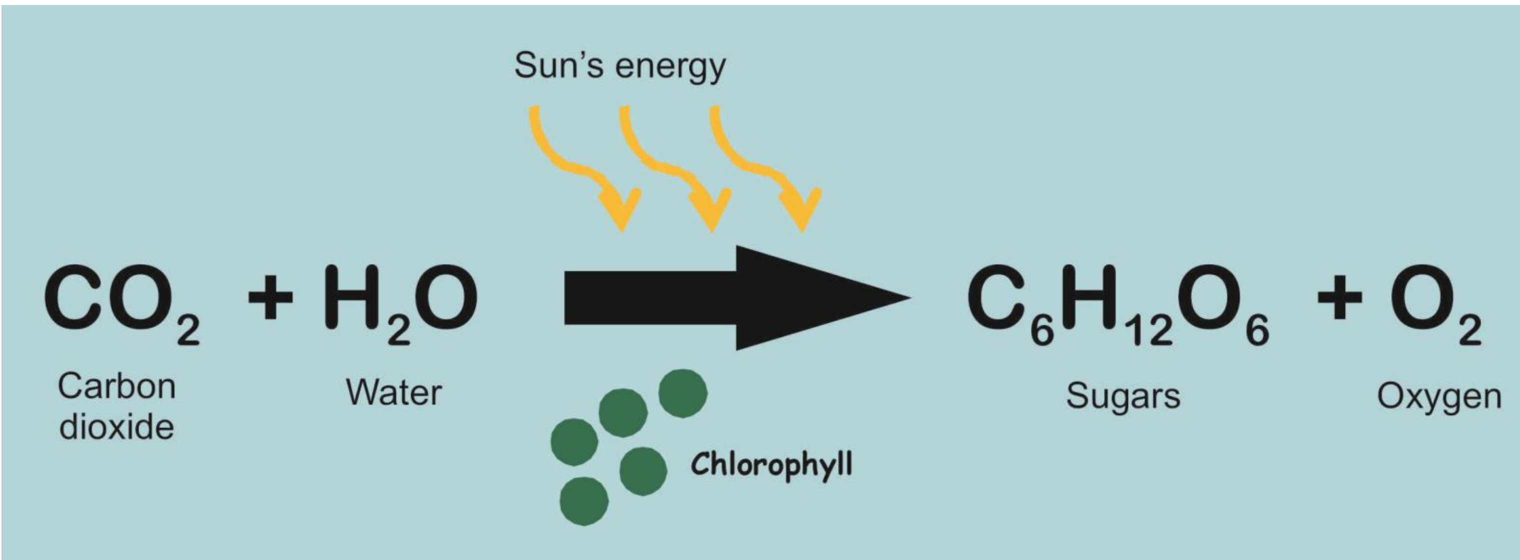
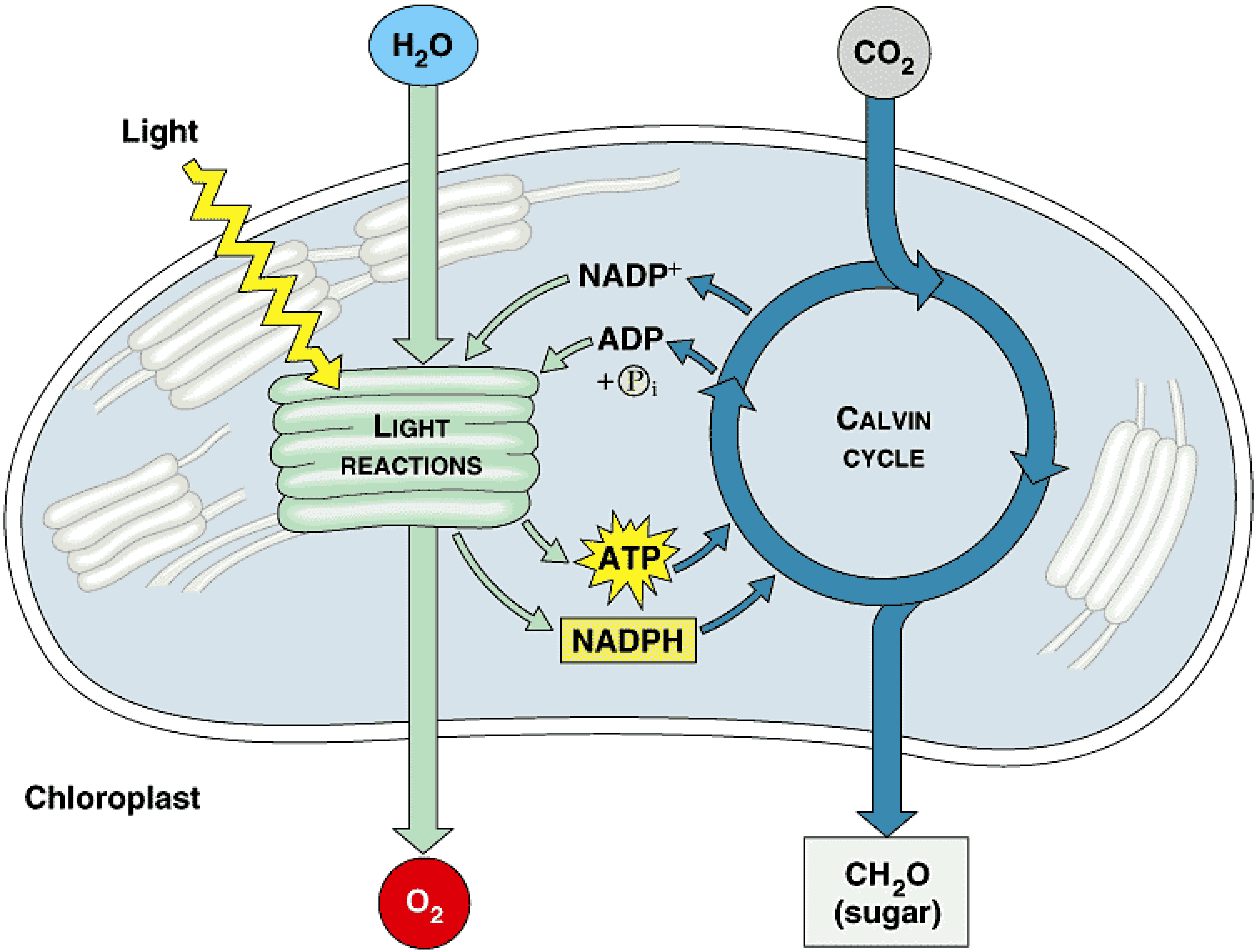
Photosynthesis:
all you need to know
in one lecture.

Photosynthesis: overall reaction



http://lifeadrift.info/ages-11-16/phytoplankon-extra.aspx



H_2O
CO_2
Light
NADP+
ADP
+ P i
LIGHT REACTIONS
CALVIN CYCLE
ATP
NADPH
Chloroplast
O_2
CH_2O (sugar)

Fig. 10.2a

Leaf— Levels of Organization (1)

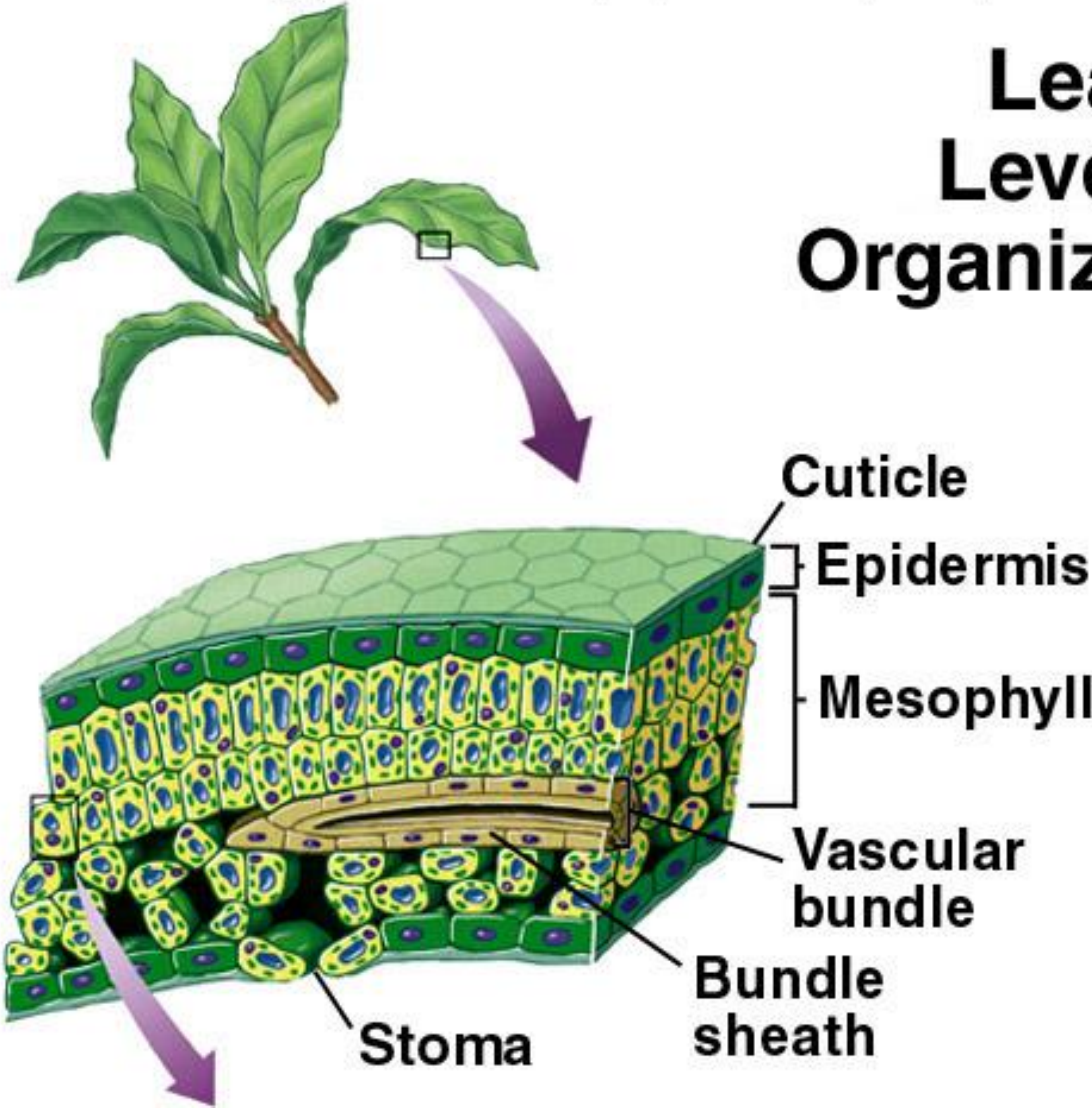


Fig. 10.2b

Leaf—Levels of Organization (2)

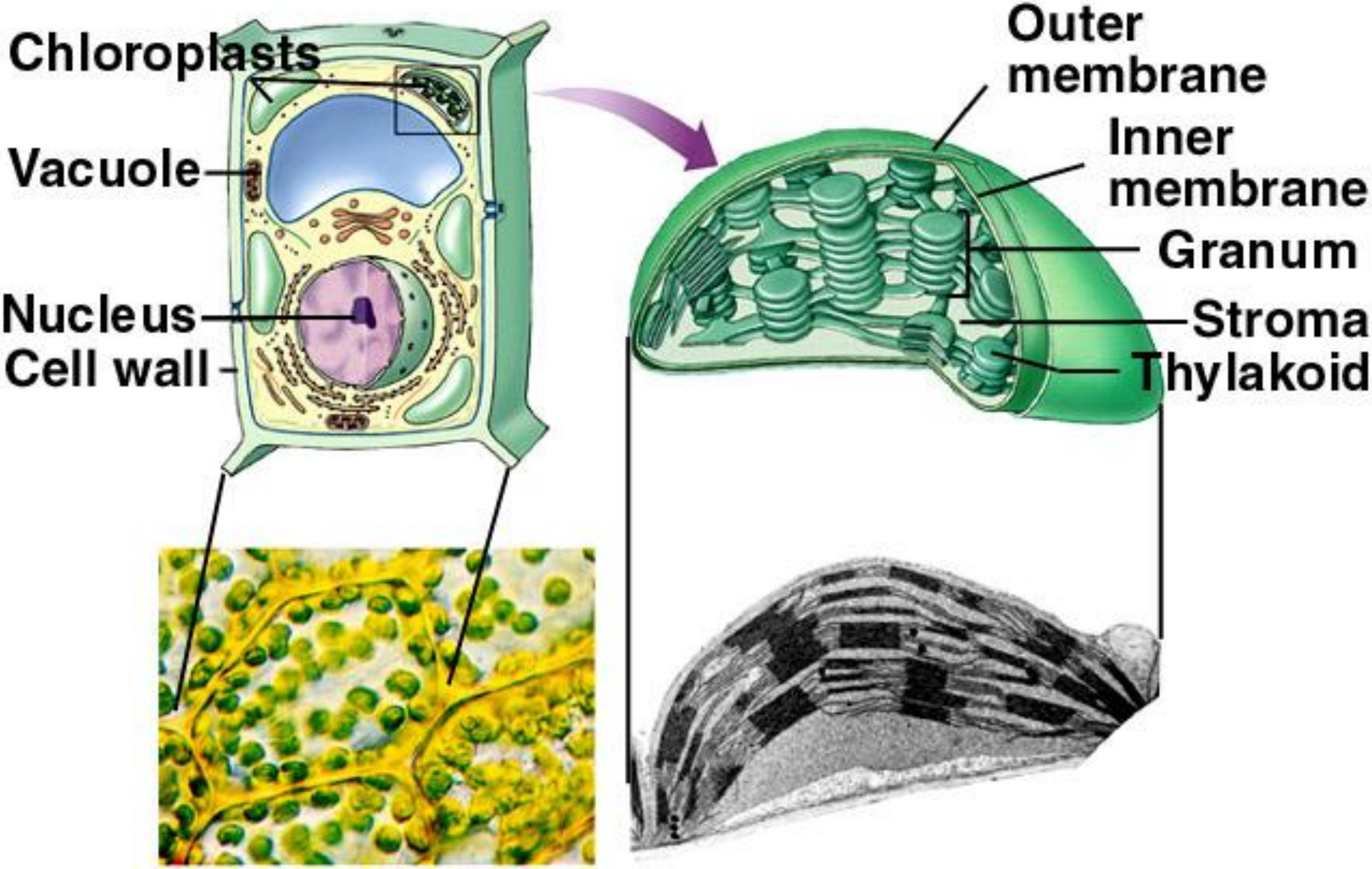


Fig. 10.2c

Leaf—Levels of Organization (3)

