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Recent developments in photosynthesis research and links to international initiatives

- Overview of the photosynthetic process
- The unique presence of ANU in photosynthetic research, both nationally and internationally
- Opportunities for improving photosynthesis and yield potential

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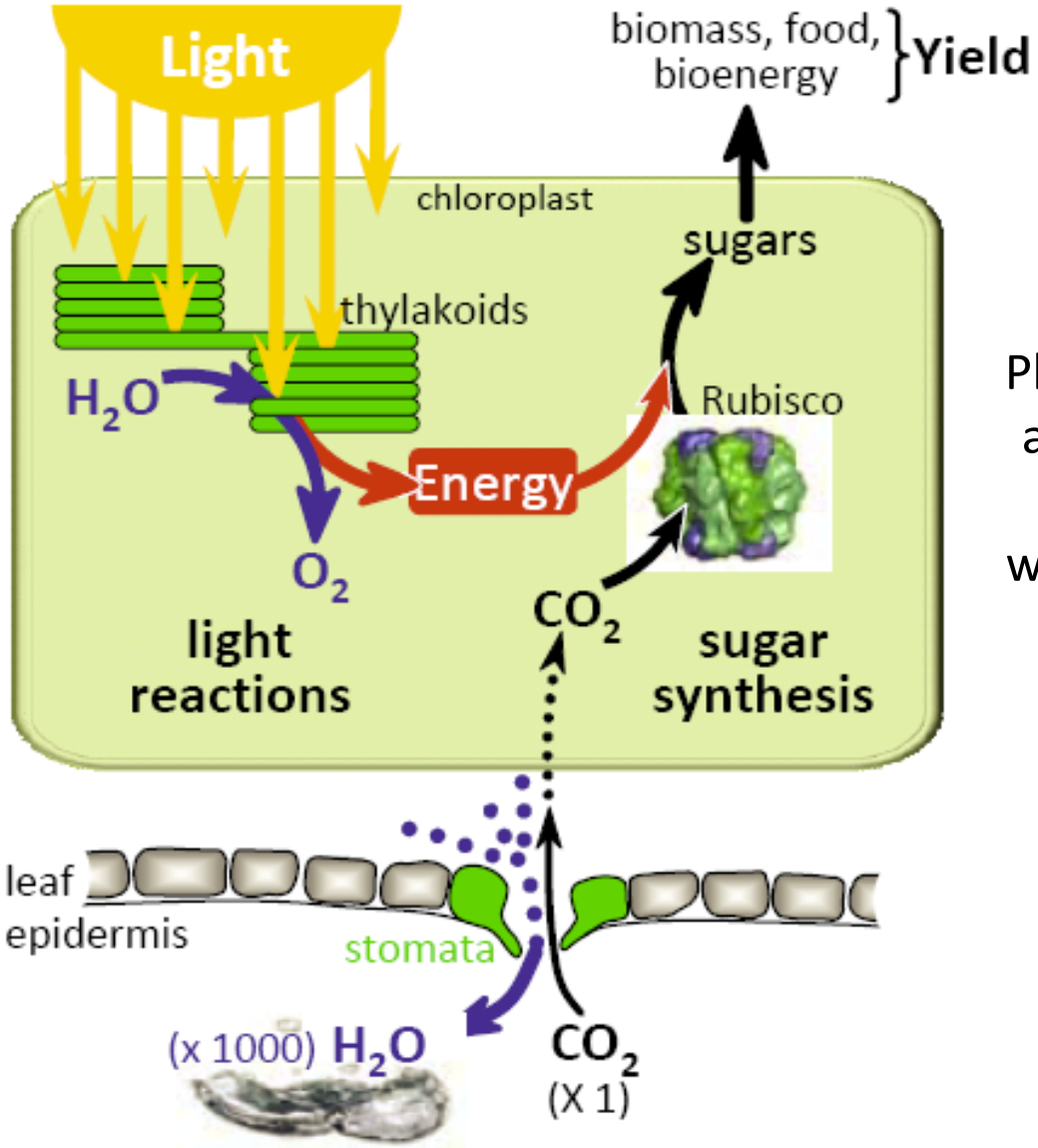
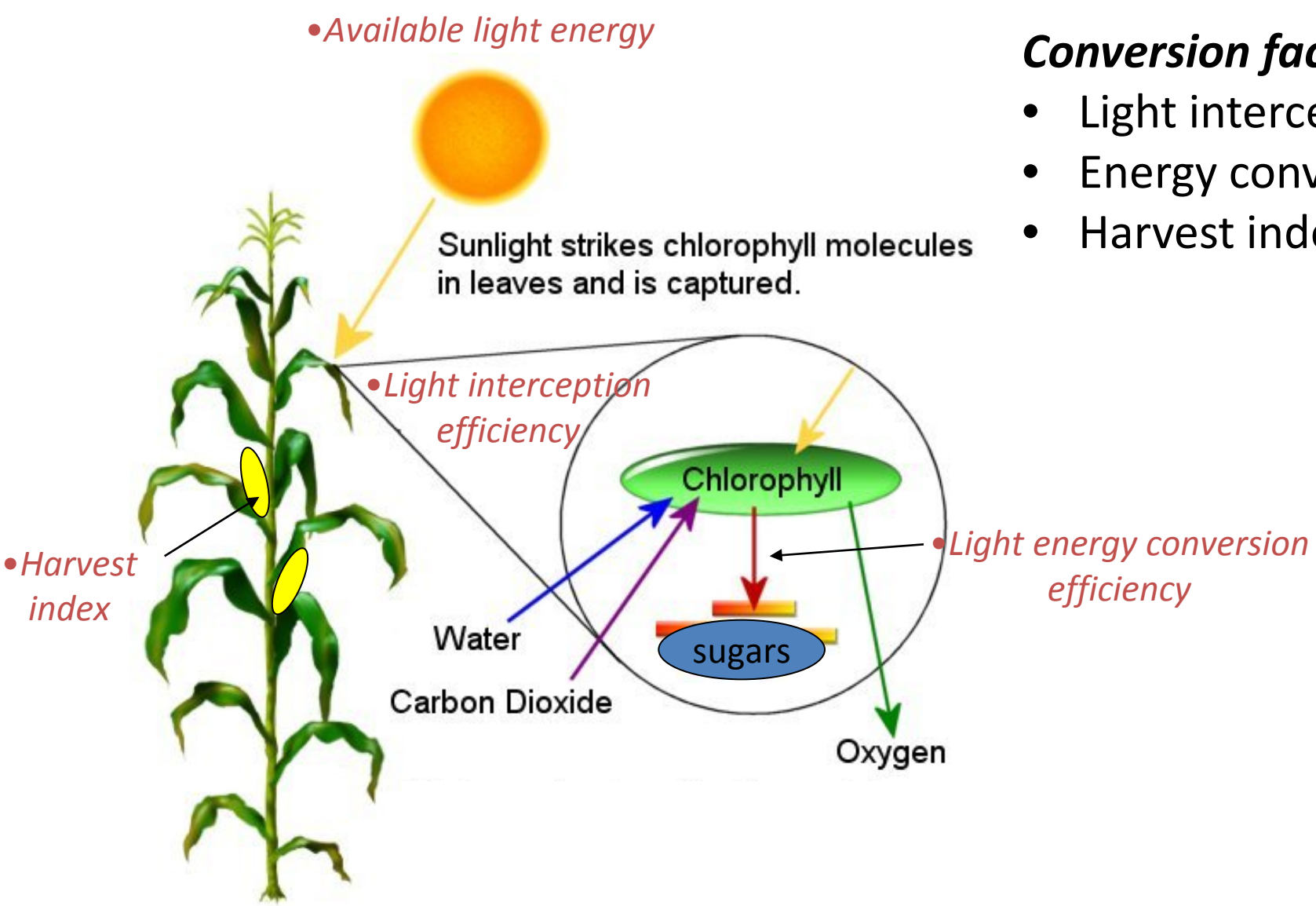
The process of Photosynthesis



