300358 UE Metabolomics, WSe 2018
Stefanie Wienkoop, Lena Fragner, Martin Brenner, Wolfram Weckwerth, **Gert Bachmann**

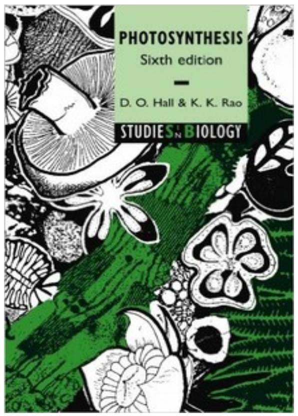
Metabolomics

Functional Plant Leaf Anatomy: Stomata
CO2 Fixation Modes: C3/C4/CAM
Ecology of Gas Exchange

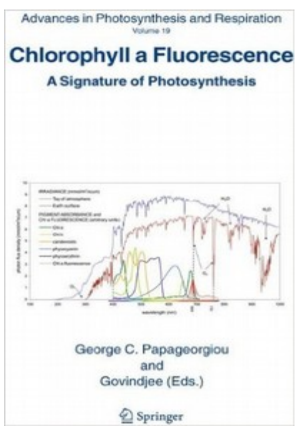
Plant Physiology


Explore the Physiolome!
F: Clusiaceae
Clusia orthoneura
(Porcelain Autograph Tree)
© 2014 - Richard Lyons Nursery, Inc.

Literature: Photosynthesis

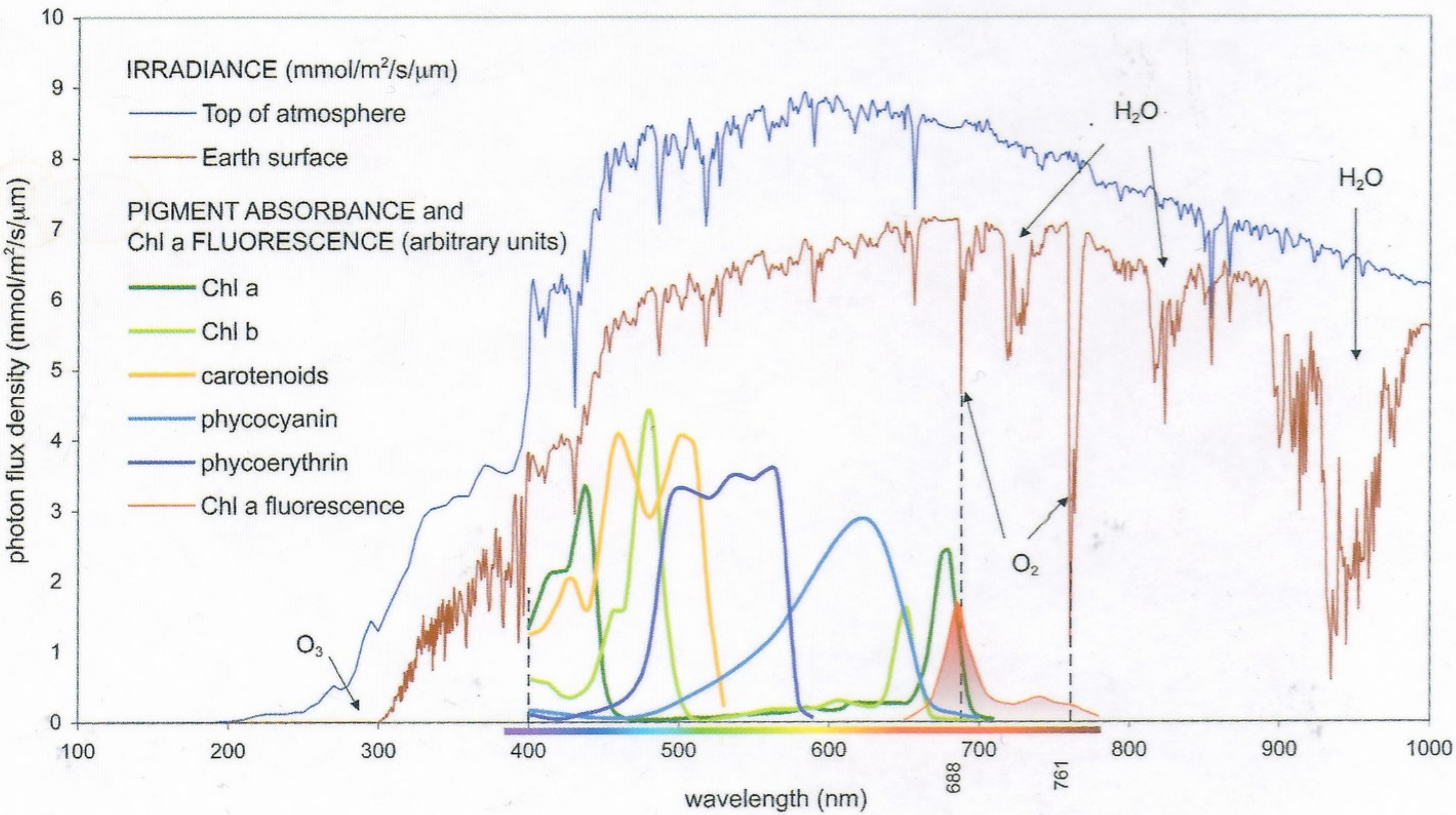


D.O.Hall & K.K.Rao
Photosynthesis 6.th. Edition
ISBN-10: 0521644976
ISBN-13: 978-0521644976



G.C. Papageorgiou (Editor), Govindjee (Editor)
Chlorophyll a Fluorescence: A Signature of Photosynthesis
ISBN-10: 0878931724
ISBN-13: 978-0878931729

Light Harvesting Molekules



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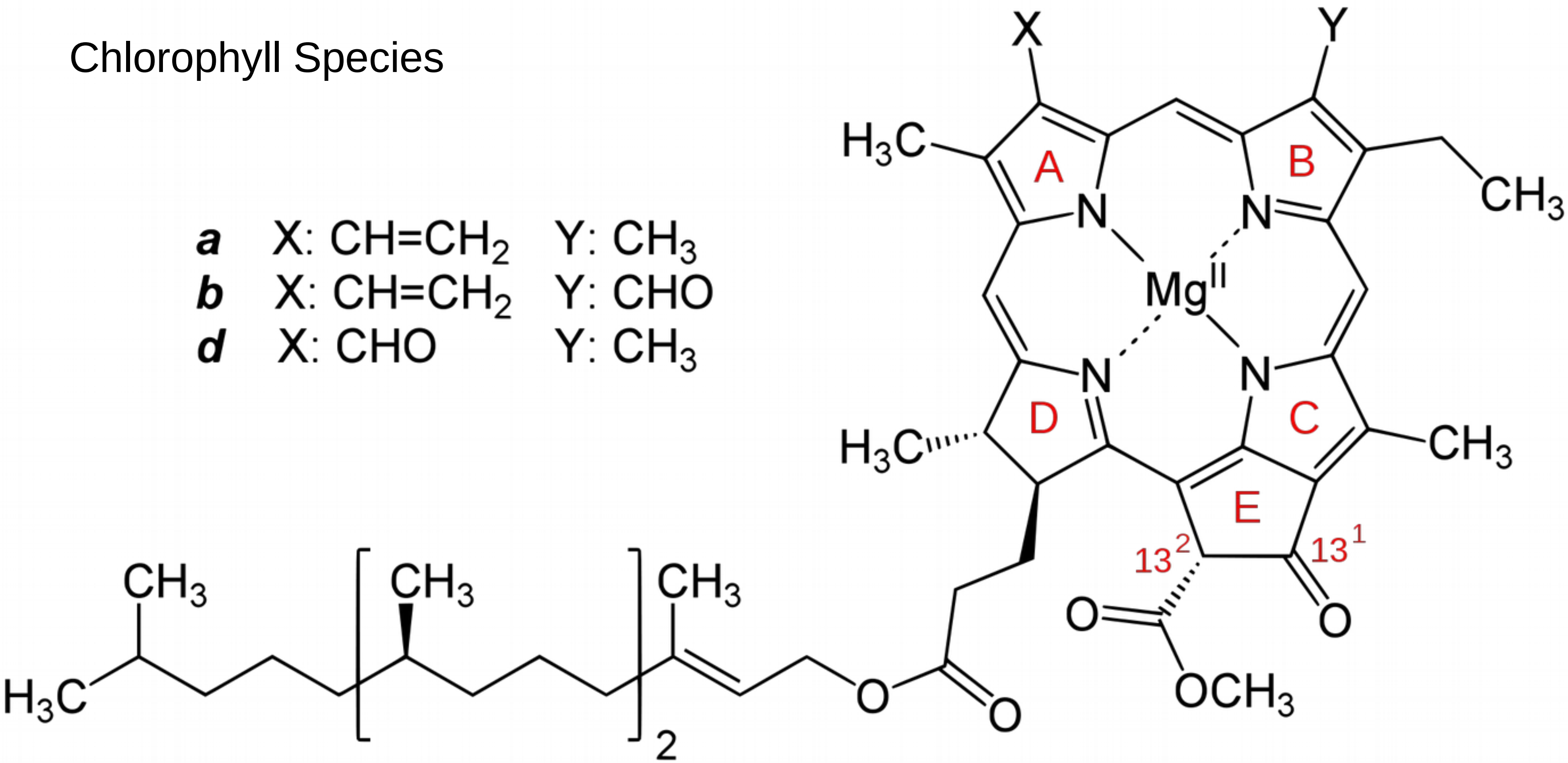
Light Harvesting Molekules

