Using evolution to improve crop productivity: The case of the C4 pathway

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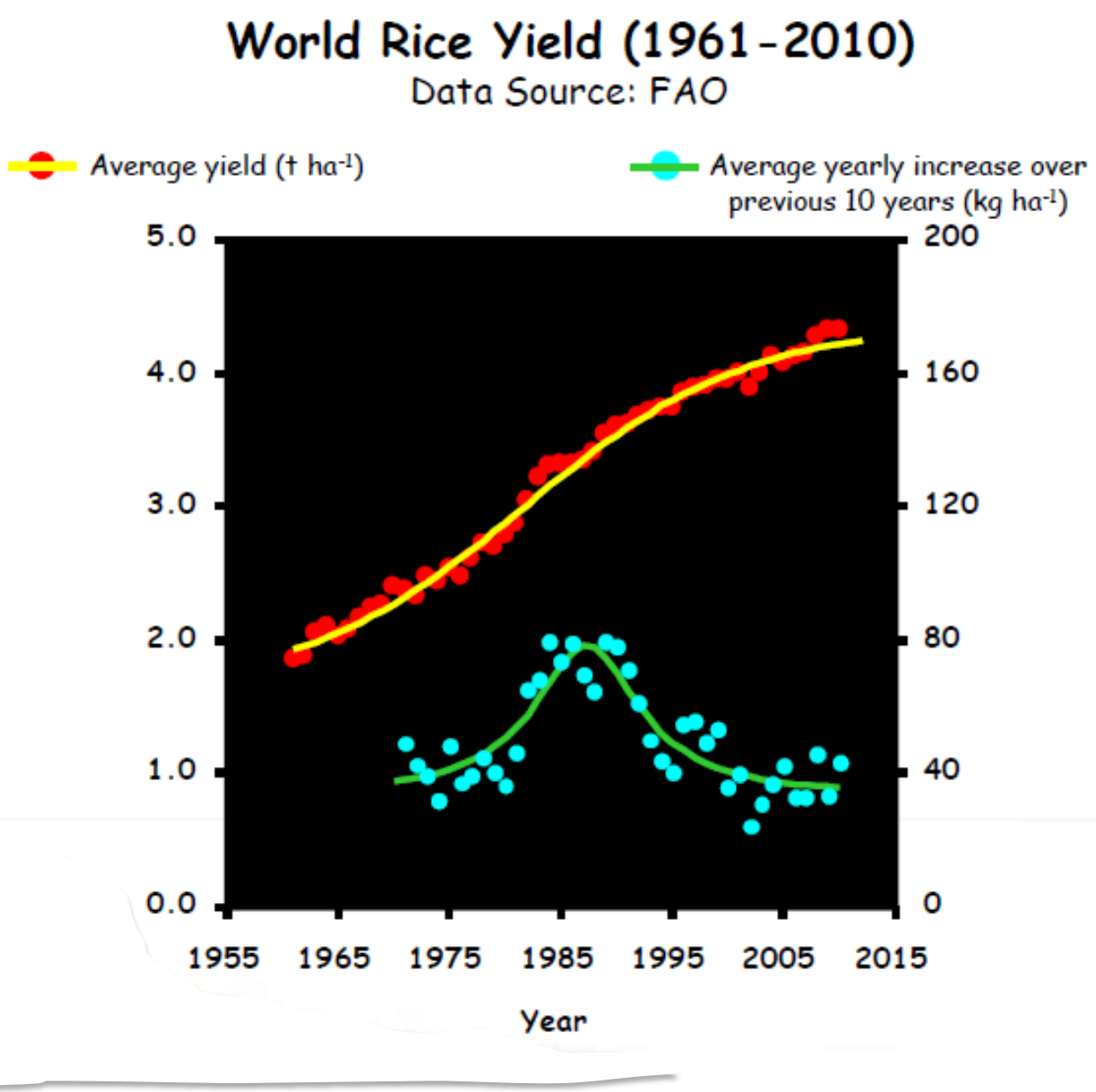