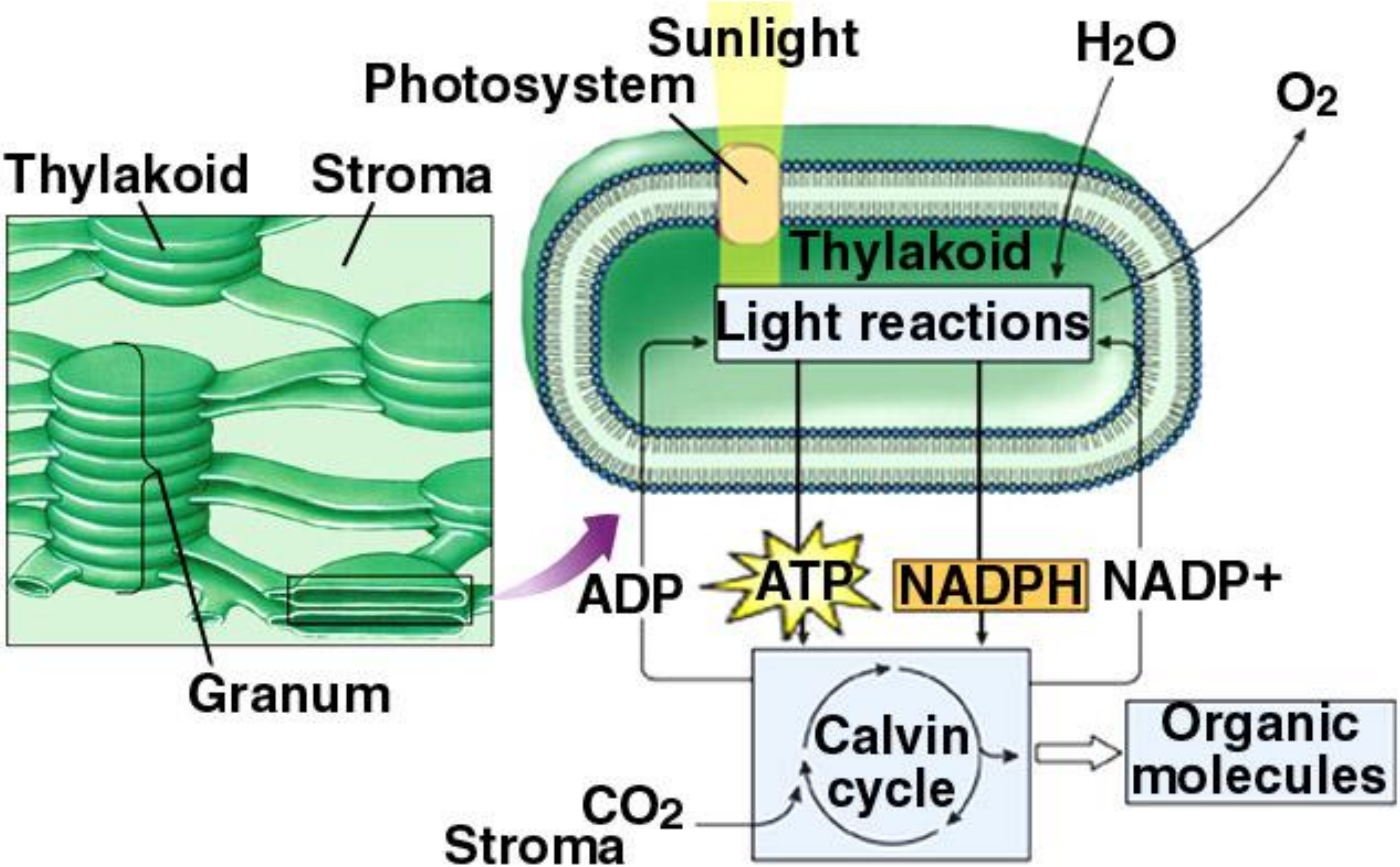
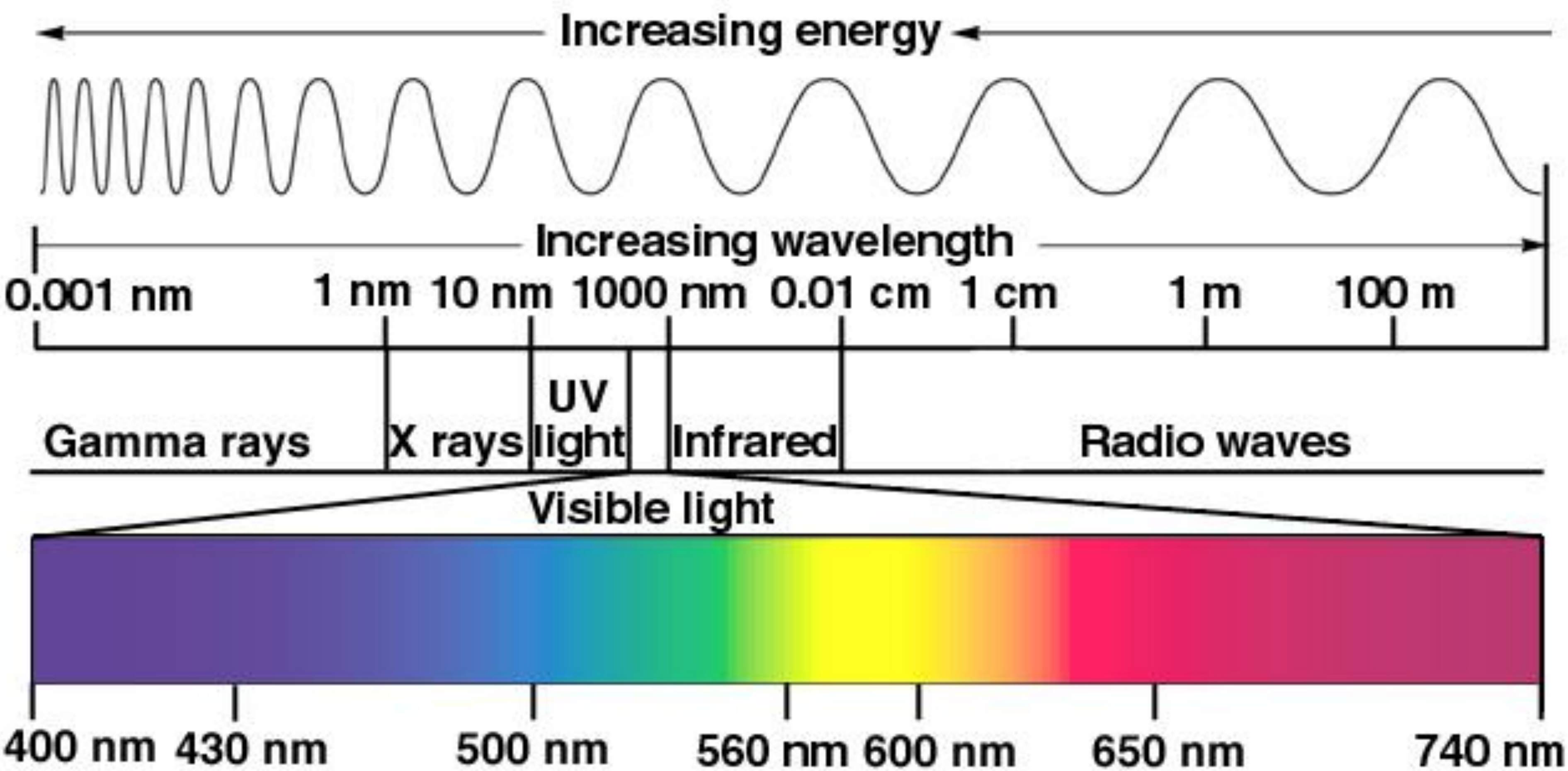


Fig. 10.4

Electromagnetic Spectrum



Chlorophyll is well-adapted to use Solar Energy

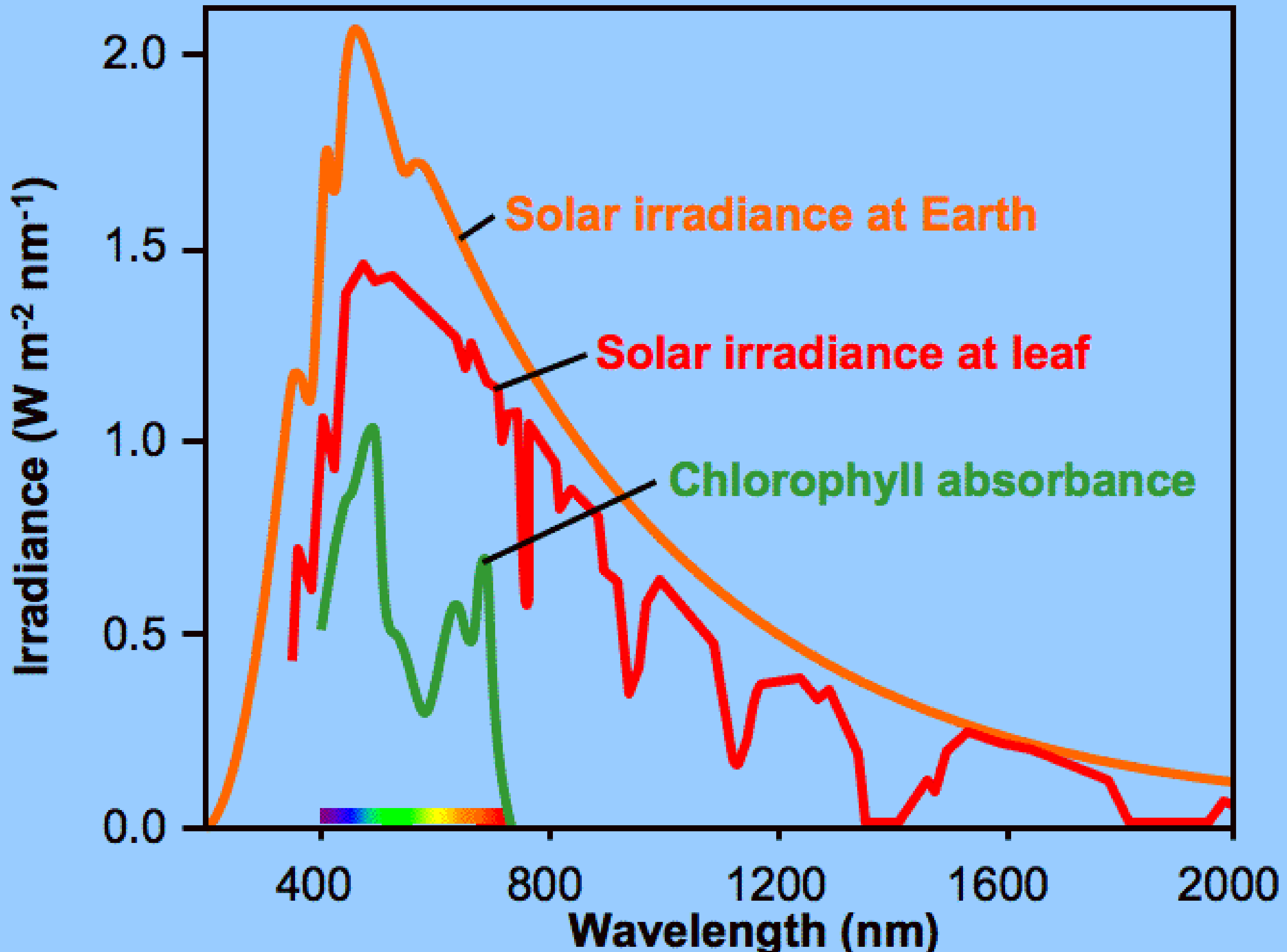
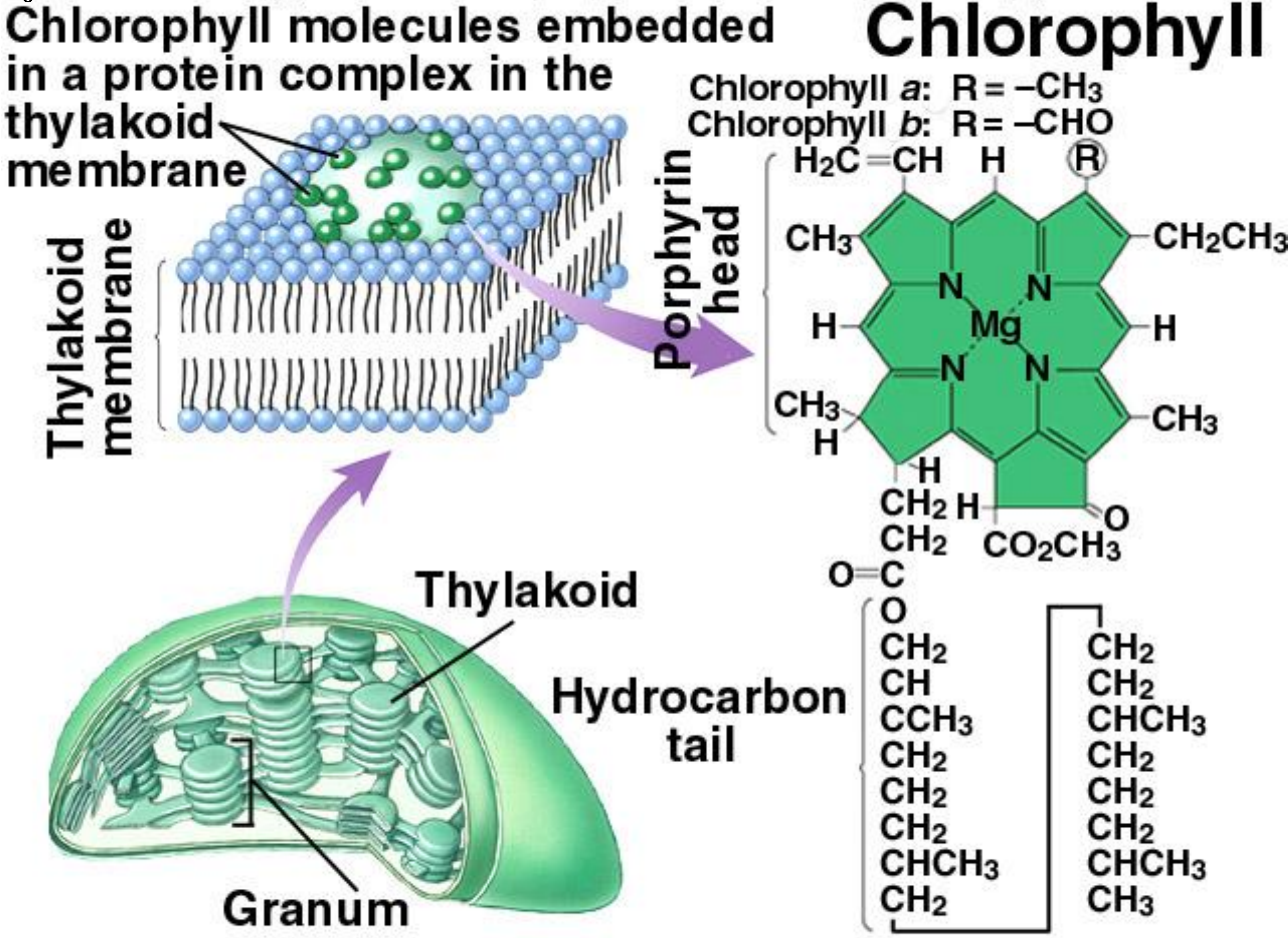