Chlorophyll Species

a	X: $CH{=}CH_2$	Y: CH_3
b	X: $CH{=}CH_2$	Y: CHO
d	X: CHO	Y: CH_3



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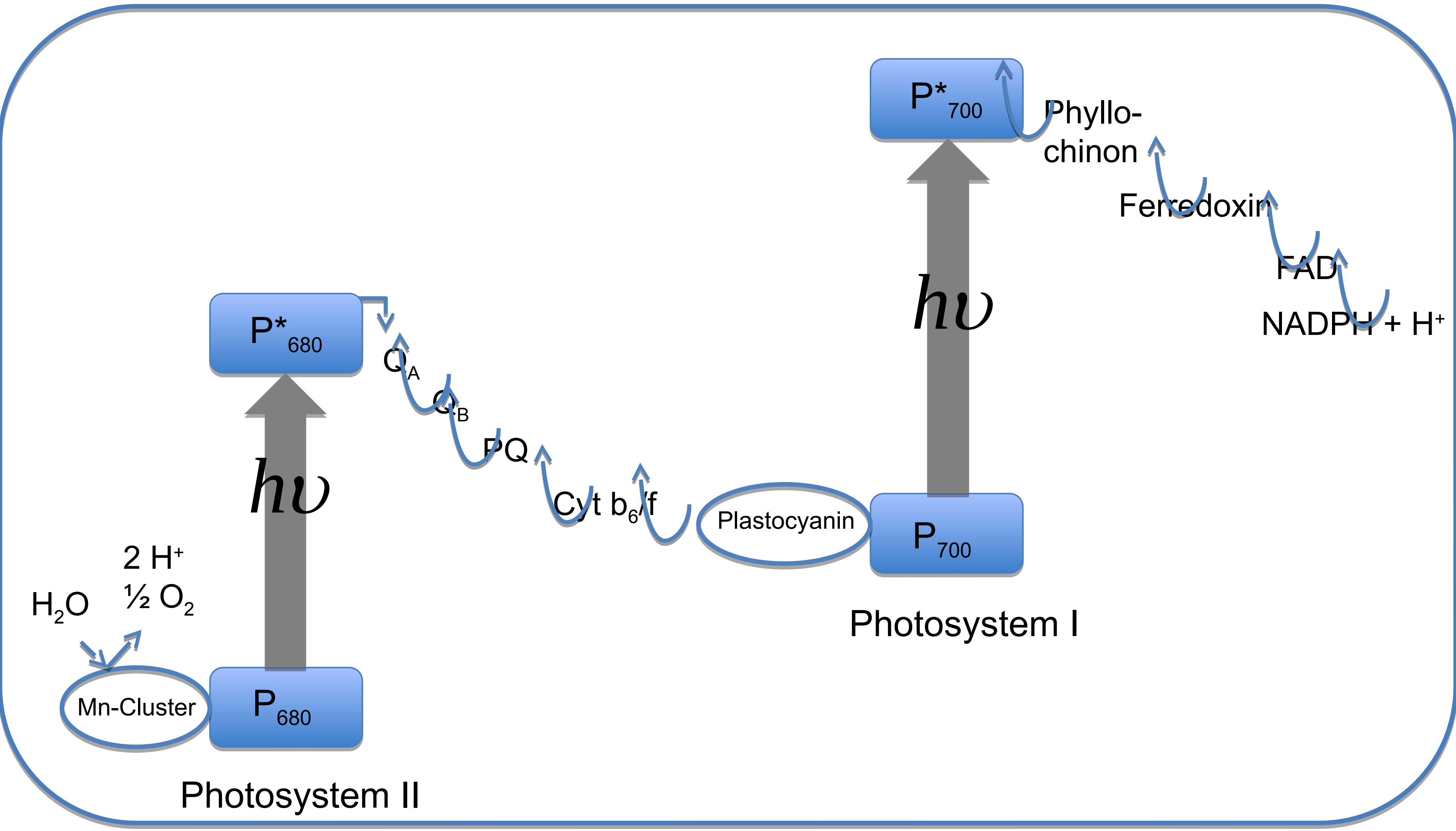
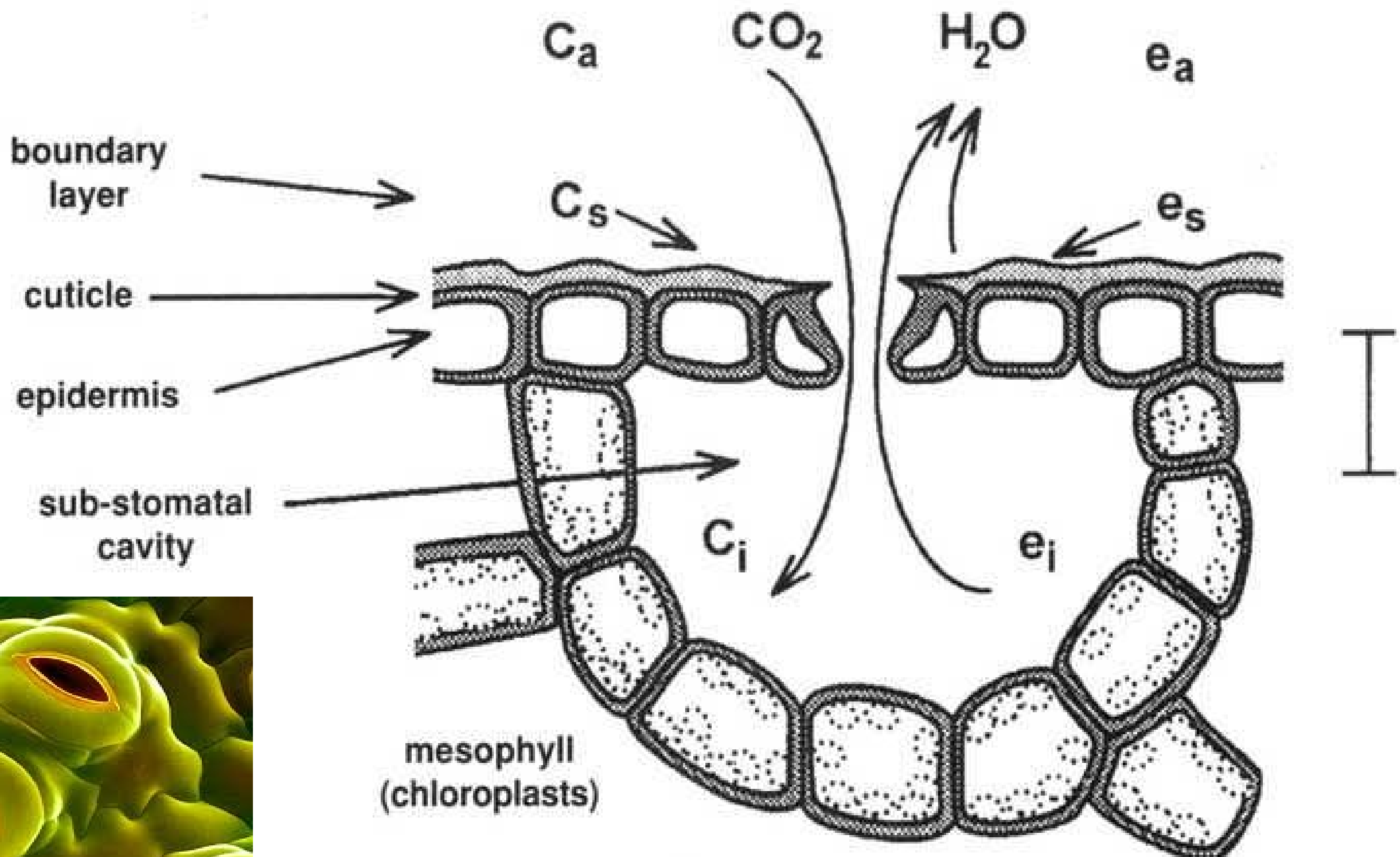
Photosynthesis:
Primary Reactions: Light Harvesting



CO_2 – fixation – secondary Reaction



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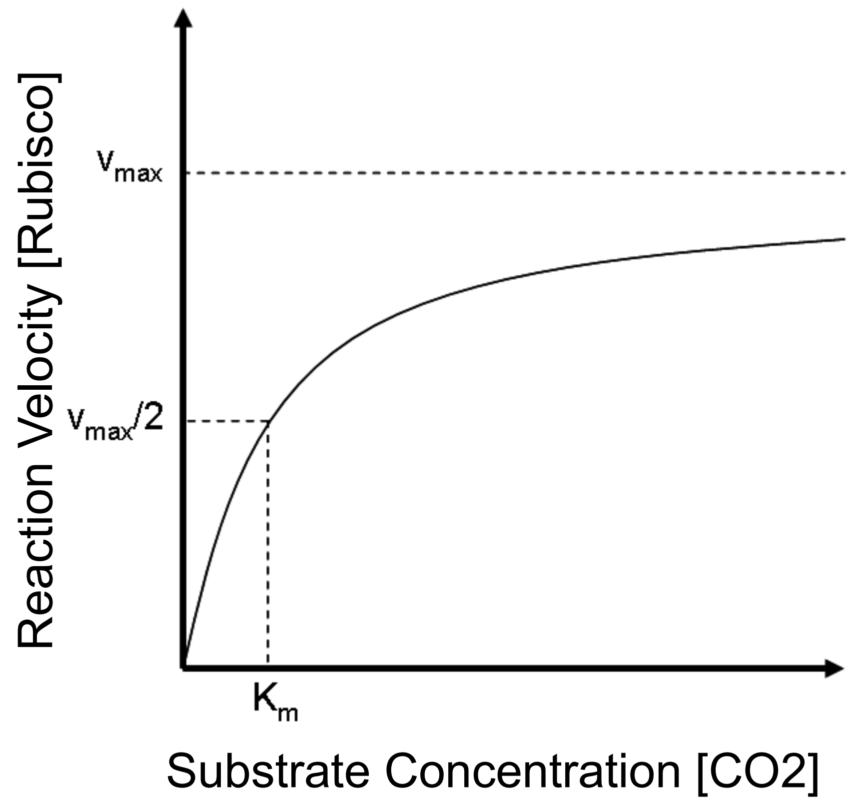
Enzyme Kinetics