Photosynthesis comprises light and sugar synthesis reactions yielding plant biomass, with water being lost from leaves in this process.

The conversion of sunlight to crop yield

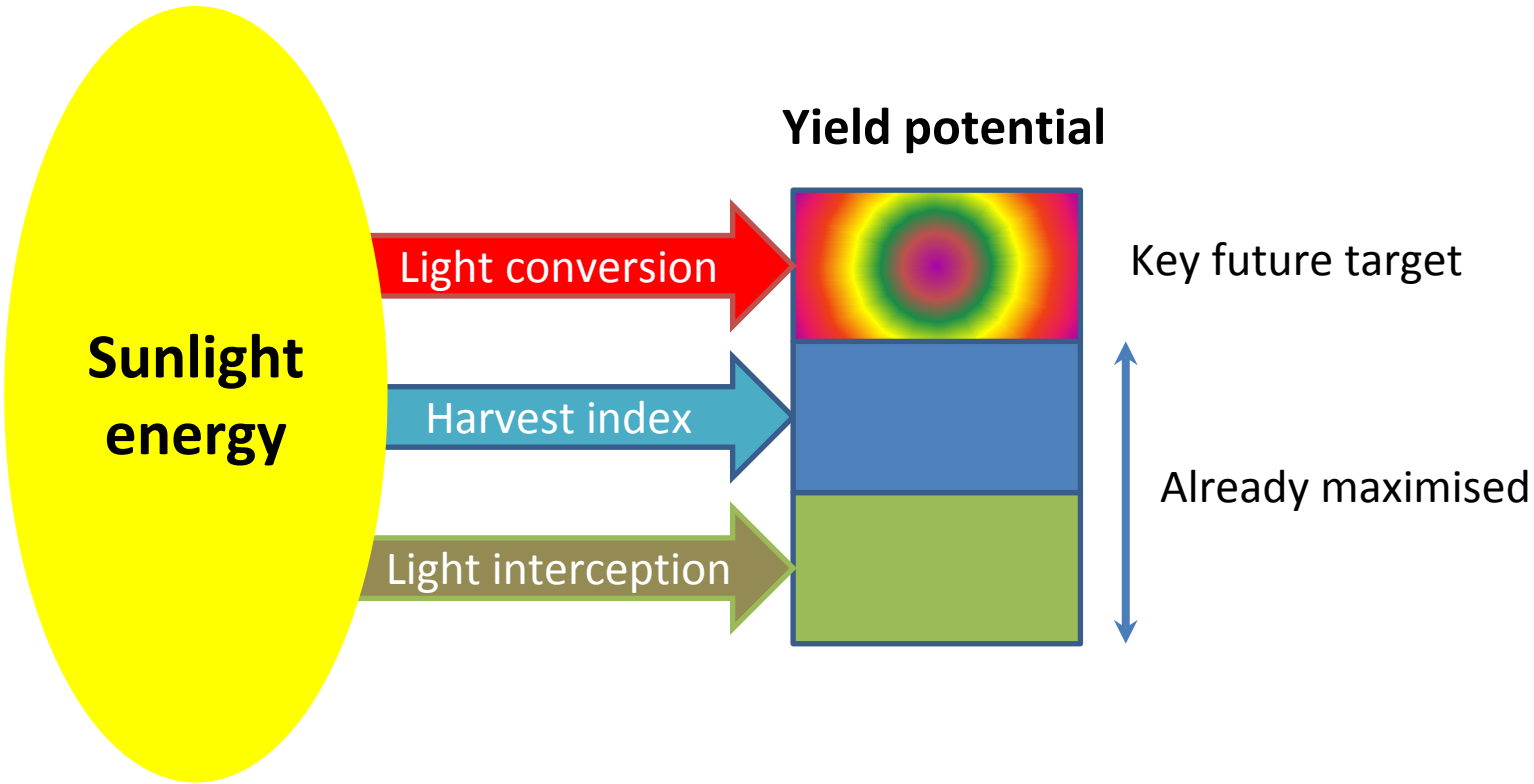


Conversion factors

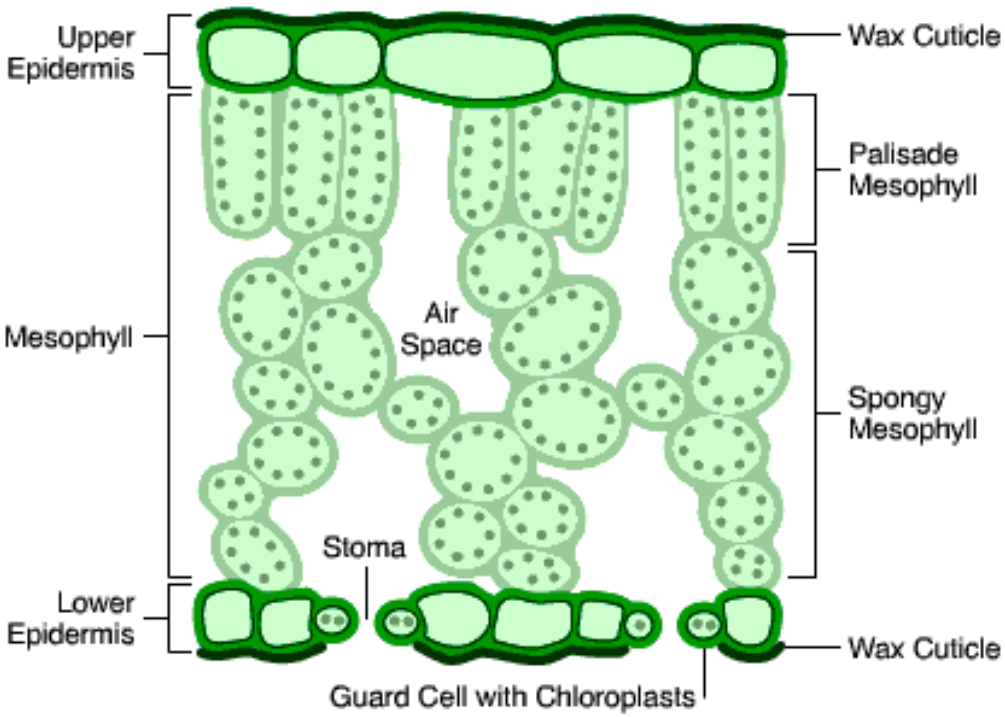
- Light interception
- Energy conversion
- Harvest index

Improving photosynthetic light conversion efficiency

a key target for yield potential improvement



Improving photosynthesis at the leaf level



- Improving the properties of a chloroplast
