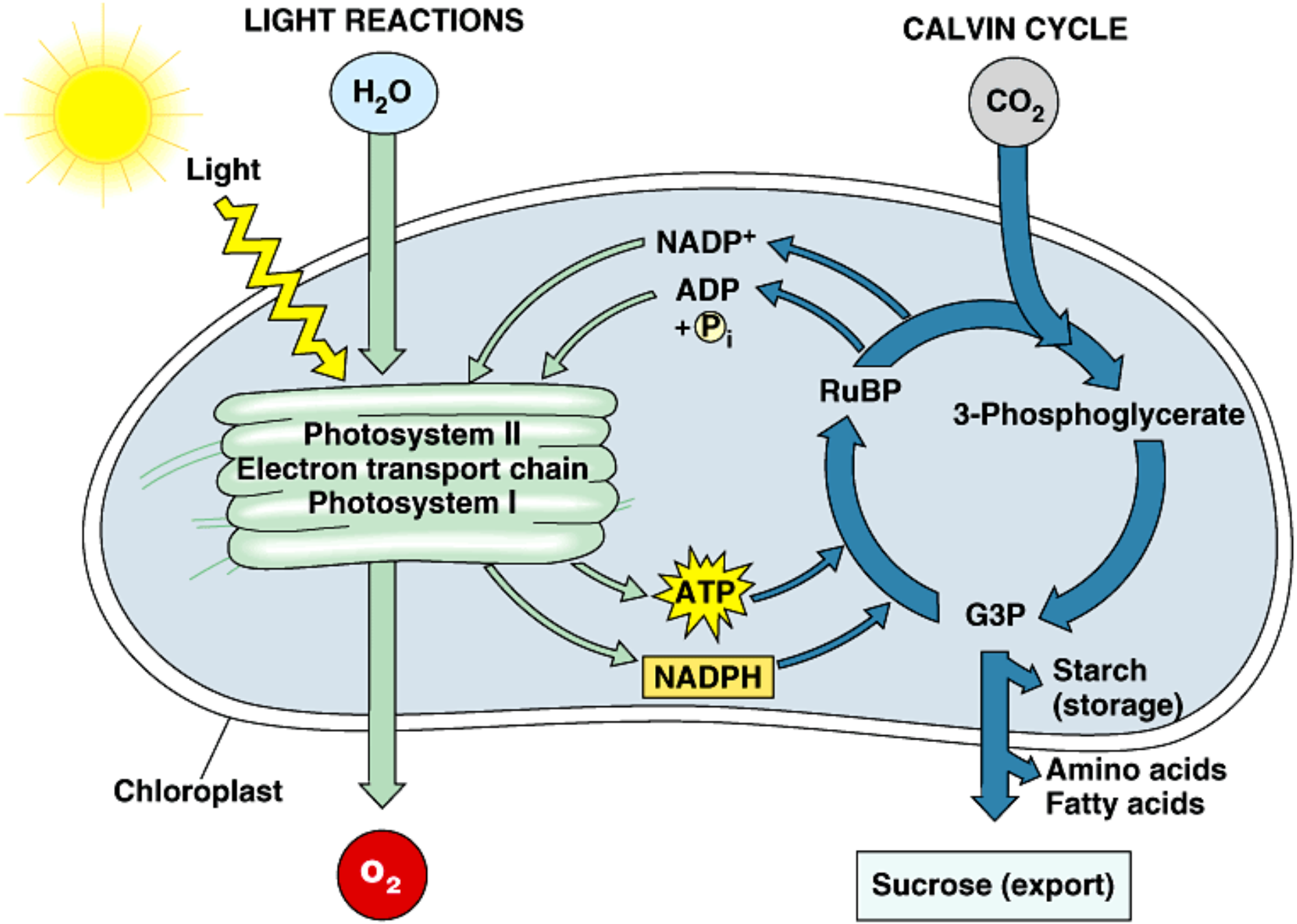

6 CO2
1 Carbon fixation combines six CO2 with six RuBP using the enzyme rubisco
6 RuBP
12 PGA
Calvin cycle
12 ATP
12 ADP
12 NADPH
12 NADP+
6 ADP
6 ATP
10 G3P
12 G3P
2 Energy from ATP and NADPH is used to convert the 12 molecules of PGA to 12 molecules of G3P
