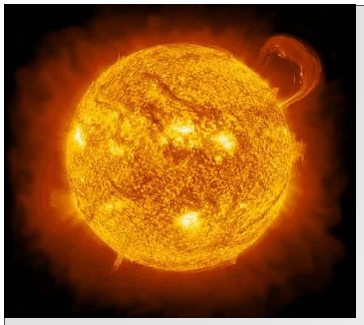
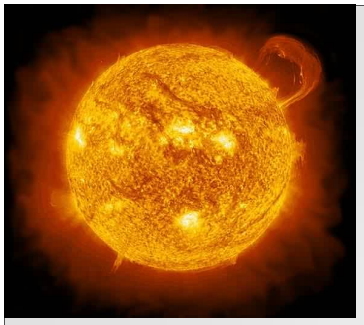


Photosynthesis as the basis of plant productivity

Imre Vass

Biological Research Centre, HAS, Szeged, Hungary



Photosynthetic light energy conversion:

Primary energy source of the biosphere

$2H_2O$

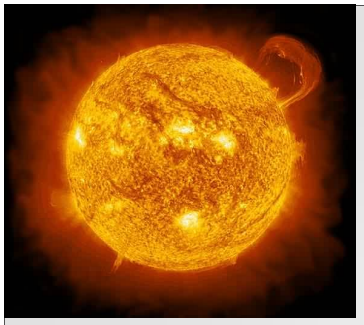
$4H^+ + O_2$

Atmospheric oxygen

CO_2

CH_2O

Atmospheric carbon dioxide



Utilization of stored solar energy

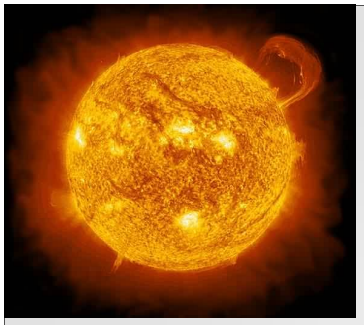
O_2 ← ← → H_2

Biomass → Fossile fuels

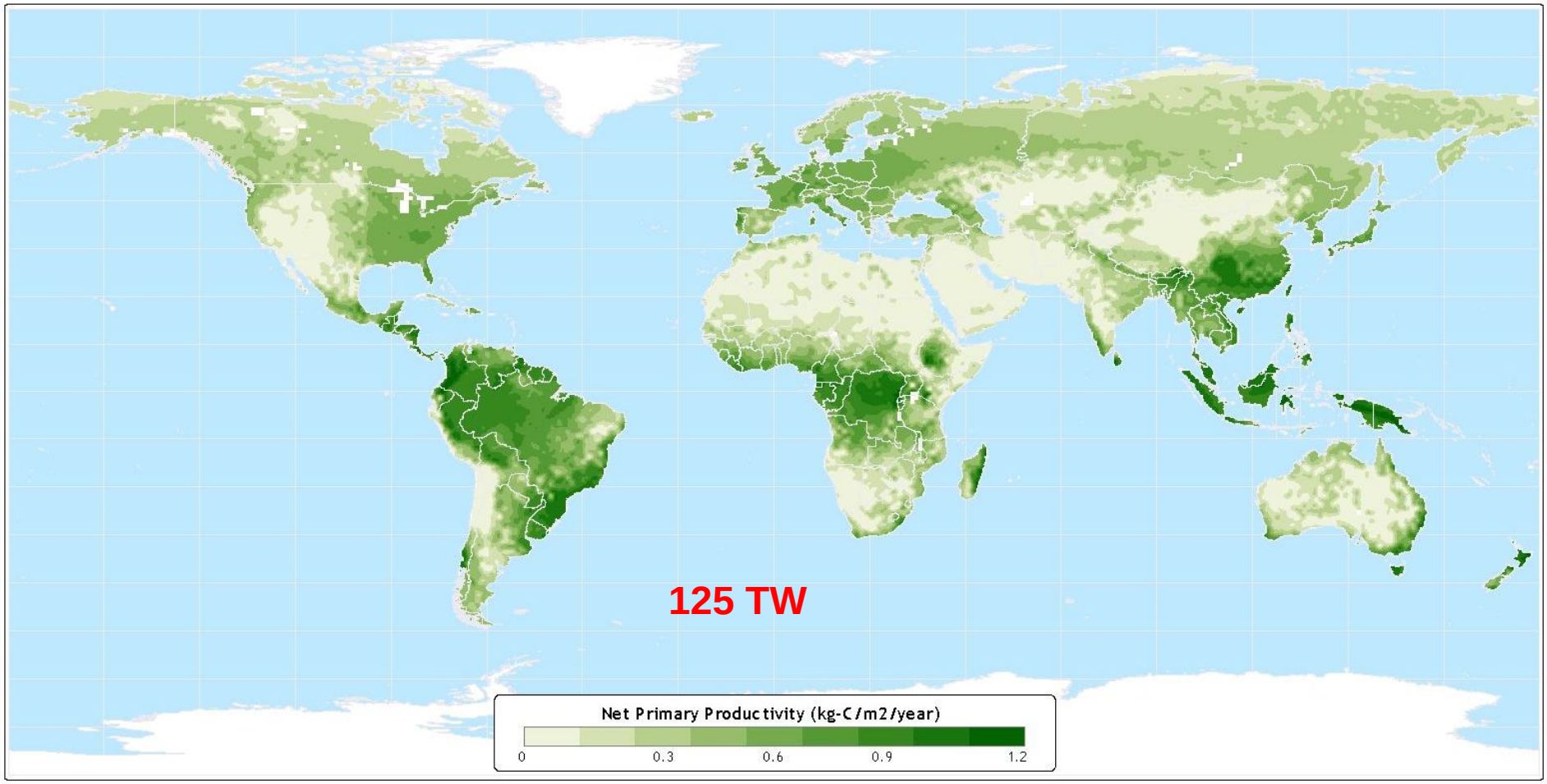
Food

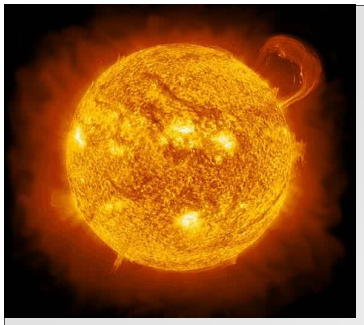
Raw material

Energy rich metabolites → Biofuels (CO_2 neutral)



Photosynthesis is a global phenomenon





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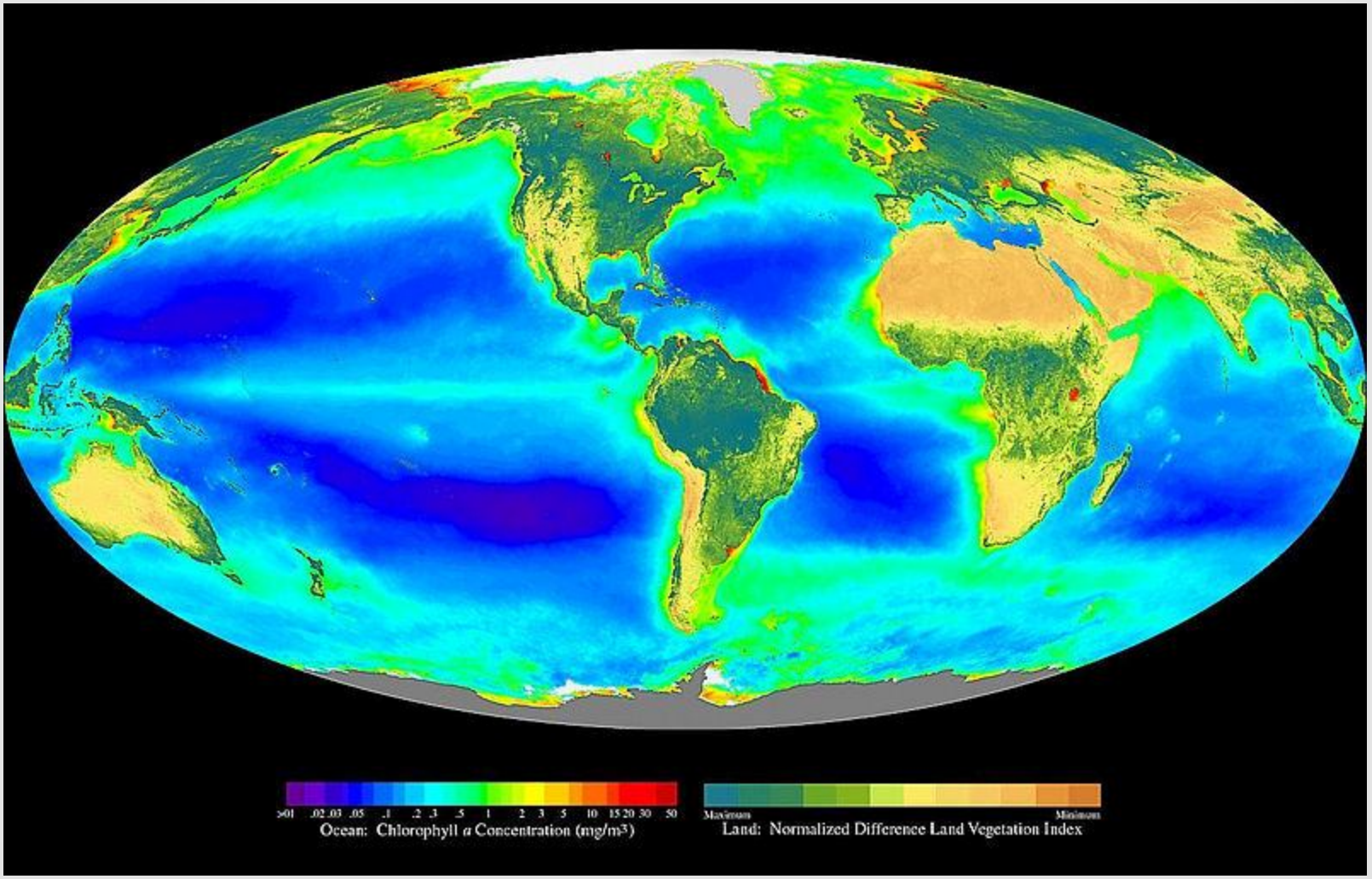
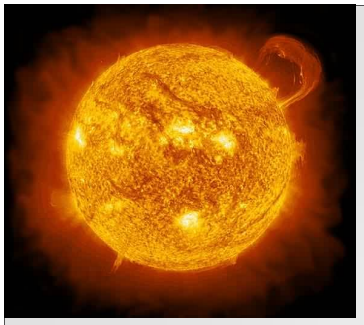
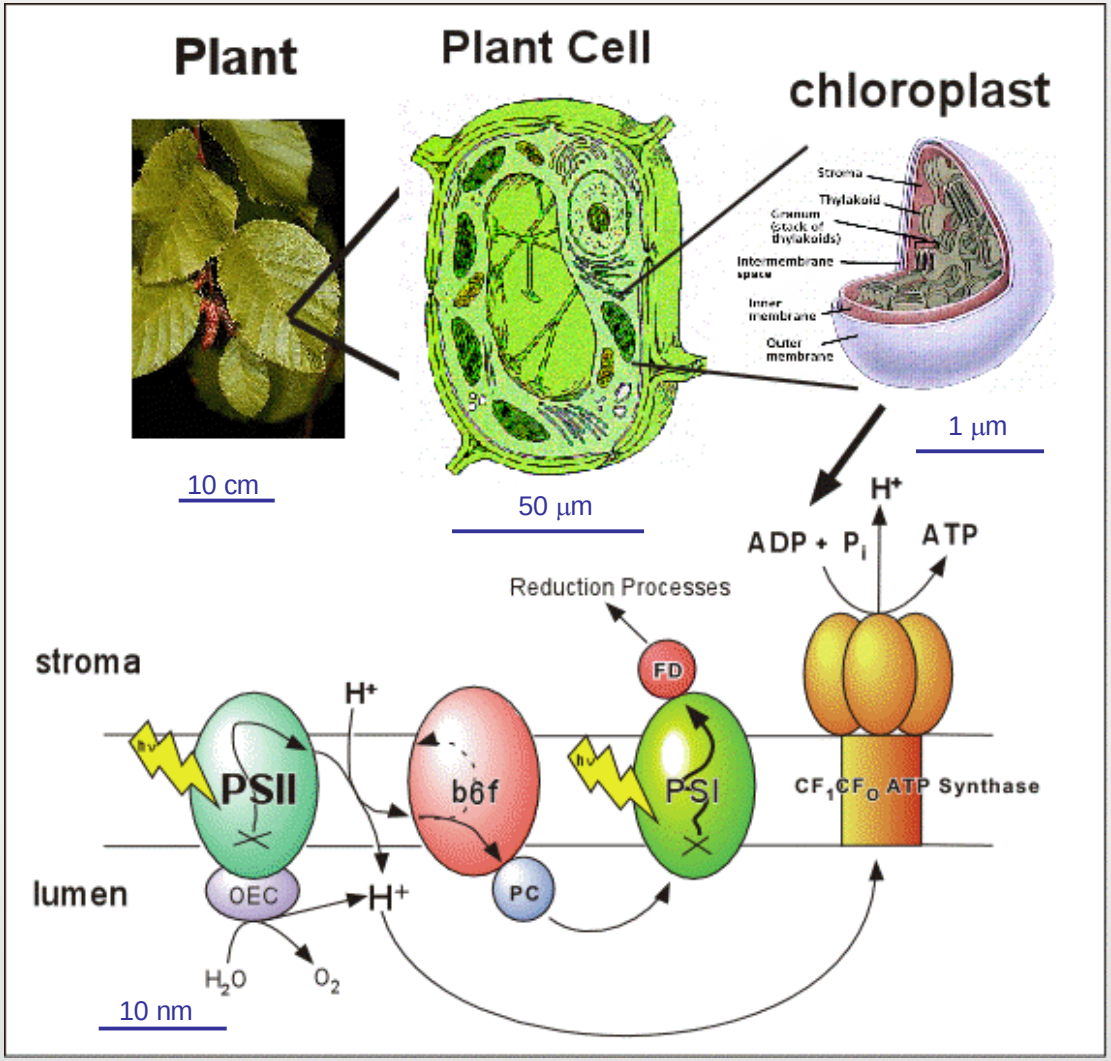
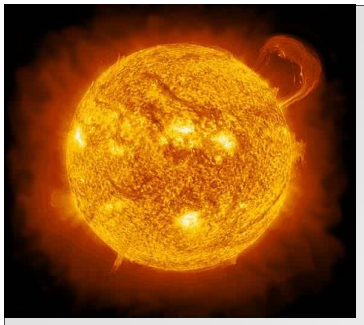