$$ES = E_{total}\frac{S}{S+K_M}$$

$$v = k_2 \cdot ES$$

$$v = k_2 \cdot E_{total}\frac{S}{S+K_M} = \frac{v_{\max}\cdot S}{S+K_M}$$

Michaelis-Menten Equation

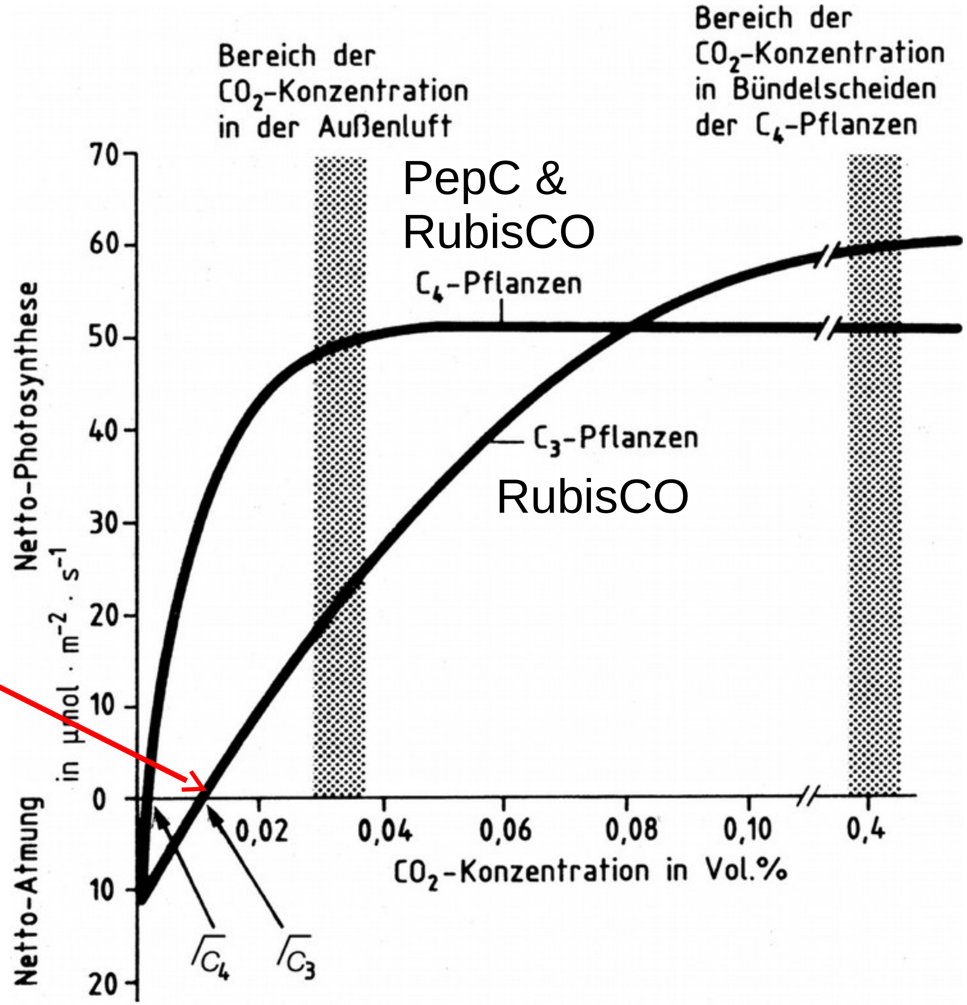


CO_2 Compensation Point

Net Photosynthesis

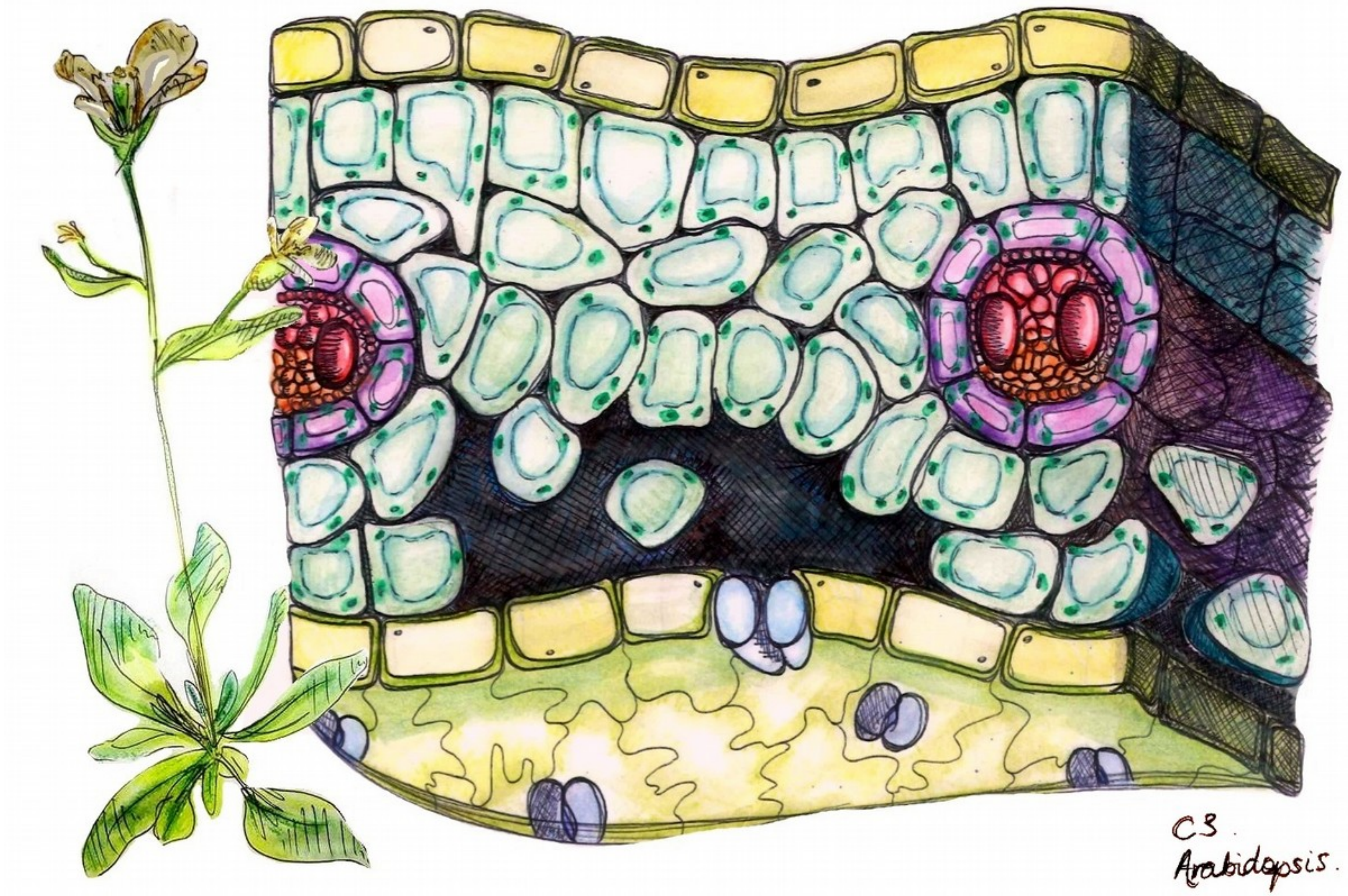
PHOTORESPIRATION

Net Respiration



Lüttge - Botanik
ISBN: 978-3-527-32030-1 Abb-27-32

C3 Anatomy: A.t.



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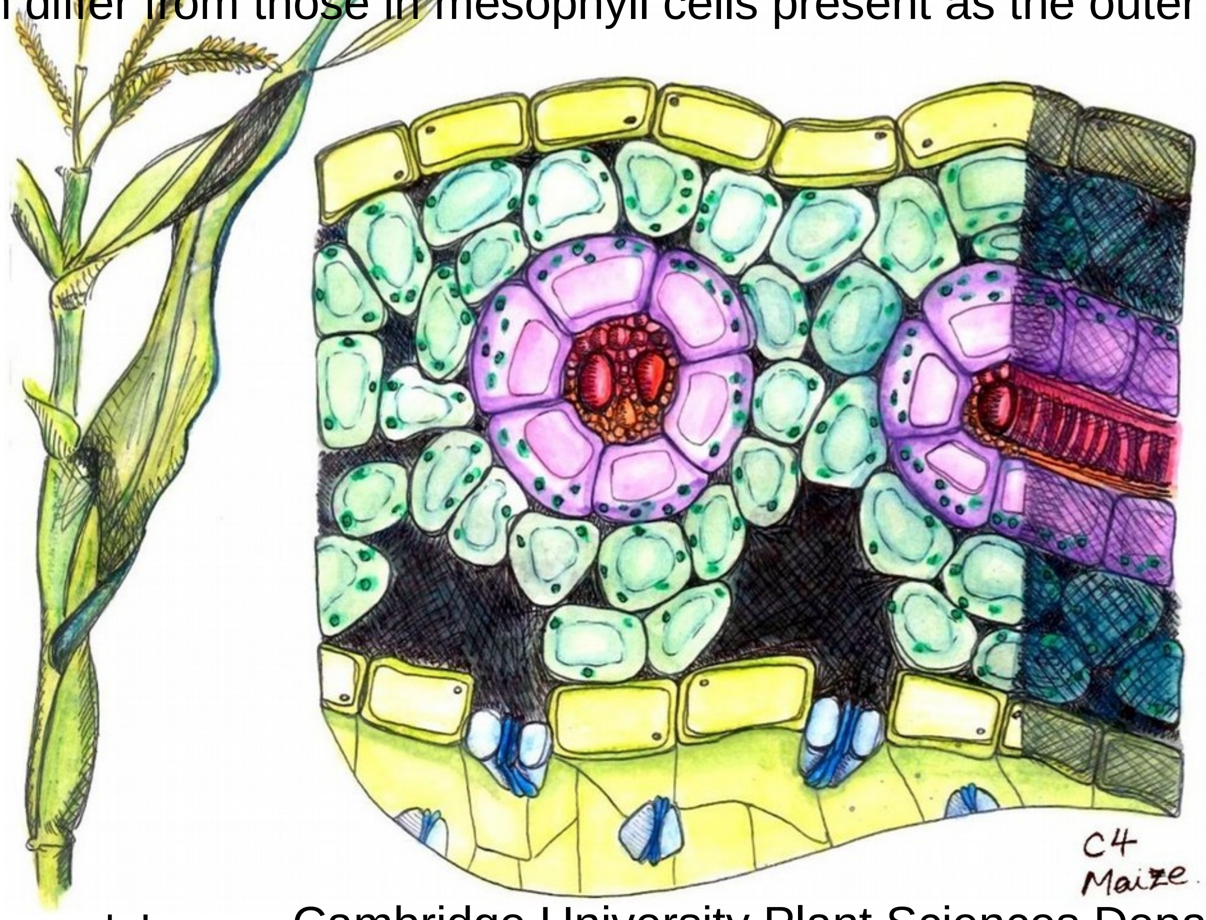
Cambridge University Plant Sciences Department.