3 Using the energy from ATP, ten of the 12 molecules of G3P are converted to six molecules of RuBP
2 G3P
4 Two molecules of G3P leaves the cycle
1 G3P + 1 G3P → 1 glucose
5 Two molecules of G3P combine to form glucose and other molecules



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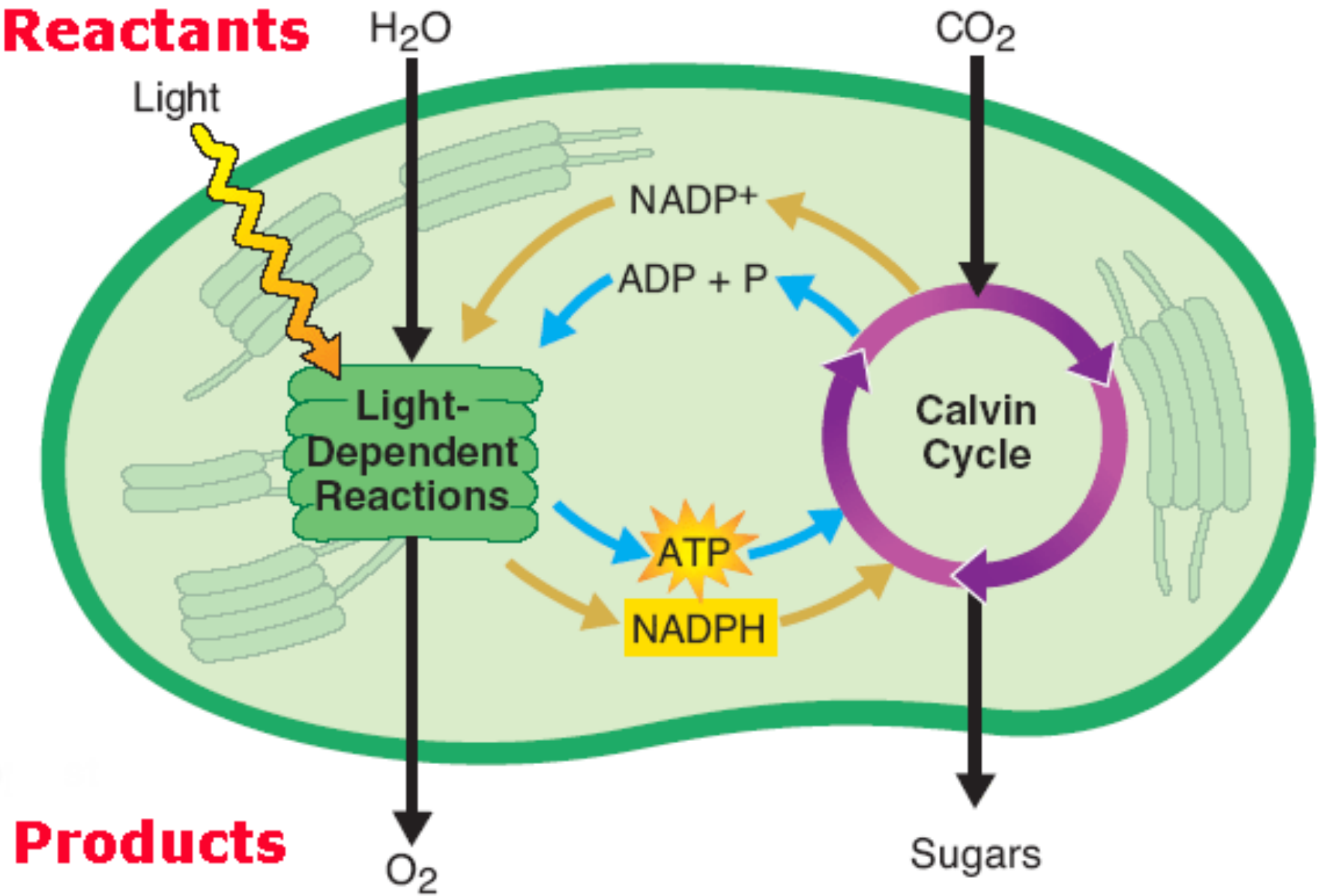
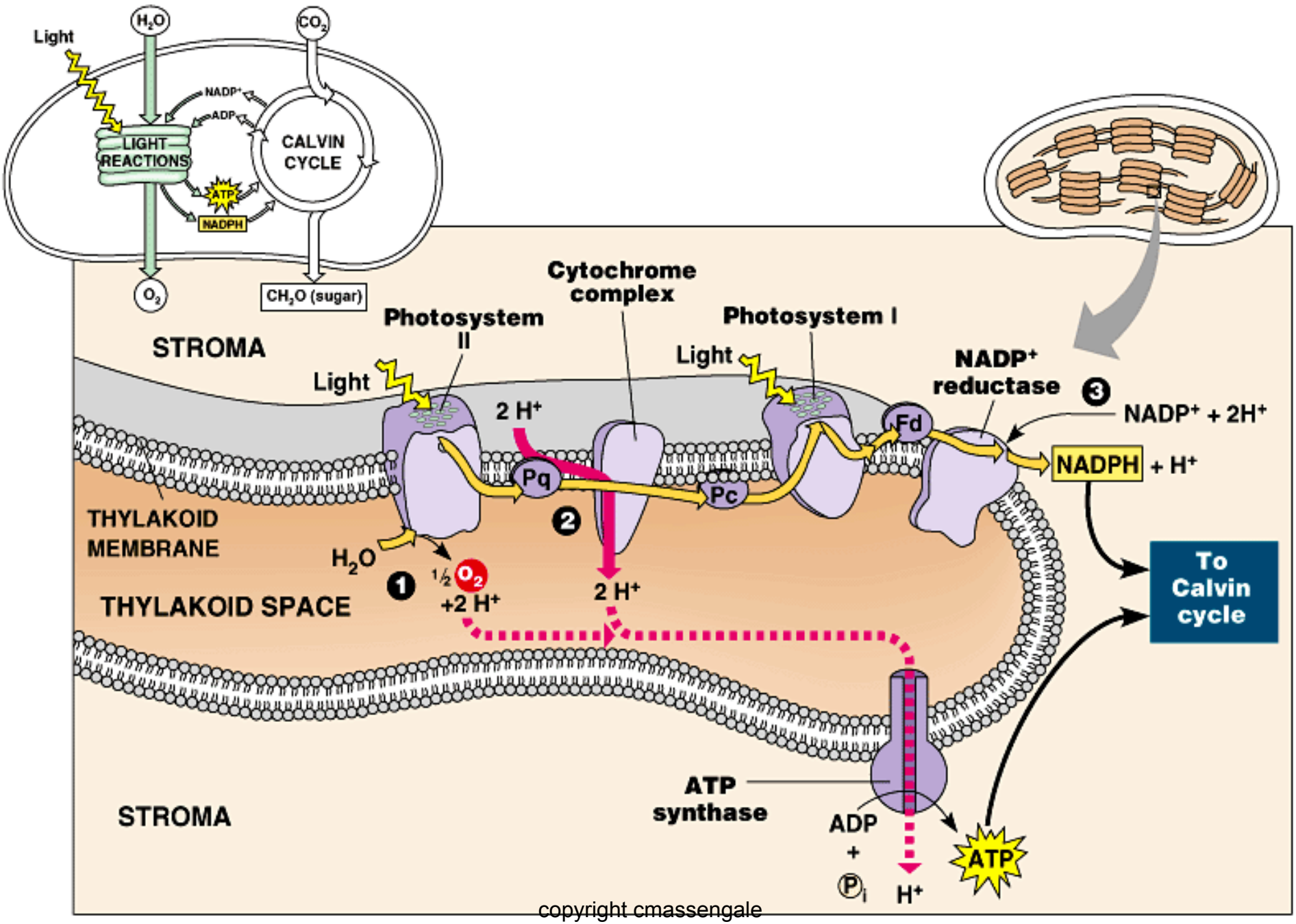

Reactants
H_2O
CO_2
Light
NADP+
ADP + P
Light-Dependent Reactions
Calvin Cycle
ATP
NADPH
Products
O_2
Sugars