We need to increase crop production

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Photosynthesis

Ingredients → *Product*

Sunlight +

$H_2O + CO_2 + Nutrients \rightarrow CH_2O + O_2$

water, carbon dioxide → carbohydrates, oxygen

Respiration

Product → *Ingredients*

$H_2O + CO_2 + Energy \leftarrow CH_2O + O_2$

water, carbon dioxide ← carbohydrates, oxygen

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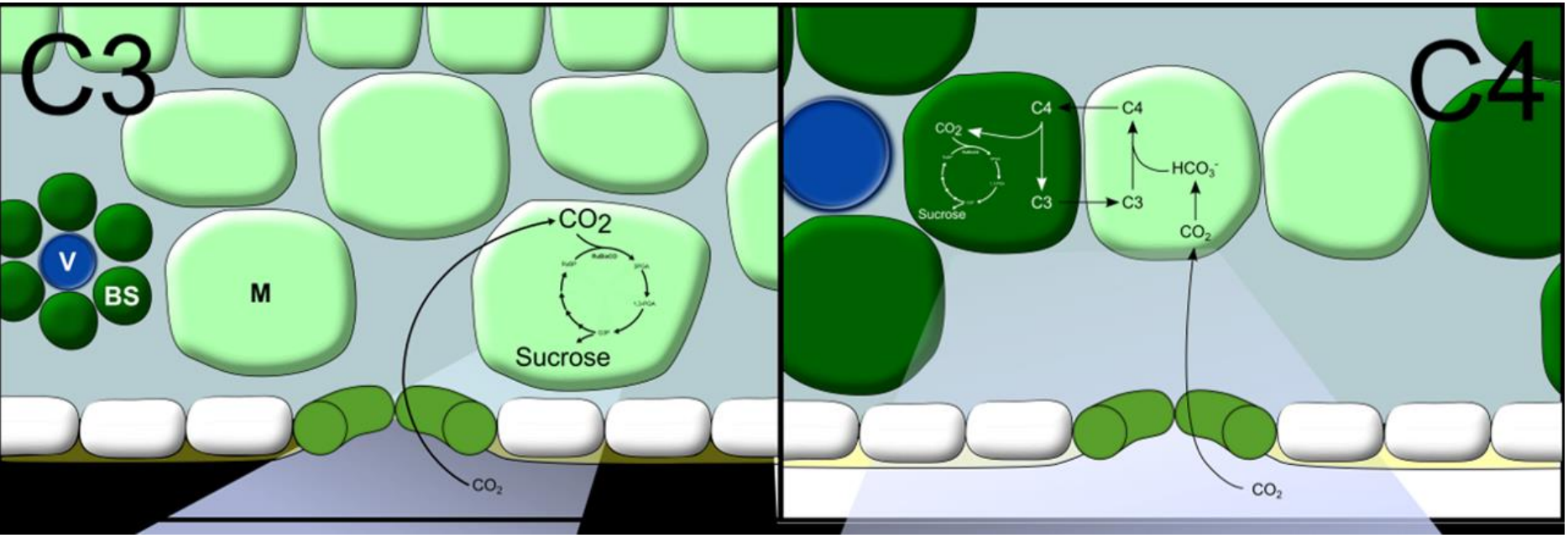
C_4 enhances photosynthesis using a two compartment C02 Concentrating Mechanism