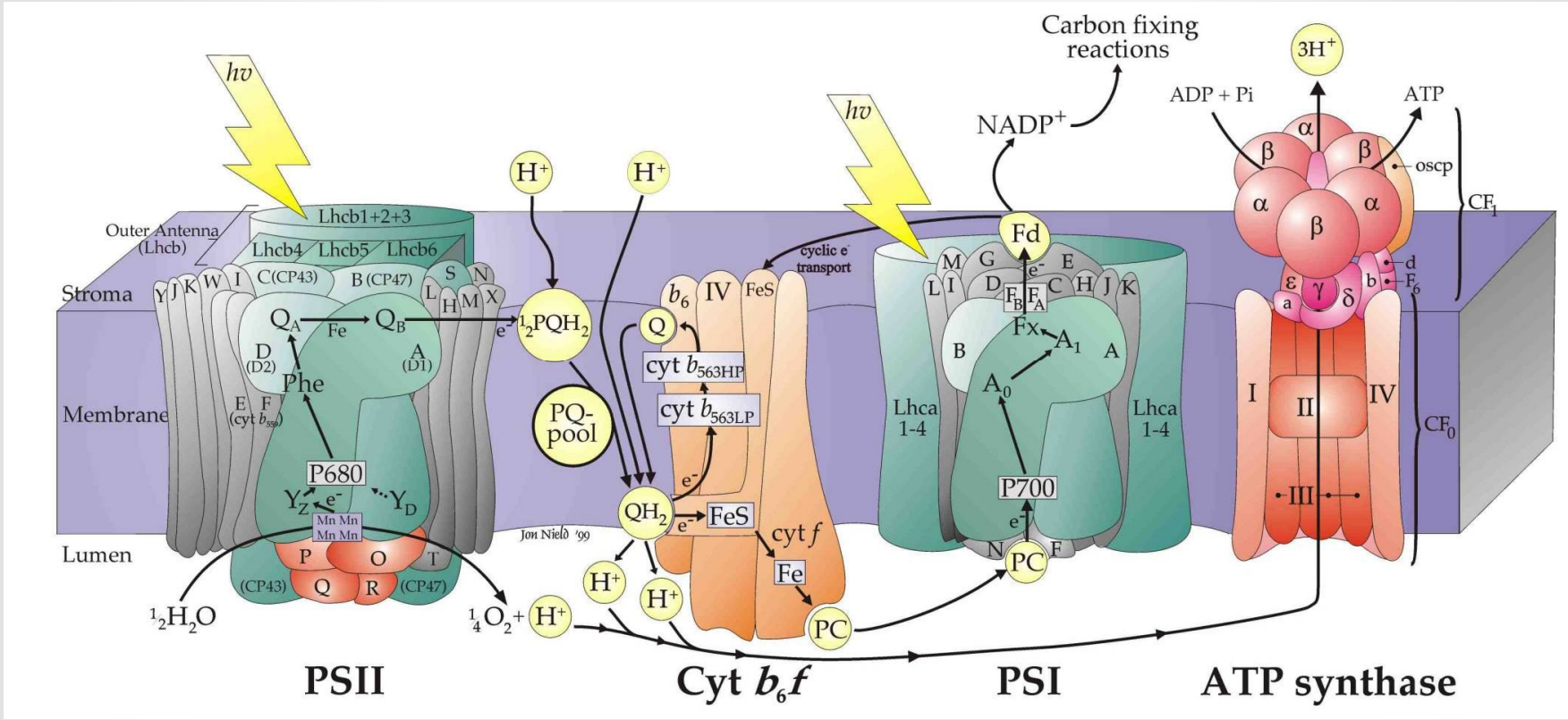


The main components of the photosynthetic apparatus

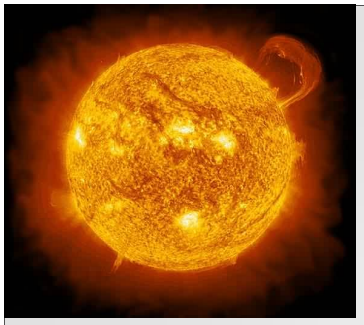




Energy converting complexes of the tylakoid membrane



Water oxidation **Proton pumping** **NADP+ reduction** **ATP synthesis**

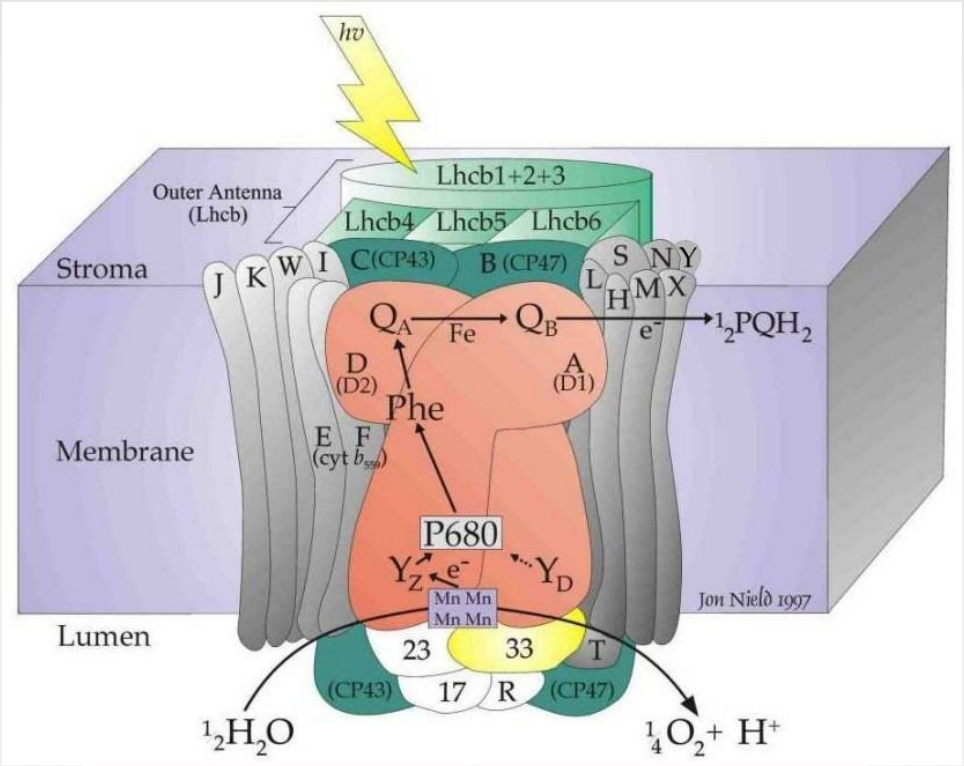


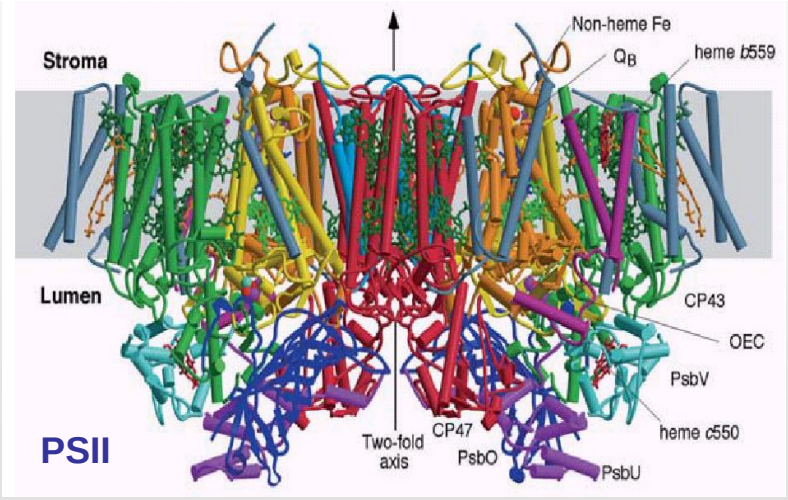
Photosystem II

Water oxidation

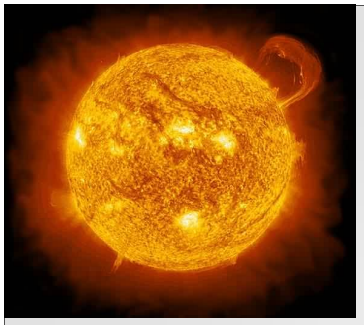
↓

PQ reduction