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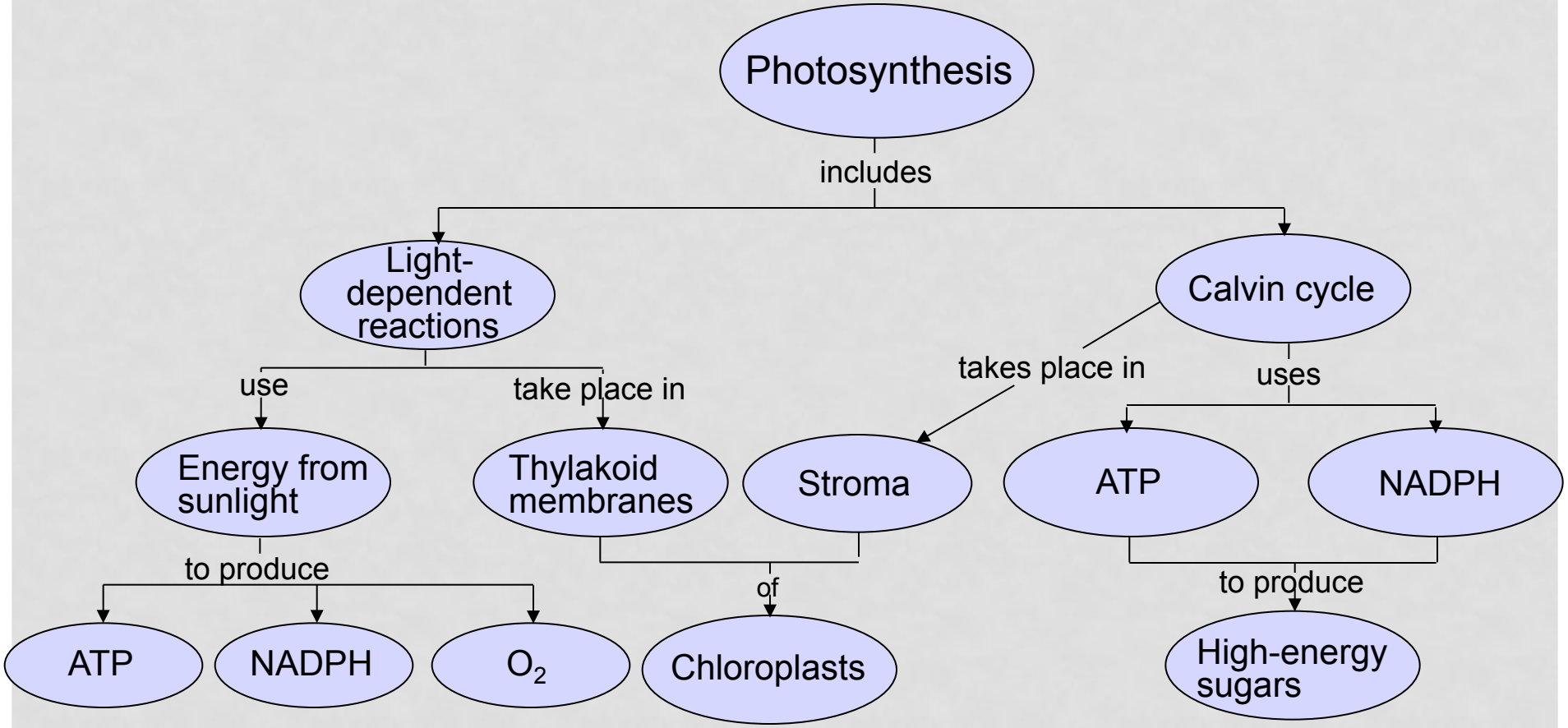
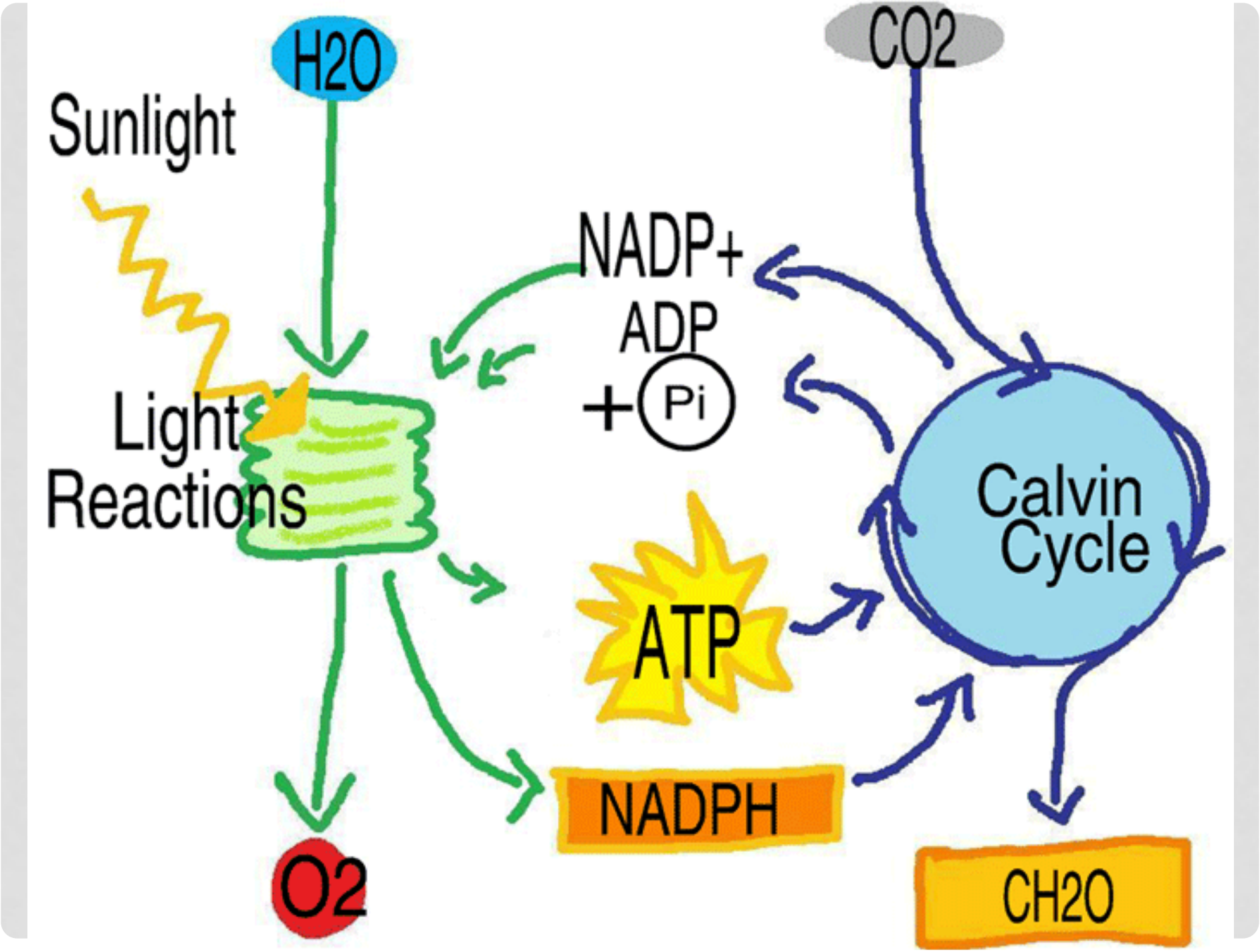
ATP AND GLUCOSE

ATP	Glucose
Short Term	Long Term Storage
Transfers energy very quickly	Takes longer to get energy out
Can’t store energy very long. (breaks down to ADP and loses energy)	Can store energy very well. 1 molecule of glucose can hold 90x more energy than ATP.

Photosynthesis Concept Map




H2O
CO2
Sunlight
NADP+
ADP
+ Pi
Light
Reactions
Calvin
Cycle
ATP
NADPH
O2
CH2O

SECTION 6-1: PHOTOSYNTHESIS