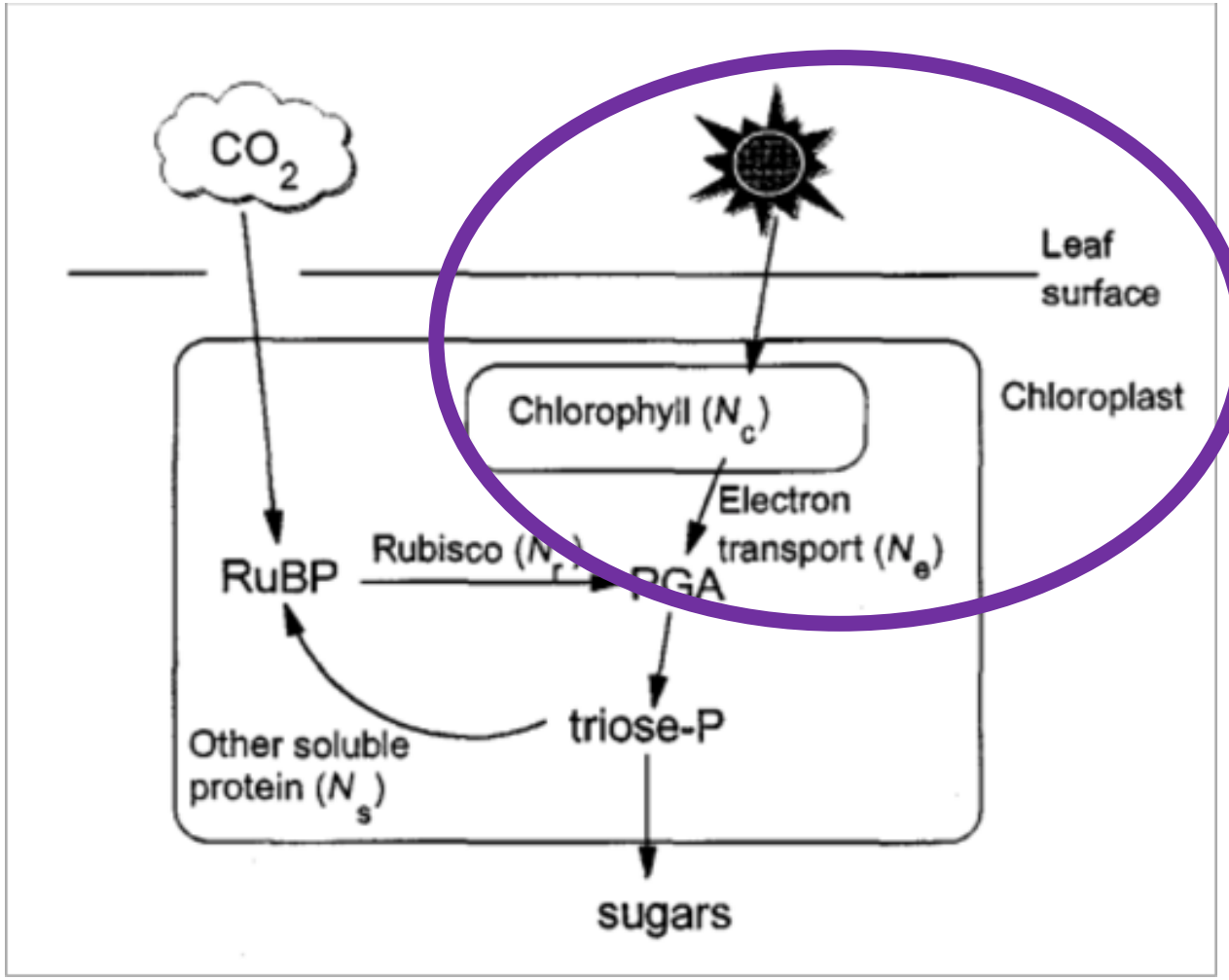
The ecophysiological consequences of light variability

February 5, 2019

How does light availability to plants vary over space and time?

Light effects on short-term plant functioning

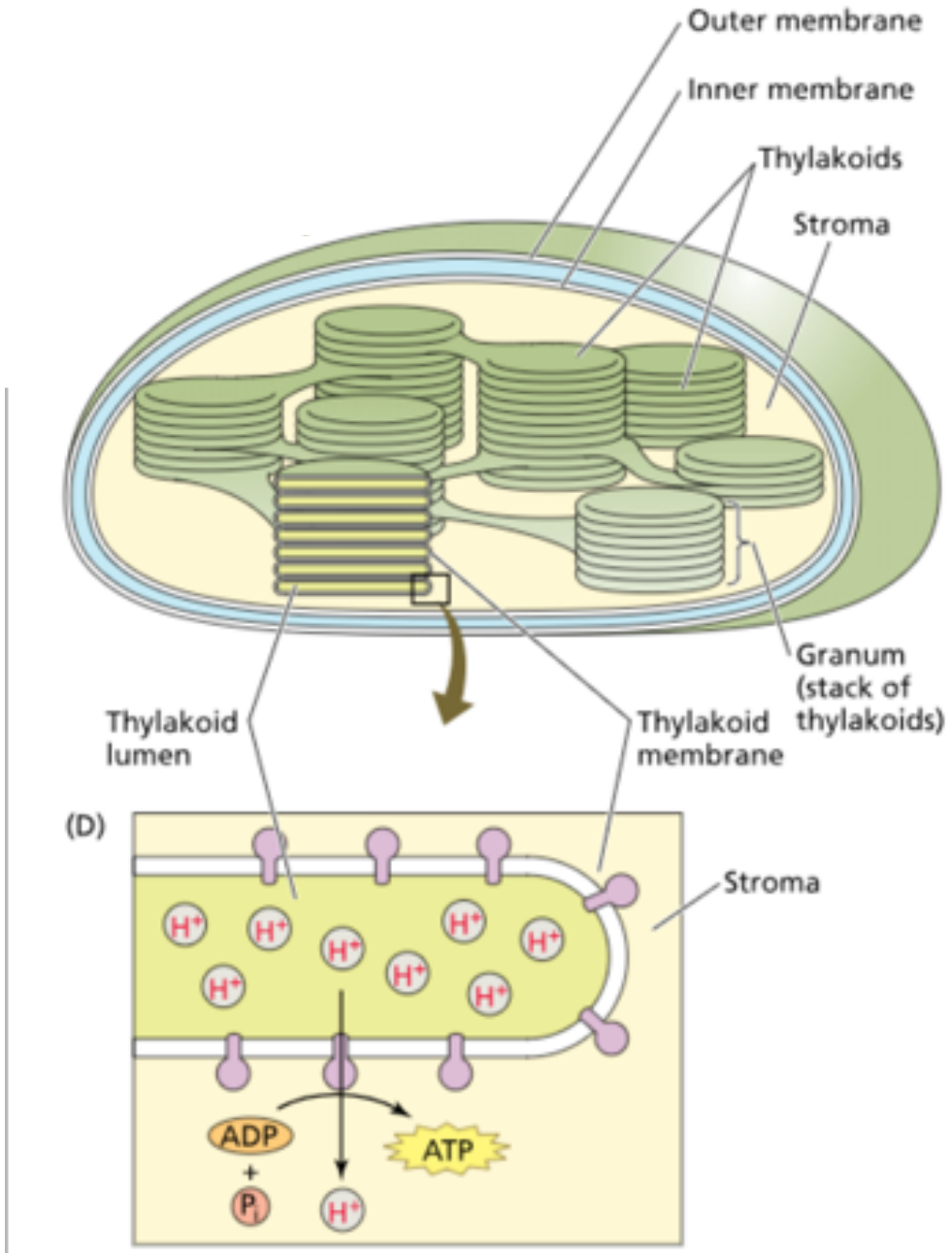
Plants use light to make energy for photosynthesis