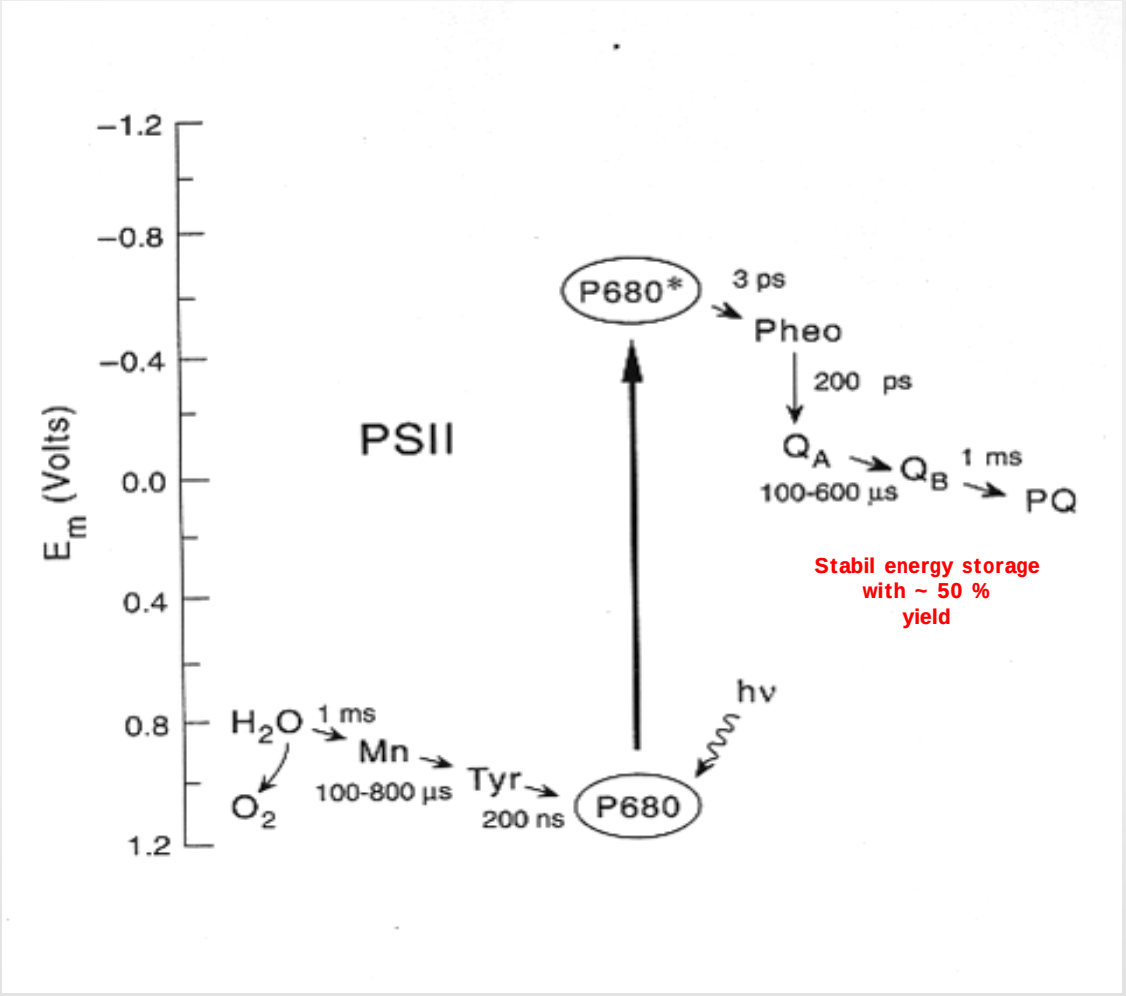


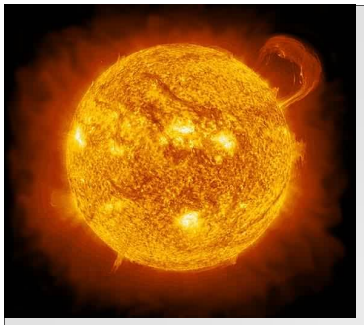


Strongly oxidizing



Photosystem II electron transport



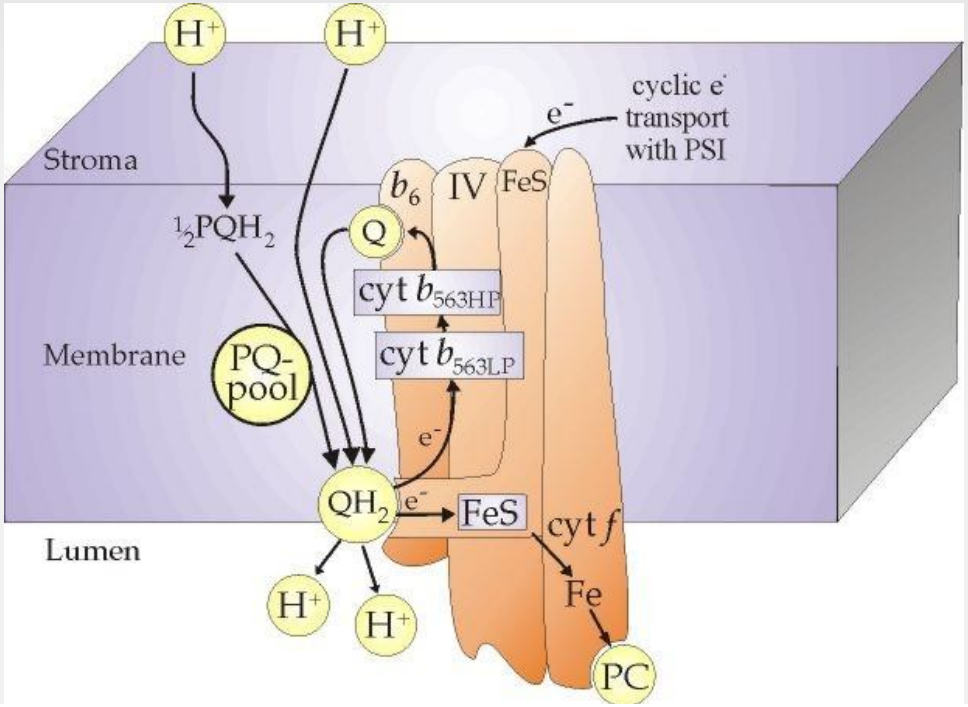


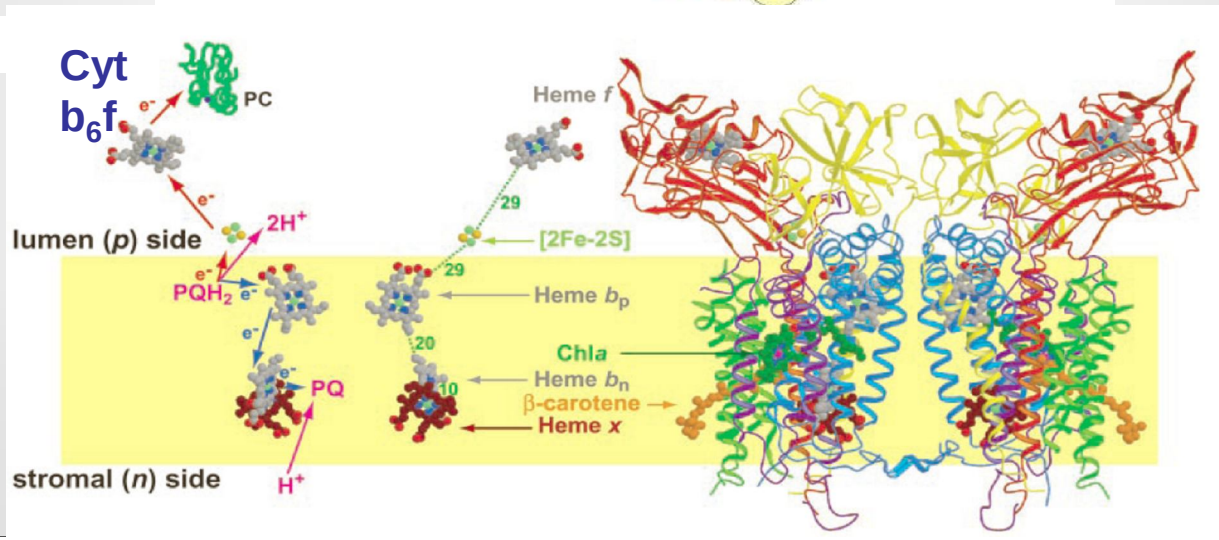
Cytochrome b_6f complex

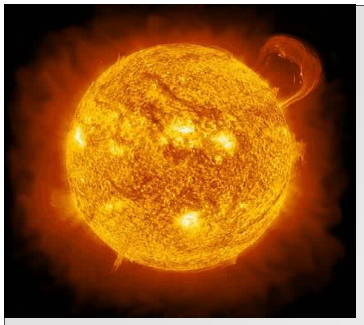
PQH2/PQ
Oxido-reduction

↓

Proton pumping

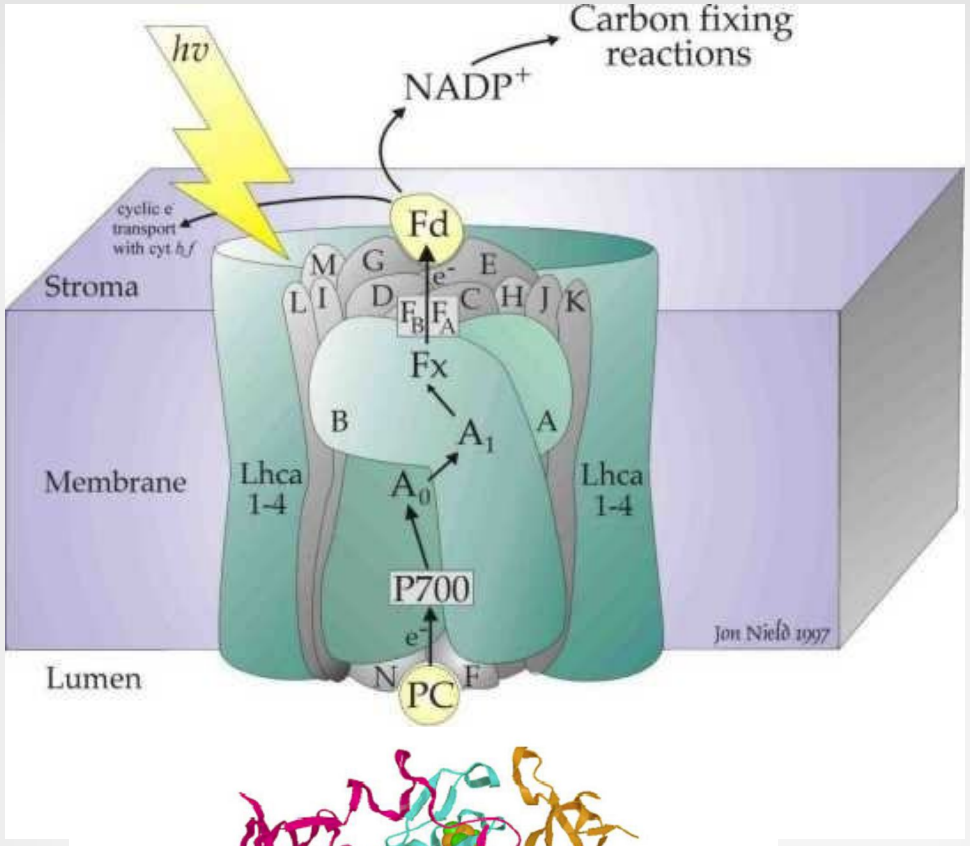


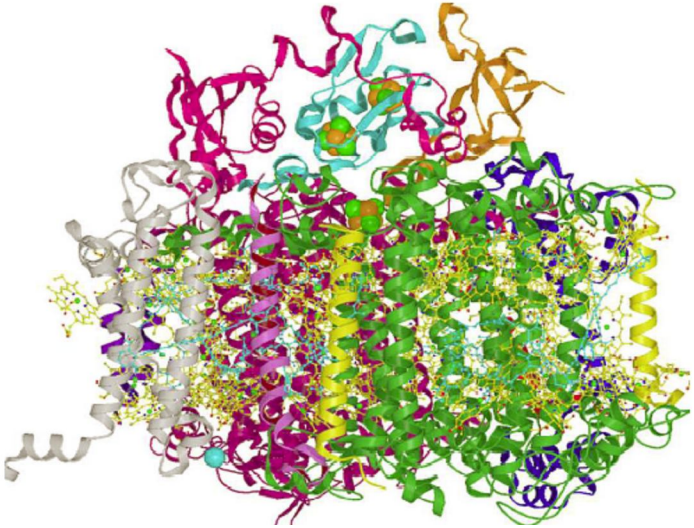




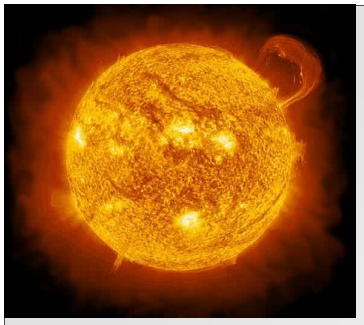