C4 Anatomy: Maize

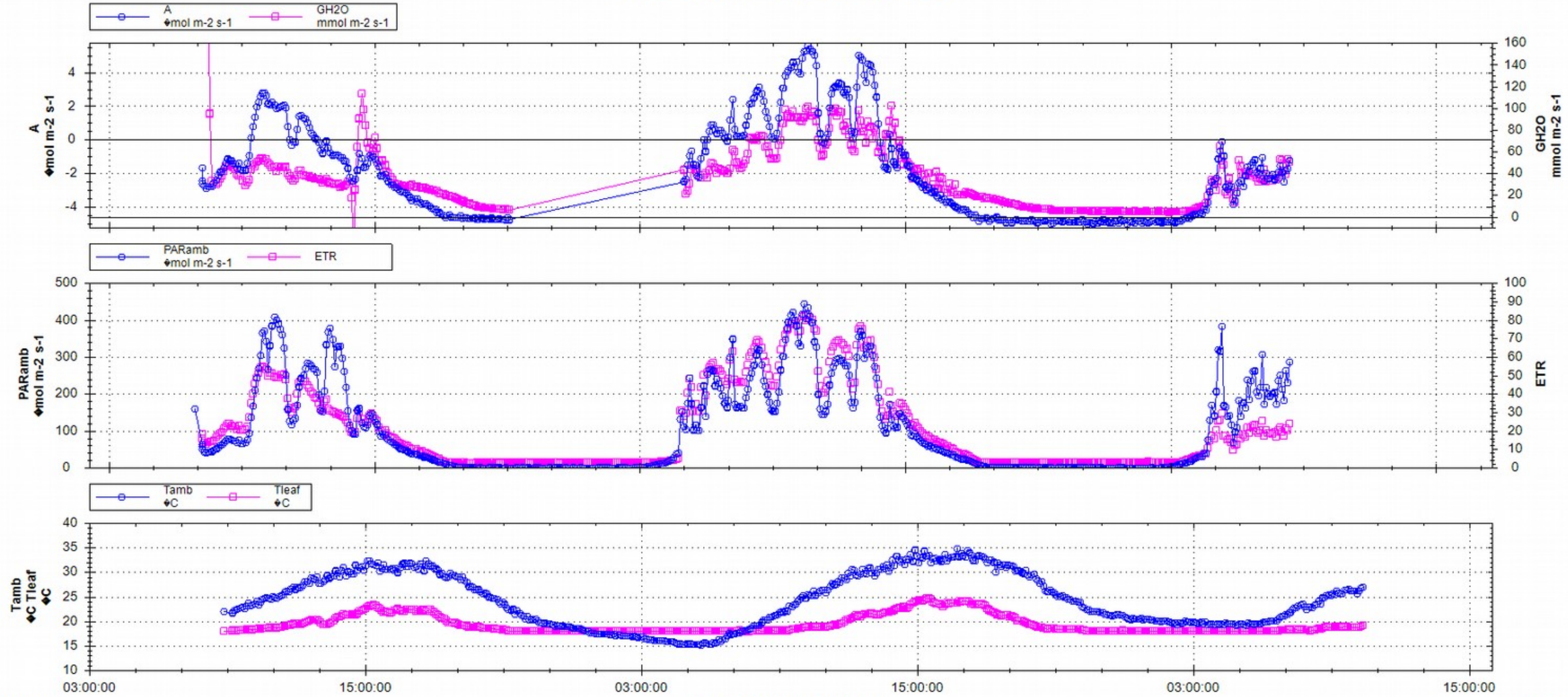
Their vascular bundles are surrounded by two rings of cells; the inner ring, called bundle sheath cells, contains starch-rich chloroplasts lacking grana, which differ from those in mesophyll cells present as the outer ring.



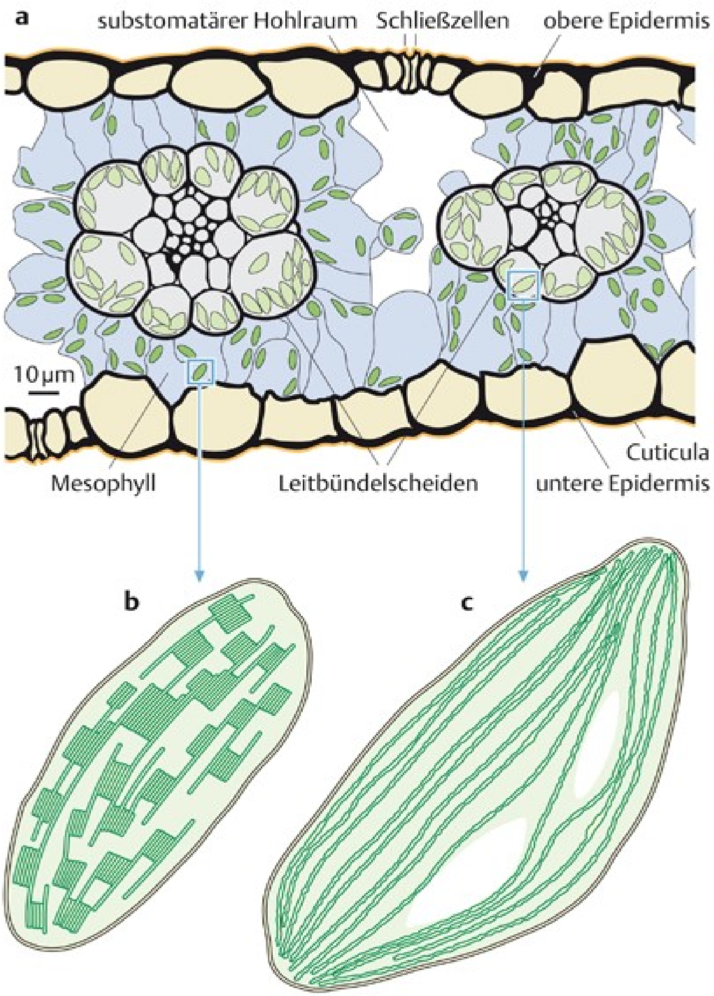
Cambridge University Plant Sciences Department.

CO2 Gas Exchange Measurement
(IRGA)

Zea01 Sach01 2016-06-07 bis 06-09



C4 Chloroplast Adaptations

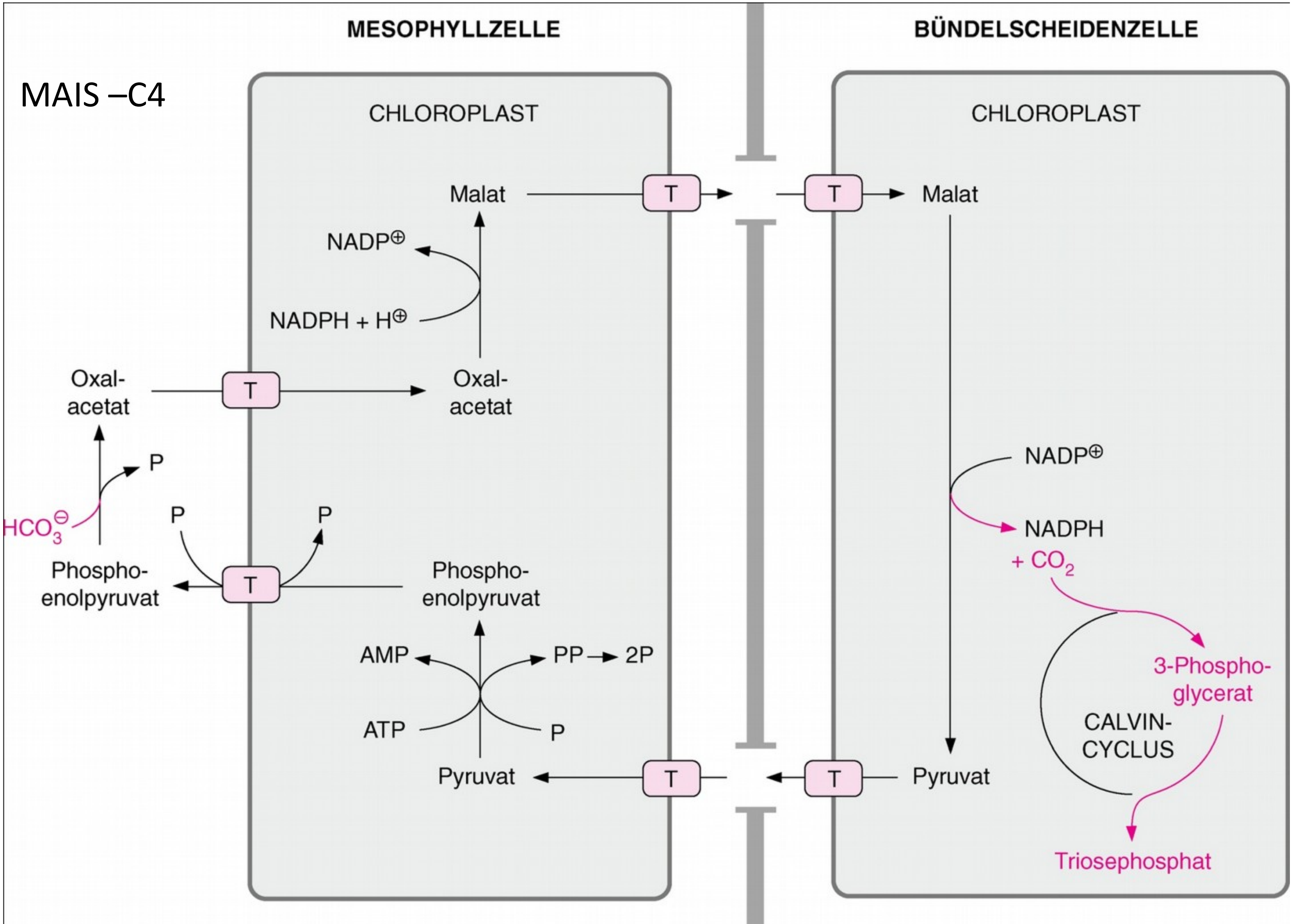


d

	Chloroplast einer Mesophyllzelle	Chloroplast einer Bündelscheidenzelle
PSI	+	+
PSII	+	–
Photolyse	+	–
RubisCO	–	+
Stärke	–	+