Medlyn 1996

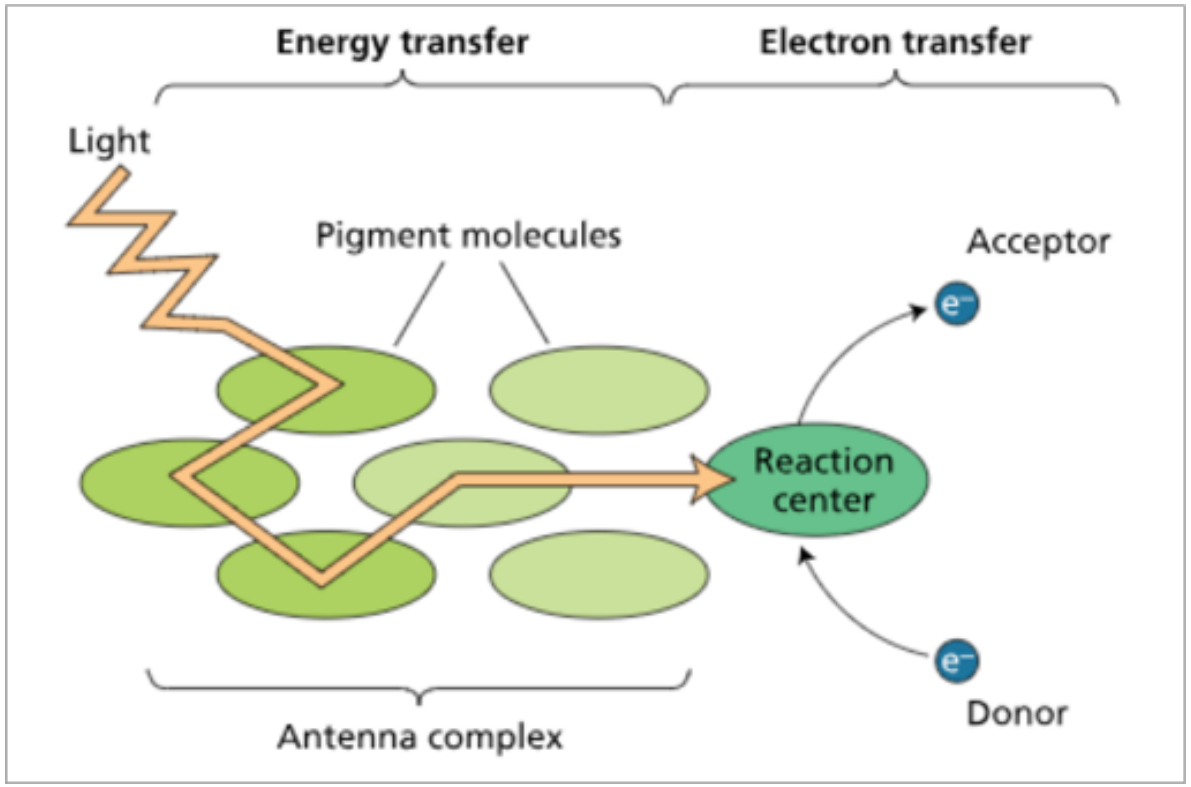
Chloroplasts

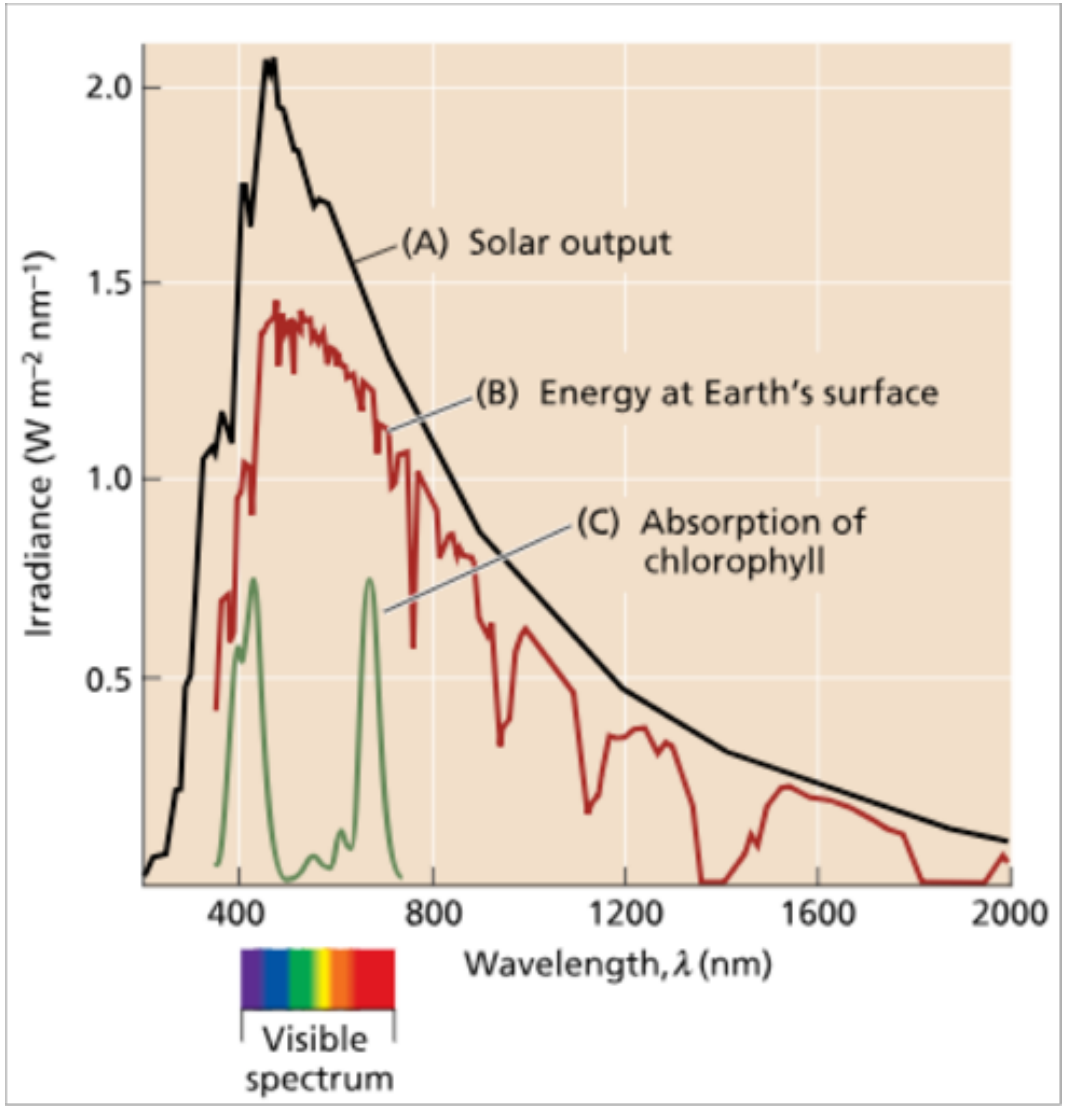
Light reaction proteins and pigments are embedded in the thylakoid membrane

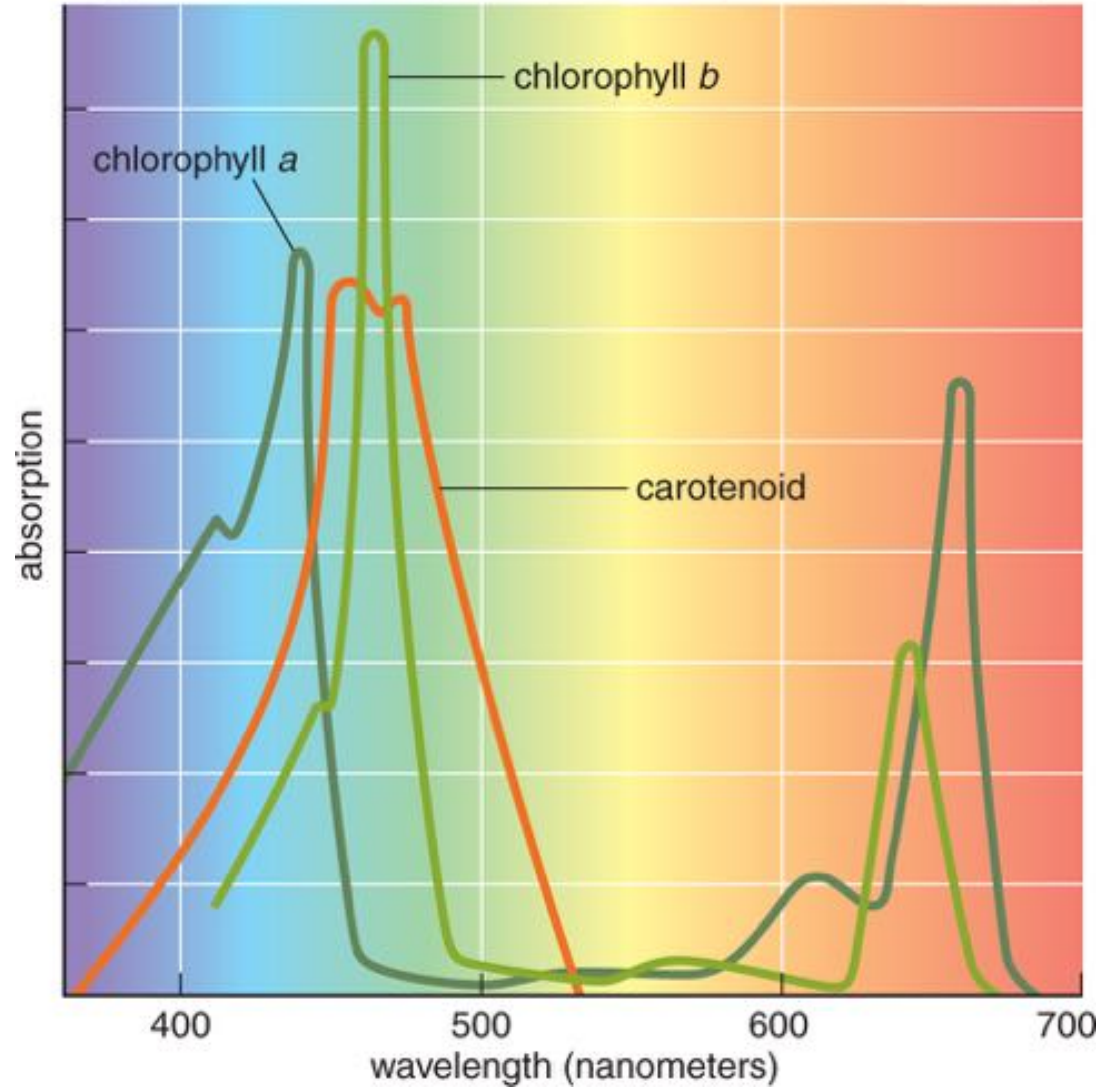


Chlorophyll

Chlorophyll pigments absorb light and create usable energy in the form of NADPH and ATP