- Altering chloroplast numbers per cell
- Changing the anatomy of the leaf (cell layers and stomata)
- Assessing improvements at the crop growth level

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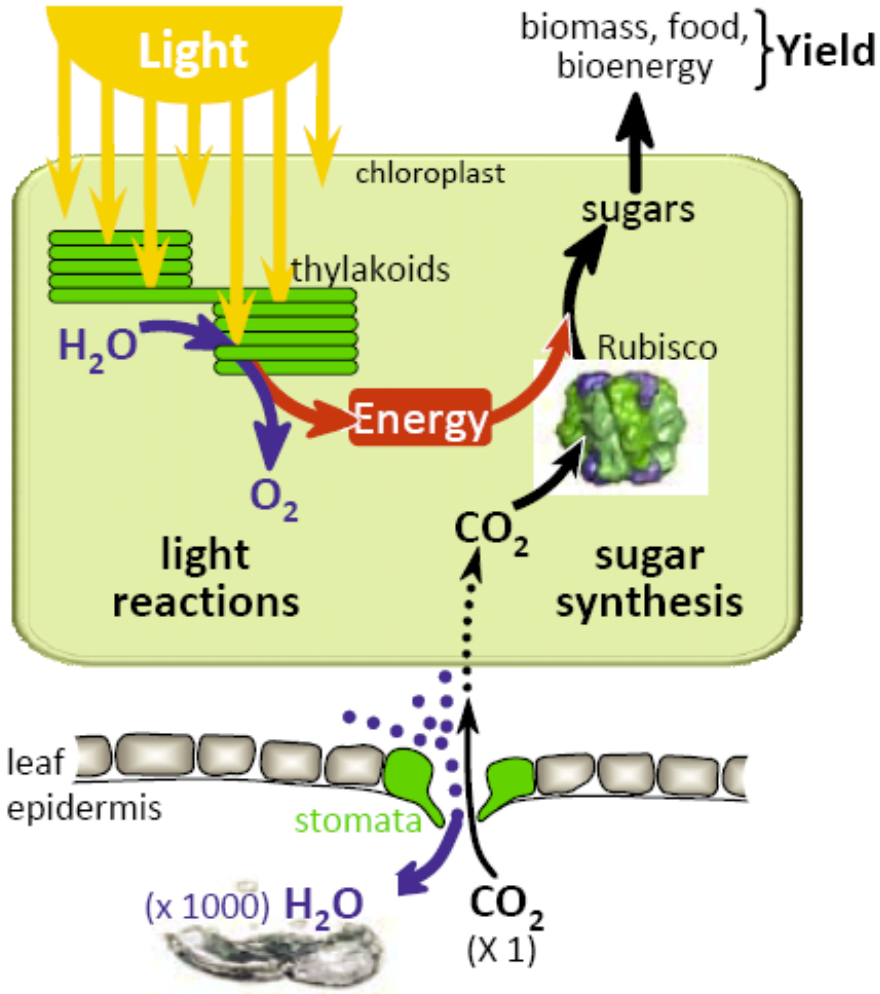
The capability of ANU in photosynthesis research

- Over the past thirty years ANU has established a team of internationally recognized researchers in the field of plant photosynthesis and water-use. Most highly cited photosynthesis group in Australia.