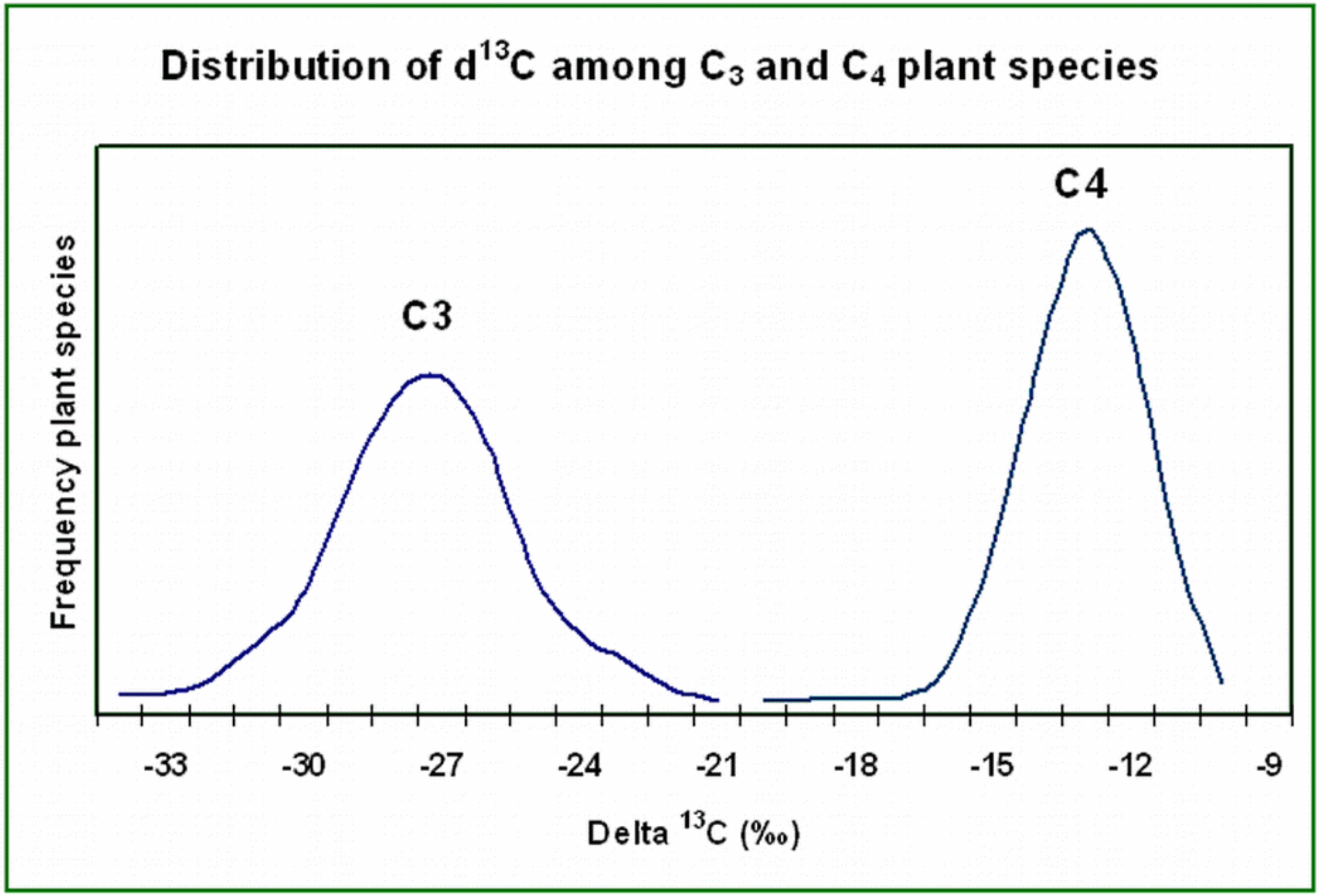
Georg Thieme Verlag, Stuttgart · New York
E. Weiler, L. Nover: Allgemeine und molekulare Botanik · 2008

MAIS –C4


MESOPHYLLZELLE
BÜNDELSCHEIDENZELLE
CHLOROPLAST
CHLOROPLAST
Malat
T
T
Malat
NADP⊕
NADPH + H⊕
Oxal-
acetat
T
Oxal-
acetat
P
HCO3⊖
P
P
Phospho-
enolpyruvat
T
Phospho-
enolpyruvat
NADP⊕
NADPH
+ CO2
AMP
PP → 2P
ATP
P
3-Phospho-
glycerat
CALVIN-
CYCLUS
Pyruvat
T
T
Pyruvat
Triosephosphat

C3 C4: $\delta^{13}C$

https://de.wikipedia.org/wiki/%CE%9413C



^{13}C-Discrimination of PEPC:

the more negative the $\delta^{13}C$, the more At%^{13}C

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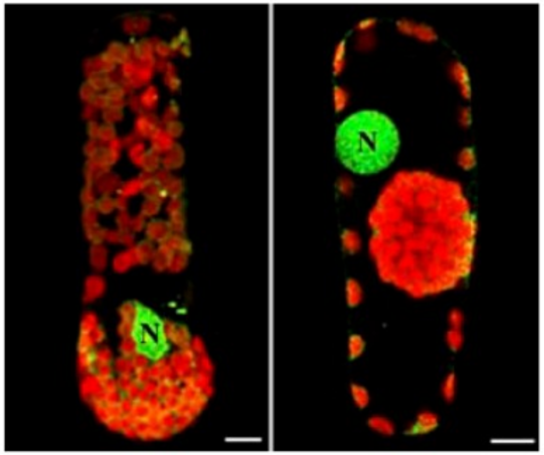
Single Cell C4- Photosynthesis

Single-Cell C_4 Photosynthesis in Chenopodiaceae Species

The family Chenopodiaceae contains ~1300 species, including vegetable crops such as spinach and beets, and desert plants such as *Atriplex* (saltbush). Many chenopod species have C_4 photosynthesis. Chenopods *Bienertia cycloptera*, *Bienertia sinuspersici*, and *Suaeda aralocaspica* recently were found to possess novel mechanisms for C_4 photosynthesis by compartmentalization of organelles and photosynthetic enzymes into distinct regions within chlorenchyma cells. This compartmentalization achieves the equivalent of the spatial separation of cells called Kranz anatomy typically found in C_4 species but within a single cell. *Bienertia* has peripheral and central compartments, while *S. aralocaspica* has distal and proximal compartments.

Chuong et al. (pages 2207–2223) investigated the mechanisms of organelle compartmentalization and the distribution of major organelles relative to the cytoskeleton in these three species using immunofluorescence and transient expression of green fluorescent protein–tagged cytoskeleton markers. The results revealed distinct cytoskeletal compartments consisting of a highly organized network of actin filaments and microtubules associated with the chloroplasts. Experiments using cytoskeleton-disrupting drugs further showed that microtubules are critical for the polarized positioning of chloroplasts and other organelles into distinct compartments within the chlorenchyma cells.

www.plantcell.org/cgi/doi/10.1105/tpc.106.180911



Confocal microscopy images show the distal and proximal compartments in *S. aralocaspica* (left) and peripheral and central compartments in *B. sinuspersici* (right). Nuclei (N) are green, and chloroplasts are red.

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CAM: crassulatian acid metabolism