Photosystem I

NADP+ reduction



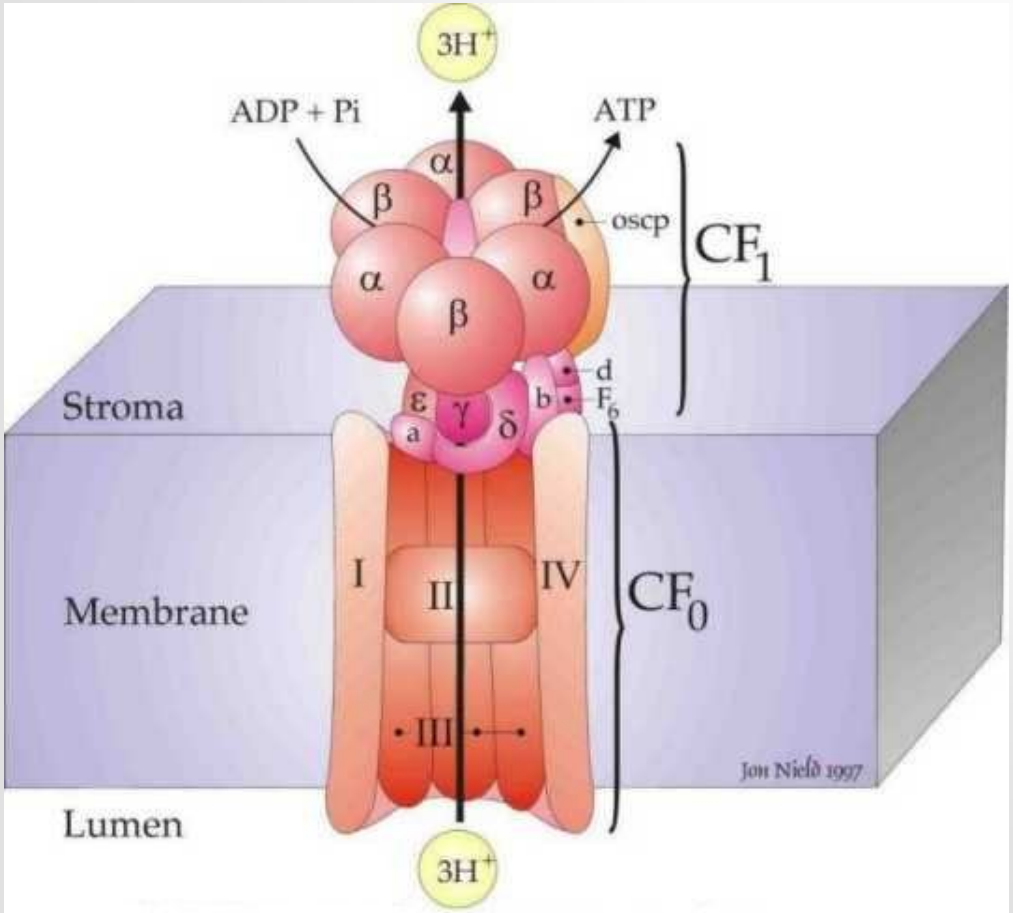


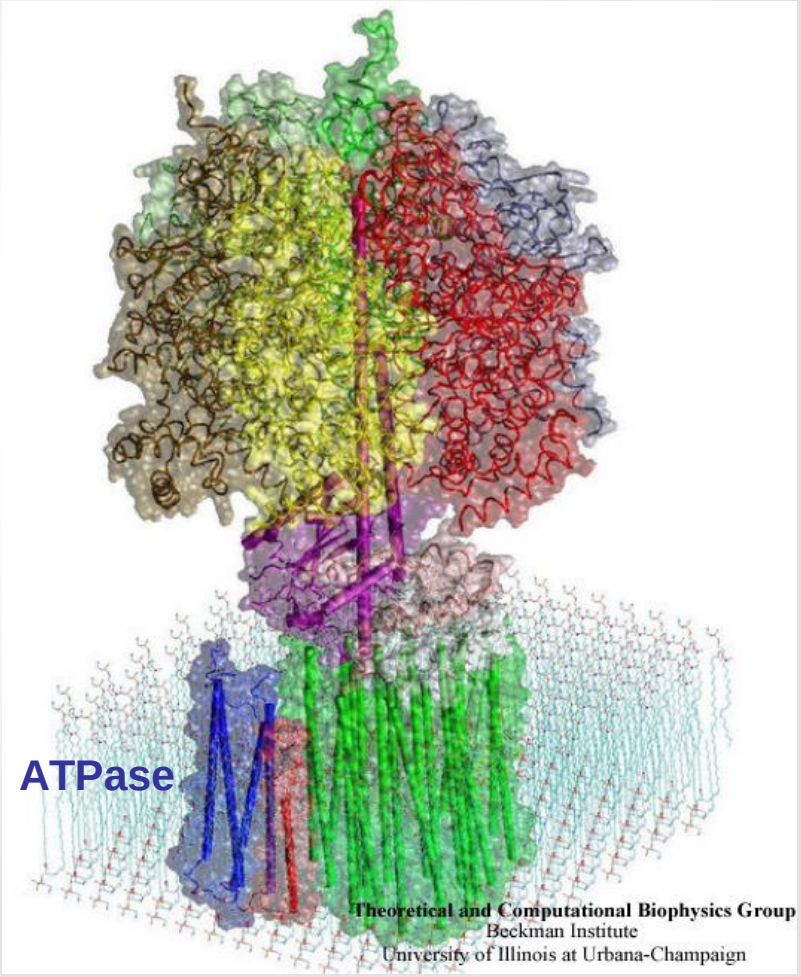
Strongly reducing

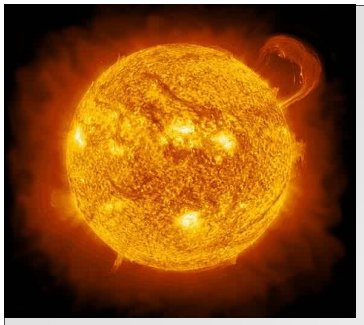


ATP synthase

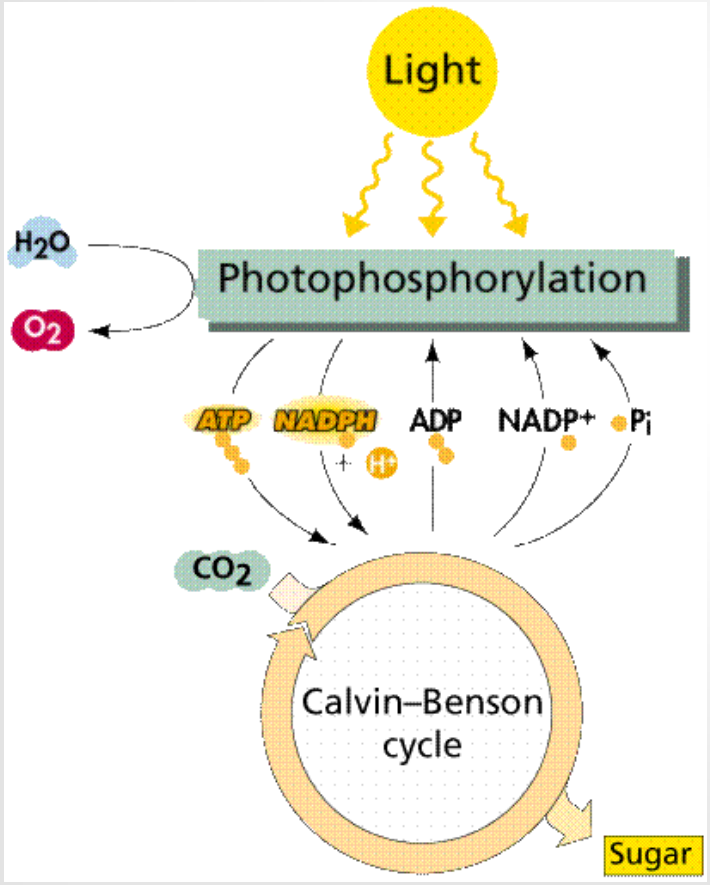
ATP synthesis by proton gradient

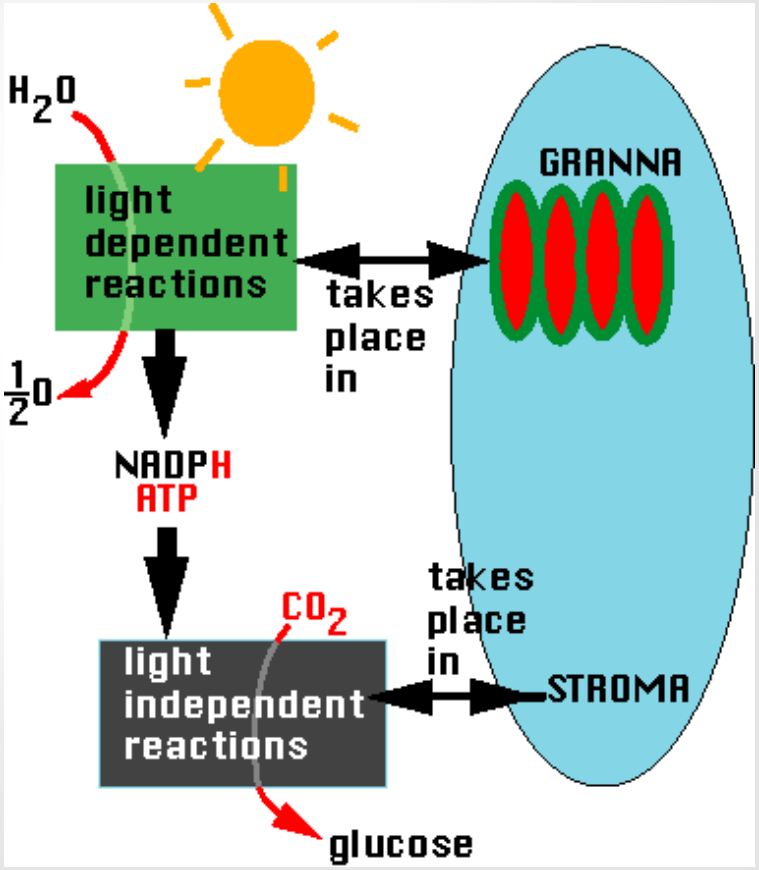


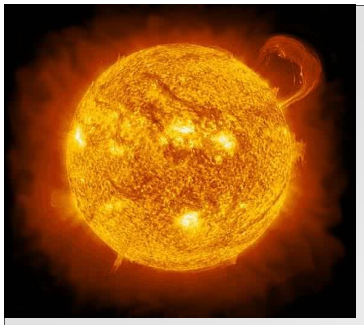




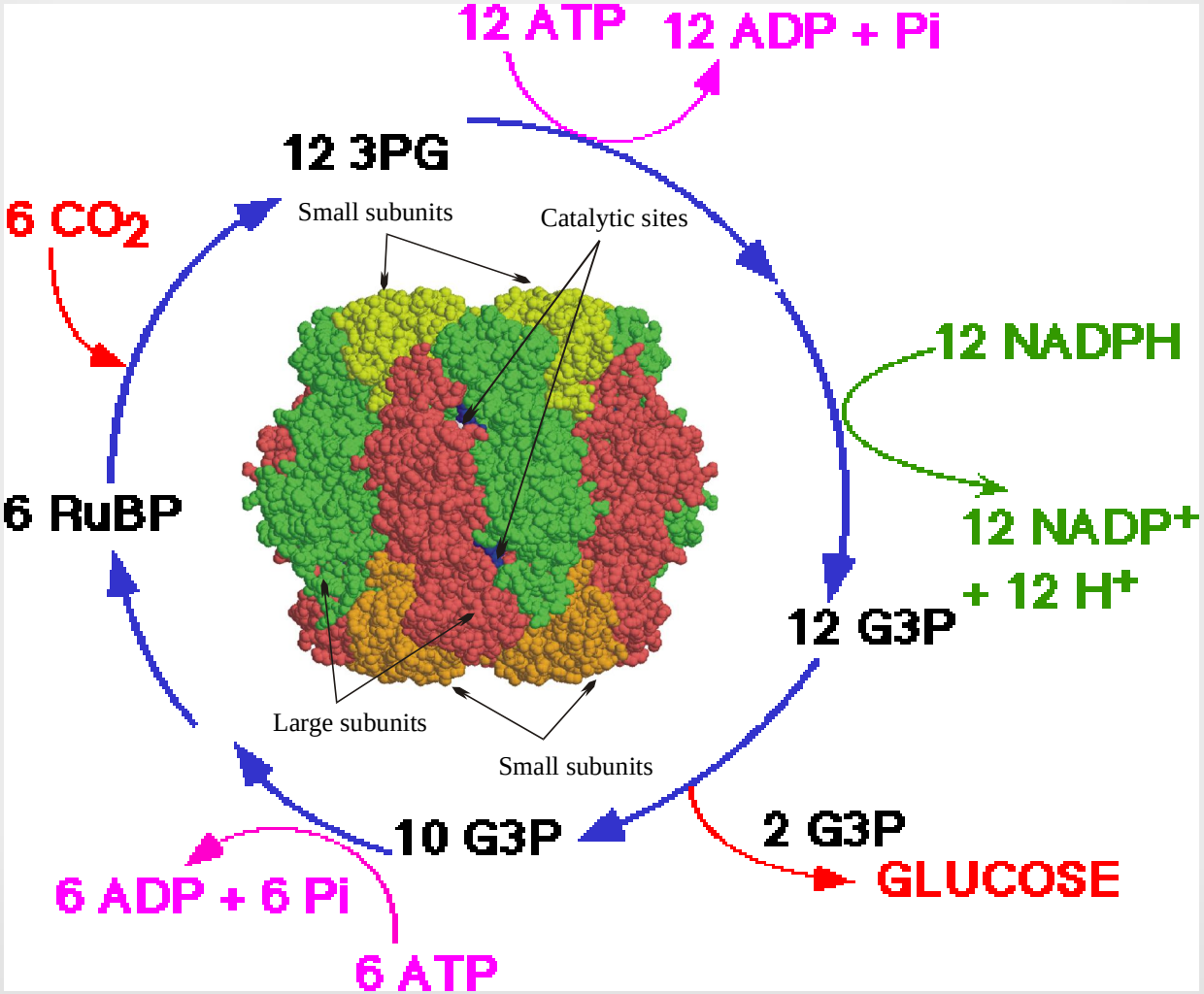
Light- and dark reactions of photosynthesis