- This team is uniquely placed to conduct research from the molecular scale through cellular, the whole-plant, and to crop plants in the field using a wide array of research approaches

- We have access to key technologies and research networks with a range of international organisations focussing on photosynthesis and crop improvement
    - IRRI, CIMMYT, ICARDA – developing countries
    - Gates Foundation (BMGF)
        - 1. C4 rice and 2. Improving C3 photosynthesis
    - European and US Photosynthesis Consortia
    - Bayer Crop Science
    - CoE in Plant Energy Biology
    - CSIRO Plant Industry

A targeted approach to improve photosynthesis

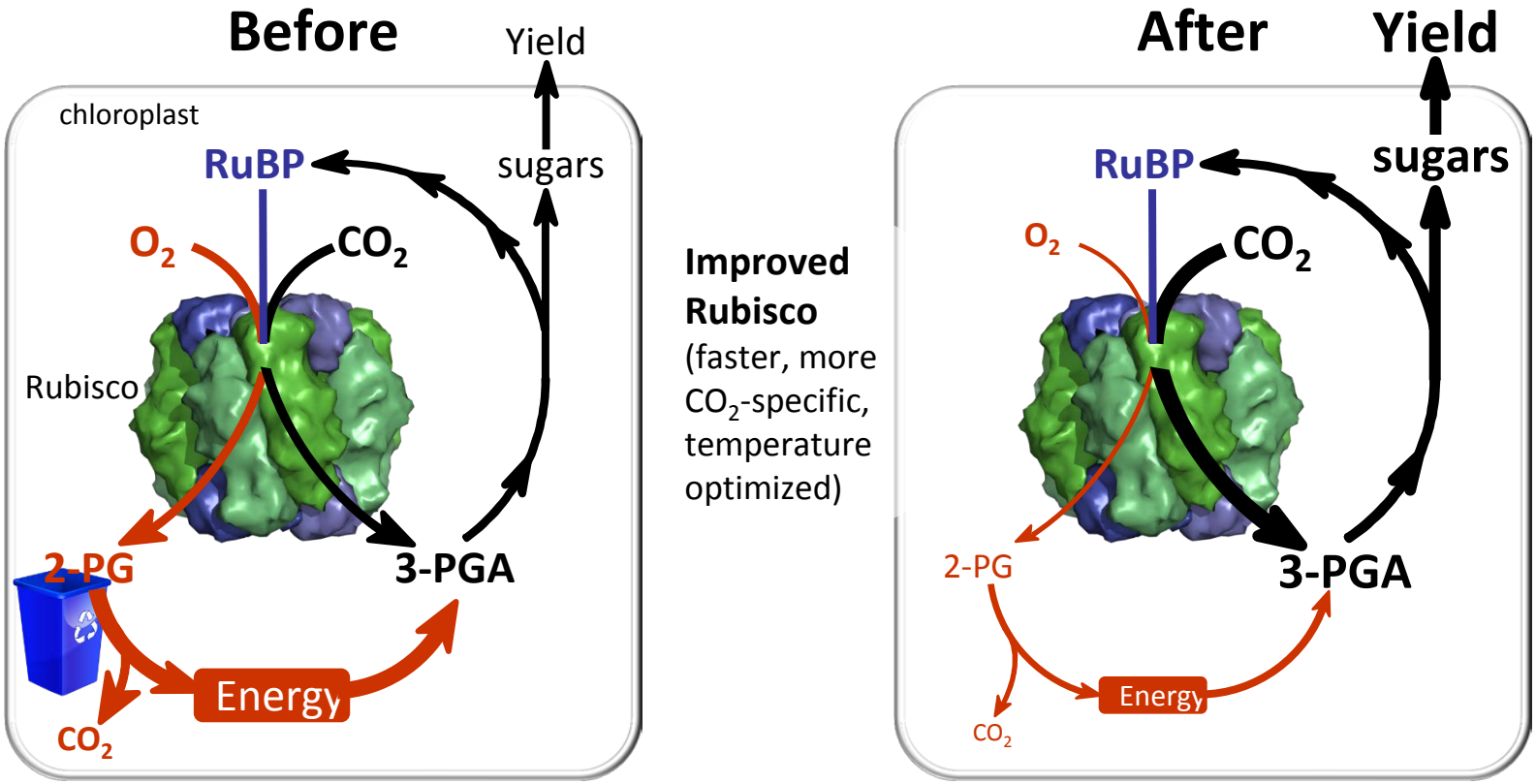


Yield potential increases of 20 -100 %

Targets to improve

- enhance CO_2-fixation rate and reduce water loss
  - ▶ improve function and performance of Rubisco, particularly at high temperature
  - ▶ concentrate CO_2 around Rubisco
  - ▶ modulate leaf development and anatomy
- boost electron transport capacity and energy supply of the light reactions
- understanding of crop response to climate and global change

