Engineering photosynthesis to feed the future

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Food insecurity:

- World crop production needs to increase 100-110% by 2050 to meet projected food demands.
- Current yield trends are insufficient to meet demands (Figure 1).
- Photosynthetic efficiency varies significantly in plants and microbes.
- In some species, so called “carbon concentrating mechanisms” deliver high concentrations of CO_2 to photosynthesis and this leads to improvements in yield (Figure 2).
- Many aspects of crop growth have been optimised since domestication, but photosynthesis is not one of them.
- We work on understanding how the most efficient versions of photosynthesis operate, and hope that in the long term this will allow significant increases in crop yield.
- One version of photosynthesis we work on (called the C_4 pathway) increases efficiency by 50%, and also increases nitrogen and water use efficiency. C_4 photosynthesis is therefore viewed as critical for increasing both yields and sustainability.

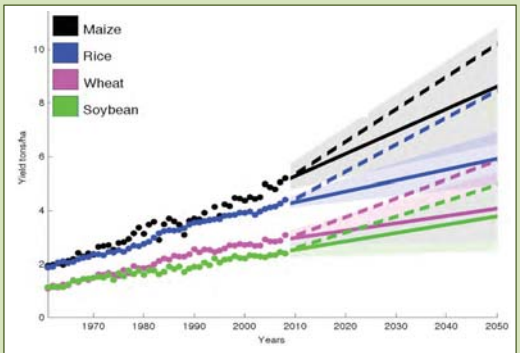

Figure 1: Historical and projected crop yields. Solid lines represent the current rate of growth, and dashed lines the rates estimated to meet food demands for 2050.

Figure 2: Variation in photosynthesis drives yield. Rice (foreground) which uses C_3 photosynthesis grows at approximately half the rate of species using the more efficient C_4 pathway.

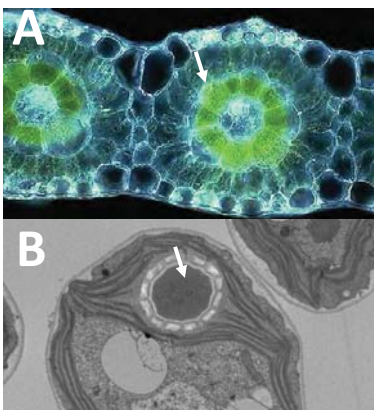

Figure 3: Specialized structures for CO_2 concentration. (A) ‘Kranz Anatomy’ in C_4 photosynthesis and (B) the algal ‘pyrenoid’.

How carbon concentrating mechanisms work:

- C_3 plants (most crops) are hindered because of low concentrations of CO_2, but also because of competition between O_2 and CO_2 during photosynthesis.
- Interestingly, some plants overcome this limitation with a genetically encoded carbon concentrating pump, termed C_4 photosynthesis (Figure 3A).
- In many algae and photosynthetic bacteria, alternate mechanisms act to pump CO_2 towards the photosynthetic apparatus (Figure 3B).

Evolutionary engineering:

- Using a mixture of mathematical, computational, biochemical, molecular and physiological approaches, we study how these types of efficient photosynthesis evolved.
- We then use this information to design our engineering efforts to substantially improve photosynthesis.

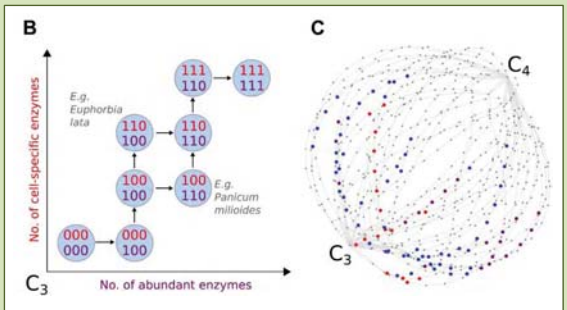

Figure 4: Evolution used four main paths to reach the efficient C_4 phenotype.