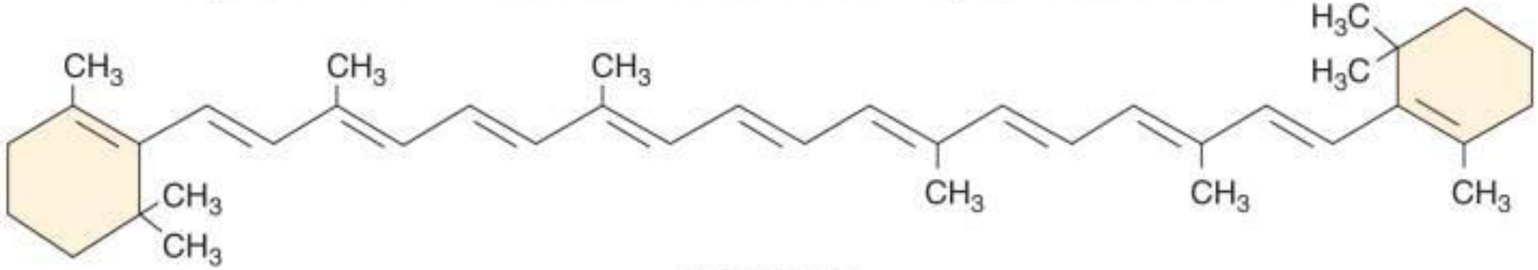
Fig. 10.6


Chlorophyll molecules embedded in a protein complex in the thylakoid membrane
Chlorophyll
Chlorophyll *a*: R = $-CH_3$
Chlorophyll *b*: R = $-CHO$
Thylakoid membrane
Porphyrin head
$H_2C=CH$
H
R
CH_3
CH_2CH_3
N
Mg
H
CH_3
H
H
CH_2
CH_2
$O=C$
O
CO_2CH_3
Thylakoid
Hydrocarbon tail
CH_2
CH
CCH_3
CH_2
CH_2
CH_2
$CHCH_3$
CH_2
CH_2
CH_2
$CHCH_3$
CH_2
CH_2
CH_2
$CHCH_3$
CH_3
Granum

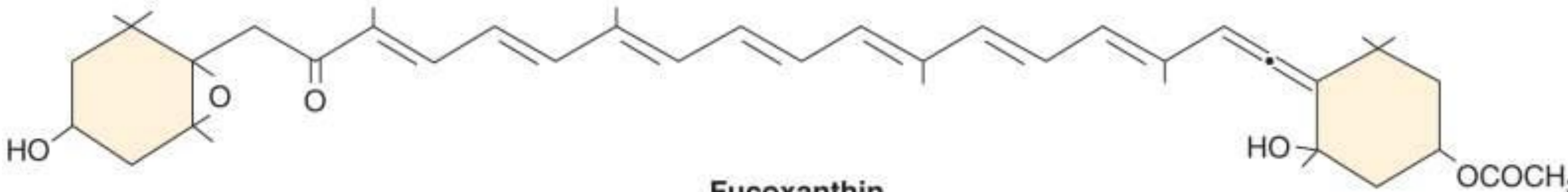
Carotenoids and Other Accessory Pigments