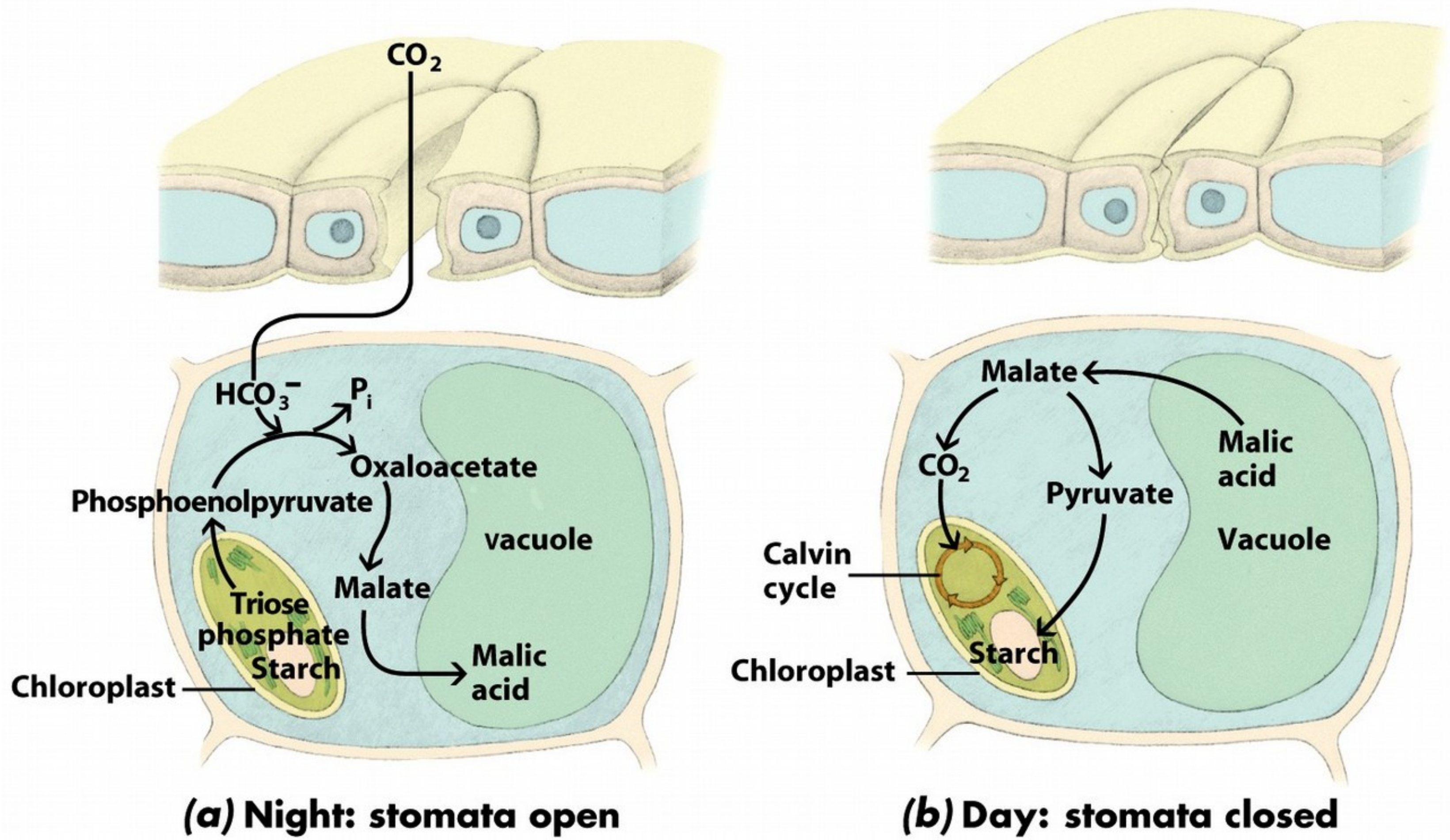
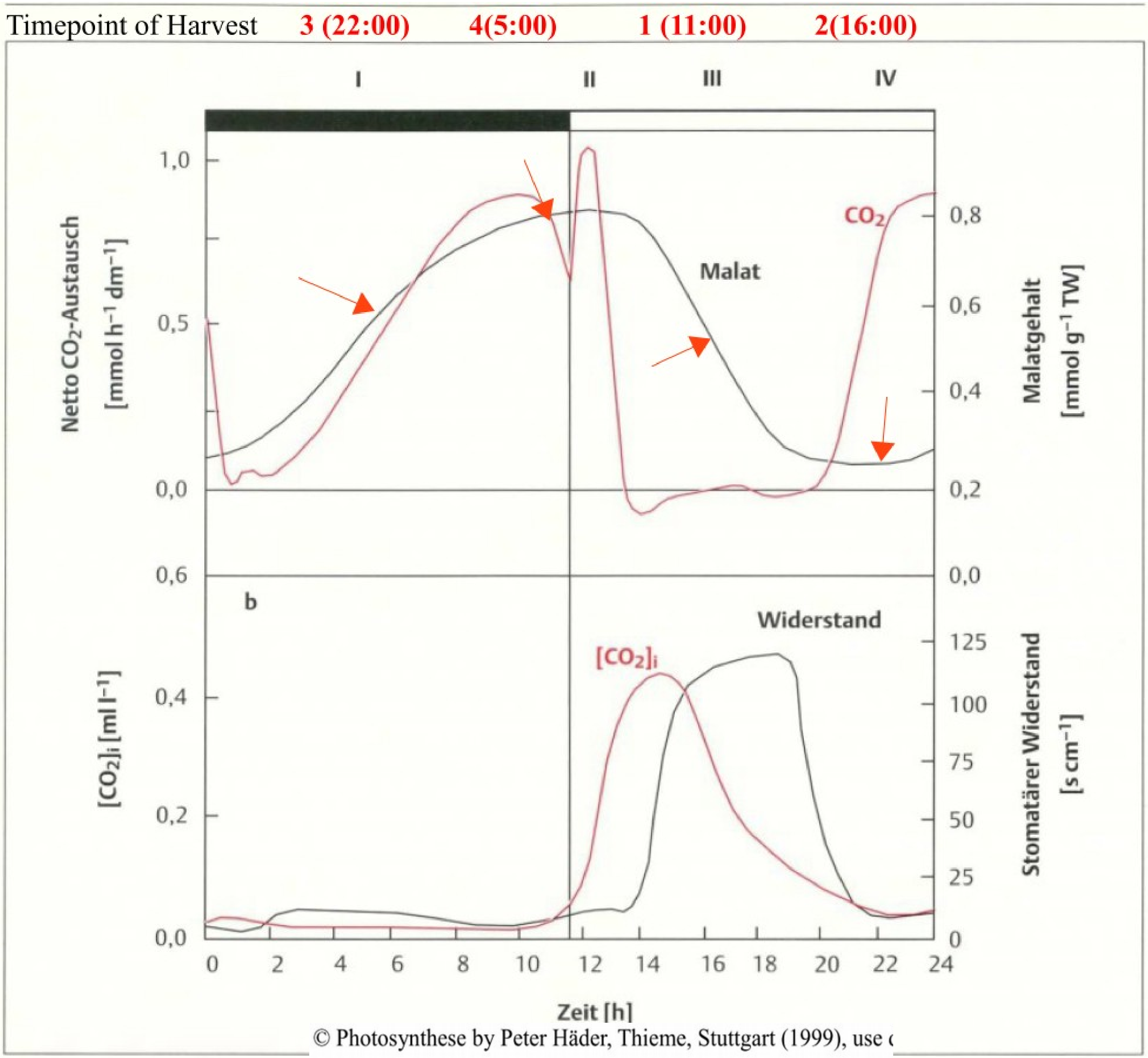


Figure 7-26
Biology of Plants, Seventh Edition

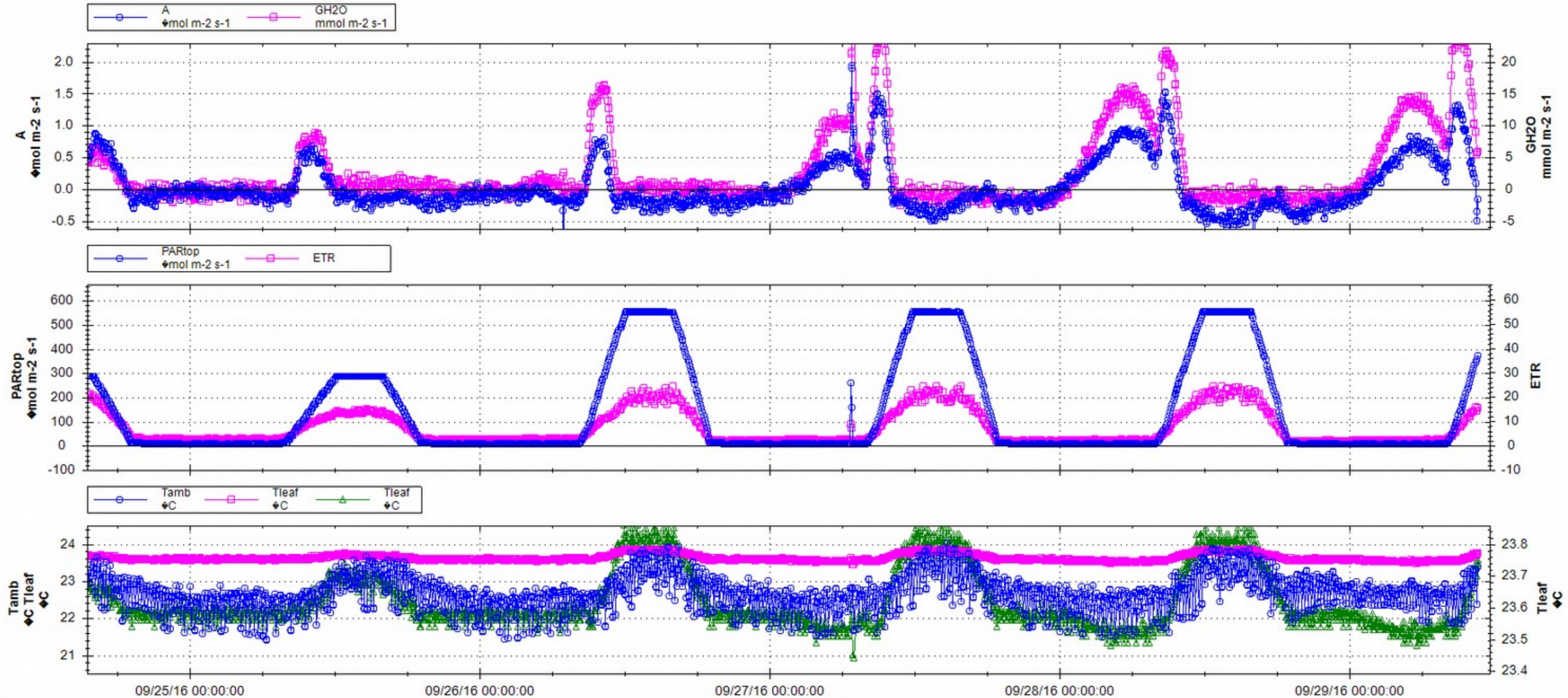
Inhibition of RUBISCO by Light or Oxygen ?

CAM:

diurnal change

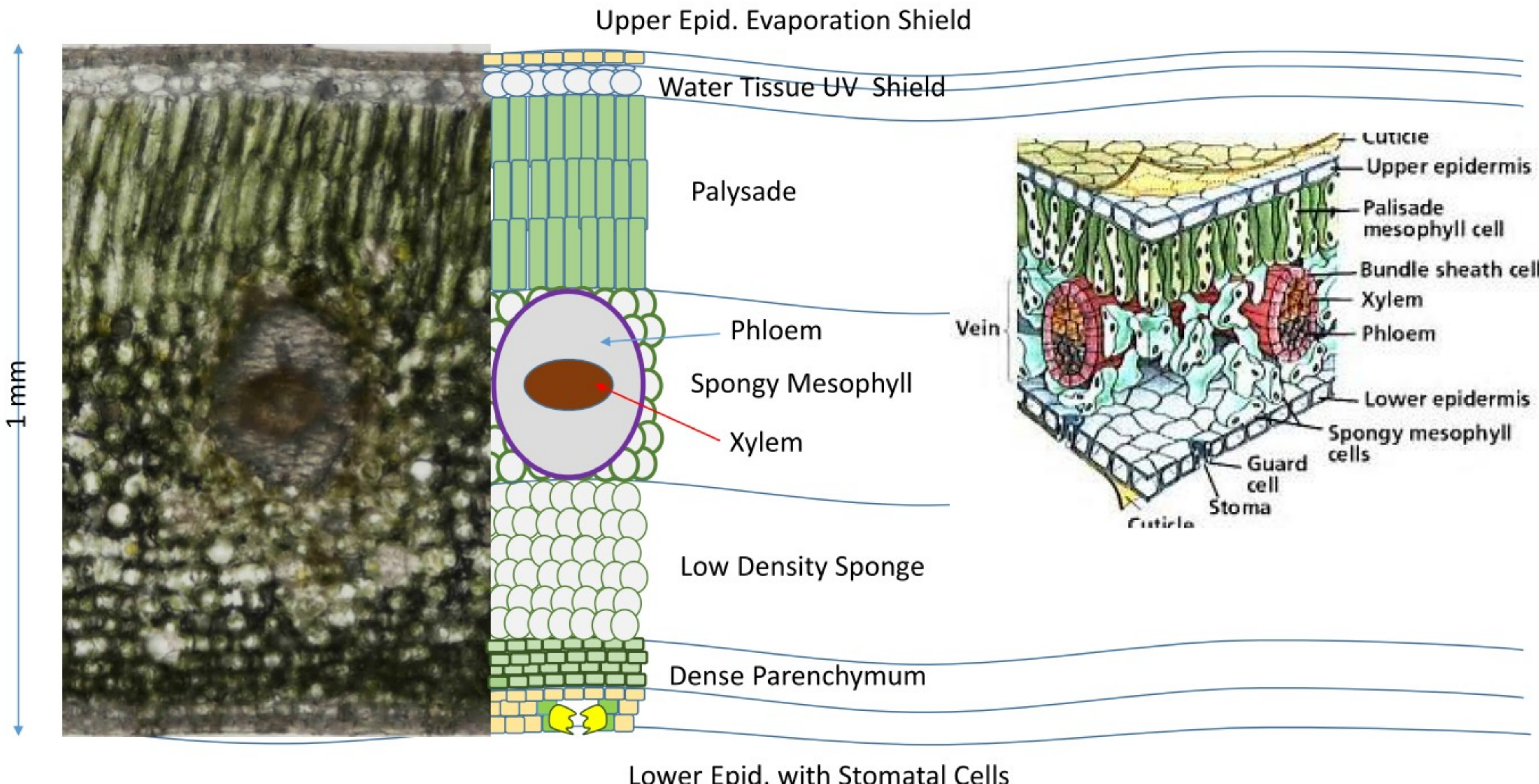


PhytoQi   C hilariana snd leaf



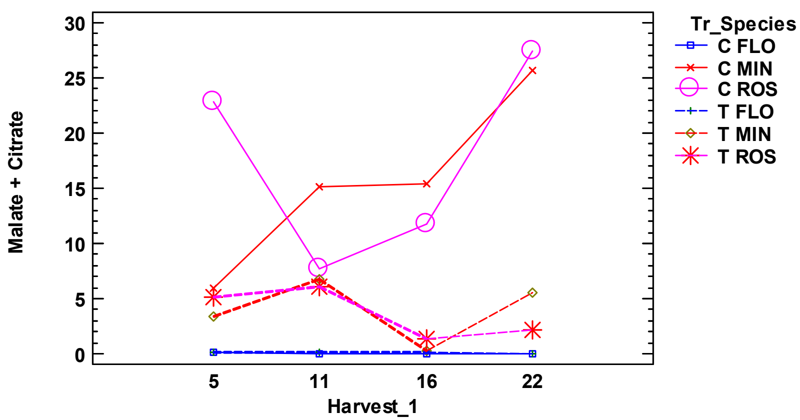
Single Cell C4- Photosynthesis in CAM ?

Clusia rosea Cross Section



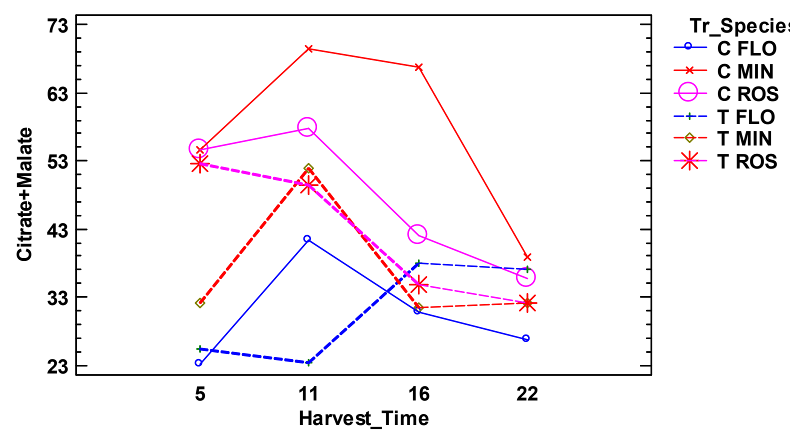
2014

Interaction Plot 2014

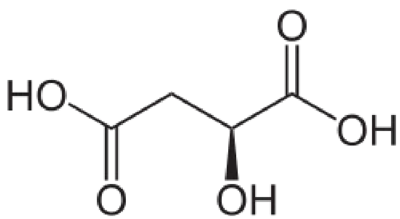


Interaction Plot 2015

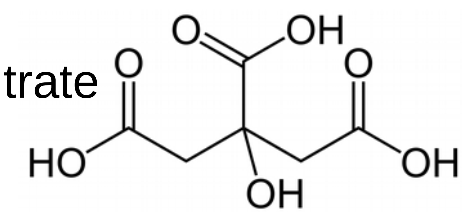
2015



malate

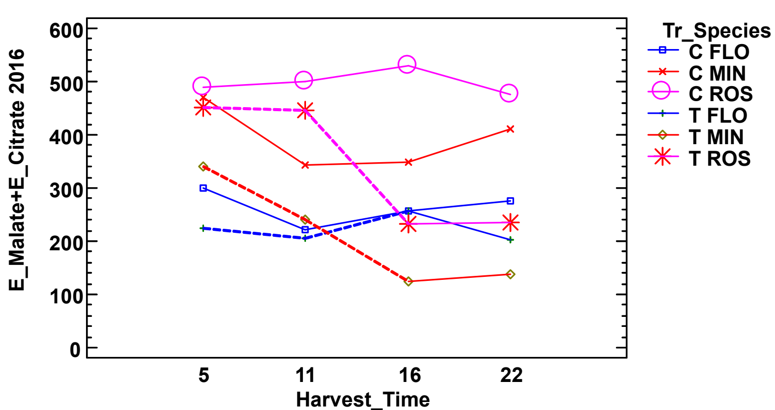


citrate



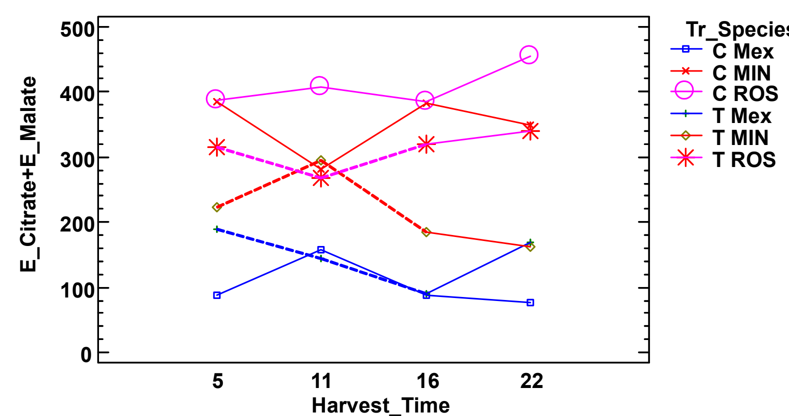
Interaction Plot 2016

2016

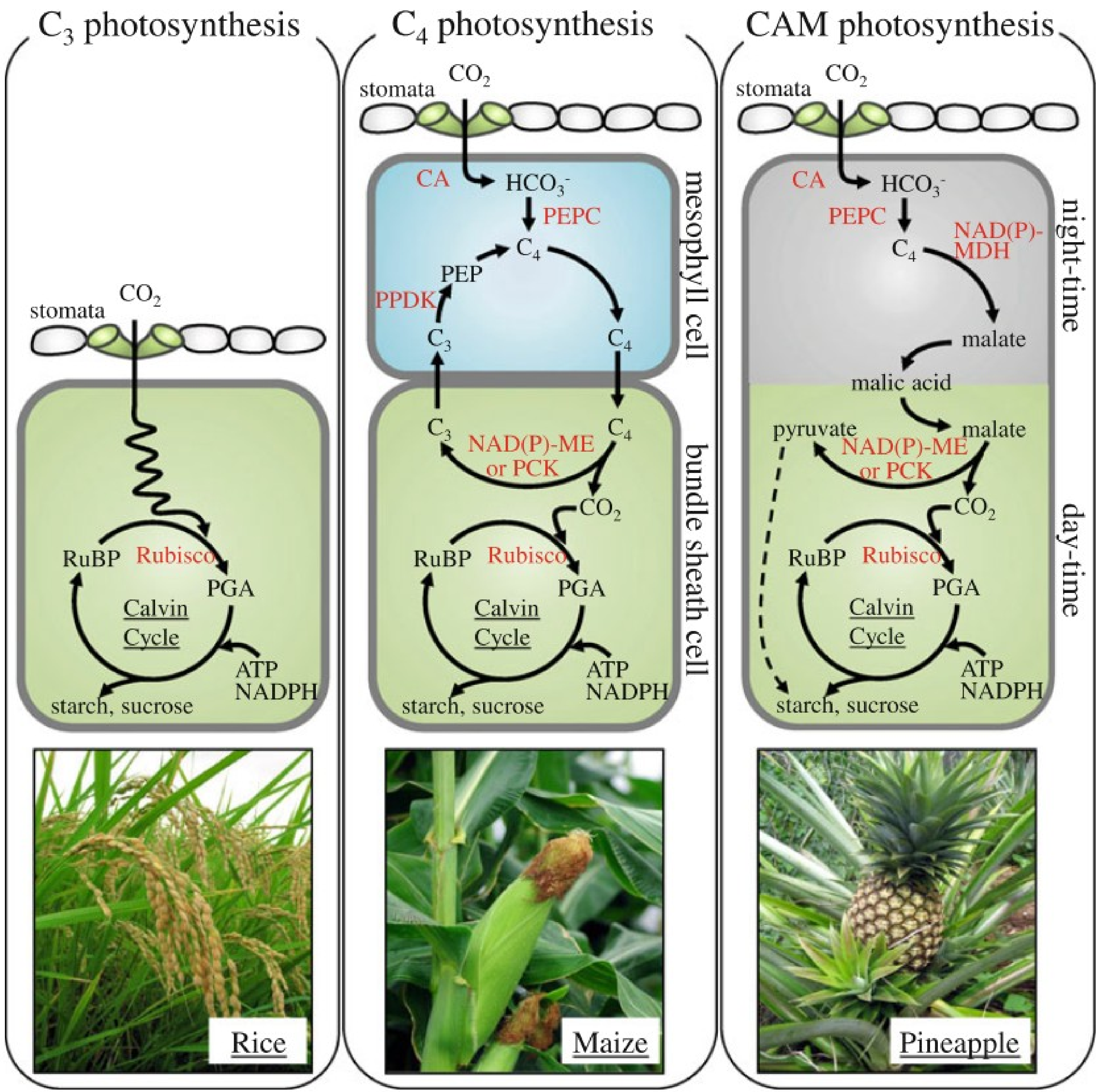


2017

Interaction Plot 2017



C3 C4 CAM



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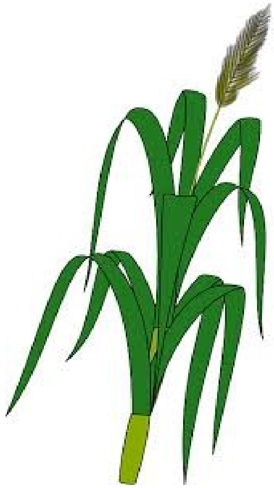
C4 plants cannot grow in dark and cold places as they need much more light to survive

C4: 1 g dry mass



250 ml water

...at ~ 40°C !