Enhancing Rubisco performance in plants

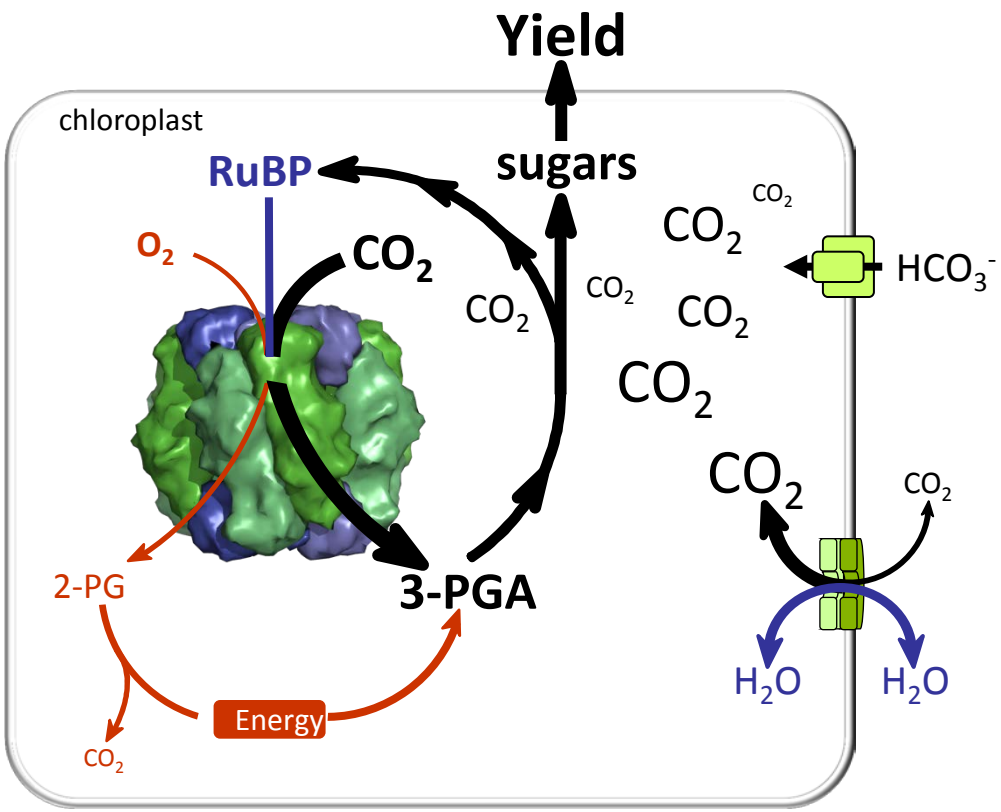


The capability exists to improve crop yield by enhancing the performance of Rubisco – increasing its rate and specificity.

Improving Rubisco

- Identifying better Rubiscos from the natural germplasm diversity of existing crops
- Transplanting better Rubiscos into target crop plants
- Engineering better Rubiscos by altering chloroplast genes

Turbo charging CO_2 supply to Rubisco

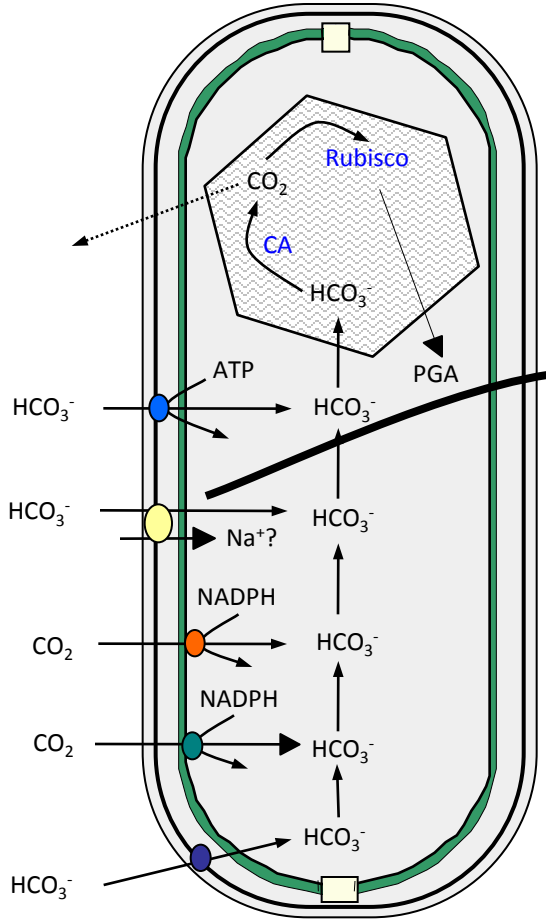


Introducing inorganic carbon pumping complexes;
Increase CO_2 concentrations in the chloroplasts

Modify aquaporin protein expression;
alter membrane permeability to reduce CO_2 loss

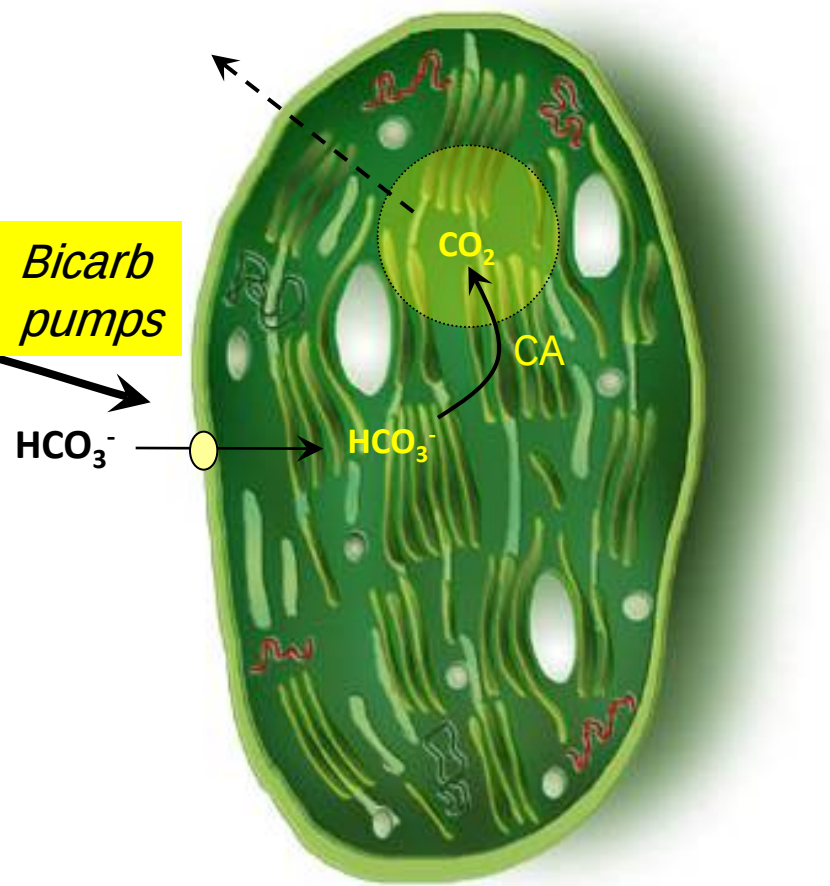
Evolution has developed a range CO_2 turbocharging options