Oak leaf in summer

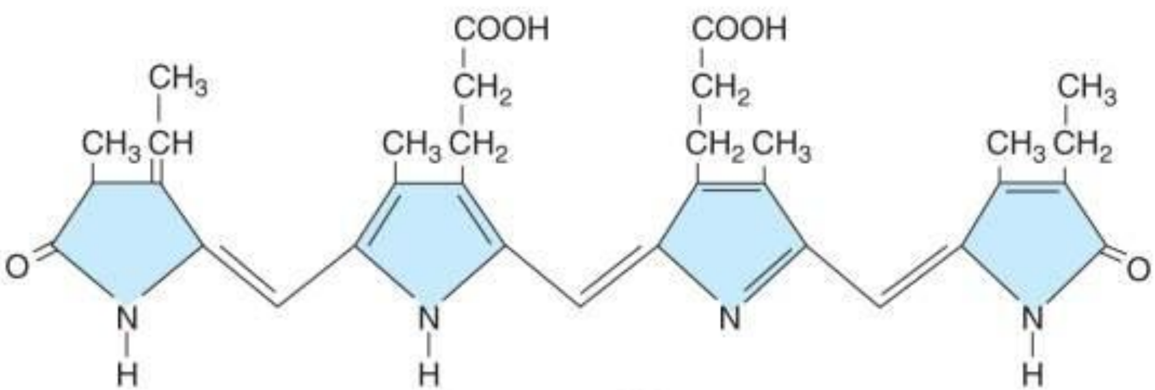
Oak leaf in autumn



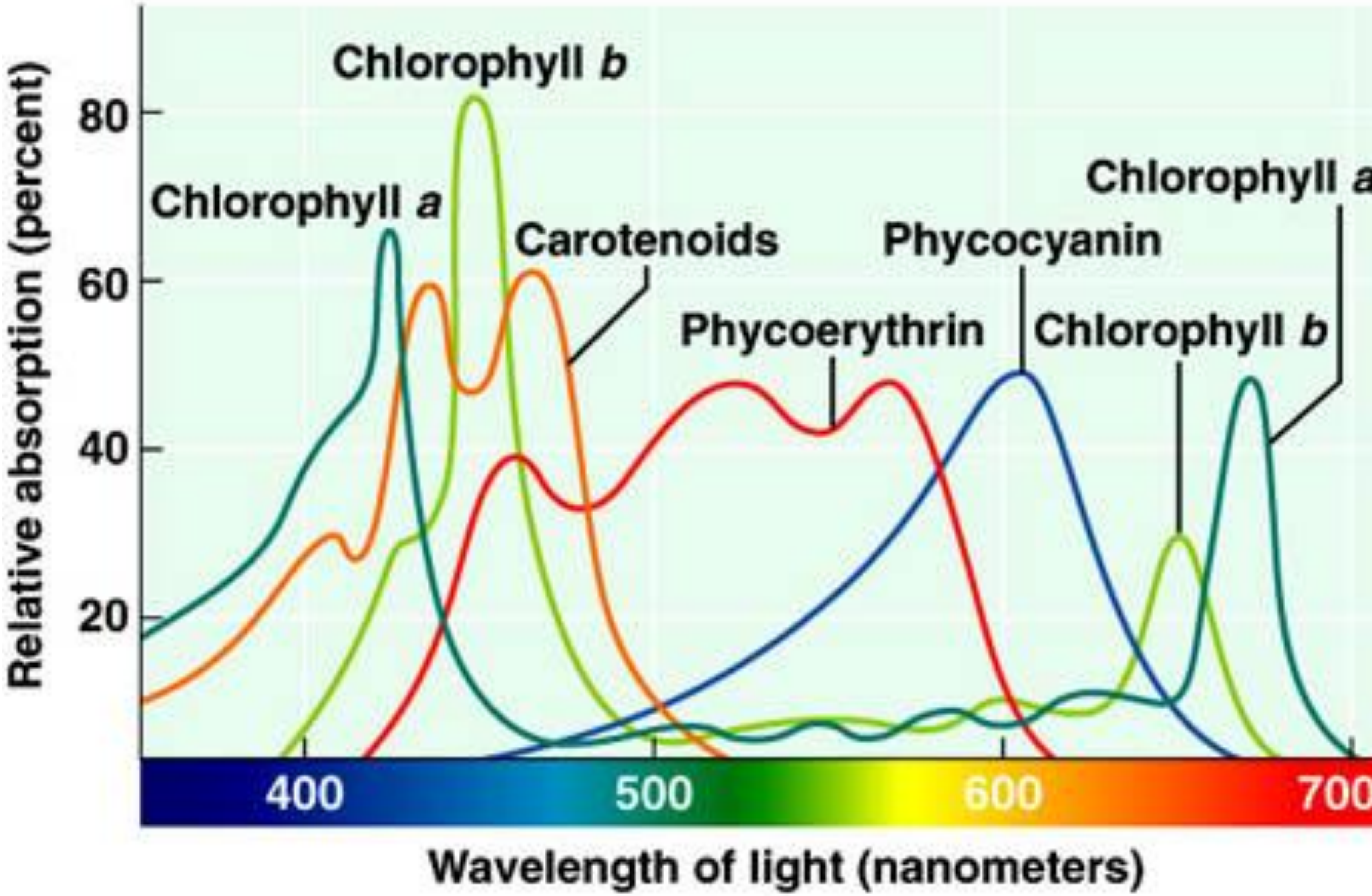
β-Carotene



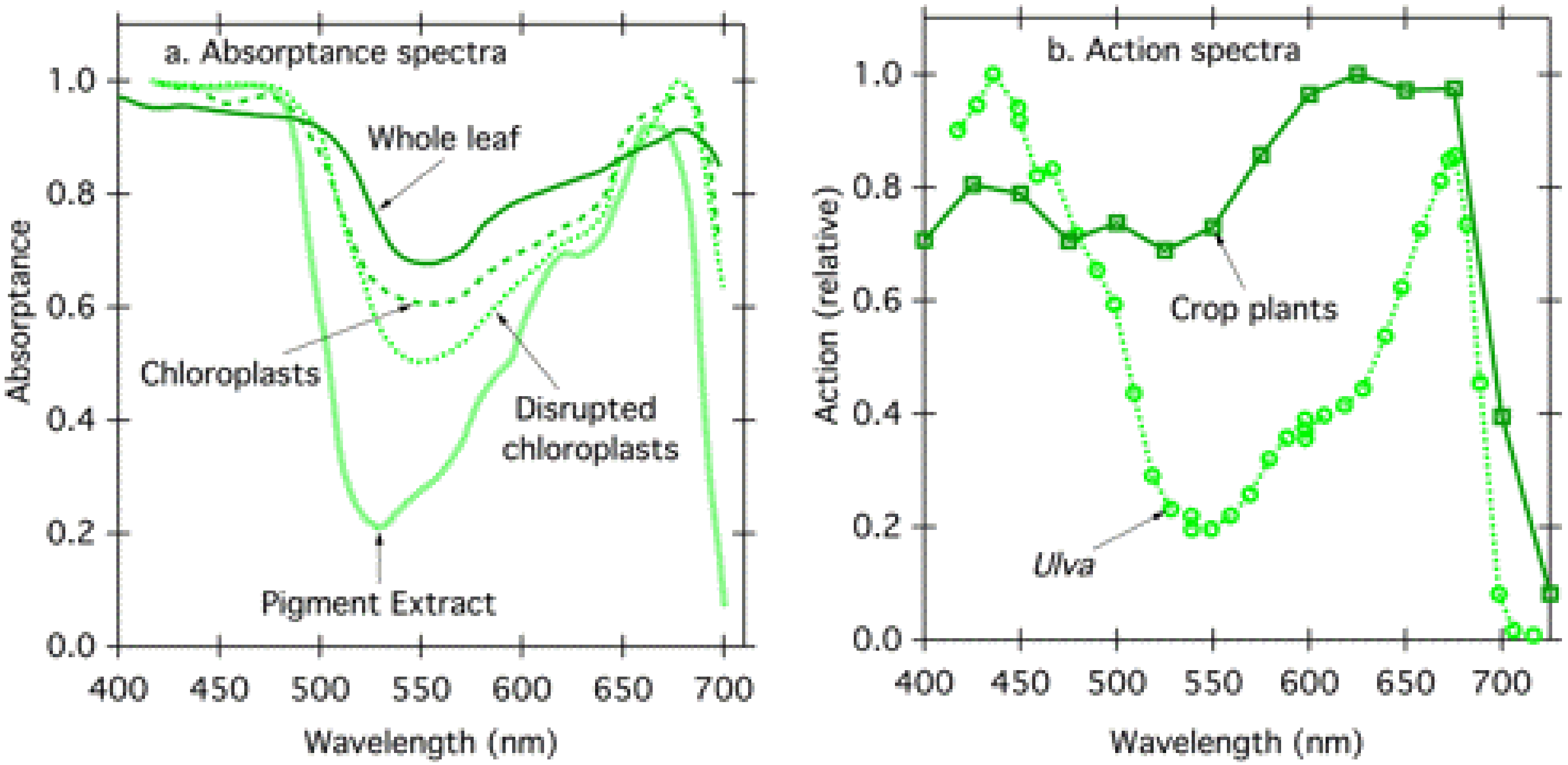
Fucoxanthin



Phycocyanobilin

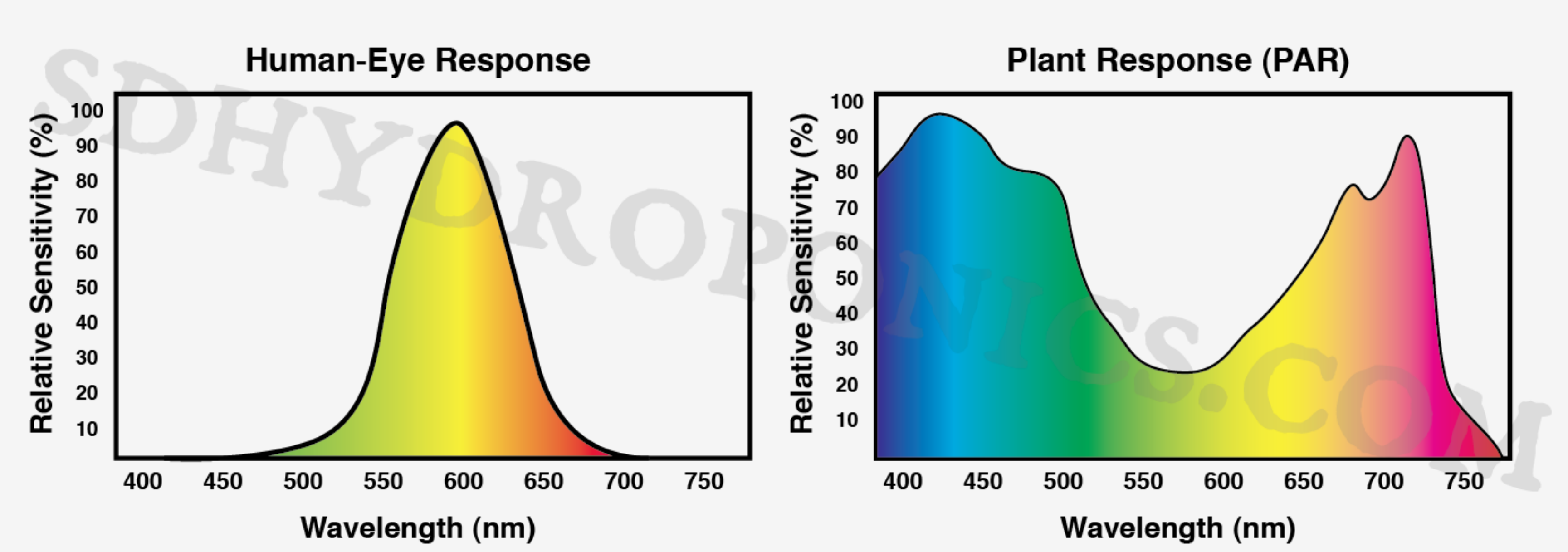

Chlorophyll b
Chlorophyll a
Carotenoids
Phycocyanin
Chlorophyll a
Phycoerythrin
Chlorophyll b
Relative absorption (percent)
80
60
40
20
400
500
600
700
Wavelength of light (nanometers)

The “green drop” of chlorophyll is minimized in most leaves.



http://www.photobiology.info/Gorton.html

Why are plants green?



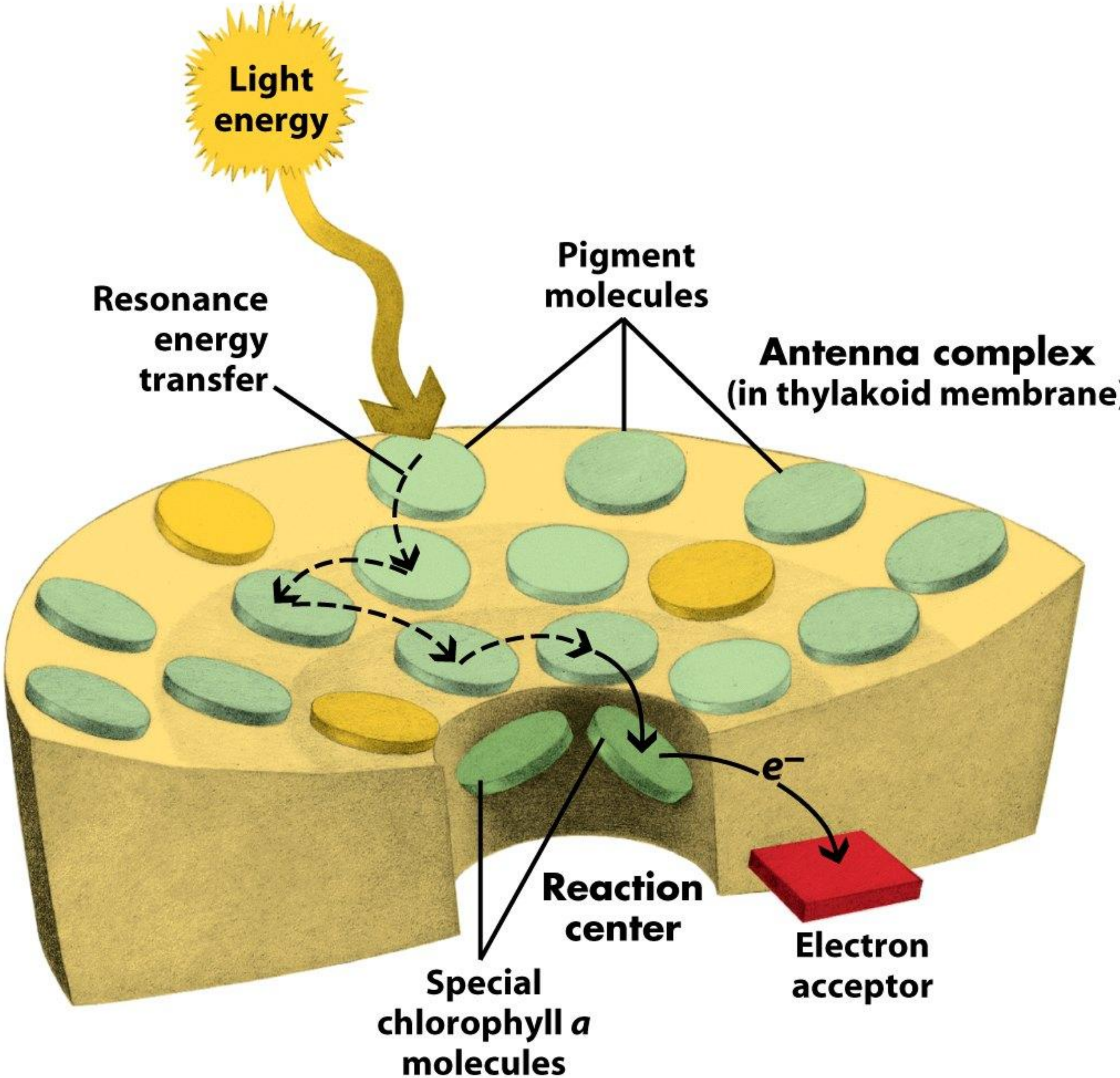


Figure 7-10
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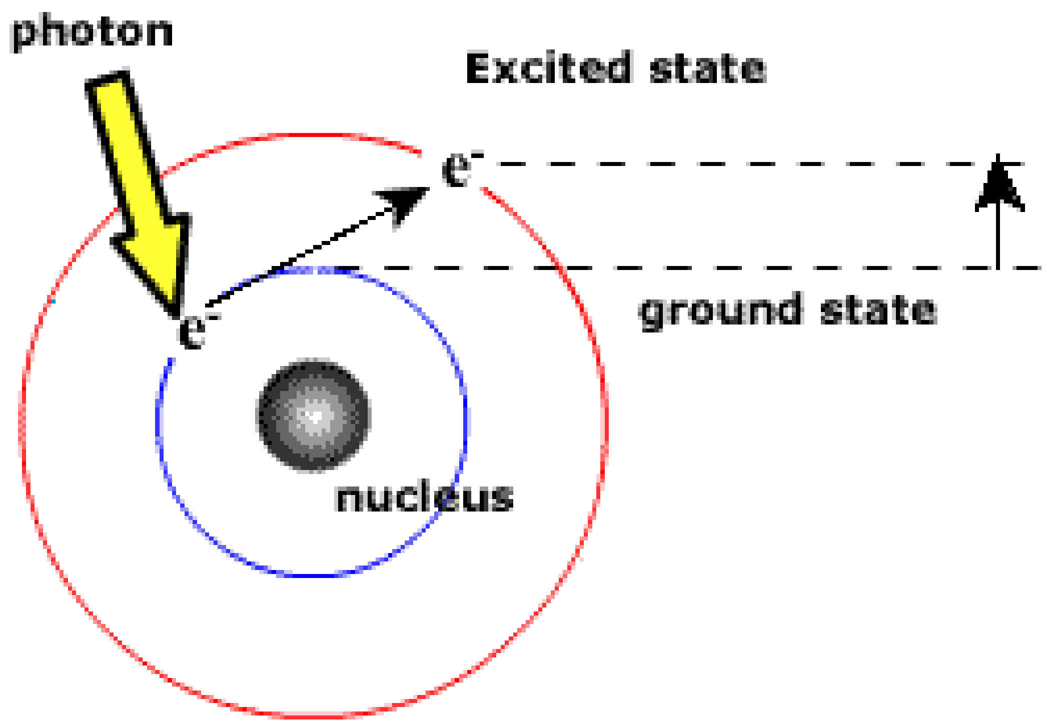
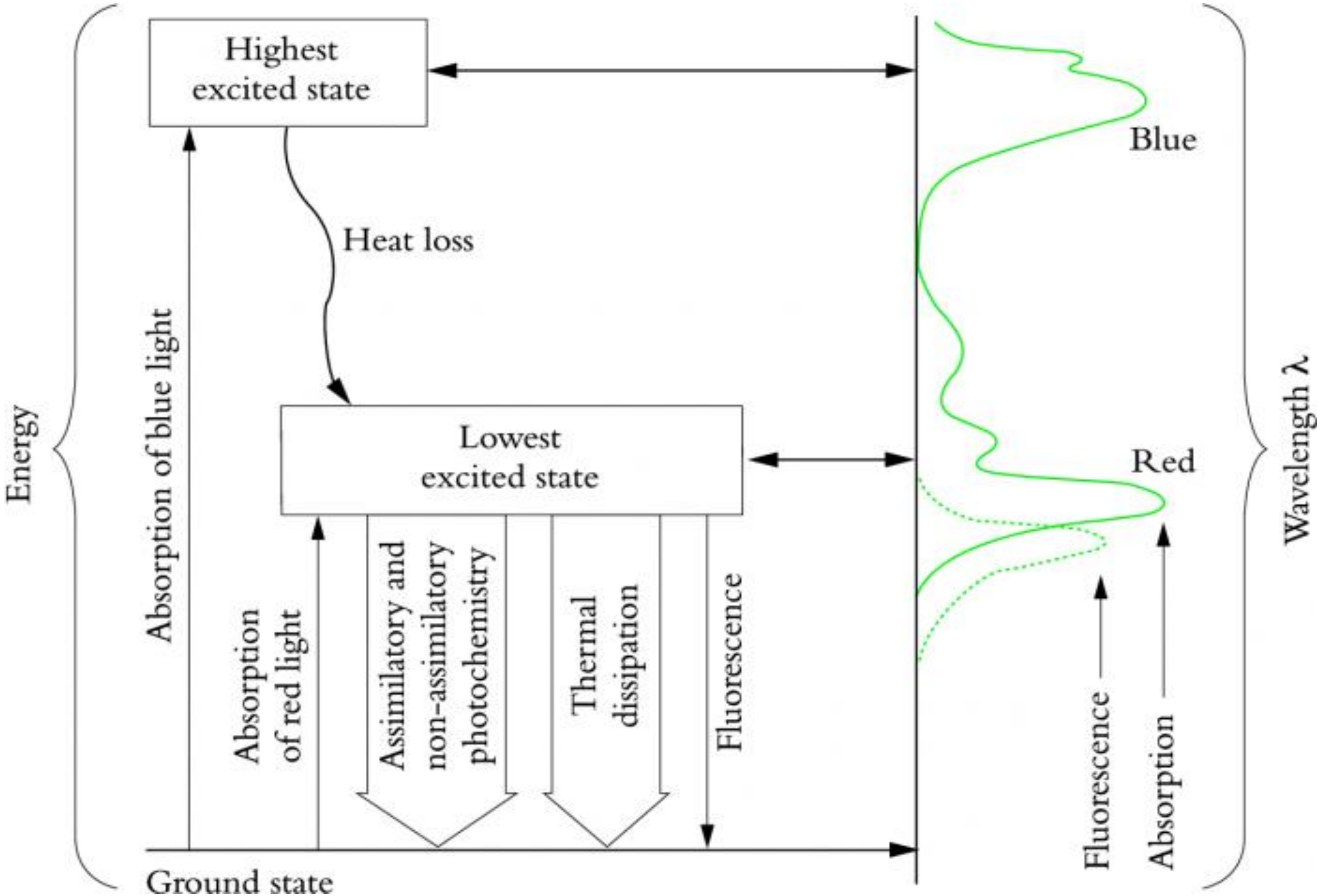
Chlorophyll and photons