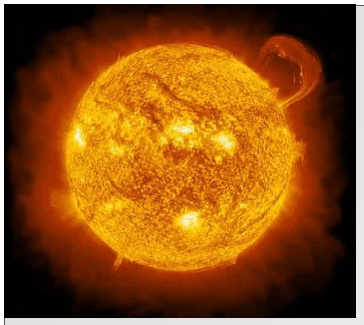




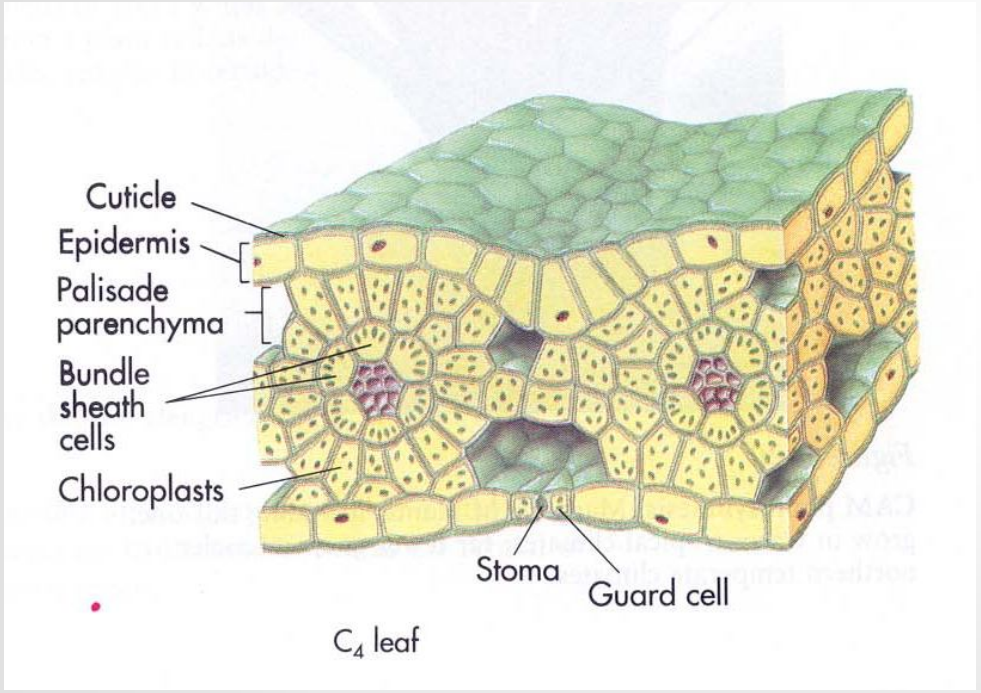


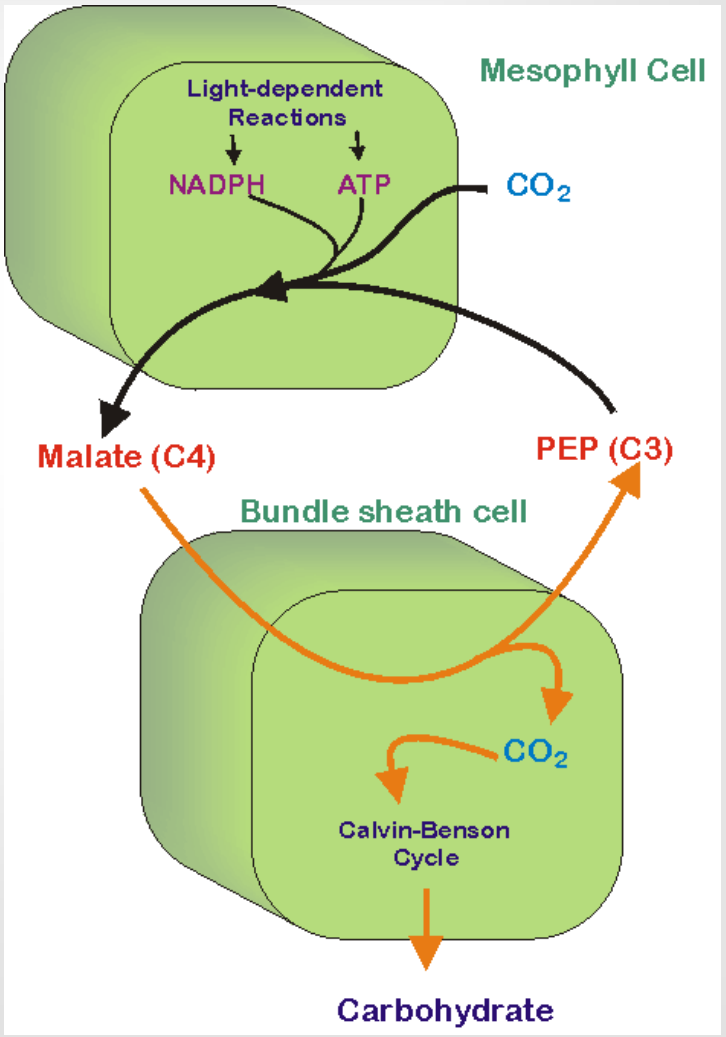
Calvin-Bensson cycle



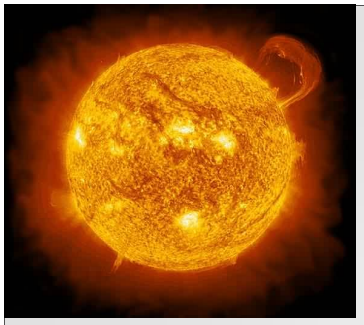


C4 pathway of photosynthesis

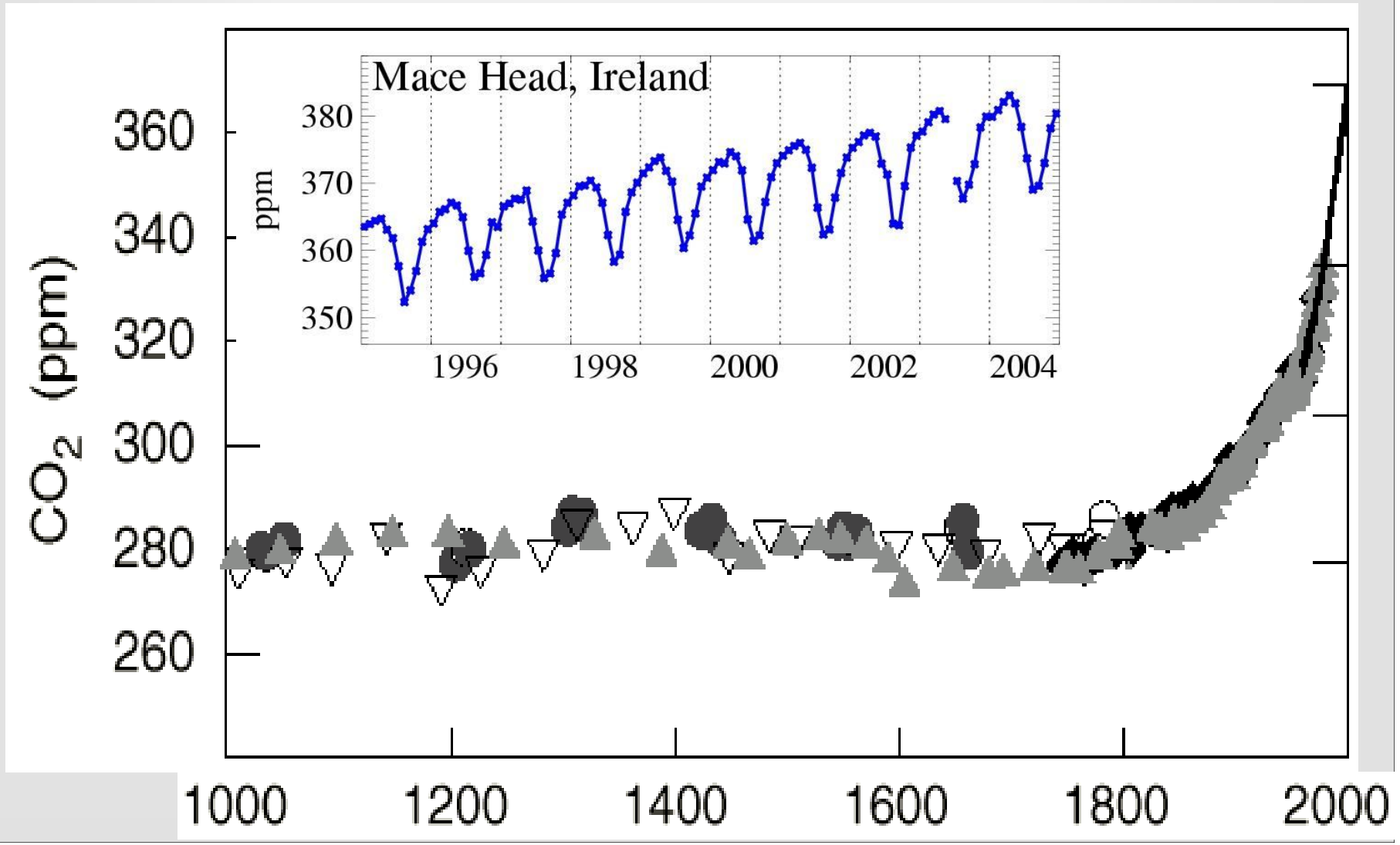


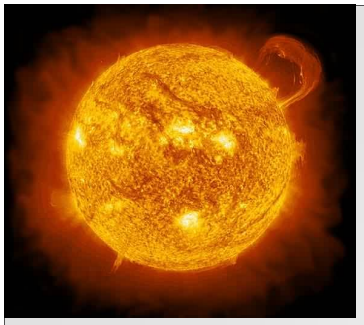


Maize
Sugar cane



Global CO_2 effect



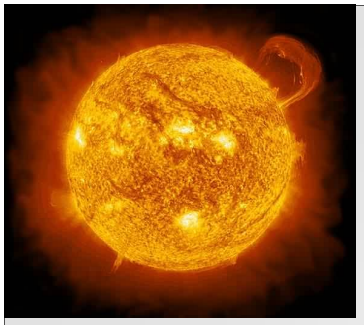


How efficient is photosynthesis?

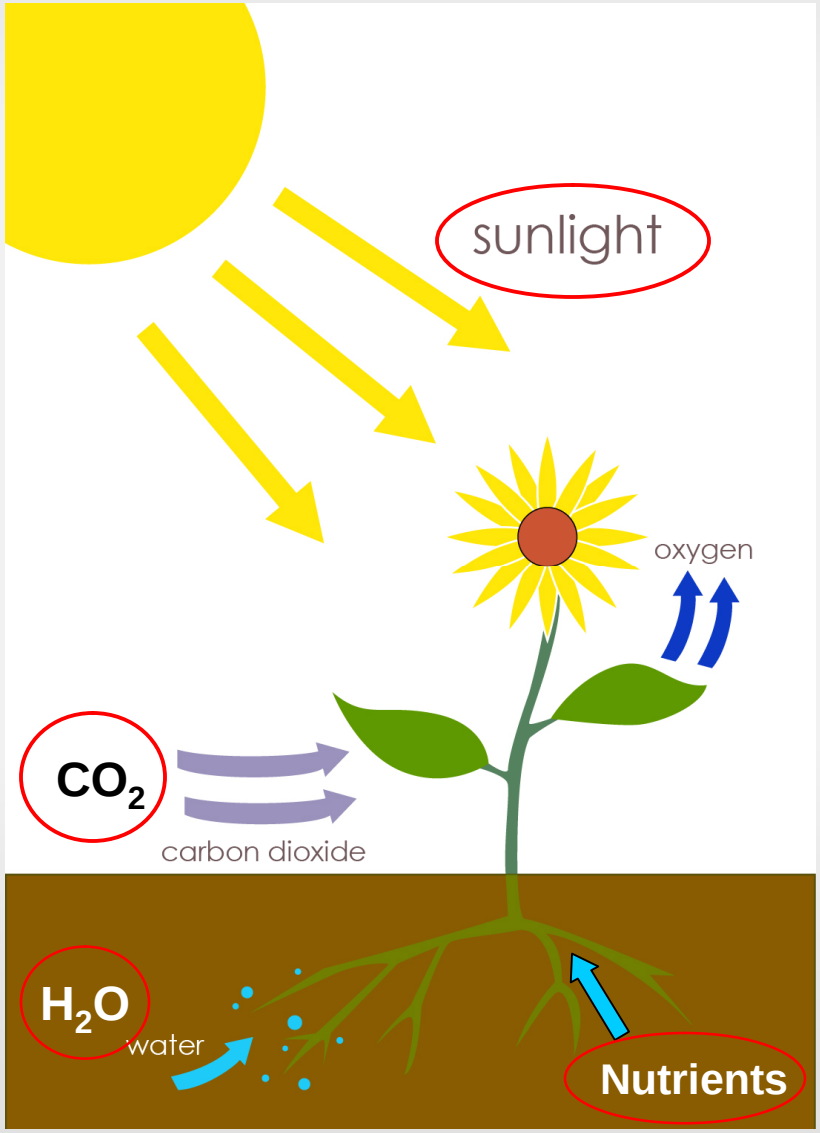
Primary charge separation	≈ 100 %
Energy storage in PSII	≈ 50 - 90 % (30 – 55 %)
CO_2 fixation	≈ 25-30 % (organic material)
Cyanobacteria, lab condts.	≈ 9 % (biomass)
Whole plant, yearly average	≈ 1 – 2 % (sugar cane)

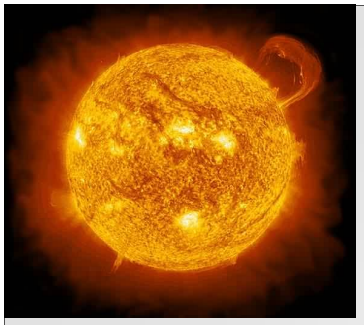
The main causes of loss:

- Thermodynamics
- Complex life phenomena
  (optimization for growth, adaptation, protection)
- Environmental stress effects
  (water, temperature, light, salt, heavy metals, pests)

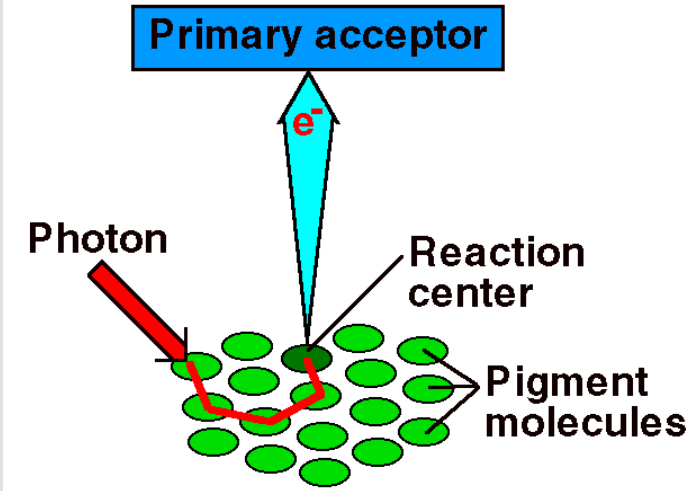


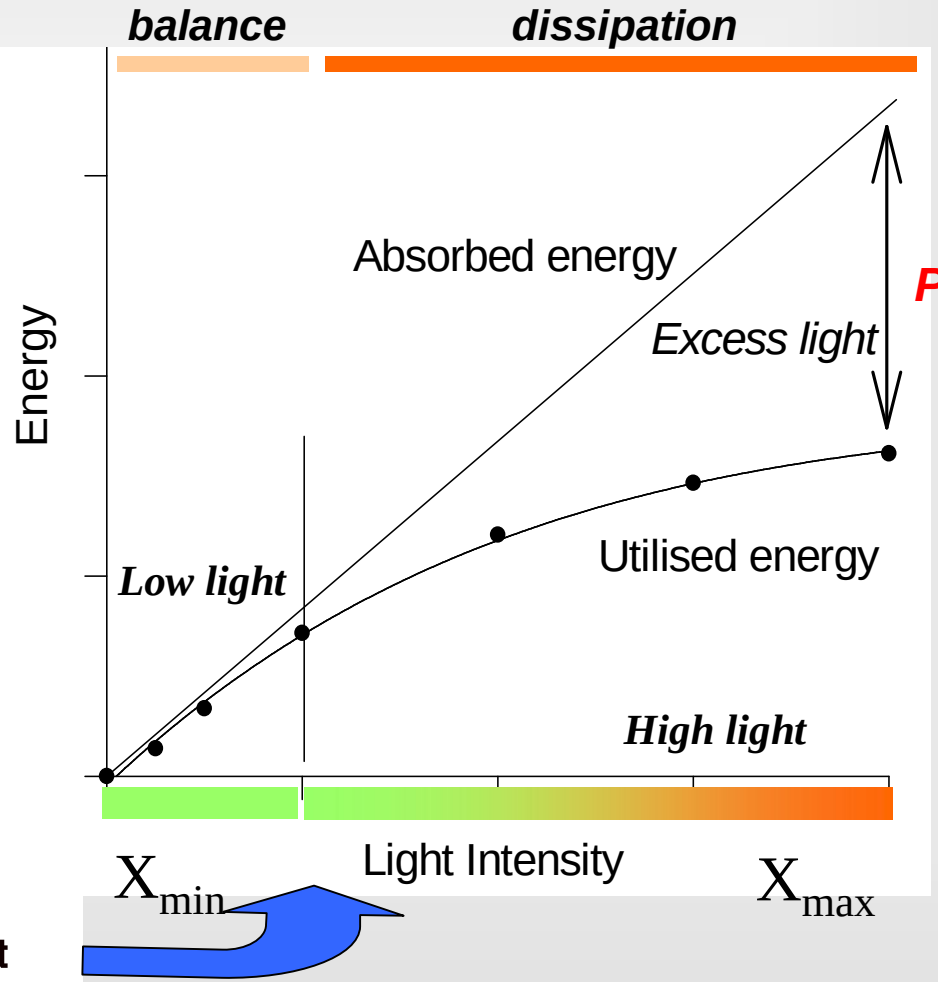
Abiotic limiting factors of plant production