Bicarbonate transporters from Cyanobacteria



Cyanobacterial cell

Bicarb pumps

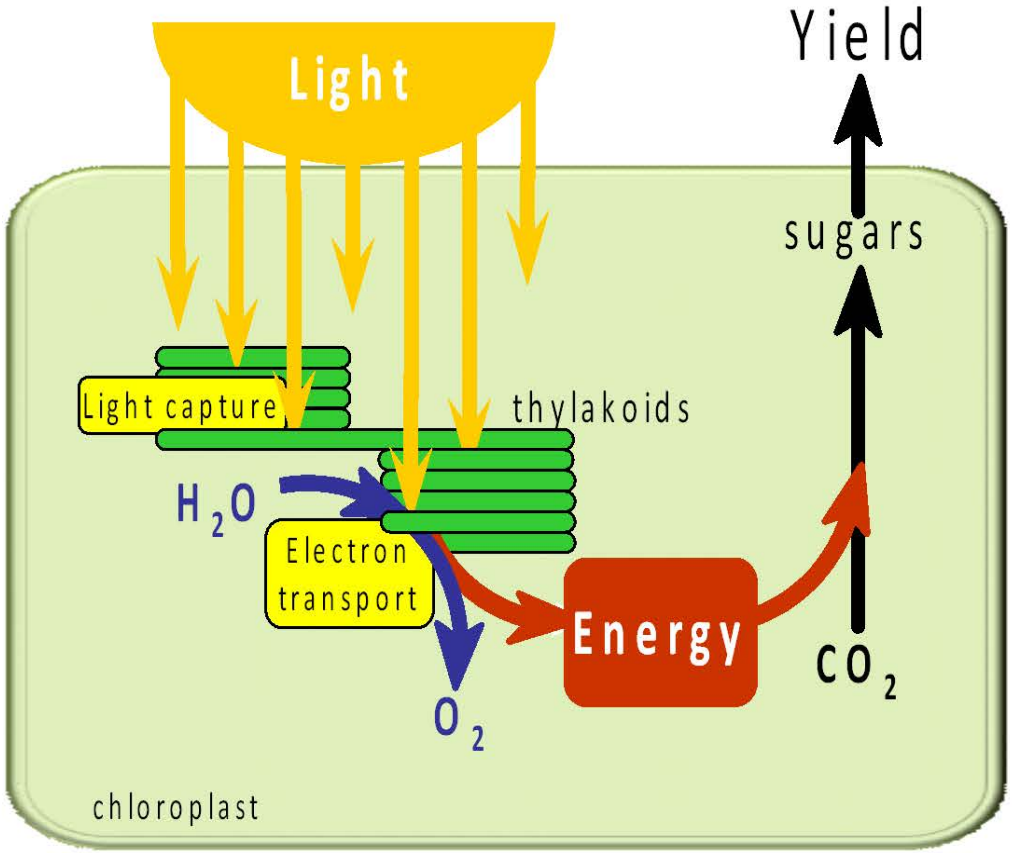


Plant chloroplast

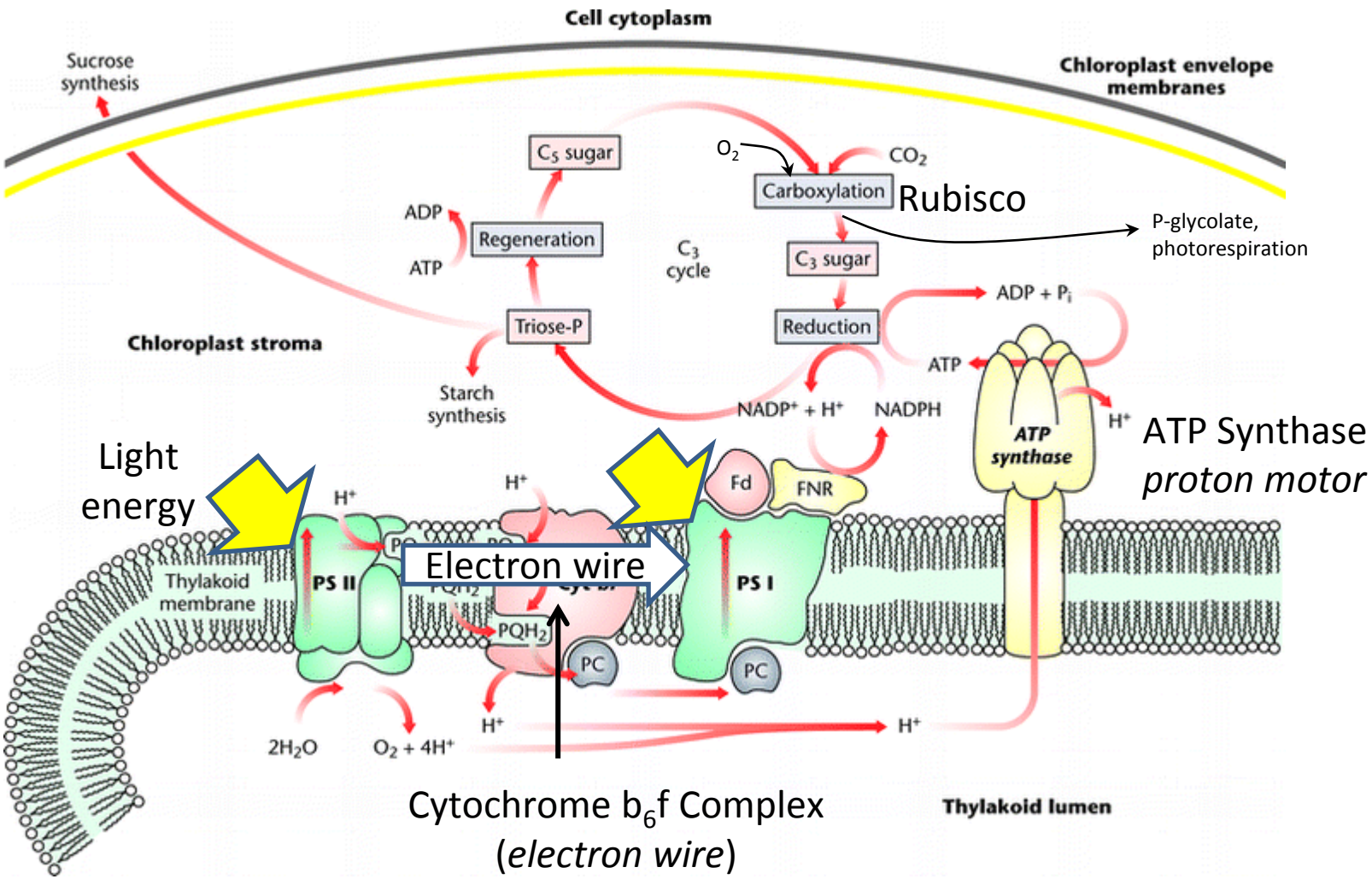
Improving photosynthetic electron energy supply

Overcome rate limitations imposed by components of the thylakoid electron transport pathway.