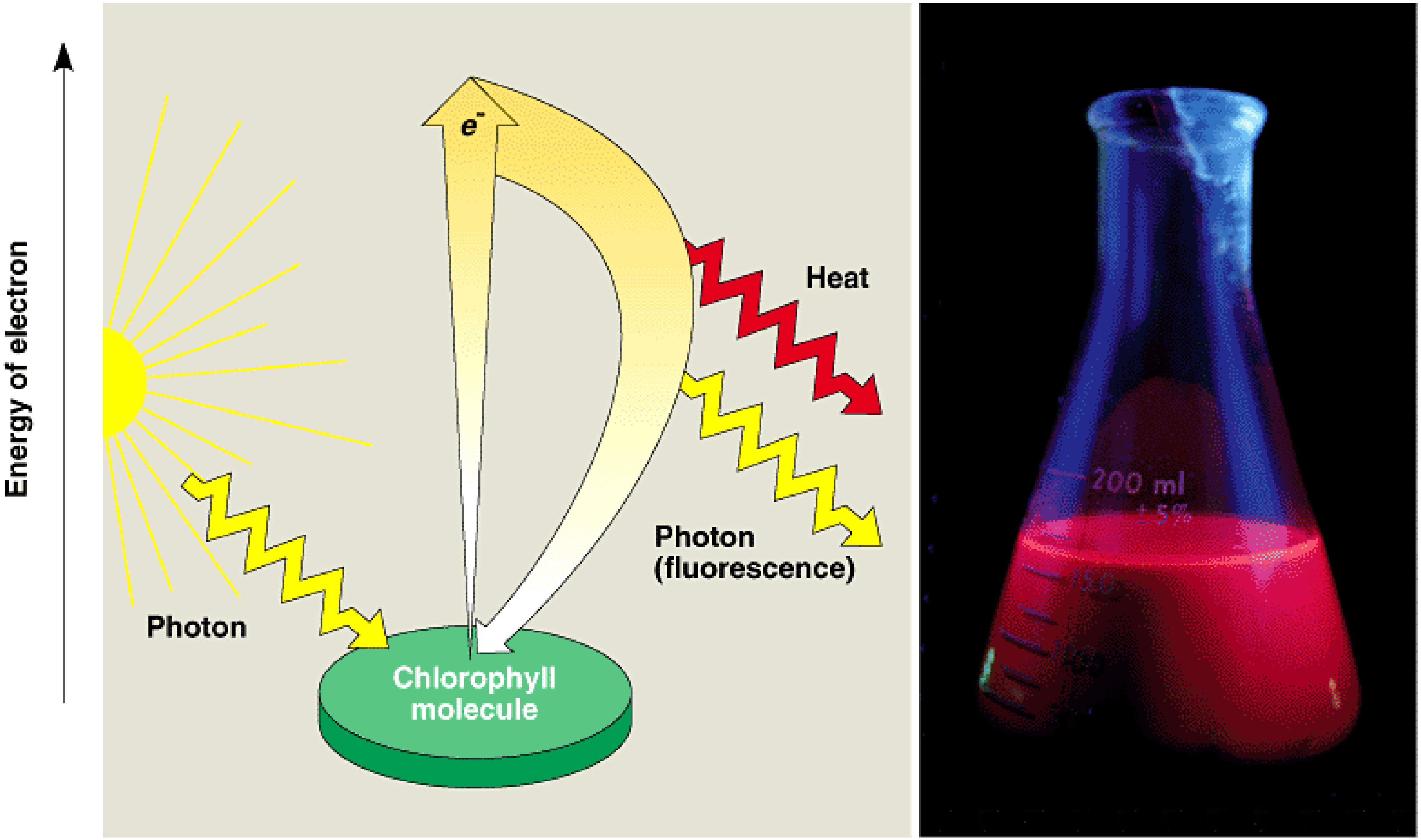


http://click4biology.info/c4b/8/resp8.2.htm

Chlorophyll and photons: colors don't matter.

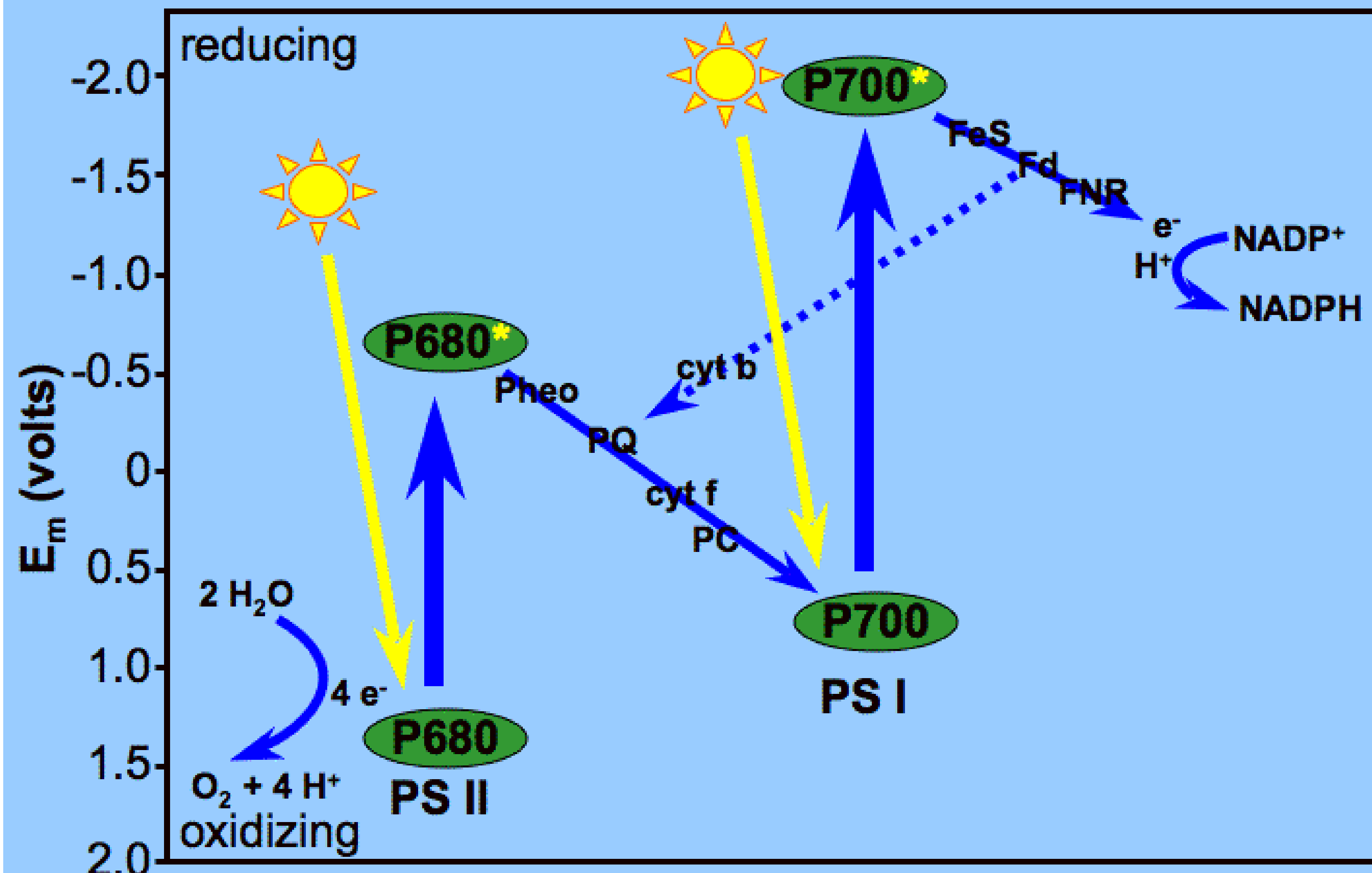


http://plantsinaction.science.uq.edu.au/edition1/?q=figure_view/601


Energy of electron
e⁻
Heat
Photon
(fluorescence)
Photon
Chlorophyll
molecule
200 ml

(a) (b)

The Z-scheme of the Light Reactions: An Energy Diagram



http://plantphys.info/plant_physiology/lightrxn.shtml

Oxygenic photosynthetic electron transport has two aims: (1) pump protons, (2) reduce NADP.

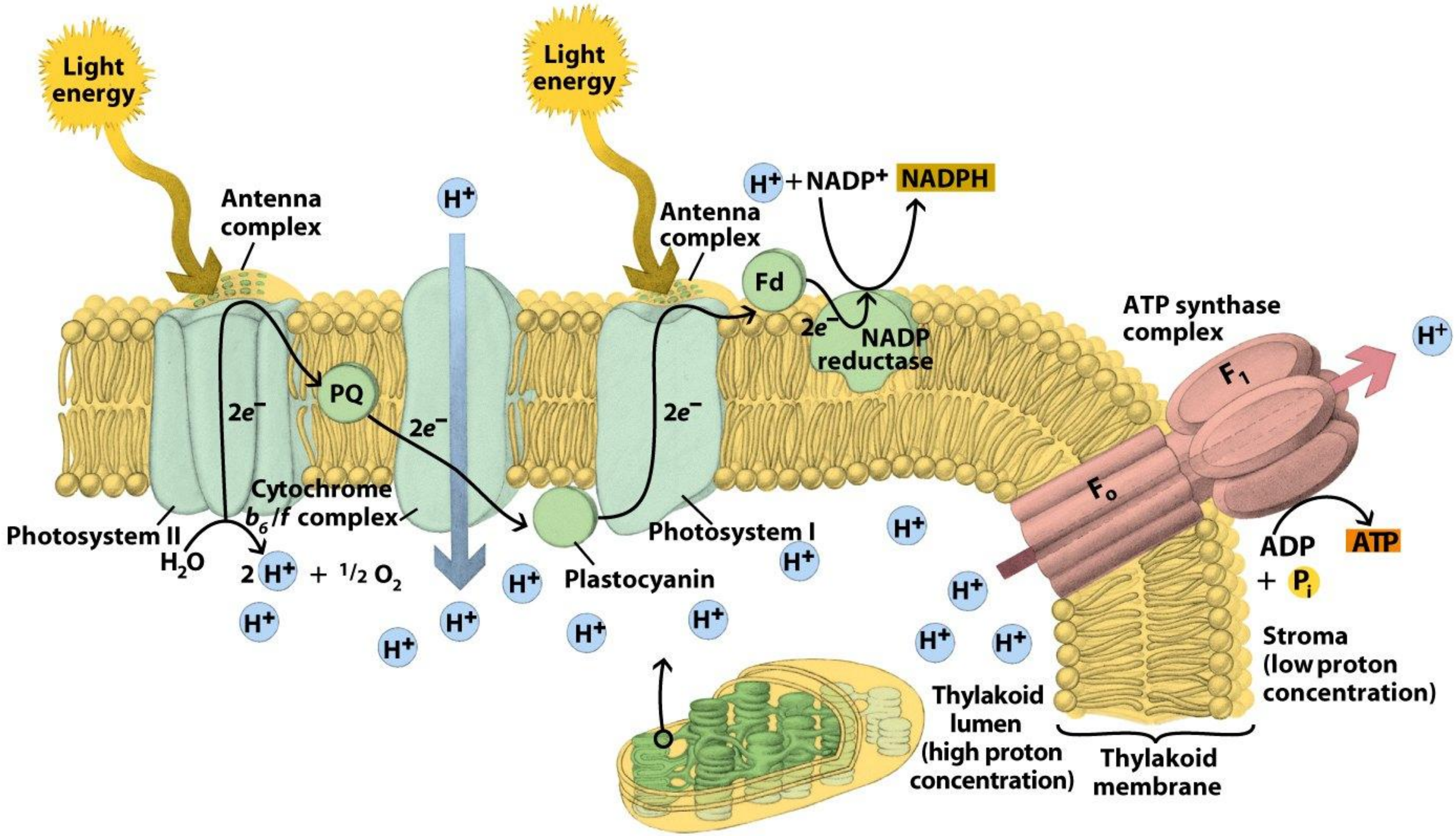
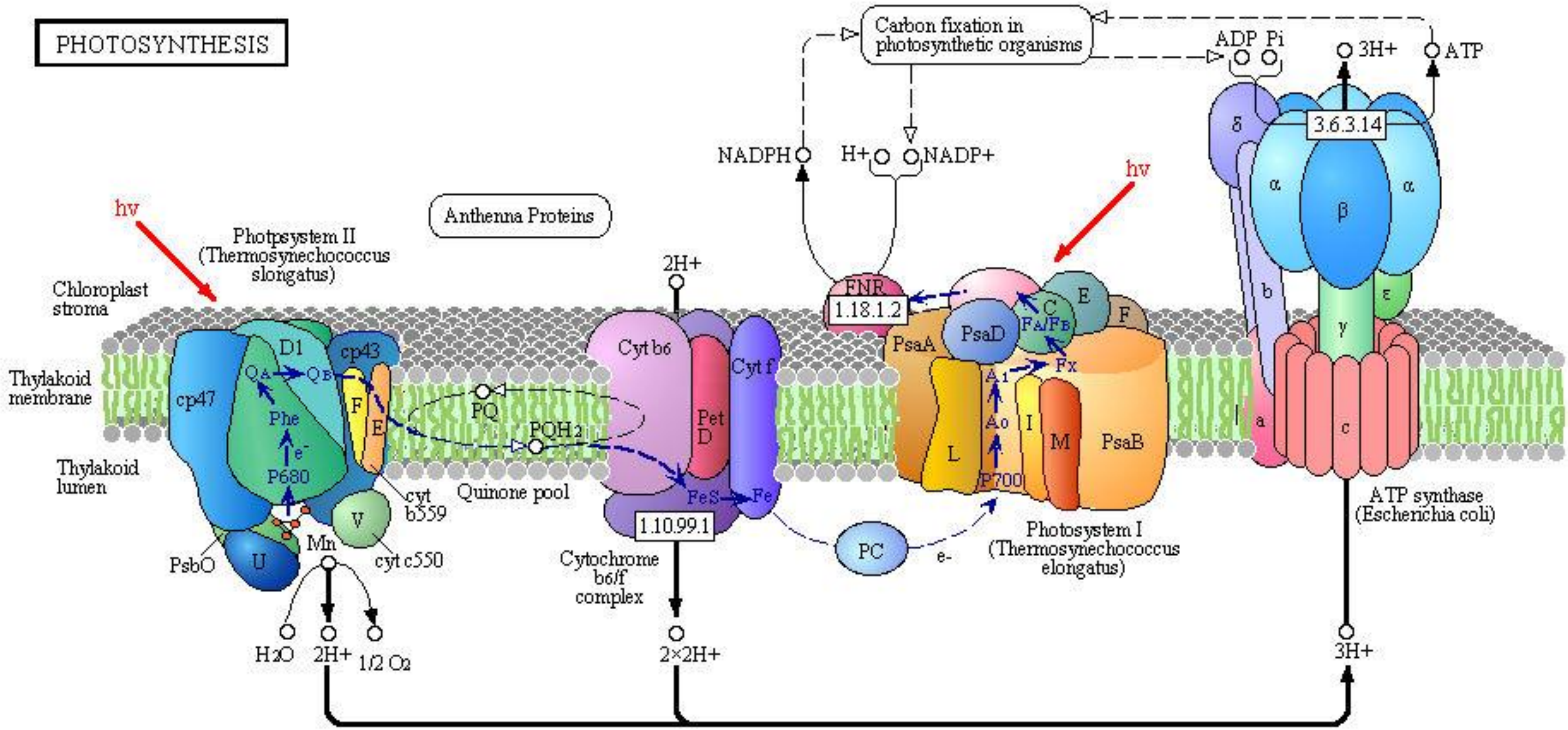