http://hibberdlab.com/about.html

The world's most productive crops use C_4 photosynthesis

Maize

Sugarcane

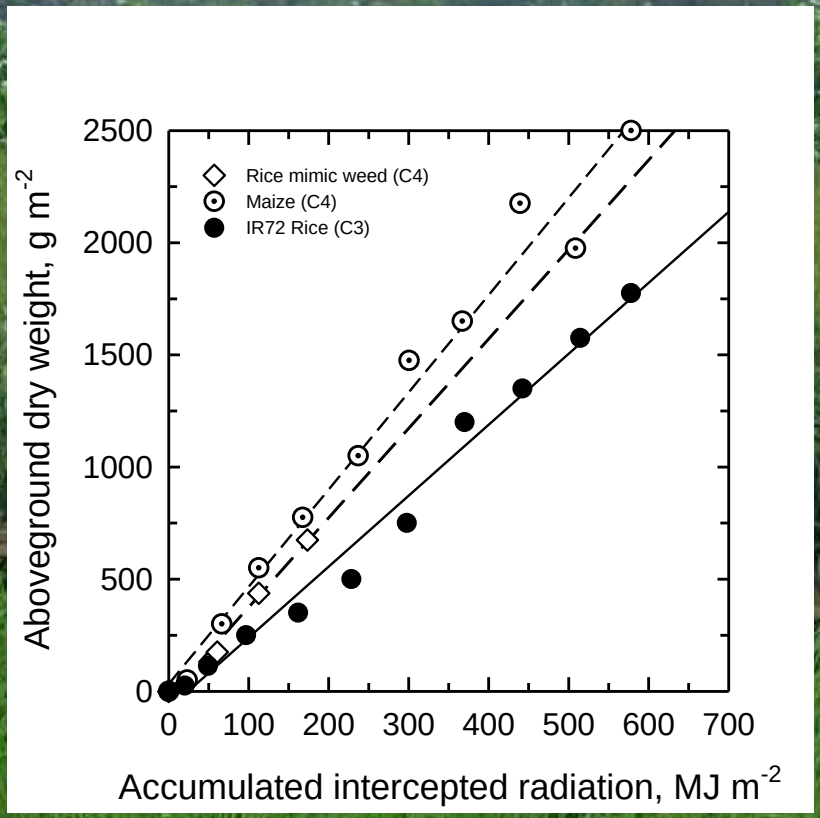
Sorghum

Millet

Miscanthus x giganteus

Switchgrass

Adaptations allow C_4 plants to outperform C_3 crops in biomass production for food



Maize (C_4): 13 Tons/ha

Rice (C_3): 8.3 Tons/ha

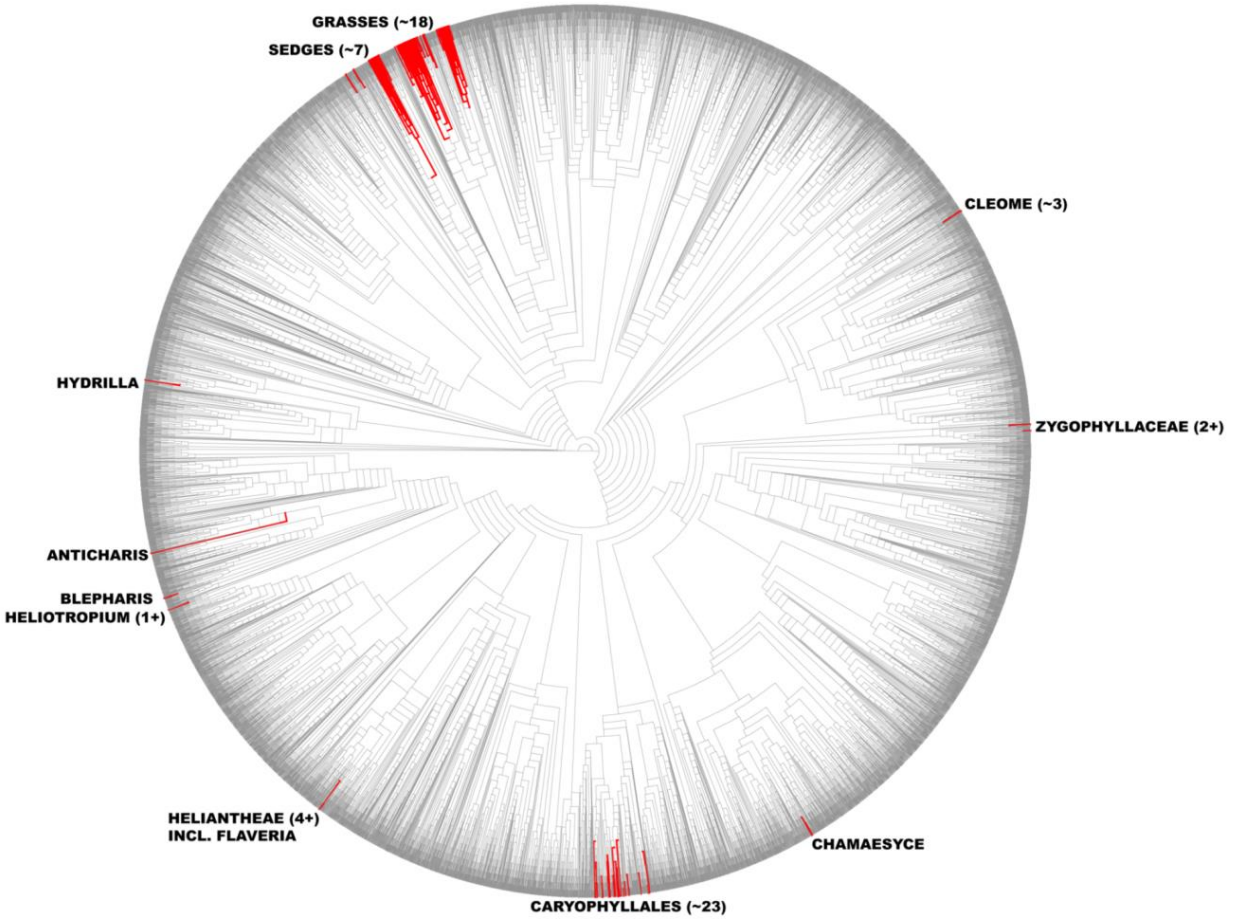
Sheehy et al. (2007); Sage and Zhu (2011) *J. Experimental Botany* 62: 2989