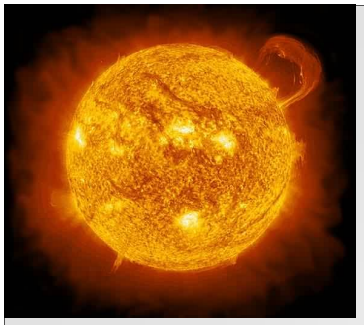


Light as a limiting factor of photosynthesis: Too little, or too much of a good thing





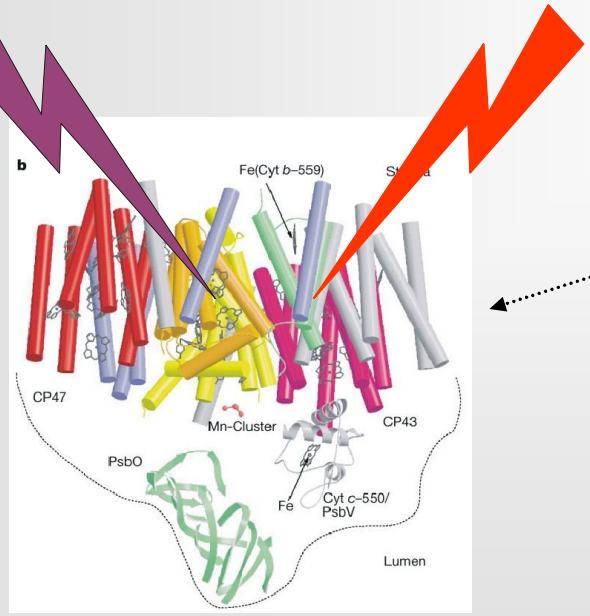
Photodamage

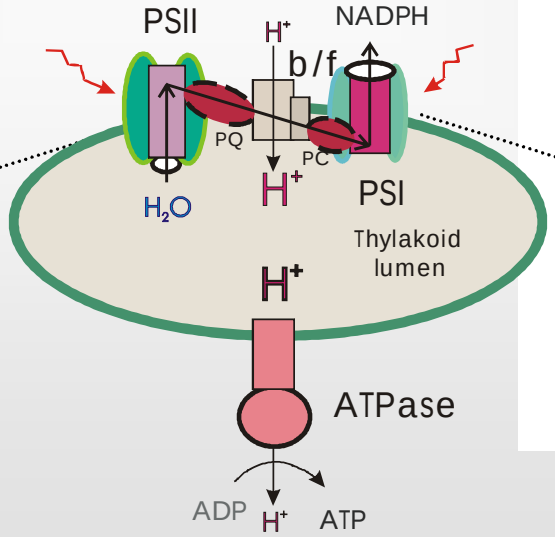


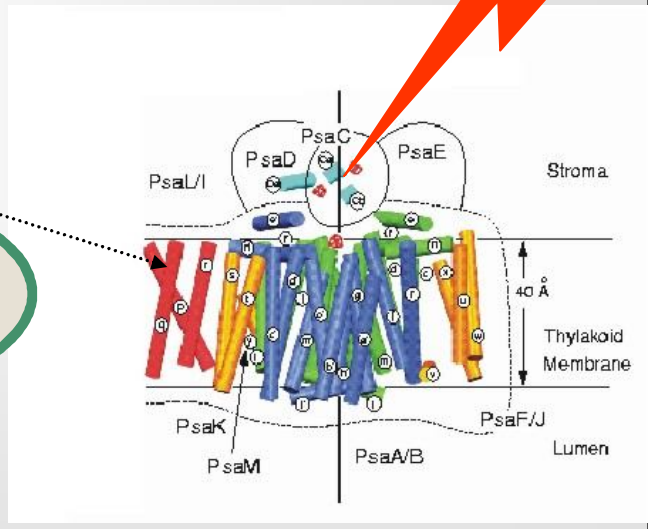
Light damage of the photosynthetic apparatus

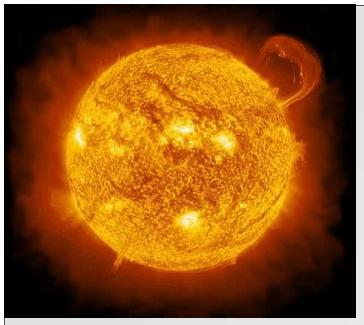
PSII is highly light sensitive.
Survives
≈10^8 hits by visible photons
≈10^5 - 10^6 hits by UV photons
Has to be replaced in every 30 min

PSI is moderately light sensitive
Survives
20-50-fold more hits than PSII
Not protected by repair

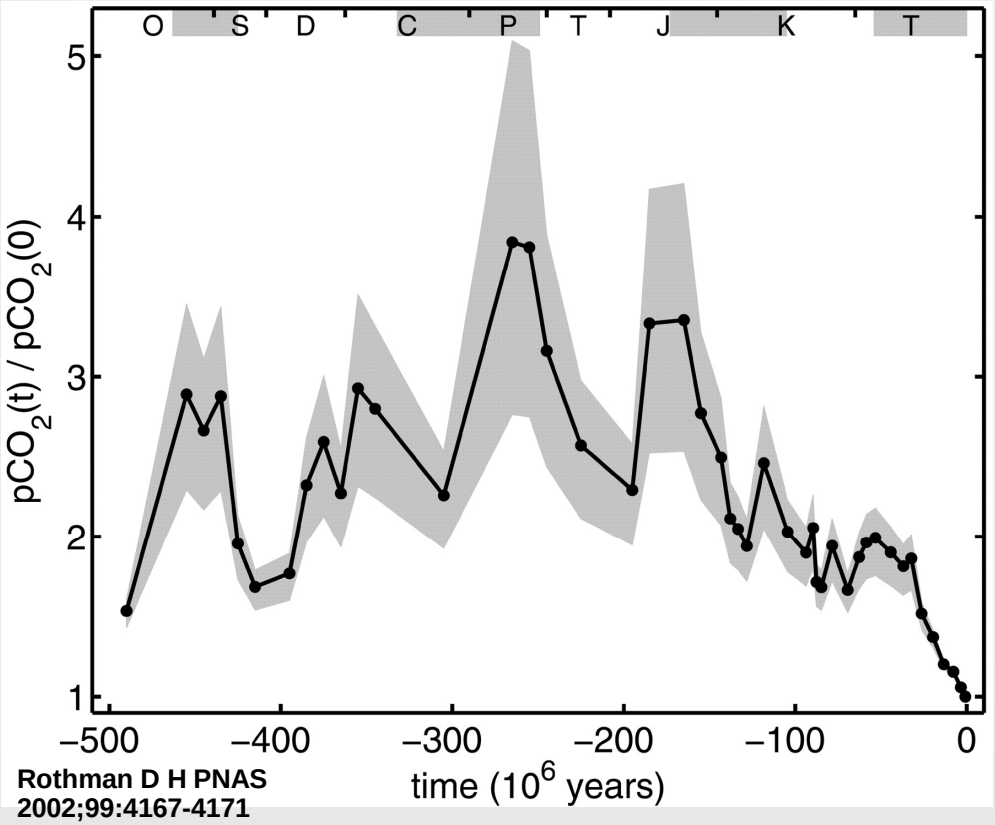




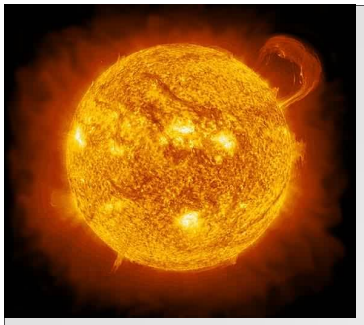




Abiotic limiting factors of plant production: CO_2



Current CO_2 levels are limiting photosyntetic plant production.
Further increase of atmospheric CO_2 would increase plant productivity especially in C3 plants.



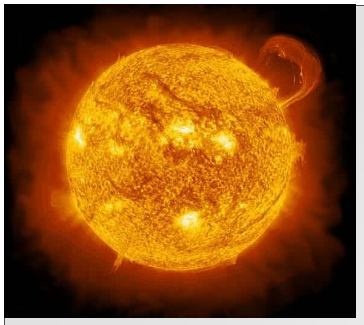
Abiotic limiting factors of plant production: H_2O

Water is a serious limiting factor of plant productivity:

- Final electron donor of photosynthesis
- Required for membrane integrity
- Required for cellular processes

However, different plants show large differences in tolerating water limitation

Characterization of drought tolerance is a major target of plant phenotyping

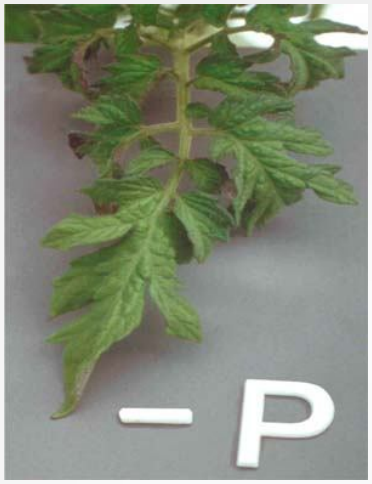


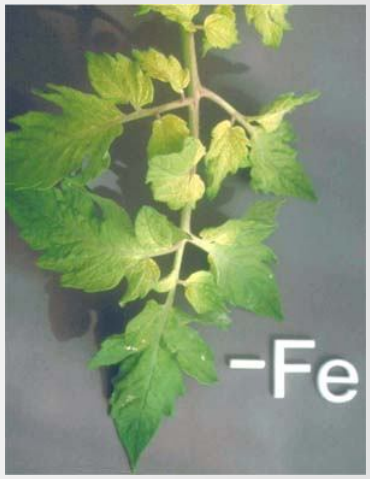
Abiotic limiting factors of plant production: Nutrients

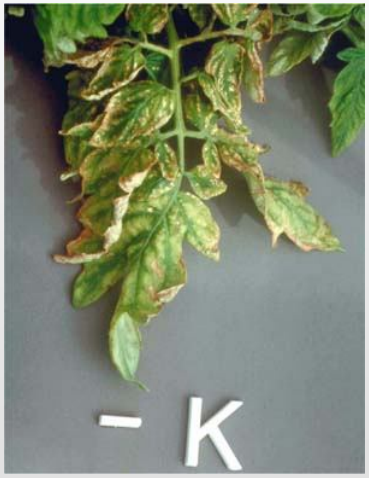
Various nutrients can seriously limit photosynthesis and plant productivity.

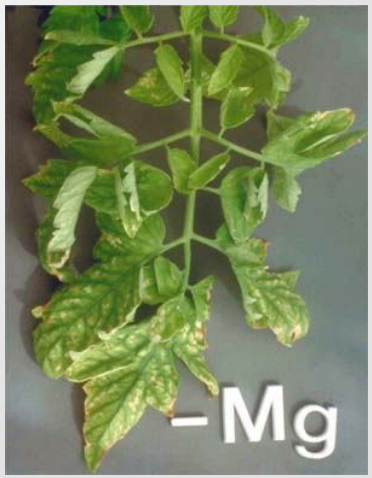
- Required for synthesis of pigments
- Energy converting complxs
- Enzyme activity, etc.