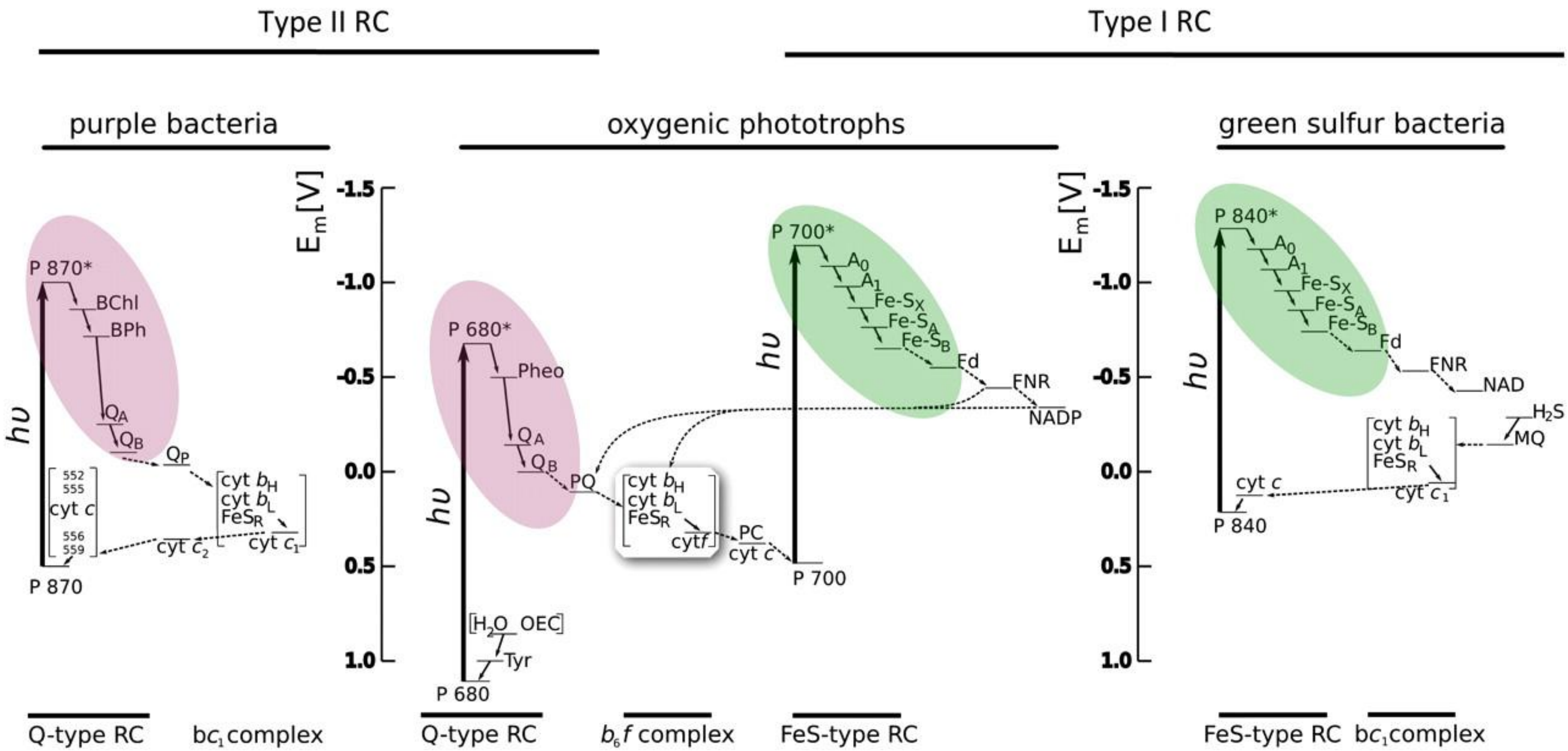
Figure 7-12
Biology of Plants, Seventh Edition

The four protein complexes of photosynthetic electron transport are big and multi-peptide.



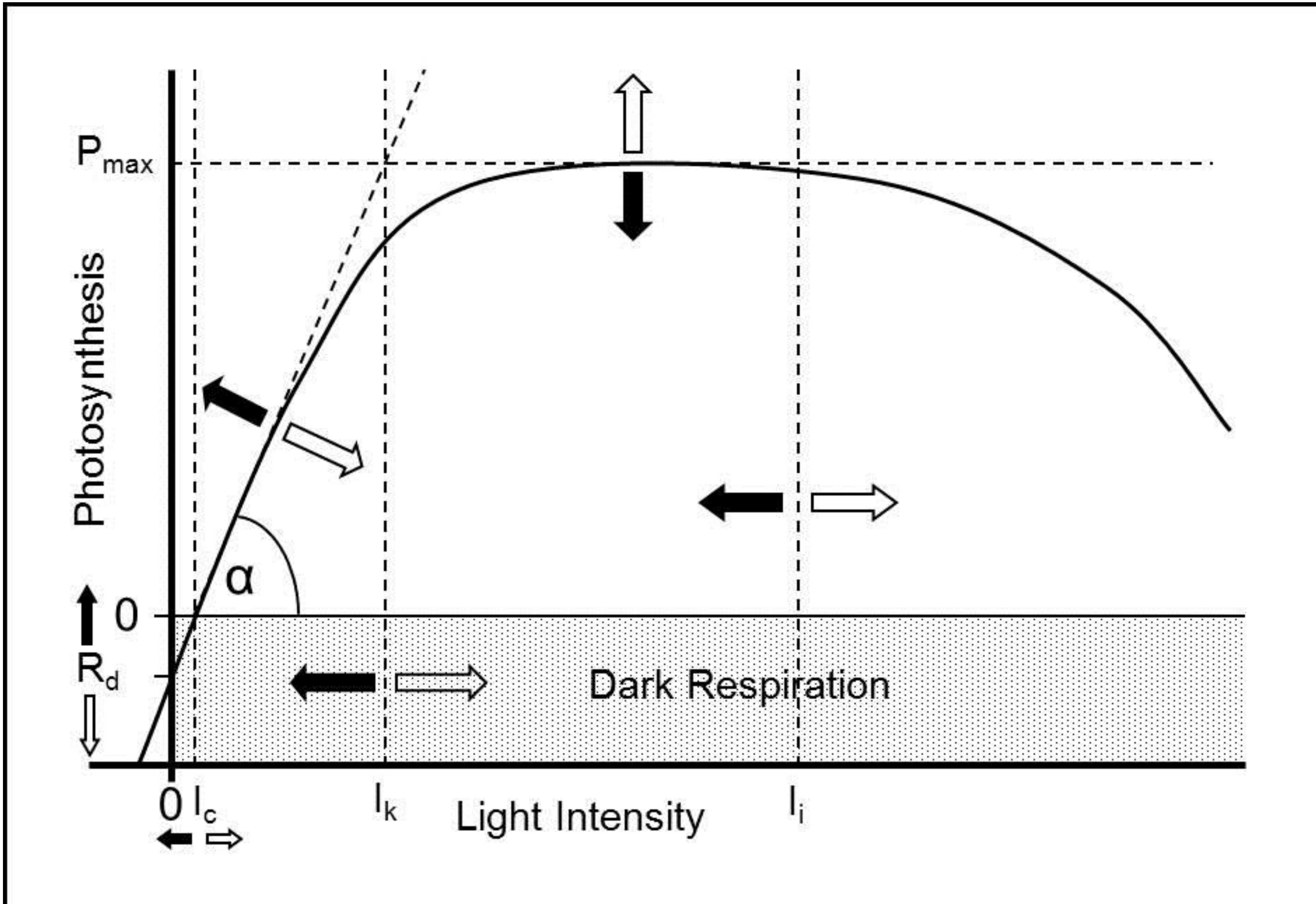
http://employees.csbsju.edu/hjakubowski/classes/ch331/oxphos/olphotsynthesis.html

Two photosystems are required to both oxidize water and reduce NADP.

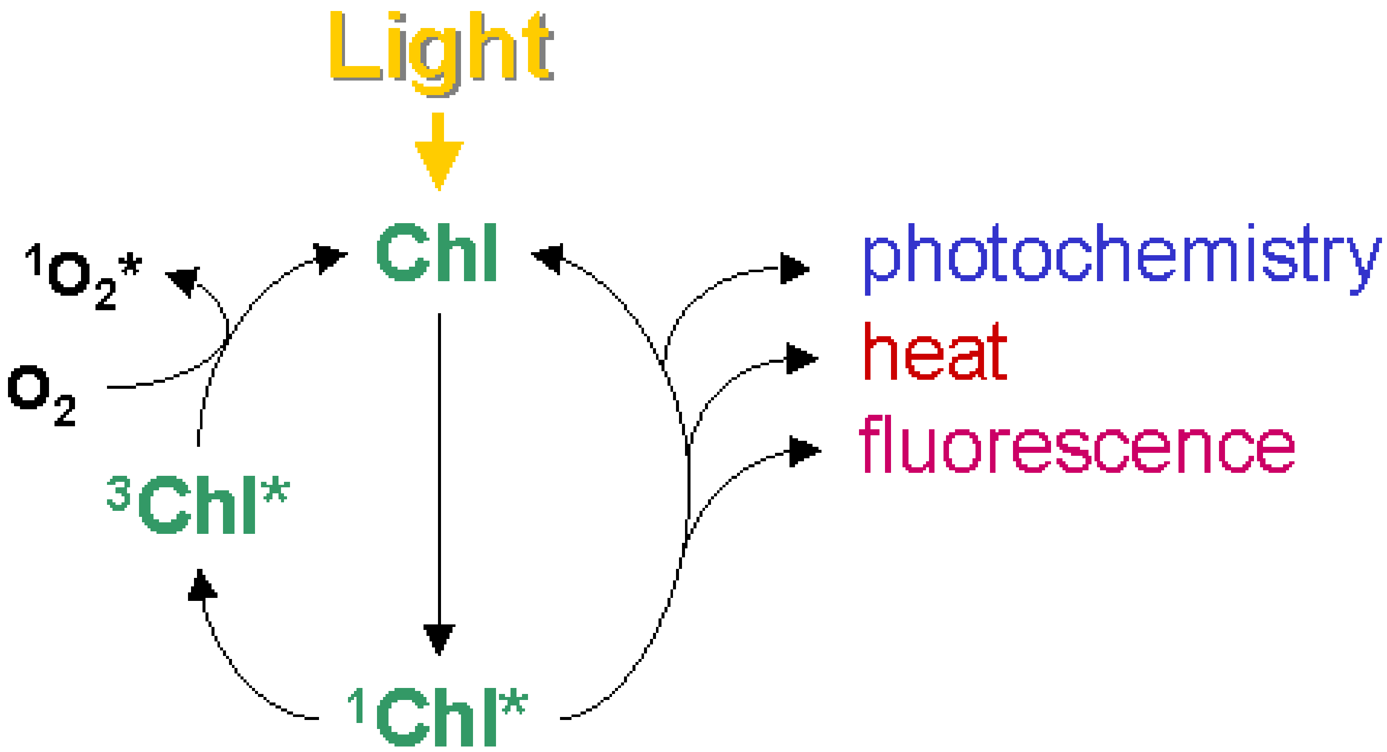


http://bio1510.biology.gatech.edu/module-3-molecules-membranes-and-metabolism/08-converting-light-energy-into-chemical-energy/

The photosynthetic light response.