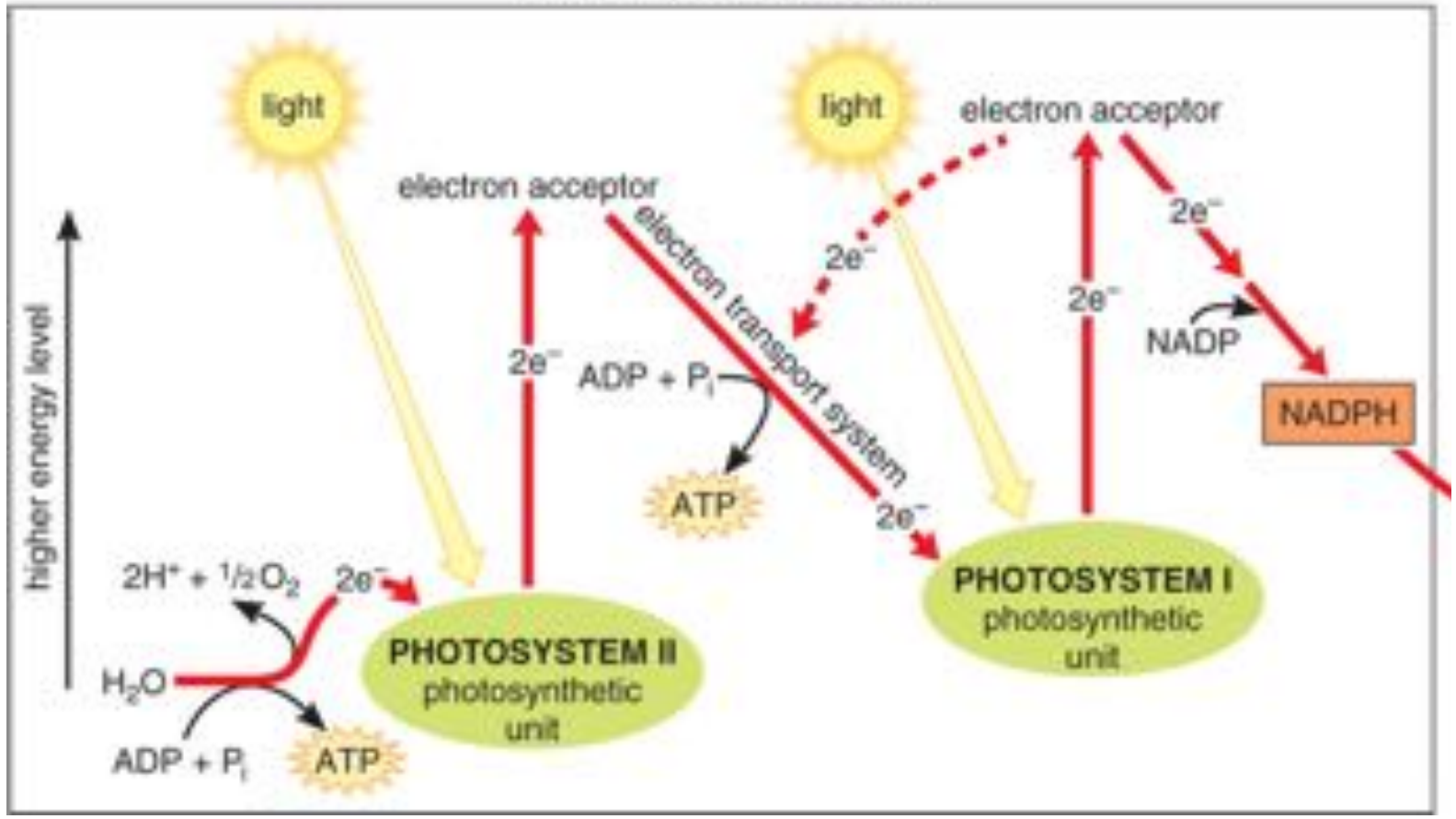



2.0
1.5
1.0
0.5
Irradiance (W m⁻² nm⁻¹)
(A) Solar output
(B) Energy at Earth's surface
(C) Absorption of chlorophyll
400
800
1200
1600
2000
Wavelength, λ (nm)
Visible spectrum


chlorophyll b
chlorophyll a
carotenoid
absorption
400
500
600
700
wavelength (nanometers)

Light-dependent reactions

1. Ingredients
   - Light
   - H2O
   - NADP+
   - ADP
   - P
2. Outcomes
   - ATP
   - NADPH
   - O2
   - H+



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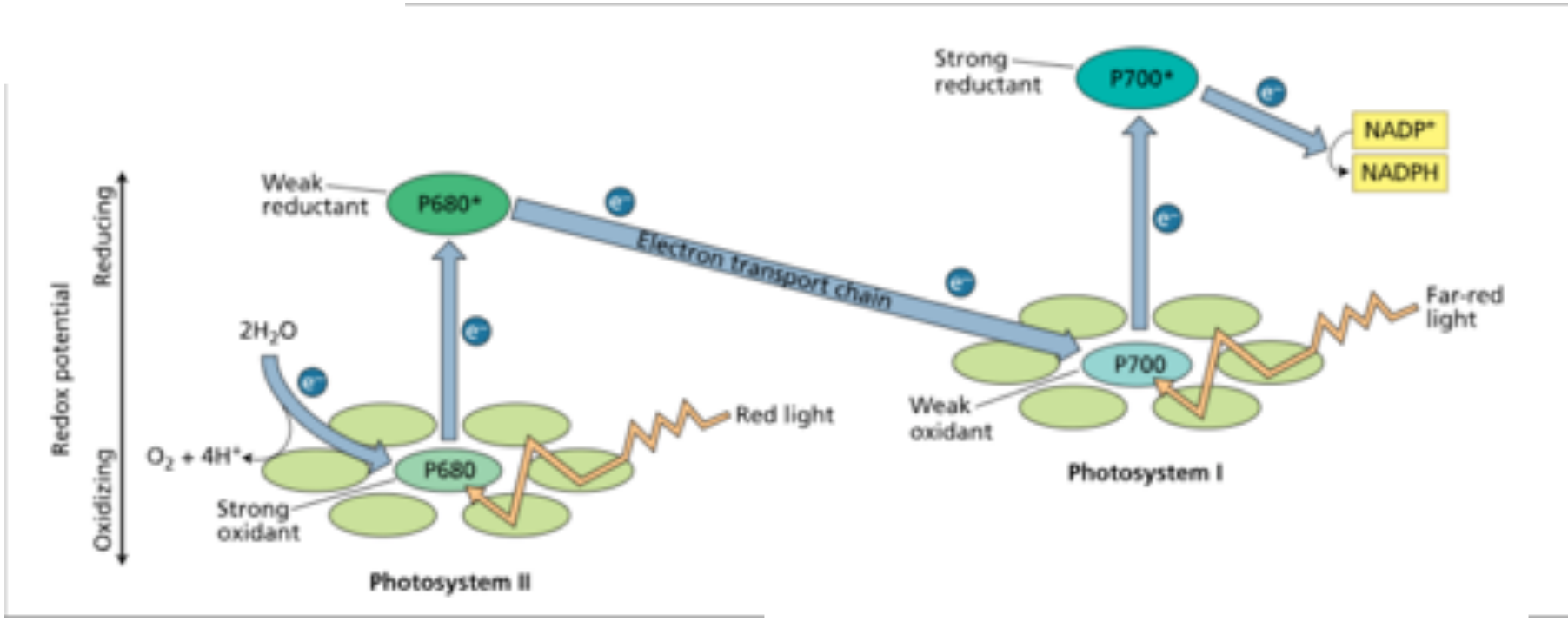
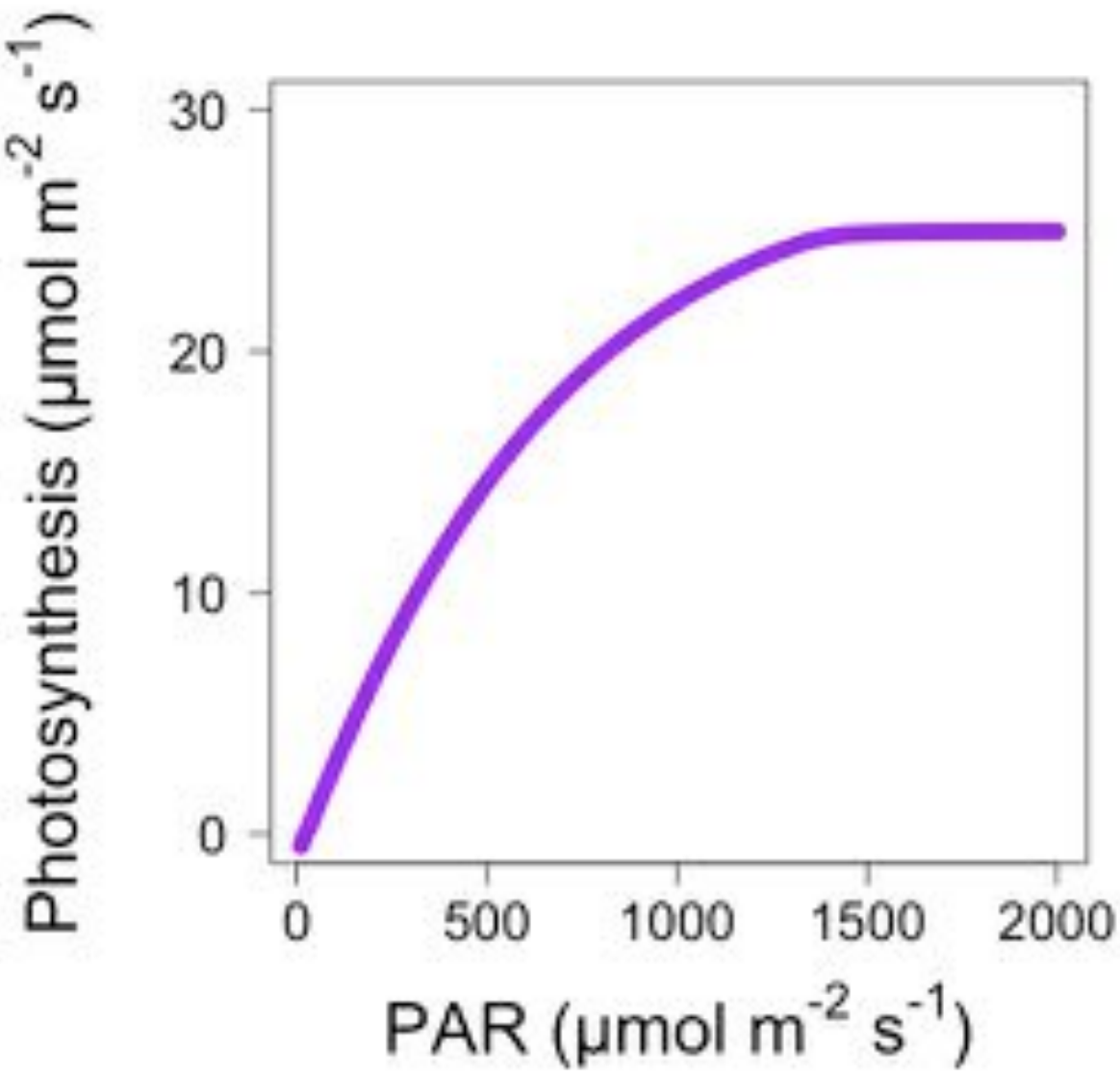
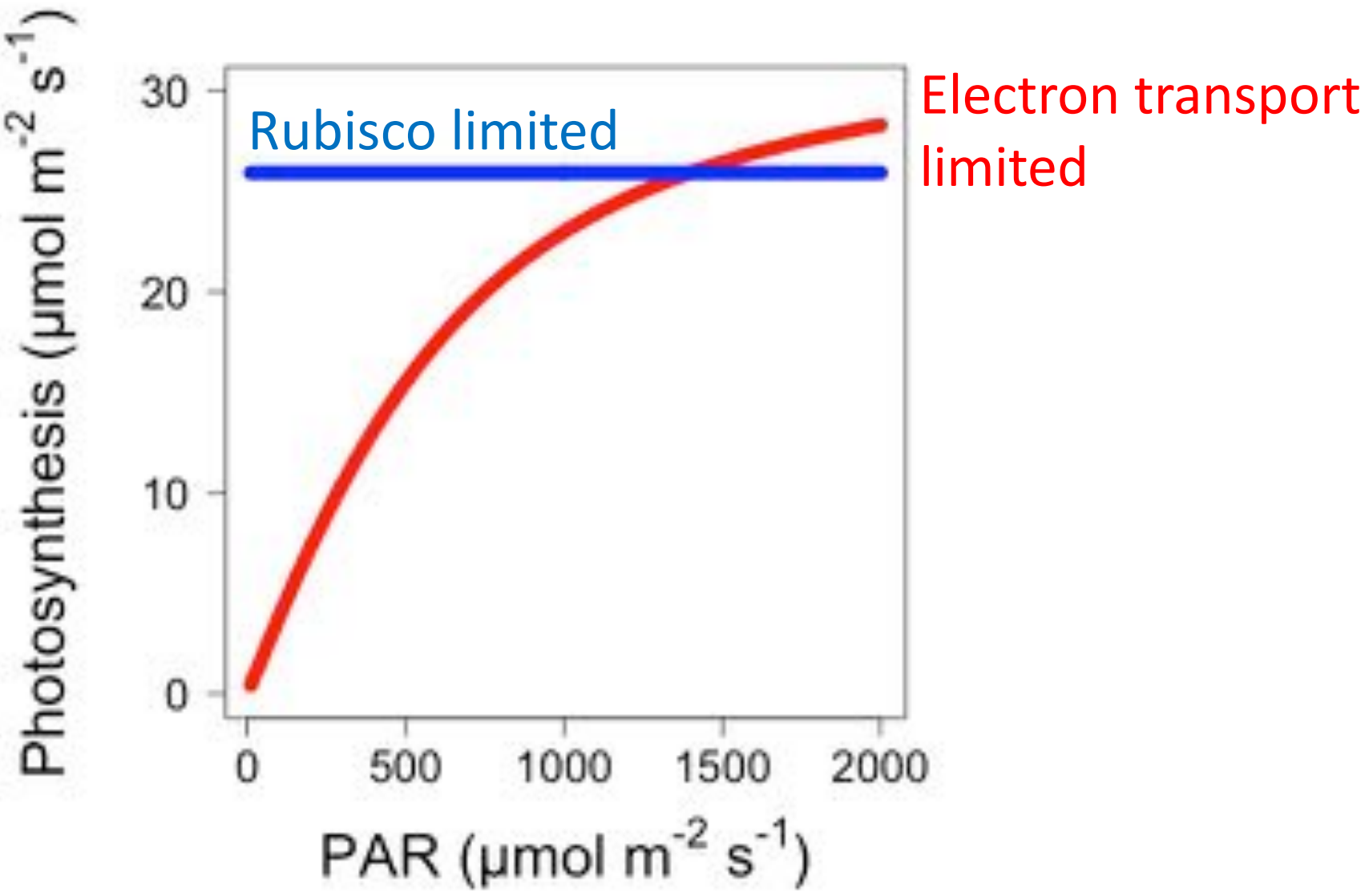
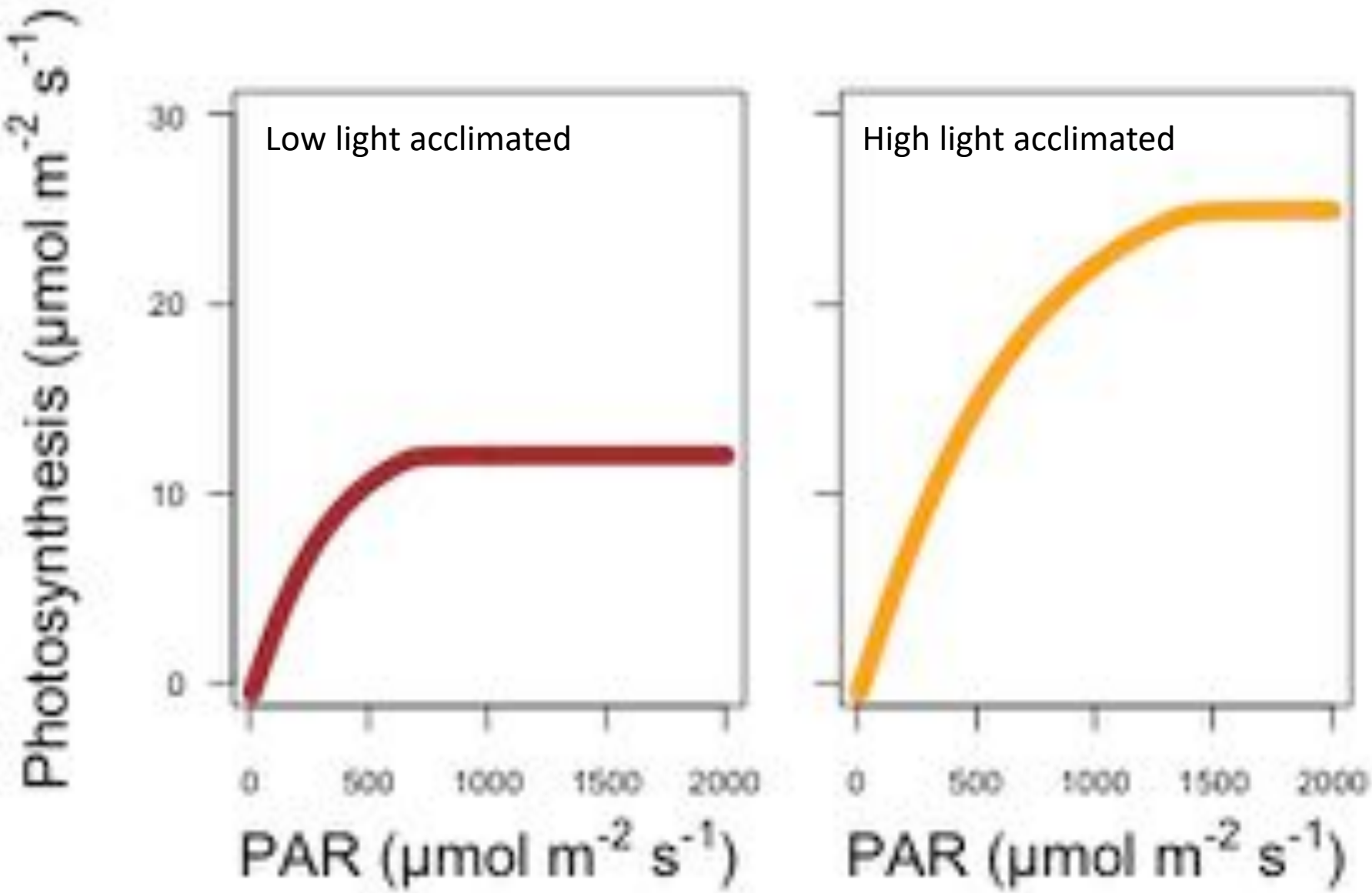