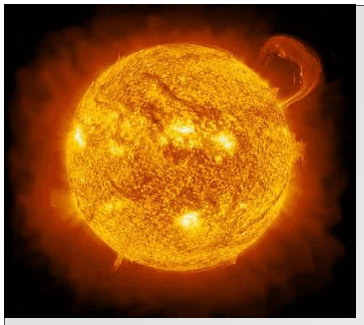
Characterization of the nutrient limitation is an important target of plant phenotyping





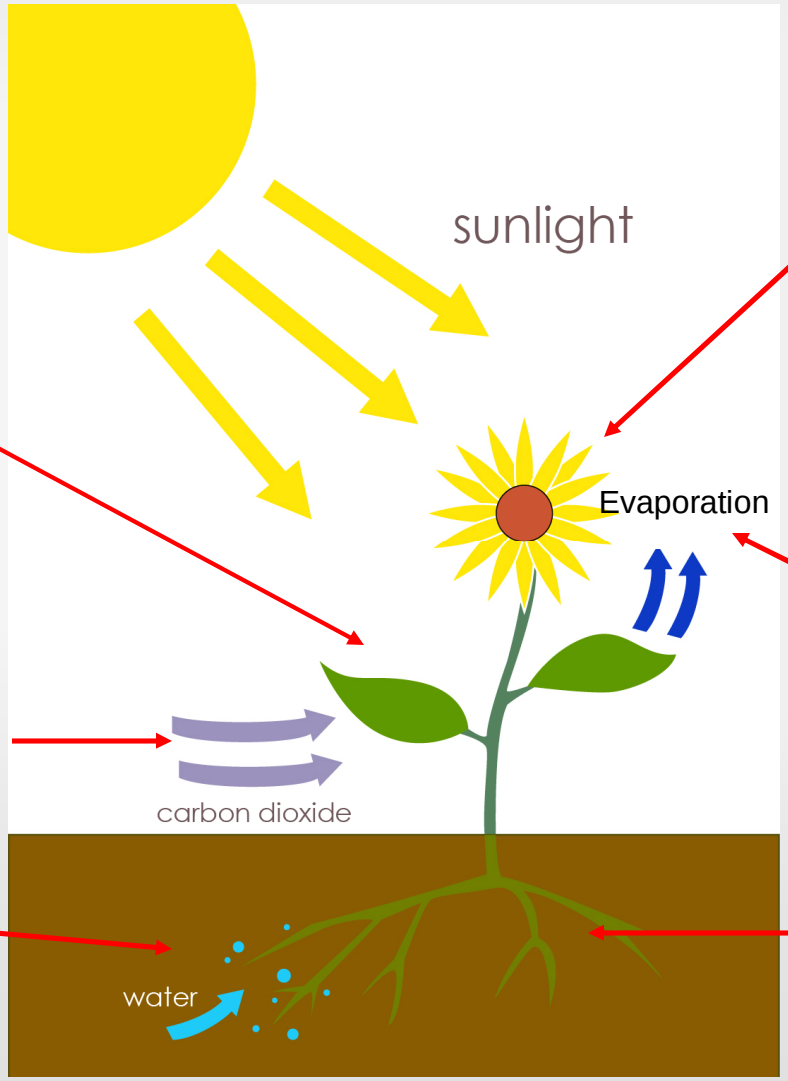






Phenotyping signatures of photosynthetic and other plant functions

Light energy utilization
- Chl fluorescence imaging
- Hyperspectral imaging
- ROS imaging



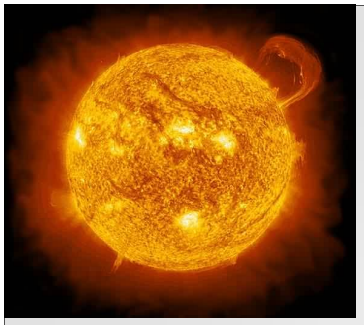
Plant growth/ morphology
- Digital RGB imaging
- 3D imaging

Leaf temperature
- Thermal imaging

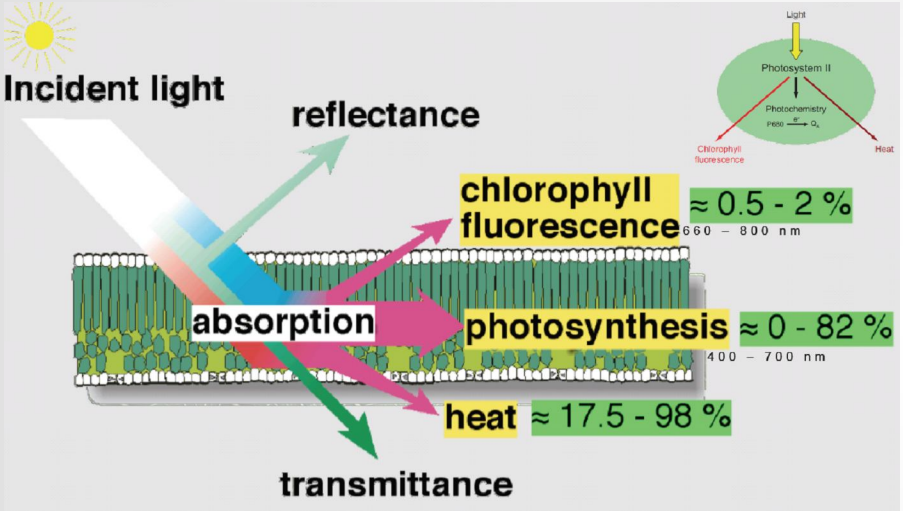
CO_2 uptake

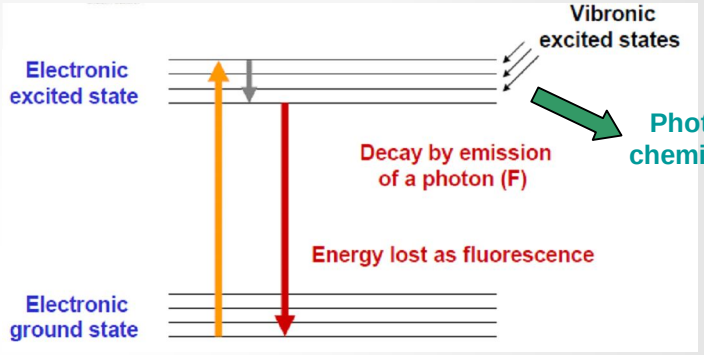
Water uptake

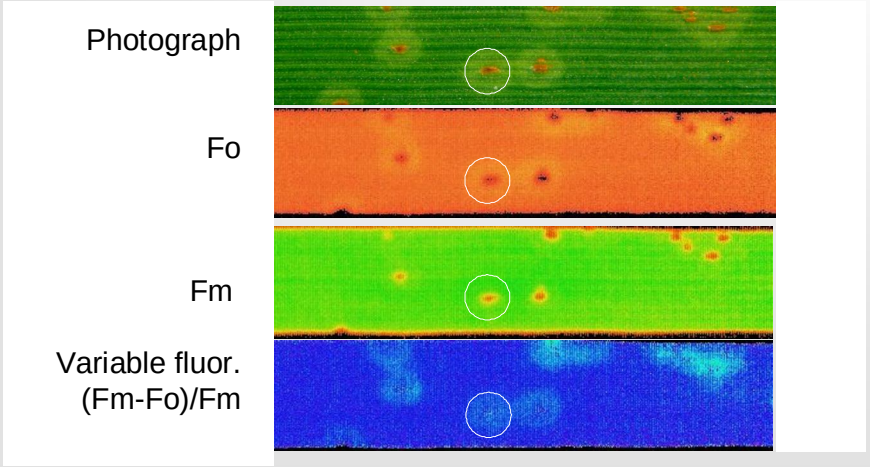
Root structure
- Digital imaging
- Confocal microscopy
- Micro CT
- NMR

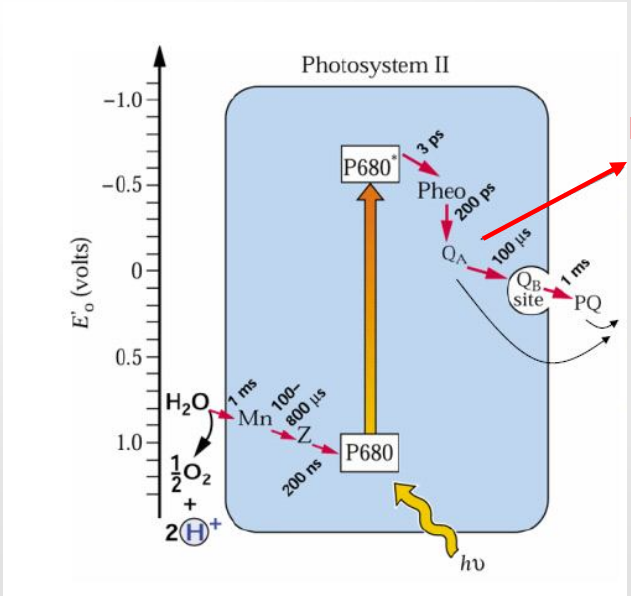


Phenotyping signatures of photosynthetic functions: Chl fluorescence imaging

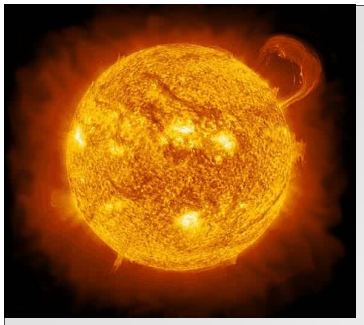




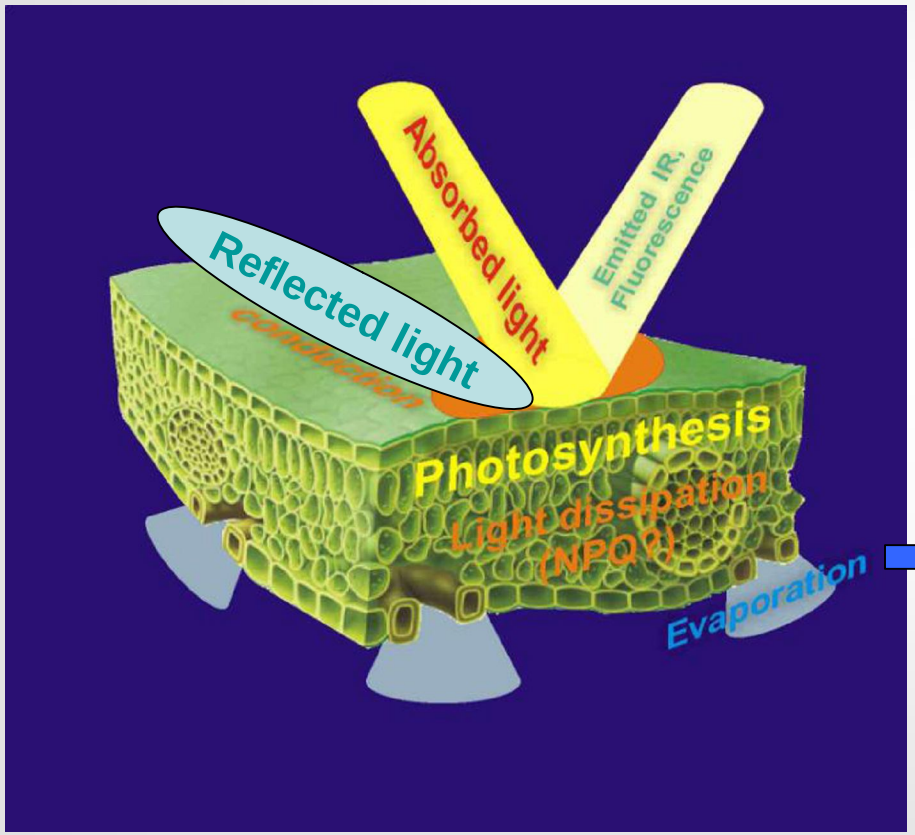




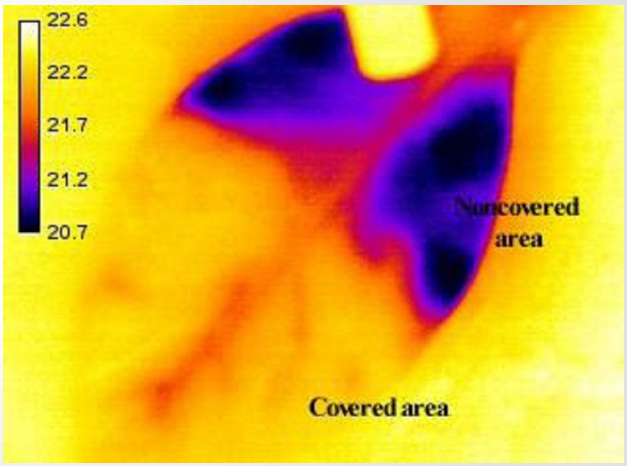
Principal regulator of fluorescence yield



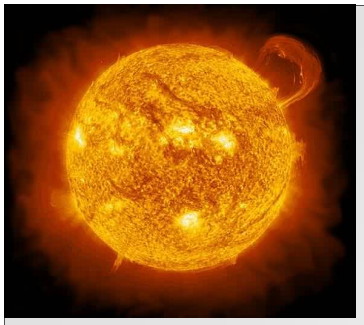
Phenotyping signatures of photosynthetic functions: Thermal imaging