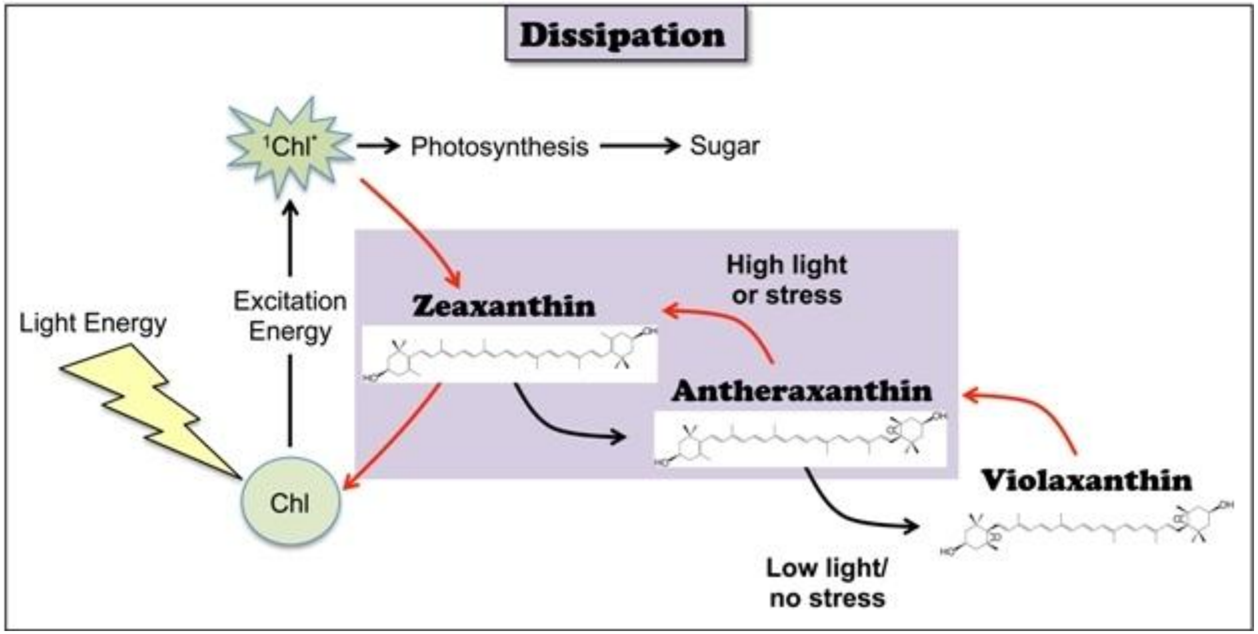


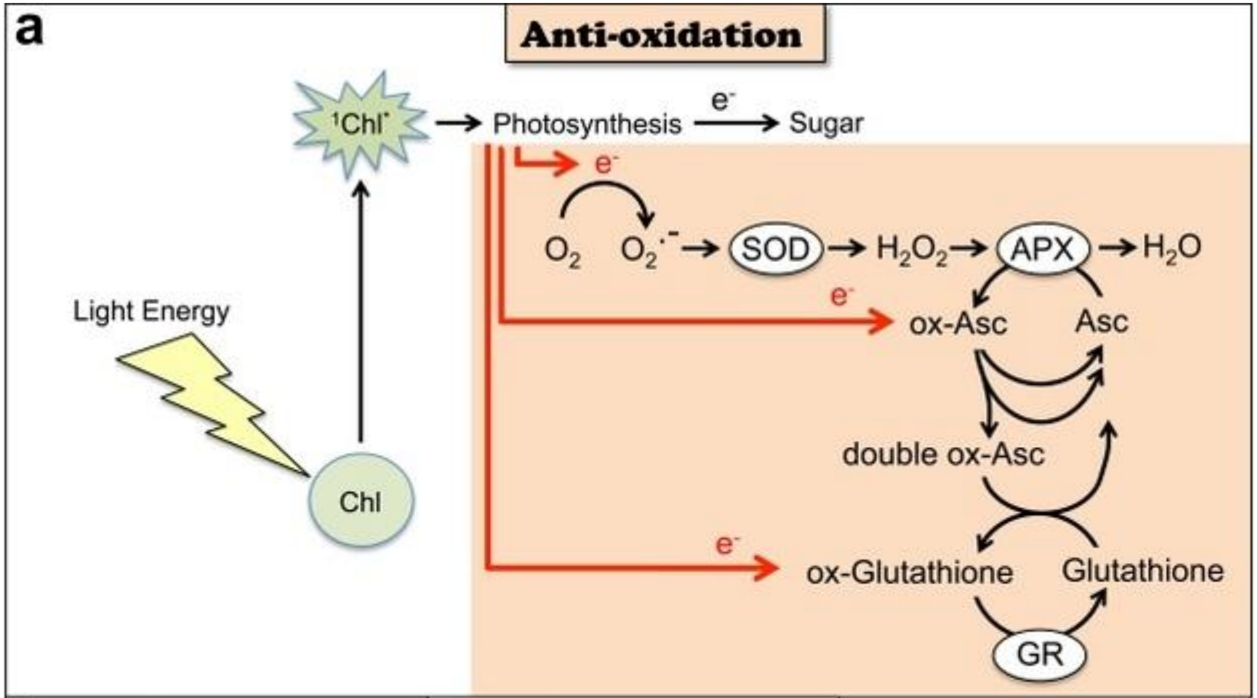
The four possible fates of an absorbed photon.



http://www.photosynthesis.ch/fluorescence.htm

Preventing damage from excess light



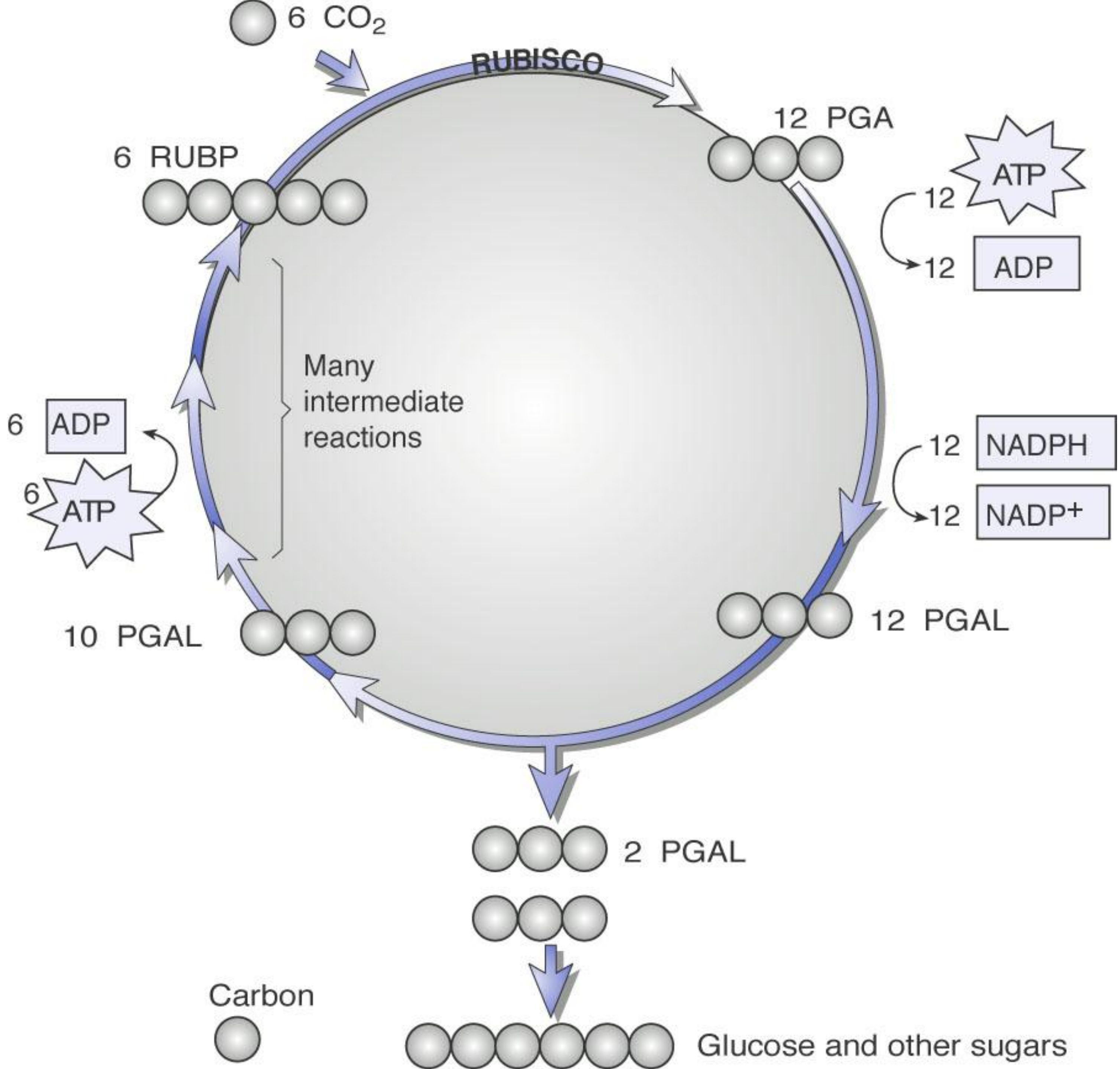


http://www.nature.com/scitable/knowledge/library/dealing-with-the-hazards-of-harnessing-sunlight-83031977

The Calvin Cycle

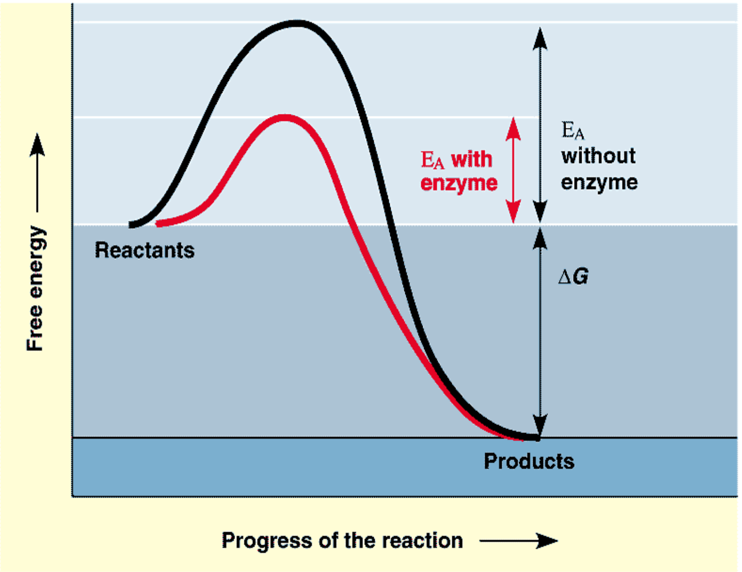
(*i.e.*, the CO_2 fixation cycle; a.k.a., the "dark" reactions)

.



Rubisco

- Ribulose bisphosphate carboxylase oxygenase
- "Fixes" CO_2 & O_2
  - Fixing O_2 is a mistake
- Enzyme in Calvin Cycle
  - Catalyzes 1^{st} step
- Most abundant protein on Earth
  - Often 25% of total leaf protein
- One of the slowest enzymes on Earth



Photorespiration

- When rubisco "fixes" O_2, not CO_2
- Lose previously-fixed C as CO_2
- Take up O_2
- Only occurs in light
- Expensive to repair the "damage"
- Occurs *ca*. 1 out of 4 reactions under today's atmospheric [CO_2], but this rate decreases with increasing CO_2
- Rate increases with temperature

Photorespiration (PR)

rubisco

5-carbon sugar + O_2 → 3-carbon compound + 2-carbon compound

3-carbon compound ↓ enters the Calvin cycle, becomes sugar

2-carbon compound ↓ enters the PR cycle; 1C lost as CO_2, 1C recovered; wastes energy