The light response of photosynthesis

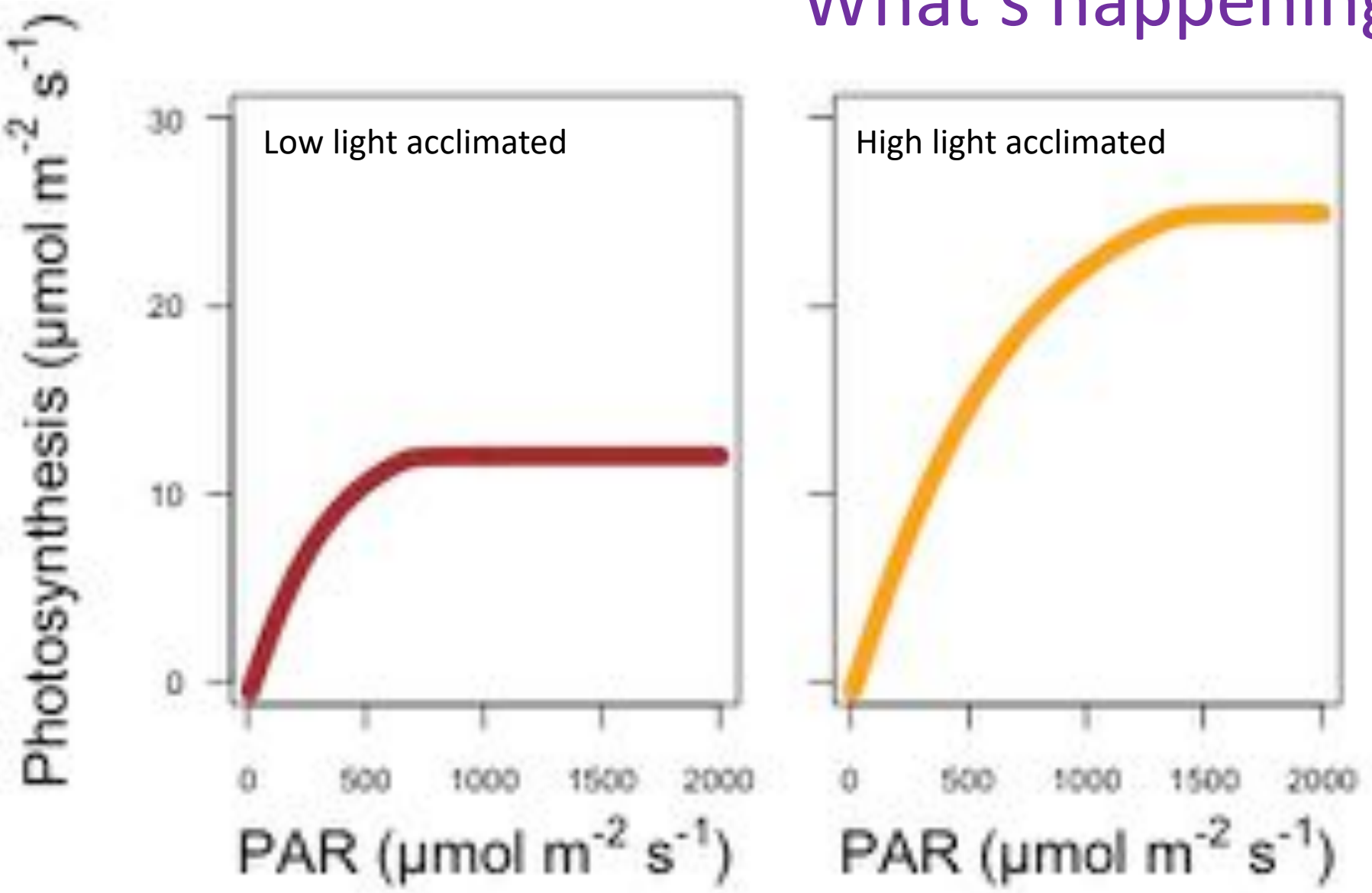

Photosynthesis (µmol m-2 s-1)
30
20
10
0
0
500
1000
1500
2000
PAR (µmol m-2 s-1)