C3: 1 g dry mass

500 - 750 ml water

C3 plants cannot grow in hot / dry areas because RuBisCO incorporates more oxygen into RuBP as temperatures increase....

	PHAR	°C	A CO_2 µM	G H_2O mM	WUE	ETR	LUE
C3_Bean	600	23	6	150	25000	200	33
C3_Raph	400	23	7.5	150	20000	90	12
C4_Zea_Sach	400	23	4	100	25000	300	75
CAM_Clusia h.	500	23	1	15	15000	20	20

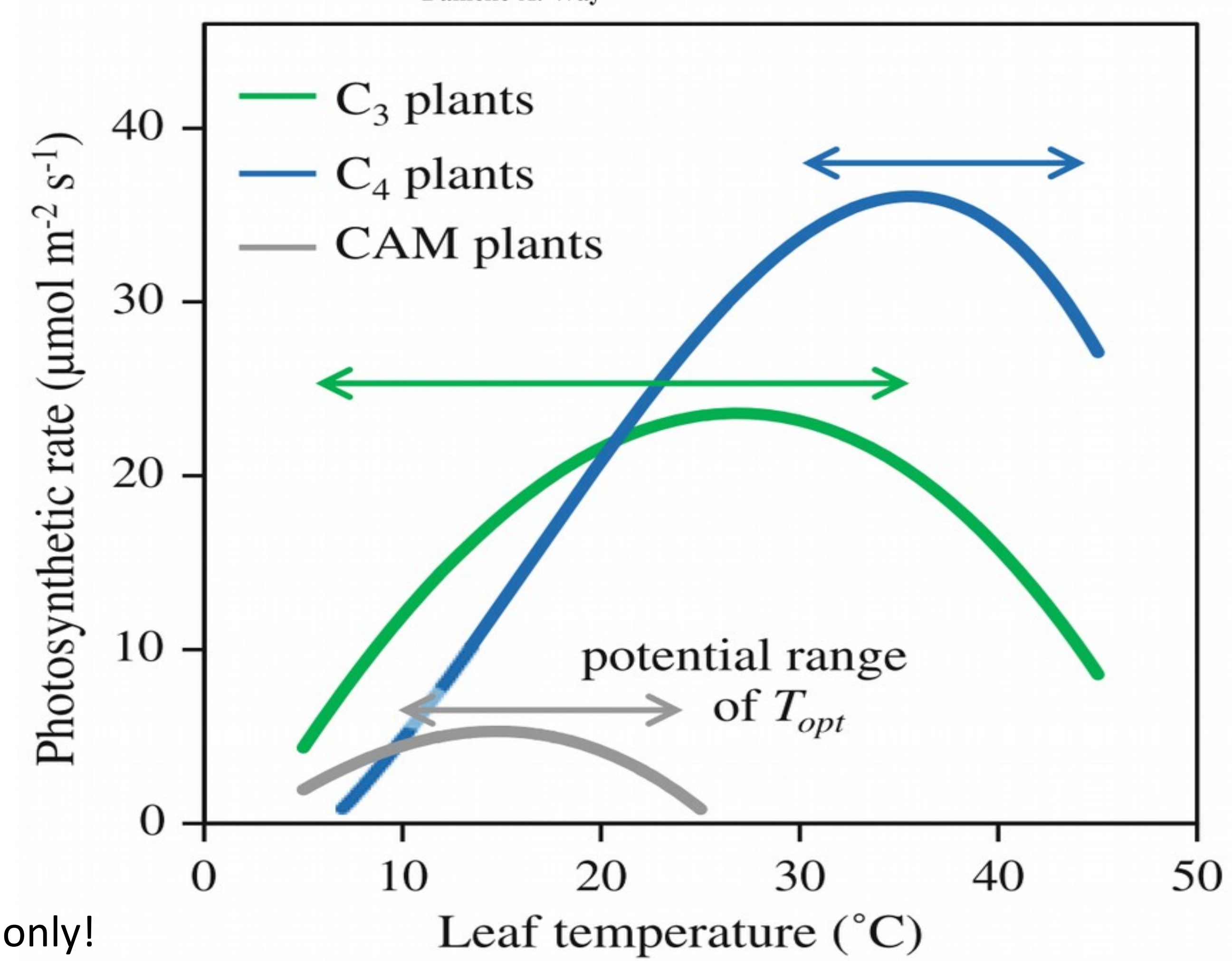
C3 C4 CAM

Photosynth Res
DOI 10.1007/s11120-013-9874-6

REVIEW

Temperature response of photosynthesis in C_3, C_4, and CAM plants: temperature acclimation and temperature adaptation

Wataru Yamori · Kouki Hikosaka · Danielle A. Way



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C3 C4 CAM

Why be efficient? A question for C4 plants

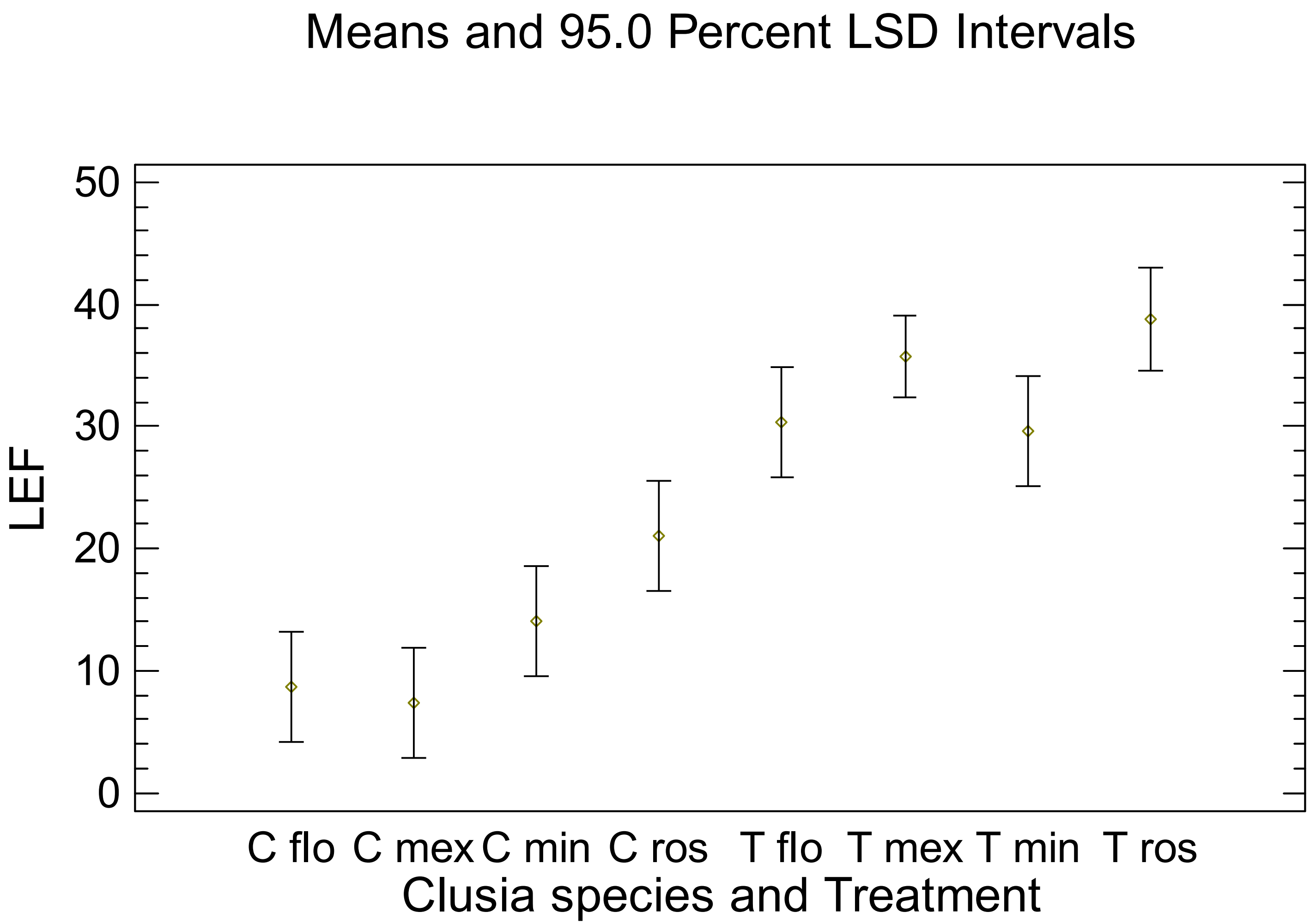
"Some of the characteristics of C4 are a bit mythological. For example, although C4's can have higher photosynthetic nitrogen use efficiency, many C4's have high tissue N concentrations and many C3's have as low an N concentration as the lowest C4. Not everything about plants is destined from photosynthetic properties". (and not all can be learned from A.t)

http://wildplantspost.blogspot.co.at/2009/11/why-be-efficient-question-for-c4-plants.html

→ Efficiency at high light and temperature is not a complete advantage for C4 Plants, if it comes with much higher nutrition (H2O, N and light intensity) requirements.

"survival of the imperfect"
(coined by Jörg Ott in the nineties)

C3: cold adapted
C4: heat adapted
CAM: drought adapted


Means and 95.0 Percent LSD Intervals
LEF
50
40
30
20
10
0
C flo
C mex
C min
C ros
T flo
T mex
T min
T ros
Clusia species and Treatment