Improve light harvesting capacity of the thylakoid chlorophyll complexes.

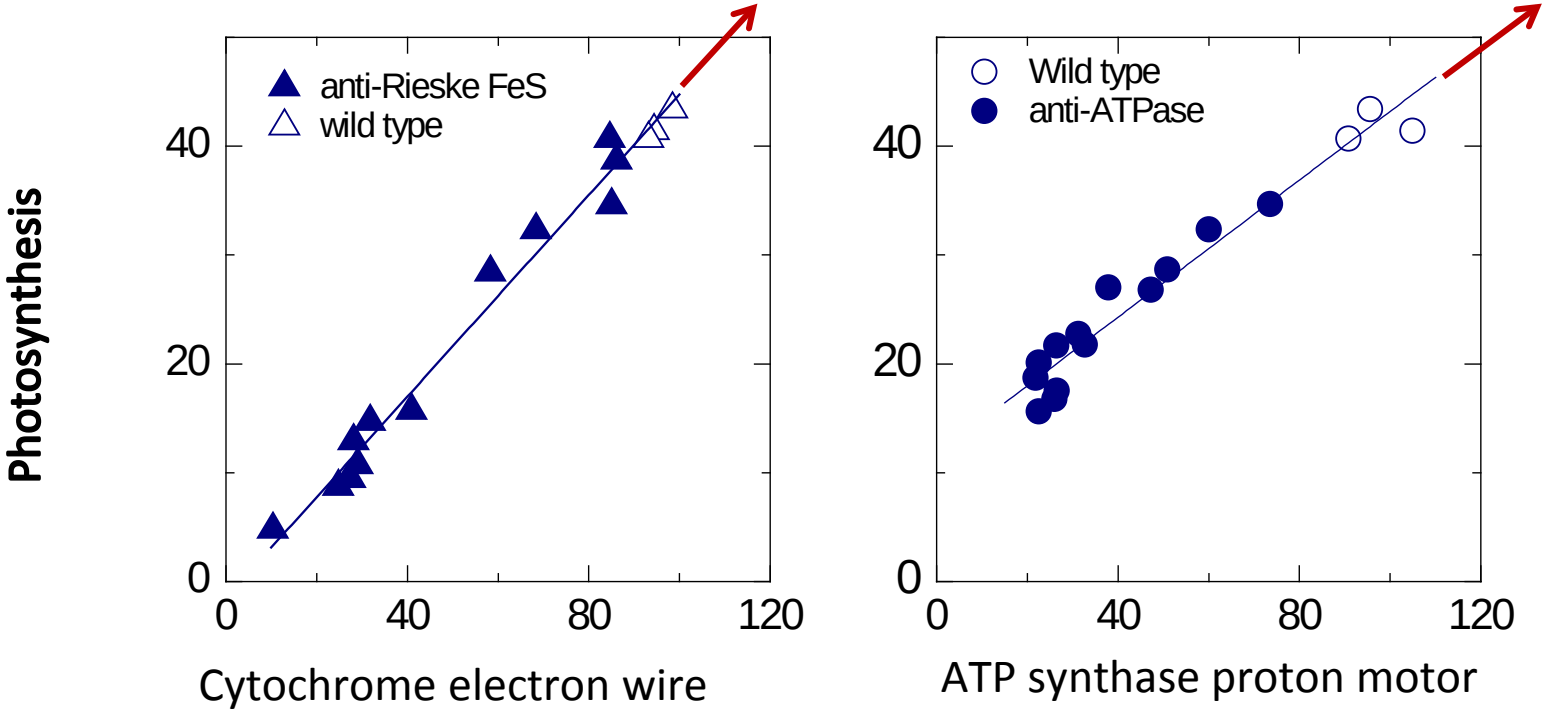


The complete photosynthetic process

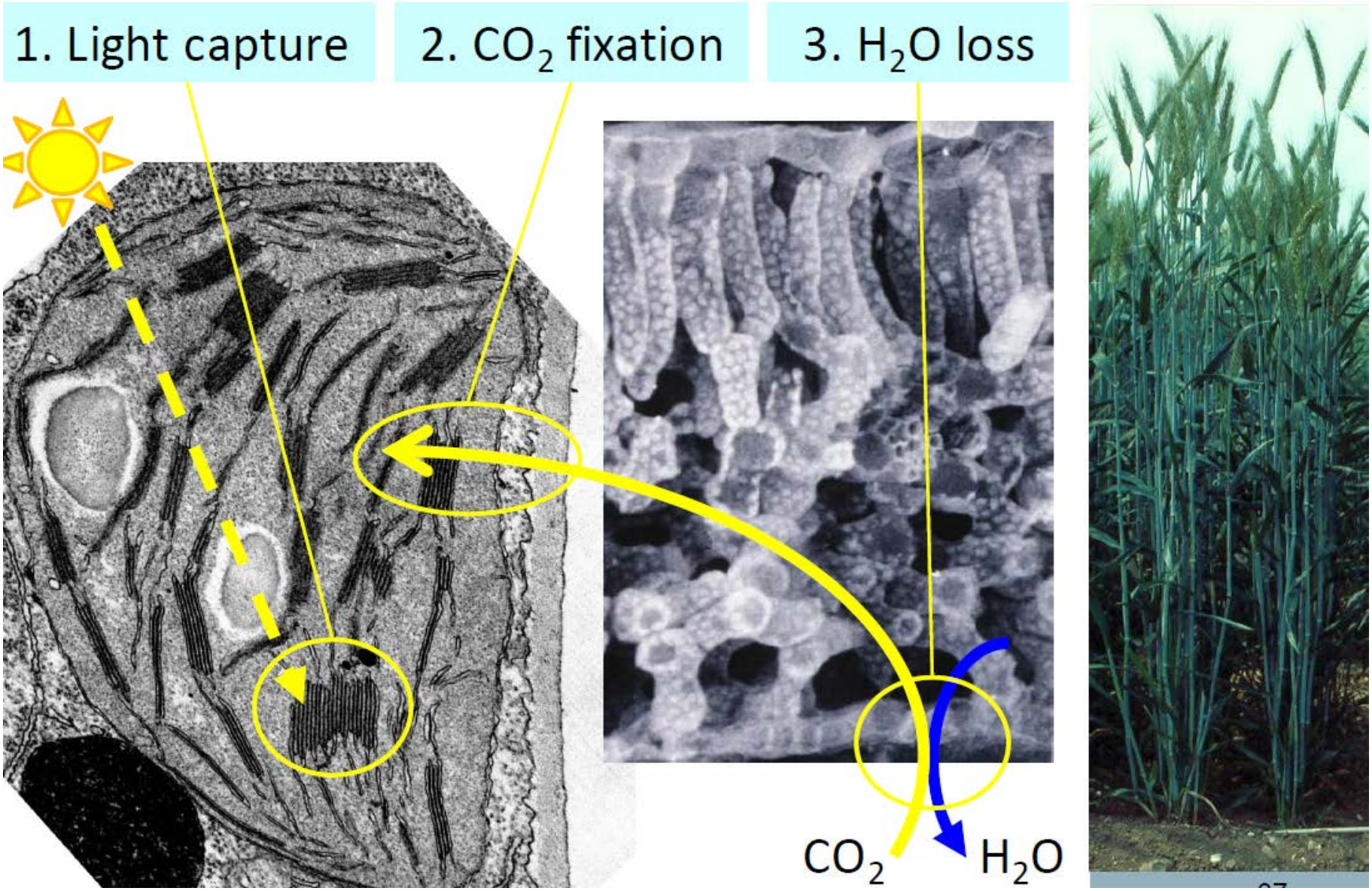


Both the electron wire and the proton motor limit photosynthesis

Research at ANU



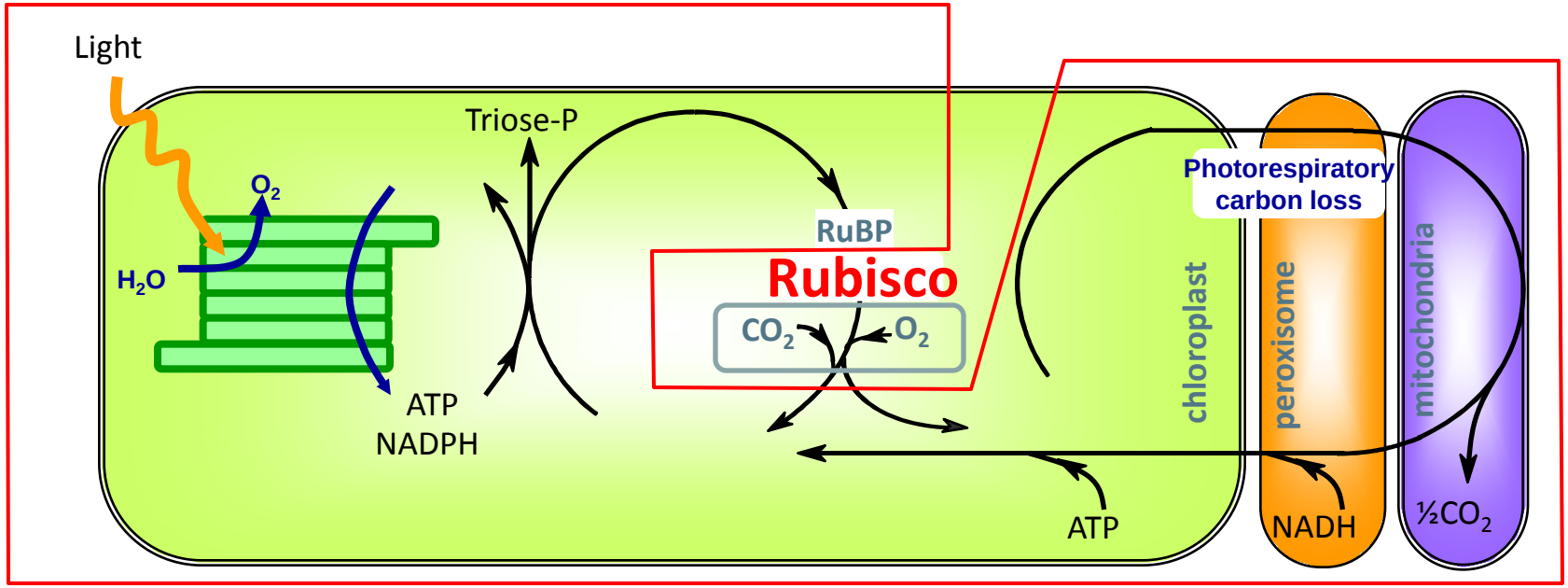
Scaling from the chloroplast to the canopy



Farquhar, von Caemmerer & Berry model of C_3 photosynthesis

Simplified all of the biochemistry into two limiting conditions

1. Rubisco activity
2. RuBP supply



Conclusions

- It is recognised that improving the efficiency of light energy conversion is a significant frontier for sustainable yield improvement. (***20-100% increase in yield potential over 10-20 years***)
- There are tractable opportunities available for immediate intervention
  - Rubisco improvement
  - Improving CO_2 concentration around Rubisco and reducing photorespiration
  - Altering the amounts of key rate limiting photosynthetic enzymes (membrane components and chloroplast enzymes)
  - Altering aspects of leaf development
  - Improving our ability to model changes in the leaf through to changes in crop and canopy photosynthesis and yield

Summary Session 1

- Global food security is a critical future issue for national security, global peace and development
- Increasing the yield potential of staple food crops offers an avenue for averting food limitation/security problems
- Improving the process of photosynthesis offers realistic opportunities for raising yield potential considerably (a new green revolution)