Photosynthesis (µmol m-2 s-1)
30
20
10
0
Rubisco limited
Electron transport limited
0
500
1000
1500
2000
PAR (µmol m-2 s-1)

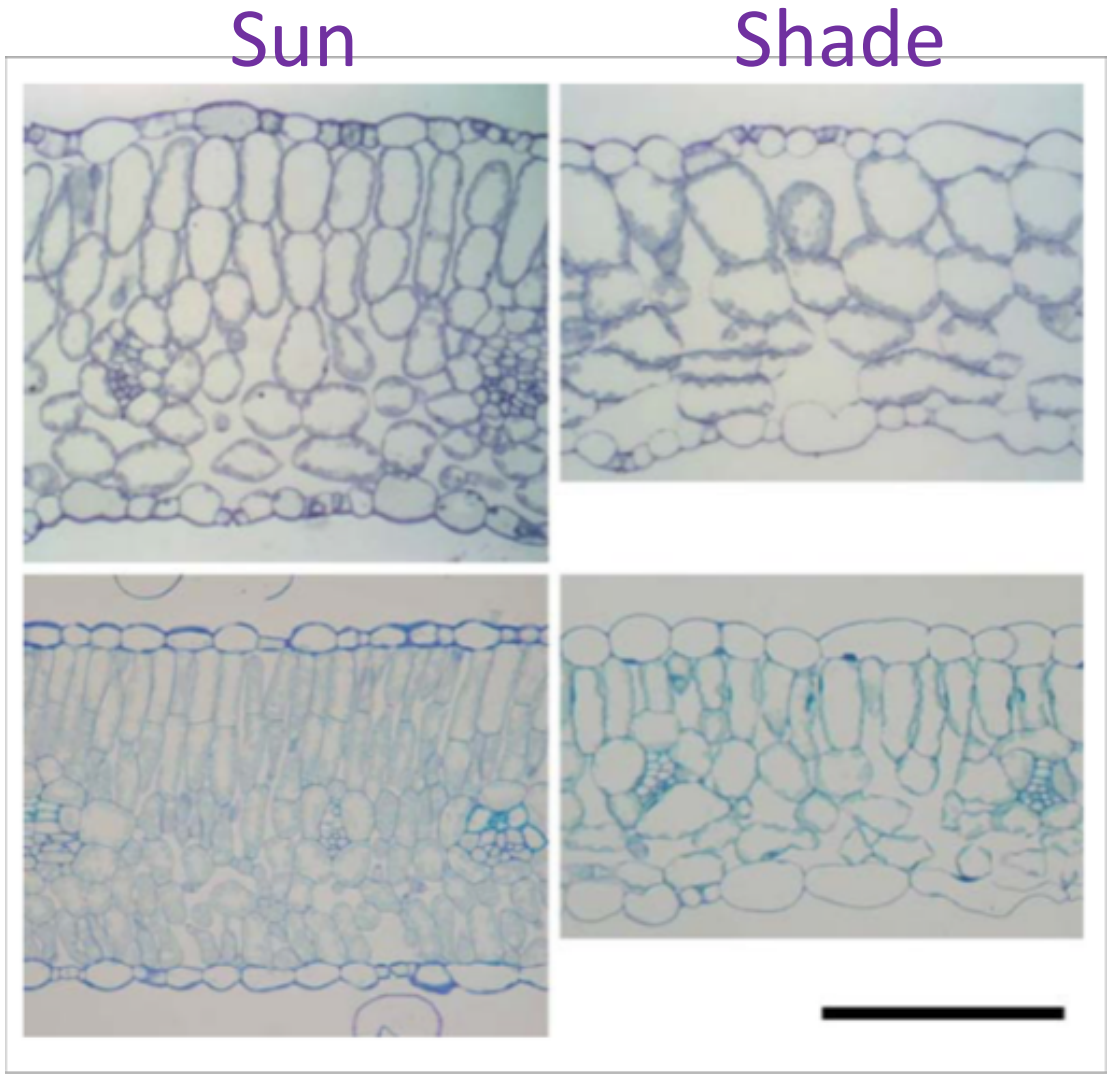
Light effects on long-term plant functioning - acclimation


Photosynthesis (µmol m-2 s-1)
Low light acclimated
High light acclimated
30
20
10
0
0
500
1000
1500
2000
PAR (µmol m-2 s-1)
PAR (µmol m-2 s-1)

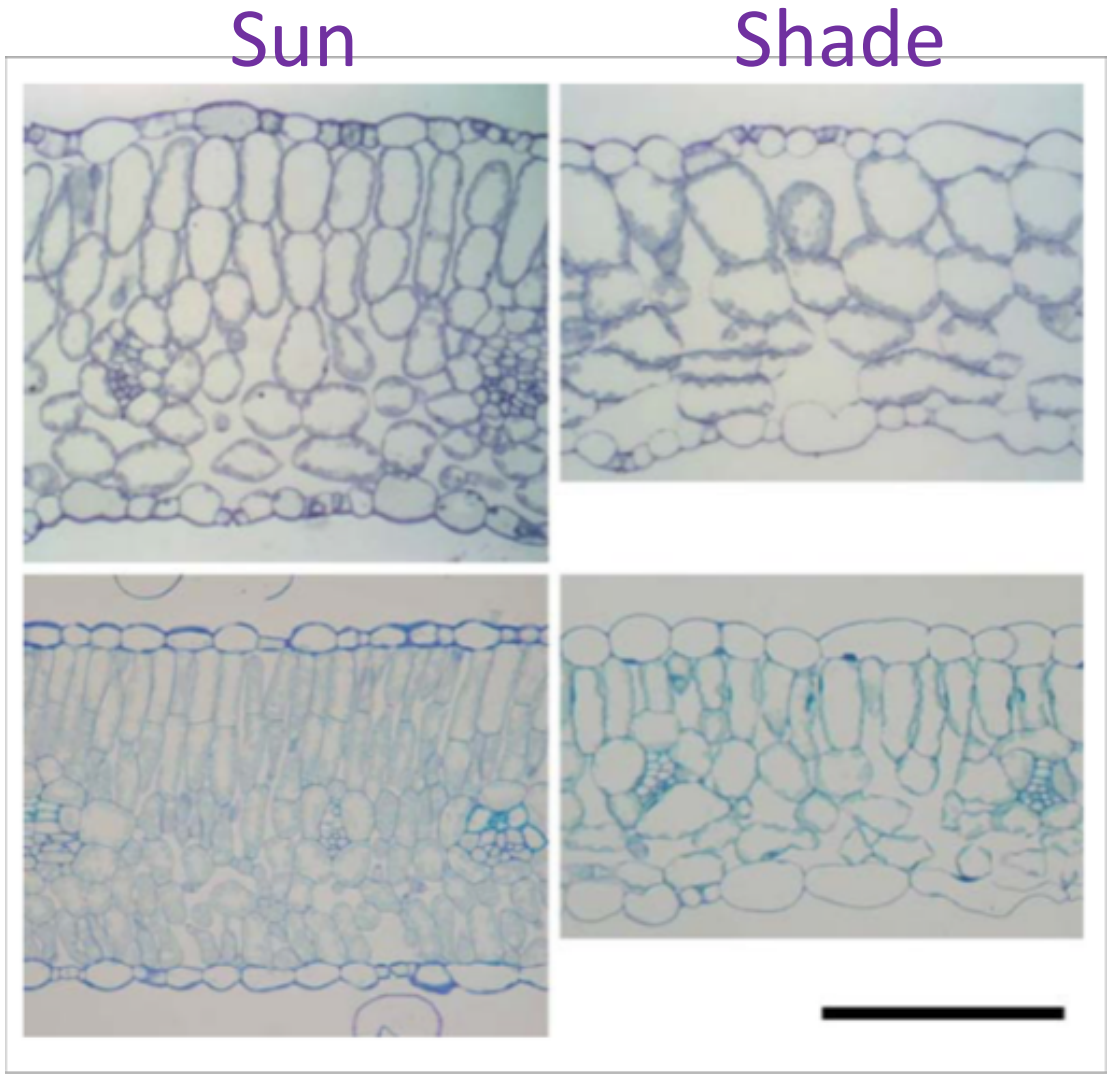
What's happening here?