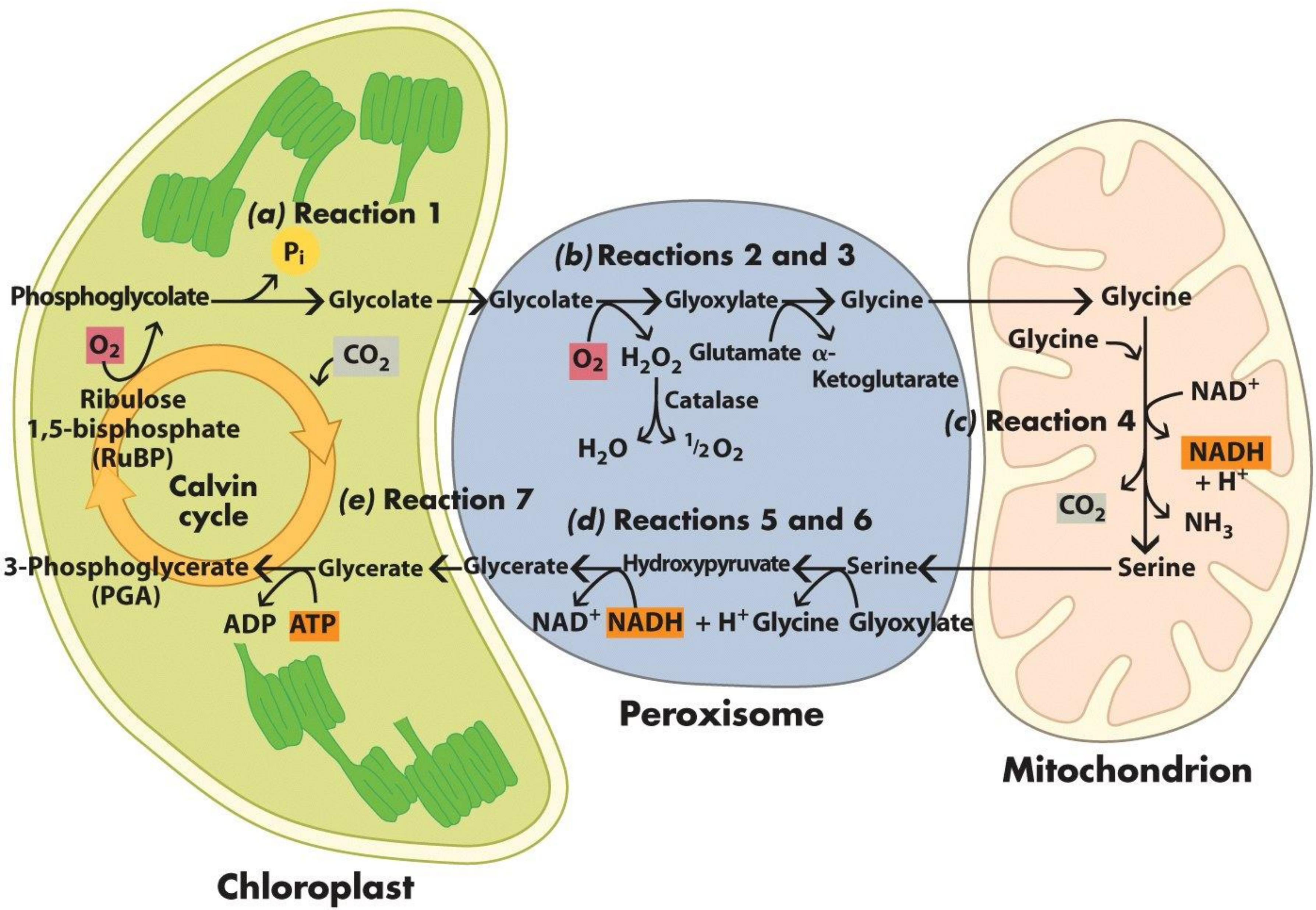


Figure 7-20
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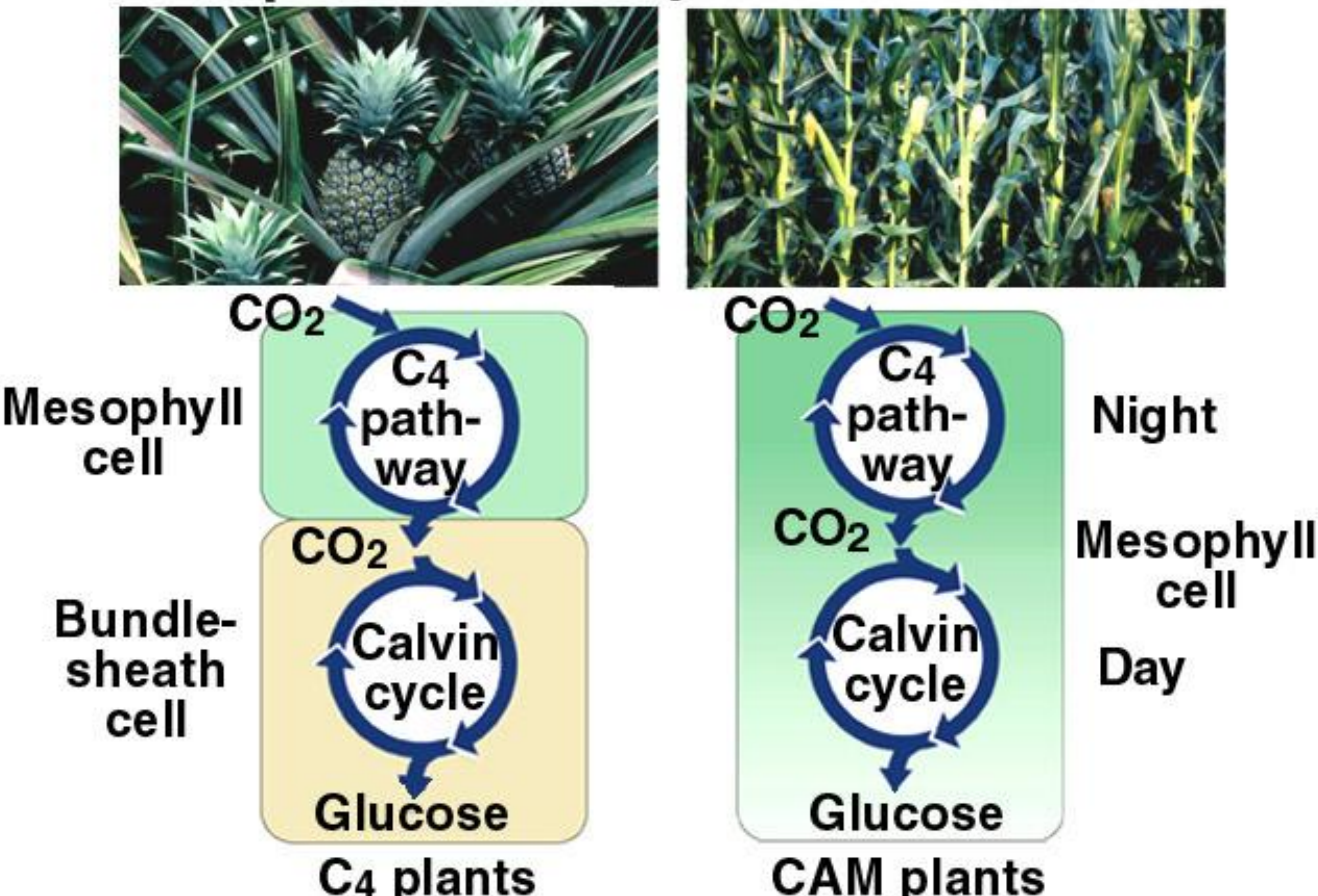
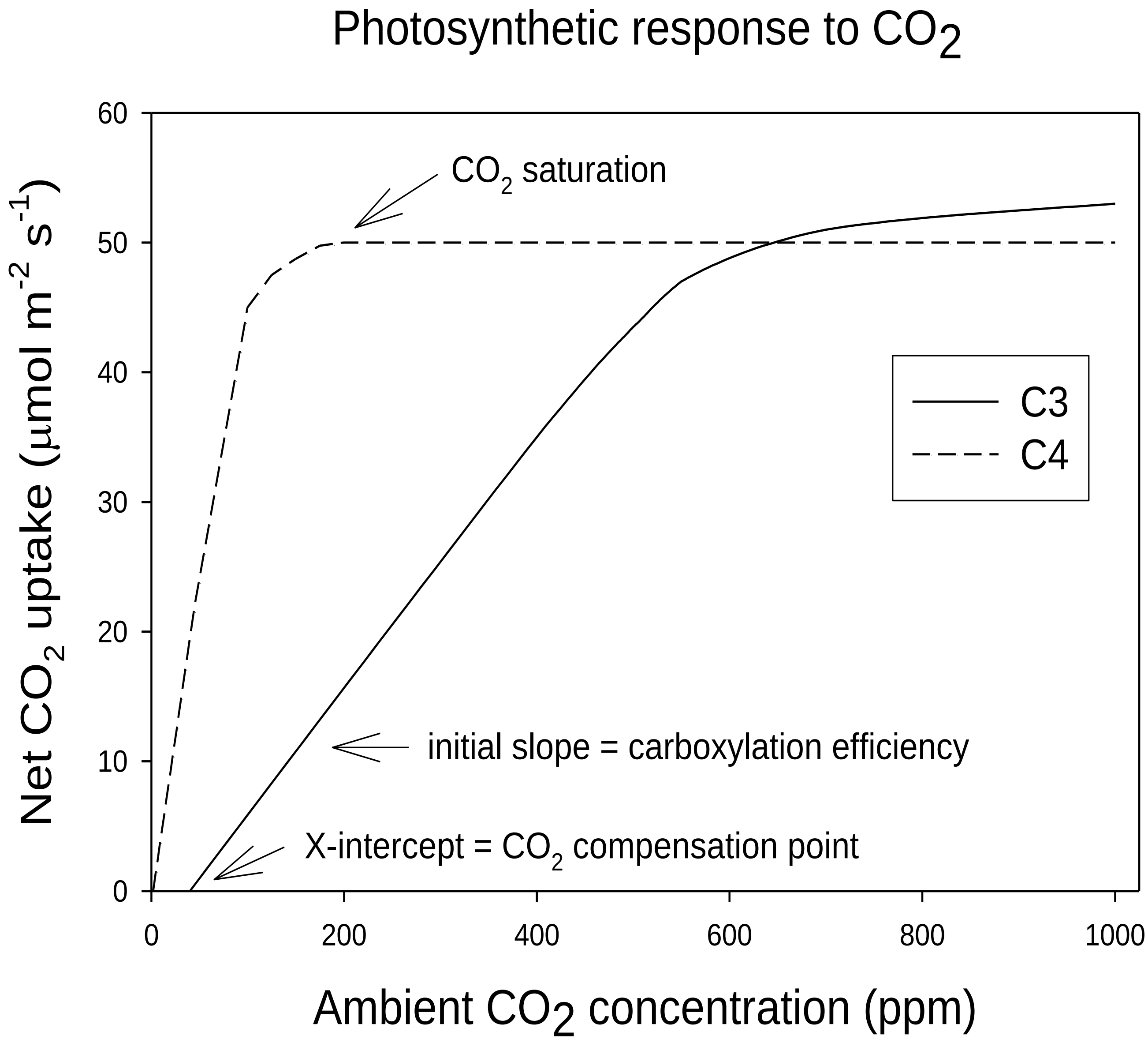
Types of photosynthesis

- C3
  - The majority of plants
  - High rates of photorespiration at today's CO_2 level
- C4
  - Have a CO_2-concentrating mechanism (aka, CO_2 "pump")
  - CO_2 first fixed by pepcase, then released and re-fixed by rubisco
  - Advantage in high light, high temperature, low CO_2, dry, saline
  - Many grasses and crops (*e.g.*, corn, sorghum, millet, sugar cane)
- CAM
  - Have similar CO_2-concentrating mechanism as C4
  - Stomata open during night, closed in day
  - Advantage in arid (dry) climates
  - Many succulents (*e.g.*, cacti, euphorbs, bromeliades, agaves)

Fig. 10.22

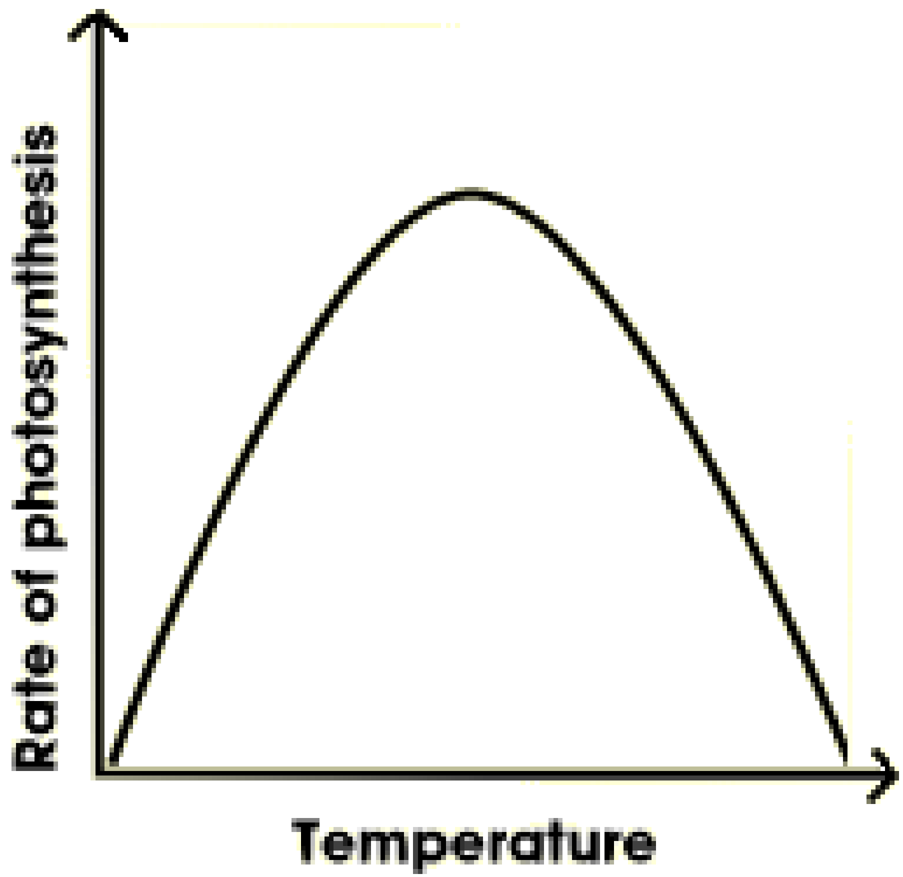
Comparison of C_4 and CAM Plants



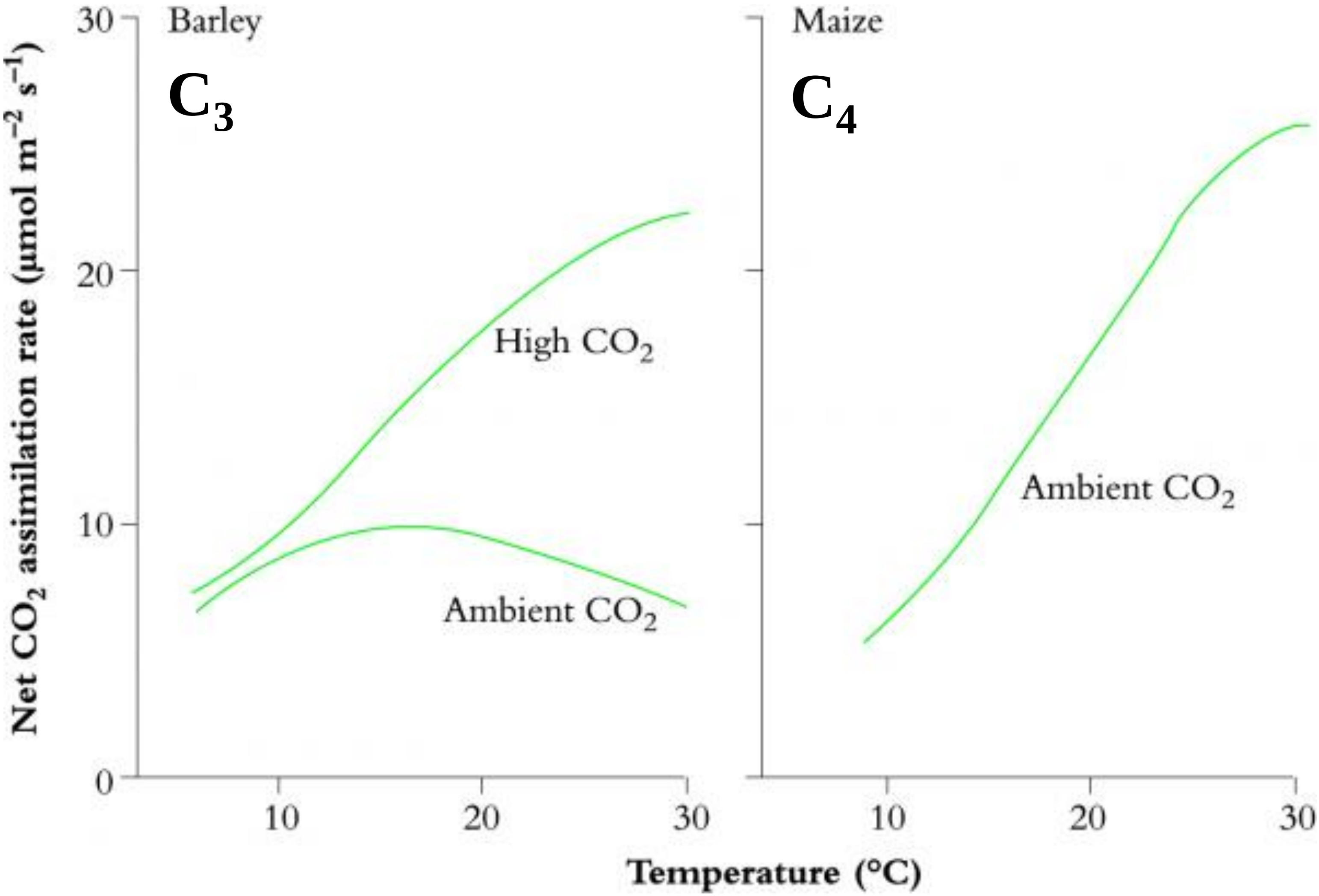


Photosynthetic response to CO2
CO2 saturation
initial slope = carboxylation efficiency
X-intercept = CO2 compensation point
C3
C4
Net CO2 uptake (µmol m-2 s-1)
Ambient CO2 concentration (ppm)
0
10
20
30
40
50
60
0
200
400
600
800
1000

The photosynthetic temperature response.



Photorespiration ↑ with temperature, ↓ with CO_2.



http://plantsinaction.science.uq.edu.au/edition1//?q=figure_view/699

To predicting effects of global environmental change on the biosphere: you must start with photosynthesis (PS)

- Human activities are:
  - Increasing atmospheric CO_2 (↑ PS)
  - Increasing average (↑ or ↓ PS) and extreme temperatures (↓ PS)
  - Increasing nitrogen (↑ PS)
  - Changing precipitation (drought ↓ PS; increased rain usually ↑ PS)
  - Increasing ground-level ozone (↓ PS)