Lessons from Evolution

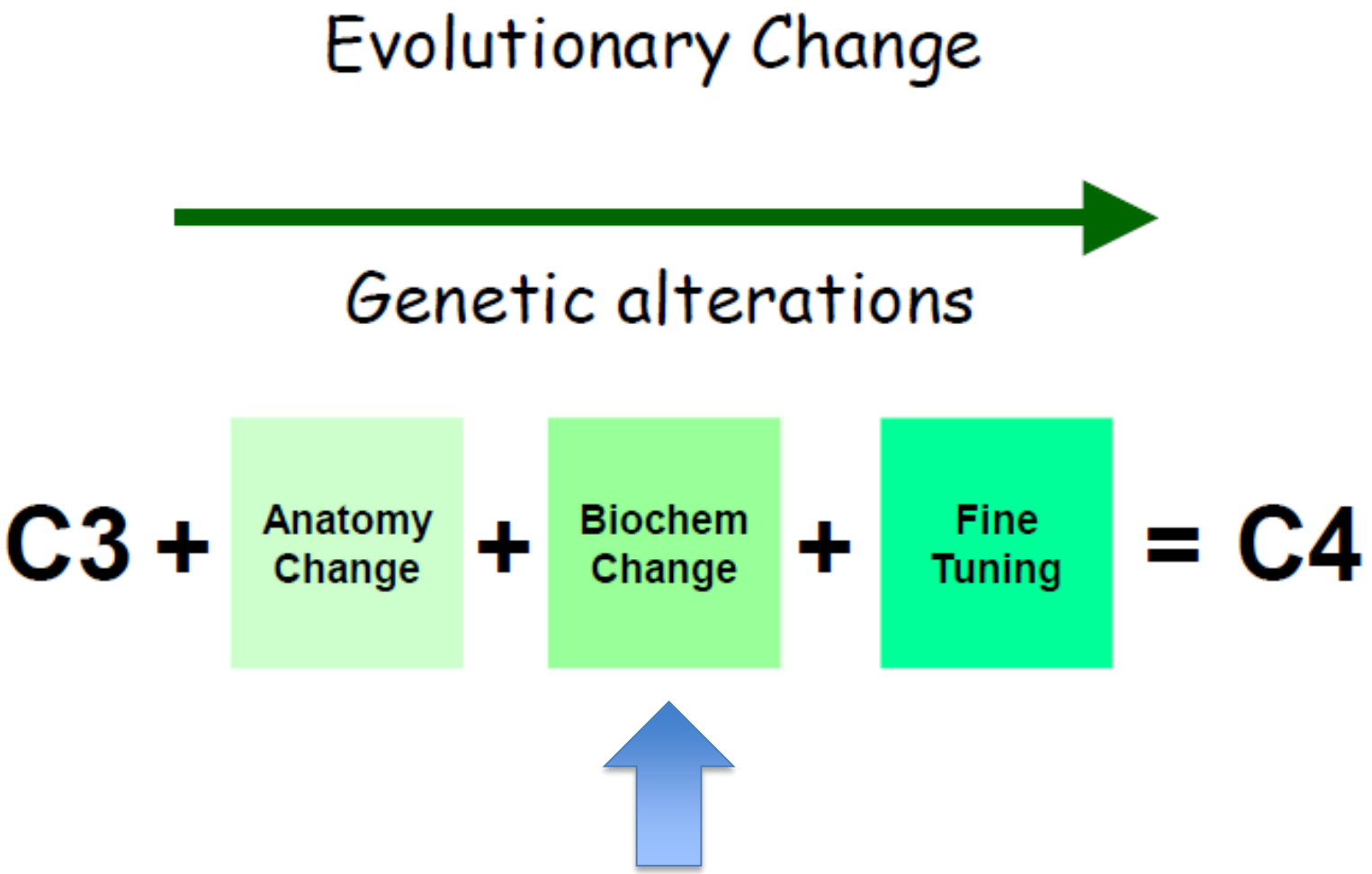
C_4 photosynthesis is one of the largest examples of convergent evolution

Despite its complexity, C_4 has evolved independently ~70 times

The acquisition of C_4 already happens in nature



Sage, Christin, and Edwards (2011)
J. Exp. Bot. 62, 3155



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Localize and characterize both pre existing and novel features relevant to the C_4 pathway

Novel Proteins

Pre-existing genes

In summary

- Understanding the evolution of complex traits is vital for crop improvement

- In the near future, we will be able to design a C_4 gene cluster and precisely install into rice or other species

Acknowledgments

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