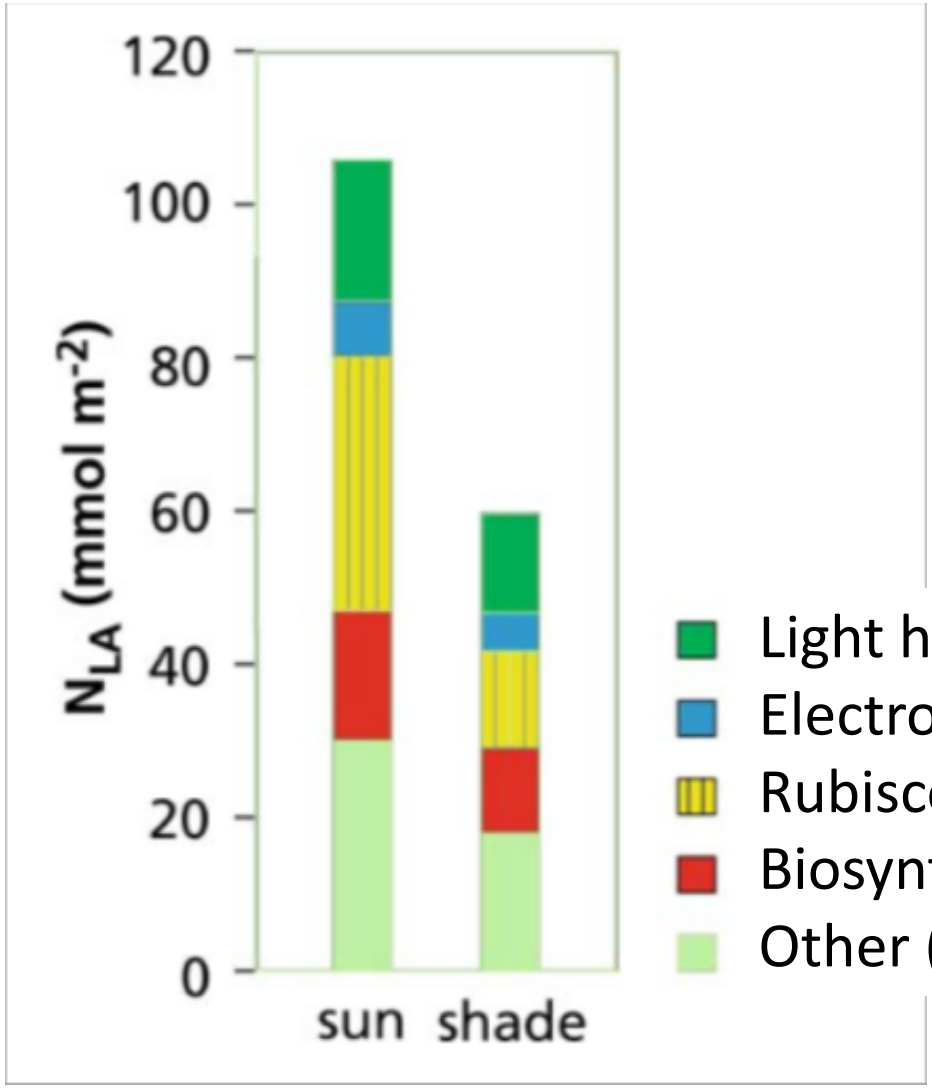
Sun leaves are thicker



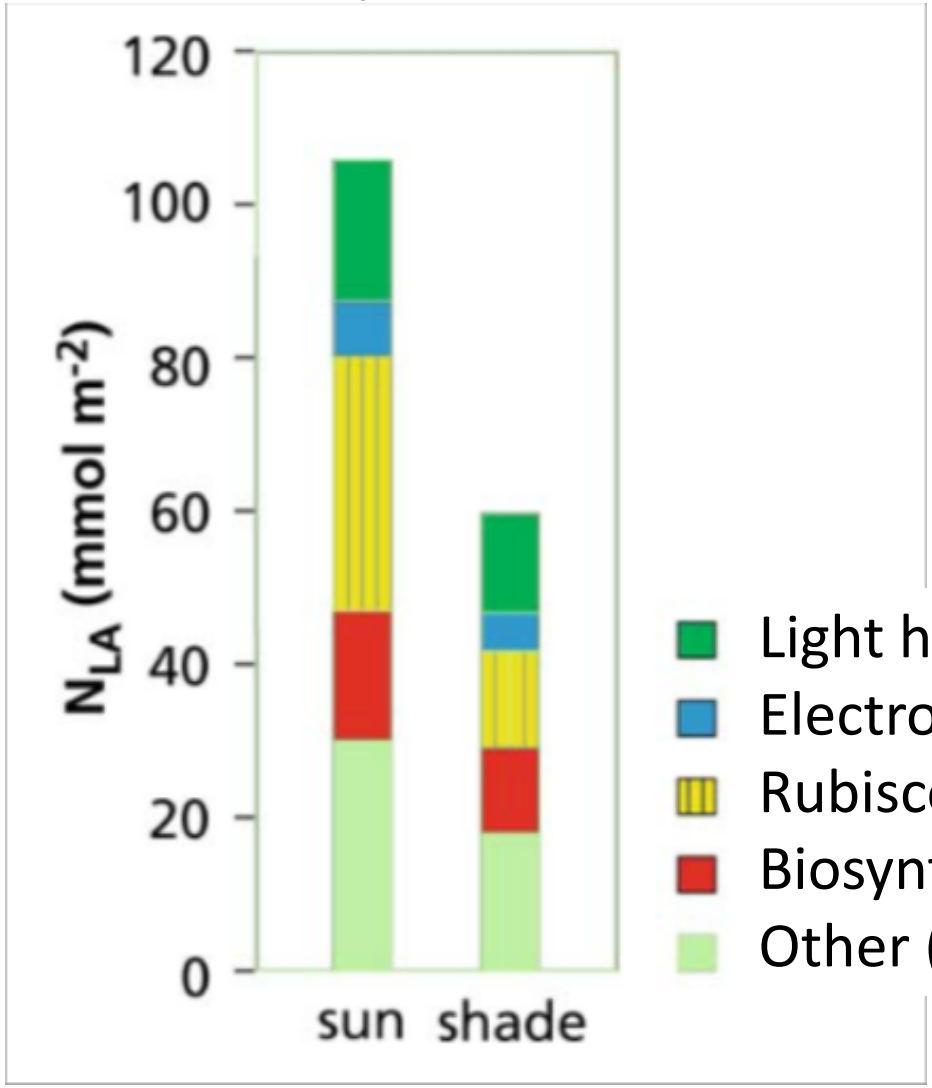
Sun leaves are thicker – why?



Sun leaves have more N invested in photosynthesis



Sun leaves have more N invested in photosynthesis – why?



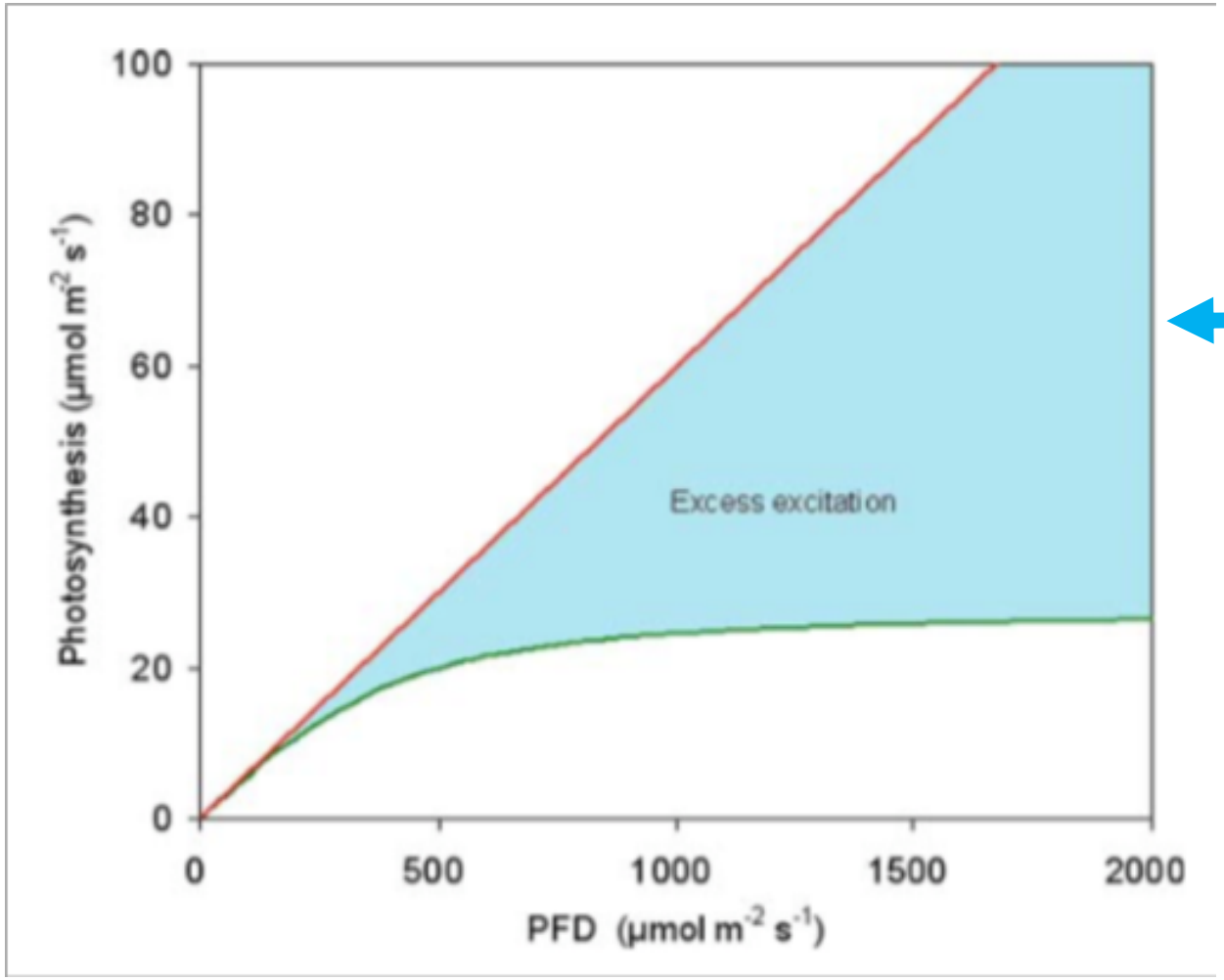
Other differences

TABLE 2. Overview of generalized differences in characteristics between shade- and sun-acclimated leaves.

	Sun	Shade
Structural		
Leaf dry mass per area	High	Low
Leaf thickness	Thick	Thin
Palisade parenchyma thickness	Thick	Thin
Spongy parenchyma thickness	Similar	Similar
Stomatal density	High	Low
Chloroplast per area	Many	Few
Thylakoids per stroma volume	Low	High
Thylakoids per granum	Few	Many
Biochemical		
Chlorophyll per chloroplast	low	high
Chlorophyll per area	similar	similar
Chlorophyll per dry mass	low	high
Chlorophyll *a*/*b* ratio	high	low
Light-harvesting complex per area	low	high
Electron transport components per area	high	low
Coupling factor (ATPase) per area	high	low
Rubisco per area	high	low
Nitrogen per area	high	low
Xanthophylls per area	high	low
Gas exchange		
Photosynthetic capacity per area	high	low
Dark respiration per area	high	low
Photosynthetic capacity per dry mass	similar	similar
Dark respiration per dry mass	similar	similar
Carboxylation capacity per area	high	low
Electron transport capacity per area	high	low
Quantum yield	similar	similar
Curvature of light-response curve	gradual	acute