Heat loss



Lecture by Radek Kana



Phenotyping signatures of other plant functions: Plant growth and water uptake

Watering

Imaging

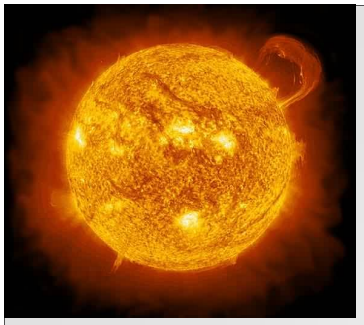
Fluoreszcence camera

Digital RGB camera

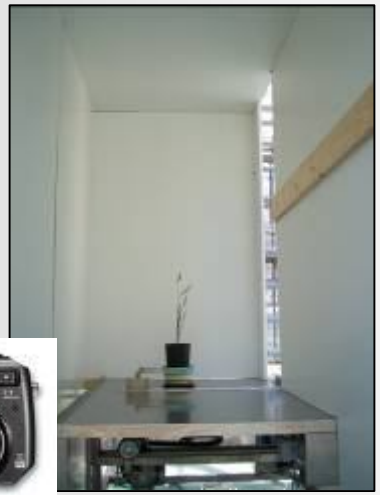
Thermocamera

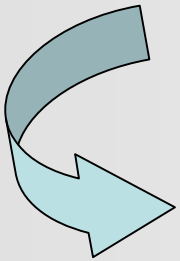
Watering

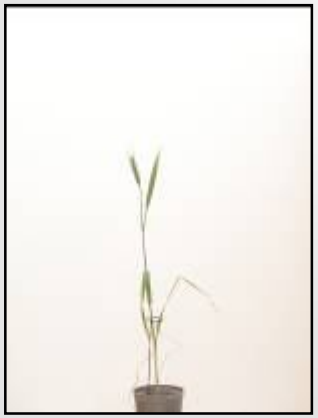
Identification

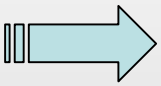


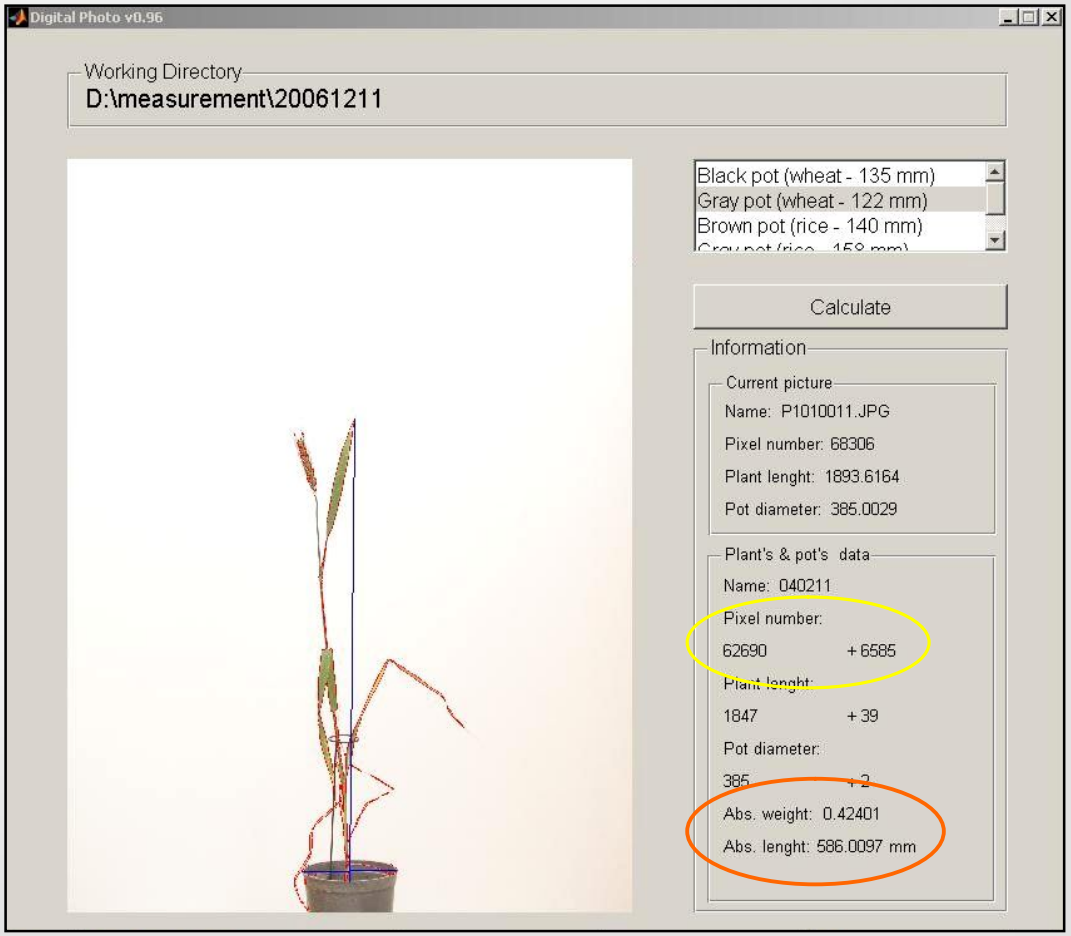
Phenotyping signatures of other plant functions: Plant growth





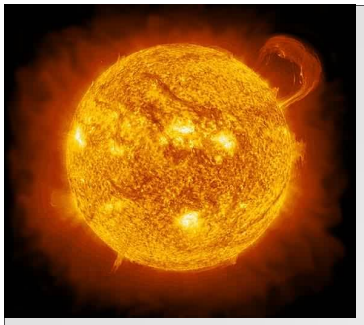




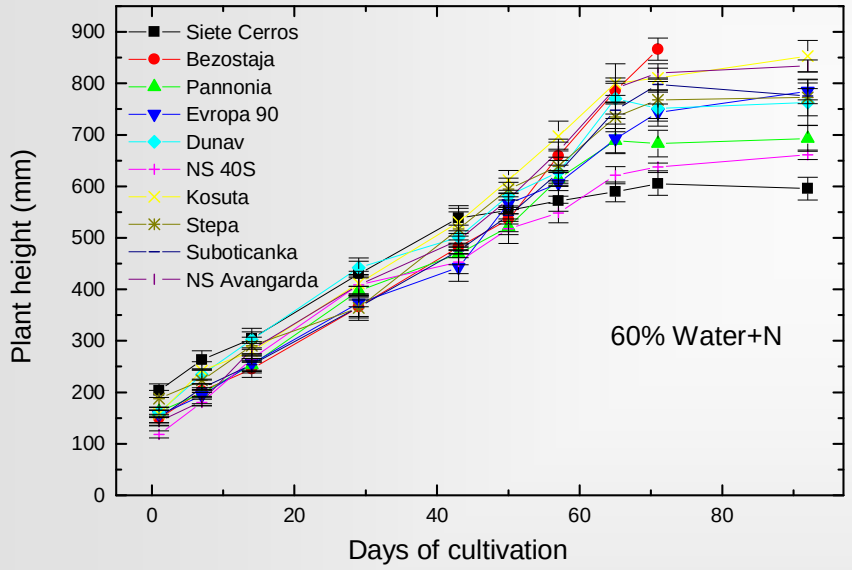


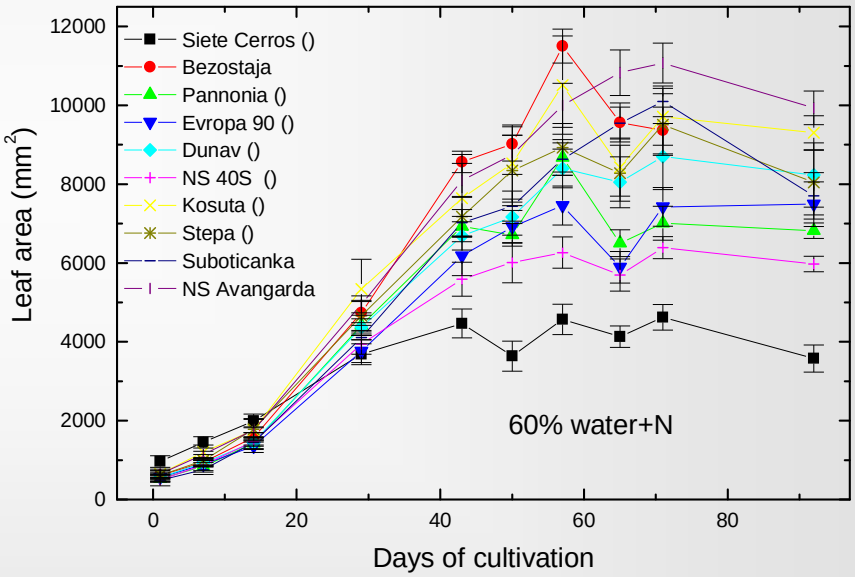
Digital image

Computer analysis

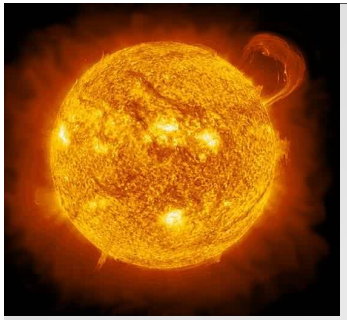


Phenotyping signatures of other plant functions: Plant growth



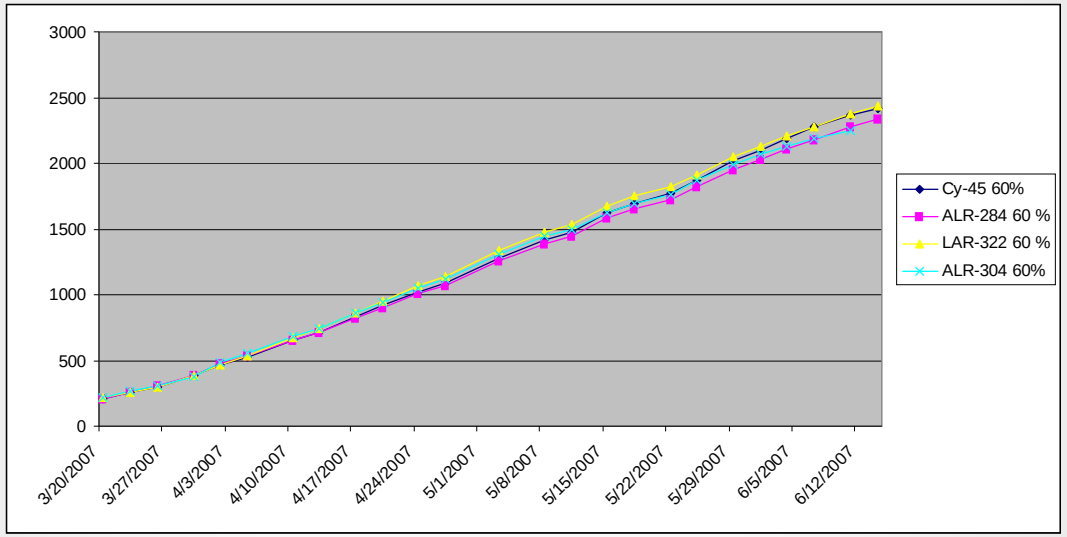


Effect of water- and N-availability on Serbian wheat cultivars

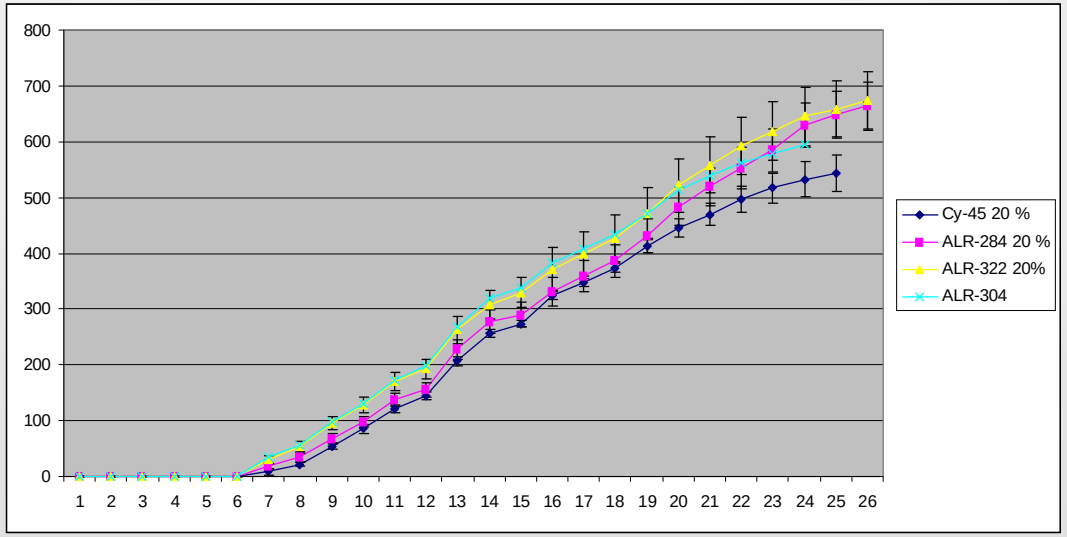


Phenotyping signatures of other plant functions: Water uptake

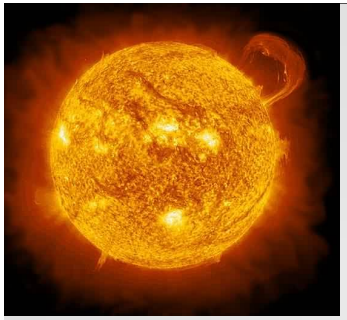
Transgenic wheat lines overexpressing alafalfa aldose reductase



Well watered



Drought stressed



Thank you for your attention