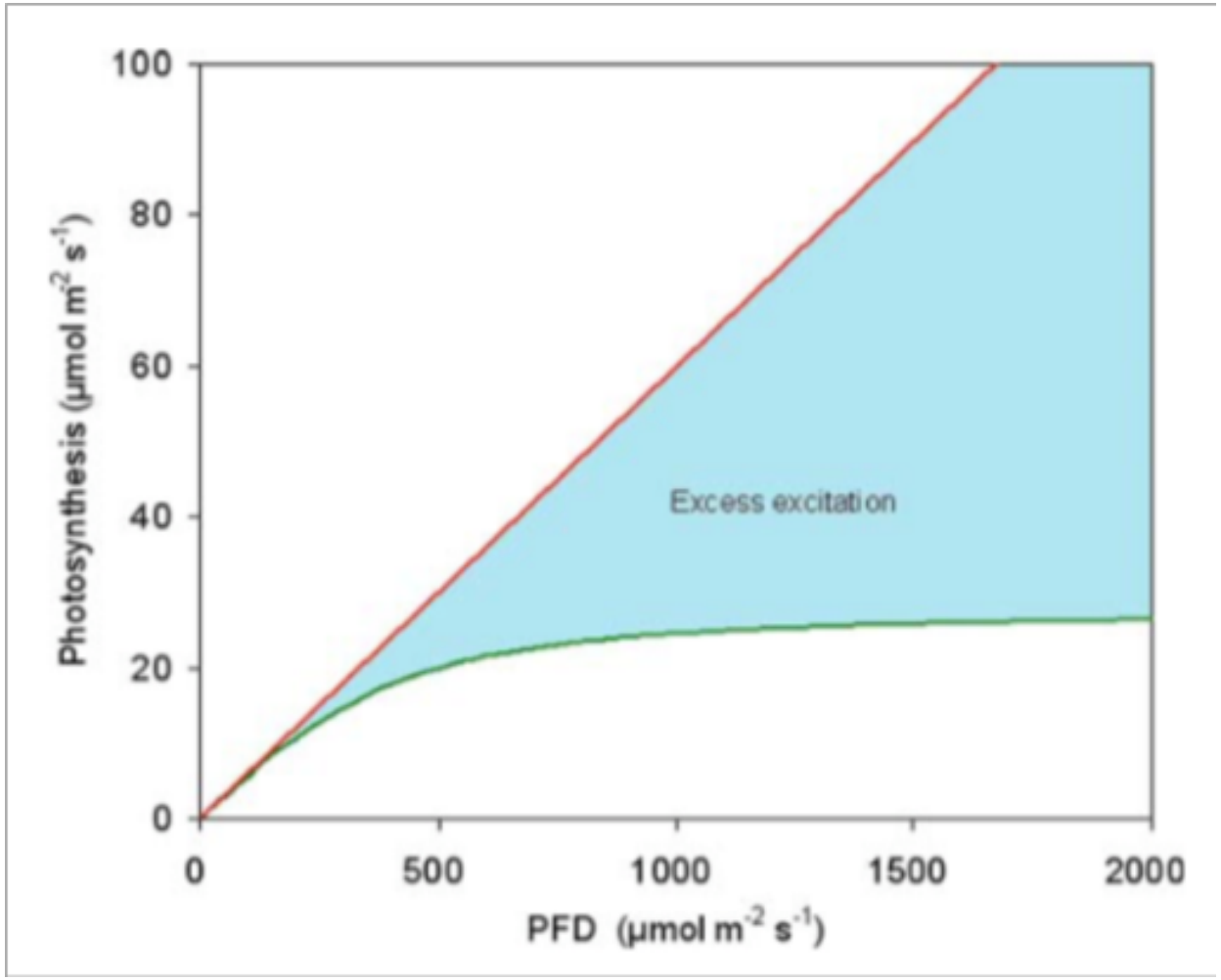
Photoinhibition

Photoinhibition



Too much excitement!

Photoinhibition



Excess energy is not dissipated, leading to the creating of ROS that damage photosynthetic complexes, reducing photosynthesis

Research

New Phytologist

Terrestrial biosphere models underestimate photosynthetic capacity and CO_2 assimilation in the Arctic

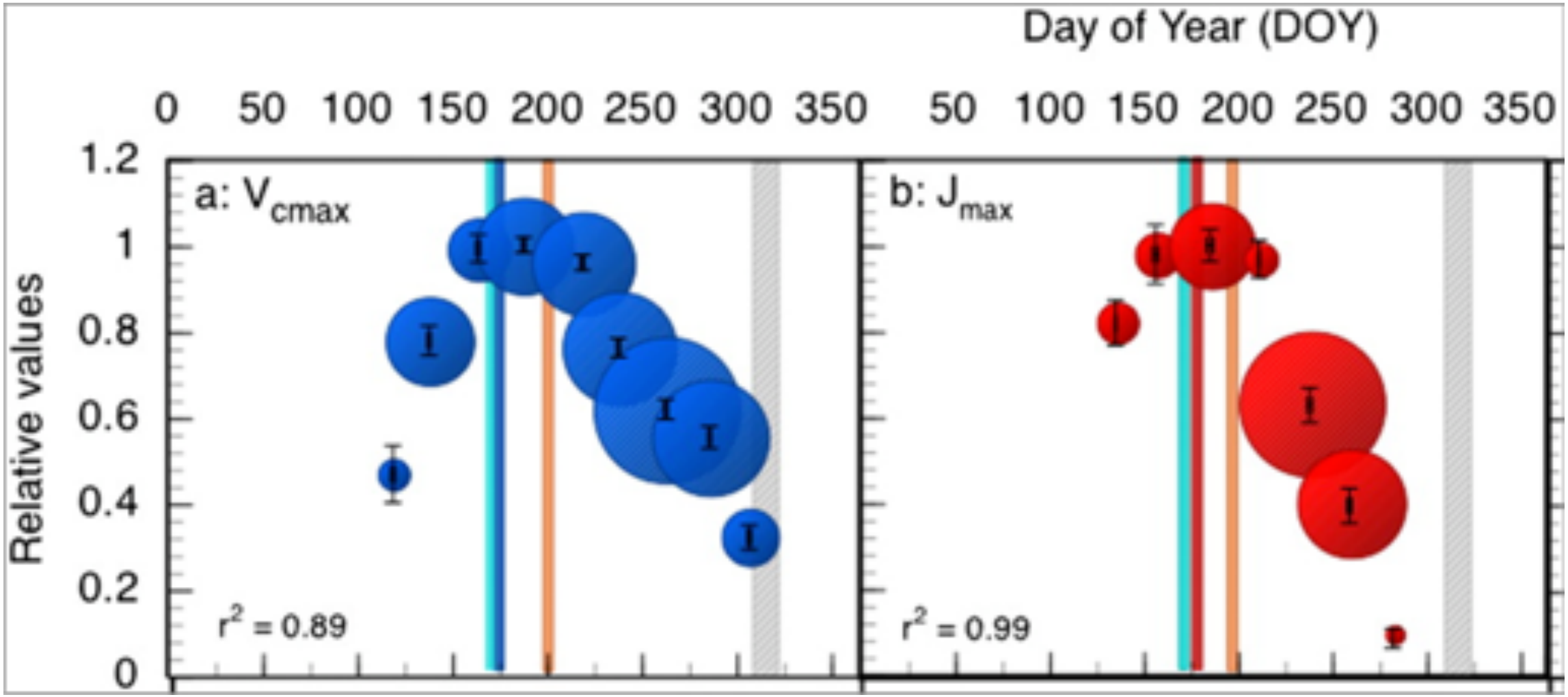
Alistair Rogers[1], Shawn P. Serbin[1], Kim S. Ely[1], Victoria L. Sloan[2] and Stan D. Wullschleger[2]

[1]Environmental and Climate Sciences Department, Brookhaven National Laboratory, Upton, NY 11973-5000, USA; [2]Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, TN 37831-6301, USA

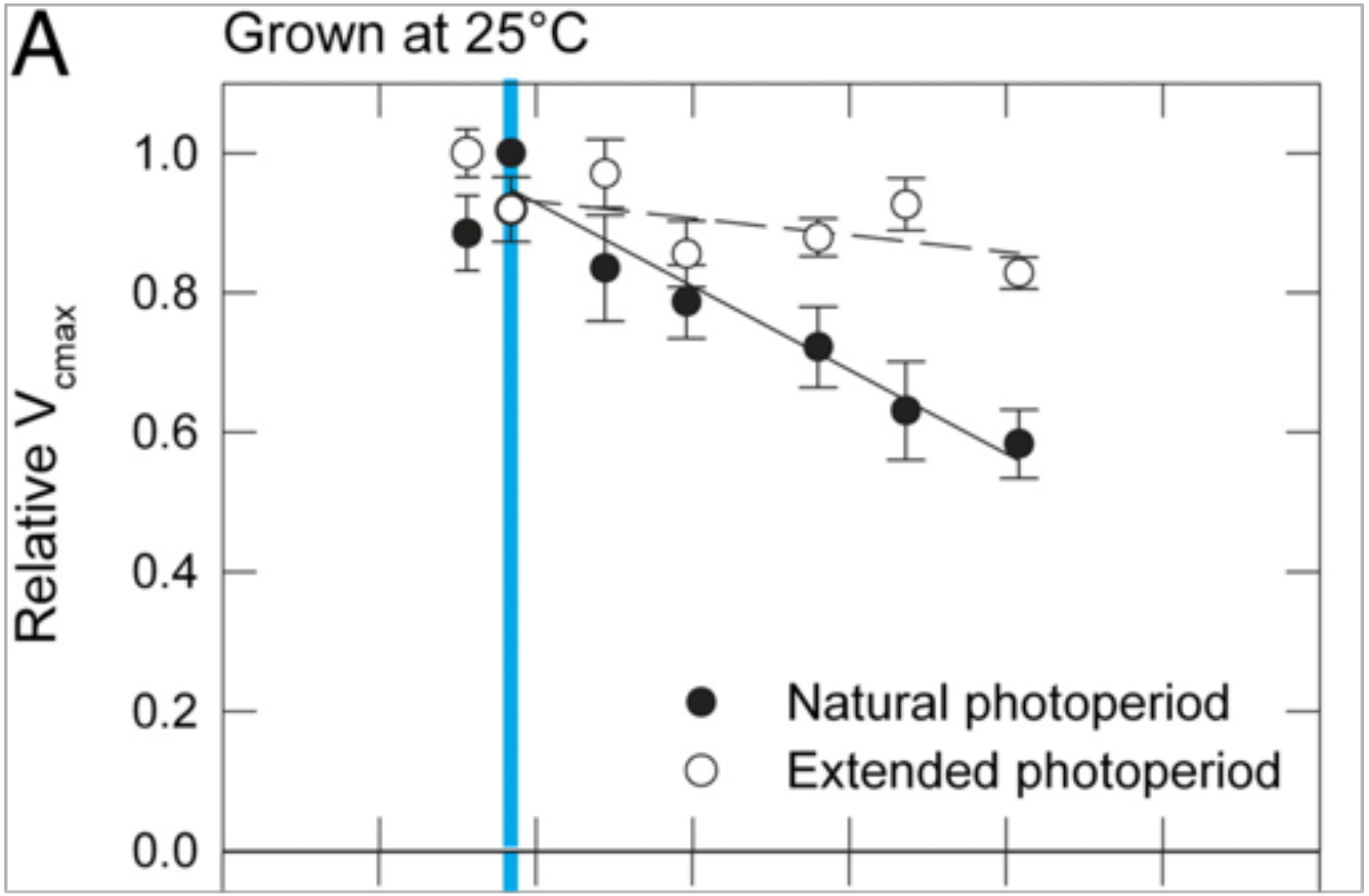
Translation: lots of Rubisco in the arctic!!
Why might this be the case?

How does light availability to plants vary over space and time?

Seasons



Bauerle et al. (2012)

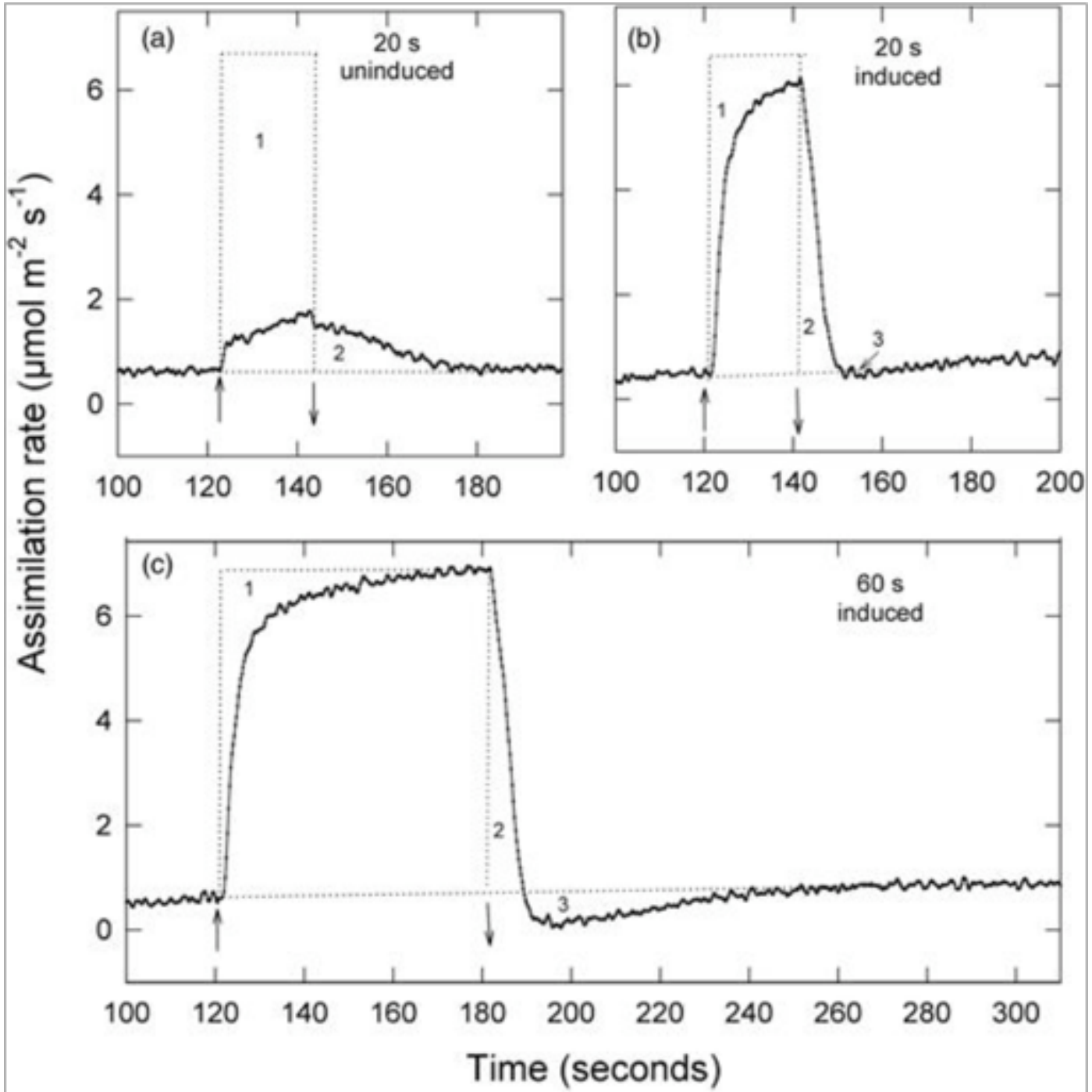


Bauerle et al. (2012)

Sunflecks

Sunflecks

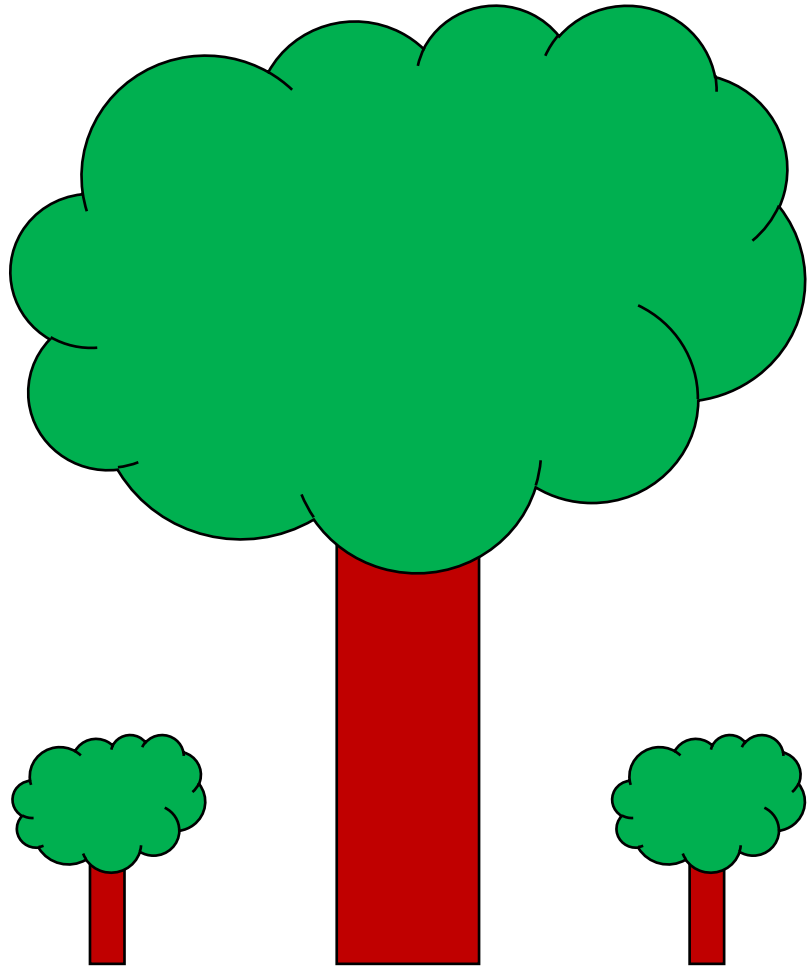
Sunflecks



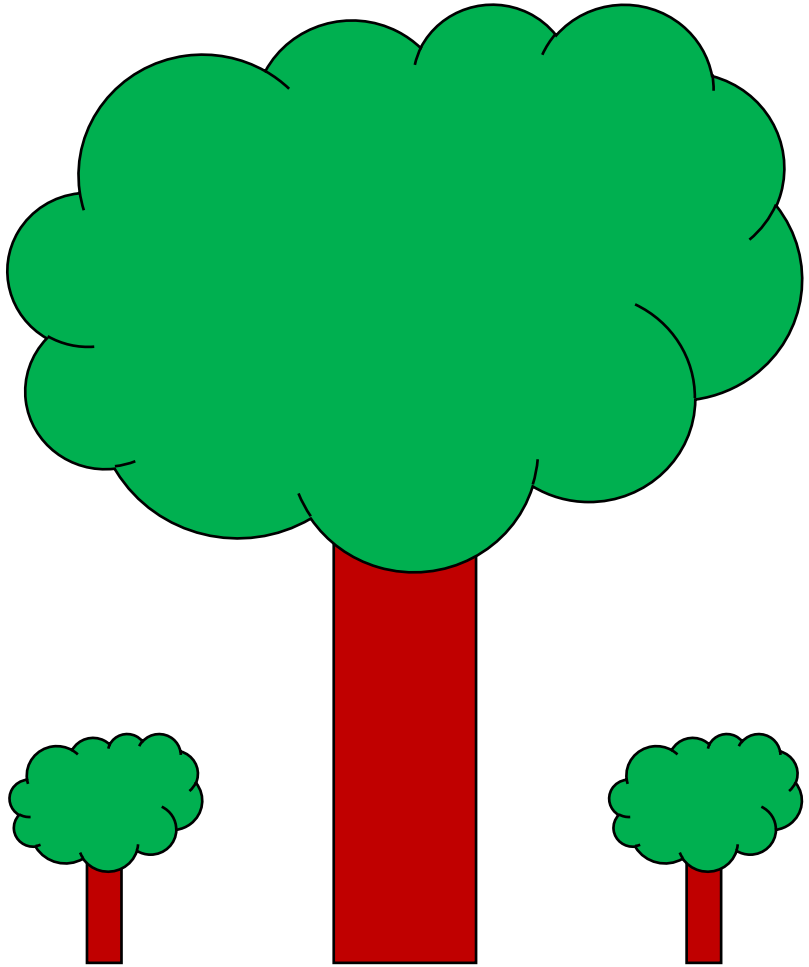
Way & Pearcy (2012)

Light competition

Light is the most strongly fought-after aboveground resource



So why aren’t plants taller?



Can an individual plant be sun and shade adapted?

Activity: how would photosynthesis, nitrogen, and LMA differ within a plant canopy?

Develop a hypothesis to answer how each trait would change within an individual's canopy

CANTRIP database

- https://github.com/trevorkeenan/traitPlasticity
- 200 species
- Data from top and bottom of canopy